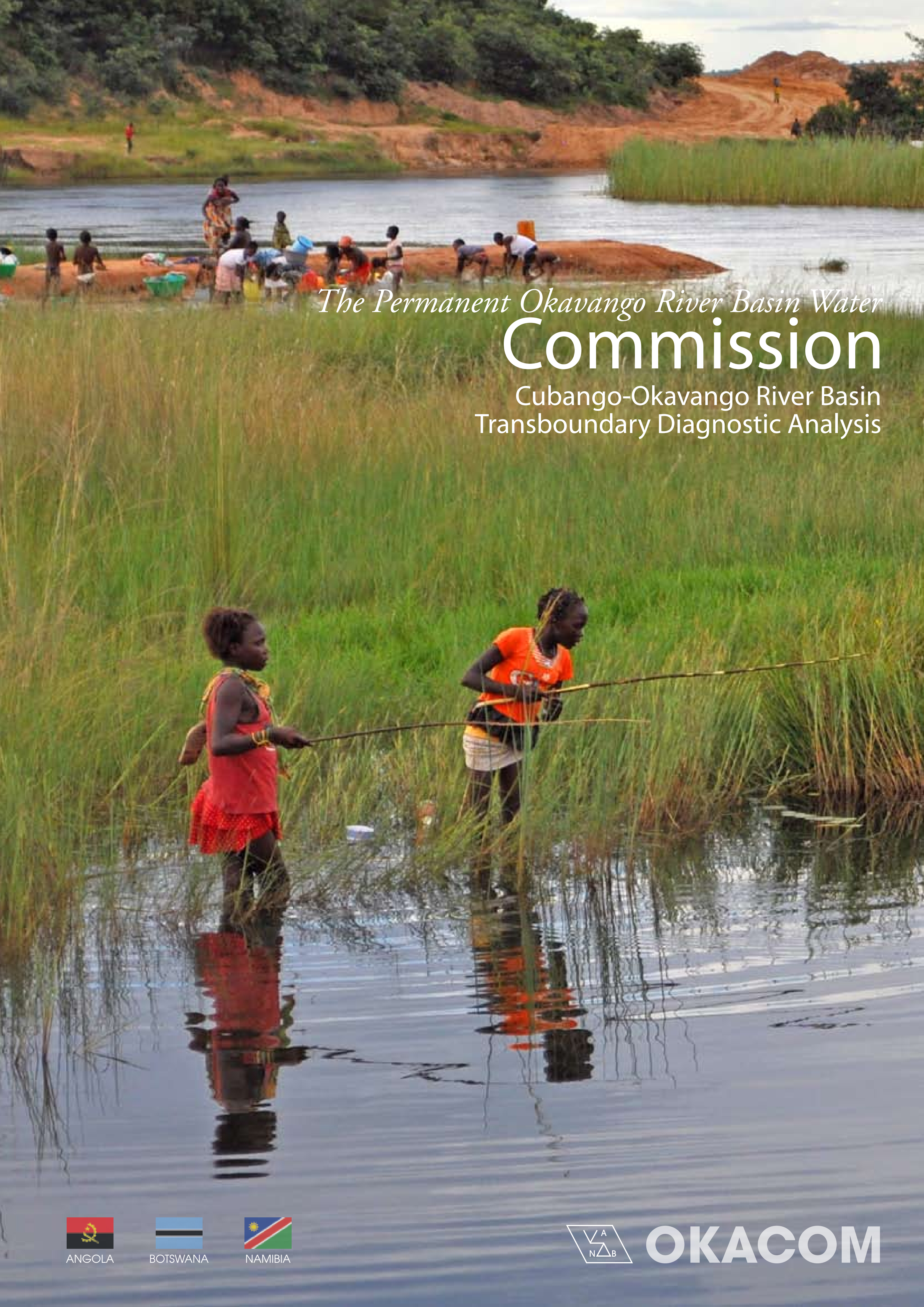

The Permanent Okavango River Basin Water

Commission

Cubango-Okavango River Basin Transboundary Diagnostic Analysis

ANGOLA BOTSWANA NAMIBIA

OKACOM

Cubango-Okavango River Basin Transboundary Diagnostic Analysis

2011

ISBN 978-99912-0-972-2

Republic of Botswana

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Front cover: Cuito River at Cuito Cuanavale, Angola
Inside front cover: Late afternoon on the Kavango River, Namibia, February 2010

ISBN 978- 99912-0-972-2
Cite as: The Permanent Okavango River Basin Water Commission. 2011. *Cubango-Okavango River Basin Transboundary Diagnostic Analysis.* Maun, Botswana: OKACOM, 2011
Photographs not otherwise credited, courtesy of Professor Jackie King and Dr Cate Brown, Wilma Matheson, Frances Murray-Hudson, EPSMO Project and OKASEC
Designed by Twin Zebras, Maun, Botswana

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ACRONYMS AND ABBREVIATIONS

AIDS	acquired immunodeficiency syndrome
BiOkavango	Building Local Capacity for Conservation and Sustainable Use of Biodiversity in the Okavango Delta, Botswana Project
CCA	Causal Chain Analysis
DSS	decision support system
EA	environmental assessment
EIA	environmental impact assessment
EPSMO	Environmental Protection and Sustainable Management of the Okavango River Basin Project
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GDP	gross domestic product
GEF	Global Environment Facility
GIS	geographic information systems
GNI	gross national income
ha	hectare(s)
HDI	human development index
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
MDG	Millennium Development Goals
mg	milligrams
mg/l	milligrams per litre
mm	millimetre(s)
Mm^3	million cubic metre(s)
mm/a	millimetres per annum

Water Lily, Okavango Delta Panhandle

Mm^3a^{-1}	million cubic metres per annum
Mm^3s^{-1}	million cubic metres per second
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
NTU	nephelometric turbidity units
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
PMU	project management units
PNGA	Programa Nacional de Gestão Ambiental
RWP	Regional Water Policy
RWS	Regional Water Strategy
SADC	Southern Africa Development Community
SAP	Strategic Action Programme
SEA	strategic environmental assessment
TDA	Transboundary Diagnostic Analysis
TDS	total dissolved solids
UN	United Nations
UNCBD	United Nations Convention on Biological Diversity
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World Health Organization

ACKNOWLEDGEMENTS

The EPSMO Project was funded by the Governments of Angola, Botswana and Namibia and the Global Environment Facility (GEF). Viewed as the first project directly commissioned by the Permanent Okavango River Basin Water Commission (OKACOM), its completion benefited from the strategic and knowledgeable leadership provided by the Commissioners Mr Armindo Gomes da Silva, Mr Isidro Pinheiro (Angola), Mr Gabaake Gabaake, Mr Boikobo Paya, Mr Steve Mona (Botswana), Mr Andrew Ndishishi, Mr Abraham Nehemia and Mrs Erica Akuenje (Namibia).

The United Nations Development Programme (UNDP) and, especially, Dr Gita Welch and Ms Gabriela do Nascimento of UNDP Angola, provided invaluable support towards the implementation of the project, while the United Nations Food and Agricultural Organisation (FAO), acting as the Executing Agency, was represented by Mr Jacob Burke through the eight long years of the project's gestation.

Flags of OKACOM member states, Secretariat, Maun, Botswana

The TDA is the product of many years of work by a dedicated team of specialists, all from the region under the overall guidance of the Okavango Basin Steering Committee (OBSC), composed of Mrs Portia Segomelo – Co-Chairperson, Ms Tracy Molefi, Mr Kalaote Kalaote (Botswana), Mr Isidro Pinheiro – Co-Chairperson Mr Carlos Andrade, Mr Paulo Emílio Mendes (Angola) and Ms Florence Sibanda – Co-Chairperson, Ms Laura Namene and Ms Pauline Mufeti (Namibia), in its capacity as the technical arm of Permanent Okavango River Basin Water Commission (OKACOM). The OBSC's technical supervision was further enhanced through the critical roles played by National Coordinators and the National Coordinating Units, headed by Mr Manuel Quintino (Angola), Ms Laura Namene (Namibia) and Ms Tracy Molefi (Botswana).

Commissioners Pinheiro, Tombale and DeWet inaugurating Secretariat, Maun, Botswana 2008

The results of the work by the dedicated TDA team of specialists could not have been achieved without the day-to-day project management and coordination jointly undertaken by the EPSMO Project Management (PMU) and the OKACOM Secretariat (OKASEC). Under the leadership of Mr Chaminda Rajapakse, the staff of the PMU in Luanda – Mr Chagas Macula, Mr Pedro André and Ms Eva Kalunga provided steady support to the project. To the OKACOM Secretariat, heartfelt gratitude is addressed to Dr Ebenizário Chonguiça and his team composed of Ms Monica Morrison, Mr Thato Pilane, Ms Motsei Tiego and Ms Olerato Ramadimo.

Additional guidance and support was provided by Dr Akiko Yamamato of UNDP/GEF Regional Coordination Unit and the UNDP Regional Environmental Project for Africa at the crucial moments of TDA revision and finalization.

Regional specialists worked structured in three sub-national teams, each with a team leader. Mr Manuel Quintino headed the Angolan team, working with scientists from the Agostinho Neto University in Luanda. Ms Shirley Bethune led the Namibian team, working through the Namibia Nature Foundation in Windhoek, and Dr Casper Bonyongo led the Botswana team from the University of Botswana's Okavango Research Centre in Maun. Other organisations that played prominent roles are ACADIR (Associação de Conservação do Ambiente e Desenvolvimento Integrado Rural), Namibia Nature Foundation, NamWater, and the HOORC Biokavango Project through its National Project Coordinator Dr Nkobi Moleele.

More than 30 authors contributed to the country reports, and the multidisciplinary research and reports for the Integrated Flow Assessment were completed by the following specialists working in discipline-based groups across the basin:

Angola OBSC member Mendes with children at Telefood event, Mucundi, Angola, 2010

Angola: Mr Manuel Quintino, Mr Carlos Andrade, Mr Helder André de Andrade e Sousa, Mr Amândio Gomes, Ms Filomena Livramento, Mr Paulo Emilio Mendes, Dr Gabriel Luis Miguel, Mr Miguel Morais, Mr Mario João Pereira, Dr Carmen Santos and Ms Rute Saraiva.

Botswana: Dr Casper Bonyongo, Mr Pete Hancock, Dr Lapologang Magole, Dr Wellington Masamba, Dr Hilary Masundire, Dr Dominic Mazvimavi, Dr Joseph Mbaiwa, Dr Gagoitseope Mmopelwa, Ms Belda Mosepele, Mr Keta Mosepele and Dr Piotr Wolski.

Namibia: Ms Shirley Bethune, Dr Colin Christian, Ms Barbara Curtis, Ms Celeste Espach, Ms Aune-Lea Hatutale, Mr Mathews Katjimune assisted by Ms Penehafo Shidute, Mr Andre Mostert, Ms Shishani Nakanwe, Ms Cynthia Ortmann, Mr Mark Paxton, Mr Kevin Roberts and Dr Ben van de Waal, Mr Petrus Liebenberg, Ms Dorothy Wamunyima, Ms Ndina Nashipili and Ms Charlie Paxton.

The international IFA process management team was led by Dr Jackie King, with Mr Hans Beuster coordinating the hydrological analyses, Dr Cate Brown guiding the river studies, Dr Alison Joubert leading design and use of the DSS software and Dr Jon Barnes leading the social studies. This team produced a further eight reports detailing the IFA process used and its outcomes, complemented by basin-wide studies, including economic analyses by Bruce Aylward.

All country and specialist reports underwent extensive review within the countries, by the OBSC, by OKACOM, and through additional external peer reviewers. All of these reviewers are acknowledged and thanked. The TDA report was written and revised through several versions by Mr Peter-John Meynell, Ms Sharon Mongomery and Mr Tim Turner, with revisions and review by Dr Jackie King, OKACOM and the OBSC. Mr Daniel Malzbender also contributed a basin wide governance report, comment and guidance as he led the preparation of the SAP. We are also grateful for the long hours put in by the translator, Mr Carlos Fiuza, the editorial team, Ms Carol du Toit and Ms Robyn Mansfield and report production team members Ms Taryn Mc Cann, Ms Chere Diviney and Mr Edwin Hwera.

The TDA could not have reached completion without the dedicated hard work of all of these people, who are thanked most sincerely for their contributions. Thanks are also due to the people of the basin for their gracious patience and useful collaboration with the numerous researchers who visited the communities.

Last but not least the invaluable knowledge, support and collaboration provided by various local and national institutions and communities is acknowledged. Their expectations for the sustainable management of the Cubango-Okavango Basin are cherished.

FOREWORD

Angola, Botswana and Namibia are privileged to own one of the world's great natural treasures, the Cubango-Okavango River system. Rising in Angola as the Cubango, it flows to the confluence with its main tributary, the Cuito River, flowing south and then east between Namibia and Angola. It then flows on into Botswana as the Okavango River. Its waters never reach the sea, and instead spread onto the flat Kalahari sands to form a wetland of global importance – the Okavango Delta.

Our three countries wish to develop some of the water resources of the Cubango-Okavango system for the benefit of our people, but to do this in a way that is sustainable and does not threaten the health of this magnificent river system. To help us plan responsibly, the Permanent Okavango River Basin Water Commission (OKACOM) embarked on a Transboundary Diagnostic Analysis (TDA) of the basin between 2008 and 2010, through the EPSMO Project. The TDA was guided by GEF best practice for such work, but deviated from the standard format, which is to assess existing development-related problems and to recommend solutions. Rather, because the river is still in near-pristine condition, OKACOM embarked on a unique TDA that looks forward to assess the positive and negative implications of possible future water resources developments. These are then addressed in a Strategic Action Programme (SAP) for the basin.

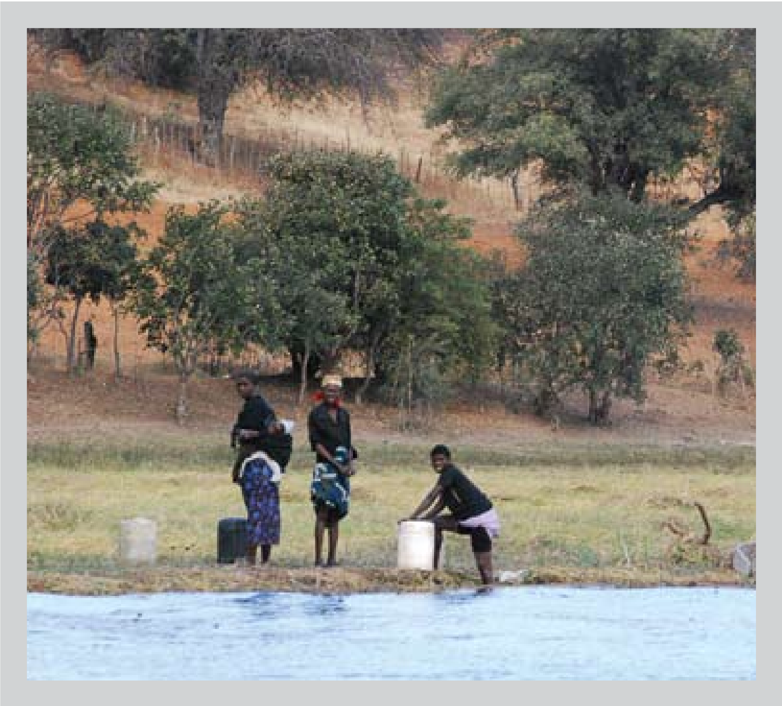
Mr Armindo Gomes da Silva, Co-Chairperson, OKACOM, Angola

The TDA is an important step towards elaboration of the SAP that will consitute the technical foundation for the signing of important agreements among the three capital Member States of the Cubango-Okavango River Basin. These agreements will allow OKACOM to have successful examples of participatory management of this important river basin and be assured that the countries who depend on its resources receive the best return on investment made in a sustainable and equitable manner.

Based on a series of specialist country reports, the TDA first summarises the present-day Okavango River Basin, its natural environment and people, and then the macro-economic status of the basin and its governance structures. This information allowed identification of a series of possible pathways, or scenarios, which water resource development could take in the future. A comprehensive Integrated Flow Assessment (IFA) was then undertaken to establish the potential ecological, economic and social implications of each scenario. The IFA was undertaken by a multidisciplinary group of scientists in each country, working with an international process management team. In total, more than 40 specialists worked together as one basin-wide team.

The report points out that the increased demand for domestic water and sanitation is likely to be comparatively small and should be promoted as quickly as possible to enhance quality of life. Other new water uses, particularly irrigation, should proceed with much more caution, with basin-wide comprehensive studies made for all major projects before decisions are taken. The report concludes that, to provide for people and protect the river ecosystem, growth and jobs that use less water would be an appropriate development pathway for the basin. These findings form the foundation of the SAP, which outlines a structured process to address peoples' needs and identifies potential threats to the basin's land and water systems.

The report concludes that, to supply the people and protect the ecosystem of the basin, the growth of productive activities using a low level of water consumption would be an appropriate development path for the basin. These findings are the foundation of the SAP, which emphasizes a structured process of addressing the needs of populations, as well as the potential threats identified for land and water resources within the boundaries of the basin.

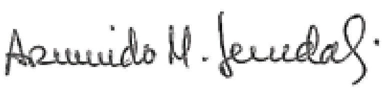


Fetching water from the river, near Rundu, Kavango Region, Namibia, 2009

Two further aids to development planning have been provided through the TDA. The first is a custom-built decision support tool that houses the knowledge and data collected during the IFA study, as well as the process for producing predictions of change. The tool can be used to explore any further water resources development scenarios of interest, and can be updated with new knowledge and technology over time. The second aid is the concept of Acceptable Development Space, which may be seen as the difference between current conditions in the basin and the furthest level of water resources development, in terms of the river degradation it would cause, that is found jointly acceptable by the countries. Identifying that limit and then planning to share the benefits of development that stay within the basin may be seen as truly sustainable development. These aids, with the findings of the TDA and the SAP, will allow our three countries to explore more water resources development scenarios of interest. We will be able to negotiate, plan and decide on the future of the basin founded on the best available knowledge and techniques.

I am proud to present this document as the fruit of several years of hard work, intensive research and a lot of patience. The various people involved in elaborating the present TDA managed to overcome difficulties in the logistics, communication and resources required for creation of this unique study. The result not only provides OKACOM with an essential reference to be used for future planning and decision making, but also enables the Commission's growth. I am certain that we have created solid pillars for a southern African River Basin Organization that is knowledge based and embraces SADC's forward looking water management principles.

We acknowledge that much remains to be done to ensure a good future for the basin and its people. I can also state with conviction that we have taken firm and sustainable steps in this shared journey.



Eng. Armindo Gomes Mario da Silva,
Co-chairperson
OKACOM, Angola

Local boatman, Namibia, 2008

EXECUTIVE SUMMARY

The Cubango-Okavango River basin remains one of the basins least affected by human impact on the African continent. In its present near-pristine status, the river provides significant ecosystem benefits and, if managed appropriately, can continue to do so. However, mounting socio-economic pressures on the basin in the riparian countries of Angola, Botswana and Namibia, could change its present character and there is therefore a critical need to establish sustainable management of its resources. The riparian countries recognize that economic and social development within the basin is essential and there is a need for it to be balanced against conservation of the natural environment and ecosystem services currently provided. This requires basin-wide understanding, agreement of the basin's problems and issues, and a blueprint for a development pathway guided by an adaptive management process.

The Cubango-Okavango River rises in the headwaters of the Cuito and Cubango Rivers in the highland plateau of Angola. The topographic extent of the Cubango-Okavango Basin comprises approximately 700,000 km^2, but derives its principal flow from 120,000 km^2 of sub-humid and semi-arid rangeland in the Cuando Cubango Province of Angola. The basin is drained by the Cubango (referred to as Kavango in Namibia and Okavango in Botswana), Cutato, Cuchi, Cuelei, Cuebe, Cueio, Cuatir, Luassíngua, Longa, Cuiriri and Cuito Rivers and the Okavango Delta. Flowing from the Angolan highlands the Cubango-Okavango forms the boundary of Namibia and Angola, and on this stretch is joined by the main tributary, the Cuito, before flowing through the panhandle as it enters Botswana and spilling into the Cubango-Okavango Delta or fan in Botswana. The outflow from the delta forms a set of evaporation pans in the Kalahari Desert, principally the Makgadikgadi Pans fed by the Boteti River.

The Cubango-Okavango River basin is internationally important for its biodiversity and biological productivity. The Okavango Delta is the best-known feature of the river basin and is one of the largest Ramsar Sites in the world. With its location, variety of habitats and resulting biodiversity it is globally one of the unique areas for biodiversity conservation. The wetland environment of the delta provides a staging post for birds migrating to southern Africa during the boreal winter and is a storehouse of globally significant biodiversity. The Cubango-Okavango River basin has national, regional and importantly global environmental value.

The basin supports predominantly rural communities most often located either adjacent to the river or along roads. Relative to capital cities and main centres of economic activity, the basin populations of these countries are remote; this is reflected in lower social development indicators in the basin than those for national social development. In general, the people of the basin are poorer, less healthy, and less well educated than other groups in their respective countries. This is particularly the case in Angola where the war curtailed social and economic development.

Forest, Cubango River, Angola, 2008

National social and economic development policies, including achievement of Millennium Development Goals (MDGs), target these communities and put added pressure on the water resources of the services provided by the river system. These services are important not only for the myriad of riparian community livelihoods they support, ranging from artesian fisheries to small scale agriculture, but also a major tourism industry in the Okavango Delta.

It has been recognised for many years that proposed water development projects may have an impact on the waters of the Cubango-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 some mechanisms and policies in place to manage potential impacts. They have an opportunity to delineate a development pathway and describe a development space for the basin that will meet national objectives without compromising the ecosystem services and diminishing the Cubango-Okavango's global value.

OKACOM AND MANAGEMENT OF THE CUBANGO-OKAVANGO RIVER BASIN

Commissioners Gomes da Silva, Angola, Paya, Botswana and Nehemia, Namibia, 2008

The 1994 OKACOM Agreement commits the three member states to promoting 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 the Permanent Cubango-Okavango River Basin Water Commission (OKACOM) was established and 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 Cubango-Okavango River basin. The role of OKACOM is to anticipate and reduce the unintended, unacceptable and often unnecessary impacts that occur as a result of uncoordinated resource development.

EPSMO AND THE CUBANGO-OKAVANGO TDA

The origin of the Global Environment Facility (GEF) Environmental Protection and Sustainable Management of the Cubango-Okavango River basin (EPSMO) Project lies with the formation of OKACOM in 1994. A preliminary Transboundary Diagnostic Analysis (TDA) was completed in 1998 and the EPSMO Project was later developed through a GEF PDF-B grant and formally launched in 2004. The project was implemented by the United Nations Development Programme and executed by the Food and Agriculture Organization (FAO).

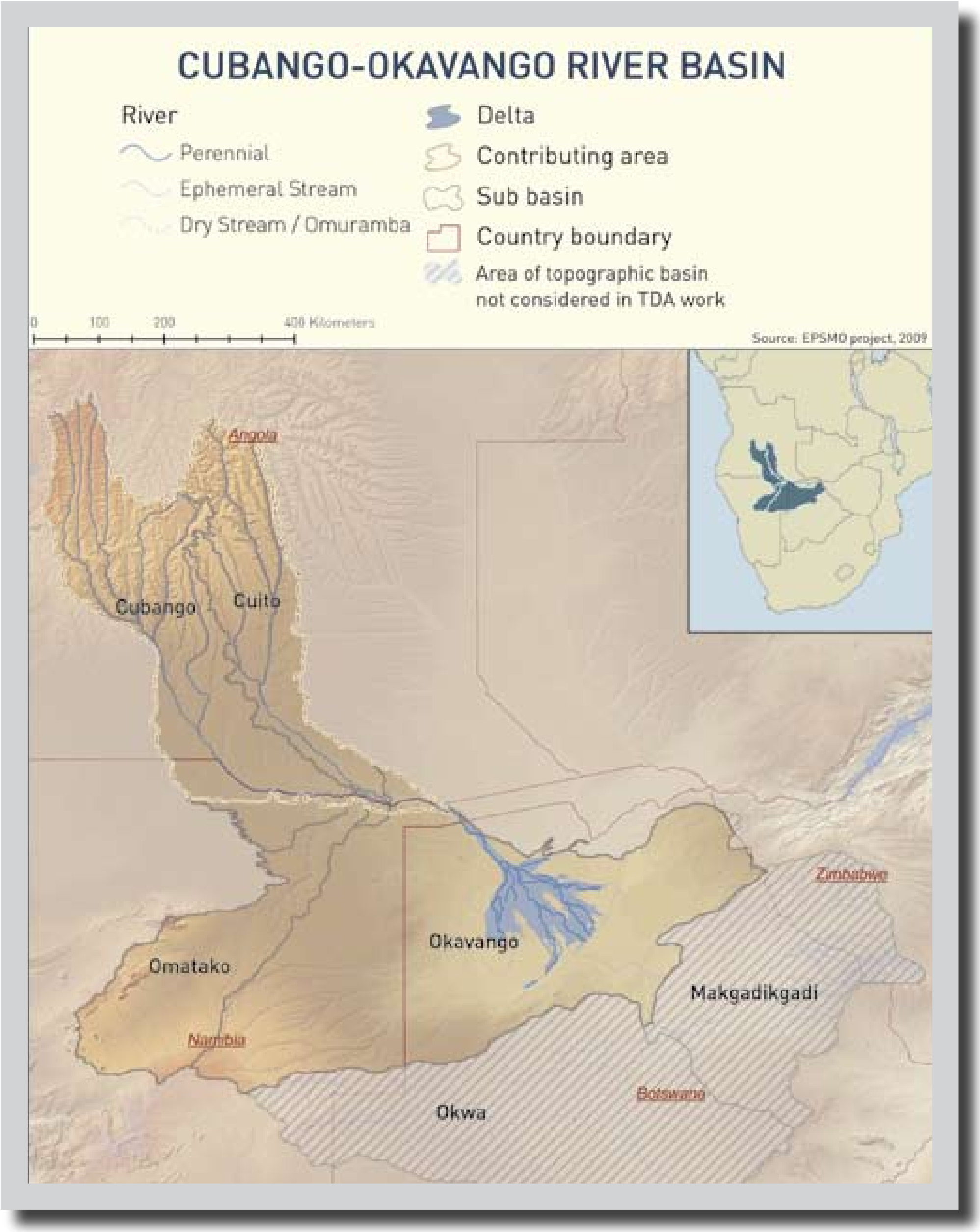
The long-term objective of the EPSMO Project was to achieve global environmental benefits through collaborative management of the naturally integrated land and water resources of the Cubango-Okavango River basin. The specific objectives of the project were to:

- 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 Cubango-Okavango River basin through a TDA.
- Develop and implement, through a structured process, a sustainable and cost-effective programme of policy, as well as 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.

The TDA is a scientific and technical assessment of the shared management issues and problems, both existing and emerging, of the Cubango-Okavango Basin. For priority issues, the analysis identifies the scale and distribution of the potential environmental and socio-economic impacts at national, regional and global levels. Through an analysis of the root causes it identifies potential remedial and/or preventative actions. The GEF International Waters (IW) TDA/SAP 'best practice' approach underpins the methodology used in the development of the Cubango-Okavango River basin TDA.

GEOGRAPHICAL SCOPE OF THE TDA

With the agreement of the Okavango Basin Steering Committee (OBSC) the geographical scope of the TDA is the whole Cubango-Okavango Basin. However, it should be noted that the TDA has limitations in some key issues such as groundwater interconnectivity. It has thus been agreed that in a future update of the TDA these issues will be addressed and the necessary studies will be included in the SAP.



Extent of the Cubango-Okavango River basin

TDA METHODOLOGY

The TDA is an analysis of the linkage between cause and effect in order to identify realistic targets and objectives to frame the SAP and to identify the most cost-effective remedial and preventative measures to address areas of transboundary concern. The areas of concern may be existing or emerging problems; in most international waters the majority are existing problems, the effects or impacts of which are observable and measureable. However, there are always emerging problems which cannot be characterized in terms of visible impacts and for which it is difficult to establish planning targets or describe preventative measures. In some special cases such as the Cubango-Okavango Basin it is the emerging problems rather than the existing problems that govern, and a standard TDA methodology does not apply.

For the Cubango-Okavango Basin, the TDA team had to re-think the objectives of the TDA and SAP and adjust the TDA methodology accordingly. The TDA's prime purpose, that of providing a scientific baseline for the SAP and helping identify, through the Causal Chain Analyses (CCA) the necessary management and decision frameworks for effective natural resources management, still remained. In addition, it also became a tool to assess the acceptable limits for basin development, providing information to establish a development 'vision' for the basin, which has been labelled the 'acceptable development space'. The steps undertaken in the TDA were as follows:

- Identification and initial prioritization of transboundary areas of concern
- Establishment of status or baseline conditions
- Identification of drivers and pressures and determination of water use scenarios
- Testing of scenarios and gathering and interpreting information on environmental impacts and socio-economic consequences of each problem through the Integrated Flow Assessment (IFA)
- Completion of a governance analysis of institutions, laws and policies
- Completion of an economic analysis of projected investments
- A Causal Chain Analysis for each identified priority problem to identify linkages and interventions for inclusion in the SAP and National Action Plans.

Four priority emerging transboundary areas of concern were identified by countries during the TDA process:

- Variation and reduction of hydrological flow
- Changes in sediment dynamics
- Changes in water quality
- Changes in the abundance and distribution of biota.

These are all emerging issues and reflect the development pressures on the basin not as yet realized.

Environmental Flows teamwork, Cape Town, South Africa, April 2009

TDA MANAGEMENT AND EXECUTION

Overall guidance for both the EPSMO Project and formulation of the TDA and SAP was provided by the Cubango-Okavango Basin Steering Committee (OBSC), one of the three organs of OKACOM. At the national level, project activities were managed by three national coordinating units (NCUs), headed by national coordinators, with sectoral integration being assured through three inter-sectoral committees. Led by the project manager and project coordinator, and in close contact with the NCUs, the project management unit (PMU), located in Luanda, Angola , coordinated all project activities. The PMU reported directly to the OBSC. In the development of the management structure for the EPSMO Project, a concerted effort was made to integrate project structures with existing regional, national and provincial structures.

In the development of the Cubango-Okavango TDA, it was decided to assemble three country teams coordinated by thematic coordinators and an overall integration team consisting of the thematic coordinators, project personnel, the country team leaders and other key specialists. The strength of this approach was that each country team was able to assemble and interpret its own national information, which was especially important in Angola, where both language and scarcity of information had been a problem in the earlier studies.

The joint understanding of transboundary issues was encouraged through a series of integration meetings of the IFA specialists and the overall TDA integration team. The TDA integration team met on three occasions 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 Analyses and refine the contents of the TDA report.

A key person in the overall development of the TDA was the EPSMO coordinator, who was directly involved with all of the studies and provided guidance and general coordination for the TDA integration team. Working with the PMU, he was supported by the national TDA coordinators in each country, who ensured linkage with the national teams and provided additional information as required.

Mother and children at the Thamalakane River, Botswana, January 2010

INTEGRATED FLOW ASSESSMENT

The IFA was a major component of the TDA, looking at the relationship between water use and changes in hydrological flow, and consequent changes in ecology and socio-economics at specific sites in the basin. The IFA took as its starting point hydrological simulations of how the pattern of flows would change along the river system under high, medium and low water-use scenarios. A regional team of experts collaborated in a research programme that ended with the capture of 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'.

Algae in Thamalakane River near Sexaxa, Botswana, 2010

The IFA provided the TDA with critical understanding of the behaviour of the basin under increasing water-use development and an indication of type and scope of 'acceptable development space'. It was a first attempt to develop such scenarios in a basin-wide exercise and questions have arisen regarding the coverage and quality of the baseline hydrological and other data and the limitations of power of the hydrological modelling. Following the predictions of hydrological change, the ensuing ecological, social and economic predictions were based largely on expert opinion because relevant data were sparse. The IFA should therefore be viewed as a pilot study and the scenario predictions used with caution and refined through future focused research.

TRANSBOUNDARY AREAS OF CONCERN

Four priority emerging transboundary areas of concern were identified by countries during the TDA process:

- Variation and reduction of hydrological flow
- Changes in sediment dynamics
- Changes in water quality
- Changes in the abundance and distribution of biota.

Four underlying driving factors were identified:

- Population dynamics
- Land-use change
- Poverty
- Climate change.

The present population in the basin is 921,890. By 2025, this is projected to increase to more than 1.28 million people, with 62 percent living in Angola, 16 percent in Botswana and 22 percent in Namibia. 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 percent, Botswana 30 percent and Namibia approximately 20 percent. Increased urbanisation leads to increased demand for services such as water supply and sanitation, which, if not regulated, could lead to increased water pollution.

Kavango River near Rundu, Namibia, 2010

Land-use change is a driving force for changes in sediment dynamics, water quality and abundance and distribution of biota, and has impacts on the hydrological regime through deforestation. Linked strongly to population growth, its impact is incremental and often very difficult to reverse. Despite the relatively low population densities in the Cubango-Okavango River basin the changes in land use and vegetation cover has been marked. There is increased demand for land for crops along the length of the river from the Angolan highlands to the panhandle and with an increasing population this trend will only accelerate.

The impact of land-use change may be more significant than that of direct increased water use and its control a more difficult challenge. A first step is to assess the problem and to recognise the barriers to reform, including national legislation and its implementation at local level. Ideally there should be a set of land-use guidelines which the local authorities can follow and implement throughout the basin, aimed at preserving the ecosystem, health and environmental services. The implementation of these guidelines will require extensive public education campaigns starting with basin communities and continuing through to local institutions.

Poverty is a feature of the human populations of the basin in all three countries. This is partially due to the remoteness of the basin, but also the highly unequal distribution of wealth in the three countries. Poverty alleviation in the basin is a major investment target for governments and the three countries have national poverty reduction strategies aimed at improving the welfare and living conditions of their populations through increased economic growth and linked to the MDGs.

An analysis of projected climate change effects predicts a rise in temperature and rainfall in the basin. Higher temperatures (2.3 °C–3 °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 percent across the Basin, with the greatest effect in the north because of the north-south rainfall gradient. In general, 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.

VARIATION AND REDUCTION OF HYDROLOGICAL FLOW

The Cubango-Okavango River is a 'losing' system in that all its water originates from the upper catchment, the headwaters of the Cubango and Cuito, and water is then lost through evapo-transpiration and groundwater recharge with small quantities of water flowing out of the delta. The water availability may be adequate during flood flows, but during low flows the lack of water may be critical. It is significant that all the water in the basin is generated upstream of the confluences of the Cubango and Cuatir Rivers in the west and the Cuito and Longa Rivers in the east. Downstream of these points, the catchments of the lower Cubango and Cuito Rivers contribute very little additional runoff. For these reasons some parts of the river can withstand hydrological change better than others.

The overall trend is for run-of-river abstractions to reduce flows throughout the year, with the effect being particularly noticeable in the dry season. Under the conditions modelled, dry-season flows would tend to be lower, start earlier and last longer with flood volumes becoming progressively smaller; the flood season would become shorter and start a little later. Flood peaks are not reduced significantly and there is no marked transfer of water from the flood season to the dry season, as there is in many developed basins, since there is little storage infrastructure within the basin.

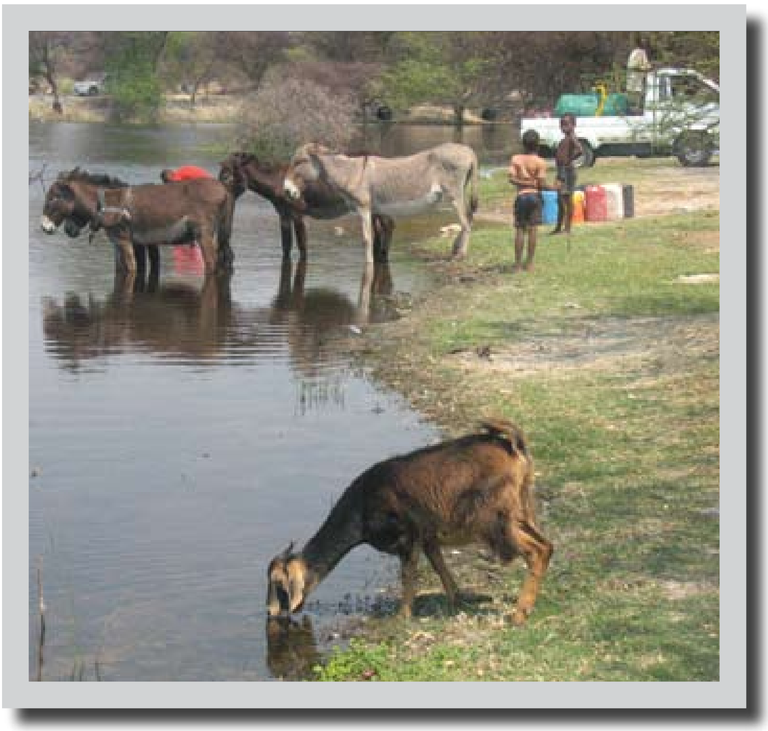
The additional water that would need to be abstracted from the river to meet the demands of various planned developments if executed in full over the next 15 years, would be 3,768 Mm^3/a, of which 3,715 Mm^3/a would be for new irrigation development. This figure compares with a mean average flow of the lower river of 9,600 Mm^3/a and a 1 in 20 year drought flow of 3,120 Mm^3/a and therefore high level abstractions cannot be supported without development of substantial upstream storage. Growth in demand over the next 15 years is dominated by an increase in irrigation demand. In comparison, the rise in domestic demand (urban and rural) of 6 Mm^3/a over the same period is insignificant and its impact on the river system would be negligible. The provision of safe drinking water for both urban and rural populations is one of the most urgent economic developments and should be advanced as quickly as possible.

It is not clear whether the potential level of irrigation development is sustainable in the Cubango-Okavango River basin for a number of reasons:

- The economic feasibility of some of the schemes is questionable even under the most favourable economic conditions once the trade-off between loss of livelihood value and increase (or loss) in national economic benefit has been taken into consideration
- The economic feasibility becomes even less favourable once the indirect as well as the direct costs of the irrigation developments are taken into account – the global value placed on the Cubango-Okavango Basin and Delta and the willingness to preserve them as biological treasures
- The remoteness of the schemes and the cost of infrastructure required to transport goods to market and the need for confirmation that the markets exist (nationally, regionally and internationally) for the planned produce
- The suitability of the soils for large irrigation schemes
- The impact of the schemes on the sediment regime and water quality, and the cost implications.

The potential irrigation schemes need to be assessed in more detail and a strategic environmental assessment for the whole basin needs to be undertaken.

While water use developments are aimed at increasing the amount of income derived from the river system, particularly in the upper basin, this may not necessarily reduce poverty. The poverty within



Using water from the Boteti River, Botswana, 2008 the basin may be exacerbated if higher uses of water are developed, because of a reduction in the all-important environmental services.

People in the Angolan part of the basin currently derive relatively little river-based income, although all the basin's water comes from Angola and it has 57 percent of the basin population. Botswana, with only 18 percent of the basin population, derives by far the bulk of the river-based income. The water use developments could reverse this imbalance but, as formulated, they could equally destroy the very significant current and future income from the lower basin, which is almost entirely dependent on ecosystem integrity.

Subsistence agriculture, Tchinhama, Huambo Province, Angola, 2007

There is a need to strengthen the meteorological and hydrological monitoring programmes in the basin. There are very few hydrological stations operable in the upper basin and this lack of baseline data is a weakness in the hydrological modelling studies undertaken. The cost of constructing new or re-establishing old monitoring stations would be considerable and would be a long-term investment.

Qualitative and quantitative research needs to be carried out to determine the hydrogeological characteristics of the basin and how these affect river flows, and to quantify the usable groundwater resources potential. The inter-connectivity of the groundwater and surface water systems should be evaluated and the contribution of groundwater should be assessed. The problem of saline aquifers and their interfaces with non-saline groundwater as well as of recharge mechanisms in the basin still need to be investigated thoroughly.

The issue of flooding and flood protection has not yet been investigated thoroughly in the context of an integrated water resource strategy. Flooding is a natural annual event central to the well-being of the river ecosystem but it can also cause tremendous damage and hardship to the basin population. There is a need to identify the areas susceptible to flooding and develop strategies to mitigate potential damage. This includes flood-preparedness plans, government response information, flow of information and lines of command and decision structures, and a public information system. Similar plans should be developed for droughts and pollution incidents.

Bird nests in river bank, Okavango Panhandle, Botswana, 2008

CHANGES IN SEDIMENT DYNAMICS

Sediment transport is known to be as important to the health of the river and delta as hydrological flows, but knowledge of the impacts caused by changes in these flows is limited. The establishment of a robust monitoring programme at key points within the system would be a first step to improving this knowledge.

Increasing erosion in the Angolan highlands as a result of deforestation and cultivation of more land has for some time been increasing sediment load. As land is cleared and cultivated more soil is eroded and carried down from the catchment into the river. Thus, not only will land areas be lost, but quantities of sediment in the river will increase, which could increase turbidity, reducing light and dissolved oxygen, and threaten aquatic habitats.

The floodplains are coming under stress from changing land-use patterns and the expansion of traditional agriculture and deforestation. Impacts include reduction of environmental services through degrading of the floodplains and alterations to the sediment regime which in turn affect the water quality and the productivity of the lower basin and the delta.

Okavango Delta before flood waters or rainfall, October 2009

Degraded riverbanks and loss of riverine forest are two of the most visible impacts of increasing land-use change. Campaigns to restore these features will directly improve the environmental status of the river and require community involvement and educational programmes to build an understanding of the importance of their protection.

CHANGES IN WATER QUALITY

At present the water quality of the Cubango-Okavango River is considered to be very good, characterized by low suspended solids and turbidity, with clear waters, low nutrients and low organic content. However, the data available on water quality is meagre and limited to a few parameters and even in the lower basin, does not give a clear picture of the current status. Thus the statements regarding water quality being generally good are considered reasonable but cannot be supported. There is some commentary on pollution sources but this is of a generic nature, and locations and impact on ambient water quality are not defined. This is one of the most critical knowledge gaps within the TDA.

Clear sweet water at Xigera area, Okavango Delta, Botswana, October 2010

Of the threats caused by direct pollution, the development of irrigation and its potential increase in discharge of agro-chemicals is probably of most concern. It is difficult to predict levels of pollutants from returned irrigation water because these will depend upon the soils, crops, cultivation practices and efficiency of irrigation, but the threat is present. In general, the greater the efficiency of irrigated water use, the lower the pollutant content in the returned water. Changes in nutrient levels affect the overall productivity of the system, probably changing the river from a nutrient poor to a nutrient rich system, with the consequent risks of eutrophication. The discharge of persistent organic pollutants such as pesticides from irrigated agriculture, malaria control and tsetse fly spraying is not significant at present. However, if these are not limited, they could enter the water, sediment and food chain of the river, with unknown long-term consequences for the health of people exposed to them.

The provision of sanitation services in the basin is limited and, for public health and environmental reasons, there is an urgent need to improve treatment of municipal waste, which is currently a major pollution source.

The balance of salinity in the delta is finely tuned and highly dependent upon the flow regimes. Local salinity changes are a recognized function in the development of islands and vegetation patterns in the delta. Overall reductions and changes in the seasonal and geographic distribution of floodwaters in the delta could increase local salinities and alter the ecosystem balance in different parts of the delta.

In addition, salinity in return waters from irrigation schemes will be elevated; it is not clear what impact this may have on the river basin and the delta.

The scale and frequency of water quality monitoring in the three countries is very limited (or non-existent, depending on the country) and establishment of monitoring programmes should be seen as a priority. The design of any monitoring programme must take into account the remoteness and extent of the region, the technical capacity available and the existing decisions that the monitoring system is to support. The inclusion of biological monitoring is seen as an ideal screening methodology for the Cubango-Okavango since it is cost effective for large areas and can be implemented by semi-skilled personnel and linked to community programmes.

CHANGES IN ABUNDANCE AND DISTRIBUTION OF BIOTA

In ecological terms the abundance and diversity of flora and fauna in the Cubango-Okavango River basin and especially in the delta is outstanding. Any human-induced change in flow regime will threaten the biodiversity make-up along riparian belts and across floodplains. Conversion of floodplains and destruction of the riparian belts will decrease the capacity of the system to buffer the hydrology and water quality of the river. The risk of losing these key natural aquatic management options is likely to increase under conditions of higher water use.

Giraffe near Mombo Camp, Okavango Delta, Botswana, October 2010

The Cubango-Okavango biosphere is under pressure from expanding human settlements and infrastructure. As the population increases, so pressure from harvesting, fishing and hunting of natural resources will increase, inevitably leading to overexploitation and reduction in the abundance and even loss of some species. Land cover changes from overgrazing, deforestation and land transformation for farming contribute to the pressures on the system, as do extensive and prolonged fires. Particular pressures can already be seen on the riparian vegetation, especially in Namibia, as well as over-use and degradation of the floodplains.

As part of the water resources assessment, minimum environmental flows should be established based on international 'best practice' at key locations in the river basin. Minimum flow restrictions would provide the bounds for any water development and help define the development space.

Knowledge of the upper basin biodiversity needs to be expanded and a monitoring programme based on revised indicator species established. Research is required into the functioning of the floodplains and the environmental services they provide, and guidelines must be produced for management of wetlands and community-based use of natural resources.

As the population grows and more land is used for agriculture and livestock so the conflicts between humans and wildlife will grow. Game corridors should be established in critical areas and strategies for mitigation of human/wildlife conflicts need to be developed at selected sites.

Invasive species are potentially one of the most damaging threats to the Cubango-Okavango and the countries need to be ever vigilant and ready to respond as quickly as possible in a coordinated manner. Knowledge of existing species and potential species needs to be expanded and counteractive measures put in place.

KEY FINDINGS AND RECOMMENDATIONS

In undertaking an expert analysis of a series of water-use scenarios, the TDA has painted a picture of change in terms of environmental and socio-economic impacts, which could emerge in the Cubango-Okavango if development is not managed. This picture is the first step in understanding how the Cubango-Okavango River system could respond to increased human pressure and its capacity to absorb change. Development is inevitable to improve the lives of the basin people, but if it is to be sustainable, the speed and scale of the development must not exceed capacity of the system to accommodate it, moving it from a high to a low productivity state.

Source of Cubango River, Angola, 2007

Political interests to utilize the Cubango-Okavango's resources are strong and need to be managed within a solid regulatory system underpinned by sound knowledge of the basin, if damaging, costly and irreversible decisions are to be averted. World experience illustrates that decisions should be made at river basin level (the natural planning unit), integrated across economic sectors and involving as wide a range of stakeholders as possible. There are guidelines and models for good governance but there are no off-the-peg solutions. The countries need to decide how best to address these issues and adapt and amend the guidelines to their specific basin characteristics.

Understanding the basin and how it could respond to development is an immensely complex task and a clearer picture is only now beginning to emerge. Development will come in all forms and in different regions of the basin, producing a mosaic of impacts. The TDA team, in particular through the IFA, has tried to predict these impacts and identify the myriad of linkages between them. It has also, through a groundbreaking economic analysis, compared and contrasted a set of development scenarios under different macro-economic backdrops. By monetizing the impacts in terms of losses of environmental services, the TDA has been able to compare the long-term economic benefits of large-scale development programmes, such as irrigation and hydropower, with more varied development pathways.

Key technical findings of the TDA and IFA in terms of forward planning:

1. The Cubango-Okavango River system is a floodplain-driven system, with floodplains that sustain the river in the dry season and store floodwaters that would otherwise increase flooding downstream. 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 Cubango-Okavango River, the Okavango Delta and the outflowing Thamalakane and Boteti Rivers are sustained largely by the annual flow regime of the Cuito. If these ecosystems and structures are taken into consideration at basin level, water resources development along the Cuito or intervention in the functioning of its floodplains should be modest and undertaken with caution.

2. The river and its floodplains provide significant ecological services which support the livelihoods of a large proportion of the basin's population. The livelihood support is more marked in the downstream countries of Namibia and Botswana than upstream in Angola. The delta, for example, is a significant source of revenue for Botswana in terms of a tourism industry estimated to be worth over US$400 million/annum.
3. While water-use developments are aimed at increasing the amount of income derived from the river system, particularly in the upper basin, this may not necessarily reduce poverty. Poverty within the basin may be exacerbated if water resources development proceeds, because this would reduce the important ecosystem services that the riparian dwellers rely on.
4. Potential growth in water demand over the next 15 years of 3,768 Mm^3/a is dominated by an increase in irrigation demand and in comparison the rise in domestic demand (urban and rural) of 6 Mm^3/a over the same period is insignificant and its impact on the river system would be negligible. The provision of safe drinking water for both urban and rural populations is one of the most urgent economic developments and should be advanced as quickly as possible.
5. The increased potential abstraction is a significant portion of the mean average flow of the lower river of 9,600 Mm^3/a and exceeds the 1 in 20 year drought flow of 3,120 Mm^3/a, and therefore the high scenario cannot be supported without development of substantial upstream storage.
6. 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.
7. Any development that does take place on upper tributaries is likely to have impacts that are largely limited to the Angolan part of the basin. The severe impacts described for the lower part of the river system under the high scenario are less easily mitigated as they would result from many developments along the whole system. Increasing the number and nature of developments as one moves from low to high scenarios will inevitably extend the impacts from localized to transboundary and push the river ecosystem into significant degradation. Mitigation could realistically only be addressed by planning and managing at basin level.
8. For all vegetation types in the delta, the high scenario would show a much greater change than the other scenarios, with the various types of permanent swamp decreasing to about 22 percent of present day average levels and seasonal swamp types increasing to 104–178 percent of present day average levels.
9. It is estimated that the livelihoods value will drop from the present day estimate of US$60 million per year to just over US$30 million per year for the Low Scenario and under US$10 million per year for both Medium and High Scenarios. A similar pattern is shown in the national direct economic contribution which shows a decline from US$100 million per year to about US$50 million per year for the Low Scenario and to under US$10 million per year for the Medium and High Scenarios. These dramatic declines in both livelihood and national incomes are primarily as a result of declines predicted for tourism in the Okavango Delta.
10. Balancing the losses in livelihood value and direct economic contributions against gains from development of irrigation, hydro-power, public water supply and sanitation, a net loss from US$700 million for the low scenario through to US$1.4 billion for the medium and high scenarios is predicted. Even under optimistic assumptions the net returns would remain negative under the low (-US$260 million) and medium (-US$1 billion) scenarios. Only with the full implementation of the irrigation schemes do net returns turn positive (+US$215 million) under the optimistic projection.
11. The economic analysis does not include an evaluation of the existence of the Cubango-Okavango River and delta – what is its global worth as a biodiversity treasure? If this were to be included, the economic viability of the Medium and High Scenarios would be further diminished.

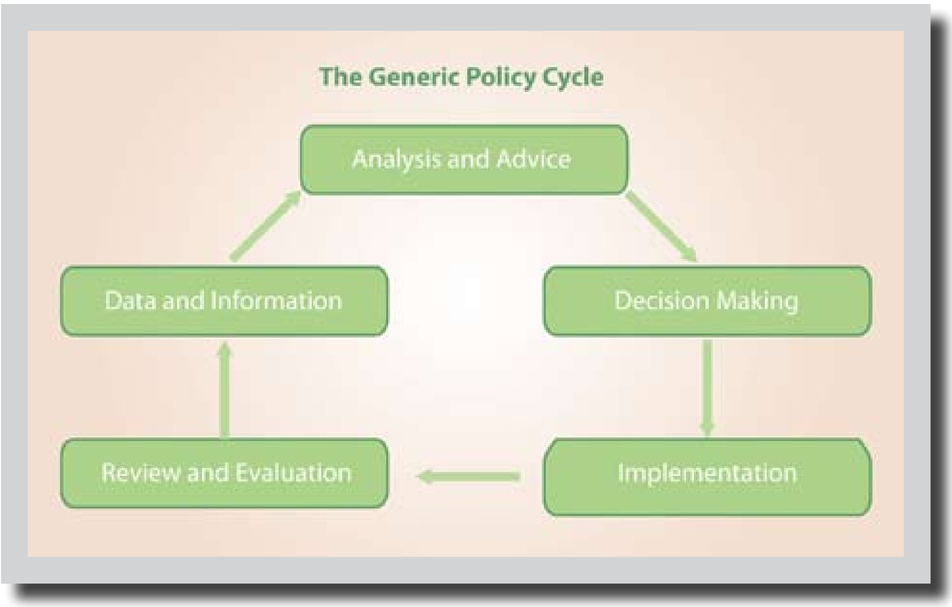
Missombo irrigation scheme, Angola, 2008

In summary, the high and medium scenarios could generate an order of magnitude of economic losses and risks that could overwhelm the potential benefits of the full suite of proposed water resources development across all three countries. Caution and further study are therefore called for before proceeding with specific development projects. There is a need to investigate alternative development pathways including the enhancement of basin livelihoods, which would take advantage of existing environmental services.

Botswana review of the TDA, OKACOM Secretariat, Botswana, 2009

Key findings from the governance and policy review:

1. The analysis of the policy and legal landscape in the three basin countries shows a relatively strong framework of natural resources management policies and legislation, although there is some variation between countries.
2. Of great importance for integrated basin management is that all countries have replaced old water legislation with integrated water resources management (IWRM)-based water legislation that emphasizes 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.
3. 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 local level, a lack of skills, management capacity and resources for integrated planning, and effective monitoring, implementation and enforcement.
4. OKACOM was established as a cooperation, coordination and information-sharing platform for the three basin states with respect to water resources management. It is clear that it has a central role to play in the management of the basin, especially as there are no established basin-wide cooperation mechanisms in other natural resources management fields, such as land use or biodiversity.
5. Integrated water resources management cannot be undertaken effectively without considering issues of land management and other natural resources use aspects. However, this need is not yet reflected in the composition of national delegations of all countries to OKACOM and/or to the OBSC. Given the importance of agriculture and energy issues, increasing the diversity of sectors represented in the different organs of OKACOM would allow greater



Generic policy cycle

consideration of and coordination between different sectors.
6. 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 a more detailed basin management plan is developed and implemented. This requires further strengthening of its capacity, particularly at an operational management level.
7. Closer direct links 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 address this matter adequately. The institutional links between local basin management committees and OKACOM could also be incorporated as an integral part of the stakeholder participation strategy.

Signing TDA community participation MOU with local NGO, Capico, Angola, 2008

From a planning perspective, the countries need to set out a vision for the basin with objectives for major directions and a description of 'acceptable development' space. As part of the vision-setting exercise, a decision framework with thresholds and trigger points should be developed to guide the decision making process and for which a decision-support system (DSS) should be developed.

Key questions to achieving sustainable development are:

1. What is the level of water resource use that is sustainable in the Cubango-Okavango River basin; what is the 'acceptable development space'?
2. How best to use the water resources available in terms of economic development – are there alternative development trajectories to those currently being proposed?

The decision support tool developed under the IFA should be expanded to a full DSS that would support a basin-wide decision framework agreed on by the countries. The DSS would consider impacts not only of variation and reduction in hydrological flow but also changes to the sediment regime, land use, water quality and biodiversity. An integral part of the DSS would be an information management system that would operate on a number of levels and contain, among others, water resources, land use, fisheries, socio-economic and biological databases.

The countries need to strengthen the governance cycles and to integrate them across the sectors: horizontally and vertically, basin-wide and to local levels. This is an immense challenge and cannot be achieved in the short term. It should be seen as work in progress but it must keep up with the planning process in the three countries.

Reviewing the recommendations in the TDA, in particular in Chapters 5, 6 and 7, and based on guidelines for Integrated Water Resources Management, the following interventions should be considered:

Establishment of shared basin-wide vision and strengthening of decision frameworks at national and basin-wide levels (decision making)

- Development of a shared vision for the development and protection of the Cubango-Okavango River system and its people
- Development of an adaptive decision framework based on IWRM principles

- Expansion of the OKACOM mandate to include natural resources management and strengthening the capacity of the OKACOM secretariat to undertake a management role, including overseeing of the Strategic Action Plan
- Establishment (where necessary) and strengthening of appropriate local level management entities in line with existing national legal frameworks
- Development and adoption of Environmental Impact Assessment/Strategic Environmental Assessment (EIA/SEA) procedures in a transboundary context.

Strengthening of natural resources management and regulation at local, national and basin-wide levels (implementation)

- Establishment of a research-based environmental flow regime for key points along the river system designed to maintain ecosystem conditions in the shared catchment vision
- Establishment of common methodology for assessment of reliable surface and groundwater yields, to include climate change scenarios
- Inventory of abstraction for both surface and groundwater
- Harmonization of land-use planning guidelines
- Development of wetland management guidelines
- Programme of riverbank and riverine forest restoration
- Establishment of game corridors
- Inventory of pollution sources
- Harmonization of water quality standards and monitoring protocols; development of a water classification system
- Strengthening of national permitting and licensing procedures for water abstraction and pollution discharge
- Strengthening of national policing and enforcement measures for water abstraction and pollution discharge
- Introduction of economic instruments to promote sustainable, integrated natural resources management
- Transboundary control programmes established for control of invasive species.

The SAP is a basin-wide mid-term planning document for the Cubango-Okavango River basin that lays down the principles for the development of the basin and improvements of the livelihoods of its people through the cooperative management of the basin and its shared natural resources. The SAP has been developed over three years (2008–2010) through a consultative process with a wide range of stakeholders from government departments, academic and scientific institutions, to civil society, the private sector and community representatives. It is a coordinated management response to the problems posed by the Driving Factors and Priority Areas of Concerns that were identified through this TDA.

Establishment and strengthening of regulatory monitoring programmes (review and evaluation)

- Strengthening of meteorological and hydrological monitoring networks for surface waters
- Development of water quality monitoring programme for surface waters
- Strengthening of groundwater monitoring network
- Expansion of biodiversity monitoring in the upper basin.

Development of basin-wide information management system and filling of knowledge gaps (data and information)

- Development of an information management system
- Conducting a contaminant survey of river sediments throughout the basin to provide a historical baseline
- Development of socio-economic database
- Mapping of land-use potential in the basin
- Vegetative mapping of basin wetlands classification based on conservation status
- Conducting a strategic environmental assessment of irrigation development in the Cubango-Okavango Basin

Fish catch on the Boteti River, Botswana, 2008

- Researching inter-connectivity of surface waters and major aquifers
- Reviewing climate change scenarios and impacts.

Development of decision support system and common planning framework (analysis and advice)

- Upgrading of water resources and hydrological models
- Development of a flood-forecasting model and early warning system
- Expert assessments of potential changes to water quality, sediment transport and biota
- Up-dating the economic assessment of development options
- Strategic environmental assessment of irrigation development in the Cubango-Okavango Basin
- Design decision support system and interface to service decision framework
- Development of a strategic water resource plan for the basin including review of development options
- Development of a water quality improvement plan.

The above represent some of the key elements to be included in the SAP for the Cubango-Okavango River basin. The SAP should also include specific interventions to enhance and develop basin livelihoods, since a clear message from the TDA was that alleviation of poverty in the basin should be achieved not only through large-scale economic development but also through supporting better use of the environmental services provided by the river ecosystem. The SAP should include pilot and demonstration projects targeted at specific livelihoods, including the establishment or development of:

- Demonstration projects on sustainable rangeland management
- Fishing reserves
- Tourism plans for the Cubango-Okavango River basin
- Feasibility studies of new or extended agricultural markets
- Community-based climate change adaptation projects linked to agriculture.

Grain storage basket, Cafima, Cunene Province, Angola

The SAP should also include a comprehensive capacity and training programme to reinforce the above interventions through promoting ‘learning by doing’. The training programme should be aimed at institutions at all levels and a wide range of stakeholders. Finally, the SAP should contain references to water supply and sanitation programmes in line with the MDGs. The TDA analysis has illustrated the economic benefits of these measures and their insignificance in terms of water use and, in the case of improved sanitation, the positive impact on the basin’s environmental services.

The SAP is a guidance document for Angola, Botswana and Namibia. Implementation of the SAP measures is through the NAPs, which underpin the SAP and are part of the national planning procedures. The NAPs address both regional and national priorities and draw upon the findings of the TDA and relevant national studies and projects.

CHAPTER 1: INTRODUCING THE CUBANGO-OKAVANGO RIVER BASIN

The Cubango-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, if managed appropriately, can continue to do so. However, mounting socio-economic pressures on the basin in the riparian countries of Angola, Botswana and Namibia could change its present character and there is therefore a critical need to establish sustainable management of its resources. The riparian countries recognize that economic and social development within the basin is essential and there is a need for it to be balanced against conservation of the natural environment and ecosystem services currently provided. This requires basin-wide understanding, agreement of the basin's problems and issues, and a blueprint for a development pathway guided by an adaptive management process.

Legal and institutional frameworks for transboundary cooperation already exist in the form of the 1994 Permanent Okavango River Basin Water Commission (OKACOM) Agreement, the 2007 Agreement on the 'Organisational Structure for the Permanent Okavango River Basin Water Commission' (OKACOM Structures Agreement) and the Southern African Development Community Revised Protocol on Shared Watercourses of 2000 (Revised SADC Protocol).

Commissioner Dr Akolang Tombale and Minister of Environment, Wildlife and Tourism Mokaile at inauguration of OKACOM Secretariat, 2008

Guided by these three agreements, the riparian countries are working towards development and implementation of an integrated management plan (IMP) for the basin on the basis of an environmental assessment (EA). In support of this objective, the Global Environment Facility (GEF) and United Nations Development Programme have provided assistance to OKACOM since 1994 to undertake a Transboundary Diagnostic Analysis (TDA) of the potential problems and threats to the Cubango-Okavango Basin and develop action programmes at basin and national levels to counter those threats. The TDA presented here was formulated by OKACOM with funding from both the GEF and the riparian governments. This document is an objective, non-negotiated analysis using best-available verified scientific information. It examines the state of the environment and identifies and describes priority transboundary issues.

Through an integrated flow assessment (IFA) study and detailed economic study of a set of water development scenarios in the basin, the Cubango-Okavango TDA goes further in identifying potential impacts and provides the foundation for decision makers to agree on a development pathway and development space for the basin. The IFA and economic study are fully described in Chapter 4 of the TDA and the supporting results are annexed.

This work exceeds what would normally be carried out for a TDA and reflects the importance the countries attach to establishing a solid management framework for future development within the Strategic Action Programme (SAP). It is seen as a model analysis for river basins where development and environmental protection need to go forward in parallel. The TDA provides the factual basis for the formulation of a Cubango-Okavango Basin Strategic Action Programme, which will embody specific policy, legal and institutional reforms and investment options that can be adopted nationally to address the emerging and existing priority transboundary problems identified in the TDA within a harmonized multinational context.

Figure 1.1: The geographic location of the Cubango-Okavango River basin in southern Africa

1.1 THE CUBANGO-OKAVANGO RIVER BASIN

The Cubango-Okavango river rises in the headwaters of the Cuito and Cubango Rivers in the highland plateau of Angola. The topographic extent of the Cubango-Okavango Basin comprises approximately 700,000 km^2, but derives its principal flow from 120,000 km^2 of sub-humid and semi-arid rangeland in the Cuando Cubango Province of Angola. The basin is drained by the Cubango (referred to as the Kavango River in Namibia and Okavango River in Botswana), Cutato, Cuchi, Cuelei, Cuebe, Cueio, Cuatir, Luassíngua, Longa, Cuiriri and Cuito Rivers and the Okavango Delta (Figure 1.1).

Flowing from the Angolan highlands, the Cuito and Cubango Rivers meet to form the Cubango-Okavango along the border of Namibia and Angola before flowing through the panhandle and spilling into the Okavango Delta or fan in Botswana. The inflow from the delta forms a set of evaporation pans in the Kalahari Desert, principally the Makgadikgadi Pans fed by the Boteti River.

The contributing area of the basin responsible for perennial surface water flow is much smaller than the topographic extent of the basin. In Namibia and Botswana only a part of the basin's population is directly dependent on surface water resources, while other parts rely on groundwater resources. The Cubango-Okavango river basin is internationally important for its biodiversity and biological productivity (Figure 1.2).

The Okavango Delta is the best-known feature of the river basin and is one of the largest Ramsar Sites in the world. With its location and variety of habitats it is a globally unique area for biodiversity conservation. The wetland environment of the delta provides a staging post for birds migrating to southern Africa during the boreal winter and is a significant storehouse of global biodiversity. The Cubango-Okavango river basin has a significant national, regional and, importantly, global environmental value.

The Cubango-Okavango river basin supports predominantly rural communities most often located either adjacent to the river or along roads. In each country, the basin populations are remote relative to the countries' capital cities and main centres of economic activity and this is reflected in social development indicators in the basin that are lower than the national figures. In general, the people of the basin are poorer, less healthy and less well educated than other groups in their respective countries. This is particularly the case in Angola where the war curtailed social and economic development.

National social and economic development policies, including achievement of the Millennium Development Goals, target these communities and put added pressure on the water resources of the basin and the services provided by the river system. The goods and services are important not only for the myriad riparian community livelihoods they support, ranging from artisanal fisheries to small-scale agriculture, but also a major eco-tourism industry in the Okavango Delta. A full description of the Cubango-Okavango Basin's physical, biological and human conditions is provided in Chapter 3.

It has been recognized for many years that proposed water development projects may have an impact on the waters of the

Cubango-Okavango river. 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 some preventative mechanisms and policies in place. They now have an opportunity to delineate a development pathway and describe a development space for the basin which will meet these national objectives without compromising the ecosystem services and diminishing the Cubango-Okavango's global value.

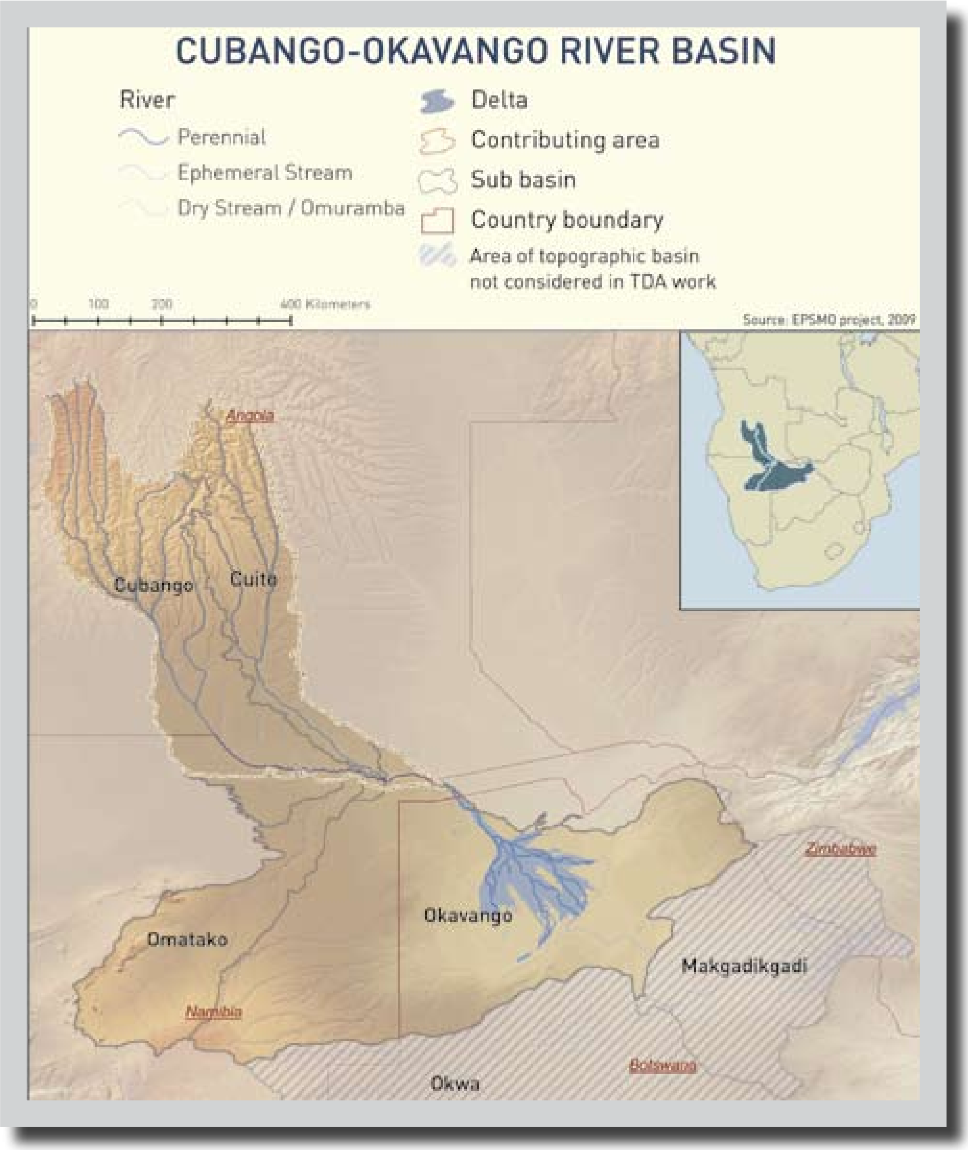


Figure 1.2: Extent of the Cubango-Okavango Basin

1.2 OKACOM AND MANAGEMENT OF THE CUBANGO-OKAVANGO RIVER BASIN

The 1994 OKACOM Agreement commits 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, the Permanent Okavango River Basin Water Commission (OKACOM) was established and mandated to advise the party states on sustainable long-term yield, reasonable demand, conservation criteria, development of water resources, prevention of pollution, addressing extreme events (short term problems such as droughts) and other matters pertaining to the management of the Cubango-Okavango river basin. The role of OKACOM is to anticipate and reduce the unintended, unacceptable and often unnecessary impacts that occur as a result of uncoordinated resource development.

In early 2007, OKACOM reviewed its organizational structure to bring it in line with the Revised SADC Protocol on Shared Watercourses. This led to the formalization of the Okavango Basin Steering Committee (OBSC) to provide technical advice and the establishment of a Secretariat to coordinate and inform decisions of the Commission.

The three contracting parties signed a further agreement on the 'Organisational Structure for the Permanent Okavango River Basin Water Commission' (OKACOM Structures Agreement). This agreement formally established the three organs of OKACOM: the Commission, the OBSC and the Secretariat.

A full analysis of the existing governance framework and proposed strengthening measures is given in Chapter 5.

1.3 SUSTAINABLE MANAGEMENT OF THE CUBANGO-OKAVANGO RIVER BASIN (EPSMO) AND THE CUBANGO-OKAVANGO TRANSBOUNDARY DIAGNOSTIC ANALYSIS (TDA)

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

The long-term objective of the EPSMO Project was to achieve global environmental benefits through collaborative management of the naturally integrated land and water resources of the Cubango-Okavango river basin. The specific objectives of the project were 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 Cubango-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.

As mentioned above, the TDA is a scientific and technical assessment of the shared management issues and problems, both existing and emerging in the Cubango-Okavango Basin. For the priority issues, the analysis identifies the scale and distribution of the potential environmental and socio-economic impacts at national, regional and global levels, and, through an analysis of the root causes, identifies potential remedial and/or preventative actions. The GEF IW TDA/SAP 'best practice' approach underpins the methodology used in the development of the Cubango-Okavango river basin TDA. Consequently the methodology for the TDA consisted of the following steps:

- Identification and initial prioritization of transboundary problems
- Description of baseline conditions
- Identification of drivers and pressures, and determination of water-use scenarios
- Creation of scenarios that describe the environmental impacts and socio-economic consequences of increases in water-resources development
- Completion of a governance analysis of institutions, laws and policies
- Completion of an economic analysis of projected investments
- A Causal Chain Analysis for each priority problem identified to determine linkages and interventions for inclusion in the SAP and NAPs.

It focuses on transboundary or shared problems without ignoring national concerns and priorities, and identifies information gaps, policy distortions and institutional deficiencies. The analysis is cross-sectoral and examines national economic development plans, civil society (including private sector) awareness and participation, the regulatory and institutional framework and sectoral economic policies and practices. A full description of the methodology is given in Chapter 2 of the TDA.

1.4 GEOGRAPHIC SCOPE OF THE TDA

With the agreement of the OBSC, the geographical scope of the TDA is the whole Cubango-Okavango Basin. However, it should be noted that the TDA has limitations with some key issues such as groundwater interconnectivity. It was therefore agreed that these issues would be addressed in future updates of the TDA and the necessary studies would be included in the SAP.

CHAPTER 2: TRANSBOUNDARY DIAGNOSTIC ANALYSIS (TDA) METHODOLOGY

This chapter describes the overall TDA process, its management and the methodologies used in developing its components. The main components include an Integrated Flow Assessment (IFA), an economic analysis, a governance and policy analysis and Causal Chain Analyses (CCA).

2.1 OVERVIEW

The Global Environment Facility (GEF) International Waters (IW) TDA/Strategic Action Programme (SAP) 'best practice' approach underpins the methodology used in the development of the Cubango-Okavango river basin TDA. The GEF guidance document was developed to provide a roadmap for best practice in formulating a TDA and SAP as part of a GEF IW project. It was prepared on the basis of discussions between specialists from United Nations Development Programme (UNDP), United Nations Environment Programme (UNEP) and the GEF Secretariat, together with practitioners who had completed the process in freshwater and marine systems. The final document reflected the experience gained in conducting TDA/SAPs between 1996 and 2003 and was intended not as a prescriptive formula, but merely as a guide that should be adapted to the cultural, socio-economic and political realities of each region.

Riverside at Shakawe, Botswana, 2008

In the case of the Cubango-Okavango river basin, which has been subjected to limited anthropogenic impacts, the focus of the TDA/SAP process was not to establish a programme to rehabilitate the system but rather to put in place preventive mechanisms that would ensure its future good governance and sustainable development. The intention was to illustrate how best resources could be used to improve the livelihoods of riparian communities, increase national benefits and at the same time protect the natural ecosystems.

The TDA is an analysis of the linkage between cause and effect in order to identify realistic targets and objectives to frame the SAP. It strives to identify the most cost-effective remedial and preventive measures to address areas of transboundary concern, which may be either existing or emerging problems. In most international waters the concerns are mainly existing problems, the effects or impacts of which are observable and measurable. However, there are always emerging problems that are not immediately noticeable and for which it is difficult to establish planning targets or describe preventive measures. In some special cases such as the Cubango-Okavango Basin, these emerging problems prevail: a standard TDA methodology thus does not apply.

For the Cubango-Okavango Basin, the TDA team had to re-think the objectives of the TDA and SAP and adjust the TDA methodology accordingly. The TDA's prime purpose remained that of providing a scientific baseline for the SAP and identifying the necessary management and decision frameworks for effective natural resources management. However it also became a tool for assessing the acceptable limits for basin development; providing information to establish a development 'vision' for the basin, which is called the 'acceptable development space'.

The TDA is not a Decision Support System (DSS) and does not pretend to establish any decision framework either at national or basin-wide level. This is a separate major activity, with significant procedural and technical components and political implications, which can only realistically be addressed at the SAP implementation stage.

The steps undertaken in the TDA were:

- Identification and initial prioritization of transboundary problems
- Establishment of status or baseline conditions
- Identification of drivers and pressures, and determination of water-use scenarios
- Testing of scenarios and gathering and interpreting information on environmental impacts and socio-economic consequences of each problem
- Completion of a governance analysis of institutions, laws and policies
- Completion of an economic analysis of projected investments
- A Causal Chain Analysis (CCA) for each priority problem identified to determine/define linkages and interventions for inclusion in the SAP and NAPs.

Kavango River at Divundu, Namibia, 2008

The TDA team established a baseline to identify emerging problems or areas of concern. It then defined a set of water-use scenarios that varied in degree (low, medium and high) and through time, by analysing the 'driving' forces and trends. The environmental and socio-economic impacts of each water-use scenario were determined using modelling tools. Based on expert analysis, acceptable levels of impact were suggested for each area of concern. This is the reverse or mirror of a CCA, where impact is observed and the cause is sought. In this TDA, the cause or 'driver' is observed and its impacts are predicted.

Thus during the TDA, a set of CCAs and Environmental Impact Assessments (EIAs) were performed to investigate issues/problems from different ends of the cause and effect linkage, depending on whether they were existing or emerging problems. This should not be seen as complicating the overall TDA process but as part of its natural structure. During the analyses the team used a driver-pressure-status-impact-response (DPSIR) approach as a guide, principally for identifying drivers, pressures and impacts where the baseline was poor and direct predictions difficult.

The overriding priority area of concern for the Cubango-Okavango river system was identified as 'variation and reduction of hydrological flow'. This has direct linkages with the three other areas of concern, namely changes in abundance and distribution of biota, changes in sediment dynamics and changes in water quality. Thus the TDA team concentrated on understanding and defining the impacts of increased water abstraction and climate change on the flow regimes in the river and the delta. They analyzed the results from a set of deterministic hydrological models covering critical basin areas. The models were used to test medium and high water-use scenarios to evaluate environmental and socio-economic impacts. This work represents a major part of the TDA. The methodology is described in Section 2.6 of this chapter under the IFA and the results are summarized in Chapter 6. The full results are presented in supporting Reports 3–15 listed in Annex 2.

The results from the IFA were used to suggest an acceptable development space for the Cubango-Okavango, although it must be stressed that the results are first efforts and need to be refined. The detailed linked economic analyses of the water-use scenarios (described in Section 2.7) looked at the changes in both the private and national well-being of riparian communities, and the balance between them.

The team realized that when analyzing the areas of concern using the DPSIR approach it was difficult to identify the policy, institutional and management responses needed to counter the pressures predicted. It was recognized that weakness in the governance frameworks at both basin-wide and national level existed but would not necessarily manifest until the pressures emerged, by which time remedial measures would be too late. The team therefore undertook a thorough governance review in line with the GEF best practice (see Section 2.8). A CCA was conducted for each area of concern (assuming the worst case scenario) to determine linkages and identify interventions and information gaps that needed to be addressed in the SAP and associated NAPs.

2.2 MANAGEMENT OF THE TDA

A concerted effort was made to integrate project structures with those existing at regional, national and provincial level when developing the management plan for the EPSMO project.

TDA meeting in Menongue, Angola, February, 2010

The Okavango Basin Steering Committee (OBSC) provided overall ESPMO project guidance and guidance for the formulation of the TDA and SAP. Project activities were managed by three national coordinating units (NCUs) headed by national coordinators who managed project activities, with three intersectoral committees ensuring sectoral integration. The project management unit (PMU), in close contact with the NCUs, coordinated all project activities and reported directly to the OBSC. Situated in Luanda, Angola, the PMU was led by the project manager and project coordinator.

In Botswana, the Okavango Wetlands Management Committee, a structure set up and coordinated in the Ngamiland district by the Department of Environmental Affairs, acted as the intersectoral committee. The executive committee of the group formed the national coordinating unit responsible for overall direction and made key decisions regarding TDA work in Botswana.

In Namibia, in line with recent government legislation, the project assisted the Department of Water Affairs to merge two existing institutions, the Okavango River Basin Association and the National Intersectoral Committee, to form the Okavango Basin Management Committee. As in Botswana, this new group acted as the intersectoral committee, with executives within the committee forming the national coordinating unit.

The considerable scope of work in Angola required a small and dynamic national coordinating unit. The intersectoral committee consisted of representatives from key sectors based in Luanda and the province of Cuando Cubango.

Three country teams were coordinated to form an overall integration team consisting of thematic coordinators, project personnel, country team leaders and other key specialists. The strength of this approach was that each team was able to assemble and interpret its own national information. This was especially important in Angola, where both language and scarcity of information had been a problem in earlier studies.

In consultation with the national coordinating units, a mix of institutions and individuals were contracted to form the three thematic teams.

- In Angola, most of the biophysical studies were undertaken by a team from the University of Agostinho Neto Science Faculty. Other key themes such as social, economic, demographic and irrigation studies were conducted by private consultants.
- In Botswana, a detailed study to develop a comprehensive management plan of the delta Ramsar Site had recently

been concluded. This plan, known as the Okavango Delta Management Plan (ODMP), contained most of the information required from Botswana to develop the TDA. Therefore the project developed a Letter of Agreement with the University of Botswana Harry Oppenheimer Okavango Research Centre (HOORC)[1] to synthesize the information for the TDA.

- In Namibia a leading environmental NGO, the Namibia Nature Foundation, developed a Letter of Agreement with the project to conduct comprehensive research towards the development of the TDA in that country. Through the efforts of the NGO, key government officials from the Department of Water Affairs (since renamed Department of Water Affairs and Forestry), officials from NamWater (Namibia Water Corporation) and private consultants also participated in the TDA.

An integration team synthesized the TDA by bringing together the different national contributions and included:

- TDA coordinator, whose task it was to coordinate the different specialists and compile the overall TDA
- 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 (also the TDA coordinator), who joined the different specialists undertaking the biological aspects of the IFA studies
- IFA coordinator, who designed and led the national IFA studies and coordinated the outputs from each national specialist to lead to a description of possible biophysical and socio-economic changes associated with changes in flow
- Geographic information system (GIS) and mapping specialist, who developed the GIS database for the environmental protection and sustainable management of the ORB. He used the GIS databases and products from the national GIS specialists to draw a consistent set of maps.
- Socio-economic specialist, who was part of the IFA team in all three countries and worked with national 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 counterparts to review the applicable laws, policies and institutions.

TDA fieldwork team, Okavango Delta Panhandle, 2008

Joint understanding of transboundary issues was encouraged through a series of integration meetings of the IFA specialists and the overall TDA integration team. The TDA integration team met on three occasions to:

- Develop the structure and outline of the TDA report
- Interact with national and process management teams at the IFA knowledge capture workshop
- Develop the CCA and refine the contents of the TDA report.

A key person in the overall development of the TDA was the EPSMO coordinator, who was directly involved in all the studies and provided guidance and general coordination for the TDA integration team. Working with the PMU, he was supported by the national TDA coordinators in each country, who ensured communication links with the national teams and provided additional information as required.

1 HOORC has since been renamed the Okavango Research Institute (ORI)

2.3 IDENTIFICATION AND INITIAL PRIORITIZATION OF KEY AREAS OF CONCERN

The first step in the TDA process was to agree on the key areas of transboundary concern. An initial stakeholder consultation undertaken as part of a preliminary TDA carried out in 1998 highlighted four main areas of concern, although they had not been prioritized. The EPSMO project revisited and confirmed these areas of concern and during the project the national thematic and integration teams examined their transboundary relevance, determined preliminary priorities and examined the scope of each. The four key areas of concern identified were:

- Variation and reduction of hydrological flow
- Changes in the abundance and distribution of biota
- Changes in sediment dynamics
- Changes in water quality.

It should be noted that these are all emerging rather than existing problems and reflect the as yet unrealized development pressures on the basin. During the consultative process a fifth transboundary area of concern was identified, that of alien invasive species. This is an existing threat and the issue of climate change was recognized as a cross-cutting issue.

In the course of developing the TDA, four consultative meetings were held in each of the three countries as well as one regional consultative meeting to discuss various aspects of the areas of concern and establish initial prioritization. These included:

- Transboundary nature of the problem
- Scale of impacts of a problem in economic terms on the environment and on human health
- Relationship with other transboundary and national problems
- Expected multiple benefits that might be achieved by addressing a problem
- Lack of perceived progress in addressing/solving a problem at the national level.

Community consultation at Mucundi, Angola, 2008

The areas of concern were also tested through a number of consultations with a wide array of stakeholders including government, non-government, academic, private and riparian communities. In addition, there was feedback from stakeholder representatives on the intersectoral committees.

Ensuring community representation required a high degree of effort and a specialized strategy, because of the remoteness of these communities. Community participation was necessary to facilitate the inclusion of their concerns, needs and variables in the TDA. This was executed in Angola and Namibia through selected NGO partners with guidance and support from the project.

In Angola, groups of community leaders were selected and trained to hold consultations with their constituencies and meetings were facilitated to discuss and reconcile the resultant information. Associação de Conservação do Ambiente e Desenvolvimento Integrado Rural (ACADIR), the selected NGO in Angola, prepared a report to keep the TDA informed of the outcomes. In Botswana, community participation exercises had been conducted in the course of developing the Okavango Delta Management Plan and the results were synthesized in the TDA.

2.4 DATA GATHERING AND BASELINE ASSESSMENT

A series of basin-wide thematic studies was undertaken to understand the current physical, biological and human status in the basin. The national thematic teams carried out these studies and used a similar structure for each country's review and report. The consultants/specialists were required to produce reports that described a particular problem and identified gaps in knowledge, environmental impacts and socio-economic consequences, drivers and trends. The results are synthesized in Chapter 3, with country reports listed in Annex 2. These studies included reviews of key sectors such as irrigation, hydropower and tourism; analyses of population dynamics; access to services such as schools, water supply and healthcare; incidence of HIV/AIDS, and institutional and governance factors. The studies provided the baseline against which changes were measured and for determining the low, medium and high water resources development scenarios used in the IFA (Section 2.6).

Fish research at Liyapeka Rapids, Angola, 2008

2.5 THE DRIVER-PRESSURE-STATUS-IMPACT-RESPONSE APPROACH

The DPSIR approach was used as a guide when investigating potential future impacts of human activities. The analysis identified:

- The **driving forces:** socio-economic and socio-cultural actions that could increase or mitigate pressures on the environment. Those identified were:
  - Population dynamics
  - Poverty
  - Land-use change
  - Climate change
- The resulting **pressures** which affect the state of the environment and, in turn, may impact on human health or ecosystems, such as reduction in flow, pollution and soil erosion
- The **status** of the environment resulting from pressures imposed (or are forecast to impose)
- The **impacts** of a degraded environment on human health, ecosystems and socio-economic/cultural conditions
- **Responses** that address the driving forces and seek to reduce the pressures on the environment and so improve the environmental status and reduce impacts.

The results are contained in Chapter 7. The DPSIR framework was particularly valuable for identifying the socio-economic and environmental impacts and, in conjunction with the CCA (Section 2.9), the responses that were incorporated in the SAP.

2.6 INTEGRATED FLOW ASSESSMENT

The Cubango-Okavango TDA process started from an analysis of the baseline – the present state of the Cubango-Okavango River basin. It used observed trends in population growth and sectoral developments and identified three water-use scenarios, which represented possible future pathways of increasing water use in the basin. The probable implications of these three water-use scenarios were then analyzed 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-economic analysis (Section 2.7).

The IFA is a major component of the TDA. It examined in detail the priority area of concern – changes in hydrological flow – by linking water resources development with changes in flow, ecology and socio-economics at specific sites.

The assessment took as its starting point hydrological simulations of how the pattern of flows would change along the river system under different scenarios. At the same time a multidisciplinary team from each riparian country collaborated in a research programme that ended with the capture of 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 people's lives i.e. 'socio-economic indicators'.

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 – the naturalized stream flow. A naturalized stream-flow record spanning a long period will show the response of a river system to the natural (or climate change induced) variability of rainfall. This could include prolonged wet or dry periods. For water resources planning purposes, estimates of future water demands and water infrastructure (dams and abstraction works) can be 'superimposed' on the naturalized flow sequence to determine the reliability with which 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.

Data on the hydrology of the Cubango-Okavango river basin is relatively poor, but was first modelled at a spatial resolution that would allow for assessments of development impacts at various locations in the basin and on inflows to the delta in 2003. For the Cubango-Okavango IFA, the hydrological working group opted to make use of the water evaluation and planning (WEAP) modelling system, 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 to the training of hydrologists in systems analysis and scenario planning techniques.

The three other hydrological models of the delta (ETH MODFLOW, DHI MIKE and HOORC) were used for different applications. The DHI model was used to determine channel flow velocities and depths, 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. Further details of the methods are given in Chapter 4 and the full results of the hydrological modelling are presented in IFA Reports no. 5, *Hydrological data and models* and no. 6, *Scenario hydrology report* contained in Annex 2.

In summary, the IFA used the following development steps:

Basin delineation:
The basin was divided into homogenous units 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 units as the focal point for data collection and interpretation. The IFA field sites are shown in Table 2.1 and Figure 2.1.

TABLE 2.1: 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	Cakanaca (Xakanaka)
8B	Botswana	Boteti	Chanoga

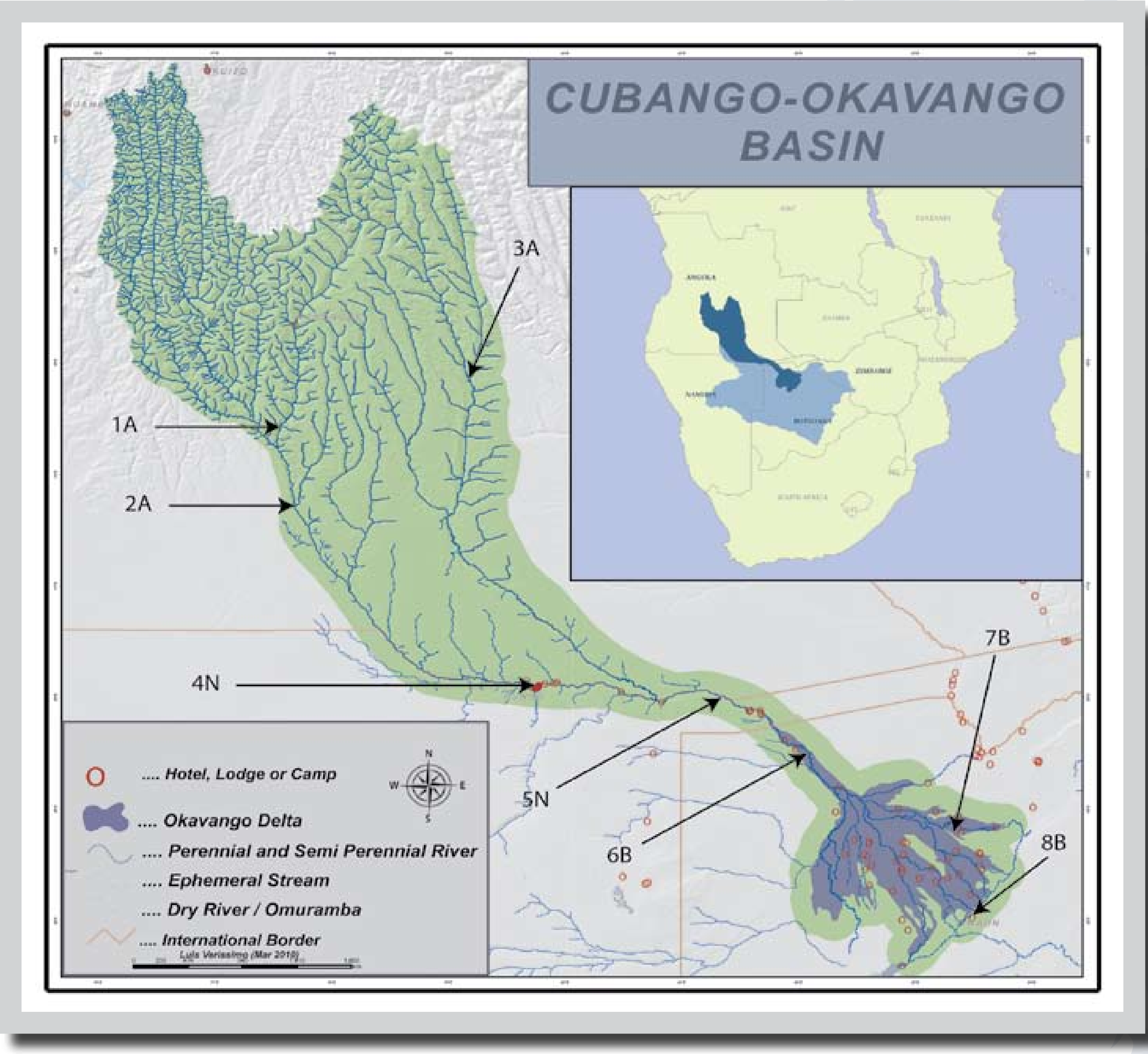


Figure 2.1: Location of the eight representative sites for the IFA

Scenario development:
An understanding of the effects of changing flow regimes was enabled by developing a series of increasing water-use scenarios, based upon potential demand for water over the next 15-20 years for water supply, irrigation, hydropower and other uses. These water-use scenarios were developed through discussions between the countries, project members and OKACOM. The discussions resulted in agreement for three scenarios of increasing water use – low, medium and high – which were compared to present-day conditions (Section 2.4).

Hydrological modelling:
Information on the various proposals for water use in each of the countries was collected in order to populate these three water-use development scenarios. Hydrological data as described above was collated and synthesized for the whole basin and the resulting flow regimes were simulated at the representative sites for each of the scenarios.

Selection of discipline indicators:
Each discipline group selected the key indicators that would show major changes or highlight issues relevant to its discipline as a result of change in the flow regime. Biophysical indicators were chosen to measure river attributes that could change

with flow change, and socio-economic indicators were chosen to measure social attributes that could change with river change. These indicators formed the focus for site visits, data collection, literature reviews and analysis. Each specialist focused on the representative sites in their country and compiled separate reports with the results for their respective disciplines.

Figure 2.1 illustrates the three sites in Angola (marked A), two in Namibia (N) and three in Botswana (B).

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

Developing the decision support tool (DST):
A DST was developed and prepared for capturing the biophysical and socio-economic specialists' knowledge. Each specialist team described the relationships between their indicators and flow, which formed the knowledge base of the system. Simulated flow regimes for each water-use scenario for the whole basin, prepared by the hydrological team, were also entered into the DST. The DST's knowledge base was used to predict the ecological and social outcomes for each scenario. These predictions of change were assessed and approved by the full IFA team. The full IFA process is described in Figure 2.2.

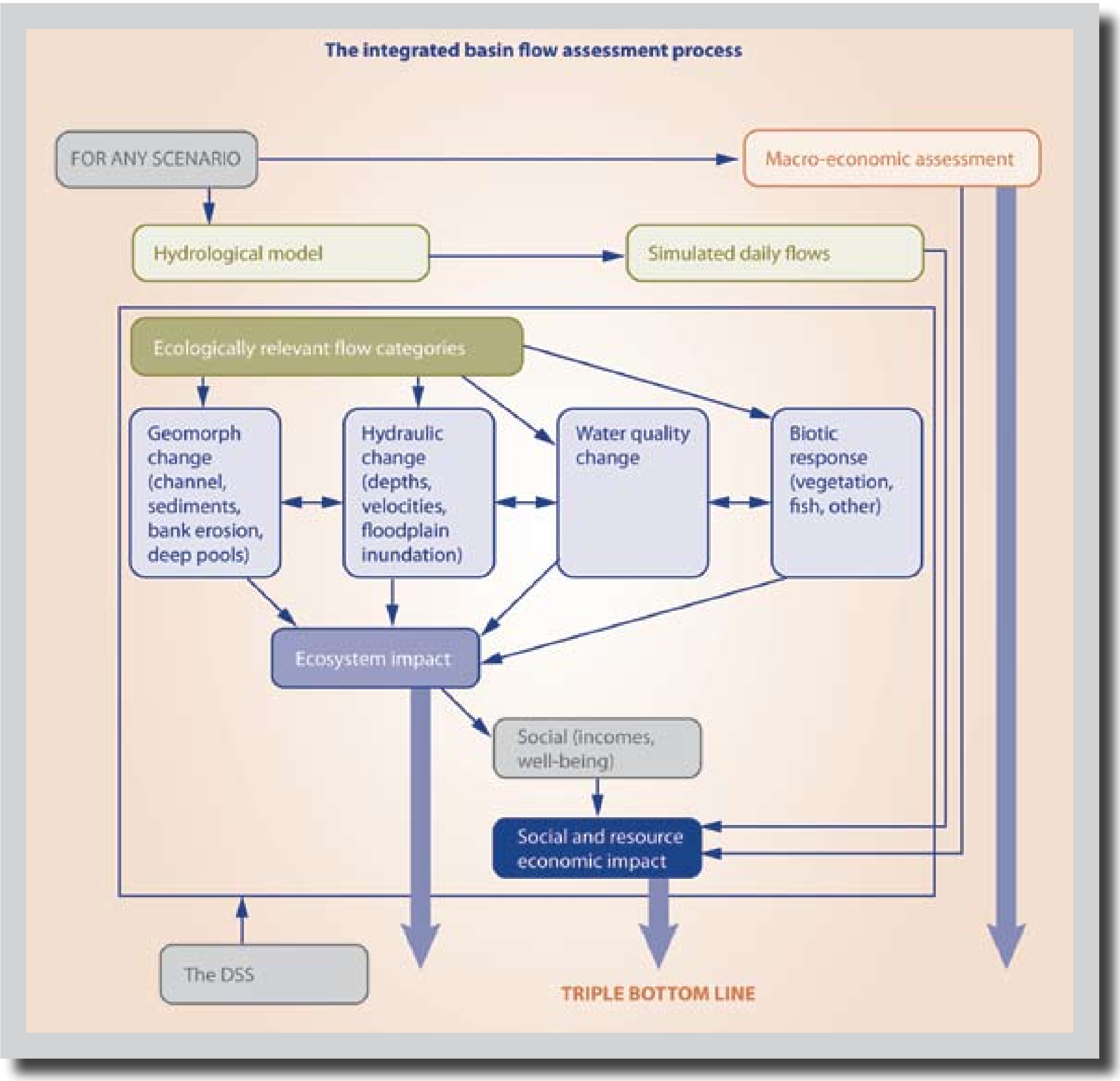


Figure 2.2: The full IFA process

While some new data was collected during the IFA, much of it was derived from the expert opinions of specialists who focused their research on the eight representative sites to gain an initial understanding of their status. Existing data and knowledge of the Cubango-Okavango and similar river systems also played an important part. However, it is recognized that this exercise was a data-poor first estimate of the changes likely to occur with development and that more detailed research will be essential in the future.

The IFA outputs describe the largely negative impacts of water resources development on the river ecosystem and its subsistence users. Development could also bring positive impacts in terms of national economies or peoples' incomes and health. The macro-economic assessment (Section 2.7) of the three development scenarios, described in Chapter 6, provides a balanced prediction of the outcome of water resources development. Together, the IFA and macro-economic assessments outline the predicted consequences of development in terms of the three pillars of sustainable development: ecological integrity, economic wealth and social well-being.

Full details of the IFA process and findings are available in the complete set of IFA reports (Annex 2). A summary of the scenario findings is provided in Chapter 6.

Hyphaene Petersiana regeneration after cutting by palm wine makers, Botswana, 2010

2.7 ECONOMIC ANALYSIS

A socio-economic analysis was conducted to determine:

1. The general social and economic baseline for the people living in the basin. (This included a description of key demographic and economic characteristics, the main challenges faced by people and observable trends).
2. What goods and services people use from the river and an estimated change 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 on the macro-economy of the basin states to enable a comparison between the current situation and alternative paths of development.

The analysis measured both the private well-being of the basin inhabitants, as well as the national well-being of the basin countries. The economic values at different levels are shown in Figure 2.3.

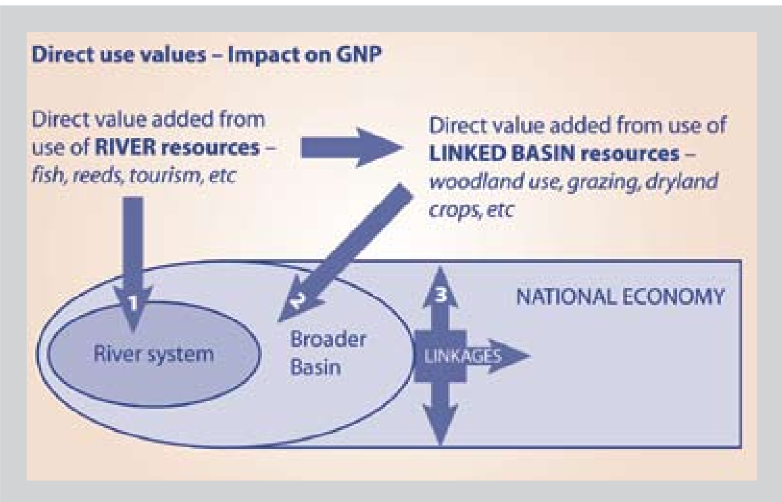


Figure 2.3: Depiction of economic values

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

Private well-being was measured as the net change in household livelihood or the net gain in household welfare accruing from the resources of the river basin and its functions i.e. the net profits earned by households in their income-earning activities. These are values that could be affected by changes in flow and included those for household use of river-based natural resources such as fish, reeds, floodplain grass, floodplain gardens and floodplain grazing, as well as commercial use and river and floodplain-based tourism. Valuation of all these natural resources use was undertaken at each of the representative sites and was then scaled-up for the basin as a whole.

TDA research team at the Boteti River, Botswana, 2008

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 national income was extended to highlight the total direct and indirect contribution of resources use to the national economies. The contributions of indirect-use values and ecosystem services to national well-being were also measured in terms of national income. National well-being as affected by non-use values (existence, bequest and option value) was assessed in terms of willingness to pay for preservation at local, national and international levels.

The economic analysis was then scaled up, applied to the different water resources use development scenarios and compared to the present-day situation. Losses 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. These losses (and gains) were then offset on a country-by-country basis, against the potential net benefits of the water resources developments that alter the flow regime.

The value of the Cubango-Okavango river basin, particularly of the Okavango Delta, is considered important by the international community. These values were estimated based on published studies of existence values for wetlands. These values could be tapped into, to yield a sustained source of financial resources for integrated river basin management and sustainable development in the Cubango-Okavango region of the three countries.

A more complete description of the methods and results of water and natural resources use and macro-economic analysis are provided in Chapter 6 and the Socio-economic assessment and Economic valuation of basin resources reports respectively in Annex 2. [2]

2.8 GOVERNANCE AND POLICY ANALYSIS

The overall objectives of the governance review were to:

- Provide an overview of the current legal, policy and strategy, and institutional landscape for the Cubango-Okavango Basin
- Analyze policy drivers that have an impact on 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.

2 Barnes, J. et al (2009) and Aylward, B. (2009)

The governance and policy review provided an overview of the constitutional order in the three Cubango-Okavango Basin states, Angola, Botswana and Namibia, with particular emphasis on the delineation of the different spheres of government. It examined the three countries' overarching national development policies and planning instruments, such as National Development Plans and key sector policies (e.g. energy, trade, agriculture) with a view to identifying key policy drivers that influence, or could do so in the future, the management of the Cubango-Okavango Basin. Based on their identification as key fields for the sustainable long-term management of the basin, the legal, policy, 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 OKACOM as the key institution for coordinating management of the basin between the three countries.

The governance analysis took into account the wide spectrum of relevant international, national and local legal and policy instruments as well as responsible management organizations 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 analyzed and compared to internationally accepted best practice. Where they existed, gaps and shortcomings in the legislative framework were highlighted. Likewise, 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 between countries. An analysis of the current strengths and weaknesses of the institutional framework was undertaken, both internally within countries as well as between 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, possible future constraints and opportunities were identified as potential development pathways for the basin are followed. In particular, the anticipated institutional challenges were highlighted, with recommendations for improvement of the current governance mechanisms and actions for the effective long-term adaptation of the governance framework according to the demands of sustainable basin management. The full analysis is presented in the supporting report No.2, Annex 2 and is summarized in Chapter 5.

2.9 CAUSAL CHAIN ANALYSES

The CCA is one of the most useful aspects of the TDA for the development of future corrective actions. The causal chain should relate the transboundary problems to their impacts, immediate physical causes and underlying social and economic root causes (Figure 2.4). The CCA was applied to each of the areas of concern and in this way, working in reverse, the immediate, underlying and root causes (the drivers) were confirmed. In addition, necessary interventions, particularly legal, institutional and governance related interventions, were identified for inclusion in the SAP. The CCA provided the project team with an understanding of the linkages between the areas of concern and insight on how best to manage them. The CCAs are presented in Chapter 7.

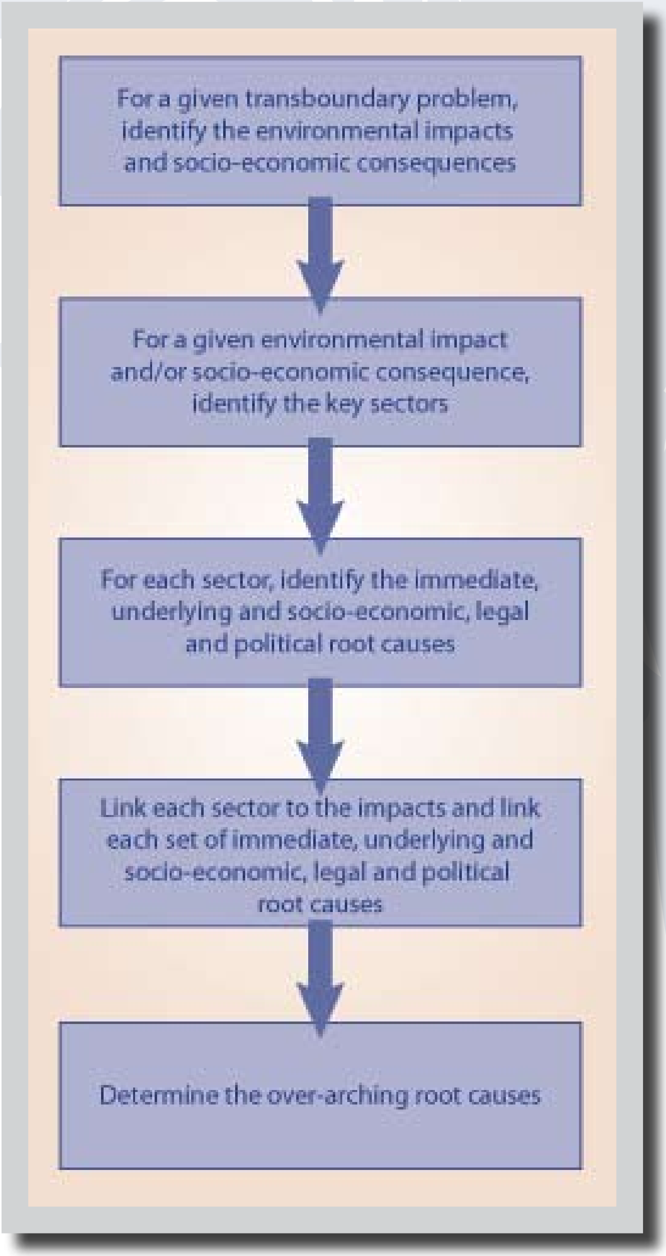


Figure 2.4: Stepwise sectoral analysis approach to developing a causal chain

CHAPTER 3: THE CUBANGO-OKAVANGO RIVER BASIN – ITS PEOPLE AND ENVIRONMENT

Chapter 3 describes the current conditions of the Cubango-Okavango river basin in the physiographic, biological and human settings. Full details can be found in supporting reports contained in Annex 2. Details of the economic and governance settings are given separately in Chapters 4 and 5 respectively.

3.1 PHYSICAL AND CHEMICAL FEATURES

3.1.1 Topography, geology and soils

Topography

The headwaters of the Cubango-Okavango river system are located on the central highlands of Angola between Huambo and Cuito, at an altitude of 1,700–1,800 metres above sea level, dropping to just over 900 metres above sea level in the delta. The elevation map of the basin (Figure 3.1), illustrates the key topographical features. The gradients of the Cubango and Cuito Rivers from the Angolan highlands to the delta are shown in Figure 3.2.

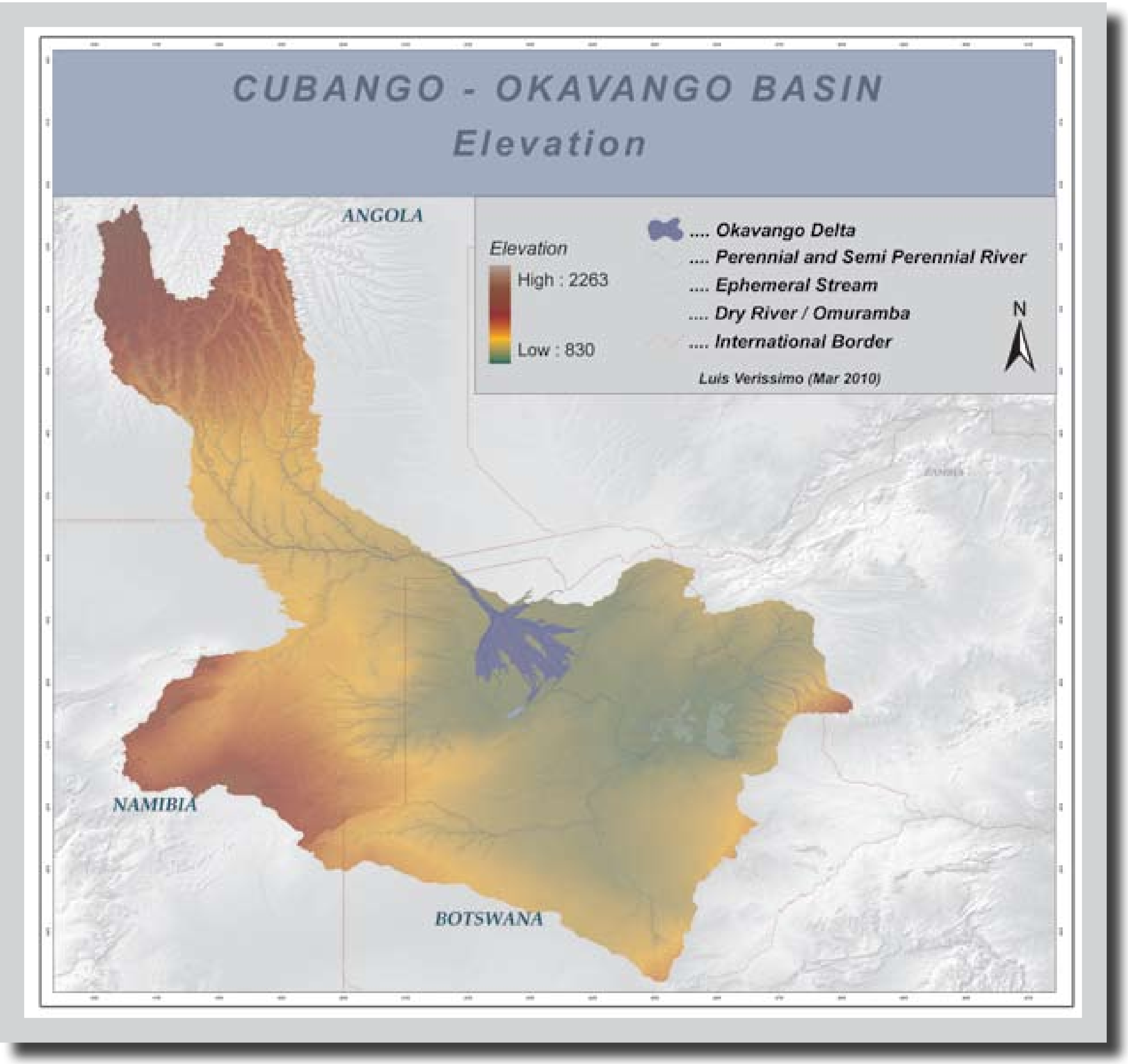


Figure 3.1: Cubango-Okavango Basin – elevation and topography

Source: Mendelsohn and el Obeid (2004)

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 hydrologically active and inactive distributary channels, islands and floodplains.

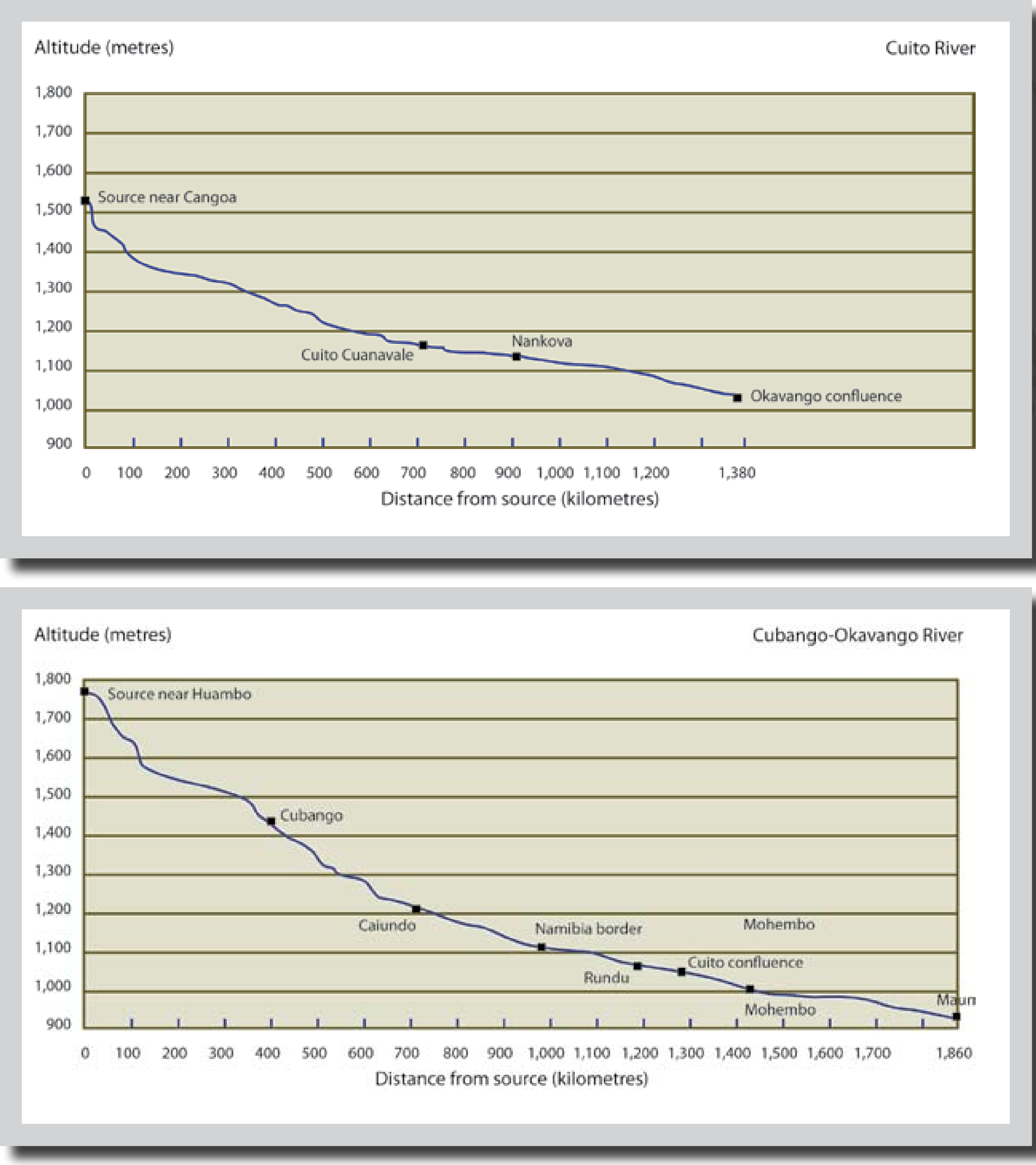


Figure 3.2: Gradients of the Cubango-Okavango and Cuito Rivers

Catchment zones and river morphology

The Cubango-Okavango River system[3] can be divided into several morphologically distinct zones. These are:

- **The Angolan headwaters** – the Cubango and Cuito catchments
- **The middle reaches** – the lower Cuito and Cubango Rivers, as well as the Kavango upstream of the panhandle
- **The panhandle** – formed by two parallel faults, where the river gradually transforms into swamp
- **The delta** – the Okavango Delta, comprising both permanent and seasonal swamp areas.

3 The river is known as the Cubango in Angola, Okavango in Botswana and Kavango in Namibia. The entire river system is the Cubango-Okavango river basin

Geology

Four major geological periods dominate the features of the Cubango-Okavango Basin (Table 3.1).

TABLE 3.1: 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 of rocks were laid down when the continent of Gondwana was created, forming the foundation of the land through which the Cubango-Okavango now flows. Through most of the past 65 million years, sediments were carried down into huge lakes and deltas and it is only in the last 2 million years that much of the basin has dried up.

Soils

The soils of the north-western part of the Cubango in Angola 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.[4]

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

In summary, most soils in the basin are quite coarse and so are not able to retain moisture and are low in nutrients, thus not conducive to crop production. The only fertile soils in the basin are scattered through parts of the delta.

3.1.2 Climate and climate variability

The Cubango-Okavango Basin lies within the 12–21° southern latitude, which is characterized 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/annum in the Huambo and Cuito areas in the headwaters of the basin, to 560 mm/annum at Rundu, 550 mm/annum at Mohembo, and 450 mm/annum at Maun (Figure 3.3). The rainfall is highly variable: there is a tendency for high rainfall years to group for a period; this is 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. The annual average temperature in the Angolan part of the basin is 20 °C, rising from north to south, with minor variations

4 Information abstracted from Mendelsohn and el Obeid (2004) and Christian, C. (2009)

throughout the year. The maximum monthly average temperatures vary between 22–24 °C, occurring from October to January, with minimum temperatures of 15–17 °C between June and August. The daily maximum temperatures are 30–32 °C and the minimum 3–8 °C.

Evaporation increases from north to south in line with increasing temperatures, as can be seen in Figure 3.4. 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 Cubango-Okavango river basin lies within a semi-arid zone.

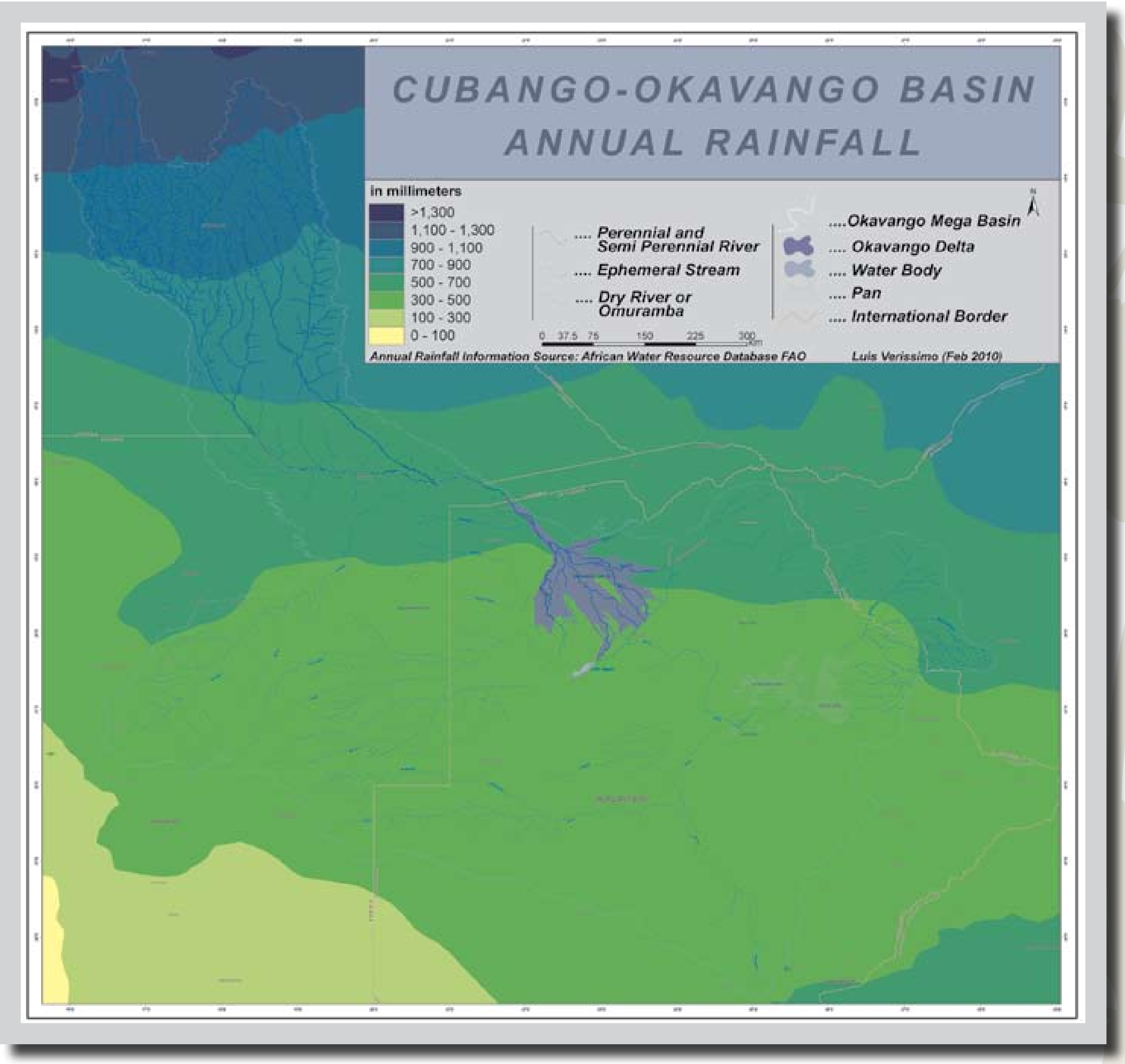
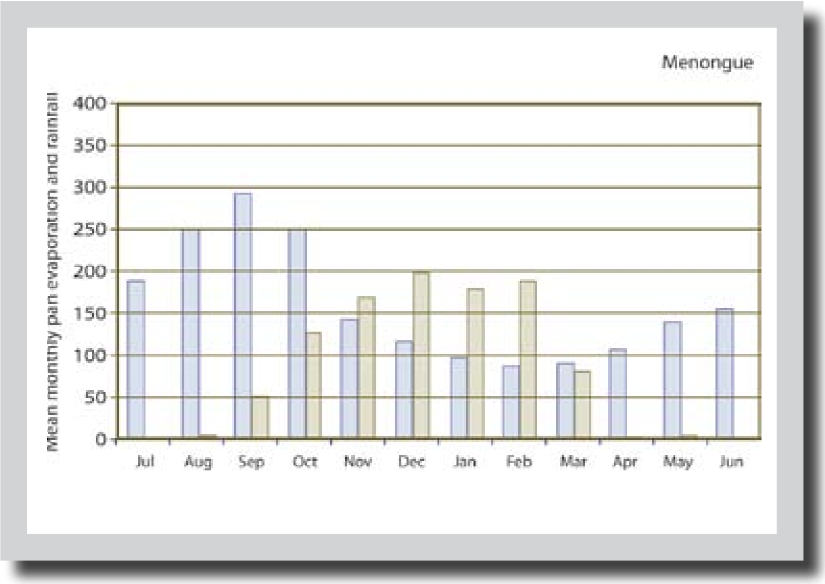
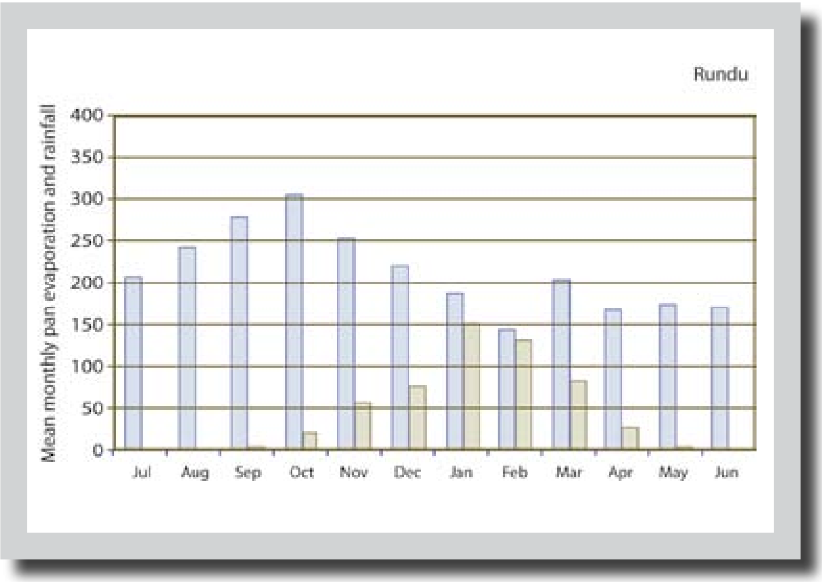


Figure 3.3: Annual rainfall patterns, showing the gradient from north to south of the basin. (Perennial rivers shown in white and dry tributaries shown in brown)

Source: Mendelsohn and el Obeid (2004)





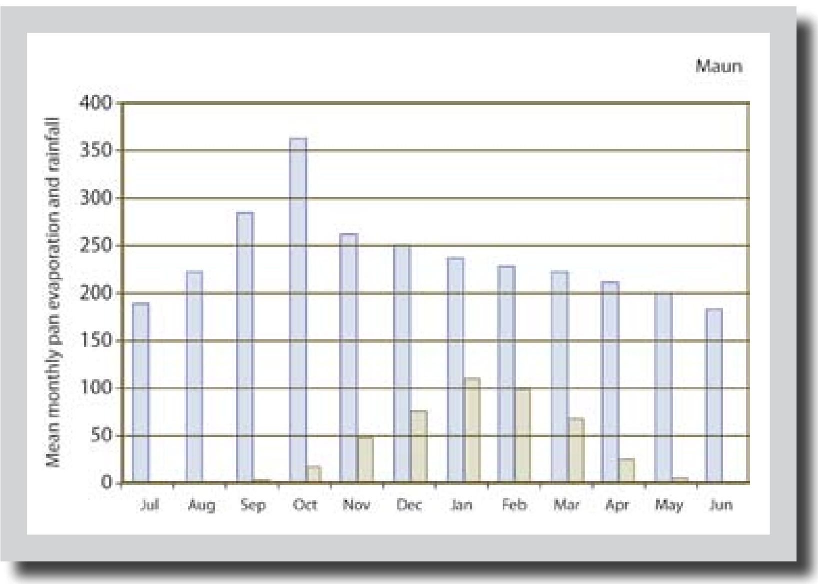


Figure 3.4: Balance of rainfall and evaporation throughout the year at Menongue, Rundu and Maun

Source: Mendelsohn and el Obeid (2004)

3.1.3 Hydrology, sediment dynamics and water quality

Hydrology

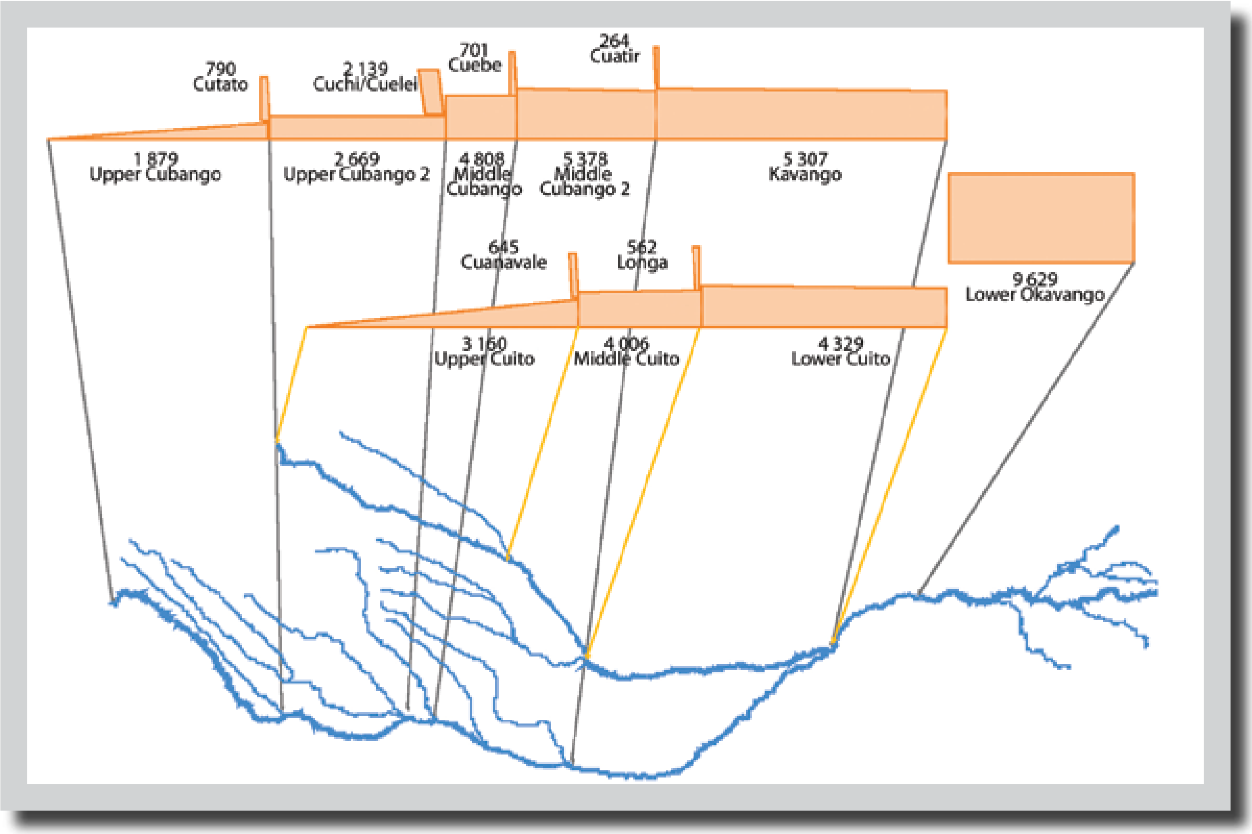
The main characteristics of the present-day hydrological regime are the large difference between the two headwater streams, the Cubango and the Cuito, and the massive storage capacity for floods in the floodplains along the system. The Cubango exhibits a flashy hydrograph with sharp increases in flow 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 groundwater contributions to base-flow and wet-season storage of floodwaters in vast floodplains and their drainage back into the river in the dry season. The Cubango-Okavango river system as a whole is a floodplain-driven system, with floodplains throughout but most prominently on the Cuito in Angola, on the Cubango-Kavango along the Angola/Namibia border, and the Okavango Delta in Botswana. These floodplains sustain the river in the dry season and also store floodwaters that would otherwise increase flooding downstream.

From the description of the rainfall patterns, it can be observed that virtually all the water flowing into the delta comes from the upstream areas of the basin – the Cubango and Cuito Rivers. Table 3.2 provides estimates of the contributions of the different rivers to the overall flow in the Cubango-Okavango river system.

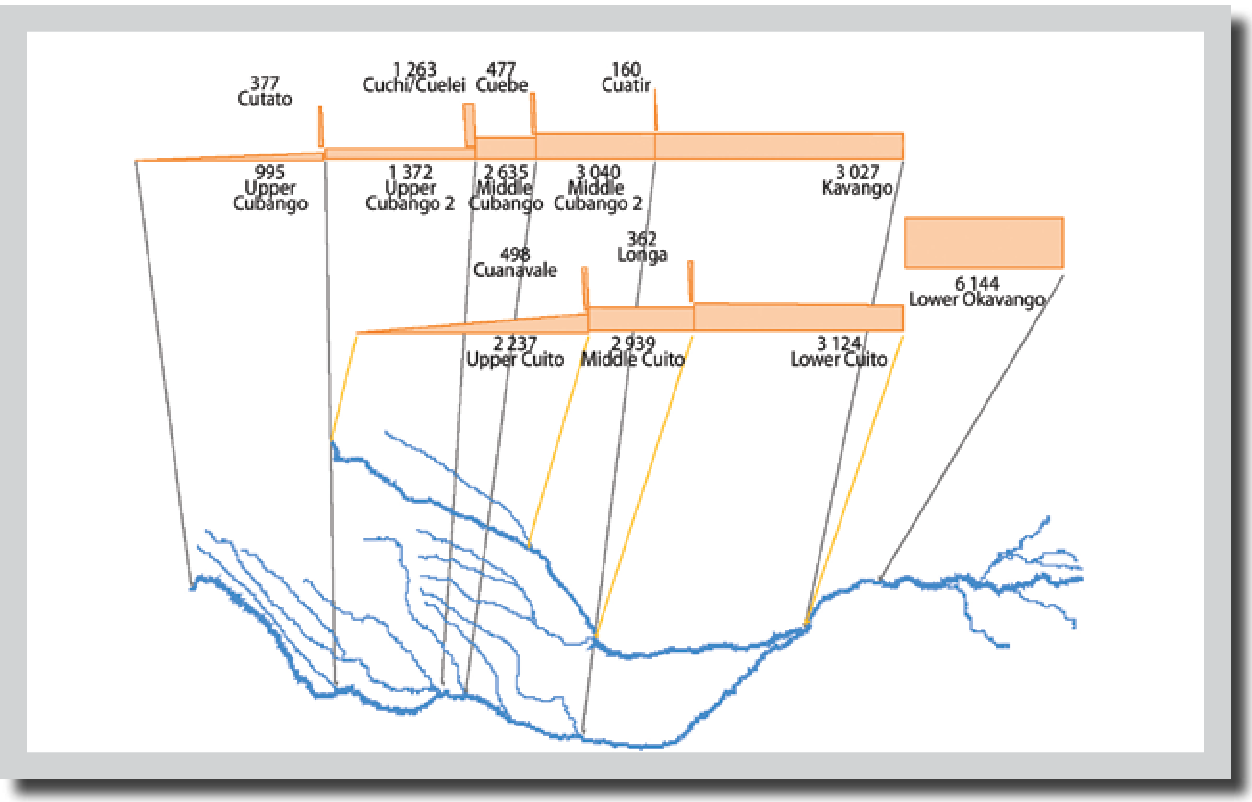
TABLE 3.2: CONTRIBUTIONS OF THE CUBANGO-OKAVANGO TRIBUTARIES TO THE MAIN FLOW IN THE RIVER

River/zone	Area km^2	Mean annual rainfall mm	Mean annual runoff Mm^3/ annum	Percentage contribution
Cubango	14,400	1,028	1,846	17%
Cutato	4,200	1,220	800	7%
Cuchi	8,900	1,117	821	8%
Cacuchi	4,800	1,207	760	7%
Cuelei	7,500	1,114	697	6%
Cuebe	11,200	969	679	6%
Cuatir	11,600	787	134	1%
Cuelo	3,700	787	57	1%
Cuiriri	12,900	986	566	5%
Cuito	24,300	1,051	3,339	31%
Cuanavale	7,750	1,073	596	5%
Lower Cubango	45,000	608	620	6%
Total (upstream of delta)	**156,250**	**837**	**10,914**	**100%**
Delta	35,300	469	0	0

Figure 3.5 shows the present-day mean annual runoff. Large losses from evaporation and about 60 Mm³/annum in abstractions (see below) reduce the runoff to about 9,600 Mm³/annum 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 3.5: Present-day flows in the Cubango-Okavango river basin

Mean annual precipitation in the upper catchment is of the same 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 the panhandle to reach the Okavango Delta, the flows are partitioned within the delta between three main tributaries, the Thaoge, Boro and Maunachira Rivers. The substratum of channels is very permeable, resulting in a substantial exchange of water between channels, floodplains and groundwater.

The hydrological measurement network across the basin is shown in Figure 3.6. Currently only 11 out of 31 stations are functional of which only four are in Angola; therefore the basis for water resources assessment and flood forecasting is limited. It should be noted that there are few operational sites upstream of Rundu, and none on the major tributaries that provide 90 percent of the runoff is currently being monitored.

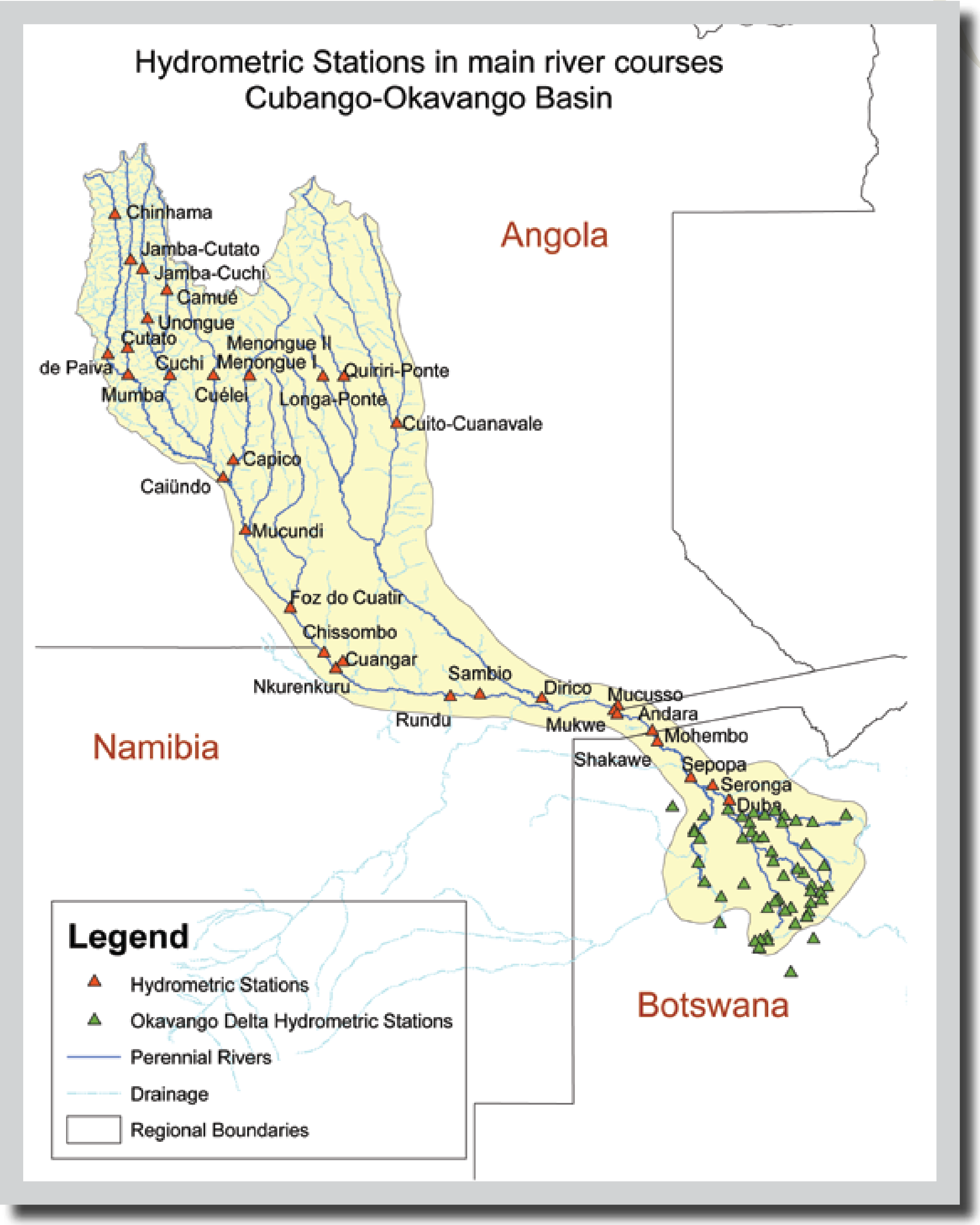


Figure 3.6: Location of hydrometric stations

Seasonal variability and floods

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-water season occurs several months after the peak flows occur in Angola.

Seasonal flooding in the Okavango Delta is the result of a complex interaction of local, regional and basin-wide influences.[5] 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 upstream western parts of the delta is strong compared to the downstream eastern parts, where water levels show little seasonal variation.

Historically, extensive flooding in the basin occurs on a regular basis. The floods of 2009–2010 in the Kavango catchment in Namibia were exceptional and seriously affected many people. They were caused by a combination of above normal rainfall in the catchments with high inflows of flood waters from southern Angola. The extensive impact of the floods was aggravated by increased population settlement and infrastructure development in the flood-prone areas in the Cuvelai, Zambezi and Kavango catchments.

Droughts

In dry years (1:20 year drought conditions) the flows in the river are significantly reduced as shown in Figure 3.5(b), which closely resembles the conditions experienced in the severe drought of 1998.

Inter-annual variability

In the Cubango-Okavango river basin, measured stream flows exhibit a long-term cyclical behaviour pattern over 65 years. There was a maximum in the 1960s, and a minimum in the late 1990s, 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.[6]

Detailed information on the basin hydrology is given in supporting Reports 7 and 8, referenced in Annex 2 of this report.

Groundwater

The aquifers in the basin can be considered in three distinct zones:[7]

Popa Falls, Namibia

- ***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 base flows and flashy hydrograph of the Cubango compared with the higher base flows and much lower seasonal variation in flows 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

5 McCarthy et al. (2000)
6 Mazvimavi and Wolski (2006)
7 Beuster, H. (2009)

gradient, the Cubango-Okavango river system recharges the aquifers, but in most sections the river gains groundwater from the permeable Kalahari sands.
- ***The Okavango Delta.*** There are three major aquifer formations in the delta – the basement rocks and the Karoo and Kalahari Group sediments. Where the 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 or ephemeral runoff, while deeper aquifers are recharged from the Kalahari basin margins or the underlying fractured aquifers. Groundwaters at the eastern boundary of the Cuvelai-Etosha Basin seem to be discharging into the Cubango-Okavango Basin. Recharge in the Okavango Delta has been estimated to be about 7–10 mm/a.

Sediment transport

Sediment dynamics in the Cubango-Okavango river system are both complex and critical to the continued maintenance of the river, its floodplains and delta ecosystems.

Three categories of sediment are transported down the river to the delta:

- *Fine sand* – the bulk of which is transported as bedload 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.

The pattern of sediment transport along the river is highly characteristic, with few clays or silt and with low concentrations of dissolved solids. By far the greatest load is the sandy bedload. An estimated 170,000 tonnes of sand moves along the river from Angola to the delta each year, where it settles out as the river flow slows and spreads across the swamps. As much as 5 cm of sand can settle out per annum, raising the channel beds and eventually causing blockages that lead to the water breaking through to new channels. In this way the layout of channels through the delta, and thus the pattern of flows, is constantly changing, re-wetting some areas and drying out others.

Surface water quality

The quality of the Cubango-Okavango rivers' water is exceptionally good, with a general level of purity and clarity that makes it possible for people to drink directly from the river. This is partly attributable to the geology of the area, with the Kalahari sands releasing few minerals and clay particles, and partly as a result of the low levels of human activity along the banks. Pollution from urban areas is localized, as is runoff from the limited agricultural areas. The low levels of dissolved salts and suspended silts that move along the river accumulate in the delta, making it nutrient rich and biologically diverse.

Data on surface water quality and pollution sources is limited; a brief summary of information available in each country is given below.

Angola: In Angola, various international water quality standards are used. For the purposes of the Transboundary Diagnostic Analysis (TDA), reference has been made to the European Union (EU) Water Quality Standards for aquatic habitats. Table 3.3 shows some recent water quality data from the tributaries of the Cubango-Okavango. The parameters measured are limited and do not include heavy metals or organic compounds and while these values 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.[8]

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.

8 Pereira (2009)

However there are localized areas where water quality has deteriorated and they have the potential to deteriorate further as a result of municipal waste waters, solid waste leachate, irrigation schemes and increased use of agrochemicals.

It is important that the river water is of good quality in Angola, because a large proportion of the people living in this part of the basin rely on river water for drinking.

TABLE 3.3: 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)

TABLE 3.4: RECENT WATER QUALITY MEASUREMENTS (WET SEASON) IN NAMIBIA AND BOTSWANA

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

Source: Ortmann, 2009 and Masamba, 2009

Table 3.4 shows recent measurements of water quality data in Namibia and Botswana that reinforce earlier water quality surveys and confirm that water quality in the Cubango-Okavango is generally very good to excellent, based on the national classification scheme. What stands out is a gradual increase in conductivity and turbidity along the length of the river, which however, decreases in the permanent swamp of the delta. Generally, dissolved oxygen is stable throughout the length of the main stream, with a predictable increase after the turbulent flow at Popa Falls. Chlorophyll – an indicator of productivity – is generally low in the riverine sections but increases in the permanent swamp.[9]

In *Botswana,* there are some differences in water quality between the 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 in salts from higher in the basin. Turbidity also shows differences between the sites, increasing in the panhandle (similar to the main stream above it) as the flow increases, while the turbidity is lower in the delta due to the filtering effects as the water flows through and is slowed down by the panhandle. In Cakanaca (Xakanaxa), in the eastern delta, and in the Boteti outflows, turbidity declines with decreasing flow.[10]

9 Ortmann, C. (2009) and Masamba, W. (2009)
10 Masamba, W. (2009)

Dissolved oxygen in the river tends to decrease with increasing flow in the panhandle, seemingly because of an increase in the oxygen demand from organic matter washed into the river during higher flows. Conversely, in the delta the dissolved oxygen tends to increase with increasing flow.

In Botswana, 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. There is localized pollution from solid wastes and waste waters from tourism camps and lodges, especially in the delta.

In *Namibia,* with the concentration of human populations along the river, there is the potential for decreasing water quality, especially during periods of low flow. 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 Cubango-Okavango.[11]

TDA hydrology research team

Localized higher values of phosphates appear to be associated with human and cattle waste and detergents used for laundry. The phosphate concentrations downstream from large agricultural developments were not significantly different than those for comparable upstream sites.[12] The main anthropogenic pollution sources are the same as in Angola, however the pollution sources tend to be more concentrated.

Information on the groundwater quality is limited to the lower basin and delta aquifers. The groundwater quality in the Kavango district of Namibia is variable with 'strips' of saline water in the Kalahari aquifer and other areas with high fluoride. Groundwater in the Kalahari aquifer along the banks of the river is often of poor quality as the result of high iron and manganese content – occasionally higher than safe limits for 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 around 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 characterized 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.

More detailed information on the basin groundwaters is given in supporting Report 9, referenced in Annex 2 of this report.

11 Ortmann, C. (2009) quoting Bethune, S. (1992)
12 Ortmann, C. (2009) quoting Trewby, F. (2003), Andersson, J. (2006) and Bethune, S. (1987)

3.2 BIOLOGICAL COMPONENTS

3.2.1 Land cover and protected areas

Land cover

The land cover classes within the basin are fairly well defined among the three countries and are shown in Figure 3.7. Moving down the basin, the wooded highlands of Angola give way to open and transitional woodlands and then to tree/shrub savannah as the river flows into and through Namibia, opening into a mosaic of flooded grasslands and swamps in the delta in Botswana.

The approximate total areas of these land cover classes for the whole basin are shown in Table 3.5.

TABLE 3.5: 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**

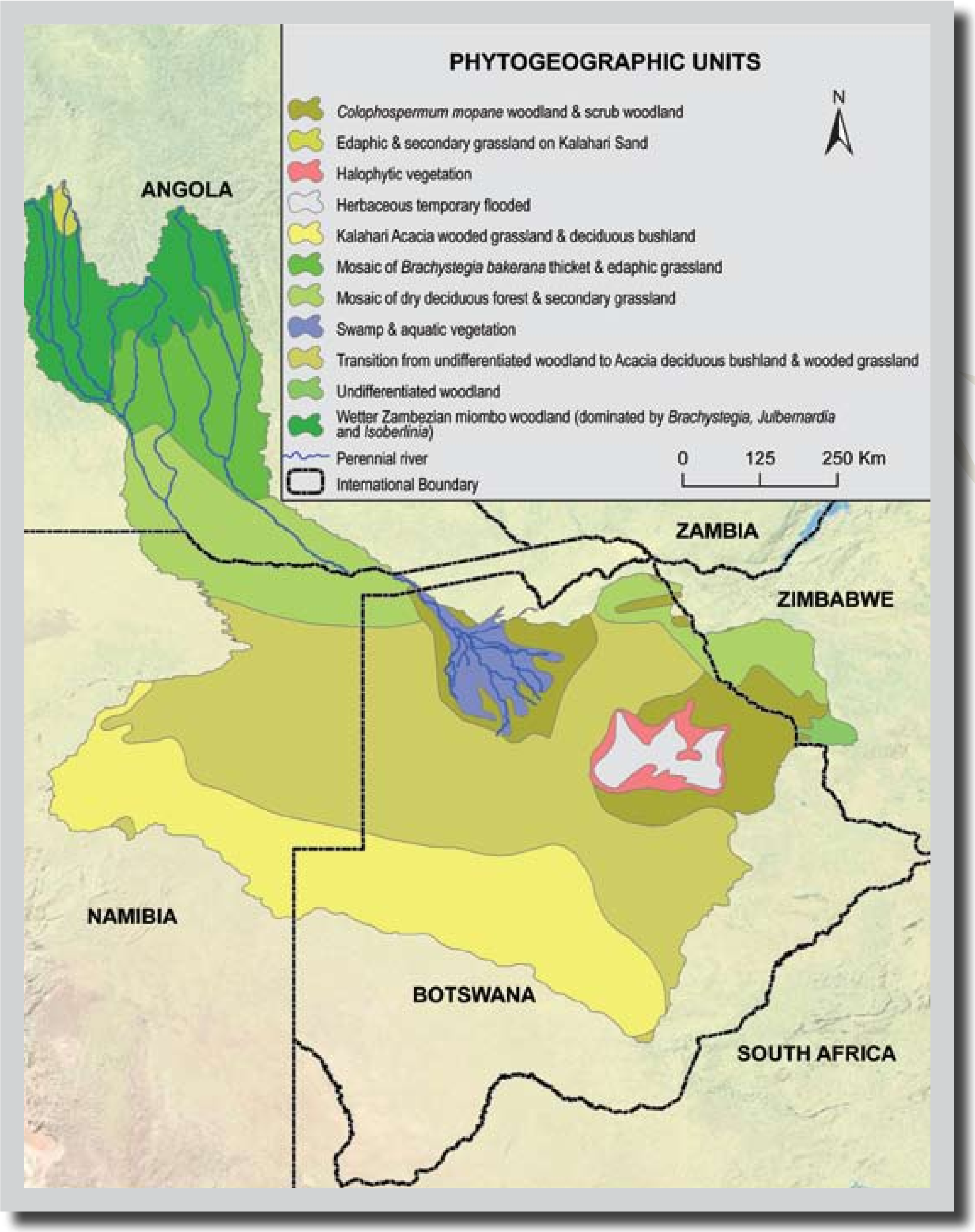


Figure 3.7: Vegetation types of the Okavango River Basin

Source: Verissimo, (2009)

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 3.8 a) 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 Botswana Government has, through an extensive process, developed an Okavango Delta Management Plan for the Ramsar Site. Namibia has no Ramsar Site in the Kavango, and Angola is not yet a signatory to the Ramsar Convention.

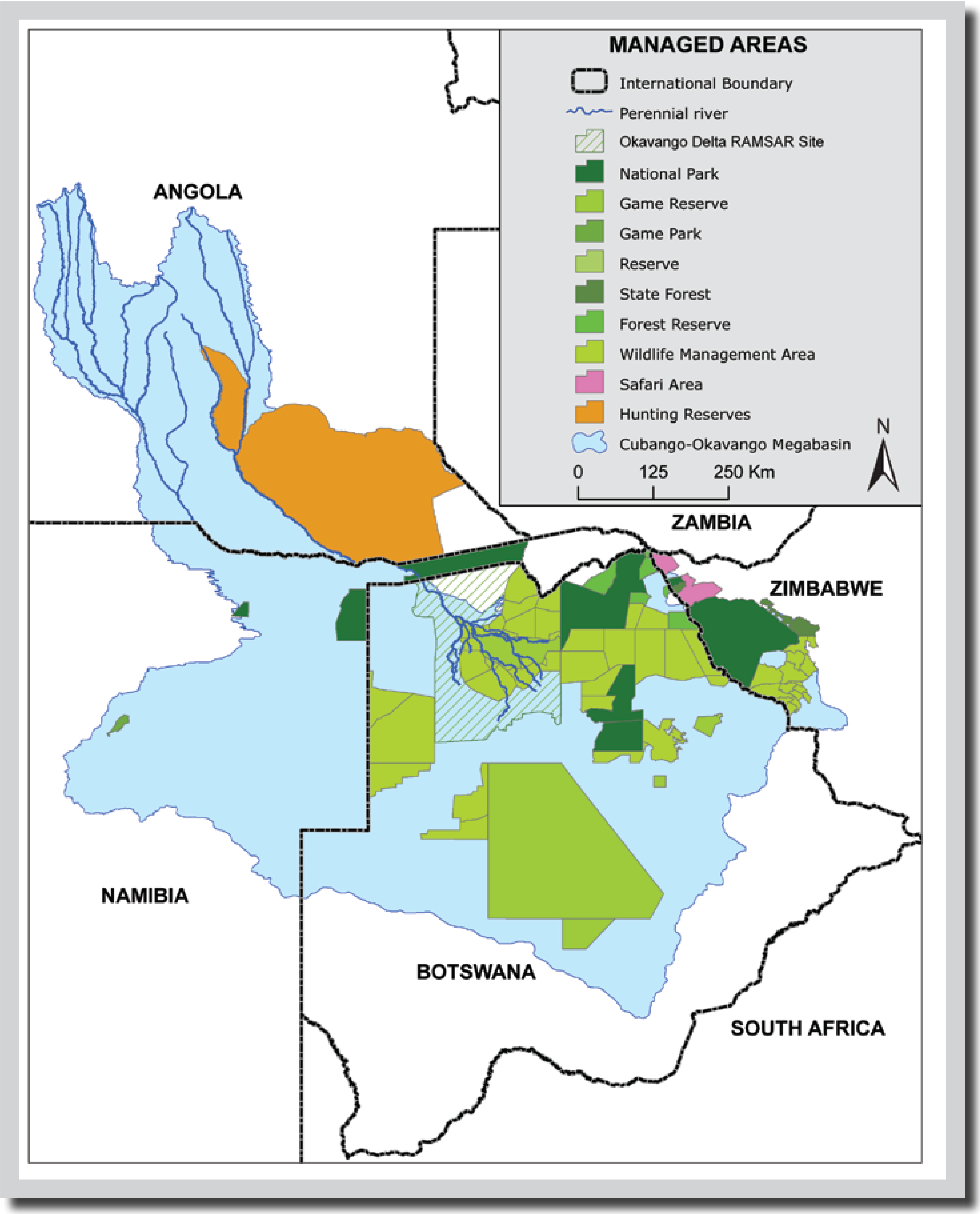
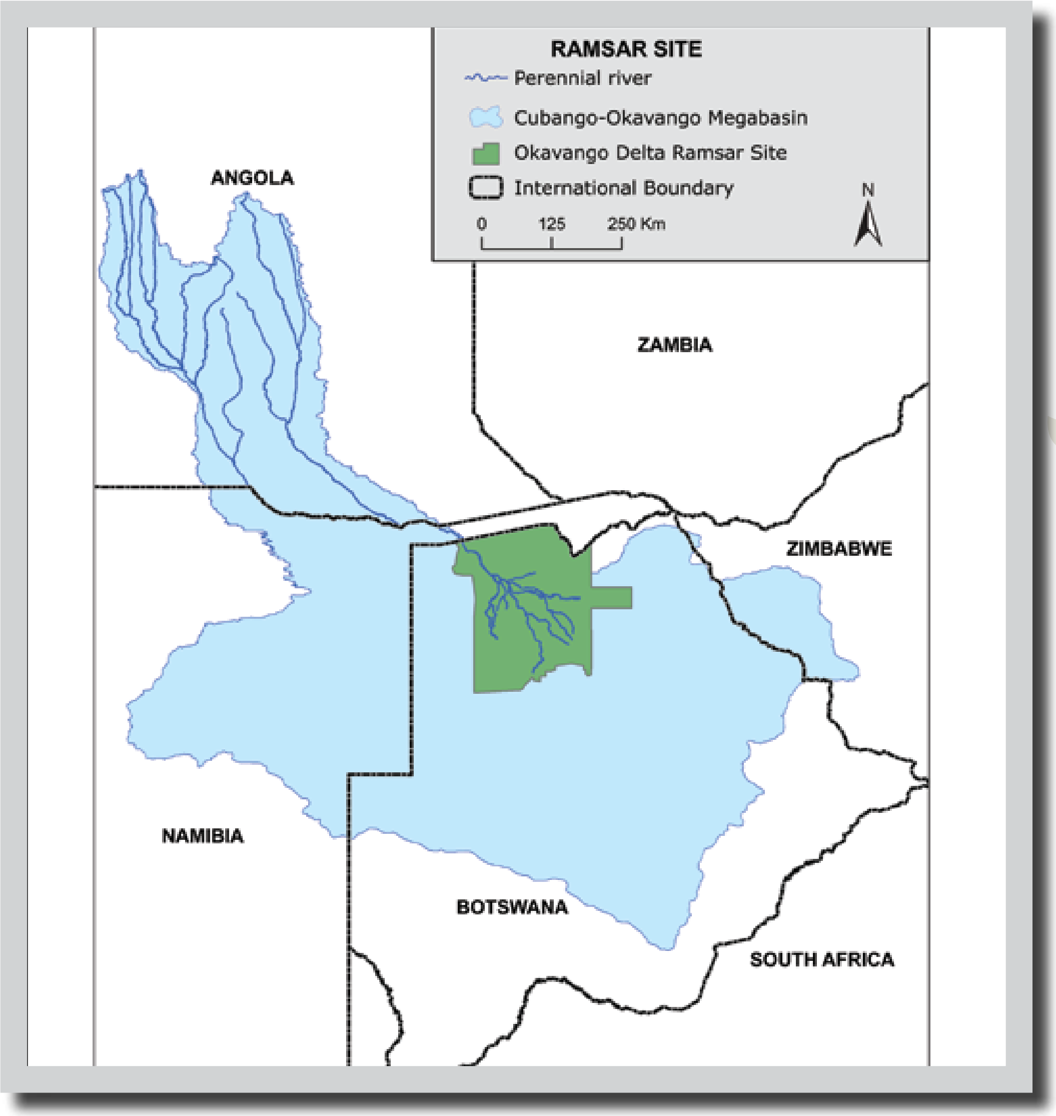


Figure 3.8: a) Protected and managed areas in the Cubango-Okavango River basin



b) Okavango Delta Ramsar Site

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.

3.2.2 Basin ecosystems

The principal basin ecosystems are arranged according to the four catchment zones.[13] The focus is on the riverine ecosystems described in terms of flora and fauna, and human pressures. Additional information from the field surveys is included in a matrix outlining the features of each Integrated Flow Assessment (IFA) field site in Annex 1 of this report.

Angolan headwaters

The Angolan headwaters are divided into the Cubango River and Cuito River catchments. Each catchment has its own ecosystem type and related fauna (Table 3.6).

13 This section has drawn upon the IFA Delineation Report No 4 and IFA specialist reports (2009) together with Mendelsohn and el Obeid (2004)

TABLE 3.6: 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, roan, 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 floodplains	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 Cuanavale 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 Kavango River near Dirico. The different ecosystems are summarized in Table 3.7.

TABLE 3.7: 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 3.8).

TABLE 3.8: 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 farming

Okavango Delta

The Okavango Delta is the best-known feature of the river basin. It is one of the largest Ramsar Sites in the world and its variety of habitats and the resulting biodiversity make it a unique area for global biodiversity conservation. The delta can be divided into five zones[14] (Figure 3.9) classified by the duration and frequency of inundation, and the response to inflow from upstream and local rainfall. It can be characterized into areas that are permanently flooded, seasonally flooded, occasionally flooded and drylands. Table 3.9 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.

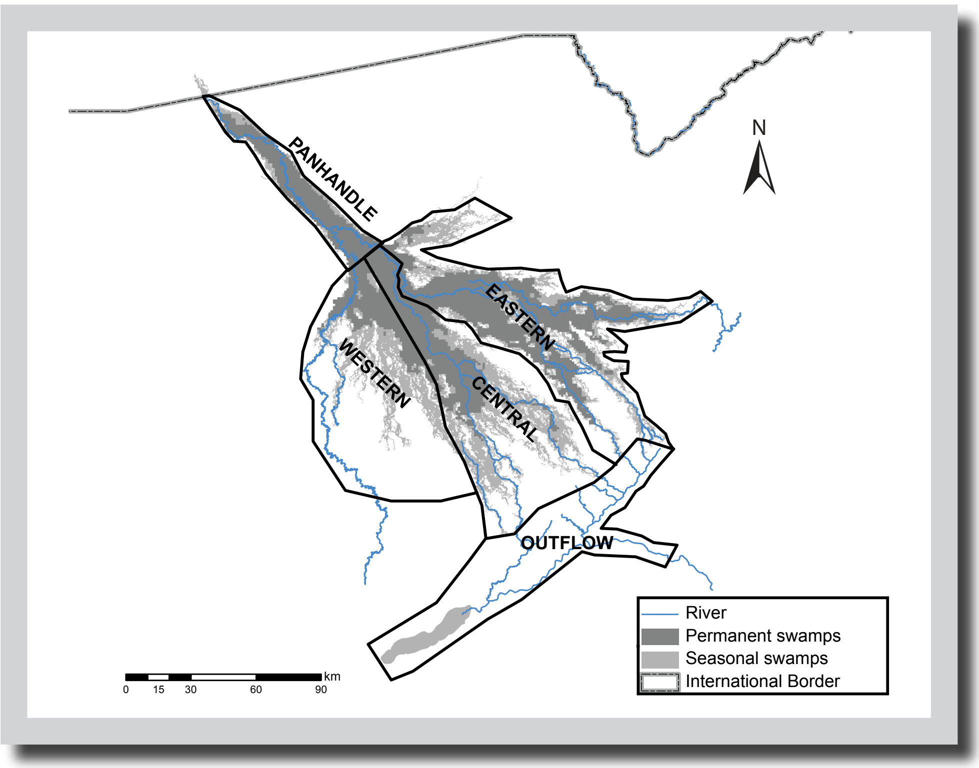


Figure 3.9: Zonation of the Okavango Delta

14 IFA Report 4 – Delineation (2009)

TABLE 3.9: 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

3.2.3 Biodiversity and biological production

The Cubango-Okavango river basin is internationally important for its biodiversity and biological production. In the delta alone 1,300 species of plants, 71 species of fish, 33 species of amphibians, 64 species of reptiles, 444 species of birds and 122 mammal species have been recorded.[15] [16] The specialist reports that provide in-depth information are included in the country reports listed in Annex 2 of this report. Table 3.10 lists a number of species and groups that are considered important indicators and their status according to the International Union for Conservation of Nature (IUCN) Red Data List.[17]

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.

TABLE 3.10: 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

15 Ramberg, L et al. (2006)

16 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 (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)

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

Throughout the basin there are a number of vulnerable and near-threatened species. There are at least 330 species of macro-invertebrates in these categories. Seventy species of fish (of which 10 have been 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, although not in the Cubango-Okavango Basin.

Elephant numbers are increasing in both Botswana and Namibia, and there are renewed reports of conflict between human populations and elephants in Angola as well. Elephants in large numbers have devastating impacts on vegetation and there are reports of damage to riparian vegetation in the Mahango.[18] However, numbers in the Angolan section of the basin are considered to be low.

The biodiversity and biological production of the Cubango-Okavango river basin is under pressure and is changing. Some of the Red Listed species are seen to be decreasing in number. Threats that can be attributed to human pressure include:

- Fires – while naturally occurring and important, increased human activity leads to more frequent fires
- Overgrazing – more cattle and smallstock are maintained by an increasing human population
- Natural resources exploitation – hunting and fishing pressures are rising on all the natural resources utilized by increasing human populations who are reliant on them
- Changes in habitat – demand for land for agriculture, especially land near the river, 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.

The wide diversity of species in the Cubango-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 the patterns of hydraulic habitat, nutrient deposits, plant succession and dependent animals.

3.2.4 Ecosystem functions and services

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

1. **Provisioning services**
   The river provides water, edible plants and animals, construction materials, fuel, genetic materials and ornamental products.

2. **Regulating services**
   The river affects the local climate of Angola, Botswana and Namibia. It regulates groundwater recharge along its length and – through its floodplains – plays an important role in flood mitigation. It removes excess nutrients and dilutes pollutants, especially in the delta. Vegetation along the river stabilizes the banks, preventing them from eroding, and the ecosystem as a whole provides nursery and breeding areas for fish, aquatic birds and other wildlife.

3. **Cultural and recreational services**
   The river contains sacred and cultural sites for the people of all three countries and while these are of great importance for riparian communities, no formal studies have been undertaken on the location and significance of these sites along the river. The river also provides inspiration for books, photography, plays and music, and is a recreation area of global significance.

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, realization 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.

The value of tourism is of significant importance to Botswana and to a lesser extent Namibia.

18 Bethune, S. (2009)

4. **Supporting services**
   The river, delta and its floodplains are important carbon sinks. They also play significant roles in nutrient management, soil formation and the accumulation of organic material. The wetlands are highly productive ecosystems for primary production and carbon sequestration by plants. The delta provides a crucial habitat for pollinators.

3.3 THE PEOPLE OF THE CUBANGO-OKAVANGO RIVER BASIN

3.3.1 Demographic characteristics

The human population in the basin consists predominantly of rural communities, most of which are located either adjacent to the river or along access routes. In each country, the basin populations are remote from the capital cities and main centres of economic activity. Table 3.11 shows the demographic characteristics of the three countries and Table 3.12 indicates more specific details for the Cubango-Okavango river basin.

TABLE 3.11 : COMPARATIVE DEMOGRAPHIC CHARACTERISTICS OF ANGOLA, BOTSWANA AND NAMIBIA

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

Note: 2008 unless otherwise stated
Sources: The national level data was 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). For Angola the national level data was extracted from documents produced by the Ministry of Planning, the National Statistics Institute (INE), the National Directorate for Studies and Planning (DNEP) under the Ministry of Planning, and the United Nations Department of Economic and Social Affairs/Population Division.

National trends

The demographic figures at country level 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: Angola's population growth rate has only very recently shown signs of slowing. This can be largely explained by the war, which curtailed social and economic development and also resulted in high rates of urbanization, primarily caused by displacement. While urbanization is normally accompanied by better education or higher incomes leading to lower birth rates, most of the urban populations in Angola lived without services during the war. 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.

Botswana and Namibia: Both Botswana and Namibia have undergone a demographic transition during the past 30 years. Fertility rates and population growth rates have slowed due to urbanization, increased female education and generally improved household income associated with social and economic development.[19] 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.[20]

Situation in the Cubango-Okavango river basin

Table 3.12 shows demographic data for the basin in each of the three countries. 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 urbanization rate of about 38 percent.

TABLE 3.12: OKAVANGO RIVER BASIN, SPECIFIC VALUES

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

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

Angola: The high urbanization rate, mainly in the larger centres of Cuito Cuanavale, 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.

TDA research site at Mucundi, Angola, 2008

The rural population 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 percent per annum.

The density of the population in the Cubango-Okavango river 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.

19 Mendelsohn et al. (2002); Dorrington et al. (2006)
20 Dorrington et al. (2006)

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.[21]

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 percent.

Namibia: In the Namibian part of the basin there are about 219,090 people, amounting to some 10.5 percent of the national population.[22] Most of these people (94 percent) live within 5 km of the river and about 20 percent of them are urban, living in Rundu. The urbanization 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.

The population growth rate in the Namibian basin has been very high – up to 7 percent per annum between 1981 and 1991.[23] This is partly the result of natural increase, but there was significant immigration from Angola during the war, for security and economic reasons. The situation has since stabilized 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 percent.[24]

Figure 3.10 shows the urban and rural distribution of the basin population.

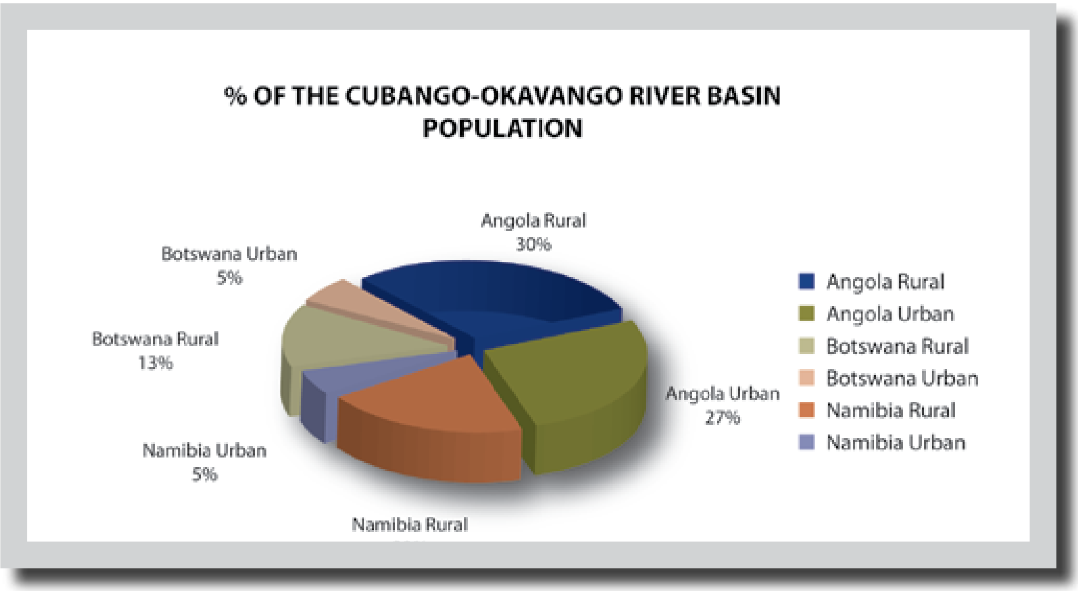


Figure 3.10: Distribution of the Cubango-Okavango Basin population in urban and rural areas

3.3.2 Population growth forecasts

The population of the Cubango-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 do 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 882,000. By 2025, the population for the basin as a whole is projected to be over 1.28 million people, with 62 percent living in Angola, 16 percent in Botswana and 22 percent in Namibia (Figure 3.11). In Angola, the population projections to 2025 for the Cubango and Cuito sub-basins are shown in Table 3.13; the projections for Ngamiland in Botswana can be found in Table 3.14 and projections for Namibia for the rural and urban population in Rundu are shown in Table 3.15.

21 ODMP (2008)
22 Based on data from Mendelsohn et al. (2002) and Mendelsohn and el Obeid (2003)
23 Mendelsohn and el Obeid (2003)
24 Detailed analysis by Dorrington et al. (2006)

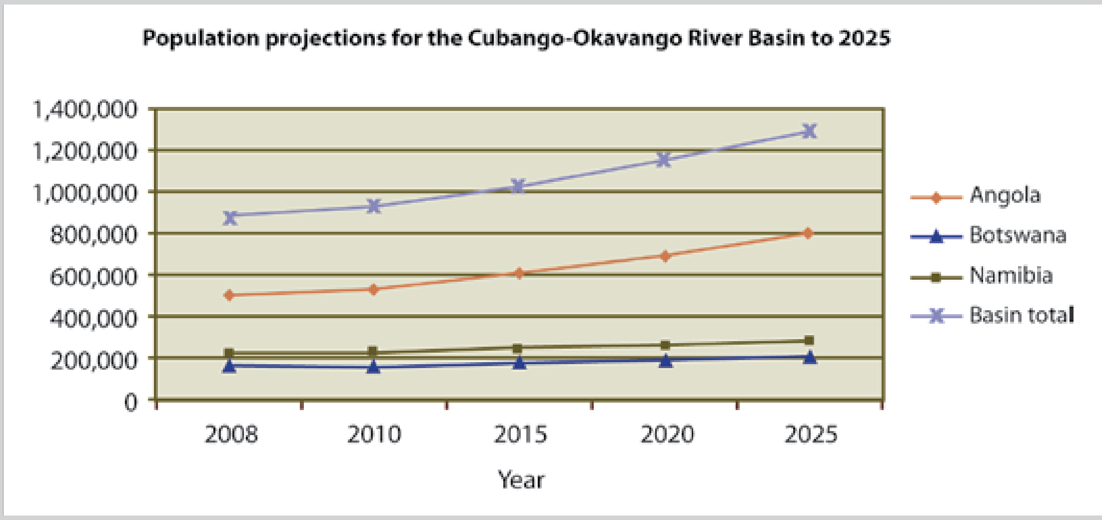


Figure 3.11: Population projections for the Cubango-Okavango River basin

TABLE 3.13: POPULATION PROJECTIONS TO 2025 FOR CUBANGO-OKAVANGO RIVER BASIN IN ANGOLA

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 3.14: POPULATION PROJECTIONS TO 2025 FOR THE CUBANGO-OKAVANGO RIVER BASIN IN BOTSWANA

Botswana	2009	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	**157,639**	**162,456**	**175,011**	**188,537**	**203,108**

TABLE 3.15: POPULATION PROJECTIONS TO 2025 FOR THE CUBANGO-OKAVANGO RIVER BASIN IN NAMIBIA

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**

Signs of rapid economic empowerment, informal market, Menongue, Angola, 2008

Throughout the basin, there is a trend towards urbanization associated with population growth and a lack of alternative livelihood options. Although the population in the basin is predominantly rural, the Angolan part of the basin has an urban population of about 40 percent, while in Namibia the figure is approximately 20 percent and in Botswana, around 30 percent. 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's population is growing at a rate of 2.5 percent per annum, compared to 1.5 percent in the rural areas of Kavango.

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

3.3.3 Ethnic diversity of the basin

There is wide ethnic diversity among the peoples of the Cubango-Okavango Basin, including Bantu and non-Bantu ethnic groups.

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

Children on road to Rundu, Namibia, 2010

- The Umbundo occupy the upper reaches of the Cubango in fairly dense settlements (about 16 percent of the basin's population) and mainly use the *olonaka* farming methods (traditional form of recessional agriculture practised in Angola).
- The Ganguela (nearly 50 percent) are mainly traditional farmers in the east, and cattle breeders in the west.
- The Lunda-Tchokwe (nearly 33 percent) 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 people 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 Khoisan populations in the province of Cuando Cubango.[25]

Botswana: The ethnic groups in Ngamiland are dominated by:[26]

- 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.

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.[27] The first two groups, who represent almost half the population in the basin, speak Rukangwali. The Shambyu and Gciriku speak Rumanyo, and the Mbukushu speak Thimbukushu. About 33 percent of Rundu residents and 15 percent of rural inhabitants speak an Angolan national language, mainly Nyemba, Ombundu, Ngangela or Chokwe.

Other groups include:

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

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

3.3.4 Social, educational and health indicators

National indicators

Table 3.16 shows a range of national-level social, educational and health indicators for Angola, Botswana and Namibia.[28]

TABLE 3.16: COMPARATIVE HUMAN WELL-BEING, HEALTH AND HUMAN DEVELOPMENT INDICATORS FOR ANGOLA, BOTSWANA AND NAMIBIA

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

Note: 2008 unless otherwise stated

25 Saraiva et al. (2009)
26 Turpie et al. (2006)
27 Yaron et al. (1992)
28 The data was extracted and synthesized from several websites, including UNHDR (http://hdr.undp.org), World Bank Key Development Data & Statistics (http://web.worldbank.org), and Population Reference Bureau (PRB) (http://www.prb.org)

At national level, the indicators of social development in Botswana and Namibia are better than those in Angola. As can be seen from the table above, 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.[29]

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

The incidence of HIV/AIDS differs significantly between Angola and the other two countries. Among adults it is 2.1 percent in Angola, but up to 23.9 percent in Botswana and 15.3 percent in Namibia. The pandemic grew very fast in the latter two countries between the mid-1980s and the late-1990s[30]. However, the prevalence rate has slowed and seems to have stabilized since 2000. The rate in Botswana has even declined slightly.

Children at Menongue, Angola, 2008

Friends at Liyapeka Rapids, Angola, 2007

HIV/AIDS increases mortality significantly among young children and people of reproductive age. This has had a significant impact on the life expectancy at birth in Botswana and Namibia, which has been reduced from around 60 years in the early 1990s to 47 and 49 years 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 3.16 show that Botswana and Namibia both have higher values, and are classified as having medium human development. Angola is classified as having low human development.

29 Administração Municipal do Cuchi 2008; Administração Municipal de Menongue 2008; GEP/Gabinete de Estudos e Planeamentos 2007; FAO/ADB Cooperative Programme 2007

30 Dorrington et al. (2006)

The HDIs for Angola increased between 2000 and 2005, but in Botswana and Namibia the indices have declined since 1990. In Namibia, although there are marked improvements in the education and income indices, the decline is a result of the mortality effect of the HIV/AIDS pandemic.[31]

Indicators in the Cubango-Okavango Basin

The main differences between national social development indicators and those of the Cubango-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 household survey indicated that fewer than 4 percent of households surveyed had access to improved water supplies, far fewer than the 51 percent for the nation as a whole. They also found that over 54 percent of rural households relied on rivers for their water source, compared to 14 percent 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 percent of those surveyed did not know how to read and write. More than 40 percent also considered that access to health services was very poor, and besides AIDS, malaria was of greatest concern.[32]

Riverside grass resources, Namibia, 2009

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 the country as a whole.[33]

Namibia: The Kavango Region has the highest incidence of poverty among all 13 regions in Namibia with 57 percent of households classified as poor [34] and 36 percent as severely poor.[35] [36] This can be compared with the incidence for the whole country where 27.6 percent of households are poor, and 13.8 percent are severely poor. Sixty two percent of rural households (which make up 80 percent of the population) are considered poor in comparison to only 33 percent 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, 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.[37]

31 Levine (2007)
32 Saraiva (2009)
33 ODMP (2008)
34 Poor household = monthly expenditure of N$262 or less per adult equivalent
35 Severely poor household = monthly expenditure of N$186 or less per adult equivalent
36 CBS (2008)
37 Mendelsohn and el Obeid (2003)

CHAPTER 4: ECONOMIC ANALYSIS

This chapter contains a macro-economic overview of the three basin states, a summary of the main economic sectors operating in the basin including agriculture, energy and tourism, and a review of international and regional market forces. The chapter also contains a micro-economic assessment of basin livelihoods and the value of ecosystem services.

Women selling fish at Menongue, Angola, 2008

4.1 MACRO-ECONOMIC OVERVIEW AND TRENDS

Angola has the largest economy of the three basin countries, eight times as large as that of Botswana or Namibia, as shown in Table 4.1. The Angolan economy is also growing at a much faster rate (almost 20 percent in 2007) than the other two economies, which are growing at about 5 percent per annum. To a great extent 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 Botswana and Namibia, while growing more slowly, have had decades of steady but significant growth. Botswana's GDP per capita at US$5,739 is by far the largest, with Angola's at US$3,068 and Namibia's US$3,573.

Botswana also has the highest level of government expenditure at 35 percent of gross domestic product (GDP), reflecting the government's efforts to provide basic services to both its urban and rural populations. This and the higher level of GDP may explain the lower level of household consumption at 24 percent in Botswana. With similar GDP per capita levels, household consumption in Namibia is much higher than in Angola, with figures at 53 and 32 percent respectively. This most likely reflects the much lower living standards of the bulk of the population in Angola. Although Angola's GDP has grown rapidly, it is not as well distributed across sectors as Namibia's, which has had a longer period to develop its economy since 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.

Tourist lodge at Shakawe, Botswana, 2008

TABLE 4.1: SUMMARY OF MACRO-ECONOMIC INDICATORS

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

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

The distribution of income in all three countries is uneven, with Gini indices[38] 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 among the urban elites, the urban poor and rural populations.

Unemployment and underemployment in Angola are major issues for the country as it demobilises armed forces and works to create economic opportunities. There are no unemployment numbers reported by UN agencies for Angola. Unemployment in Botswana is relatively low for the region at 17.5 percent. In Namibia in 2006 the rate was almost double this at 33.8 percent and has since risen to 51 percent.

All three countries have strong export-led economies, reflected in positive or near-positive trade balances, as well as current account balances. In terms of liquidity, at the end of 2007, Angola had US$19 billion in liquid reserves (excluding gold). Botswana had half this amount, and Namibia had just US$1.2 billion.

The World Bank classifies Botswana and Namibia as upper-middle-income countries. Neither is 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 World Bank and may engage in borrowing in the future. Botswana recently completed a Country Partnership Strategy

38 The *Gini* index measures inequality of income

(CPS) with the World Bank, which looks to re-engage in lending to Botswana in the near future.

Angola is classified as a lower-middle-income country by the World Bank and is IDA-eligible. The World Bank and other donors have been supporting Angola's transition since the civil war ended. With the recent rapid growth in the country, the European Union (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 reported 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.

Villagers crossing bridge at sundown, Cuito Cuanavale, Angola, 2008

4.2 SECTORAL BASELINE

4.2.1 National perspectives

Angola

The dominant feature of Angola's economy is the extractive sector, particularly oil and gas, which accounts for over half of GDP (Table 4.2). The combined resources sector – agriculture, hunting, forestry and fisheries – are the third most prominent, making up 7.8 percent of GDP or US$3.8 billion in 2006. Despite their relatively small participation in GDP, the combined resources sector employs a large share of the workers in the country; by some estimates up to 85 percent. In addition, a large percentage of this activity is of a subsistence nature. Just 10 percent 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 4.2: ANGOLA, GDP BREAKDOWN BY SECTOR, 2007[39]

Economic Activity	Share of GDP (%)	GDP Value (in US$ million)
Oil and refined oil	44.51	33,173.3
Commerce, banks, insurance and services	20.52	10,051.4
Agriculture, forestry and livestock	9.39	4,600.3
Fishery and derivatives	0.34	165.1
Diamonds and other	4.03	1,050.7
Processing industry	6.44	3,154.3
Electricity and water	0.1	49.3
Construction and public works	5.98	2,930.7
Other	8.7	59.437

Botswana

Botswana, like Angola, is heavily reliant on extractive industries for its economic well-being (Table 4.3). Diamond mining brings in 40 percent of GDP. Manufacturing is limited to just 3.7 percent of GDP. Given the climate, agriculture is limited, making only a 1.6 percent 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

39 Source: Ministry of Planning (Angola). (2010)

the economy. Tourism plays a modest role in the country's economy providing almost US$200 million (2.16 percent), a large share of which comes from the Cubango-Okavango. Water and electricity are also responsible for US$200 million (2.16 percent) 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/annum per capita.

TABLE 4.3: BOTSWANA, GDP BREAKDOWN BY SECTOR, 2007[40]

Economic Activity	Share of GDP (%)	GDP Value (in US$ millions)	GDP change (%)	Employment rate (%)
Mining	40.7	3,775	5.2	2.63
General government	15.6	1,447	1.7	19.18
Banks, insurance and business services	10.3	955	6.6	1.56
Trade	8.3	770	15.5	14.36
Construction	4.5	417	8.7	5.12
Social and personal services	3.8	352	1.6	4.56
Manufacturing	3.7	343	12.0	6.67
Transport	3.5	325	20.3	2.98
Water and electricity	2.2	204	5.9	0.77
Hotels and restaurants	2.1	195	19.7	2.72
Agriculture	1.6	148	2.9	28.35

Namibia

Namibia has the most diversified economy of the three countries. Trade, transport, manufacturing and mining all contribute around 10 percent of the GDP (Table 4.4). Agriculture and forestry contribute 6.6 percent or US$491 million. Farming itself is fairly limited owing 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 percent or US$139 million. A portion of this tourism comes from the Cubango-Okavango region, although the bulk of it is associated with Etosha National Park, the coast and the dunes. Water and electricity contribute an additional US$99 million, or on average US$50/annum per capita.

Sunset over Kavango River near Rundu, Namibia, 2008

40 Source: Central Statistics Office (Botswana), in Boccalon (2008)

TABLE 4.4: NAMIBIA, GDP BREAKDOWN BY SECTOR, 2007[41]

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	

4.2.2 Basin perspective

Agriculture is the main activity practiced by the inhabitants of the basin; predominantly extensive livestock farming. At present irrigated agriculture is limited but there are plans, particularly in Angola and Namibia, for large expansion of cultivated areas which will have consequences for river flow. Other basin activities include hunting, the tourism and concession industry, hydropower, aquaculture and rural households collecting natural resources for food (predominantly fish), construction and fuel.

4.2.2.1 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 4.1, while the present intensity of cropping is shown in Figure 4.2.

Hut surrounded by maize crop, between Menongue and Rundu, 2010

41 Source: Central Bureau of Statistics (Namibia), in Boccalon (2008)

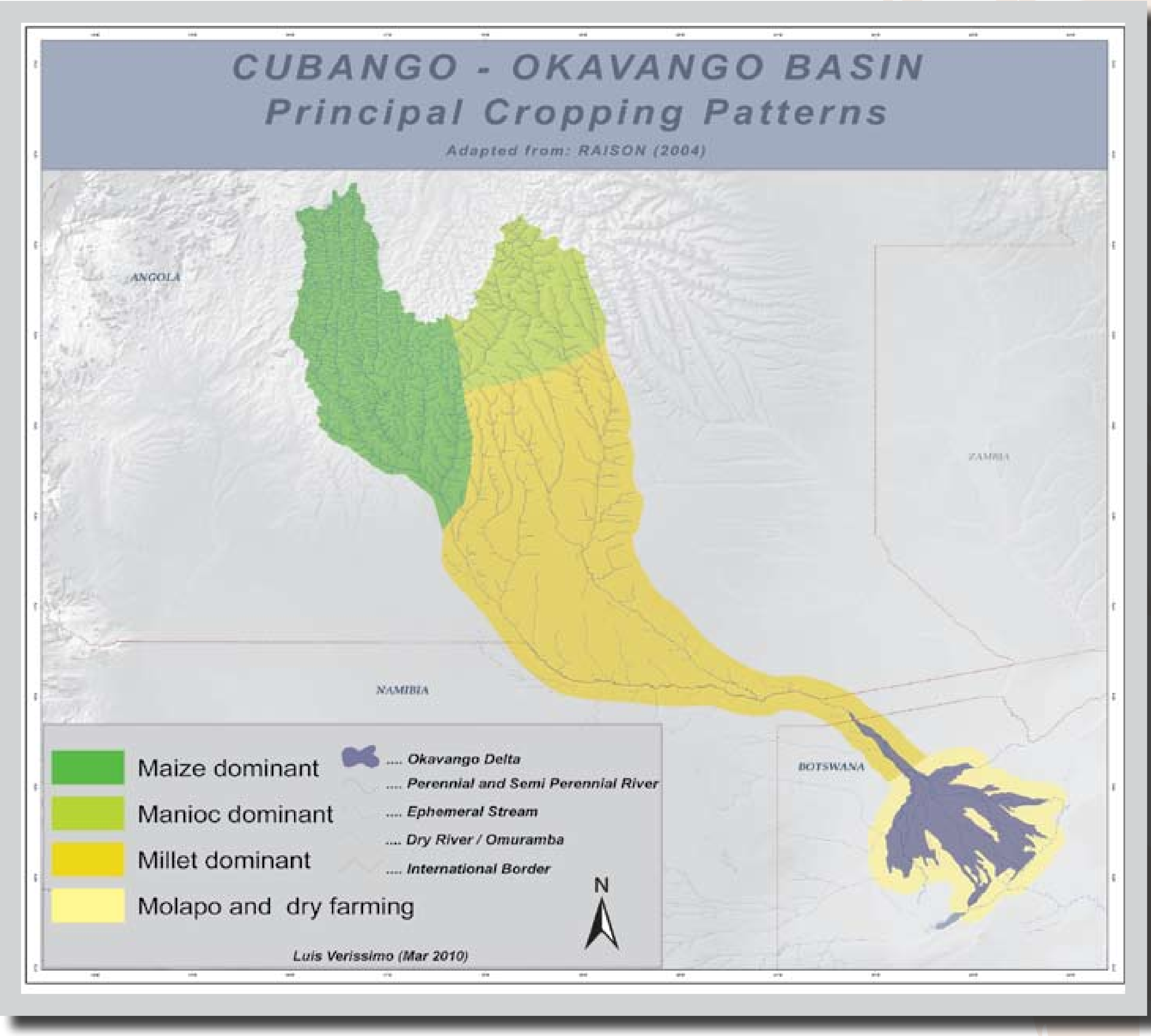


Figure 4.1: Principal cropping patterns

Source: Mendelsohn and el Obeid (2004)

Cultivation and cropping depends on the season, with intense activity just before the rains. Most farmers do not use agricultural chemicals or fertilizers, with little use of compost or organic manures.[42] 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.

While the population density in the basin overall is relatively low in comparison with other major river basins, there are certain areas of the basin, for example in the Kavango Region in Namibia, which have high population densities. The pressure of human activities on land use and vegetation cover is marked. For example, in the basin in Namibia, only 26,000 ha of woodland had been cleared in 1943; this increased to 72,000 ha in 1972 and to 194,500 ha in 1996 – an annual increase of about 3.9 percent.[43]

42 Mendelsohn, J. (2009)
43 Mendelsohn, J. (2009)

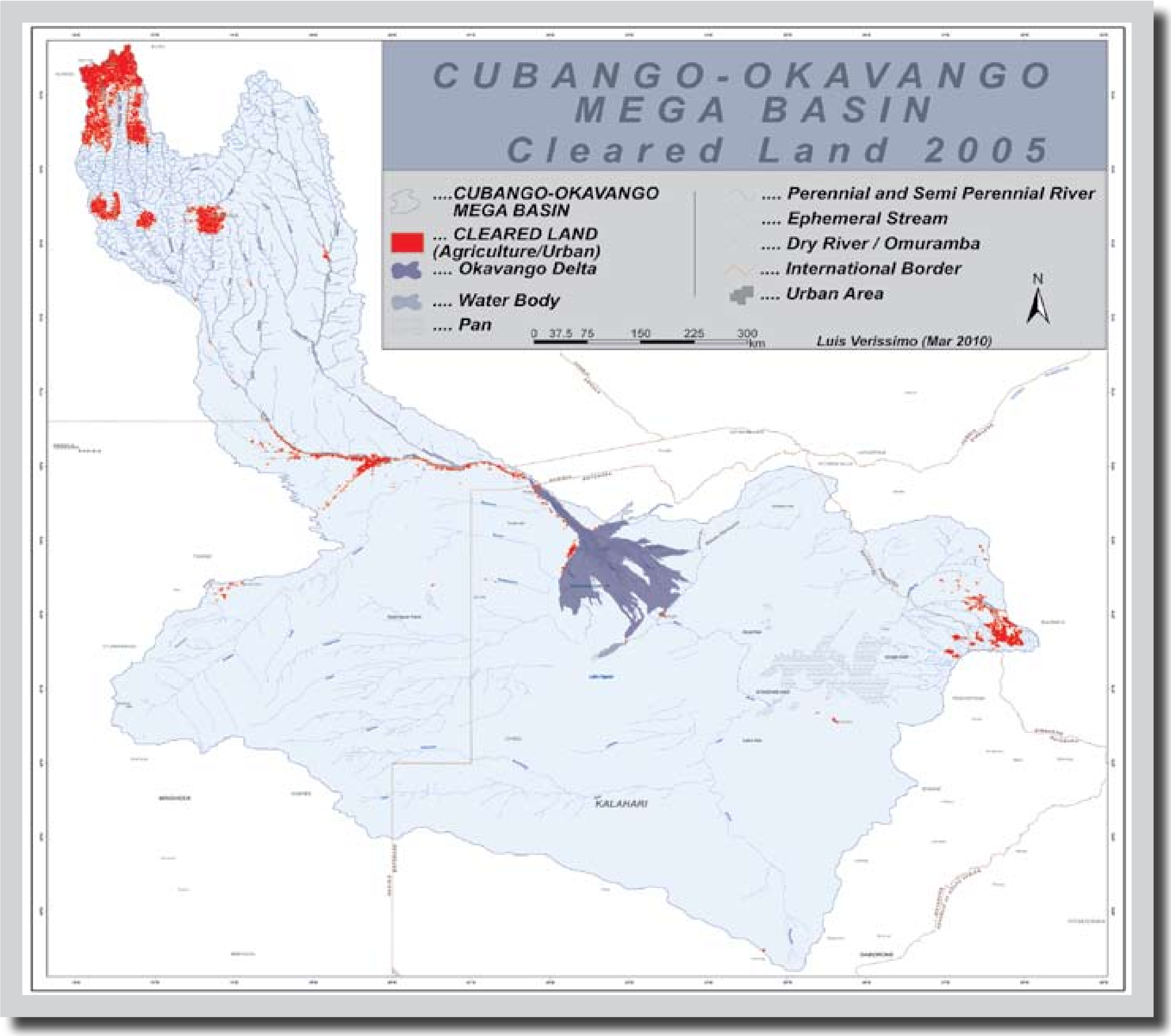


Figure 4.2: Intensity of cultivation – cleared land

Source: Mendelsohn and el Obeid (2004)

4.2.2.2 Irrigated agriculture

Irrigated agriculture has the potential for much higher productivity than rain-fed agriculture in the dry lands.[44] The present schemes in the three riparian countries:

- In *Angola* there are currently three schemes totalling about 1,200 ha of land which may be irrigated. All three schemes abstract water from the Cuebe River.
- In *Botswana* around the delta, of the 188 ha allocated for irrigation only 31 ha (17 percent) is currently being utilized.
- *Namibia* has invested the most in irrigated agriculture to date, 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.

However, there are a considerable number of large proposals for large irrigated agriculture schemes, principally in Angola and Namibia, with limited schemes in Botswana, which would draw upon the water resources of the Cubango-Okavango river basin, although the feasibility of many of these schemes has not yet been confirmed.

44 Information from Duarte, J. (2009), Liebenberg, P. (2009), Masamba, W. (2009) and Beuster, H. (2009)

In *Namibia*, irrigated agricultural development is already well advanced, but there are a number of additional proposed schemes. These estimates are based on a crop water-demand of 15,000 m^3/ha/annum. (Table 4.5a. and b.)

TABLE 4.5(A): WATER DEMAND UPSTREAM OF THE CUITO RIVER

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 4.5(B): WATER DEMAND DOWNSTREAM OF THE CUITO RIVER

No	Tribal area	Place (if known)	Existing area under irrigation (ha)	Future planned irrigation area (ha)
4	Gciriku	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**	

In the medium term in Angola, about 270,000 ha of new irrigation schemes are proposed, most of which are located in the Cubango catchment, especially on the Cuchi and Cuebe Rivers. In the longer term, a further three large schemes are proposed, bringing the total irrigated land to 490,000 ha. The water demand for these schemes is estimated to be 3,510 Mm^3/annum[45] in the medium term and 6,400 Mm^3/annum in the long term. A listing of the proposed large-scale schemes is provided in Table 4.6. In addition, as detailed in Table 4.7, there are proposals for the rehabilitation of existing irrigation schemes, as well as 186,000 ha for the development of new small- and medium-scale schemes by 2025.

45 Based on 13,800 m^3/ha/yr.

TABLE 4.6: PROPOSED IRRIGATION SCHEMES IN ANGOLA[46]

Municipality	Name of irrigation scheme	Source of irrigation water	Flow to be abstracted from river, m^3/s	Annual water requirement Mm^3/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 Lyapeca
Cuvango	Cuvango	Cubango 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 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 and Cubango 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 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

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

TABLE 4.7: 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 upgrading	1,200	3,800		**5,000**
TOTAL				**186,323**

Source: Ministry of Agriculture, Angola; Duarte, J. (2009)

A major limiting factor for the development of irrigated agriculture in Angola and other parts of the basin is the suitability of soils as shown in Table 4.8. The feasibility of these schemes will also depend on agro-ecological features, agricultural practices and market opportunities. It is likely that horticulture and fruit production will be the principal irrigated crops, while cereal crops will continue to be cultivated as rain-fed crops.

In some places in Angola a lack of water, irrespective of environmental concerns, will limit the development of irrigated agriculture; for example, the proposed Missombo Irrigation Scheme (1000 ha), Menongue Agricultural Scheme (10,000 ha) and EBRITEX (17,000 ha) along the Cuebe River could be limited since the estimated water requirement is 28 m^3/sec while during the dry season the flow of Cuebe River can drop to 10–13 m^3/sec.

TABLE 4.8: 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
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
Namibia	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, maize, millet, mahangu, sorghum

Source: Gomes (2009), Liebenberg (2009), Masamba (2009)

4.2.2.3 Livestock

Throughout the Cubango-Okavango Basin, livestock are a critically important feature of livelihoods and land use, with many households owning a number of 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 five percent of households, in comparison to Kavango and Ngamiland where about 50 percent of all households own some livestock.

The estimates of current numbers of livestock in the whole basin are shown in Table 4.9. 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.[47]

47 Mendelsohn and el Obeid, (2004)

TABLE 4.9: LIVESTOCK NUMBERS IN CUBANGO-OKAVANGO RIVER BASIN[48]

	Cattle	Goats	Sheep	Donkeys	Pigs
Angola, Cuando Cubango Province	192,200	66,327	12,598		22,827
Ngamiland, Botswana	625,000	243,000	21,000	70,000	n/a
Kavango, Namibia	125,972	44,135	1,472	1,555	1,778
TOTAL Cubango-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.

4.2.2.4 Harvesting of natural resources

All the communities in the Cubango-Okavango river basin use the natural resources of the river and the surrounding land as an important contribution to their livelihoods. The importance of fisheries to livelihoods varies in different sections of the river.

In *Angola*, local fishermen recognize 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.[49]

The most productive section in *Botswana* is in the north of Ngamiland, around the panhandle, where 65 percent of the population depend on fishing. In 2004/2005, almost 130 tonnes of fish were caught in the delta, of which 68 percent were bream and 25 percent were catfish. This is about 80 percent of Botswana's freshwater fish production.[50]

In *Namibia*, fishing also makes an important contribution to the livelihoods of riparian communities, although they recognize that the fish catches have been changing, with fewer cichlids being caught in some areas as a result of selective gillnetting. It was observed that fish catches around the Mahango Game Reserve have been better protected.[51]

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 and large amounts being collected in Angola. It therefore 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.

The proportion of household income derived from river/wetland resources in the three riparian countries is illustrated in Table 4.11 of this chapter.

4.2.2.5 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.

48 Data collected by Beuster H (2009) for hydrological modelling.
49 Saraiva, R. (2009)
50 FAO Fishery Country Profile (2007)
51 Van Der Waal, B. (2009)

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 guided mobile and self-drive camping 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.

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 percent per annum, with about 40,000 visiting the core Moremi Game Reserve in 2006.[52] 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 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.[53]

The distribution of tourism development in the three countries is shown in Figure 4.3.

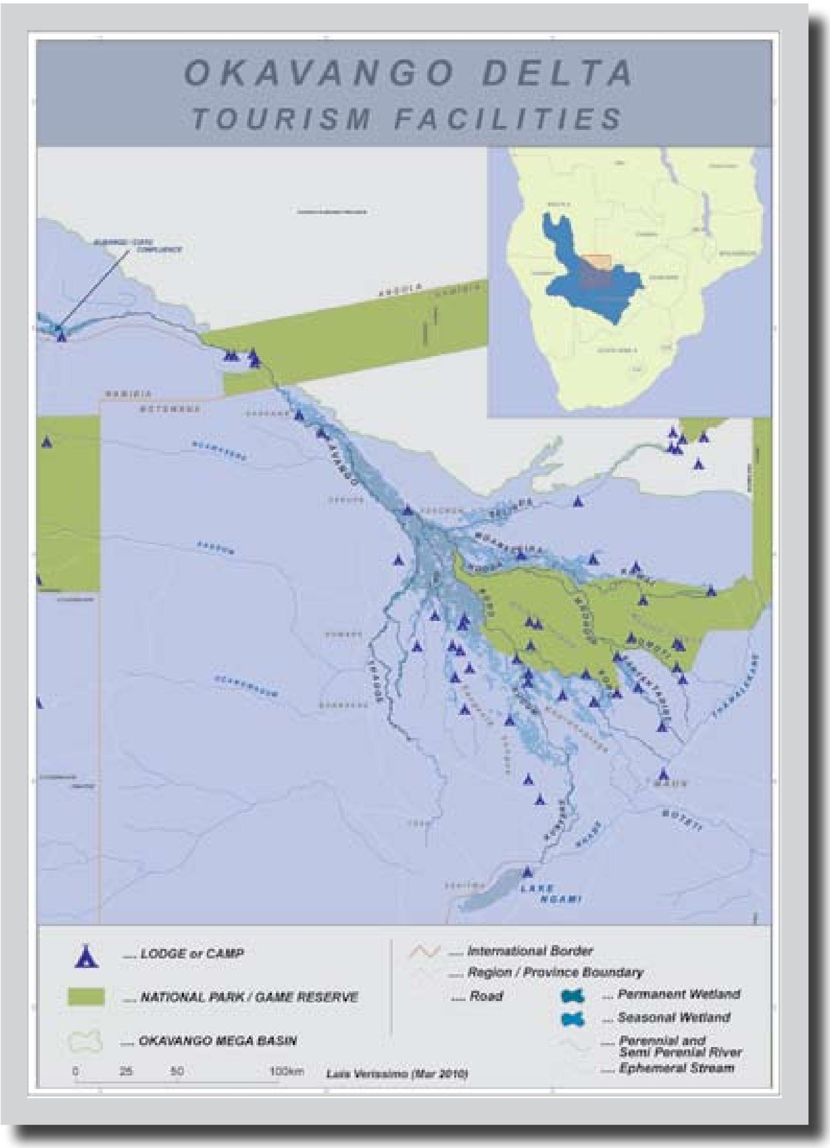
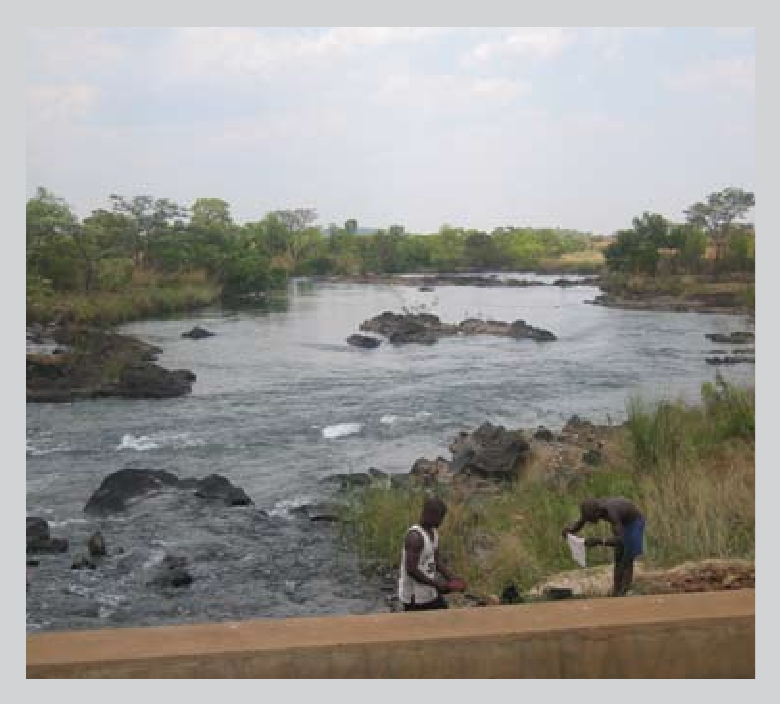


Figure 4.3: Distribution of tourist accommodation throughout the Cubango-Okavango River basin

Source: Mendelsohn and el Obeid (2004)

52 Mbaiwa, J. (2009)
53 Mbaiwa, J. (2009)



Using the river at Capico, Angola, 2008

4.2.2.6 Energy

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.

Both Angola and Namibia have considered the construction of hydropower schemes on the Cubango-Okavango river system (Table 4.10). The hydrological studies indicate that the combined output of the hydropower schemes included in the High water-use Scenario would be about 460 Gigawatt-Hour.

In *Angola*, prior to independence, 17 potential hydropower sites were identified in the basin, and although detailed feasibility studies have not been conducted for all sites, only the projects indicated in Table 4.10 are considered feasible by the government.

Feasibility and design studies for three hydropower sites are being prepared, at Lyapeka on the Cuebe River, Malobas on the Cuchi River and Maculungungu on the Cubango River, with target operational dates in 2013. All three are designed as run-of-river schemes, and with the exception of Malobas, with relatively low weirs and small reservoirs. The Malobas reservoir design has a 47 m high dam wall with an active storage of 1,634 Mm^3, surface area of 120 km^2 and an installed capacity of 84 MW.

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 was considered in 2003 in an attempt to preserve the falls themselves because of their high tourism value. However, the proponent, NamPower has shelved the proposal, because of operational constraints, and at present there are no plans to build the Popa Falls Hydropower Scheme.[54]

Rapids at Popa Falls, Namibia

54 Christian, C. (2009)

TABLE 4.10: PROPOSALS FOR HYDROPOWER SCHEMES IN THE CUBANGO-OKAVANGO RIVER BASIN[55]

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	Run-of-river 26m fall	Not functioning	No date	1.8	-	-	-	-	-	-
Cutato	Cutato	1483 masl	Run-of-river 45m fall	Planned	-	-	-	-	-	-	-	-
Cuchi	Cuchi	1420 masl	Run-of-river 16m fall	Study	-	1.8	-	-	-	-	-	-
Cuelei	Cuelei	-	Run-of-river 22m fall	Project preparation	-	3.2	-	-	-	-	-	-
Lyapeka	Cuebe	Missombo	Run-of-river 16m fall	Project preparation	-	3.6	-	-	-	-	-	-
Maculungungo	Cubango	Caiundo 1173 masl	Run-of-river 16m fall	Study	-	3.5	-	-	-	-	-	-
Mucundi[55]	Cubango	Mucundi 1153	Armazenamento	-	-	-	-	-	-	-	-	-
Cuito Cuanavale	Cuito	13 km of confluence	Run-of-river 14m fall	Planned	-	-	-	-	-	-	-	-
M'Pupa	Cuito	M'Pupa	Run-of-river 7m fall	Study	-	5	-	-	-	-	-	-
Chamavera	Cuito	M'pupa	Run-of-river 6m fall	Planned	-	-	-	-	-	-	-	-
Namibia												
Popa Falls	Kavango	Popa Falls	Run-of-river, 9.75 m high weir			20	5.3	9.75			2820	22.5

55 Mucundi: this use will allow regulation of the river between Mucundi and the Caprivi Region.

4.2.2.7 Aquaculture

There is currently one small aquaculture scheme in Angola at Menongue, which abstracts 10 m^3 per month from the Cuebe River. 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 percent of the water abstraction in Namibia.[56] 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.[57]

4.3 INTERNATIONAL AND REGIONAL MARKET FORCES

International and regional markets will continue to have an impact on 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.

Basket maker at Capico, Cuando Cubango Province, Angola, 2007

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 water transfer 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 6), 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.

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.

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.

56 Nashipili, N. (2009)
57 FAO Fishery Country Profile (2007)

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 deepens, tourism numbers and incomes may fall, with fewer opportunities for employment.

4.4 BASIN LIVELIHOODS AND ECONOMIC VALUE OF THE RIVER

4.4.1 Rural livelihoods in the basin

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 practice small-scale traditional land and natural resources use. It is common for households and communities to be settled close to riverbanks 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 percent 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 percent. Crop production is 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. Crop production is less important for households in the two countries 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 percent 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.

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.[58] More detail regarding the value of ecosystem services is given in supporting Report 2: Socio-economic Assessment Final Report.

Tourism in the Namibian and Botswana parts of the basin is overwhelmingly non-consumptive and nature-based. Local households may provide direct small-scale services to tourists, such as guided canoe trips, which supplement the commercial lodge operations.

58 Barnes et al. (2005)

4.4.2 Contribution of Cubango-Okavango resources to livelihoods

Table 4.11 shows the estimated proportions of household income provided by river and wetland natural resources that can be affected by flow change only, i.e. those that formed the Integrated Flow Assessment indicators (Chapter 6). 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 4.11: PROPORTIONS OF HOUSEHOLD INCOME IN ANGOLA, BOTSWANA AND NAMIBIA DERIVED FROM RIVER/WETLAND RESOURCES[59]

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

In *Angola*, households derive only about 19 percent of their income from river/wetland resources. There are smaller areas of floodplain, and river/wetland resources use is limited mostly to fish from the river channels, and reeds and grass from the riverbanks. Crops are important for Angolan livelihoods, but most are grown in rain-fed areas away from 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 4.4 shows the proportions contributed by different river/wetland-based natural resources use to 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 annum.

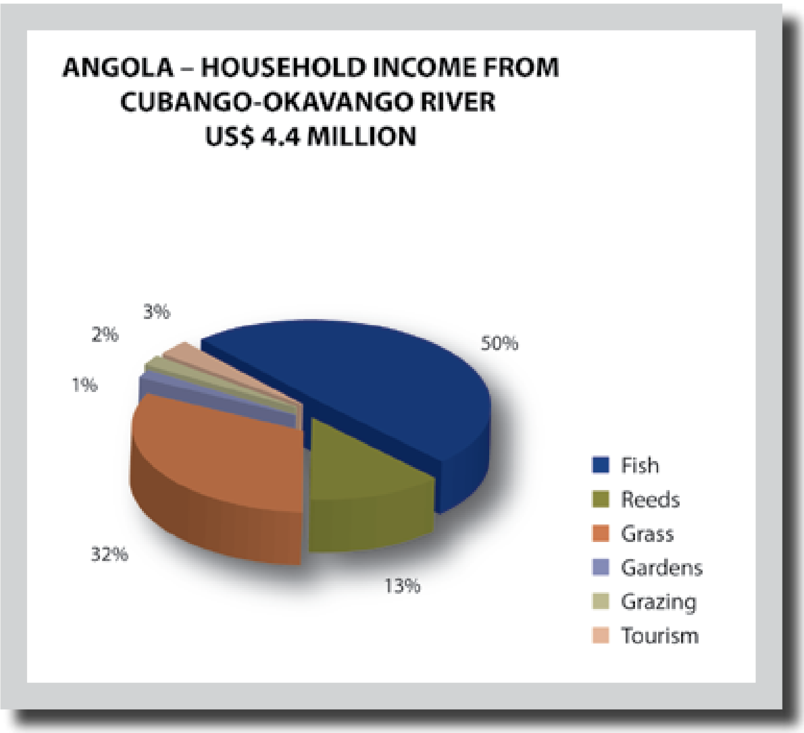


Figure 4.4: Estimated livelihood value of river/wetland-based natural resources use in Angola in 2008

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

In *Botswana*, the panhandle and delta form a vast floodplain area. The north, west, and south-eastern parts are occupied by rural communities, while the central and north-eastern parts are reserved for tourism concessions based on wildlife and the natural environment. Households around the delta derive nearly half (45 percent) their income from this large floodplain area, illustrating the great dependence on the 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, and also through small-scale tourism services, craft sales, and as community-level royalty payments from tourism operators. Figure 4.5 shows the proportions contributed by different river/wetland-based natural resources use to household livelihoods in Botswana. The impact of tourism contributions to livelihoods is very evident, consisting of nearly 94 percent of the total livelihoods derived from the river, which amount to US$22.7 million. The contribution of fish, reeds and grass, the direct products from the river, is just over US$1 million in Botswana, significantly less than in Angola and Namibia.

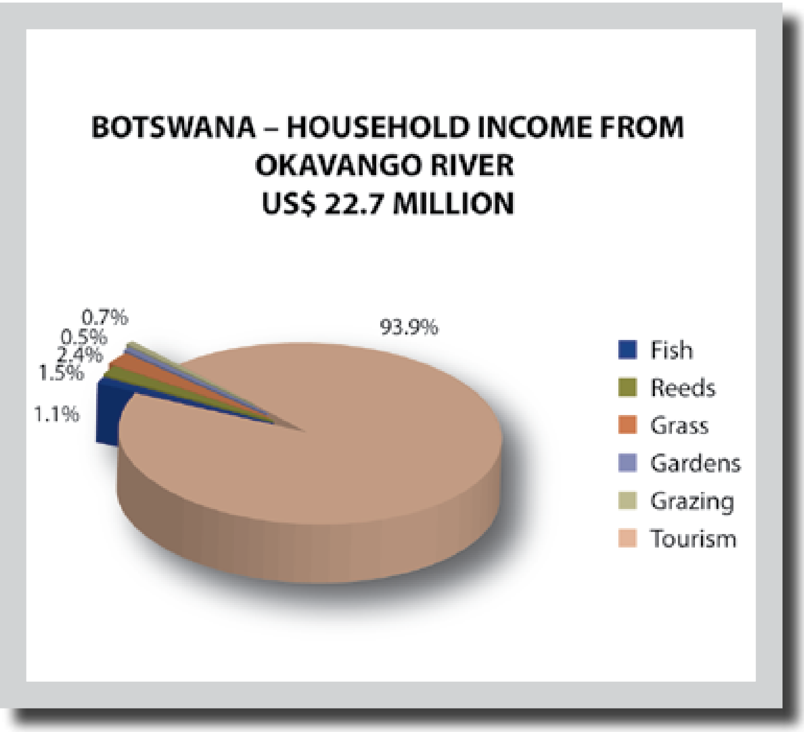


Figure 4.5: Estimated livelihood value of river/wetland-based natural resources use in Botswana in 2008

In *Namibia*, there are larger areas of floodplains and a fair amount of tourism development that allows households in the basin to derive about 32 percent of their income from river/wetland resources. The floodplains provide some income from wetland crop production, where better soil and moisture conditions 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 on the floodplains. In both cases the higher values of crops and livestock are directly due to the river and its wetlands.

The river and wetlands support tourism activities that would not otherwise be there, for example, approximately 30 private commercial, medium to large-scale lodge investments. Figure 4.6 shows the proportions contributed by different river/wetland-based natural resources use to household livelihoods in Namibia. The total livelihood values of fish, reeds and grass are very similar to those in Angola.

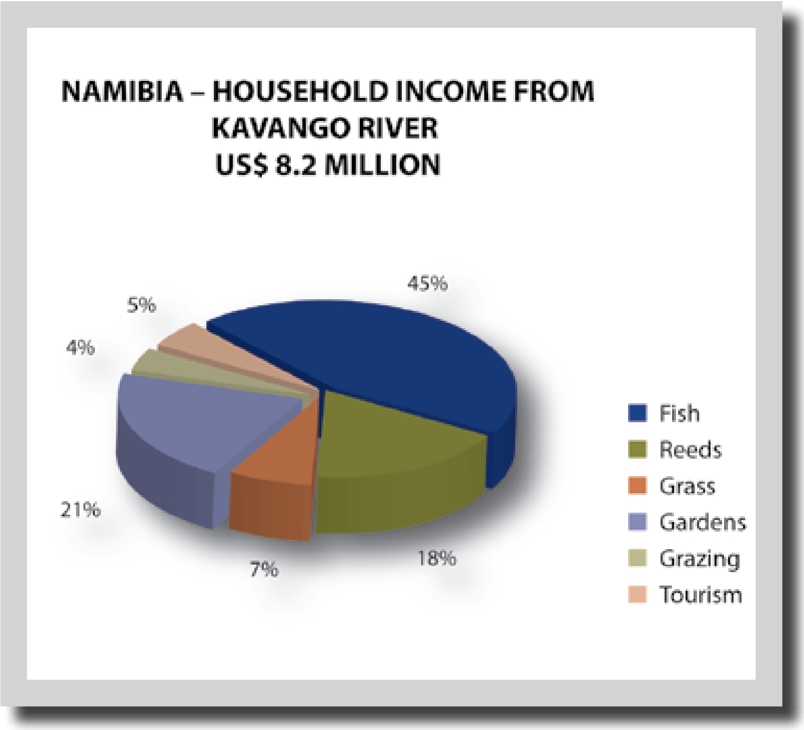


Figure 4.6: Estimated livelihood value of river/wetland-based natural resources use in Namibia in 2008

Figure 4.7 shows an aggregate of these national figures for the basin as a whole. This shows the weight of tourism contributions to the livelihoods of the people in the basin at 71 percent of the total US$35.1 million, while fish, reeds and grass make up 25 percent of the livelihoods.

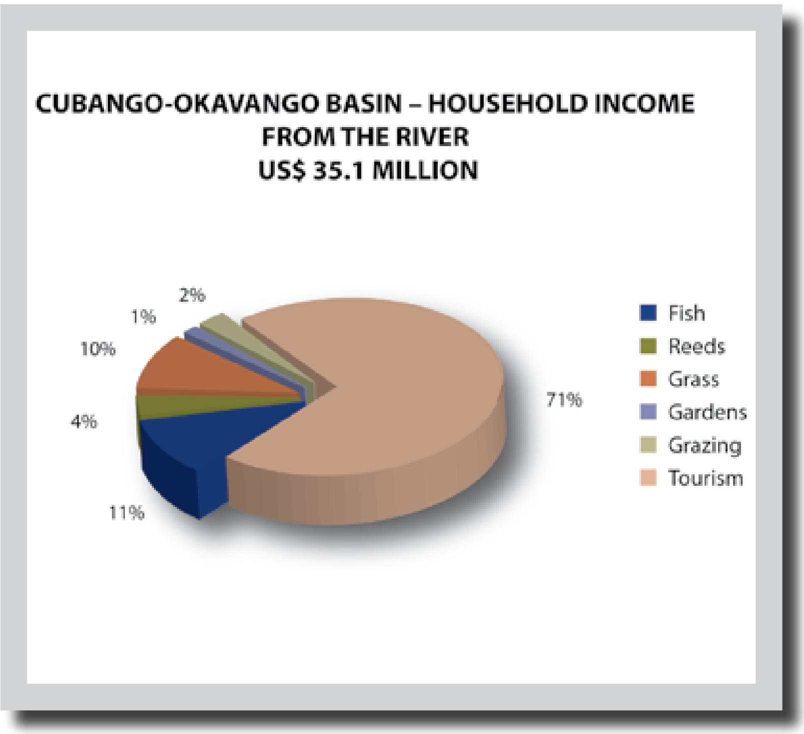


Figure 4.7: Estimated livelihood value of river/wetland-based natural resources use in Cubango-Okavango Basin in 2008

When these livelihood values are attributed to the rural population, the differences between the three countries becomes even more apparent, as shown in Table 4.12. In terms of livelihoods based on the use of the wetland natural resources (excluding tourism incomes), Namibia's rural population earns about US$25/person/annum, compared to Angola's rural population that earns about US$16/person/annum. In Botswana, the reliance on the river's resources is as low as about US$13/person/annum. When tourism incomes are taken into account, Botswana's rural population earns a total of US$205/person/annum, compared to Namibia's US$47/person/annum, and Angola's US$16/person/annum.

TABLE 4.12: 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$/a	US$/a		US$/a	US$/a
Angola	4,158,400	4,284,200	262,600	15.84	16.31
Botswana	1,395,100	22,711,400	110,630	12.61	205.29
Namibia	4,475,000	8,175,400	175,270	25.53	46.64
BASIN	10,028,400	35,170,900	548,500	18.28	64.12

Figure 4.8 shows the total livelihood and economic values for each country and for the basin as a whole, based upon the figures shown in the table above.

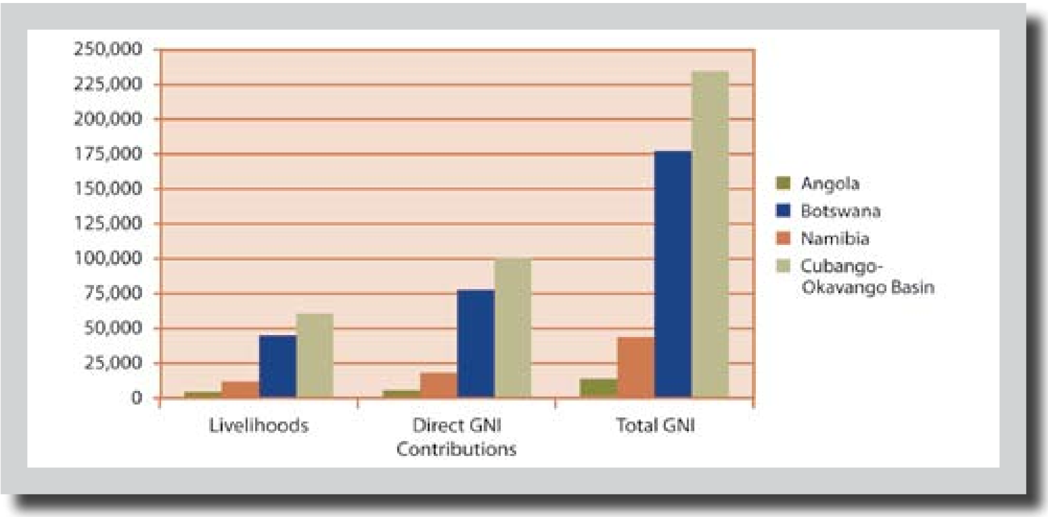


Figure 4.8: Estimated contributions of river/wetland-based natural resources

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)

Estimates of the economic incomes generated from the Cubango-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.[60] 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 tourism. The global willingness to pay for existence-value in the delta is likely to be significant as the area is widely known and respected as a conservation site. It is probable that these non-use values are significantly underestimated.

It is also clear that the contribution of the Cubango-Okavango river and wetlands to national economies is significant. For every dollar contributed to the livelihoods of basin residents, some US$1.60 is contributed directly to the national income. If the impacts of the income multiplier, indirect-use values and non-use values are taken into account, the total impact on the broader economies rises to about US$4.00.[61]

Full details of the above economic assessment and valuation of basin resources is available in supporting Reports 1 and 2 listed in Annex 2 and available in full on the accompanying CD.

60 Turpie et al. (2006)
61 Lange et al. (2004), Turpie et al. (2006)

CHAPTER 5: GOVERNANCE REVIEW

This chapter covers the governance and organization of the three riparian countries and describes legislation, policies and institutions that have an impact on environmental management relevant to the River basin. The chapter also contains a summary of the current governance shortfalls and proposals for their remediation. The full governance review report (Report 15, Annex 2),[62] which can be found on the CD accompanying this document, contains summary tables of applicable international and national policies, strategies and action plans for select natural resources management fields, and the institutional responsibilities for this management in the three countries.

5.1 ORGANIZATION OF STATES

All three Cubango-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 Cubango-Okavango Basin states, see Figure 5.1.

Road to Cuito Cuanavale, Angola

Angola

The Angolan Parliament approved a new Constitution on 20 January 2010, which follows the 2001 Strategic Plan for Deconcentration and Decentralisation that envisaged a reformed structure of government over time, ultimately culminating in the creation of autonomous local municipalities.[63] Under the new Constitution, Angola now has three spheres of government (previously four) – national (central) government, provincial governments and municipal administration. Traditional authorities continue to play an important role in local-level decision making under the new government structure, particularly concerning issues of land allocation.

Botswana

Botswana has no separately administered provinces or states; it has national and local government levels only. Local government is single-tiered, comprising both urban (two city councils, five town councils, one township authority) and rural councils (10 district councils).[64] 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.[65] As in Angola, traditional authorities play an important role in local-level decision making, particularly concerning issues of land allocation.

Councils have their own jurisdiction but their activities and plans are coordinated through various mechanisms and forums organized by central government, for example national and local-level decentralized development planning, National District Development Plans and the National Development Plan.[66] 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.[67]

62 Malzbender (2009)
63 Ibid
64 CLGF (2006)
65 Ibid
66 Ibid
67 Ibid

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, communities or 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 Angola and Botswana, traditional authorities play an important role in local decision making, particularly with respect to land allocation.

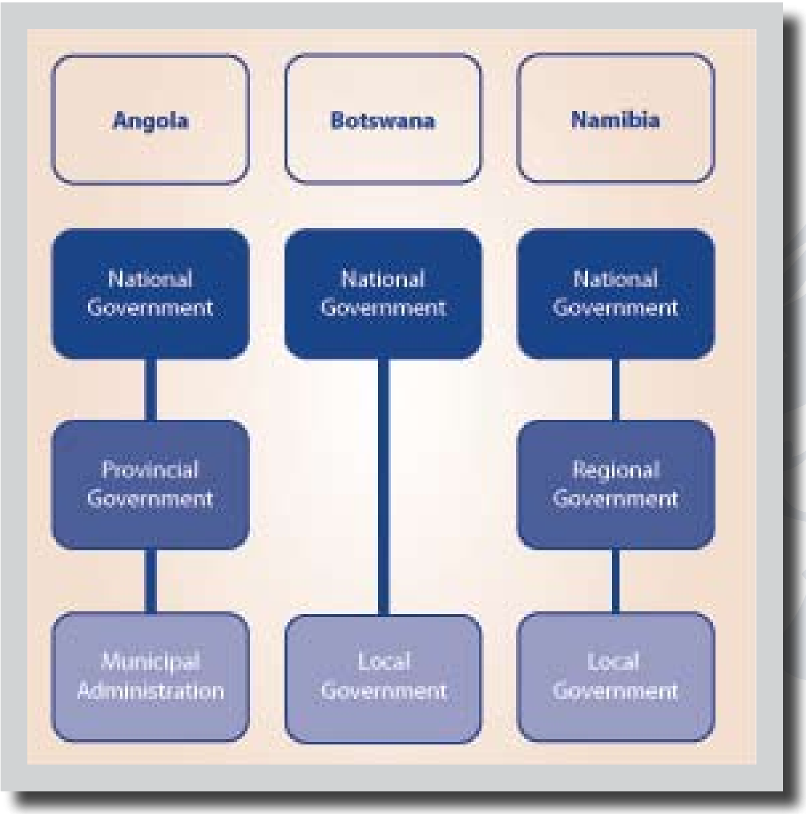


Figure 5.1: Overview of spheres of government in the three Cubango-Okavango Basin states

5.2 NATURAL RESOURCES MANAGEMENT LAWS, POLICIES AND INSTITUTIONS

Water resources management

In 1994, the three Cubango-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 utilization in Article 4(3)) it is largely of procedural nature and does not itself establish these principles as substantive 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 utilization
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) Southern African Development Community (SADC) Protocol on Shared Watercourses in 2003, these three key legal rules for shared waters are today applicable treaty law for the Cubango-Okavango Basin states, as they have all ratified the Revised Protocol. In addition to these principles, the Revised Protocol[68]

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

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 on 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 recognizes the environment as a resource base and legitimate user of water in its own right.

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

Governor of Cuando Cubango Province Eusébio de Brito Teixeira with Manuel Quintino, EPSMO Project, February 2010

Angola
Under the scope of the new Constitution, the Ministry of Energy and Water responsible for water-related issues was restructured. It consists of two major national directorates: the Water Supply and Sanitation Directorate and the Water Resources Management Directorate. Angola has an Inter-ministerial Committee for International Water Agreements and has recently approved the creation of the National Institute for Water Resources Management. In addition to the above, the Institutional Development Programme for the Water Sector (PDISA) was approved, comprising a number of actions related to water supply and sanitation, as well as water resources management.

The Angola Water Act (2002) establishes the state as 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 Cubango-Okavango is in the process of being set up and will have responsibility for the planning and management of the river's resources from the Angolan side. The development of a Master Plan for the Angolan portion of the Cubango-Okavango Basin has recently started. At present, draft regulations for the General Use of Water Resources and for Public Water Supply and Wastewater Sanitation are under development.

Botswana
Botswana is in the process of reforming its domestic water legislation and institutional structure for water resources management, parallel to the development of a national IWRM plan. This restructuring process is a result of recommendations by the Botswana National Water Master Plan Review (2006). The institutional structure reform will allow the Ministry of Minerals, Energy and Water Resources to focus on formulating, directing and coordinating overall national policies on water resources, energy and minerals. The Department of Water Affairs will be responsible for assessment, national planning, developing and managing water resources for short, medium and long-term purposes while the Water Utilities Corporation takes on the responsibility of a water supply authority (including waste water operations) for all cities, townships and villages. The proposed Water Regulator will ensure financial sustainability across the water sector, and reduce wastage by facilitating the streamlining of operations and determining revenue requirements to inform regular tariff adjustments.

A process of extensive consultation on the Draft Botswana National Water Conservation Policy (2004) has been initiated. The policy provides a national framework that facilitates access to water of suitable quality and standards for the citizenry and provides a foundation for sustainable development of water resources in support of economic growth, diversification and poverty reduction. A draft Water Bill, 2006, has also 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. The forthcoming Act also establishes a new Water Resources Council with key decision making functions in water resources management, allocation and development of policies related to water resources. Notably, the Water Resources Council shows strong elements of inter-ministerial cooperation, as a wide range of relevant line-ministries need to be represented on the council. Large industrial water users and civil society will also be represented as interested and knowledgeable water sector stakeholders.

In terms of regional policy/strategy on natural resources, 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, 2002, led to the establishment of the Okavango Wetlands Management Committee (OWMC) to coordinate district-level wetlands management initiatives.

Namibia
Namibia is currently going through a transitional phase. The 1956 Water Act (still applicable) was due to be replaced by the Water Resources Management Act (2004) but a further revision of the 2004 Act is currently ongoing. Meanwhile, Namibia has already started implementing significant elements of the new Act, among 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.

TDA meeting Rundu, Namibia, March 2008

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

- In sufficient quantities
- Of quality suitable for customer 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 delivering water-related services, supplying facilities and granting rights to customers upon their request. The Water Supply and Sanitation Sector Policy of 2008, following on from the 1993 Water Supply and Sanitation Policy (WASP) and 2000 Namibia Water Resources Policy, 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.

More details can be found in the full Governance Review, supporting Report 15.

Land Management

The most important international agreements applicable to the basin with respect to land-use management are the United Nations Framework Convention on Climate Change (UNFCCC) and the United Nations Convention to Combat

Desertification (UNCCD), which provide an international legal framework for adaptation measures and land management. At regional level, the SADC Protocol on Forestry promotes sustainable forestry and related land-use management.

Angola
Angola has two primary policies relating 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, 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 Environmental Framework Act (1998) and the Land Act (2004), both of which follow the sustainable development principles contained in the Land Law. Angola currently has five ministries involved in land-use management: the Ministry of Planning, Ministry of Construction and Urbanization, Ministry of Environment, Ministry of Agriculture, Rural Development and Fisheries and the Ministry of Territorial Administration. Local authorities play an important role in decision making on land allocation matters.

Botswana
Botswana has a multitude of policies and laws that have direct impact on land-use management. These include the country's National Strategy and Action Plan to Combat Desertification under the UNCCD. The Okavango Delta Management Plan (ODMP) aims to align sustainable land use with other natural resources use. In Botswana, eight ministries are involved in land-use management as well as several multi-departmental entities which are also highly relevant, including the land boards and tribunals. Traditional authorities play a key role in the allocation of land.

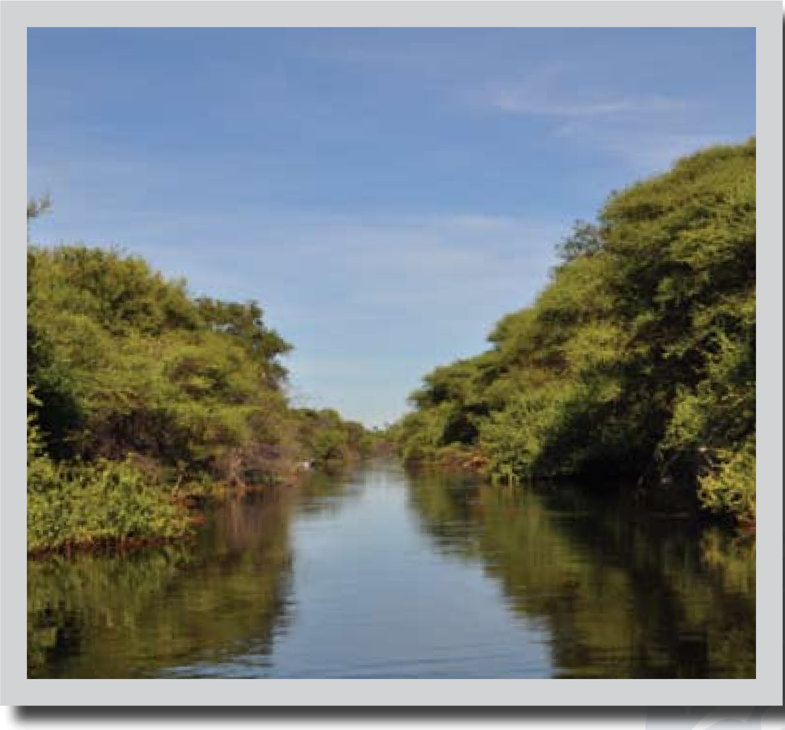
Foot and Mouth Disease Control point, Botswana, 2008

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 resources 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 UNCCD. Of particular relevance to the Cubango-Okavango Basin is a regional land-use plan for the Kavango Region, which was completed in the second half of 2010.

Namibia has seven ministries which each oversee land-use management to a varying degree. Multi-departmental entities are also central to land management in Namibia, and include the land boards and management committees. Traditional authorities play a large role in land-allocation decision making.

Biodiversity Management

The applicable international law framework for biodiversity management and protection in the basin is provided by the United Nations Convention on Biological Diversity (UNCBD), the Convention on International Trade in Endangered Species (CITES), and the Bonn Convention on Migratory Animals, complemented by the SADC Protocol on Wildlife Conservation and Law Enforcement, which promotes conservation and the sustainable use of biodiversity on a regional level.



Boro River, Botswana, May 2009

Angola

Angola's overarching environmental policy is the PNGA (2009), which deals 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 includes the Environmental Framework Act (1998), which contains provisions for pollution prevention and natural ecological protection as well as the Law on Aquatic Biological Resources, which provides for the protection of aquatic biodiversity. A Policy on Forests and Wildlife was approved and a Draft Law on Forests and Wildlife, which also aims at providing for the protection of biodiversity, is pending enactment. At present, six ministries in Angola are involved in biodiversity management, of which the Ministry of Environment is the leading line 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 recognizes biodiversity conservation as a major economic development opportunity (through *inter alia* eco-tourism). This aspect is further strengthened by 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. Four ministries are presently responsible for the protection of the country's biodiversity.

Namibia

Namibia has several policies impacting on biodiversity protection in the country, which are predominantly agricultural in nature. The National Agricultural Policy (1995) and the National Drought Policy (1997), which make provision for drought management procedures in order to reduce long-term vulnerability to drought, are both underscored by sustainable land and resources 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 emphasize sustainable biodiversity use through community-based natural resources management (CBNRM). Like Angola and Botswana, Namibia has also developed a National Biodiversity Strategy and Action Plan under the 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 imports and exports are regulated under the F (2006).

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

5.3 NATIONAL DEVELOPMENT POLICIES AND KEY SECTOR POLICIES

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 resources management.

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.

Current policy

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

While emphasizing the need for economic growth and associated increasing water demands, all three countries recognize the importance of the environmentally sustainable use of natural resources and have made it an integral part of their national policy framework. Botswana in particular has identified the economic opportunities from ecosystem preservation and sustainable natural resources 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 emphasize the need to strengthen the agricultural sector to ensure food security, and both Angola and Namibia have identified areas in the Cubango-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.

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.

Energy policies

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, recognize the relationship between energy generation from fossil fuel sources and climate change, and place 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 Cubango River is currently being considered. With the exception of Mucundi, all the planned schemes in the Angolan portion of the Cubango-Okavango river basin would be run-of-river schemes.

Review of key national development and sector policies

Angola

Angola's post-conflict priority on economic growth and development for poverty reduction and improvement of livelihoods 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.

Rural homes near Sexaxa, Botswana, 2009

The long-term strategy is complemented by the Strategy to Combat Poverty 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 are *inter alia* to minimize the hunger risk, to enable rural economies, and to reconstruct, rehabilitate and expand basic infrastructure in order to foster socio-economic development. The government of Angola has launched an ambitious rural water supply programme popularly known as 'Água para Todos' or 'Water for All', which is being 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 Cubango-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) prioritize 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 short, medium and long-term development plan (until 2025) for agriculture. In the short-term (2009–2013) several national programmes are planned, namely a programme for building and rehabilitation of irrigated perimeters, a vegetation health regulatory programme, a livestock farming support and development programme (aimed at veterinary supervision, disease control and meat production increase), a natural resources sustainable management programme and an apiculture development programme.

With respect to disaster preparedness and management, Angola has created a National Commission for Civil Protection under the Law on Civil Protection (Law No. 28/03 of 7 November) that aims to safeguard the rights of citizens and create adequate mechanisms to protect their interests. The National Commission for Civil Protection is chaired and directed by the President.

In addition, the National Council for Civil Protection under the direct purview of the Minister of the Interior has been created, including key ministries at the national level, as well as provincial and municipal administration levels. The main role of the National Council is to carry out vulnerability risk assessments and provide information at all levels, to raise awareness on disaster prevention and planning for emergency solutions. The council will also develop an inventory of available resources and disaster preparedness tools.

Botswana

Vision 2016 is the country's overarching development vision, the aim of which is to achieve sustainable economic growth and development of the country by 2016, highlighting the importance of the Okavango Delta in achieving development objectives of the country and the need to manage it sustainably and jointly with the other riparian states.

The National Development Plan 10 (2009–2016) 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, strategies and at district level, its implementation is complemented by the Ngamiland District Development Plan 7 (2009–2016).

River crossing, Boteti River, Botswana, 2008

In Botswana several policies have had and continue to have a bearing on land-use planning (zoning) and strategy in the basin. Most influential have been the Wildlife Conservation Policy (1986) and the Wildlife Conservation and National Parks Act (1992) which provide the legal framework for the establishment and management of national parks and game reserves and wildlife management areas (WMAs). Tourism is also a major development principle which is supported by several frameworks including the Tourism Policy (1990), Tourism Master Plan (2000), Ecotourism Strategy (2001), the Tourism Act (1992, revised 2010), and the Botswana Tourism Organization Act (2004, revised 2010) providing for national tourism development strategy in general, and for the delta in particular. The CBNRM policy (2007) supports and facilitates community participation in the tourism industry.

The National Policy on Agricultural Development (1991) objectives, are to improve food security, diversify the sector, increase employment and conserve scarce agricultural resources for future generations. This policy is similar to the 1975 Tribal Grazing Land Policy and the 1977 Arable Land Development Programme. These agricultural policies are complemented by the newer Botswana National Master Plan for Arable Agriculture and Dairy Development (2002), which seeks to increase the commercialization of agriculture through easier access to agricultural land and a steady stream of agricultural inputs.

Botswana has adopted a National Policy on Disaster Management (1996) that is supported by the National Disaster Risk Management Plan (2008), the National Disaster Relief Fund Order (1996), the National Hazard Identification, Vulnerability and Risk Assessment Study (2007) and the National Level Contingency Plan. A National Disaster Management Office has been established in the Office of the President, which oversees the National Committee on Disaster Management and the National Disaster Management Technical Committee. District Disaster Management Committees have been established at district level.

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 detailed planning document with an overall theme of accelerated economic growth through extensive rural development. Productive and sustainable utilization of natural resources and environmental conservation are its key goals.

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

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 recognizes 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 gross domestic product (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 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 that would lead to increased exports.

Disaster prevention and preparedness in Namibia is guided by the Namibian National Disaster Risk Management Policy. A draft Disaster Risk Management Bill based on the principles of the policy has been produced and is expected to be promulgated as an Act in the near future. At the core of the National Disaster Risk Management Policy is the establishment of the National Disaster Risk Management System in the Office of the Prime Minister, replacing the previous National Emergency Management System. Responsibilities for disaster management are allocated throughout all spheres of government from national to local level through the National Disaster Risk Management Committee, the Directorate of Disaster Risk Management, Regional Disaster Management Committees, the Constituency Disaster Risk Management Committees, the Local Authority Disaster Risk Management System and the Settlement Disaster Risk Management Committees.

5.4 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 utilization of water resources of common interest. Whereas the OKACOM Agreement does not create substantive rights (see above) 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 Organizational Structure of OKACOM' (the OKACOM Structure Agreement) which establishes the organs of OKACOM as:

- The Commission
- The Okavango Basin Steering Committee (OBSC)
- The Secretariat.

Issues on which OKACOM is mandated to advise the Parties

- Measures and arrangements to determine the long-term safe yield of water available from all potential water resources in the Cubango-Okavango River basin
- The reasonable level of demand for water from consumers in the Cubango-Okavango River basin
- The criteria to be adopted in the conservation, equitable allocation and sustainable utilization of water resources in the Cubango-Okavango River basin
- The investigations, separately or jointly by the Contracting Parties, related to the development of any water resources in the Cubango-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 Cubango-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 Cubango-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.

The Commission is 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 structure agreement defines the functions of the three organs in significant detail, together with regulating other procedural matters relevant to 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.

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.

Canoe on Boteti River, Botswana, 2008

The Commission consists of the three national delegations, each comprising three Commissioners appointed by their respective countries. 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 firmer administrative footing. Guided by the Secretariat's three-year plan, it provides the necessary support for the Commission to operate effectively and meet its increasing responsibilities.

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

People bathing, Cuito River, Cuito Cuanavale, Angola, 2007

5.5 KEY FINDINGS AND RECOMMENDATIONS OF GOVERNANCE REVIEW

The key findings and recommendations of the governance review are summarized below in Table 5.1 while critical aspects, including legislative and policy frameworks, inter-sectoral planning, local institutions and the role of OKACOM are discussed in more detail in sections 5.5.1–5.5.4.

TABLE 5.1: 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 harmonized 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 • Unharmonized land-use and development plans • No integrated biodiversity management systems • Inadequate basin-wide climate change adaptation and mitigation strategies

5.5.1 Policy and legislation frameworks

The analysis of the policy and legal landscape in the three basin countries shows a relatively strong framework of natural resources management policies and legislation, although variations occur 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, having passed a Water Act and other environmental legislation, and with a number of environmental policies and strategies being completed or under development (see overview of existing policies contained in the supporting report accompanying this document).

The strength of the current policy landscape is the recognition of the economic and social development opportunities of sustainable natural resources management. Particularly in Botswana and Namibia, emphasis is placed on sustainable resources use as an economic driver, primarily through tourism and 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. However, a number of existing or potential conflicts between sector policies remain that require resolution in order to determine the development pathway for the basin.

Sport fishing at Mucundi, Angola, 2008

Of great importance for integrated basin management is that all countries have replaced old water legislation with IWRM-based legislation that emphasizes 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.

River between Menongue and Rundu, February, 2010

On the other hand, there are 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.[69]

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 one in this respect is the shortcomings in the land-allocation and tenure system, which are of concern in all of the countries. No transboundary environmental impact assessment/strategic environmental assessment (EIA/SEA) procedures (based on the Espoo Convention on Environmental Impact Assessment in a Transboundary Context) have been adopted by the 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 harmonized land-use planning framework between the three countries that allows integrated basin-wide planning. Similarly, harmonized 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 effective implementation, as well as 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 local level, lack of skills, management capacity and resources for integrated planning, effective monitoring, implementation and enforcement.

Overgrazed river banks, Shamvura, Namibia, 2008

69 Malzbender (2009)

5.5.2 Inter-sectoral planning

The overview of responsibilities of different line-function ministries in the respective natural resources management fields shows that numerous ministries and departments need to be regularly involved in most planning and decision making processes and subsequent implementation.[70] While the required coordination between national ministries does happen, 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 (see more details in the full Governance Review; Report 15).

There is an immediate priority need for the joint development of comprehensive disaster preparedness, implementation and management plans, protocols and decision support systems for the basin to mitigate the possible effects of floods, droughts and major pollution accidents.

Typical components of such a disaster management system would include:

- *A disaster information management system* to predict the extent and severity of flooding, droughts and pollution plume dispersion.
- *Emergency response plans* to define emergency responses to floods, droughts and pollution. The protocols should consider critical issues such as early trans-boundary notification, internal communication and early response (evacuation, recovery and rescue plans).
- *Disaster preparedness plans* to enhance flood, drought and pollution disaster preparedness, including government response information, flow of information and lines of command and decision structures, and a public information system.
- *A mitigation preparation plan*. Once the emergency responses to the disaster have been delivered, the responsible governments will need to deal with rehabilitation, restoration and possibly repatriation. This requires a general framework and guidance for preparation and implementation of these activities. The plan should emphasize logistic, organizational, legal, financial and international aspects and make recommendations for organizing rehabilitation and reconstruction works.[71]

River grasses and reeds near Rundu, Namibia, 2008

Planning and decision making across sectors and line-function ministries or departments are arguably easier to achieve at local level where common 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 the failure to implement them altogether.

70 Malzbender (2009)
71 Beuster (2010)

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 comprises representatives from a wide range of national ministries, local government and other relevant stakeholders, ensuring that a diversity of management responsibilities and sector interests are considered in basin planning. The effectiveness of these basin-management committees for integrated basin management requires strong institutions with adequate skills and capacity levels, as well as effective coordination and cooperation between the local committees in the three countries, directly and/or through OKACOM.

Local Soba meeting place, Cuelei, Angola, 2007

5.5.3 Local level institutions

The need for strong institutions at local level is at present the biggest governance challenge in the Cubango-Okavango Basin. All three countries have made provision in law or policy to strengthen and provide 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 – it has limited decision making powers, resulting in central government remaining the dominant development decision making power. Likewise, local basin-management committees established under the respective national water acts have low levels of skills and financial capacity. They require significant strengthening in order to fulfil their roles in an effective manner.

OBSC meeting, Johannesburg, April 2011

5.5.4 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, especially as there are no established basin-wide cooperation mechanisms in other natural resources management fields, such as land use or biodiversity. However, integrated water resources management cannot be undertaken effectively without considering issues of land management and other natural resources use aspects. OKACOM itself has already recognized the integrated nature of water resources management institutionally by establishing the Biodiversity Task Force.

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 or 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 recognized and is – to some extent – reflected in policy and legislation. Examples are:

- In Angola, the formation of Grupo de Apoio Técnico à Comissão Inter-Ministerial para os Acordos sobre Águas Internacionais (GATECI –Technical Support Group to the Inter-ministerial Commission for International Water Treaties)
- In Botswana, the proposed Water Resources Council of the Botswana draft Water Bill.

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 issues, increasing the diversity of sectors represented in the different organs of OKACOM would allow greater consideration of and coordination between different sectors.

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.

Botswana Commissioner Steve Monna and Professor Max Finlayson at Flood Pulsed Wetlands Symposium, UB Professor Susan Ringrose looking on

Closer direct linkages between OKACOM and the broad range of stakeholders in the basin are also desirable 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 further strengthening of its capacity, particularly at 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 will have to play a stronger role, possibly over time, taking on a key role in day-to-day monitoring and overseeing of joint activities as well as 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 that its institutional capacity is progressively strengthened in line with its evolving role and increased scope of activities.

CHAPTER 6: INTEGRATED FLOW ASSESSMENT

Chapter 6 provides a summary of the Integrated Flow Assessment (IFA) methodology, including a description of the water-use scenarios, representative sites and the hydrological models. The chapter includes assessments of the various water-use scenarios in terms of impacts on flow regime and river ecosystems and socio-economic and macro-economic implications. Finally, it contains a trade-off analysis comparing the net benefit streams associated with water resources development with cost streams associated with the losses of ecosystem services. Full details are given in Supporting Reports 10 to 13 listed in Annex 2 and are available on the CD accompanying this document.

6.1 INTRODUCTION TO THE IFA

In conjunction with, but parallel to the TDA, the Environmental Protection and Sustainable Management of the Okavango River basin (EPSMO) Project undertook the development of a decision support tool: the Integrated Flow Assessment (IFA). This assisted in answering questions concerning the priority Area of Concern – that of variation and reduction of hydrological flow. Using existing hydrological models, a set of water resources use scenarios were tested to determine changes in the hydrological regime and the environmental and socio-economic impacts they would engender. An interesting feature of the IFA was the evaluation of ecosystem services to the river basin communities and how this would change under different water-use scenarios. In addition, the IFA could estimate the trade-off of economic advantages gained at the national level with those lost at the private level. The IFA provides the decision makers not only with quantifiable environmental, but also economic trigger points for decisions and solid pointers for basin development.

TDA meeting at Kamutjonga Inland Fisheries Research Institute, Divundu, Namibia, October, 2008

The IFA is seen as a model tool for basin planning and while it cannot be described as a Decision Support System (DSS), dealing as it does principally with a single Area of Concern in isolation (sedimentation and water quality are not addressed), it is a good foundation for DSS development and provides the riparian countries with a scientific basis to begin their negotiations on basin development. One aspect of the IFA which needs to be re-examined is the viability of a number of the component projects included in the High and Medium Scenarios and the planning horizons in which the scenarios are set.

6.2 METHODOLOGY

The Cubango-Okavango TDA process started from an analysis of the baseline – the present state of the Cubango-Okavango river basin. It used observed trends in population growth and sectoral developments and identified three water-use scenarios which represented possible future pathways of increasing water use in the basin. The probable implications of these three water-use scenarios were then analysed using two interrelated processes:

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

As a major component of the TDA, the IFA examined the priority Area of Concern in detail – that of changes in hydrological flow – by linking water resources development with changes in flow, ecology and socio-economics at specific sites. The basin-wide studies undertaken by the thematic teams allowed these observations to be extrapolated, and highlighted the emerging basin-wide trends and issues.

The IFA took as its starting point hydrological simulations of how the pattern of flows would change along the river system under different scenarios. At the same time a multidisciplinary team from each riparian country collaborated in a research programme that resulted in the acquisition 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'.

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 – the naturalized stream flow. A naturalized stream flow record spanning a long period will show the response of a river system to the natural (or climate change induced) variability of rainfall. This could include prolonged wet or dry periods. For water resources planning purposes, estimates of future water demands and water infrastructure (dams and abstraction works) can be 'superimposed' on the naturalized flow sequence to determine the reliability with which 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.

Data on the hydrology of the Cubango-Okavango river basin is relatively poor, but was first modelled at a spatial resolution that would allow for assessments of development impacts at various locations in the basin and on inflows to the delta in 2003. For the Cubango-Okavango IFA study, the hydrological working group opted to make use of the WEAP modelling system, 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. The three other hydrological models of the delta (ETH MODFLOW, DHI MIKE and HOORC) were used for different applications. For the Cubango-Okavango IFA study, the DHI model was used to determine channel flow velocities and depths, while the HOORC model was used to determine inundation extents and frequencies in the delta, as well as wetted length and state changes along the Boteti River. Full details of the methods used and the results of the hydrological modelling are presented in the IFA Reports 5 – *Hydrological Data and Models* and 6 – *Scenario Hydrology Report*[72] available on the CD accompanying this document, and listed in Annex 2.

The following steps were taken in the development of the IFA:

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.

Scenario development: An understanding of the effects of changing flow regimes was enabled by developing a series of increasing water-use scenarios, based on potential demand for water supply, irrigation, hydropower and other uses. These water-use scenarios were developed through discussions among the countries, project members and OKACOM. The discussions resulted in agreement for three scenarios of increasing water use – Low, Medium and High water use, which would be compared to present day (PD) conditions.

Hydrological modelling: Information on the various proposals for water use in each of the three countries was collected in order to populate these three water-use development scenarios. The hydrological data was collated and synthesized for the whole basin as described above. The resulting flow regimes were simulated at the representative sites for each of the three water-use development scenarios.

Selection of discipline indicators: Each discipline group selected the key indicators representing the major changes or issues relevant to the discipline that would result from change in the flow regime. Biophysical indicators were chosen to measure river attributes that could change with flow change and socio-economic indicators were chosen to measure social attributes that could change with river change. These indicators formed the focus for site visits, data collection, literature

72 Beuster, H. (2009)

reviews and analysis. The results were presented in specialist reports, one per discipline per country, with each specialist focusing on the representative sites in the country.

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

Development of a Decision Support Tool (DST): A Decision Support Tool was developed and prepared for capturing the biophysical and socio-economic specialists' knowledge. Each specialist team described the relationships between their indicators and flow; these relationships formed the knowledge base of the system. Simulated flow regimes were prepared by the hydrological team for each water-use scenario for the whole basin, and were also entered into the DST. The DST used its 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 full IFA process is described in Figure 6.1 below.

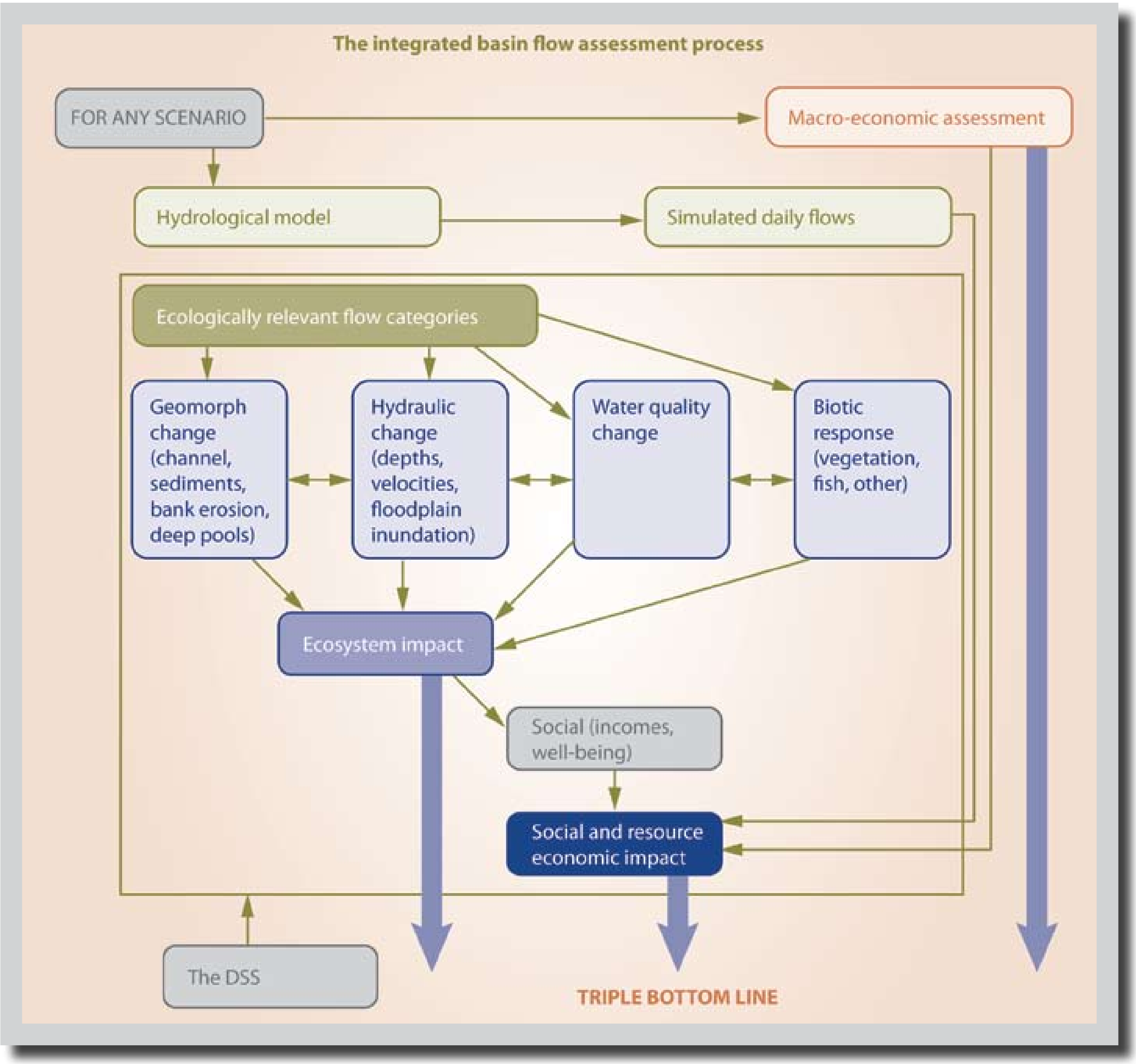


Figure 6.1: IFA development process

In the IFA, some new data was collected but the major dependence was on expert opinion from specialists who were focused on visiting the eight sites and gaining an initial understanding of their nature, and on existing data and knowledge of the Cubango-Okavango and similar river systems. It was recognized that this exercise was a data-poor first estimate of the changes likely to occur with development and that more detailed research would be essential in the future.

The IFA outputs describe the largely negative impacts of water resources development on the river ecosystem and its subsistence users. Development also brings positive impacts, perhaps in terms of national economies or peoples' incomes and health. The macro-economic assessment of the three development scenarios described in Section 6.8 provides a balanced prediction of the outcome of water resources development. Together, the IFA and macro-economic assessments outline the predicted consequences of development in terms of the three pillars of sustainable development: ecological integrity, economic wealth and social well-being. Full details are given in supporting Report 2 listed in Annex 2.

A socio-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 and economic characteristics, the main challenges faced by people, and observable trends.

2. What goods and services people use from the river and estimated changes in their values (and resulting changes in welfare) as water resources developments increase from the PD 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.

The economic analysis measured both the private well-being of the basin inhabitants, as well as the national well-being of the basin countries. The economic values at different levels are shown in Figure 6.2.

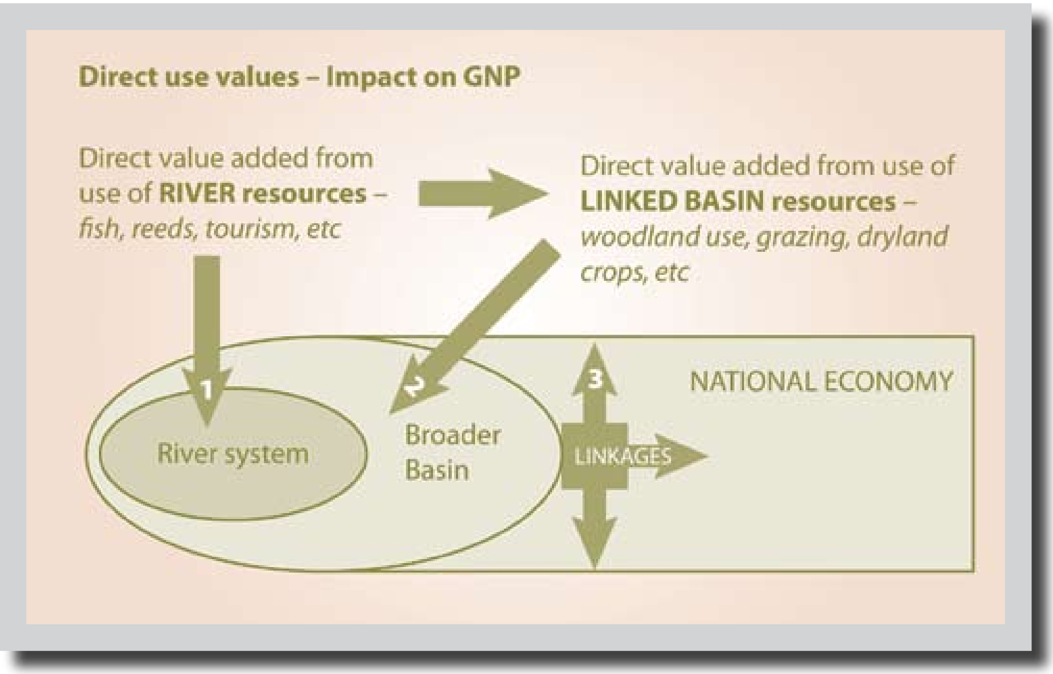


Figure 6.2: Depiction of economic values

Private well-being was measured as the net change in household livelihoods or the net gain in household welfare owing to the resources of the river basin and its functions. This is the net profit earned by households in their income-earning activities. The values that could be affected by changes in flow included values for household use of river-based natural resources such as fish, reeds, floodplain grass, floodplain gardens and floodplain grazing, as well as commercial, river and floodplain-based tourism. Valuation of all the natural resources use was undertaken at each of the field sites. These values were then scaled-up for the basin as a whole.

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 resources use to the national economies. The contributions of indirect-use values and ecosystem services to the national well-being were also measured in terms of national income. National well-being as affected by non-use values (existence, bequest and option values) was assessed in terms of willingness to pay for preservation at local, national and international levels.

The economic analysis was then scaled up, applied to the different water resources use development scenarios and compared to the PD situation. The losses 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. On a country-by-country basis these losses (and gains) are then set off against the potential net benefits of the water resources developments that alter the flow regime.

The value of the Cubango-Okavango River basin, particularly of the Okavango Delta, is considered important by the international community at large. As part of the scenario analysis these values are estimated, based on available studies of existence values for wetlands. These values might be tapped to yield a sustained source of financial resources for integrated river basin management and sustainable development in the Cubango-Okavango region of the three countries.

6.3 SCENARIO SETTING

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 Cubango-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, maximizing 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.

TDA habitat research team, Cuito Cuanavale, Angola, 2008

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

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

TDA research team with OBSC member Paulo Emilio Mendes, Capico, Angola, 2008

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.

Increasing water demands can take many forms. Irrigated agriculture is often the main demand, and its impacts include reduction of river flow as water is abstracted for crops, drainage of fertilizers, 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 have an impact on 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 riverbeds, banks and floodplains. Hydropower dams do not reduce the overall amount of water in the river and are of limited capacity, but they do affect 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 could have an impact on the river include 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. The nature of some of the changes that can be expected with water resources developments described in this chapter could be seen as benefits, and some as costs.

The water-use development scenarios used to represent a possible level of future water use were:

The Present Day (PD) Scenario

This includes all existing water resources 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).

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.

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
- About 198,000 ha of irrigation at various locations in Angola
- First phase development of the Eastern National Water Carrier transfer project (17 $Mm^3 a^{-1}$) for water supply from the Kavango to Grootfontein and Windhoek
- One storage-based and four run-of-river hydropower stations in Angola.

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 are unrealistic, in order to assess if at this stage the river ecosystem would start to show severe degradation and its users would thus feel severe impacts. Additional developments 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 and nine run-of-river stations
- Completion of the second phase of the Eastern National Water Carrier transfer project (total capacity 100 $Mm^3 a^{-1}$)
- Development of a scaled-down version of the schemes for increased domestic water supply provision for communities, and urban and industrial water supply from the delta to Maun.

NamWater has indicated that the Eastern National Water Carrier project would transfer a maximum of 100 Mm^3/annum when fully developed, from which on average 75 Mm^3/annum would be used within the Cubango-Okavango Basin (mainly for irrigation in the Grootfontein-Otavi area and development in the Otjozondjupa region) and an estimated 25 Mm^3/annum would be transferred out of the basin to meet the water demands of Windhoek.

TDA review meeting, Mussulo Island, Luanda, Angola, 2009

It should be noted that in order to meet all demands under the High Scenario 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 multi-seasonal storage.

Further details of the scenarios and their breakdown can be found in the IFA Delineation Report 6.

6.4 REPRESENTATIVE SITES

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 6.3, Table 6.1). Each of these points represents a longer length of river and the surrounding social area. Some parts of the basin could not be represented due to the time and financial limitations of the project.

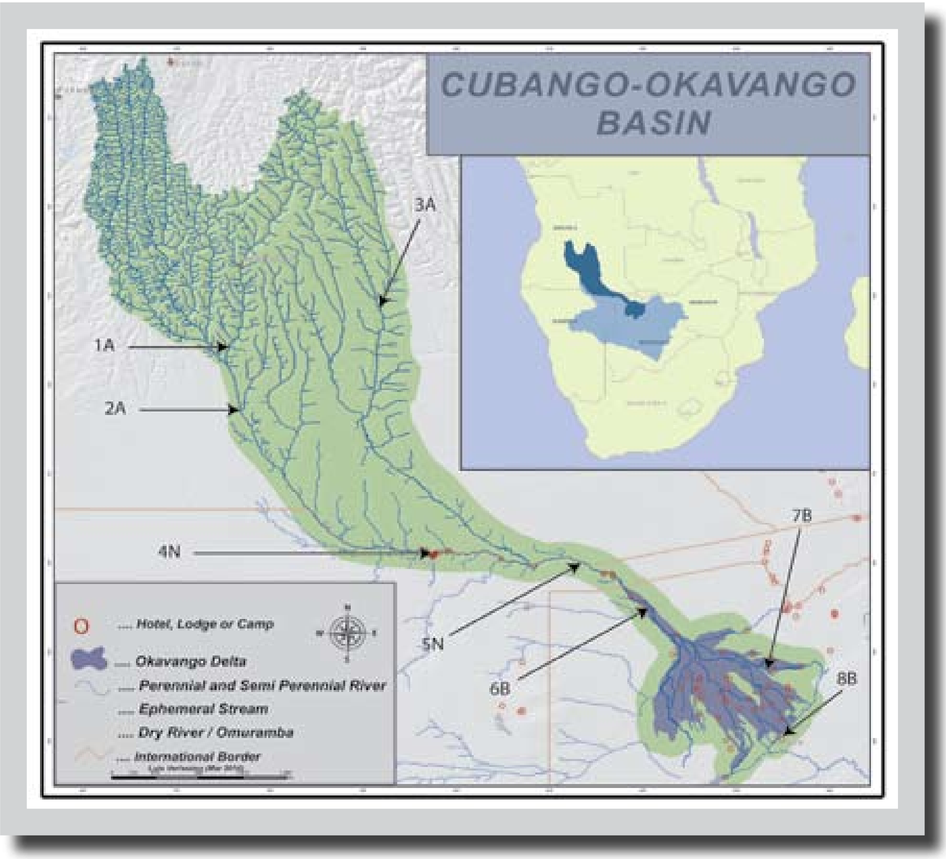


Figure 6.3: Location of the eight representative sites: three in Angola (marked A), two in Namibia (N) and three in Botswana (B)

Source: Mendelsohn and el Obeid (2004)

TABLE 6.1: 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	(Cakanaca) Xakanaka
8B	Botswana	Boteti	Chanoga

The water-use development scenarios were inserted into the basin hydrological model, which predicted how flows along the Cubango-Okavango river drainage basin could change (Section 6.5). The flow changes were then interpreted to give predicted changes in the river ecosystem and its dependent wildlife (Section 6.6.2), and how these environmental changes could affect people's lives and livelihoods (Section 6.7). The macro-economic implications of the developments are addressed in Section 6.8.

6.5 THE IMPACT OF WATER RESOURCES DEVELOPMENTS ON THE FLOW REGIME

6.5.1 The context

The PD flow regime of the whole system is close to natural, which is extremely unusual for a large transboundary river. A prominent and important characteristic of this PD flow regime is the great difference between the two headwater tributaries, the Cubango and the Cuito Rivers, 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 Cubango-Okavango river system as a whole is a floodplain-driven system, with floodplains throughout but most prominently on the Cuito in Angola, on the Cubango-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.

View from bridge at Cuito, Angola, 2008

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 had been 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 extent of inundation
- In the Thamalakane/Boteti system downstream of the delta
  - Presence or absence of water (wet river bed or disconnected pools or dry riverbed).

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

Table 6.2 summarizes how each of the variables would change through the scenarios and along the river. The overall trend would be for run-of-river abstractions to be reducing 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 occurs in many developed basins, because there would not be enough dams with sufficient storage to effect this.

TABLE 6.2: MEDIAN VALUES OF THE ECOLOGICALLY RELEVANT SUMMARY STATISTICS FOR EACH SCENARIO FOR RELEVANT RIVER SITES.

A) MEAN ANNUAL RUNOFF (Mm³)

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 (m^3s-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 (m^3s-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 (Mm³)

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, which flows between Angola and Namibia and into the top end of the delta. This part of the system would feel a significant impact from water resources development because it is downstream of almost all the potential infrastructure development. Its MAR could potentially reduce to 69 percent 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 percent 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 percent of PD (Table 6.3, Figure 6.4; Figure 6.5).

TABLE 6.3: 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

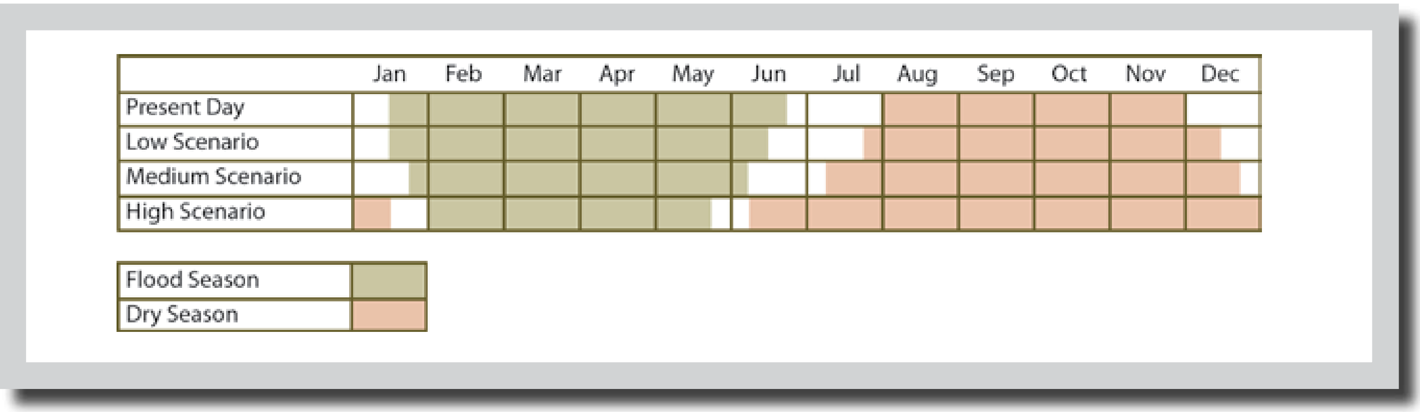


Figure 6.4: Changes in onset and duration of dry and flood seasons at Popa Falls and the panhandle under different scenarios. White areas are times of transitional flow between flood and dry seasons

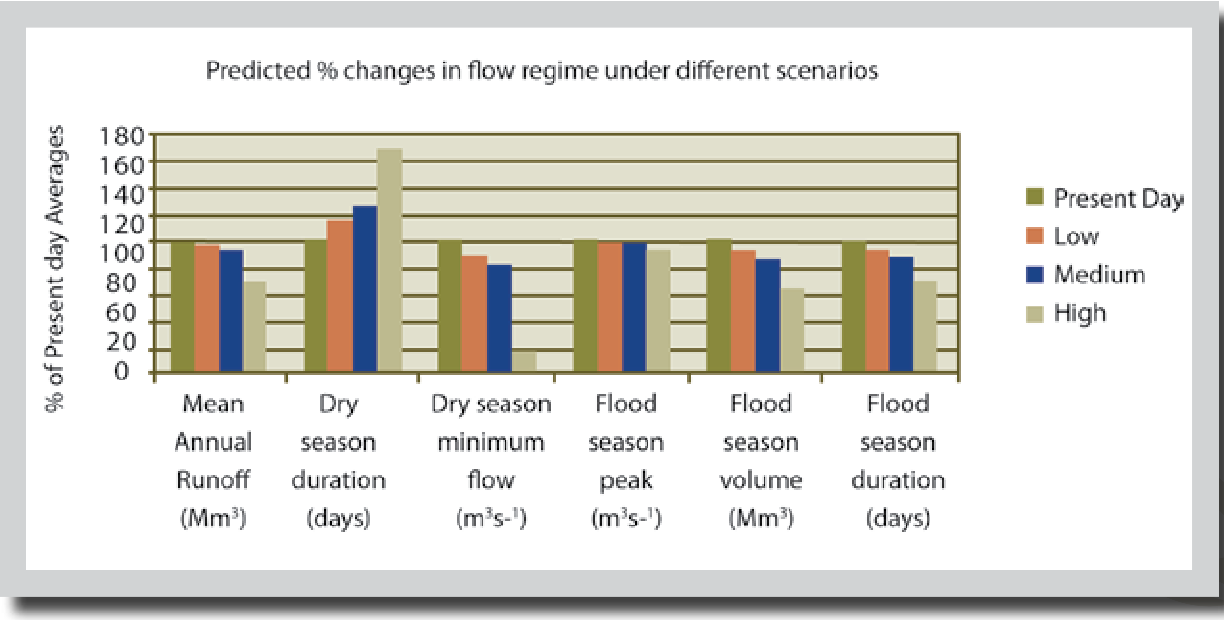


Figure 6.5: Predicted changes in the flow regime at Popa Falls and the panhandle, compared to PD under different scenarios

6.5.3 Sites 7 and 8: the delta and outflow sites

Cakanaca (Xakanaxa)[73] in the delta would receive essentially the same amount of water as the panhandle, in the same pattern of flows 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.

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 riverbed/disconnected pools/dry riverbed) 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 percent of PD average levels and seasonal swamp types increasing to 104–178 percent 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 (Tables 6.4 and 6.5).

Comparison of the Present Day and potential High Scenario 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.

TABLE 6.4: 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

73 Site 7

TABLE 6.5: 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

The out-flowing Boteti River at Chanoga[74] 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 (Figures 6.6 and 6.7). State changes in the Thamalakane/Boteti system for PD conditions and the Low, Medium and High water-use Scenarios are shown in Figures 6.6 – 6.9.

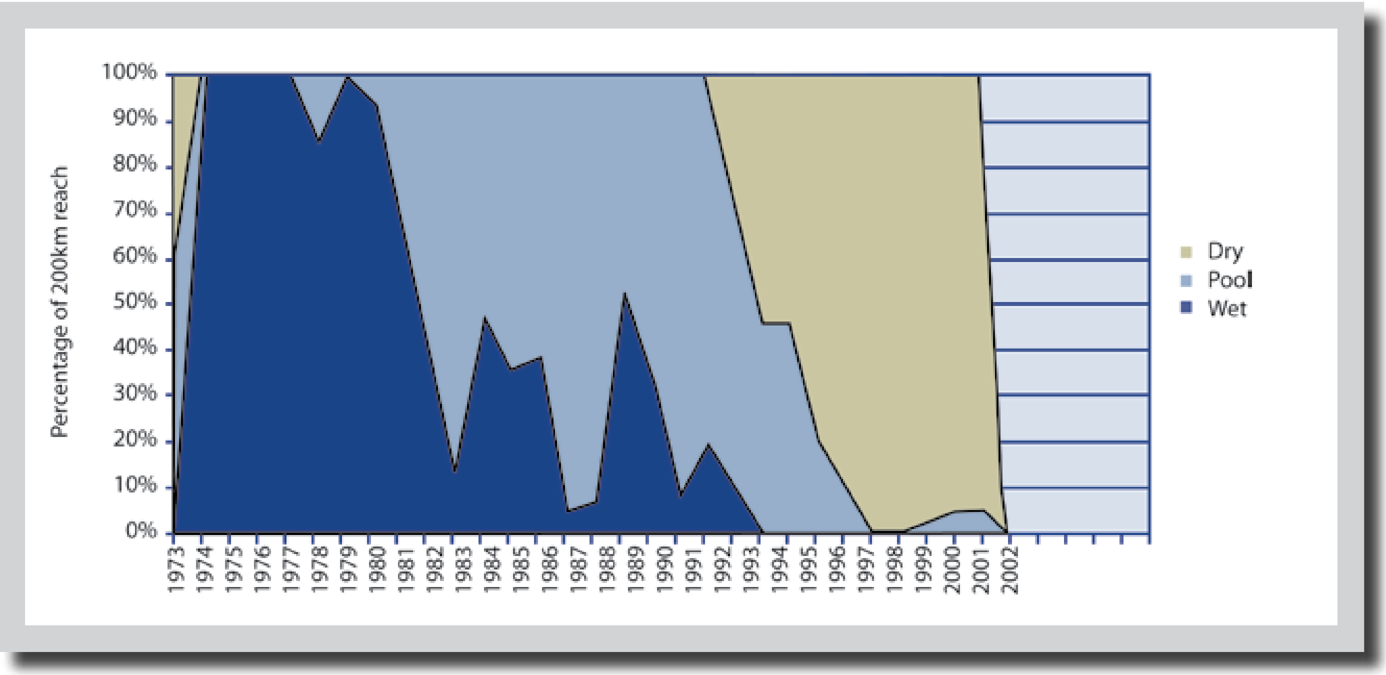


Figure 6.6: Percentage of the 200km study reach of the Boteti River that will be inundated (wet); isolated pools (pool) and dry under present-day simulated conditions given climatic conditions that prevailed from 1973–2002

74 Site 8

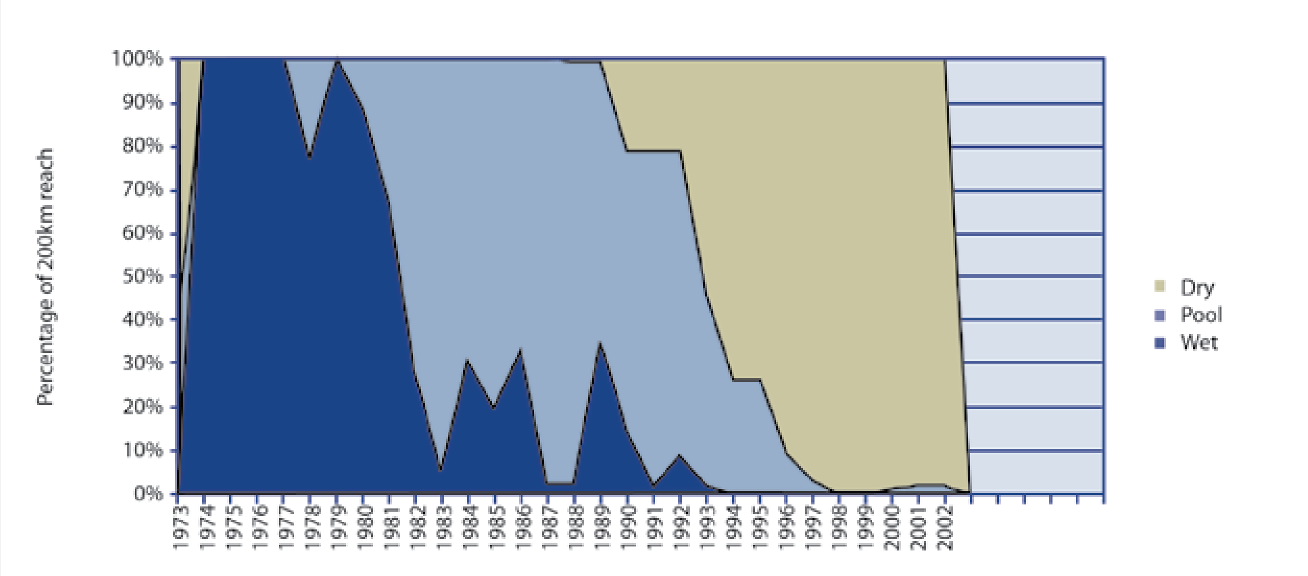


Figure 6.7: Percentage of the Boteti River study reach that will be inundated (wet); isolated pools (pool) and dry under the Low Scenario

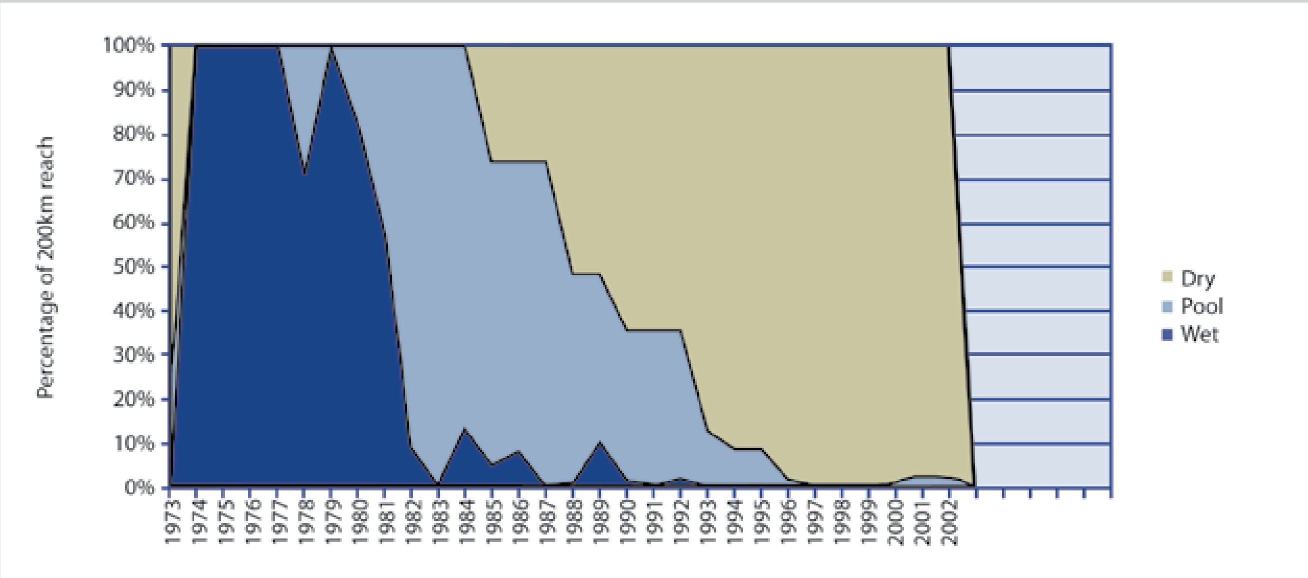


Figure 6.8: Percentage of the Boteti River study reach that will be inundated (wet); isolated pools (pool) and dry under the Medium Scenario

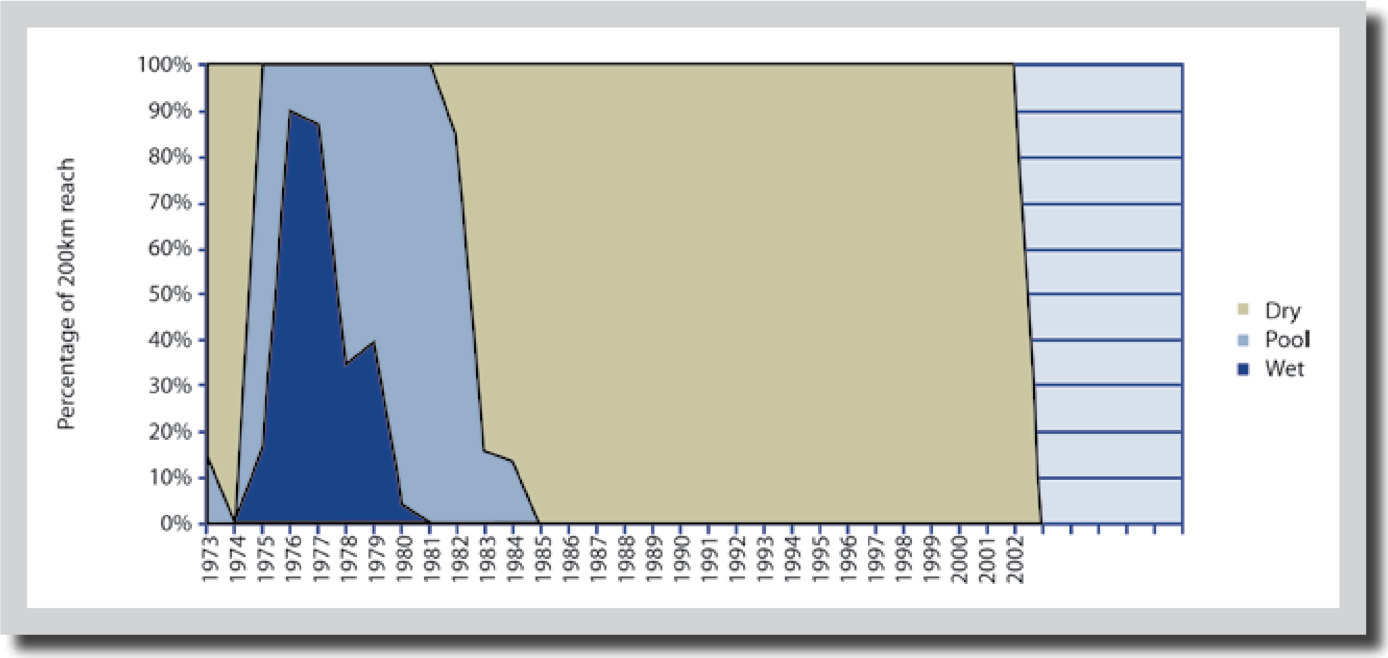


Figure 6.9: Percentage of the Boteti River that will be inundated (wet); isolated pools (pool) and dry under the High Scenario

6.5.4 Conclusion on potential flow changes

The Cubango-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 owing 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. Average minimum flow in the dry season in the Cuito River is 100 m^3/s and in the Cubango is 25 m^3/s. The Cuito River is thus much more important than the Cubango in maintaining the lower Cubango-Okavango ecosystem during the dry season.

If this is of concern at the basin level, water resources development along the Cuito River, or interventions in the functioning of its floodplains should be modest and undertaken with caution. The severe impacts on the flow regime predicted for Site 1 could be mitigated by opting for a series of developments that are less detrimental to the 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 localized to transboundary conditions. Mitigation could realistically only be addressed by planning and managing at the basin level.

6.6 IMPACTS ON THE RIVER ECOSYSTEM

6.6.1 The context

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

- The magnitude of flows
- Their frequency
- Their timing
- Their duration
- The overall variability of flows on every scale from daily to decadal.

The flow changes described in the last section would have impacts on all these aspects of the flow regime and so the river ecosystem would inevitably change. These ecosystem changes were described using 70 biophysical indicators.[75]

The indicators covered the major parts of the ecosystems:

- 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 7 of the Environmental Flows series of reports and summarized in Table 6.6 below.

TABLE 6.6: SUMMARY OF PREDICTIONS OF ECOSYSTEM CHANGE UNDER THE THREE DEVELOPMENT SCENARIOS

Ecosystem component	Predicted change
Channel	There would be a trend towards stabilization 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 Cubango-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.
Vegetation	Aquatic and semi-aquatic vegetation would be negatively affected at Capico, Mucundi, Popa Falls, the panhandle and in the Boteti at Chanoga[73] , 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, Cakanaca (Xakanaxa) and in the Boteti at Chanoga, while 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, Cakanaca (Xakanaxa) and in the Boteti at Chanoga[74] 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 Chanoga[75], especially under the High Scenario, with some local extinctions. At Cakanaca (Xakanaxa), conversely, there would be mild to moderate increases in several indicators as open water and permanent swamp give way to seasonal grass and sedgeland. 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 Cubango-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 Cubango-Okavango river system 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

75 Table 3.1 in Report 7 in the IFA Report Series
76 Sites 1, 2, 5, 6 and 8
77 Sites 4, 5, 6, 7 and 8
78 Sites 1, 2, 4, 6 and 8

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

6.6.2 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. The general aim among countries using such a system is to not allow any rivers to fall below a D category and to keep those of conservation value at B or a high C. In 2008 the Cubango-Okavango River system was estimated 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'.

The IFA predicted how the overall health of the system could change under the three scenarios. In the ecosystem health plot (Figure 6.10) 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 B to C at an integrity value of about -0.5. Present-day health is rated at 0, and the thin blue line indicates that all sites are presently sitting above the B to C transition, i.e. in a B condition.

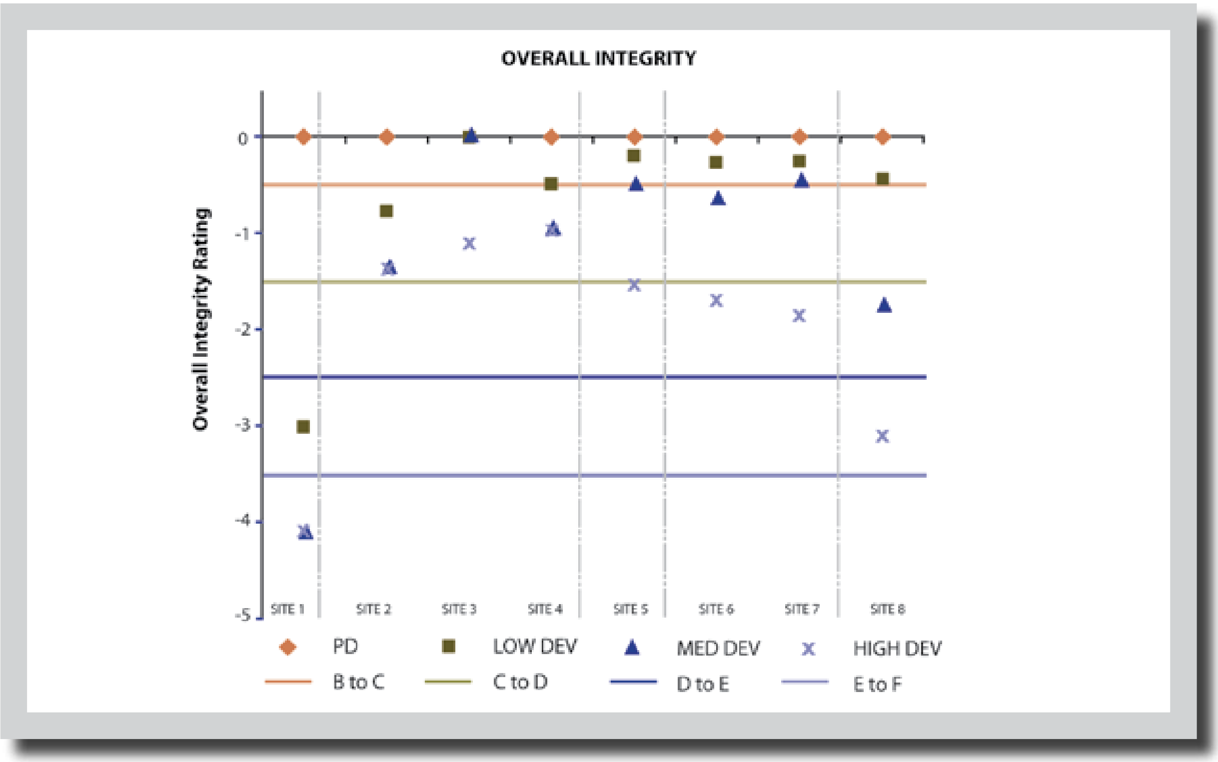


Figure 6.10: Overall ecosystem health for the three water-use scenarios at each of the study sites, showing the health (integrity) value of each site under each development scenario and the approximate transitions of shifts to lower health causes

It was predicted (Figure 6.11) that with the water resources development encompassed in the three scenarios, ecosystem health would decline, i.e. 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 is 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 and 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. Under all scenarios, ecosystem health would generally decline with distance downstream.

6.6.3 Status of river zones

The impacts predicted for the representative sites can be translated to expected impacts over the whole river network. In the figure depicting ecosystem health of the basin (Figure 6.11), 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 under the High Scenario were to be constructed with their assumed design and operating rules, 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 localized 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.

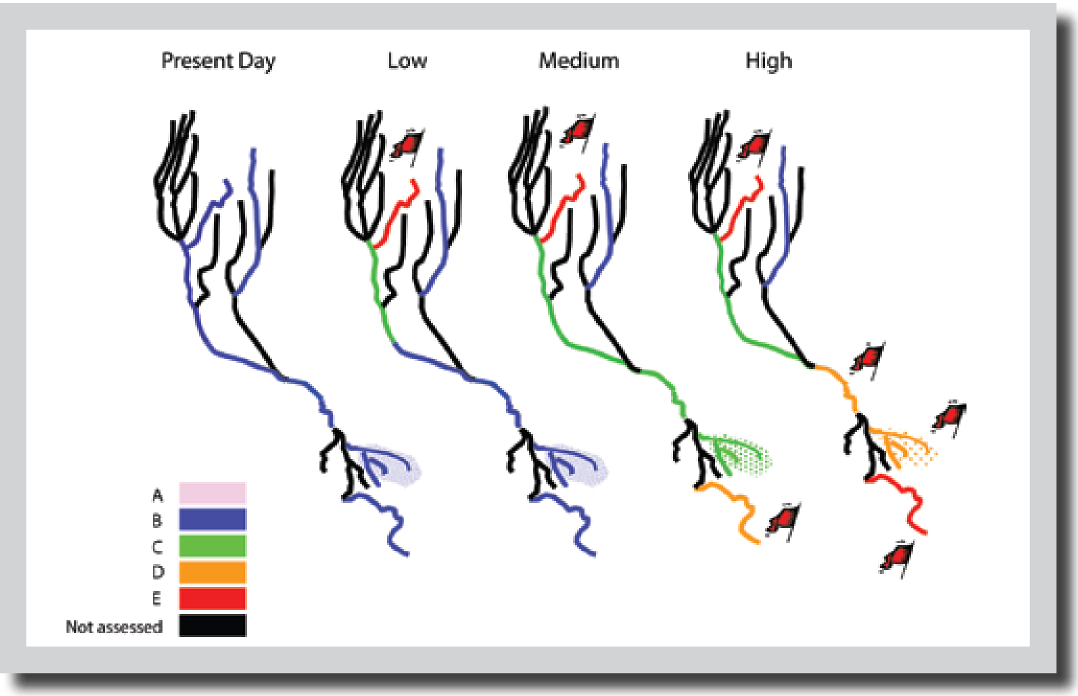


Figure 6.11: Summary of expected changes in ecosystem health for the Low, Medium and High water-use Scenarios

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

6.7 SOCIO-ECONOMIC IMPLICATIONS[79]

6.7.1 Short-term livelihood implications of developing water resources

The present-day livelihood values are discussed in Chapter 4 under the economic setting and are summarized in Table 6.7. More details are given in Chapter 4, Section 4.4.

TABLE 6.7: 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$/a	US$/a		US$/a	US$/a
Angola	4,158,400	4,284,200	262,600	15.84	16.31
Botswana	1,395,100	22,711,400	110,630	12.61	205.29
Namibia	4,475,000	8,175,400	175,270	25.53	46.64
BASIN	10,028,400	35,170,900	548,500	18.28	64.12

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 annum, to less than US$10 million per annum for both the Medium and High water-use Scenarios (Figure 6.12).

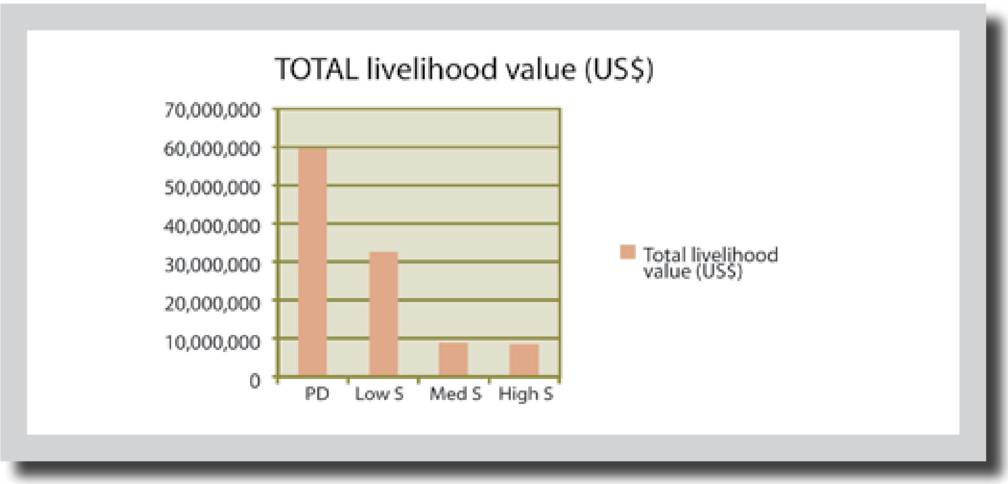


Figure 6.12: The short-term implications of water-use scenarios for livelihoods in the Cubango-Okavango River basin – Present Day (PD), Low water-use (Low S), Medium water-use (Med S) and High water-use (High S) Scenarios (US$, 2008)

These predicted changes can be scaled up to economic national incomes (as shown in Figure 6.13), combined for the basin as a whole. Direct economic contribution to the national income provides a better measure of the real impact on socio-economic welfare than household net income.[80] This variable shows a decline from US$100 million per annum to less than US$10 million per annum for the Medium and High water-use Scenarios.

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

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

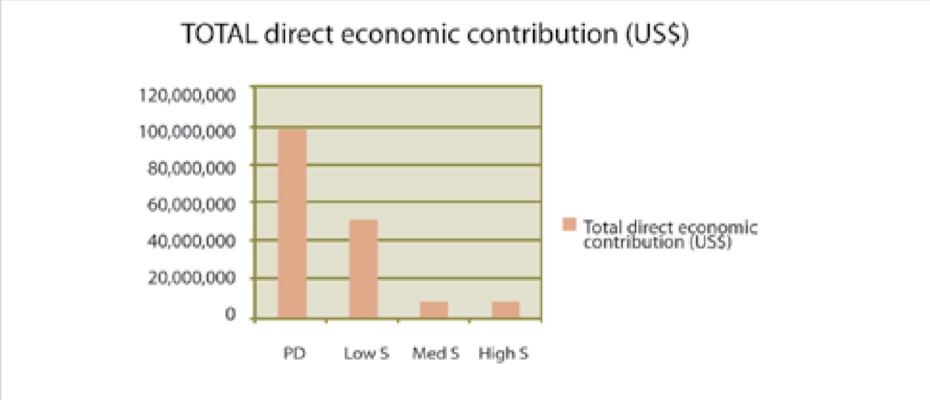


Figure 6.13: The short-term implications of water-use scenarios for direct economic income in the Cubango-Okavango River basin – Present Day (PD), Low water-use (Low S), Medium water-use (Med S) and High water-use (High S) Scenarios (US$, 2008)

The significant declines in both these indicators through the water-use scenarios are primarily linked to declines in tourism. Both the economic model and surveyed tour operators in Botswana predicted that tourism in the delta would follow a short-term response, with turnover dropping by about 15 percent as the flood regime of the delta changed (Figure 6.14). Flooding levels that are both higher and lower than natural would result in a reduction in tourist numbers. Relatively small, sustained reductions in tourism demand would severely reduce livelihood values and economic contributions to national incomes.

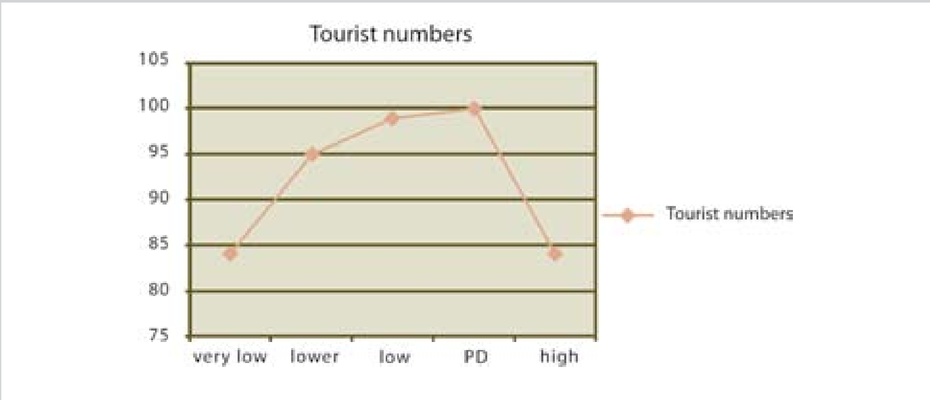


Figure 6.14: Response of tourist numbers (as a percentage of Present Day) to four changes in average delta flood levels, as predicted by tourism operators in Botswana. (PD = 100 percent)

6.7.2 Longer-term economic implications of developing water resources

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 percent per annum in Botswana and Namibia, and 2.7 percent in Angola. Tourism growth was anticipated to be 5 percent per annum on average in all scenarios. Where tourism was found to collapse as a result of drying out of the lower Cubango-Okavango, its output was assumed to settle at different levels for each scenario (25 percent, 10 percent, and 5 percent 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 (in

Zimbabwe). Carrying capacity limits to growth for certain activities were also assumed (+75 percent of starting output in the case of tourism, and +100 percent 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.

People and societies adapt to change if they can, although with high levels of poverty and vulnerability, adaptation can be both risky and costly if indeed at all possible. When the predicted changes in natural resources were modelled over a longer, 40 year period, with possible adaptations included, the scenarios that emerged showed more realistic overall impacts. 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 resources use by about 40 percent (Table 6.8). 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 6.15). The value of fish would be affected most, with about 60 percent of income lost in each scenario. The other main river wetland resources used – reeds and floodplain grass – would lose about 30 percent of their value.

TABLE 6.8: EFFECT ON 40 YEAR NET PRESENT VALUES OF DIRECT ECONOMIC INCOME OF ALL RIVER/WETLAND NATURAL RESOURCES USE IN THE CUBANGO-OKAVANGO RIVER BASIN WITH INCREASING WATER USE IN THE CUBANGO RIVER BASIN

ANGOLA	Present day	Low Water Use	Med Water Use	High Water Use
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 resources 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 resources 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

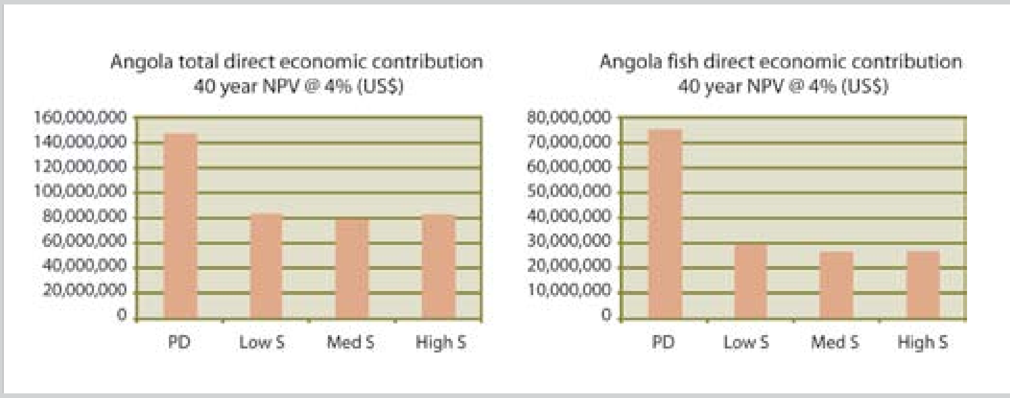


Figure 6.15: Effect on 40 year net present values of direct economic income of all river/wetland natural resources use in the Cubango-Okavango River basin with increasing water use. Scenarios: Present Day (PD), Low water-use (Low S), Medium water-use (Med S) and High water-use (High S).

Botswana

It is predicted that increasing water use would reduce the direct income derived from tourism by about 40 percent in the Low Scenario, rising to a 90 percent loss for the Medium and High Scenarios (Table 6.9). The effect would be similar for all income generated, whether by household or tourism sector activities, or both (Figure 6.16). 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 6.9: EFFECT ON 40 YEAR NET PRESENT VALUES OF DIRECT ECONOMIC INCOME OF ALL RIVER/WETLAND NATURAL RESOURCES USE IN THE BOTSWANA CUBANGO-OKAVANGO RIVER BASIN WITH INCREASING WATER USE

BOTSWANA	Present day	Low Water Use	Med Water Use	High Water Use
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 resources 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

Figure 6.16: Effect on 40 year Net Present Values of direct economic income of all river/wetland natural resources use in the Botswana Cubango-Okavango River basin with increasing water use. Scenarios: Present Day (PD), Low water-use (Low S), Medium water-use (Med S) and High water-use (High S).

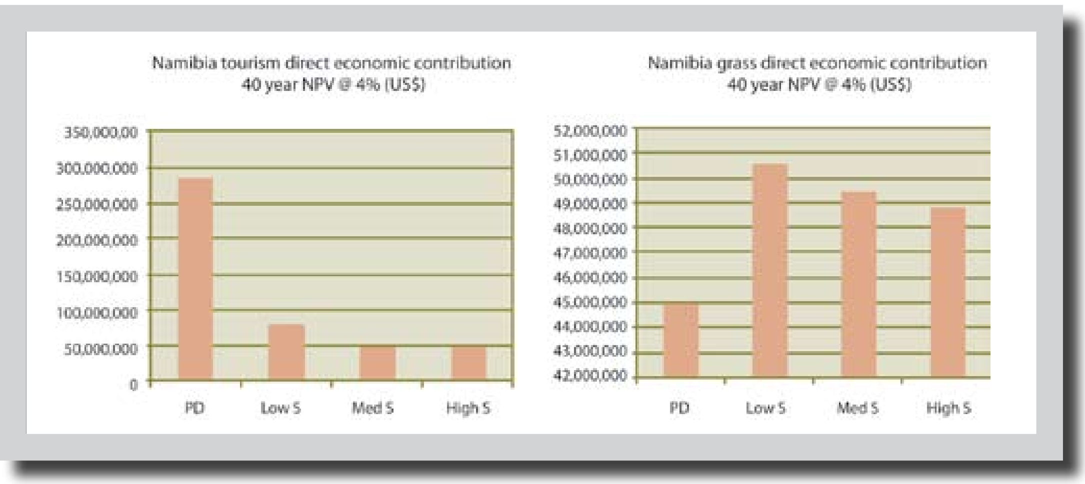
Namibia

It is predicted that increasing water use would reduce the direct income derived from the river's natural resources use by about 60 percent – more than in Angola (Table 6.10). As the PD values for Namibia are much higher than those for Angola, the losses would be even more significant.

TABLE 6.10: 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 NAMIBIAN OKAVANGO RIVER BASIN

NAMIBIA	**Present Day**	**Low Water Use**	**Med Water Use**	**High Water Use**
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 percent and the Medium and High Scenarios would have much the same impact (Figure 6.17). The highest impact would be on tourism income, a reduction of about 75 percent. Household income from reeds, floodplain grass, crops and grazing would be likely to rise by about 10 percent as permanent swamp areas transformed 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.



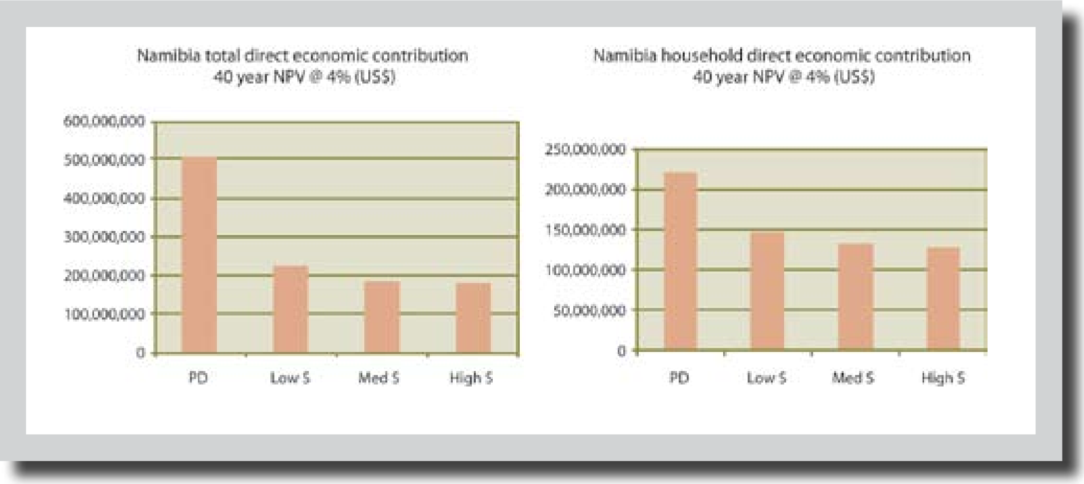


Figure 6.17: Effect on 40 year net present values of direct economic income of all river/wetland natural resources use in the Namibian Cubango-Okavango River basin with increasing water use. Scenarios: Present Day (PD), Low water-use (Low S), Medium water-use (Med S) and High water-use (High S).

The whole Cubango-Okavango Basin

For the Cubango-Okavango Basin as a whole, income losses in Botswana dominate the picture (Table 6.11). The negative impacts of the Low Scenario would be significant, but those of the Medium and High Scenarios would be highly significant (Figure 6.18).

TABLE 6.11: EFFECT ON 40 YEAR NET PRESENT VALUES OF DIRECT ECONOMIC INCOME OF ALL RIVER/WETLAND NATURAL RESOURCES USE IN THE WHOLE CUBANGO-OKAVANGO RIVER BASIN WITH INCREASING WATER USE

CUBANGO-OKAVANGO BASIN	Present Day	Low Water Use	Med Water Use	High Water Use
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 resources 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

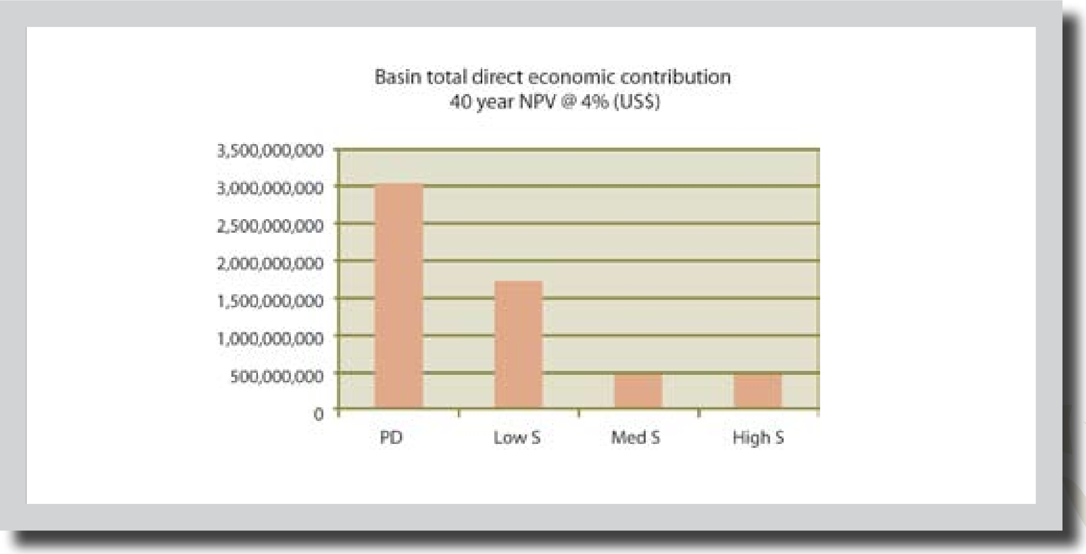


Figure 6.18: Effect on 40 year net present values of direct economic income of all river/wetland natural resources use in the Cubango-Okavango River basin as a whole with increasing water use. Scenarios: Present Day (PD), Low water-use (Low S), Medium water-use (Med S) and High water-use (High S).

The results suggest that the levels of water development 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 the household level in the three countries. Within the socially defined areas linked to the river, Angolans derive 19 percent of their total household income from it, Botswana 45 percent and Namibians 32 percent. With the predicted changes in the river, the percentage of their annual income that they might lose ranges from 8 percent to 39 percent, with a basin average of about 20 percent loss under the Medium and High Scenarios (Table 6.12).

TABLE 6.12: 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 Water Use**	**Medium Water Use**	**High Water Use**
• Angolan basin	0%	8%	9%	9%
• Botswana basin	0%	18%	38%	39%
• Namibian basin	0%	11%	13%	13%
Whole basin	**0%**	**11%**	**20%**	**20%**

These aggregate losses will have an 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 6.12), the impact on the main income earners in this industry – the investors, owners of capital, government and employees, including wage earners from the 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 well-being

Private values effectively measure how the *investor*, in the basin context usually a household, loses or benefits from natural resources use. This benefit/loss is the *net gain* from the activity in terms of either own consumption or money. Thus a household that depends on fishing might acquire a canoe, some nets, hooks and line to undertake fishing in the river/floodplain system. The fisherman 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 costs in terms of fuel, 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 well-being was measured as the direct net change in *national income*. The specific national income measure used was *gross national product.*

6.8 MACRO-ECONOMIC IMPLICATIONS

6.8.1 Developing a trade-off analysis

Developing the basin's water resources will involve economic trade-offs.[81] Economic benefits can be increased by abstraction of water and altering the river's flow regime for municipal and individual water supplies, and for irrigation and hydropower generation. These alterations in the hydrological regime 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. The countries themselves need to make a value judgement on how much they are willing to lose for the benefits they aspire to.

This macro-economic trade-off analysis can inform their discussions and negotiations. In it, the existing natural resources 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 development. A full listing of potential ecosystem services is given in Table 6.13. The trade-off analysis carried out for the IFA is not a complete valuation of all ecosystem services, 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.

81 Full details of this section are in Aylward (2009)

TABLE 6.13: FULL LIST OF AQUATIC ECOSYSTEM SERVICES RECOGNIZED IN THE MILLENNIUM 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 stabilization • 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		

Assumptions made and data used in the trade-off analysis are:

- There will be progressive growth of improved water supply and sanitation
- Both *conservative* and *optimistic* projections for economic profitability are provided, using data as follows:
  a) Irrigation – net operating income of US$0.05 (optimistic) to US$0.015 (conservative) m^3 for irrigation water and investment cost of US$10,000 (O) to 15,000 (C) ha^{-1}
  b) Hydropower – revenue at US$0.1 (O) to US$0.08 (C) KwH^{-1}, investment cost at US$2,500 (O) to US$2,500 MW^{-1}(C) and Operational and Maintenance costs at 3 percent (O) to 5 percent (C) of investment costs
  c) Water supply and sanitation benefits and costs for improvements, based on WHO methodology
- The costs and benefits are discounted at 8 percent to arrive at present values for each sector by country. A sensitivity analysis was done using a discount rate of 4 percent.

The trade-off analysis compares the net benefit streams associated with water-use development with cost streams associated with the losses of ecosystem services discussed above. This is done for both the conservative and optimistic assumptions.

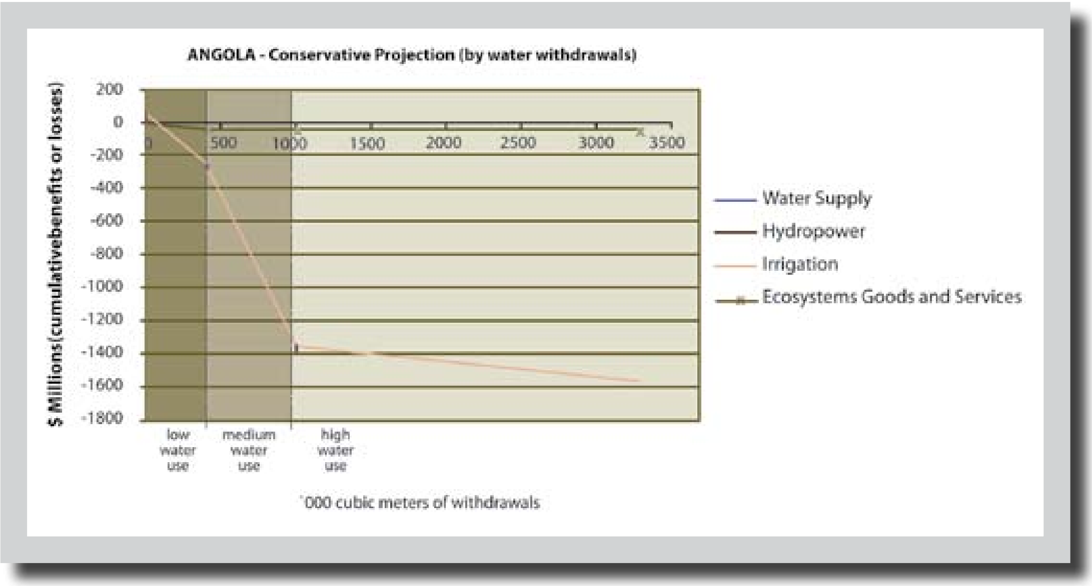
6.8.2 Predicting the macro-economic consequences for each country

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 6.19). 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 amounts from US$5 to US$85 million as services expanded. 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 an area remote from major markets and with poor soils (Chapter 4, Section 4.2.2).

Under the optimistic projection, the net benefits of hydropower would double in value and water supply and sanitation would generate increasing net economic benefits from the Low to High Scenarios from US$10 to US$85 million. 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. 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

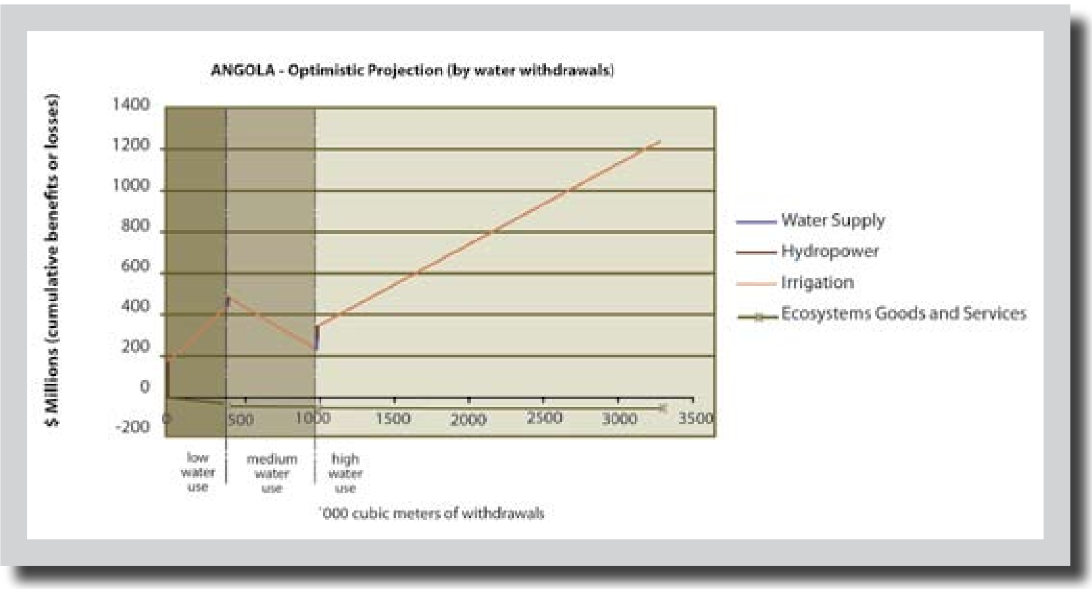


Figure 6.19: Macro-economic trade-offs for the water-use scenarios according to the quantity of water diverted for Angola[82]

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.

82 Given that the analysis envisions further developments 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.

Under the optimistic projection 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 of 4 percent 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.

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 small net benefits, 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.

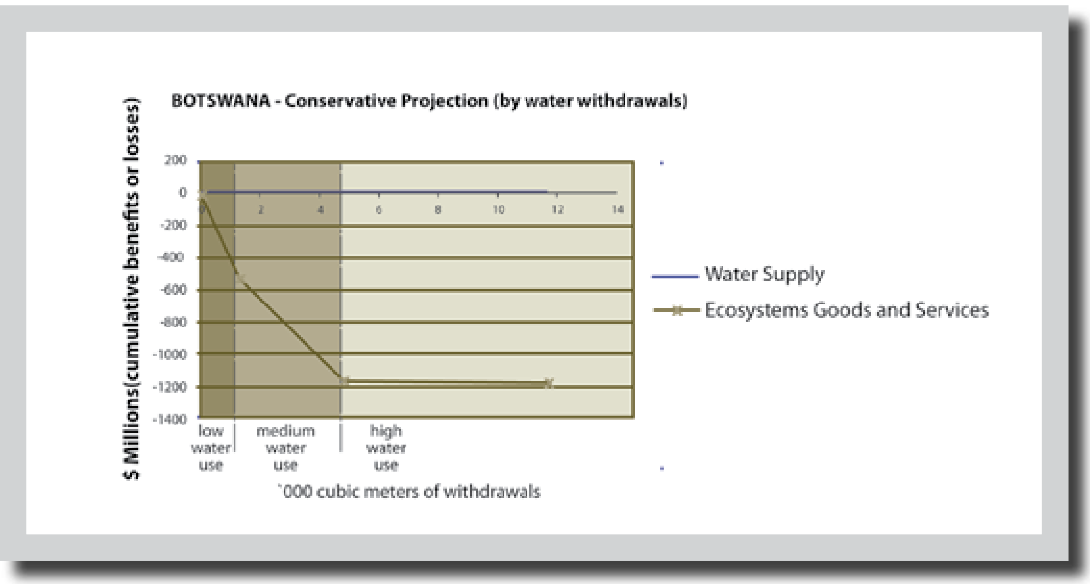
Ecosystem losses due to changes in harvesting and use of natural resources would be of the order of US$4 to US$8 million, while losses from a strong decline in tourism revenues would result in losses of US$500 million under the Low Scenario. Under the Medium and High Scenarios the losses would be over US$1,150 million (Figure 6.20).

Under the low discount rate the water supply and sanitation net benefits and the ecosystem losses would practically double in size, increasing 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 US$1 million through to 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 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 indicates would have devastating impacts on tourism in the delta and on the delta economy.

a) Conservative projection



b) Optimistic projection

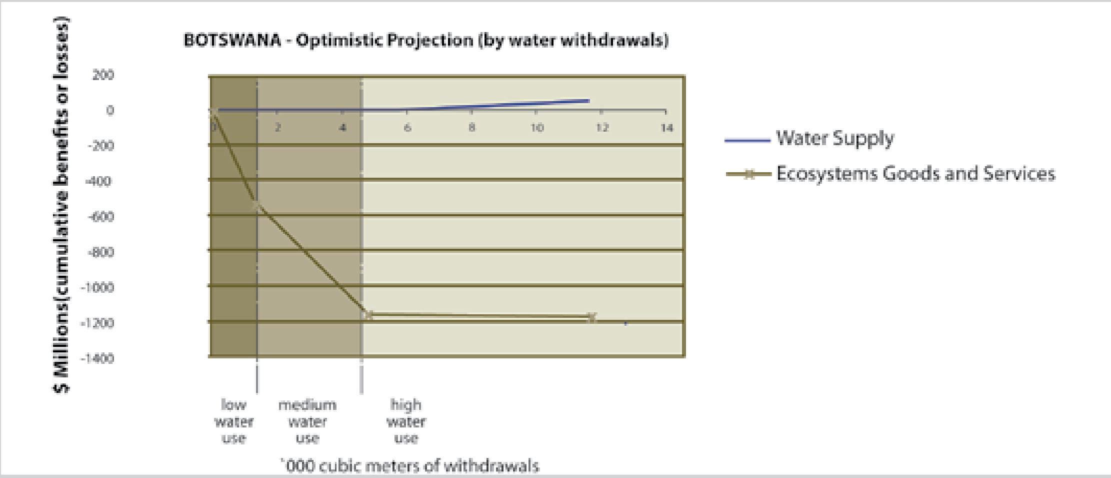


Figure 6.20: Macro-economic trade-offs for different water withdrawals according to quantity of water diverted for Botswana

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 minor losses and gains for the limited hydropower and irrigation developments – the water developments under the Low Scenario would provide little economic return, but under the High Scenario this would grow to US$60 million.

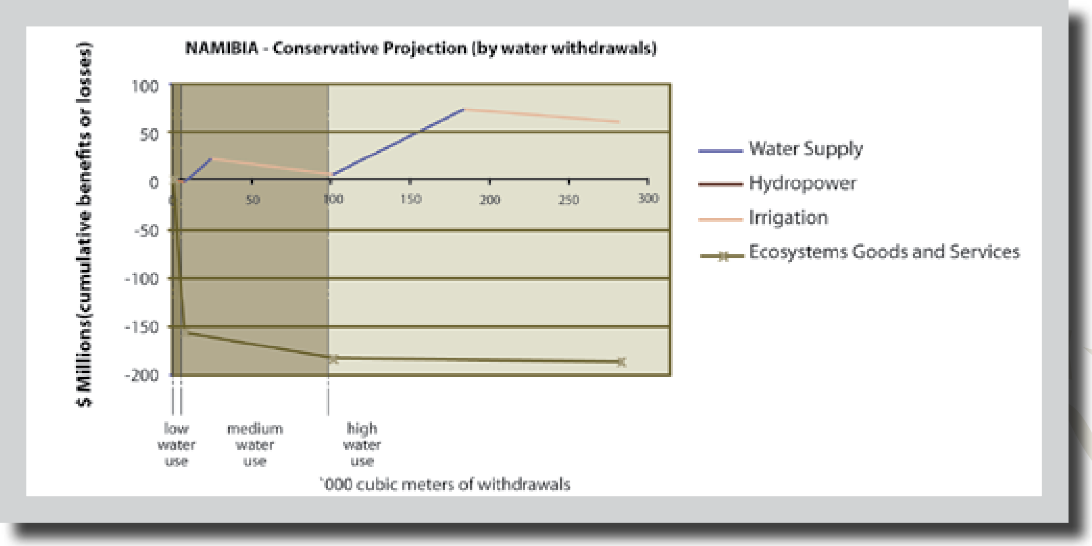
Under the optimistic projection, Namibia would benefit even more from improvements in water supply and sanitation – up to US$230 million under the High Scenario, with hydropower and irrigation net benefits ranging from US$6 to US$90 million in the Low to High Scenarios (Figure 6.21).

The negative impact on ecosystem services on the Namibian economy would be considerable, particularly in terms of the loss of tourism revenues. It is calculated that losses from US$150 million to US$190 million would accrue in the Low to High Scenarios.

Investment costs for the water resources development projects would range widely from one with maximum investment costs for the Low Scenario of 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 from Rundu, some of which would be an inter-basin transfer to Windhoek and some an intra-basin transfer to Grootfontein.

Bridge over Cubango River, Angola, 2010

a) Conservative projection



b) Optimistic projection

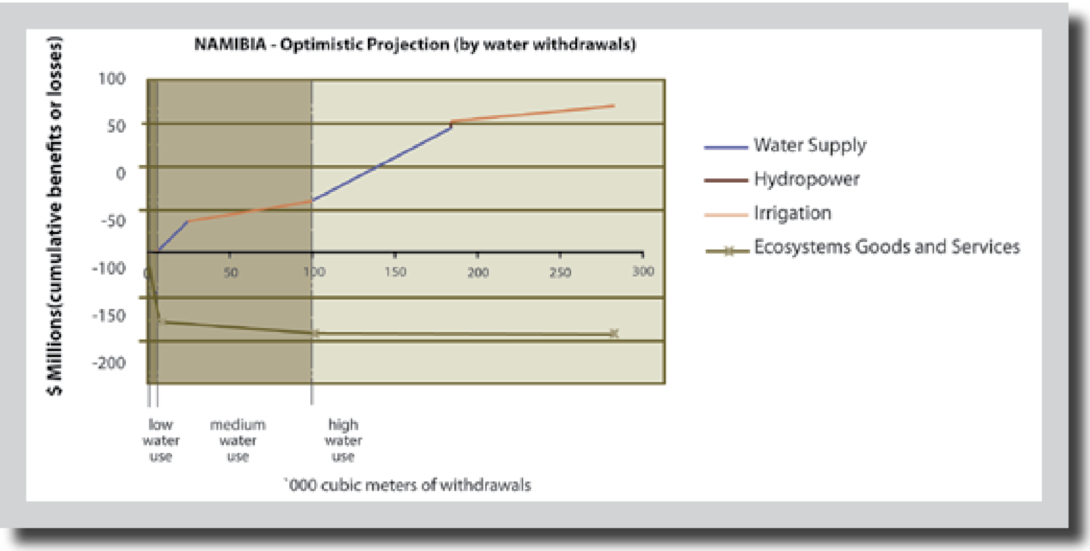


Figure 6.21: Macro-economic trade-offs for different water-use scenarios according to quantity of water diverted for Namibia

Totalling up gains and losses, under the conservative projection large economic losses would be generated for the Namibian economy, of US$125–175 million.

On the positive side, there would be benefits from improving water supply and sanitation.

At the lower discount rates the water-supply benefits and ecosystem losses would increase significantly for all scenarios. At a discount rate of 4 percent there would be a break-even point where water supply benefits matched ecosystem losses at the High Scenario.

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 percent discount rate to US$530 million at 4 percent).

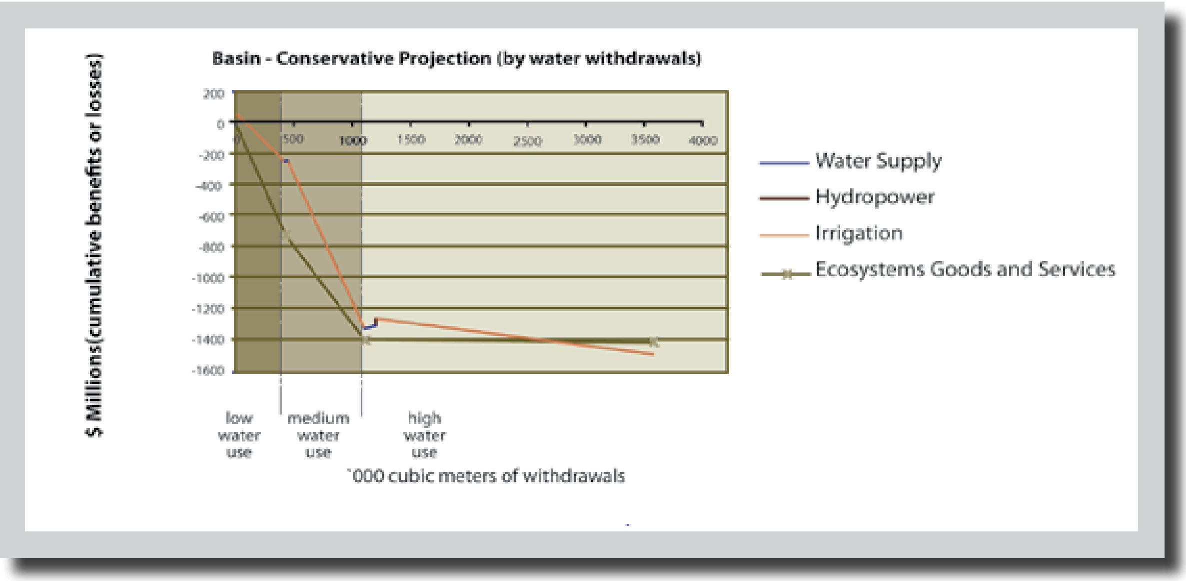
Practically all the positive benefits in Namibia would come from improvements in water supply and sanitation, which, owing to the small volumes of water involved, would have little effect on the ecosystem losses. The optimal choice for Namibia would be to avoid the ecosystem losses and economic risks associated with major water withdrawals for irrigation, and move forward with improvements in water supply and sanitation.

6.8.3 A basin perspective

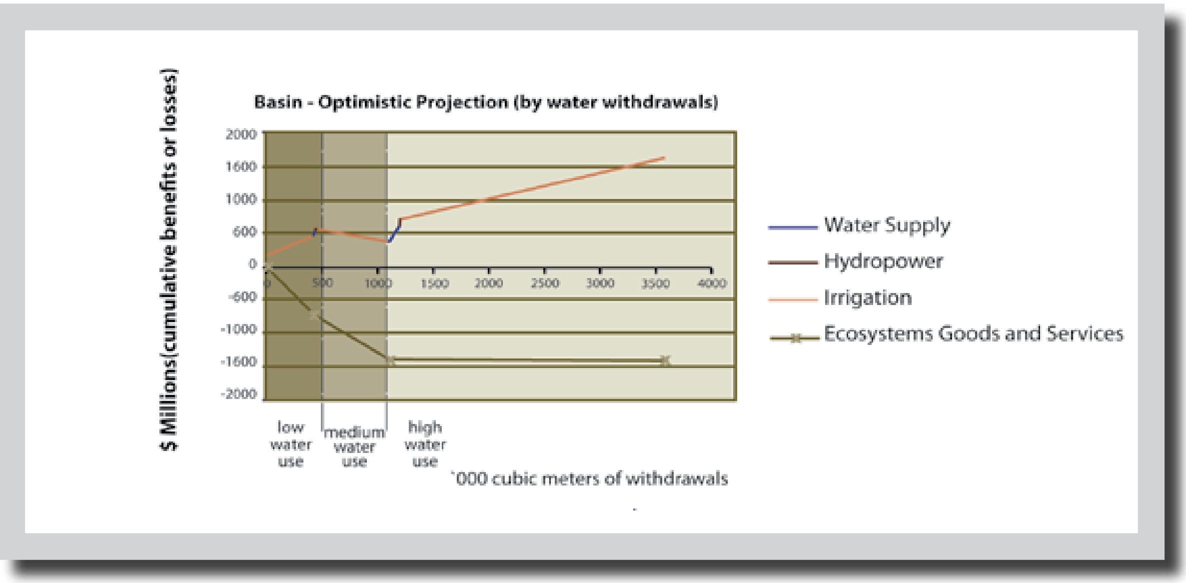
From a basin perspective, the potential large ecosystem losses faced by the downstream riparian countries in particular would be from US$700 million for the Low Scenario through to US$1.4 billion for the Medium and High Scenarios. Under conservative assumptions regarding irrigated agriculture, net returns could double the losses in ecosystem services in size, with the large expansion of irrigated areas under the Medium and High Scenarios. Even under optimistic assumptions, net returns would remain negative under the Low (-US$260 million) and Medium (-US$1 billion) Scenarios (Figure 6.22). Only with full implementation of the large Cuchi irrigation scheme and under the optimistic projection do net returns become positive (+US$215 million). However it should be noted that 60 percent of the positive returns under this alternative derive from water supply and sanitation, and hydropower.

However, it is important to note that none of this analysis takes 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)

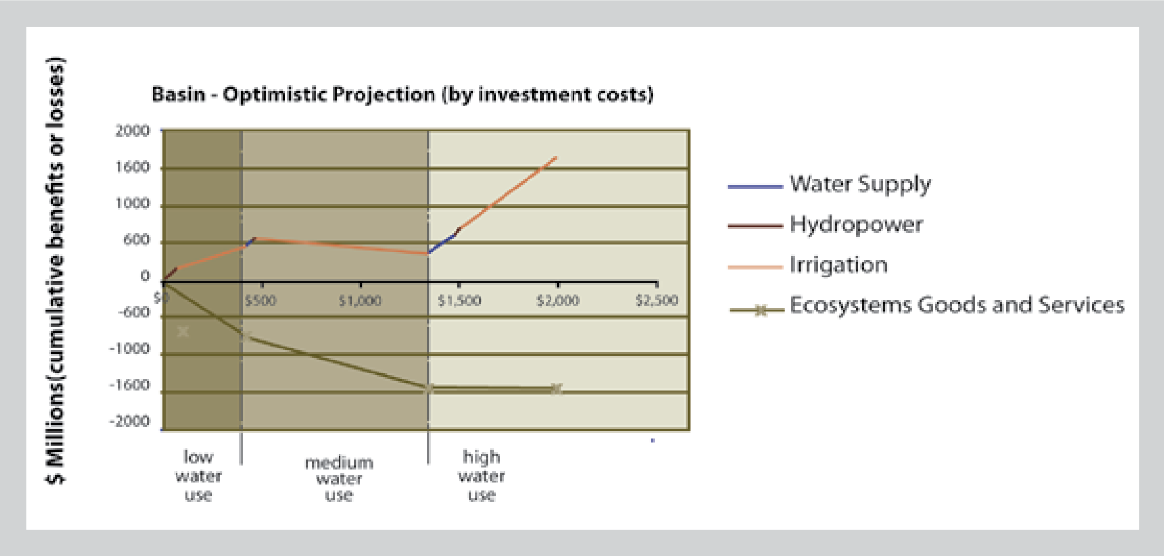


Figure 6.22: Macro-economic trade-offs for different water withdrawal alternatives from a basin perspective

In summary, water resources use would generate a magnitude of economic losses and risks that would overwhelm the potential benefits of the full suite of proposed water-use developments across all three countries. From a basin-wide perspective, caution and further study is called for before proceeding with the different water resources 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.

TDA Research team collecting samples in Kavango River, Namibia, 2008

CHAPTER 7: AREAS OF CONCERN

7.1 AREAS OF CONCERN AND THEIR DRIVERS

Chapter 7 builds on the knowledge of the present status of the basin described in Chapters 3, 4 and 5. It presents the problems and examines the trends within and linkages between the priority transboundary Areas of Concern. The four priority transboundary Areas of Concern identified by countries are:

- Variation and reduction of hydrological flow
- Changes in sediment dynamics
- Changes in water quality
- Changes in the abundance and distribution of biota.

The chapter reviews the underlying driving forces and presents a Causal Chain Analysis (CCA) for each Area of Concern and identifies the knowledge gaps and main short-to-medium term responses to each Area of Concern.

As discussed earlier, these are all emerging issues rather than existing problems and reflect the as yet unrealized development pressures on the basin. In particular, climate change was recognized as a cross-cutting issue and external driver.

TDA research team in Okavango Panhandle, 2008

As the Transboundary Diagnostic Analysis (TDA) and CCA process focused on emerging transboundary issues rather than existing problems/issues, it was easier to identify the potential drivers and causes (e.g. unsustainable management of fish stocks) rather than predict the impacts (e.g. decline of fish stocks). Even when analyzing an existing problem the temptation is to take a shortcut and identify the causes and remedies without looking at the impacts. In the normal state of events, impacts are observed and causes are deduced. Each problem causes a conglomeration of impacts, which interact with one another. The impacts may have multiple causes and common drivers, thus creating a very complex picture. Through the CCA it was possible to tease apart the impacts, identify the causal paths and gain insight into the design of an effective and efficient response programme. It is therefore essential that the Areas of Concern are looked at in parallel and that the linkages between them are thoroughly investigated.

When dealing with emerging rather than existing issues, the key question lies in how to predict and foresee the various interactions. In the Cubango-Okavango, an expert analysis was undertaken as part of the Integrated Flow Assessment (presented in Chapter 6), and an evaluation made of similar basins in southern Africa and where appropriate, the rest of the world. This analysis was then fed into the CCA; the results are described below.

Within each Area of Concern there is a description of the problem, its impacts, linkages with other Areas of Concern, responses, and its knowledge gaps. While identifying the responses and gaps in knowledge, the team looked closely at each element of the governance cycle (Figure 7.1) and assessed the gaps exposed under the Areas of Concern and the current existing governance situation. The findings of Chapter 5 were central to these assessments.

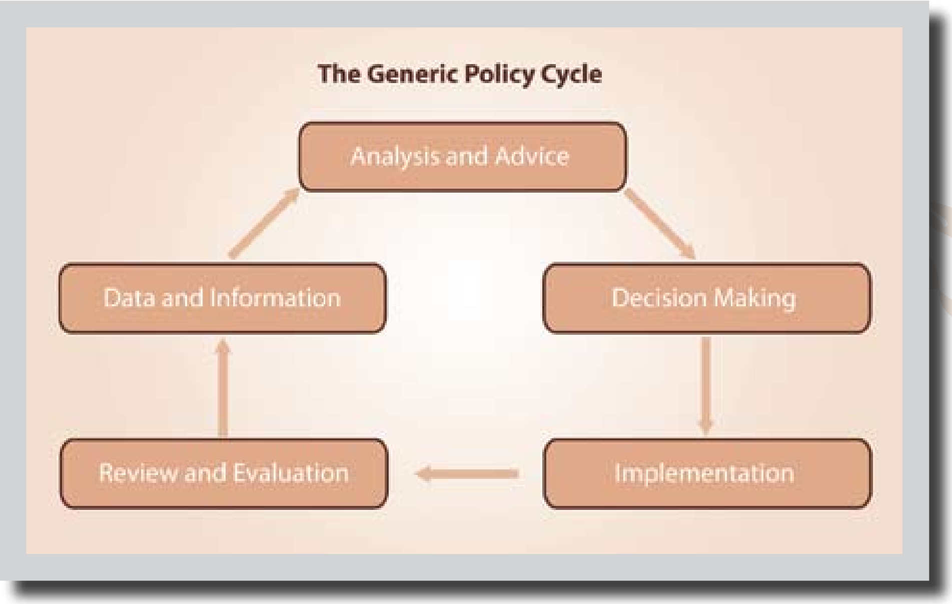


Figure 7.1: Generic policy cycle

The first step in the analysis was to identify the internal and external causes that are driving the emergence of these issues in the Cubango-Okavango river basin. The project quickly identified the following key drivers:

- Population dynamics and urbanization
- Land-use change
- Poverty
- Climate change.

These drivers are discussed below.

7.1.1 Population dynamics and urbanization

The population of the topographic Cubango-Okavango River basin in all three countries is increasing steadily and this, with the concurrent increase in demand for goods and services, is a key driver of change in the basin. Even if the basin populations do not increase as predicted, the demand for goods and services will increase as a result of increasing standards of living among all basin inhabitants.

Children take a break from bathing in river at Longa, Angola, 2008

The present population in the basin is 921,890. By 2025, this is projected to increase to more than 1.28 million people, with 62 percent living in Angola, 16 percent in Botswana and 22 percent in Namibia (Figure 7.2). In Angola, the population projections to 2025 for the Cubango and Cuito sub-basins are shown in Table 7.1; those for Ngamiland in Botswana are in Table 7.2; and the populations of urban Rundu and rural Kavango in Namibia are depicted in Table 7.3.

TABLE 7.1: POPULATION PROJECTIONS TO 2025 FOR THE TOPOGRAPHIC CUBANGO-OKAVANGO RIVER BASIN IN ANGOLA

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 7.2: POPULATION PROJECTIONS TO 2025 FOR THE CUBANGO-OKAVANGO RIVER BASIN IN BOTSWANA

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**

TABLE 7.3: POPULATION PROJECTIONS TO 2025 FOR THE CUBANGO-OKAVANGO RIVER BASIN IN NAMIBIA

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**

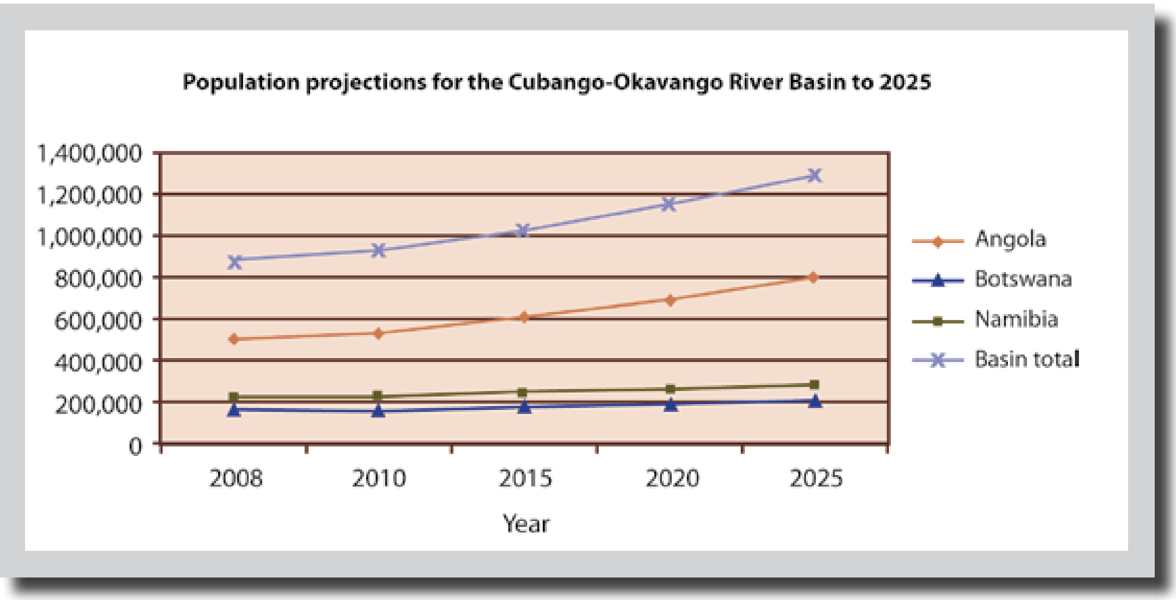


Figure 7.2: Population projections for the Cubango-Okavango River basin

Throughout the basin, there is a trend towards increasing urbanization 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 percent, while in Botswana the figure is approximately 30 percent and in Namibia around 20 percent. The centres of Menongue and Cuito Cuanavale in Angola, Maun and, to a lesser extent, Gumare and Shakawe in Botswana, and

Rundu in Namibia are all growing in size. In particular, Rundu is growing at a rate of 2.5 percent compared with a growth rate of 1.5 percent per annum in the rural areas of Kavango. Increased urbanization leads to increased demand for services such as water supply and sanitation and this could, if not regulated, lead to increased water pollution.

7.1.2 Land-use change

Land-use change is a driving force for changes in sediment dynamics, water quality and abundance and distribution of biota, and through deforestation has impacts on the hydrological regime. Linked strongly to population growth, the impact of land-use change is incremental and often irreversible. Despite the relatively low population densities in the Cubango-Okavango river basin the changes in land use and vegetation cover have been significant. There is increased demand for land for crops along the length of the river from the Angolan highlands to the panhandle and with increasing populations this trend will accelerate.

Floodplain grazers, Namibia, 2008

In Section 7.2.2, satellite images of land use at three river sites over a 25-year period show a decline in upper basin forest cover and ever-increasing crop areas in the lower riparian zones. The use of fire to clear land is becoming more prevalent, which has an impact on composition and density of vegetation. Livestock numbers are expected to increase substantially in Angola and Namibia, leading to overgrazing and bush encroachment, resulting in a change in species composition from palatable perennial species to less palatable annual species. The issue of land-use change is discussed in more detail in the section on changes to the sediment regime (7.2.2) to which it is closely linked.

The impact of land-use change may be more significant than direct increased water use and its control may become more difficult. A first step is to assess the problem and recognize the barriers to reform, including national legislation and its implementation at local level. Ideally there should be a set of land-use guidelines which local authorities can follow and implement throughout the basin; this should be aimed at preserving the ecosystem health and environmental services. Implementation of these guidelines will require extensive public education campaigns, beginning with basin communities and moving through to local institution level.

7.1.3 Poverty

As described in Chapter 3, poverty is a feature of the human populations in all three basin countries, with a much higher incidence in the Cubango-Okavango Basin than in other parts of the countries. This is partially due to the remoteness of the basin, but also to the highly unequal distribution of wealth in the three countries. Poverty alleviation in the basin should be a major investment target for governments and the ambitious water-use development plans inherent in the water-use scenarios suggest that this is the case, particularly in Angola and Namibia. As discussed in Chapter 5, all three countries have national poverty reduction strategies aimed at improving the welfare and living conditions of their populations through increased economic growth.

The importance of the contribution that natural resources make to the livelihoods of the people living in the Cubango-Okavango river basin has been stressed. Most people in the basin live in rural areas, and are thus more dependent on natural resources for food, fibre and fuel. As the population increases, so the pressure on these natural resources will increase too. Assuming that current patterns of use of natural resources remain the same, the pressure on these resources will increase by nearly 50 percent in Angola and by about 25 percent in Botswana and Namibia. This will inevitably lead to further degradation and loss of critical habitats such as the floodplains and riparian woodland, as trees are cut down for construction and firewood, and reeds and grasses are cut for household use, baskets and matting. To some extent these natural resources are sustainable, re-growing each year, but if they are over-harvested the vegetation stock may be damaged or lost completely, so that the wider habitat is changed. There is evidence of this in some parts of the Namibian basin where, for example, riparian vegetation has changed to such an extent that it no longer provides the natural resources it used to. It is essential therefore for the river to remain in a good condition, since its resources often provide important 'safety nets' for poor communities in adverse times.

Paved road in Botswana part of the Basin, 2008

While water-use developments are aimed at increasing the economic value derived from the river system, particularly in the upper basin, this may not necessarily reduce poverty. Poverty within the basin, which tends to be worse than in the broader societies of basin countries, may be exacerbated if higher uses of water are developed (see Chapter 6, Section 6.8). Where developments form part of the formal sector, and particularly where most of the economic linkages fall outside the basin, the benefits will be skewed towards high income segments of society. In the basin the poorest elements of resident societies have tended to rely almost entirely on direct use of natural resources. The expected losses in livelihoods for these communities resulting from water-use developments, could significantly increase their vulnerability (see Chapter 6, Section 6.8).

7.1.4 Climate change

The Cubango-Okavango river basin is subject to long-term climate variability and climate change impacts. Desegregating these two effects and interpreting how they will affect available water resources and their management is extremely complex and our current understanding is limited. A full report on climate change is available on the accompanying CD and is listed in Annex 2, supporting Report 18, and is summarized below.

There is long-term variability in the flow of the Cubango-Okavango river system 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 clear relationship between the long-term rainfall in the Cubango-Okavango and a long-term mode of variability in sea surface temperatures known as the Pacific Decadal Oscillation (PDO). This could mean that the observed long-term variability of rainfall in the Cubango-Okavango Basin is caused by conditions similar to those present when El Niño affects rainfall in many parts of the world. This hypothesis allows projections on the predictability of long-term variability of rainfall and runoff, because the PDO is considered to result from natural processes. Recent research suggests that it is sustained under conditions of greenhouse gas-driven climate change. The alternative to this hypothesis is randomness. The reality is probably a combination of both – the effect of the PDO modified by unpredictable randomness.

An analysis of projected climate change effects[83] 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, with increasing evaporation. There is a projected increase in rainfall of 0–20 percent across the basin, with the greatest effect in the north because of the north-south rainfall gradient. In general, 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.

83 Wolski (2010)

Three climate change scenarios were investigated for the Okavango Delta: Dry, Moderate and Wetter than Present Day.

In the Dry Scenario, an increase in evaporation and transpiration may exceed the increase in local rainfall and inflow from the catchment, resulting in drier conditions; a decrease in frequency and duration of flooding throughout the delta; and a reduction of low flows in the rivers draining the system. However, in the Wetter Scenario, the rainfall would increase substantially, which would present an increase in duration and frequency of inundation throughout the delta, with an increase of high and low flows in the rivers draining the system. In both the Moderate and Wetter Scenarios there would be an expansion of the areas that are subject to long or permanent inundation, while in areas subject to short inundation, there would be a relative reduction.

Fish catch, Kavango River, Namibia, 2009

7.2 ANALYSIS OF AREAS OF CONCERN

With stakeholder representation from the three countries, the TDA team carried out a CCA for each Area of Concern. This provided insight into the responses needed to prevent or reduce envisaged impacts. The following section summarizes the findings of this analysis.

7.2.1 Variation and reduction in flow

7.2.1.1 The problem

The water resources of the Cubango-Okavango river system have not been extensively exploited to date. Namibia uses more of the water resources from the Cubango-Okavango River than Angola and Botswana combined, with the latter relying mostly on groundwater sources. Table 7.4 shows the water use of each country in the basin[84], while Table 7.5 indicates a forecast of demands that need to be met in the three countries over the next 10–15 years.

TABLE 7.4: PRESENT DAY WATER USE BY COUNTRY

Water users	Angola	Botswana	Namibia
	Water use – Mm³/a		
Urban domestic	8.20	3.55	7
Rural domestic	5.10	0.29	2
Livestock watering	2.50	15.92	3
Irrigated agriculture	15.60	0.52	36
Fish farming	0.00012	0	2
Tourism industry	0	0.2	1
Total	**31.40**	**20.48**	**51**
Basin Total	**102.88**		

Note: Water use by wildlife is considered as part of ecosystem demand

84 Estimates are based on figures developed by the TDA hydrological team, Beuster (2009)

TABLE 7.5: PROJECTIONS OF WATER USE TO 2025 IN THE CUBANGO-OKAVANGO RIVER BASIN

	2020			2025		
	Angola	**Botswana**	**Namibia**	**Angola**	**Botswana**	**Namibia**
Water users	**Water use Mm³/a**			**Water use Mm³/a**		
Urban industrial and domestic	11.0	4.7	3.9	12.5	5.1	3.9
Rural domestic	5.6		2.7	6.4		2.7
Livestock watering	6.3	13.7	4.2	7.2	13.6	4.2
Irrigated agriculture	1653.0	10.0	125.7	3471.1	20.0	125.7
Water Transfers			17.0			17.0
Total	**1675.9**	**28.4**	**153.5**	**3497.2**	**38.7**	**153.5**
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) water-use Scenarios

As illustrated above, growth in demand of 3,768 Mm³/annum over the next 15 years is dominated by an increase in irrigation demand that is set to rise from the present 52 Mm³/annum to 3,714.5 Mm³/annum in the various proposed schemes (see Chapter 3). By comparison, the rise in domestic demand (urban and rural) of 6 Mm³/annum over the same period is insignificant and would not have a major impact on the health of the river ecosystem or its services. In Namibia there is a proposal for transferring water from the Kavango River through the Eastern National Water Carrier that links the river with the Grootfontein-Omatako Canal to supply water to the central area of Namibia. The demand from this scheme is initially low at 17 Mm³/annum, although the demand could rise to 100 Mm³/annum; this is still relatively insignificant, especially as a portion of this water would be used within the Cubango-Okavango Basin itself. The growth in domestic and livestock demand for groundwater abstraction in all three countries is also forecast to be minimal.

The threat of reduction in flow is therefore linked strongly to the proposed increase in irrigation demand in the basin in both Namibia and Angola. These proposed in-river abstractions are unsustainable, as can be seen by comparing the 1:20 year drought flow of 3,124 Mm³/annum at the panhandle. As hydrological modelling has shown, this level of abstraction cannot be supported without upstream multi-seasonal storage infrastructure and it is predicted that the resultant downstream impacts would be considerable.

Chimapaca reservoir to hold water through the dry season, mainly for watering cattle, Cunene Province, Angola, 2007

Three questions need to be answered:

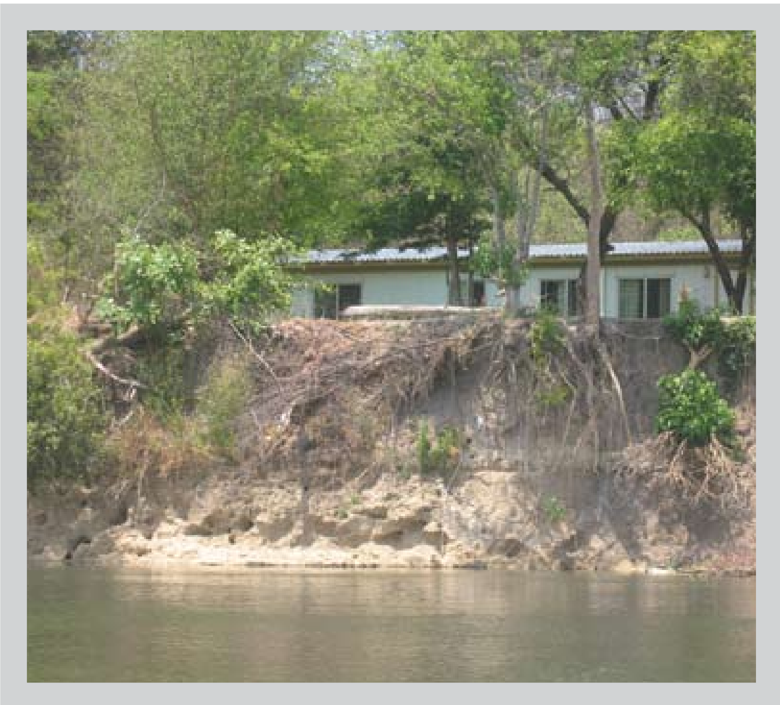
1. To what level is irrigation development in the basin possible without compromising the health of the river ecosystem or threatening the livelihoods of the riparian communities?
2. To what degree are the proposed schemes described in Chapter 4 technically and economically feasible?
3. Is the development of irrigation the most cost-effective development strategy and what other development trajectories could be considered?

The proposed development of the new hydropower schemes listed in Chapter 4 will affect the hydrological regime of the river locally and to some degree, across the entire basin (Sections 7.2.2 and 7.2.3). However, most proposals are for small in-river schemes with minimum storage, with the exception of two, which would have significant associated storage.

Any consideration of variation in flow must also take into account the varying impact on human populations of the extremes of flooding in the Cubango-Okavango river basin, which is characterized 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 Kavango region in Namibia was subject to severe flooding in 2009 and 2010, with the flood in 2010 having been the largest so far in terms of the geographical area affected and damages caused. In 2009 in Namibia, floods caused an estimated N$1.7 billion (1 percent of Gross Domestic Product) worth of damages and losses to the public and private sectors. At the time of publication there were no figures available for the 2010 flood.

Gauge at Divundu Bagani, Namibia, 2008

The extensive nature of the flood impact in Namibia was attributed to increased population settlements in the floodplains in Caprivi and Kavango Regions, road and rail construction, and emerging informal settlements in peri-urban areas that interfered with the natural river flows. Flooding in some urban areas was mainly the result of inadequate stormwater drainage. Another major contributing factor was the construction of infrastructure in the floodplains 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.



Natural erosion on Okavango Delta Panhandle river bank, 2008

Flooding events were contrasted by severe droughts in 1998 and 2007. These severely reduced the resilience of a significant number of poor households reliant on water sources other than the Cubango-Okavango. As 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, which would exacerbate the overall impact of drought in the basin.

The impacts of the combined demand and economic assessments of various water-use scenarios are addressed in detail in Chapter 6.

7.2.1.2 Impacts and linkages

The impacts and linkages, as well as the causes, were investigated through the CCA, the results of which are shown in Table 7.6.

TABLE 7.6: CAUSES AND CONSEQUENCES OF CHANGES IN RIVER FLOW REGIME

Locations	**Causes**	**Issue**	**Impacts**	**Locations**
Throughout the basin	Abstraction of water for water supply		Shortages of water for water supply, for irrigation schemes	Angola, esp. on Cuebe, Namibia
Menongue, Cuito Cuanavale, Rundu, Maun	Increased abstraction for urban use (urban expansion)		Loss in biodiversity and river ecosystem productivity, resilience and services – o Floodplains (grazing)	Angola, on Cuito, Namibia, delta
Throughout the basin, esp. Botswana, Namibia	Water for livestock		o Riparian belt (collapse of river banks)	Namibia
In Angola, especially on Cuebe and Cubango rivers and Namibia	Irrigation schemes abstracting water		o Decline in veld and medicinal plant resources	Throughout the basin
In Angola on Cubango and Cuito, at Popa	Hydropower dams – run-of-river	**Change in Flow Regime**	o Reeds, fisheries, wildlife, rare and red data species	Throughout the basin
In Angola at Mucundi on Cubango	Hydropower dams – storage dams		o Reduction in water quality	Angola, Namibia, Botswana
In Namibia	Water diversion schemes	**Key Indicators**	o Reduced water recharge	Namibia, Botswana
		o Magnitude of flows	o Loss of sediment transport	Namibia, Botswana
Throughout basin	Inefficient and inappropriate water use	o Frequency o Timing (dry season and flood season onset)	Loss in household livelihoods and commercial productivity – (low and extended low water flow)	Throughout the basin
In Angola	Changing land use and resettlement		o Declining water quality and in some places loss of access to river water	Throughout the basin
In Angola and Namibia	Land cover change – overgrazing, fires, deforestation and land transformation for farming	o Duration of dry and flood seasons o Overall variability of flows	o Declining fish for food and sales, reeds (construction, mats), grass (thatching), grazing, veld foods and medicines	Lower Cubango and Cuito, Namibia, panhandle, delta
Global	Climate change		o Floodplain crops	Cuito, Namibia
			o Tourism employment	Namibia, Botswana
			o River navigation	Throughout the basin
			o Reduced quality of life (e.g. recreation, cultural practices such as baptism in river)	Throughout the basin
			o Increased water-borne disease (e.g. gastro, bilharzia)	Throughout the basin
			Loss in economic productivity – fish, reeds, agriculture (livestock and irrigation), tourism, urban water supply	Throughout the basin
			Loss of local, national and global existence values (willingness to pay for the continued existence and integrity of the Cubango-Okavango)	Throughout the basin, but especially the delta

The flow regime of the river can be affected in two ways:

- The average quantity of the flow or the mean annual runoff (MAR) can be changed through water abstractions and changes in land cover.
- Abstractions, impoundments and land-cover changes can affect the timing or the seasonality of the flow regime such as the onset, peak, volume and duration of the dry-season or flood events.

TDA research site at Mucundi, Angola, 2008

Changes in flow regime will have consequences for the different uses of the river. The Cubango-Okavango is a 'losing' system in that all its water comes from the upper catchment, and water is lost through evapo-transpiration and groundwater recharge, with small quantities of water flowing out of the delta. In other rivers where rainwater flows into the system throughout the length of the river, abstractions may be less critical, but in the Cubango-Okavango, abstraction in one part of the river inevitably means that there is less water available in other parts downstream. The water availability may be adequate during flood flows, but during low flows, the lack of water may be critical.

This has significant implications for water-use schemes in the lower basin – Botswana and Namibia – that may have more restricted water availability if some of the large irrigation schemes in Angola and Namibia are implemented. Even in Angola, hydrological modelling has shown that fairly modest developments (in all scenarios used on the Cuchi River) may result in headwater streams drying up during dry seasons. It is significant that the water in the basin is generated upstream of the confluences of the Cubango and Cuatir Rivers in the west, and the Cuito and Longa Rivers in the east. Downstream of these points, the catchments of the lower Cubango and Cuito Rivers contribute very little additional runoff. For these reasons some parts of the river can withstand hydrological change better than others. When comparing abstraction sites, location is a key factor, as the impact on each site's hydrology is likely to differ.

Oxbow backwater near Shamvura, Namibia, 2008

The overall trend is for run-of-river abstractions to reduce flows throughout the year, with the effect being particularly noticeable in the dry season. Under the conditions modelled in the three scenarios, dry-season flows would tend to be lower, start earlier and last longer than in the Present Day, with greatest effect experienced at Capico, Popa Falls and in the panhandle.[85]

85 Sites 1, 5 and 6

Pelicans at recently flooded Lake Ngami, Botswana, 2010

Flood volumes would become progressively smaller and the flood season would become shorter and start a little later. 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 would happen in many developed basins, as there would have been little storage developed within the basin.

Under the scenarios, some stretches of the river would have very low dry-season flows with the onset of the dry season starting earlier than usual and/or lasting longer than usual. If water is stored in dams, the flood season would start later and/or end earlier than under natural conditions. Floodplains along the river, especially in Angola and Botswana would be severely affected by changes in the flow regime. In Angola and along the Angola/Namibia border certain floodplains would not flood at all or only flood occasionally. Areas that were once under water could become stagnant pools. Changes in flow patterns would either increase or decrease the exposure of riverbanks and change the availability of backwaters along the river. In the Okavango Delta changes in the seasonality and the quantity of flow would drastically change the relative composition of temporary swamps, permanent swamps and savannahs.

Hydrological modelling (Chapter 6) has shown that under increasing water use the headwater streams in Angola would be vulnerable to dry-season drying. Most potential development in the Cuito River is confined to its lower reaches, while its upper reaches would remain in good condition as long as its floodplains were left intact. Progressive levels of water use in the Cubango would extend lowered integrity along the length of river, past the confluence with the Cuito and up to the beginning of the panhandle. The panhandle would experience progressive deterioration with increased water use upstream, as would the eastern channels within the delta. The outflows represented by the Boteti River are clearly another very sensitive part of the system, deteriorating markedly with increased water abstraction upstream.

Flooding at Toteng Bridge, Botswana, July 2010

The delta receives the same amount of water as the panhandle, in the same pattern of flows described above. Increased water use upstream would cause 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, seasonal sedgeland, seasonal grassland) as well as in dry-floodplain savannah. The out-flowing Boteti River at Chanoga, which normally exhibits dry and wet cycles over a number of years, would be similarly affected, with a progressive decline in the number of years that it contains water.

The characteristic features of the Cubango-Okavango Basin – its floodplains – are threatened by reduction in river flows. They extend from quite high up in the Cuito sub-basin down to the confluence with the Kavango River. There are also smaller floodplain areas on the Cubango and on the shared Angolan-Namibian section of the river which are under threat.

TDA floodplain research site at Kapako, Namibia, 2008

The floodplains are critical for maintaining the flows in the river throughout the year; they act as storage areas for floodwater, delaying the release of water back into the main channel. If the floodplains shrink, the hydrograph of the river will become more subject to flash floods, like those experienced by the Cubango River, with less water available during the dry season.

The floodplains are also reservoirs of natural resources. They contain extensive productive areas of reeds and grasses and it is the seasonal variation between flood and dry seasons that contributes to their productivity. The diversity of habitats, reed beds, backswamps, meanders and oxbow lakes are used as nursery grounds by fish and by a wide range of species for feeding and breeding, moving between the main channel and seasonally flooded areas to take advantage of the rich and secure conditions found there. Without the floodplains, the overall productivity and diversity of the river would be significantly lower.

The impacts of deforestation on water availability in the Cubango-Okavango river basin was initially assessed as part of the Twinning European and third world countries' river basins for development of integrated water resources management (TwinBas) project, and subsequently used to assess the impacts on the flooding regime of the delta as part of the Okavango Delta Management Plan (ODMP, 2008).

The study found that deforestation can have significant effects on the water availability and flooding regime of the river, while increased population pressure along the riverbanks would lead to a 2 km wide band of deforestation along the main river courses. Analysis of the hydrological impacts of the deforestation scenario indicated that average inflow to the delta would increase by around 7 percent, with an associated increase in average groundwater levels. These increases were partially offset by increased evapo-transpiration from the greater flooded area.

Other hydrological impacts that could 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.

People and local communities use the natural resources of the floodplains extensively. In some places, floodplain cultivation of crops is also practised, taking advantage of the rich soils and good supply of water.

Key ecosystem services affected by changes in the floodplains would be:

- Food, such as fish, vegetable, fruit products and medicinal plants
- Fodder for livestock
- Fibre from reeds and grasses for thatching and basket making
- Fuel from woody plants.

It is likely that these would all decline as a result of changing flows, declining water quality and changing sediment dynamics. These would have significant economic and nutritional consequences for the people living along the river and adjacent to the delta, who are usually the poorest and most vulnerable members of the population.

Taking the basin as a whole, the effect of decreasing natural resources with increase in water resources development on the livelihoods of the people (measured by private net income) is shown in Figure 7.3.

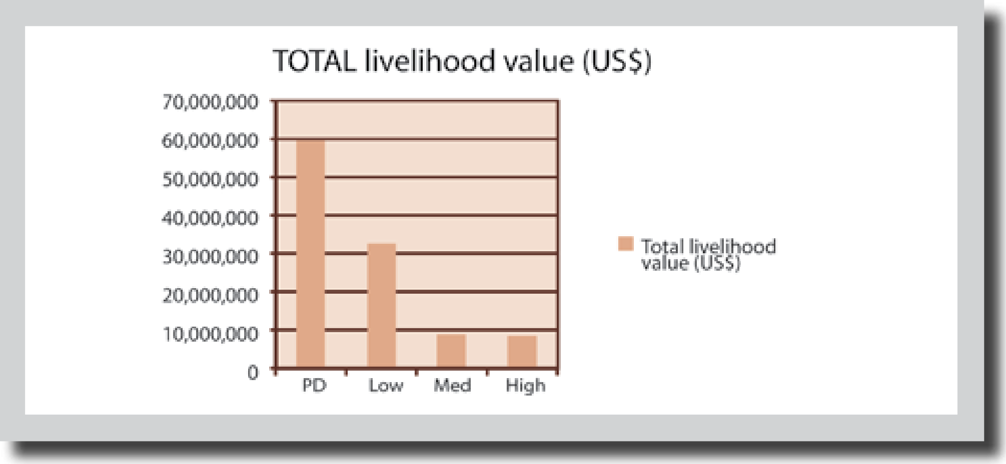


Figure 7.3: The short-term implications of water-use scenarios for livelihoods in the Cubango-Okavango River basin. Scenarios: Present day (PD), Low water-use (Low), Medium water-use (Med) and High water-use (High) (US$, 2008)

It is estimated that the livelihoods value will drop from the current estimate of US$60 million per annum, to just over US$30 million per annum for the Low water use to under US$10 million per annum for both Medium and High water-use Scenarios. A similar pattern is shown in the direct economic contribution which shows a decline from US$100 million per annum to about US$50 million per annum for the Low Scenario and under US$10 million per annum for the Medium and High Scenarios.

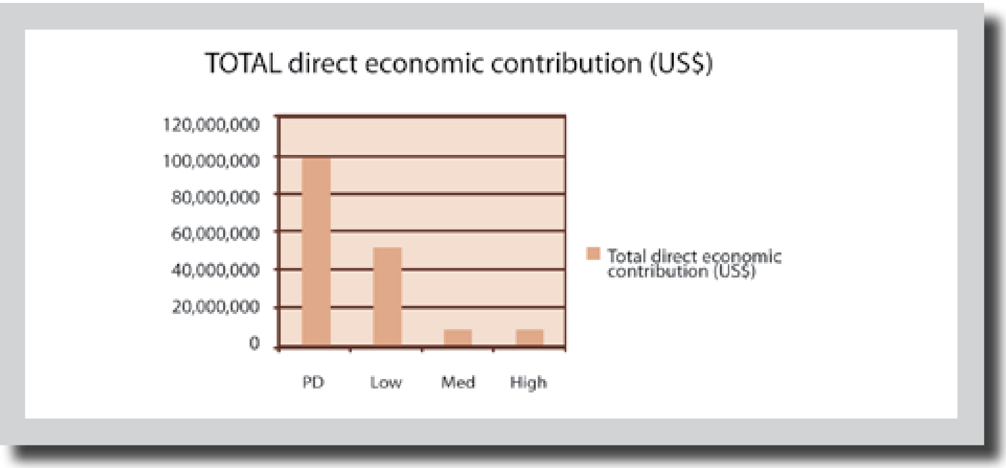


Figure 7.4: The short-term implications of water-use scenarios for direct economic income in the Cubango-Okavango River basin Scenarios: Present day (PD), Low water-use (Low), Medium water-use (Med) and High water-use (High) (US$, 2008)

There are significant differences between country dependence on the use of the river's natural resources. The people of Angola are dependent on the river, mainly for water supply, fish and, to a limited extent, floodplain products, whereas the people of Botswana and Namibia have a more varied use of resources. In Botswana there is great dependence on eco-tourism, and under the Medium and High water-use Scenarios, a decline in such tourism in the lower part of the river system would result in heavy basin-wide economic losses.

Tourist operators in Botswana predict that there would be short-term changes in tourist numbers depending on the extent of the flooding in the delta. High flooding levels in the delta would reduce tourist numbers markedly, with a more gradual decline as flooding levels decrease with increasing water use upstream.

Services provided by the river ecosystem include water purification, and if the floodplains and riverbank vegetation are degraded, this could lead to a reduction in water quality. Shortages of water in the river at certain times of the year would lead to reduced groundwater recharge; this could become an issue for Namibia, which relies heavily on groundwater sources for domestic supply. Users of the river for water supply, which is particularly important in Angola, would suffer because of declining water quality.

TDA Popa Falls research site, Namibia, 2008

Shrinking floodplains would reduce the productivity of floodplain and recession agriculture. Declining productivity of the river's natural resources such as fish, reeds, grasses, grazing for livestock, foods and medicines, would impair local livelihoods and river-dependent businesses, with implications for poverty and increased vulnerability.

Changes in flows could also lead to reduced quality of life, with less water in the river at certain times of year, increasing the difficulties of navigation, recreation and cultural practices such as baptism in the river. Many cultural and spiritual sites are located along the river, with particular morphological features such as pools, waterfalls and large trees being sacred sites. Changes in the river, its morphology and loss of vegetation may lead to the loss of such culturally rich sites Some places would be affected by increased walking distance to collect water while others may even experience loss of access to the river altogether.

Throughout the system, changes in flow may also lead to increased water-borne diseases. Lower flows in the river mean less dilution of pollution, with greater risks of gastro-intestinal disease. Slower flows and greater human use of the river may lead to increases in the habitat for the snails that carry the bilharzia parasite.

7.2.1.3 Responses and knowledge gaps

The identification of knowledge gaps in the changes and reduction in river flows resulted in the creation of the following major response objectives:

- Review of meteorological and hydrological monitoring programmes and recommendations for their strengthening
- Development of strategic, phased investment programmes for the improvement of meteorological and hydrological networks, including institutional components

There is a clear need to **strengthen the meteorological and hydrological monitoring programmes** in the basin. As reported in Chapter 3 there are few hydrological stations operating in the upper basin and this lack of baseline data is a weakness in the hydrological modelling studies that have been undertaken. The cost of rehabilitating or constructing monitoring stations would be considerable and would therefore be long-term investments. The data will be valuable for both operational and planning purposes. The investment could be phased over a long period with key locations at transboundary points and downstream of major abstractions given priority. This investment could be part of a wider national strengthening of the monitoring system and should include technical capacity building at the basin and national level.

- Design and implementation of a groundwater monitoring programme for the major aquifers and at key locations
- Assessment of groundwater yields in major aquifers

A basin groundwater monitoring programme should be developed to provide improved operational and planning knowledge, including information on water quality. The inter-connectivity of the groundwater and surface water systems should be evaluated and the contribution of groundwater from peripheral areas of the basin should be assessed. Currently, the information on groundwater contribution to the available and potential water resources is weak. The problem of saline aquifers and their interfaces with non-saline groundwater, as well as the understanding of recharge mechanisms in the basin still needs to be investigated thoroughly. The groundwater resources of the basin and their recharge are not quantified and their interaction with surface water so far remains unclear. Qualitative and quantitative research will be carried out to determine the hydrogeological characteristics of the basin, how these affect river flows and to quantify the usable groundwater resources potential. Saline aquifers need to be localized and their extension verified.

- Review of water resource demands

A detailed listing of current abstractions (both licensed and actual amounts) should be assembled and compound demand forecasts to beyond 2035 should be prepared. The forecasts should consider in detail the potential irrigation demand, transfers and hydropower schemes as well as municipal demand based on a range of economic scenarios. It is important that these forecasts be undertaken using consistent methodology.

- Review of implementation of water abstraction licensing procedures and their implementation and enforcement and proposals for their improvement

It is unclear from TDA investigations what the status of regulations on water resources on the ground is or how performance may be improved. **The strengthening and capacity building of local regulatory bodies will be an important element** in any proposals but the development of pragmatic, community-level approaches to enforcement, which are cost effective and not burdensome, are also crucial. The flow of information is important; simple systems should be in place to deliver knowledge from the communities up to national centres. This bottom-up approach should be developed not only for management of water but all other natural resources.

- Upgrading and expansion of hydrological models for the Cubango-Okavango Basin

The current hydrological models have limitations both technically and in geographical scope. **The models should be upgraded to improve their capabilities**.

- Development of a decision support system and information management system for the Cubango-Okavango Basin and provision of advice on acceptable development space

The decision support tool developed during the TDA should be expanded into a **full decision support system** (DSS) to support a basin-wide decision framework agreed by the three countries. A DSS could consider impacts, variation and reduction in hydrological flow and also changes to sediment regime, land use and water quality. An integral part of a DSS would be an information management system that would operate on a number of levels and contain, among others, water resources, land-use, fisheries, socio-economic and biological databases. Such a DSS could be used to assist in defining the development space and thereby a vision for the basin.

- Review of water resources options of Cubango-Okavango Basin and development of water resources plan harmonized with IWRM plans at national level

A water resources development plan should be developed in line with the basin 'vision'. This could look at all the potential water resources options needed to meet the various water demand scenarios. This water resources development plan should be linked with existing national IWRM plans and basin specific plans such as the ODMP and the Cubango IWRM plan (currently being developed).

- A review of impact of climate change on water resources and water demands

The current climate change study should be revised and a more detailed set of scenarios developed to investigate the impact, on both water resources and water demand throughout the basin. As the countries look ahead 15 to 25 years, this will become an ever more important issue and it should be addressed at basin-wide and national levels.

- Development of drought management plans
- Development of flood forecasting model and flood preparedness plans.

Drought management plans linked to the overall water resources development plans should be developed, with clearly defined thresholds at which decisions are to be made. The issue of flooding and flood protection has not yet been investigated thoroughly in the context of an integrated water resources strategy. Flooding is a natural annual event central to the well-being of the river ecosystem but it also can cause tremendous damage and hardship to the basin population. There is a need to identify the areas susceptible to flooding and develop strategies to mitigate potential damage. This includes flood preparedness plans, government response information, flow of information, lines of command and decision structures, and a public information system. Similar plans should be developed for droughts and pollution incidents.

Loading water from the Cubango, Angola, 2008

7.2.2 Changes in sediment dynamics

7.2.2.1 The problem

Road through forest, Angola, 2008

There are several issues associated with sediment transport in predictions for the Cubango-Okavango river system. The first is the increasing erosion in the Angolan highlands as a result of deforestation and cultivation of more land. As land is cleared and cultivated, more soil is eroded and carried down from the catchment into the river. There is thus a tendency for sediment levels to increase. It is evident from satellite images that natural erosive processes in the Cuito River sub-basin have been occurring over many years.[86] The risk is that with increasing cultivation, such natural erosion processes will be enhanced. Not only will land areas be lost, but quantities of sediment in the river will increase. With accelerated erosion and consequent increase in sediment loads to the channels of the Cubango and Cuito Rivers, turbidity could increase, reducing light and dissolved oxygen, threatening aquatic habitats.

In Landsat images for the upper Cubango River basin in the Angolan highlands, the population pressure is clearly visible. Three temporal examples from the 1970s, 1990 and 2003 illustrate the Divundu/Shakawe area on the border between Namibia and Botswana, and the Rundu/Calai area in Namibia. The images are replicated in Figures 7.5 to 7.7.

Figure 7.5 shows the progressive increase in the mosaic of croplands in different parts of the upper Cubango River. In 1975, settlements and cropland are relatively small and isolated, as shown by the white patches among 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 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.

Cattle post near Lake Ngami, Botswana 2010

86 Verrisimo, L. (2009)

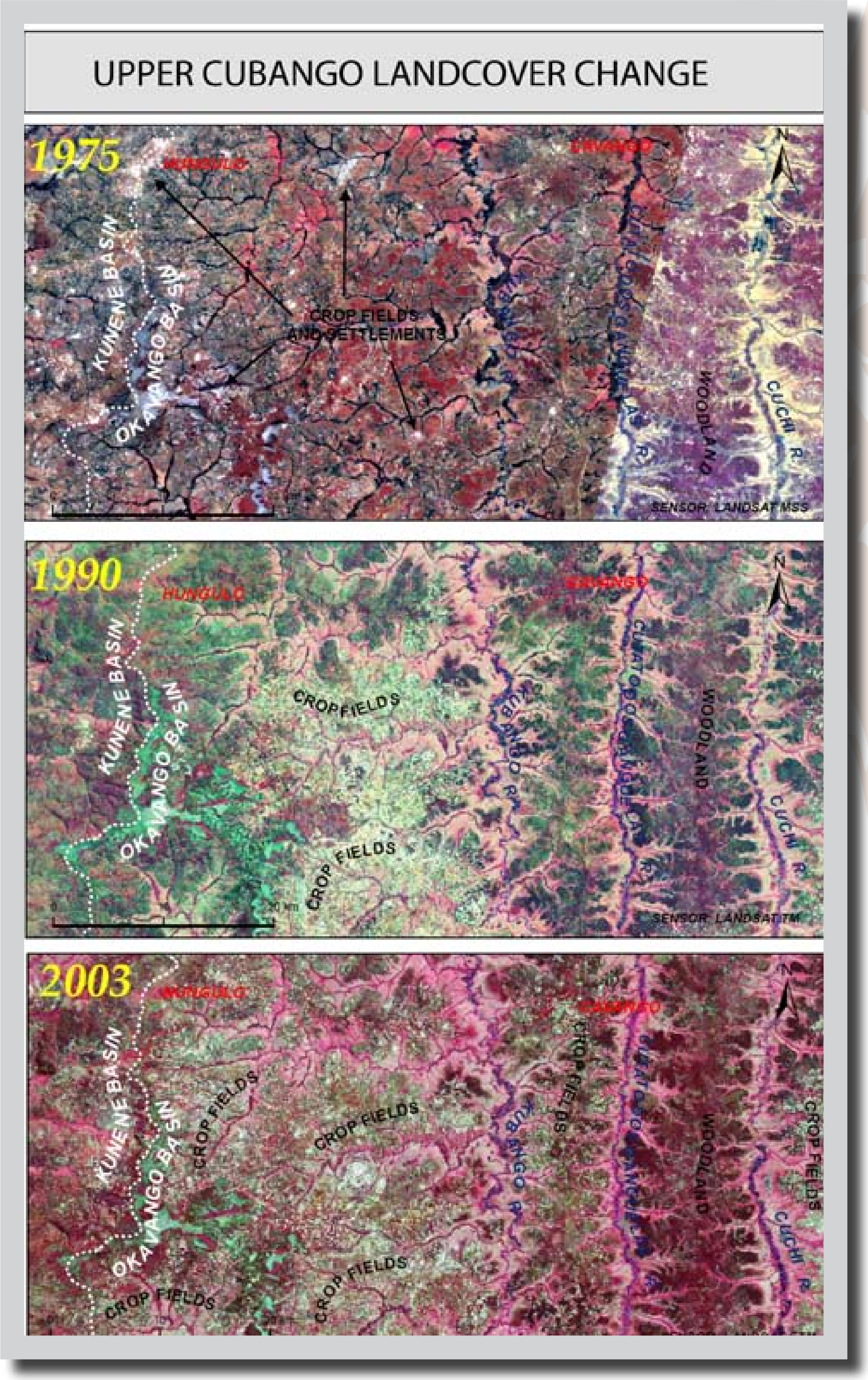


Figure 7.5: Landcover changes in the Upper Cubango sub-basin 1975, 1990 and 2003

In the Divundu–Shakawe Landsat images (Figure 7.6), 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 lower population pressure compared with the Rundu area.

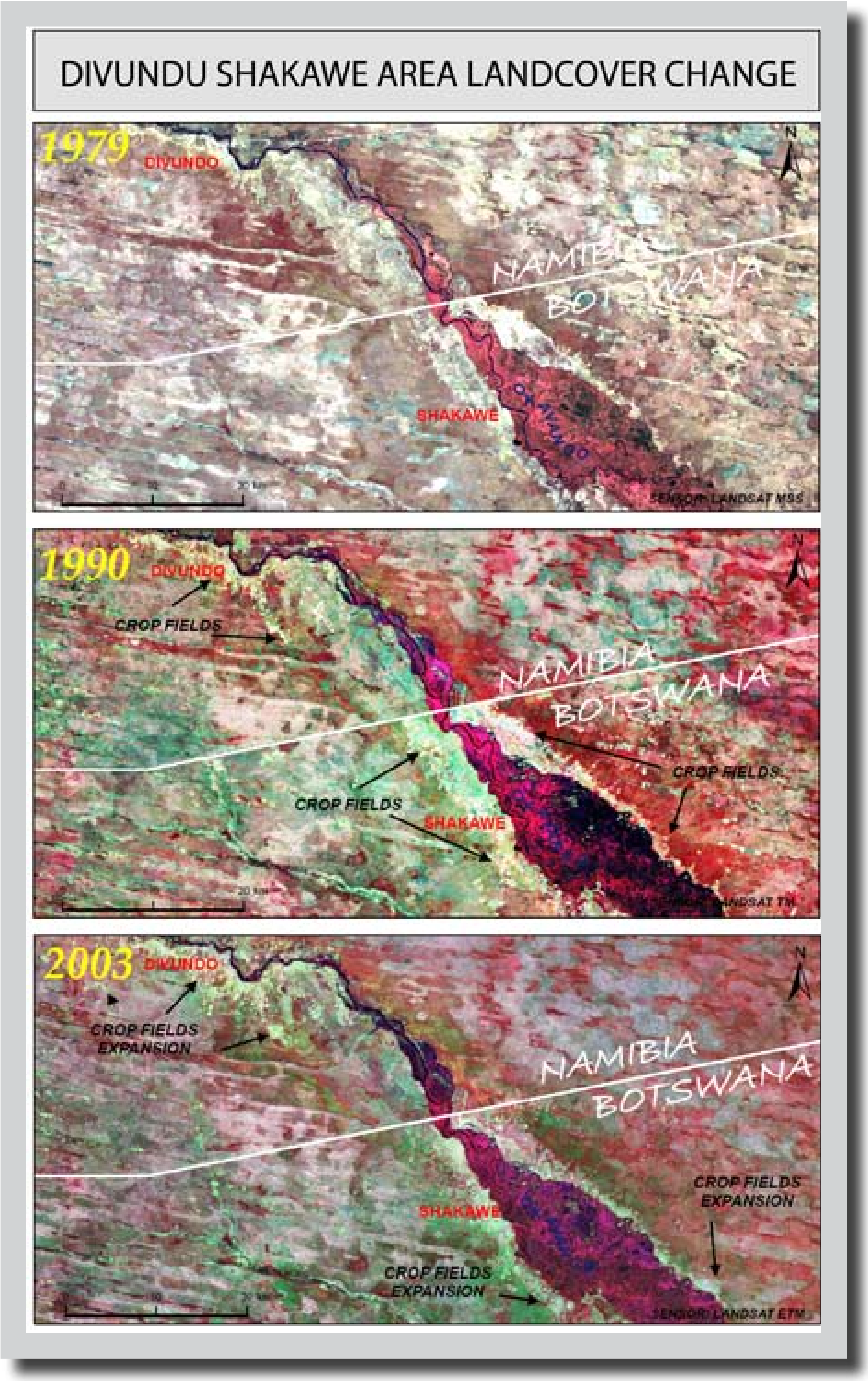


Figure 7.6: Landcover changes between Divundu and Shakawe 1979, 1990 and 2003

In the Rundu/Calai area (Figure 7.7) in 1973, woodland covered both the Namibian bank to the south of the Kavango River and the Angolan bank to the north. The floodplain areas are clearly visible along the river valley. By 1990, the woodland areas along both banks had been essentially cleared and crop fields 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 have 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 groundwater 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 emphasizes the rate of clearance of areas of woodland in Kavango, estimated at 3.9 percent per annum between 1943 and 1996.[87]

87 Mendelsohn (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 below 50,000 in 2003. In the early 2000s there was intense spontaneous resettlement of populations along the Kavango River, with many people having been displaced into Namibia from Angola as a result of the conflict there. 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 Kavango in Angola will increase.

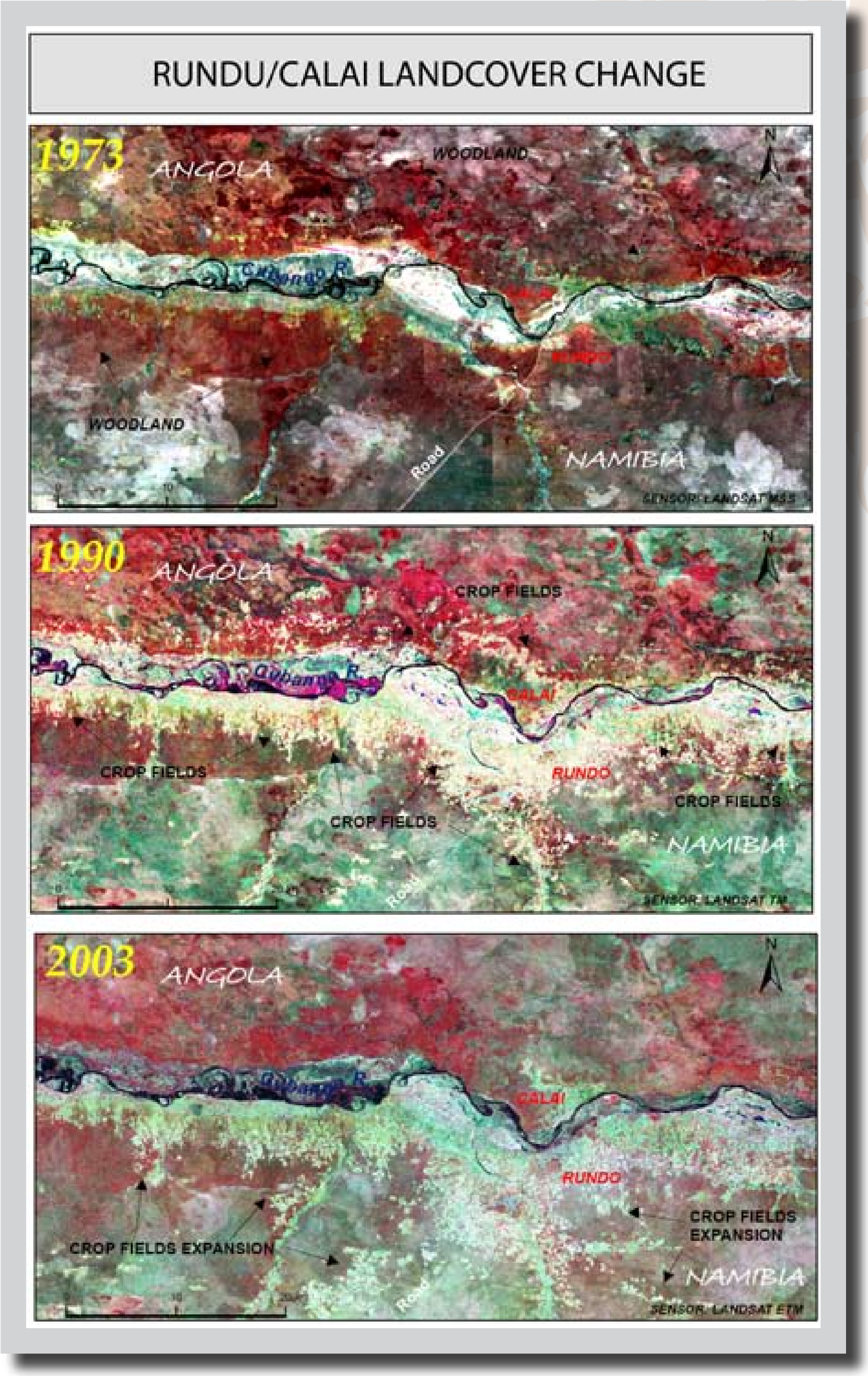
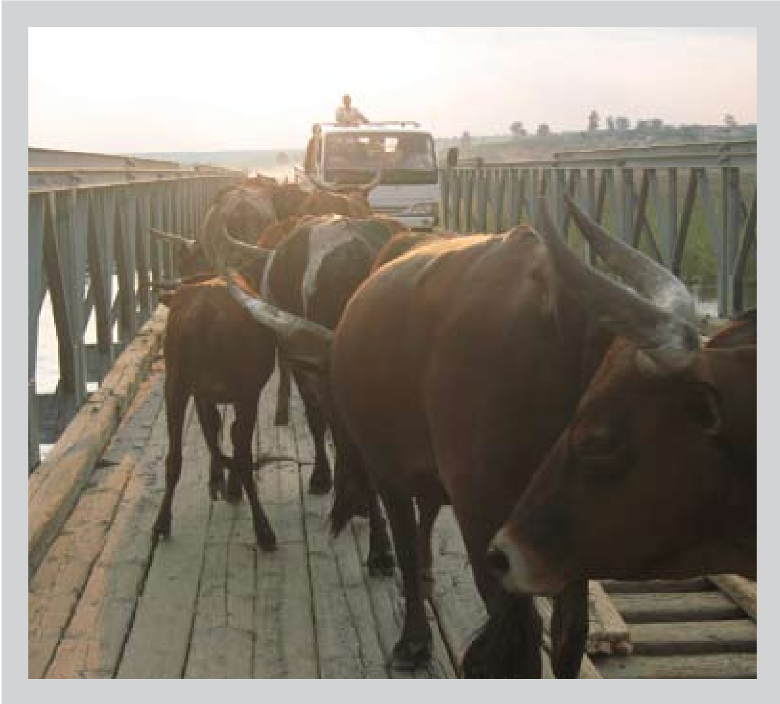


Figure 7.7: Landcover changes around Rundu/Calai, Namibia, 1973, 1990 and 2003

Significant numbers of livestock can degrade riparian vegetation. The river provides a focus for medium and high density livestock numbers, especially in Namibia and along the western side of the Okavango Delta, putting stress on the banks.

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



Cattle on bridge, Cuito Cuanavale, Angola, 2008

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.[88] 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 localized impact on the riverine and floodplain vegetation.

Bank erosion is a concern for riparian land owners in Namibia and in the panhandle area of Botswana. The process of channel formation involves depositions of sediments in some parts of the channel, which force the currents to change and erode banks on the inside of bends in the river. The banks may be several metres high and usually consist of unconsolidated sand that can erode easily. The loss of riverine vegetation, such as can be seen along the Kavango in Namibia, reduces the protection that these trees and shrubs provide. Riverbank erosion can be expected to get worse as riverine vegetation is lost. Changes in flow regime as a result of abstractions, or downstream of hydropower schemes, can aggravate the situation.

7.2.2.2. The impacts and linkages

River bank erosion, Shakawe, Botswana, 2008

The impacts and linkages and causes were investigated through the CCA, the results of which are shown in Table 7.7, and described below.

88 Fraser and Mabusela (2003)

TABLE 7.7: CAUSES AND CONSEQUENCES OF CHANGES IN SEDIMENT DYNAMICS

Locations	**Primary Causes**	**Issue**		**Impacts**	**Locations**
In headwaters of Cubango, along river on common Namibia-Angola border	Land cover change – overgrazing, fires, deforestation and land transformation for farming	**Change in sediment dynamics** **Key indicators** o Bedload annual quantities transported o Suspended solids (TSS, turbidity) o Dissolved solids (conductivity)	Decrease in sediment bedload transport	Causes hydrological change with associated changes in river morphology – channel formation and reduced flood spillage	Throughout basin
Longa, Cuito, Lupire	Cultivation of rice, sugar in floodplains			Loss of floodplain and delta dynamics	Cuito, Namibia, delta
Cuchi & Mucundi	Dams for irrigation and hydropower (stop bedload transport)			'Sediment hungry' flows downstream of dams increase riverbank and bed erosion	Angola
Angola, Namibia	Increase in sediment and dissolved solids in returned waters from irrigation			Impacts on river, floodplain, panhandle and delta ecosystem functioning	Throughout basin
Angola, Namibia	Sand mining			Increased salinization	delta
Common Namibia-Angola section and areas with higher human population	Destruction of riparian belt			Riverbank erosion	Mid section between Mucundi and the panhandle
Throughout basin	Peri-urban (small cluster settlements) population increases			Impacts on infrastructure – roads, water abstraction schemes	Throughout basin
			Increase in water column sediments (increase in turbidity)	Increase in total suspended solids (TSS) decreases aquatic productivity o In severe cases leading to decline in aquatic vegetation	Throughout basin
Cuito headwaters	Climate change			o Increase in floating algae	Throughout basin
				o Declining potability and gastro problems in people and animals	Throughout basin
				o Blocks fish gills - fish kills, reduced productivity	Throughout basin
				o Reduces hunting efficiency of fish and macro-invertebrate species hunting by vision	Throughout basin
				Increased deposition downstream on floodplains, panhandle and delta	Panhandle, delta
				Smothering of habitats and sedentary communities (mainly rocky areas)	Angola, Namibia, esp. Popa Falls
				Increased water treatment costs	Throughout basin
				Impacts on infrastructure	Throughout basin

The sediment dynamics in the Cubango-Okavango system are both complex and critical to the continued maintenance of the river, its floodplains and delta ecosystems. The 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 bedload by siltation 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 – 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.

Cubango River, Angola, 2007

Changes in the flow regime will alter the balance of all three components of sediment, reducing the bedload. However higher erosion processes in the upper catchment will tend to increase the suspended load and the return of irrigation waters to the river will bring an increased concentration of both fine sand, and solutes from the agricultural fields. Conversely, changes in sediment dynamics will alter the hydraulics and river morphology and in the delta and floodplains the depositing sediments would be responsible for channel blockage and formation, meanders and oxbow lakes.

Popa Falls, Namibia, 2008

Hydropower schemes cause decreases in sediment. The bedload sediments will be trapped behind them and their designs need to incorporate methods for clearing the sediment and passing it downstream. If flushes of high concentrations of sediment are passed in a short space of time, this will influence the water quality and the ability of the river downstream to cope with raised sediment levels. Sediment-passing mechanisms are never completely effective, so inevitably there would be a loss of fine sand in the river.

After passing through a dam, the waters tend to carry less sediment creating the symptom of 'sediment hungry' rivers. Water which has lost its natural load of sediment, tries to pick it up again through eroding banks and riverbeds downstream of dams. Infrastructure lying near the eroding riverbanks may be washed out, including roads, water abstraction points and flow monitoring equipment. Another factor contributing to the removal of fine sands from the river is sand mining. Although there is no estimate of the extent of this mining, it has been raised as a concern in Namibia.

An increase in Total Suspended Solids (TSS) in the water due to increased land erosion decreases the penetration of light. TSS in the Cubango-Okavango are currently very low and water clarity is high. In the Cubango-Okavango system, nutrients are limited, so there is relatively little algal production. Increases in TSS might lead to the loss of higher aquatic plants and an increase in filamentous algae. High TSS can block gills and breathing pores of macro-invertebrates and fish, leading to mortality or reduced productivity. If visibility in the water decreases, fish and insects that depend on their vision for hunting will be disadvantaged. Increased sediments smother sensitive aquatic habitats, e.g. gravel and rocky riverbeds that may be important for fish spawning.

It is not clear what the cumulative impact of all these changes would be and further data and information about the sediment transport system of the river is required through the establishment of a sediment monitoring programme. There is a great deal of knowledge about the sediment regime of the delta, but it is unclear what quantitative impacts there could be on the basin ecosystem and services because of changes to the sediment components caused by upstream development and change in land use. These are complex questions which need to be addressed as part of the development of any DSS.

7.2.2.3 Responses and knowledge gaps

The following major responses to, and knowledge gaps in, changes in sediment dynamics have been identified:

- Mapping of land-use potential (sensitivity map) of the basin and detailed assessment of land-use policies, legislation and regulations
- Erosion hazard mapping
- Harmonization of land-use planning guidelines

The TDA has focused on the impact of increasing water use on the health and functioning of the river ecosystem and its delivery of environmental services. The question of changing land use has been studied in less detail and its impact may be more significant and its control a more difficult challenge. The first step is to assess the problem and to recognize the barriers to reform, including national legislation and its implementation at the local level. As pointed out in Chapter 5, land-tenure is a key issue in land-use reform in a number of the countries. Ideally there should be a set of land-use guidelines which the local authorities can follow and implement throughout the basin, aimed at preserving the ecosystem health and environmental services. The implementation of these guidelines will require extensive public education campaigns beginning with the basin communities through to local institutions.

- Establishment of sediment monitoring programme and determination of sediment flux in the basin
- Investigation of the rates of change of river morphology and physiology

The information collected by the TDA on the sediment transport in the river and changes in topography has been scant and academically based. The sediment transport is known to be as important to the health of the river and delta as hydrological flows, but knowledge of the impacts caused by changes in sediment transport, certainly at the level of the regulators, seems to be limited. The establishment of a proper monitoring programme based at key points within the system would be a first step. It is understood that a monitoring programme exists in the delta but this should be extended to the rest of the river system. Where changes are known to be occurring, the sediment fluxes should be monitored and the local changes in topography observed.

- Determination of the relationship between composition of the various flood plain vegetation communities and depth, frequency and timing of inundation

The floodplains are an important component of the river ecosystem and provide a range of environmental services, including flood storage. Knowledge of how these biological systems function is important in order to determine how best to manage, use and preserve their intrinsic value.

- Degraded riverbanks and riverine forests restored and vegetative buffers established based on best practice guidelines

Degraded riverbanks and loss of riverine forest are two of the most visible impacts of increasing land-use change. Campaigns to restore these features will directly improve the environmental status of the river but community involvement and educational programmes are also essential to build an understanding of the importance of their protection.

- Demonstration of sustainable rangeland management practices at priority sites.

As part of a larger campaign to improve basin livelihoods (see Chapter 8), rangeland 'best practice' should be demonstrated in all three countries.

7.2.3 Changes in water quality

7.2.3.1 The problem

At present the water quality of the Cubango-Okavango system is considered to be very good, characterized by low suspended solids and turbidity, with clear waters, low nutrients and low organic content. It is an oligotrophic river, with dissolved oxygen content adequate for maintaining biological diversity. It is more sensitive than a eutrophic river and any pollution will be more evident and damaging. There are existing local areas of reduced water quality as a result of:

White Faced Ducks at river near Rundu, Namibia, 2009

- Geological conditions such as increased levels of iron and manganese
- Urban areas where untreated waste water and solid waste leachate may be discharged untreated, raising the organic content and nutrients of the water
- Areas where livestock are watered, increasing solids in suspension and organic matter from excrement
- Agricultural areas, especially where irrigation water is returned to the river, carrying nutrients such as nitrates and phosphates and agricultural chemicals such as pesticides.

There may also be seasonal shifts in water quality as runoff carries sediment, organic matter and nutrients into the waters during the rainy season. During dry periods, the conductivity and nutrients may become more concentrated because of evaporation.

The concern is that with the basin developments, irrigation schemes in particular, and the change in land use, there could be a serious decline in the water quality. With the reduction in flow the carrying capacity of the river would be compromised and changes in riparian vegetation could limit the system's natural buffering capacity. The impacts of reduced water quality in the Cubango-Okavango would be wide-ranging and as mentioned previously could severely impact on ecosystem services. There are currently no permanent monitoring systems on the river and no record of pollution sources and their discharges; it is therefore impossible to establish a meaningful pollution regulatory system. At present pollution loadings in the basin are generally at a low level although they are higher in the urban areas. A review of the municipal waste water treatment facilities, or lack of them, shows the scale of the problem.

In Angola access to sanitation services is limited. There are no waste water treatment facilities in the urban areas and solid waste is often dumped in the river.

In Botswana there is a relatively new sewage treatment plant in Maun designed in 1993 but this experiences regular breakdowns and may be reaching its capacity by now.[89] Other waste water treatment systems in Botswana include a 100 m^3/ 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 is required to have its own waste water disposal system. There is concern that there may be localized water pollution and eutrophication of the wetlands around tourist facilities.[90]

Maun's growing urban area, Botswana, 2010

In Namibia approximately 82 percent 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. Only 15 percent of the inhabitants of Rundu are connected to a central sewer system.[91]

Rural village in Matala, Huila Province, Angola, 2007

With the forecast increase in population and a trend towards urbanization, local sanitation might deteriorate further, threatening potable supplies of water and public health.

89 ODMP (2008)
90 Masamba, W. (2009)
91 Nashipili, N. (2009)

7.2.3.2. Impacts and linkages

The impacts and linkages and causes were investigated through the CCA, the results of which are shown in Table 7.8, and described below.

TABLE 7.8: CAUSES AND CONSEQUENCES OF CHANGES IN WATER QUALITY

Locations	Primary Causes	Issue	Impacts	Locations
Menongue, Huambo, Rundu, larger settlements, including tourism lodges, schools	Untreated waste water discharge and accidental spillage (e.g. through flooding) from urban centres, tourism and other infrastructure	**Change in Water Quality** **Key Indicators** ○ pH ○ Conductivity ○ Dissolved oxygen ○ Temperature ○ Organic matter ○ Turbidity ○ Suspended solids ○ Nutrients ○ Toxic chemicals	Increased cost of treating water for human consumption	At towns and settlements throughout the basin where water is abstracted from surface waters – mainly Angola
Rundu, Menongue, Mucusu, Maun and associated with larger settlements, some tourism sites	Solid waste in river and on river edges (including litter)		Impacts on groundwater quality – increased costs of treating groundwater supplies	At towns and settlements throughout the basin where water is abstracted from groundwaters – mainly Namibia and Botswana
At larger settlements and all along river wherever people are settled	Nutrient inflows from human (and livestock) defecation in river and on edges		Impacts on public health (including diarrhoea, dysentery, bilharzia)	Around major settlements throughout the basin
Larger agricultural schemes in Angola and Namibia	Return flows from irrigation with increased nutrients		Impact on water use for irrigation	Irrigation schemes in Angola and Namibia
Larger agricultural schemes, human settlement, malaria spraying base camps	Pesticides – from agric, human health (malaria spraying) and animal disease (tsetse fly spraying) control		Impact on recreation and cultural uses of river and wetlands	Particularly in the delta, panhandle, Popa Falls areas
At a few fish farm sites in Namibia and Angola	Aquaculture discharges carrying organic matter, nutrients		Impact on economic productivity – decline in fisheries	Throughout the river system, especially in Angola, Namibia and around panhandle
In headwaters of Cubango, along river on common Namibia/Angola border	Land cover change – overgrazing, fires, deforestation and land transformation for farming – increased sediment		Impact on economic productivity – tourism	Particularly in the delta, panhandle, Popa Falls areas
Common Namibian-Angolan section and parts of Botswana	Destruction of riparian belts, including by elephants		Impacts on biodiversity and ecosystem functioning	Especially in floodplains, the panhandle and delta
Floodplains in Angola, Namibia, panhandle, delta	Degradation of wetlands		Loss of ecosystem functioning purification of water	Especially in floodplains, the panhandle and delta

As more water is abstracted, the water quality in the river will change with decreasing flows. With higher levels of water use, water quality may be expected to decline, especially in the lower sections when there is no additional runoff to dilute contaminants. Increased water-use developments may also cause additional decline in water quality because of increased effluent from urban areas, agricultural return flows with their loads of pesticides and fertilizers, and changed oxygen and temperature levels caused by storage dams.

Of the threats due to direct pollution the development of irrigation is probably of most concern, with its increased use of fertilizers, fungicides and pesticides. The impact of the latter can be insidious and long-lasting. Only about 15 percent of the water abstracted for irrigation will be returned to the river, and this will carry excess nutrients that have not been absorbed by the plants, and any residues of agricultural chemicals. It is difficult to predict the levels of nutrients in returned irrigation waters, because these would depend on the soils, crops, cultivation practices and efficiency of irrigation. In general, the greater the efficiency of irrigated water use, the lower the nutrient content in returned waters.

Catfish sample from Kavango River, Namibia, 2008

Changes in nutrient levels affect the overall productivity of the system, probably changing the river from a nutrient poor to a nutrient rich system, with the consequent risks of eutrophication. The discharge of persistent organic pollutants, such as pesticides from irrigated agriculture, malaria control and tsetse fly spraying, although not significant at the moment, could increase if not controlled, and enter the water, sediments and food chain. The consequences for the long-term health of people exposed to these chemicals is unknown.

The balance of salinity in the delta is finely tuned and highly dependent on the flow regimes. Local salinity changes are a recognized function in the development of islands and vegetation patterns in the delta. Overall reductions and changes in the seasonal and geographic distribution of floodwaters in the delta could increase local salinity and alter the ecosystem balance in different parts. In addition, the salinity in return waters from the irrigation schemes will be elevated and it is not clear how this would affect the river basin and the delta. Again, much depends on the efficiency and management of the schemes.

The Cubango-Okavango Basin ecosystem provides extensive services in terms of water purification through its floodplains and riparian vegetation, which degrade organic matter, re-oxygenate the waters and bind nutrients in the growing vegetation. Changes in the extent of floodplains, as a result of changes in the flow and land use will reduce the capacity of the river to provide these ecosystem services. The buffers that these areas provide against pollution and eutrophication may therefore be compromised.

There is also increased loading from urban and rural waste waters, the majority of which are discharged untreated. As well as the increase in nutrient loading there is the danger of bacterial contamination from sewage and faecal matter increasing the risks to public health, especially for those depending on the river as their main source of drinking water. The costs of treating these consequent diseases and the loss of productive capacity of people are likely to increase.

There could be a serious impact on the fish and fisheries in the basin; polluted and poor quality water, if it does not kill them immediately, will drive fish away to other areas that are less polluted. Ultimately there could be a loss of the more sensitive species in certain parts of the river and a decline in fishery productivity overall with negative economic and nutritional consequences.

Poor quality stretches of the river will have an impact on recreational and cultural uses of the river as they will be less attractive for visitors engaged in boating and fishing. There will be social and economic implications if stretches of the river with poor water quality become extensive. Poor water quality is usually local, and the river's self-purification function helps to improve water quality downstream. With heavy pollution loads and loss of reedbeds and floodplains, the purification ability may be impaired.

Boating in Okavango Delta, Botswana, 2008

If the water in the river becomes more polluted or more turbid as a result of changes in flow and sediment dynamics, the costs of water treatment for urban water supply are likely to increase. The trend towards greater urbanization will lead to changes in the structure of provision from surface and groundwater sources. It is expected, for example, that direct access to river water will diminish as groundwater sources are exploited under rural water supply programmes in Angola. However, the links between surface and groundwater throughout the basin are close, and contamination of surface waters may lead to contamination of the groundwater sources in some areas.

Thermoclines can develop in larger storage dams and lower temperature and oxygen-deficient water can be released from the lower stratas of the reservoir. These waters may also have higher sediment loads, all of which may have adverse impacts on the downstream river water quality.

Laundry and bathing at Cuito Cuanavale, Angola, 2010

7.2.3.3 Responses and knowledge gaps

The following major responses to, and knowledge gaps in, changes in water quality have been identified:

- A survey of contamination levels in sediments throughout the basin to provide a baseline
- Review of water quality monitoring network, including laboratories, and recommendations for strengthening
- Implementation of strategic, phased investment programme for improvement of the water quality monitoring network, including capacity building components
- Development and introduction of a biological based water quality monitoring programme
- Review of implementation and execution of regulatory function and recommendations for their improvement

Data available to the TDA on water quality was meagre and limited to a few parameters. Even in the lower basin, it did not give a clear picture of the current status. The statement that the water quality is generally good is considered reasonable but cannot be supported. There is commentary on pollution sources but this is of a generic nature and their location and impact on ambient water quality is not defined. This is one of the most important knowledge gaps within the TDA. A survey of contamination levels of sediments at strategic locations in the river basin, including cores, will provide the necessary baseline for key contaminants such as heavy metals and organics. A survey of the water and suspended solids phased over a year would also help to develop a clearer picture of the existing water quality problems and issues and provide insight for addressing up-coming problems.

The scale and frequency of water quality monitoring in the three countries varies and is very limited or non-existent, depending on the country. The design of the monitoring network must take into account the remoteness and extent of the region, the technical capacity available and the existing threats and decisions the monitoring system needs to support. The inclusion of biological monitoring is seen as ideal screening methodology for the Cubango-Okavango since it is very cost-effective for large coverage areas and can be implemented by semi-skilled personnel and linked to community programmes. This would be backed up by more detailed investigations where problems or changes were observed.

- Harmonization of water quality standards and monitoring protocols. Establishment of water classification system and agreement on water objectives
- Development of action plan for improvement of water quality including an inventory of existing discharges and listing of potential threats
- Emergency response plans.

The harmonization of water quality standards and monitoring protocols should be seen as a long-term aim since it will need to be agreed at national level and not just at basin level. In this regard, the countries should perhaps investigate whether the South African systems could be adapted for their use.

Mapping of existing discharges (locations, volumes, discharge standards, compliance etc.) needs to be drawn up and analysed against water quality objectives. An action plan should be developed and an investment programme determined for water quality improvement measures. This work will also help in setting discharge standards for new developments and in the design of an overall monitoring programme. Where there are major discharges which could have serious implications for the basin, emergency response plans should be developed.

7.2.4 Changes in the abundance and distribution of biota

7.2.4.1 The problem

Rough estimates of the amount of natural habitat remaining within the Cubango-Okavango Basin in each country show that a very high value of 90–95 percent 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. The ‘changes in the abundance and distribution of biota’ is a cross cutting area of concern, linked strongly to all the preceeding areas of concern and a number of other key causes.

In ecological terms the abundance and diversity of flora and fauna in the Cubango-Okavango River basin and especially in the delta is outstanding. Any human induced change in flow regime will threaten the biodiversity make-up along riparian belts and across floodplains. Conversion of floodplains and destruction of the riparian belts will decrease the capacity of the system to buffer the hydrology and water quality of the river. The risk of losing these key natural aquatic management options is likely to increase under conditions of higher water use. The productive value of riparian zones in terms of economic and ecological services is already apparent to communities linked to floodplains, but these benefits extend beyond the basin, securing national, regional and even global benefits, for example the flyways for migrating bird species that use the Cubango-Okavango as a destination.

The importance of the contribution that natural resources make to the livelihoods of the people living in the Cubango-Okavango river basin has been stressed. As the population increases, so the pressure on these natural resources increases. This will inevitably lead to further degradation and loss of critical habitats. To some extent these essential natural resources are sustainable, re-growing each year, but if they are over-harvested the vegetation stock may be damaged or lost completely, so that the wider habitat is changed.

Fish drying at Boteti River, Botswana, 2008

There is also evidence that fish populations have changed under fishing pressure, for example by the use of gill nets in the stretch of river between Kapako and the confluence with the Cuito, so that the larger, commercially attractive species are less available. In comparison the protection afforded by the Mahango Game Reserve has preserved a more diverse population of fish species.[92] This does not seem to have happened in the panhandle yet, arguably the most productive fishery of the basin, but increased fishing pressure with new and improved fishing methods will surely bring about such changes in the future.

There is a great imbalance in the large wildlife populations between the three countries, with most living in Botswana, some high concentrations focused in pockets in Namibia, and relatively scarce large mammals in Angola. Historically, the populations of wildlife in Angola would have been much higher than at present, especially in the southern parts of the basin, where dry woodland savannas are similar to conditions in Botswana and Namibia (outside the delta). The wildlife populations have been severely disturbed by civil war and depleted by subsistence hunting for food.

Light aircraft used in Botswana to fly to tourist camps

There are reports that the numbers of elephants and other wild animals are rising in Angola. For example, in the Coutada Publica do Mucusso there is already conflict between humans and animals in search of water from the Cubango-River, with resulting crop damage the main cause for concern. In Botswana and Namibia, where there has been a history of wildlife management and protected areas, the wildlife numbers and diversity can be spectacular. The income generated by tourism, both nationally and at community level, has ensured that the value of wildlife resources in the delta has been protected.

7.2.4.2 Impacts and linkages

The impacts and linkages and causes were investigated through the CCA, the results of which are shown in Table 7.9, and are described below.

92 Van der Waal (2009)

TABLE 7.9: CAUSES AND CONSEQUENCES OF CHANGES IN BIODIVERSITY AND SPECIES ABUNDANCE, AND ECOSYSTEM SERVICES

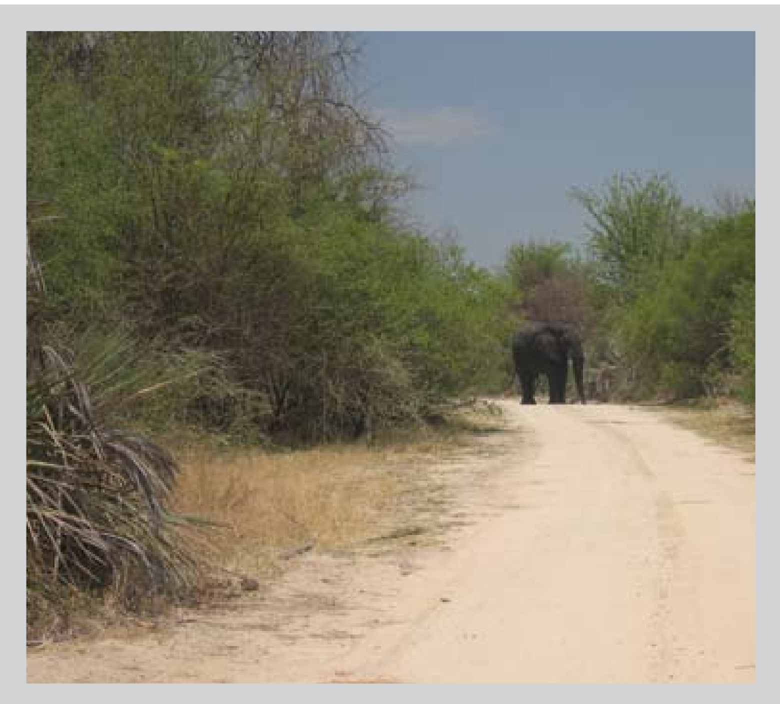
Locations	**Primary Causes**	**Issue**	**Impacts**	**Locations**
Throughout basin	Changes in flow regime	**Change in Diversity and Abundance of Fauna and Flora** **Changes in Ecosystem Functioning and Services** **Key Indicators** ○ Riparian vegetation ○ Floodplain vegetation ○ Extent of permanent / seasonal swamp ○ Fish species diversity and abundance ○ Amphibians and reptiles (frogs, monitor lizards and crocodiles) ○ Macro-invertebrates, esp. dragonflies ○ Water dependent mammals (hippos, otters, elephant) ○ Grassland grazers	Reduced fish harvesting	Throughout basin
Throughout basin, especially near urban areas	Changes in water quality		Reduction in household livelihood – reduced income and food security	Throughout basin
Return waters from irrigation schemes, Angola and Namibia	Poisons, pesticides and toxins		Increased human – animal conflict	Throughout basin, including Angola
Throughout basin	Changes in sediment transfers		Reduced access to medicinal plants, timber, firewood and other household and cultural resources	Throughout basin
Angola-Cubango headwaters, Namibia, panhandle	Expanding human settlements and infrastructure		Reduction of other wetland resources (grazing, reeds, etc.)	Throughout basin
Angola, Cubango & Cuito headwaters, floodplains, Namibia, panhandle	Land-cover change – overgrazing, fires, deforestation and land transformation for farming		Loss of rare, Red Data and high value spp.	Throughout basin
Shared border between Namibia and Angola	Destruction of riparian belt		Loss of undescribed and little known spp. before they and their values to society and ecosystems are known	Throughout basin, esp. in Angola
Angola, Cuito, Botswana, Namibia	Floodplain degradation		Reduction in global gene pool	Throughout basin
Throughout basin	Over harvesting and hunting		Resilience of ecosystem will be reduced	Throughout basin
Throughout basin, especially near centres of population	Overfishing		Decline in ecosystem functioning and ecosystem services	Throughout basin
			Reduced tourism value	Throughout basin, esp. in Namibia and delta
			Loss of tourism income or opportunity	Angola, Botswana and Namibia
Throughout basin	International pressures, markets and conventions, e.g. CITES, Kyoto – biofuels		Loss of Ramsar status resulting in loss of international recognition and marketability	Botswana, delta
Global	Climate change		Opportunities to adopt low impact biodiversity-based development may be lost	Throughout basin

A river ecosystem is much more than a wetted channel. Swamps, deltas, floodplains, marshes, riverbanks, complex secondary-channel networks and 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. This dynamic, ever-changing environment creates the physical environment in which the river 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. 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. 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.

Biodiversity changes may be observed in the changes in habitats in the river ecosystem, in the occurrence and abundance of different species, as they adapt to the ecological changes. Some high value species may be lost, e.g. the near endemic slaty egret and near-threatened bird species such as the African skimmer and rock pratincole, as well as charismatic bird species such as wattled cranes, may be at risk. The global existence of species is unlikely to be threatened, because no truly endemic species have been found in the basin. The lack of information on the biodiversity in the upper reaches of the Cubango and Cuito Rivers may mean that if change occurs quickly, any undescribed and little known species living in the headwaters may be lost before studies can be carried out.

Open Billed Storks, Ludwigia and Phragmites near Rundu, Namibia, 2008

Although there might be an initial increase in the larger grassland mammals with an increase in seasonal wetlands, the decreased flows into the delta will cause longer-term biodiversity changes. The area may become less attractive to tourists, leading to lower income from tourism. This will have consequences for both local employment and contributions to national income. The risk is highest for Botswana, which has made considerable investment in developing tourism, but the effects will also be felt in Namibia. The opportunities for the incipient tourism industry in Angola, which may develop as part of wider Cubango-Okavango tourism initiatives, will be lost before they can be fully realized. The opportunity to develop a low-impact, low water use, biodiversity-based development for the region as a whole would be lost, and this would be compounded by increased water abstraction.



Elephant on road in Mahango Game Reserve, Namibia, 2008

If dry seasons become more prolonged, there may be increased human-animal conflict as elephants use the river for watering and feed on crops grown nearby. This will apply especially in Botswana and parts of Namibia, and is already increasing as elephants move back into Angola.

Decline in water quality resulting from organic pollution will cause lowering of the dissolved oxygen, and could lead to reduction in macro-invertebrates and fish species living in that locality, e.g. around urban areas. Increases in nutrients could lead to eutrophication of the waters, with high algal productivity. This in turn would lead to changes in the species diversity of macro-invertebrates and fish. Pesticides and toxins, principally from the return waters of irrigated fields, can cause fish kills, or accumulated toxins in fish flesh. This would be passed on to humans who eat them, as well as to fish-eating birds and mammals.

The changes in sediment dynamics may affect the river morphology so dramatically that the biological features of the river may change too, adapting to the new conditions, e.g. as permanent swamps in the delta dry out, and seasonal swamps turn to grasslands, the grazing wildlife populations may rise.

The Cubango-Okavango biosphere is under pressure from expanding human settlements and infrastructure. As the population increases, so pressure from harvesting, fishing and hunting of natural resources will increase, inevitably leading to overexploitation and reductions in abundance and even loss of some species. Land cover change caused by overgrazing, deforestation and land transformation for farming contribute to the pressures on the system, as do extensive and prolonged fires. Particular pressures can already be seen on the riparian vegetation, especially in Namibia, and overuse and degradation of the floodplains is evident.

The risk of introducing new invasive alien species, although at present not considered high, may become a serious area of concern with changes in flow and mobility of populations. Two species stand out – *Salvinia molesta* and *Oreochromis niloticus.* Kariba weed, or *Salvinia molesta,* is an aquatic plant that spreads rapidly through waterways and is known to exist in the Zambezi system. The possible spread of *Salvinia* through the Selinda spillway is of concern to the Botswana Government, and measures for natural insect management using weevils are in place. So far, the spread of the weed has been contained.

Oreochromis niloticus is a favoured aquaculture species throughout the world, and escapees have been found to invade river systems with an already impoverished fish fauna. At present *O. niloticus* is not found in the Cubango-Okavango river basin, despite its use in aquaculture in other parts of the region, including parts of Namibia. It is interesting to note that none of the existing aquaculture ponds in the basin culture this species, preferring the indigenous *O. andersonii.*

7.2.4.3 Responses and knowledge gaps

The identification of knowledge gaps in the changes and abundance in biota resulted in the creation of the following major response objectives:

- Establishment of minimum environmental flows in key locations in the catchment

As part of the water resources assessment, minimum environment flows should be set based on international 'best-practice'. The minimum flow restrictions would provide the bounds for any water development and help define the acceptable development space.

- Design and implementation of a biodiversity monitoring programme linked to the existing Okavango Delta Management Plan (ODMP) programme, including a review of indicator species
- Vegetative mapping of basin wetlands and classification based on conservation status

The biodiversity monitoring programme associated with the ODMP and knowledge of the delta ecosystem is extensive, but there is less knowledge of the biodiversity of the upper catchment and its associated wetlands.

- Establishment of game corridors in critical areas
- Strategies for mitigation of human/wildlife conflicts developed at selected sites

As the population grows and more land is used for agriculture and livestock, so the conflicts between humans and wildlife will grow. The wildlife populations in Botswana and Namibia are large but in Angola are relatively small. Some organized relocation of wildlife to Angola is already taking place. Maintaining (and re-opening) traditional wildlife migration routes will ease the movement of wildlife and contribute to reducing human-wildlife conflicts, particularly as human developments grow in scale.

- Development of best-practice guidelines for community-based use of natural resources
- Development of guidelines for management of different categories of wetlands
- Creation of transboundary fishing reserves

The above proposals are part of a wider livelihood development programme described in Chapter 8.

- Mapping and assessment of the impact of invasive species in the basin and identification of future threats
- Development of transboundary programmes for control and spread of alien plant species

Invasive species are potentially one of the most damaging threats to the Cubango-Okavango and the countries need to be ever vigilant and ready to respond as quickly as possible in a coordinated manner. Knowledge of existing species and potential species needs to be expanded and counteractive measures put in place.

- Status of the environment report produced every two years.

The status report will provide a record of the improvement or decline of the environment as development increases. It will draw on data and information from the information management system and will inform the DSS and the updating of the TDA, SAP and NAPs.

7.3 SUMMARY

The TDA process, through the identification of the Areas of Concern, root causes/drivers and pressures, creates a picture of the change in the environmental status, which may arise with increasing utilization of natural resources. In undertaking the CCA, the linkages between the various Areas of Concern and the effects within such linkages are starting to be recognized. The strengths and nature of the correlations are not yet known, but there is clearer understanding of the governance and management frameworks needed to address them and to achieve sustainable development. This would balance the three Es – economic efficiency, social equity and ecosystem sustainability. Through the governance review and country studies, the need to strengthen existing governance frameworks at national and basin levels has been identified; strengthening the realization of what will be required over the next 10–15 years as the pressures mount. This

Community meeting at a soba, Cuelei, Angola, 2008 knowledge is summarized in the findings and recommendations in Chapter 8 and has been fed into the development of the Strategic Action Programme (SAP).

However the question that the TDA-SAP process does not answer, the one which is uppermost in all decision makers' minds, is to what level economic development can be permitted in the basin before it threatens the balance of the three Es and sustainable development? What is the acceptable development space available? As has been mentioned throughout this report, the near-pristine Cubango-Okavango river basin is unique as an international river, subject as it is to limited human impact. Given that development needs to occur to match population growth and meet social equality objectives such as the Millennium Development Goals, what development thresholds should be set for the Cubango-Okavango Basin and what form of development or mosaic of development is most efficient and sustainable?

TDA research at Liyapeka, Angola, 2008

This is an extremely complex question or rather, set of questions, which can be approached seriously only, in a step-wise manner, requiring adaptive management to be applied at all stages. To achieve this aim, a development vision for the Cubango-Okavango Basin first needs to be agreed between the countries and provisional targets set. Monitoring programmes of all forms then need to be established or re-established to record key indicator parameters, improve the basin knowledge and define trends. A decision framework (the set of questions to be answered) and Decision Support System should also be constructed to assist decision makers. All these elements are contained in the SAP, with implementation planned for the next 5–10 years.

Sunset at Rundu, Namibia, 2008

CHAPTER 8: KEY FINDINGS AND RECOMMENDATIONS

This chapter summarizes the main findings and recommendations of the various components of the Transboundary Diagnostic Analysis (TDA), including those from the Integrated Flow Assessment (IFA). The chapter lists proposed interventions for inclusion in the Strategic Action Programme (SAP) under the following five strategic objectives:

- Establishment of shared basin-wide vision, development of decision frameworks at national and basin-wide levels and strengthening of local and basin-wide institutions (decision making)
- Strengthening of natural resources management and regulation at local, national and basin-wide levels (implementation)
- Establishment and strengthening of regulatory monitoring programmes (review and evaluation)
- Development of basin-wide information management system and filling of knowledge gaps (data and information)
- Development of a decision support system (DSS) and common planning framework (analysis and advice).

The Cubango-Okavango river system is unique. It is a large international river relatively untouched by human activity, with natural river flows, high water quality and a large percentage of natural habitat remaining (90–95 percent). The basin population is currently small, principally rural – although there is a trend towards urbanization – and the basin itself is remote from the country capitals and centres of commerce.

River view from Maun Lodge, Botswana, 2008

There are increasing pressures to develop the basin's resources, particularly in the upstream countries, in order to increase economic national incomes and alleviate poverty in the basin population. Basin and sectoral development plans exist, which propose a significant increase in the area of irrigated lands, small-scale but significant hydropower developments and, in Namibia, there are proposals for an inter-basin transfer to meet water demand in the south of the country, all of which could have significant impact on the basin and the downstream delta. There are also plans to improve access to clean water and sanitation services in the basin, lifting levels toward national averages and meeting Millennium Development Goals.

As a consequence of these pressures, four priority emerging transboundary Areas of Concern were identified by the three countries during the TDA process:

- Variation and reduction of hydrological flow
- Changes in sediment dynamics
- Changes in water quality
- Changes in the abundance and distribution of biota.

These are emerging issues rather than existing problems and reflect development pressures on the basin that have not yet been realized.

The TDA, in undertaking an expert analysis of a series of water-use scenarios, has painted a picture of changes in terms of environmental and socio-economic impacts which could emerge in the Cubango-Okavango if development is not managed. This picture is the first step in understanding how the Cubango-Okavango river system could respond to increased human pressure and its capacity to absorb change. Development is inevitable in order to improve the lives of the basin people, but if it is to be sustainable, the nature and scale of the development must not exceed the capacity of the system to accommodate it, moving it from a high to a low productivity state.

Fish trap, Angola, 2007

The political interest to utilize the Cubango-Okavango's resources is strong and must be managed within a comprehensive basin-wide regulatory system, underpinned by sound knowledge of the river basin, if damaging, costly and irreversible decisions are to be averted. World experience tells us that decisions should be made at river basin level – the natural planning unit, integrated across the economic sectors – and involve as wide a range of stakeholders as possible. There are guidelines and models for good governance, but the countries need to decide how best to address these issues and adapt and amend the guidelines to their specific basin characteristics.

Understanding the basin and how it could respond to development is an immensely complex task, with development occurring in many forms and in different regions of the basin, and producing a mosaic of impacts. The TDA team, in particular through the Integrated Flow Assessment (IFA), has tried to predict these impacts and identify the innumerable linkages between them. Through a groundbreaking economic analysis it has also compared and contrasted a set of development scenarios under different macro-economic backdrops. By monetizing the impacts in terms of losses of environmental services, the TDA has been able to compare the long-term economic benefits of large-scale development programmes, such as irrigation and hydropower, with more varied development pathways.

The IFA was a first attempt to develop such scenarios in a basin-wide exercise. There are questions regarding the coverage and quality of the baseline hydrological and other data and the limitations of power of the hydrological modelling. Following the predictions of hydrological change, the ensuing ecological, social and economic predictions were based largely on expert opinion because relevant data was sparse. The IFA should therefore be viewed as a pilot study and the scenario predictions used with caution and refined through focused research. Despite these constraints, some key findings have emerged:

1. The Cubango-Okavango river system is a floodplain-driven system, with floodplains that sustain the river in the dry season and store floodwaters that would otherwise increase flooding downstream. 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 river, the Okavango Delta and the outflowing Thamalakane and Boteti Rivers are sustained largely by the annual flow regime of the Cuito. If these ecosystems and structures are of concern at the basin level, then water resource development along the Cuito, or intervention in the functioning of its floodplains, should be modest and undertaken with extreme caution.

2. The river and its floodplains provide significant ecological services that support the livelihoods of a large proportion of the basin's population. The livelihood support is more marked in the downstream countries of Botswana and Namibia than upstream in Angola. The delta for example is a significant source of revenue for Botswana in terms of its tourism industry, estimated to be worth over US$400 million/annum.
3. While water-use developments are aimed at increasing the amount of income from the river system, particularly

in the upper basin, this may not necessarily reduce poverty. Poverty within the basin, which tends to be worse than that in the broader societies of basin countries, may be exacerbated if water resources development proceeds, because this would reduce the important ecosystem services that riparian dwellers rely on.

4. Potential growth in demand over the next 15 years of 3,768 Mm^3/annum is dominated by an increase in irrigation demand and in comparison, the rise in domestic demand (urban and rural) of 6 Mm^3/annum over the same period is insignificant and its impact on the river system would be negligible. The provision of safe drinking water for both urban and rural populations is one of the most important economic developments and should be advanced as quickly as possible.

5. The increased potential abstraction is a significant portion of the mean average flow of the lower river of 9,600 Mm^3/annum and exceeds the 1 in 20 year drought flow of 3,120 Mm^3/annum, and as a result, the High Scenario cannot be supported without development of substantial upstream storage.

6. A progressive decline in the 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.

7. Any development that takes place on upper tributaries is likely to have impacts that are limited largely to the Angolan part of the basin. The severe impacts described for the lower part of the river system under the High Scenario 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, will inevitably extend the impacts from localized to transboundary and push the river ecosystem into significant degradation. Mitigation could realistically only be addressed by planning and managing at basin level.

8. In the delta, the High Scenario would show a much greater change than the other scenarios for all vegetation types, with the various types of permanent swamp decreasing to about 22 percent of present day average levels and seasonal swamp types increasing to 104– 178 percent of present day levels.

9. It is estimated that the livelihoods value will drop from the present day estimate of US$60 million/annum, to just over US$30 million/annum for the Low Scenario to under US$10 million/annum for both Medium and High Scenarios. A similar pattern is shown in the national direct economic contribution which shows a decline from US$100 million/annum to about US$50 million/annum for the Low Scenario and to under US$10 million/annum for the Medium and High Scenarios. These dramatic declines in both livelihood and national incomes are primarily as a result of declines predicted for tourism in the Okavango Delta.

Cyperus Papyrus at Shakawe, Botswana, 2008

10. Balancing the losses in livelihood value and direct economic contribution against gains from development of irrigation, hydropower, public water supply and sanitation, a net loss is predicted from US$700 million for the Low Scenario through to US$1.4 billion for the Medium and High Scenarios. Even under optimistic assumptions,

the net returns would remain negative under the Low (-US$260 million) and Medium (-US$1 billion) Scenarios. Only with full implementation of the irrigation schemes do net returns turn positive (+US$215 million) under the Optimistic Scenario.

11. The economic analysis does not include a valuation of the existence of the Cubango-Okavango and the delta, as a globally significant ecosystem. If this were to be included, the economic viability of the Medium and High Scenarios would be further diminished.

In summary, the High and Medium Scenarios could generate a magnitude of economic losses and risks that could overwhelm the potential benefits of the full suite of proposed water resources developments across all three countries. Caution and further study is therefore called for before proceeding with specific development projects. There is a need to investigate alternative development pathways, including the enhancement of basin livelihoods, which would take advantage of existing environmental services.

The IFA is an excellent first analysis that needs to be deepened and widened in order to support the critical decisions that the countries need to make in the next five to ten years. The challenge for the countries is to manage these development pressures on a basin-wide level and in an integrated and sustainable manner. In order to do this, the basin states need to look at strengthening their natural resources governance, in particular their decision making, planning and regulatory frameworks. Strong political commitment and leadership will be required to coordinate and cooperate in future development for the good of the whole basin.

OBSC member Tracy Molefi leading NAP consultation, Maun, Botswana, December 2010

The key findings from the Governance and Policy Review are as follows:

1. The analysis of the policy and legal landscape in the three basin countries shows a relatively strong framework of natural resources management policies and legislation, although there is some variation between countries.

2. Of great importance for integrated basin management is that all countries have replaced old water legislation with Integrated Water Resources Management (IWRM)-based water legislation that emphasizes 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 establishing local-level basin management committees, the composition of which legally requires inter-sectoral representation.

3. The most significant constraints for the effective sustainable management of the basin lie in the institutional framework. These constraints are of a largely 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
   - Effective monitoring, implementation and enforcement.

4. Established as a cooperation, coordination and information-sharing platform for the three basin states with respect to water resources management, it is clear that the Permanent Okavango River Basin Water Commission (OKACOM) has a central role to play in the management of the basin, especially as there are no established basin-wide cooperation mechanisms in other natural resources management fields, such as land use or biodiversity.

5. Integrated water resources management cannot be undertaken effectively without considering issues of land management and other natural resource-use aspects. However, this need is not yet reflected in the composition of the national delegations of all the countries to the OKACOM and/or Okavango Basin Steering Committee. Given the importance of agriculture and energy issues, increasing the diversity of sectors represented in the different organs of OKACOM would allow greater consideration of, and coordination between, different sectors.

6. 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 a more detailed basin management plan is developed and implemented. This requires the further strengthening of its capacity, particularly at an operational management level.

7. 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.

Decision makers need to balance economic, social equality and environmental objectives and find a trade-off that is acceptable both nationally and across the basin. This is going to be a difficult task, since the balance will be different for the three countries and will not be constant, but will move as their economic landscapes change. Compromise will be needed as the countries establish a common development 'vision' or 'space' for the basin that will make best use of its natural resources and take into account the existence value of the Cubango-Okavango and its delta. There is not one optimal development pathway and final selection will depend on many internal and external factors.

OKACOM representatives with community members at Capico, Angola, 2010

The establishment of a strong management/decision framework is going to be very challenging. The decision framework will not only give the countries a 'vision' of potential development – its magnitude and form over a given time period – but also the trigger points/thresholds at which management direction has to be changed. In establishing the decision framework the three countries need to seek out pragmatic and practical solutions, conscious of the financial and capacity constraints. If decision makers are going to have confidence in their decisions, they will need a decision support system that brings together and analyses available data and information that is comprehensive and quality assured. The support system will rely on a range of experts and tools to analyse the data and from it create a reliable knowledge base.

Adaptive management will be the key to successful sustainable management of the Cubango-Okavango Basin. Identifying the trigger points will require extensive, but not necessarily expensive, monitoring and data collection. In this, the task of strengthening governance communications will be vital, within governments, between governments and with the key basin stakeholders at all levels, but particularly at community level. As the TDA has indicated, inter-sectoral coordination/

communication and strengthening of local institutional networks are key factors that require attention in the sustainable development of the Cubango-Okavango Basin. The development of a sophisticated, wholly centrally managed system will not be affordable or even desirable in the first instance, and there will be great reliance on local communities for data collection and monitoring that will underpin the decision framework.

Institutional structures need to be established to allow local stakeholders/communities to become involved in the day-to-day management of their natural resources within an agreed basin-wide framework. In addition, for the local institutions to be sustainable, responsibility for their functioning must lie with the local people and therefore their purpose in the decision making process must be understood and unequivocal.

The countries need to strengthen governance cycles and to integrate them vertically, from basin-wide to local levels, and horizontally, across the sectors. This is an immense challenge and cannot be achieved in the short term. It should be seen as a work in progress but it must keep up with planning processes in the three countries. Looking at the generic governance cycle once more (Figure 8.1), strengthening needs to occur at each step and can be split into the following areas:

- Establishment of shared basin-wide vision, development of decision frameworks at national and basin-wide levels, and strengthening of local and basin-wide institutions (decision making)
- Strengthening of natural resources management and regulation at local, national and basin-wide levels (implementation)
- Establishment and strengthening of regulatory monitoring programmes (review and evaluation)
- Development of a basin-wide information management system and filling of knowledge gaps (data and information)
- Development of a decision support system and common planning framework (analysis and advice).

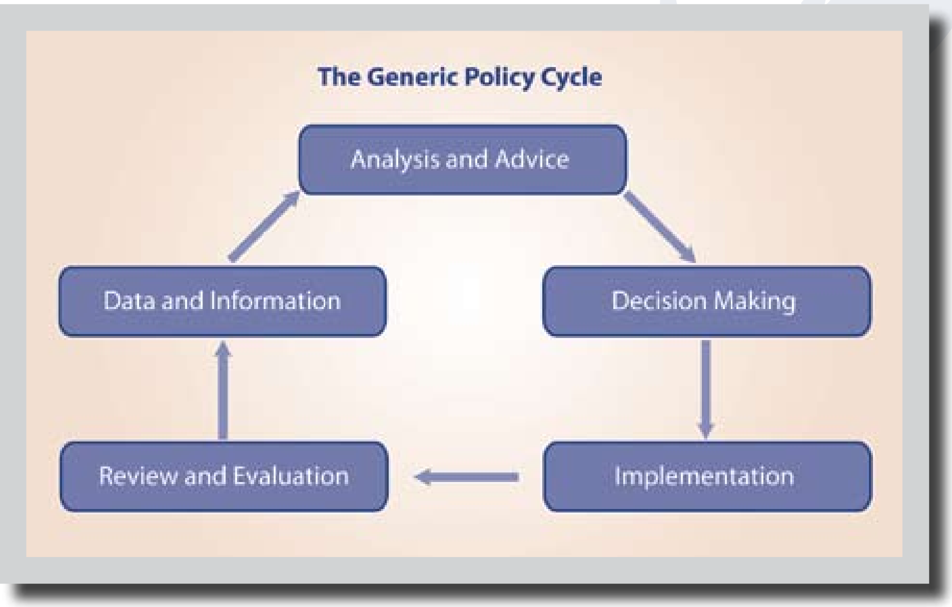


Figure 8.1: Generic policy cycle

Reviewing the recommendations in the TDA, in particular those in Chapters 5, 6 and 7, and based on guidelines for IWRM, the following interventions should be considered:

Establishment of shared basin-wide vision and strengthening of decision frameworks at national and basin-wide levels (decision making)

- Creation of a shared vision for the development and protection of the Cubango-Okavango river system and its people
- Development of an adaptive decision framework based on IWRM principles
- Expansion of the mandate of OKACOM to include natural resources management and strengthening of the capacity of the OKACOM secretariat to undertake a management role, including supervision of the Strategic Action Programme (SAP)

- Establishment (where necessary) and strengthening of appropriate local level management entities in line with existing national legal frameworks
- Development and adoption of environmental impact assessment/strategic environmental assessment procedures in a transboundary context.

Strengthening of natural resources management and regulation at local, national and basin-wide levels (implementation)

- Establishment of a research-based environmental flow regime for key points along the river system, designed to maintain the ecosystem conditions in a shared catchment vision
- Establishment of a common methodology for assessment of reliable surface and groundwater yields, to include climate change scenarios
- Inventory of abstractions for both surface and groundwater
- Harmonization of land-use planning guidelines
- Development of wetland management guidelines
- Programme of riverbank and riverine forest restoration
- Establishment of game corridors
- Inventory of pollution sources
- Harmonization of water quality standards and monitoring protocols, development of a water classification system
- Strengthening of national permitting and licensing procedures for water abstractions and pollution discharges
- Strengthening of national policing and enforcement measures for water abstraction and pollution charges
- Introduction of economic instruments to promote sustainable, integrated natural resources management
- Transboundary control programmes established for control of invasive species.

Boys harvesting wild mushrooms from riverine forest, Angola, 2007

Establishment and strengthening of regulatory monitoring programmes (review and evaluation)

- Strengthening of meteorological and hydrological monitoring networks for surface waters
- Development of a water quality monitoring programme for surface waters
- Strengthening of the groundwater monitoring network
- Expansion of biodiversity monitoring in the upper basin.

Development of a basin-wide information management system and filling of knowledge gaps (data and information)

- Development of an information management system
- Contaminant survey of river sediments throughout the basin to provide historical baseline
- Development of a socio-economic database
- Mapping of land-use potential in the basin
- Vegetative mapping of basin wetlands classification based on conservation status
- Strategic Environmental Assessment of irrigation development in the Cubango-Okavango Basin
- Research into inter-connectivity of surface waters and major aquifers
- Review of climate change scenarios and impacts.

Development of a decision support system and common planning framework (analysis and advice)

- Upgrading of water resource and hydrological models
- Development of flood-forecasting model and early warning system
- Expert assessments of potential changes to water quality, sediment transport and biota
- Updated economic assessment of development options
- Strategic Environmental Assessment of irrigation development in the Cubango-Okavango Basin
- Design of decision support system and interfaces to service decision framework
- Development of a strategic water resources plan for the basin including review of development options
- Development of a water quality improvement plan.

Joint TDA research teams compiling environmental flows data, April 2009

The above represent some of the key elements to be included in the SAP for the Cubango-Okavango river basin. The SAP should also include specific interventions to enhance and develop basin livelihoods, since a clear message from the TDA was that alleviation of poverty in the basin should be achieved not only through economic development but also through supporting better use of the environmental services provided by the river ecosystem. The SAP should include pilot and demonstration projects targeted at specific livelihoods, including:

- Demonstration projects on sustainable rangeland management
- Establishment of fishing reserves
- Tourism development plans for the Cubango-Okavango river basin
- Feasibility studies for new or extended agricultural markets
- Community based climate change adaptation projects linked to agriculture.

The SAP should also include a comprehensive capacity and training programme that would reinforce the above interventions through promoting 'learning by doing'. The training programme should be aimed at institutions at all levels and at a wide range of stakeholders. Finally, the SAP should contain reference to water supply and sanitation programmes in line with the Millennium Development Goals. The TDA analysis has shown the great economic benefit of these measures and their insignificance in terms of water use, and in the case of improved sanitation, the positive impact on the basin's environmental services.

The SAP is a guidance document for the three countries. Implementation of SAP measures is through the National Action Plans (NAPs) which underpin the SAP and are part of the national planning procedures. The NAPs address both regional and national priorities and draw upon the findings of the TDA and relevant national studies and projects.

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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 Lyapeka.
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 waters 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 *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 macro-invertebrate 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.

Site	Field Site 2 – Angola, Mucundi on Cubango River	
	Existing conditions	**Changes with water use developments**
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.	

Site	Field Site 3 – Angola, Cuito Cuanavale on the Cuito River.	
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 where 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 Kavango 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 living 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.

Site	Field Site 4 – Namibia, Kapako on the Kavango River	
	Existing conditions	**Changes with water use developments**
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 are 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.

Site	Field Site 4 – Namibia, Kapako on the Kavango River	
	Existing conditions	**Changes with water use developments**
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 Kavango 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 8km2 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 Cubango-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 addresses the High Scenario unless otherwise stated. There is a 200%-250% increase in exposed rocky and sandbar habitat in the dry season under the High Scenario. This is a massive impact on the ecosystem, because living space, critical habitats and refuge areas are lost.

Site	Field Site 5 – Namibia – Popa Falls on the Kavango River.	
	Existing conditions	**Changes with water use developments**
Water quality	The water quality is good and after the confluence of the Cuito with the Cubango-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.
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 outbreak has been increasing caused by humans. 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.

Site	Field Site 6 – Botswana, Panhandle at Shakawe	
	Existing conditions	**Changes with water use developments**
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 up 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 EFA 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.

Site	Field Site 6 – Botswana, Panhandle at Shakawe	
	Existing conditions	**Changes with water use developments**
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 – Cakanaca (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 Cakanaca (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 – Cakanaca (Xakanaxa) in the Delta.	
	Existing conditions	**Changes with water use developments**
Fish	Similar to the Panhandle, six guilds of fish are recorded 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. One of the 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. wildebeest, zebra) 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 practiced 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 of many years length. 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.

Site	Field Site 8 – Botswana, Boteti at Chanoga.	
	Existing conditions	**Changes with water use developments**
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.	
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*
		Miguel, Gabriel Luís	*Análise Técnica, Biofísica E Sócio-Económica do Lado Angolano Da Bacia Hidrográfica do Rio Cubango : Subsídio Para o Conhecimento Hidrogeológico Relatório de Hidrogeologia*
		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 and 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*
		Pereira, Maria João	*Análise Diagnóstica Transfronteiriça da Bacia do Rio Okavango: Módulo do Caudal Ambiental: Relatório do Especialista: País: Angola: Disciplina: Qualidade da Água*
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