Okavango River Basin Transboundary Diagnostic Analysis Technical Report

OKACOM

The Permanent Okavango River Basin Water Commission

Economic Valuation of Basin Resources: Final Report to EPSMO Project of the UN Food & Agriculture Organization as an Input to the Okavango River Basin Transboundary Diagnostic Analysis: Final Draft

Bruce Aylward

October 2009

Environmental protection and sustainable management of the Okavango River Basin

EPSMO

SOCIOECONOMIC SERIES

Economic Valuation of Basin Resources

Final Report to EPSMO project of the UN Food & Agriculture Organization as an input to the Okavango River Basin Transboundary Diagnostic Analysis

Final Draft October 2009

Bruce Aylward

PO Box 2602, Bend, OR 97709, USA

bruce@ecosystemx.com

(541) 480-5694

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ACRONYMS	
EPSMO	Environmental Protection and Sustainable Management of the Okavango
FAO	UN Food and Agriculture Organization
BRD	International Bank for Reconstruction and Development
IDA	International Development Association
IFA	Integrated Flow Assessment
GDP	Gross Domestic Product
GEF	Global Environmental Facility
HEP	Hydroelectric power or hydropower
M&I	Municipal and Industrial
O&M	Operations and maintenance
TDA	Transboundary Diagnostic Analysis
UN	United Nations
UNDP	United Nations Development Programme
WTP	Willingness to pay
WHO	World Health Organization

NOTES
All $ (dollar) figures refer to US $. References to other national currency are made explicit as follows:

N$ = Namibian dollar

Pula = Botswana Pula

Kwanza = Angolan Kwanza

ZAR = South African Rand

1. Introduction

This report serves as a portion of the work carried out under the auspices of the EPSMO project, which is a Global Environment Facility grant under the GEF's International Waters Program. A Transboundary Diagnostic Analysis (TDA) for the Okavango River Basin along with the preparation of a Strategic Action Program forms the basis of the work under EPSMO. The UN Food and Agriculture Organization is the executing agency under arrangement with the United Nation Development Program. This report serves as an input to the TDA.

The terms of reference for the consultancy entitled "Value of Basin Resources" calls for the following outputs:
an economic valuation of the basin resources (including ecosystem services) under current

- development and use patterns;
- total for the basin
- disaggregated by sector and
- disaggregated by country

1. valuation of direct and indirect contribution of basin resources (including ecosystem services) to the national economies in all three countries
2. analysis of macro-economic benefits of three specified water resources development scenarios and corresponding costs of possible losses in ecosystem services
3. a sectoral analysis (i.e. tourism, agriculture, forestry, ecosystem services etc) focusing on feasible development pathways corresponding to the specified water resources development scenarios.

During the course of the work the unfolding scope of the companion Integrated Flow Analysis (IFA), in particular the socio-economic component, as well as the specific demands of the TDA itself helped to shape the ultimate interpretation of the terms of reference and the research tasks. The end result of this work is incorporated in the TDA document, however, a full write up of the approach, data and results is provided here as a reference for those so interested.

The document begins with a brief review of the macroeconomic context in order to provide the setting within which the resources of the Okavango River will be managed. A brief section then outlines the economic issues confronted by the TDA, principally being the existence of market failure at the regional with regard to water allocation between countries and the resulting uncertainty of water management in the Basin. The quantitative analysis of potential economic consequences of future alternatives for the management of water in the basin is then explored, with sections on the analytical framework and then the data and assumptions employed and results. Given issues of uncertainty, the timing of future investment decisions, as well as the reversibility of the alternatives considered, the report concludes by briefly suggesting the basis for a qualitative analysis that might be employed to better frame investment decisions in the basin regarding water infrastructure in the future.

2. Macro-economic Status

2.1 Country Status and Trends

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

Botswana also has the largest level of government expenditure at 35% of GDP, reflecting the government's efforts to provide basic services to its rural populations. In part this factor, plus the higher level of GDP may explain the lower level of household consumption at 24% in Botswana. With similar GDP per capita levels, household consumption in Namibia is much higher than that in Angola, with figures at 53% and 32%. This most likely reflects much lower living standards of the bulk of population in Angola. In other words, Angola's GDP has grown rapidly but is not as well distributed as that in Namibia which has had a longer period to develop post-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.

The latest UNDP figures on gini coefficients suggest that income inequality remains more exaggerated in Namibia (74) than Botswana (60). No inequality measure was available for Angola, however, it is likely to exceed that of both of the other countries. Exploitation of the countries oil reserves, the rapid rise in the price of oil and the resulting windfall profits are likely exacerbating the gap between the urban elites, the urban poor and rural populations. Unemployment and underemployment in Angola are major issues for the country as it demobilizes forces and works to create economic opportunities. No unemployment numbers are reported by UN agencies for Angola. Unemployment in Botswana is relatively low for the region at 17.5%, while in Namibia the rate is fully double this at 33.8%.

Finally, 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 $19 billion in liquid reserves (not counting gold). Botswana had half this amount, but Namibia had just $1.2 million. The World Bank classifies Namibia and Botswana as upper-middle-income countries. Neither Namibia nor Botswana are currently IDA eligible for grants from the World Bank Group, but could qualify for IBRD loans. Namibia has developed an Interim Strategy Notes with the Bank and may engage in borrowing in the future. Botswana recently completed a Country Partnership Strategy with the Bank, which looks to reengage in lending with Botswana in the near future.

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

Table 1: Summary of Macroeconomic Indicators

Indicator	Angola	Namibia	Botswana	Source
Population 2007 (millions)	17.02	2.07	1.88	UNPD
Unemployment rate 2006/7	20%	33.8%	17.5%	Various
Gini Coefficient 2007/8	n/a	74.3	60.5	UNDP HDR
Gross Domestic Product 2007				
GDP (NC millions)	4,006,900	52,208	66,287	UNSD
GDP (US$ millions)	52,237	7,410	10,798	UNSD
GDP per capita (US$)	3,068	3,573	5,739	UNSD
GDP growth (average, 5 yrs)	14.96	4.68	5.92	UNSD
GDP growth (average 10 yrs)	9.87	4.27	5.91	UNSD
Composition of GDP (as % of GDP)				
Household Consumption	32%	53%	24%	UNSD
Gross Capital Formation	12%	26%	18%	UNSD
Government Expenditure	22%	24%	35%	UNSD
Exports	71%	49%	58%	UNSD
Prices				
CPI - 2007 (%)	12.25	6.73	7.08	IMF IFS
GDP Deflator (average, 2002-07))	20%	14%	20%	UNSD
Exchange Rates				
NC/$ -2007 average (NC/$)	76.71	7.05	6.14	IMF IFS
2008 end of period (NC/$)	75.17	9.31	7.52	IMF IFS
Balance of Payments 2007 (US$ millions)				
Goods Imports	(13,662)	(3,102)	(3,447)	IMF IFS
Goods Export	44,396	2,922	5,158	IMF IFS
Trade Balance	30,734	(180)	1,711	IMF IFS
Goods& Service Balance	18,402	(95)	1,675	IMF IFS
Current Account Balance	9,402	693	2,434	IMF IFS
International Liquidity (US$ millions)				
Reserves 2007 (less Gold)	18,359	1,293	9,118	IMF IFS

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

2.2 Sectoral Baseline: Angola

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

Table 2: Angola, GDP Breakdown by Sector, 2006

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

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

2.3 Sectoral Baseline: Namibia

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

Table 3: Namibia, GDP Breakdown by Sector, 2007

Economic Activity	Share of	GDP Value (in	GDP change	Employment rate (%)
	GDP (%)	US$ million)	(%)	
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	4.36	323	2.4	
Services				
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	

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

2.4 Sectoral Baseline: Botswana

Botswana, like Angola, is heavily reliant on extractive industries for its economic well-being. Diamond mining brings in 40% of GDP. Manufacturing is limited at just 3.7% of GDP. Given the climate agriculture is limited, making only a 1.6% contribution to GDP, the lowest of the three countries. As a consequence, services – government, banking, trade, transport, tourism, utilities and social services – make up a large portion of the remainder of the economy. Tourism plays a modest role in the country's economy providing almost US$ 200 million, a large share of which comes from the Okavango (as discussed later in this report). Water and electricity are also responsible for US$ 200 million in value added. The higher level of development in the country compared to its neighbors is revealed by the higher level of spending on these basic services at $100/per capita.

Table 4: Botswana, GDP Breakdown by Sector, 2007

Economic Activity	Share of GDP	GDP Value (in	GDP change (%)	Employment
	(%)	US$ millions)		rate (%)
Mining	40.7	3,775	5.2	2.63
General Government	15.6	1,447	1.7	19.18
Banks, Insurance and Business	10.3	955	6.6	1.56
Services				
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

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

2.5 Basin Macroeconomic Issues and Opportunities

The brief macroeconomic review provided above shows that each of the three countries in the basin have strong, open economies that have benefited from sound macro-economic management and the intelligent use of their natural endowments. That said the Okavango Basin region clearly is on the periphery of the economy for each of the countries. Probably the most significant economic activity in the basin is that of the tourism in Botswana's Delta region (and in the panhandle in Namibia). Even in this case the contribution to GDP is small in relative terms. Still, given the low populations in the basin there is no need for the basin to be a dominant economic force in each country's economy. In fact, it may be useful going forward to consider what the areas in each country within the basin have in common – and to try and build off these regional strengths in further developing the basin economy.

With this in mind a number of macroeconomic issues and opportunities were identified in the process of preparing the TDA. These relate more to the macro-economy of the basin, linked as it is by the water resource, rather than the macroeconomy of each country.

Regional Integration. There is a need to consider how to achieve closer social and economic integration between the basin areas in each of the three countries. Such integration would assist in building forwards and backwards economic linkages in the basin. One idea that surfaced was to consider whether there are artificial trade barriers, particularly in the panhandle area where all three countries come together. Finding ways – such as through including Angola, or the basin in the existing Customs Union – to promote the movement of tourists, workers, families, as well as goods and capital within the border area or the basin as a whole might yield considerable economic efficiencies and create new opportunities.

Basin Comparative Advantage. While natural endowments of water, land, carbon, flora and fauna, ecosystem goods and services in the basin appear advantageous it is largely only in the Delta that commercial use of the resources occurs. The majority of basin inhabitants live are engaged in subsistence activities. While it is fortunate that resources are plentiful enough to supply this subsistence there are two routes for the basin to develop. The first is for each country's province in the basin to remain on the periphery and rely on resources from the center to provide basic services while waiting for economic opportunities to arise. The second is for the basin to determine what is its comparative advantage and market this advantage to bring in the revenues needed to bring sustained livelihoods and economic development to the basin. Central to this conversation over comparative advantage will be the discussion over how to deploy the water resource to further – rather than retard – development. At present if the basin has a comparative advantage it is its reliance on wildlife tourism and its relatively undeveloped state. Its comparative disadvantage remains its geographic isolation and hence the distance to central markets and populations in each country.

Further effort is required to evaluate these issues and then strategize and plan in what direction to move the basin macro-economy. Using the water resource as the driver for this effort is sensible given its importance to livelihoods and income under present conditions, as well as its role in linking communities in each of the three countries. In the next section a brief description of the overarching economics driving water allocation and use in the basin is provided and its relevance to the transboundary analysis.

3. Transboundary Analysis, Market Failure and Basin Water Allocation

From an economic perspective the need for a transboundary analysis presupposes the existence of some critical market failure between countries. For example if all goods and services in the Okavango Basin, including those in the three countries of Angola, Namibia and Botswana were private goods, traded in markets and not subject to any unusual degree of government regulation then a transboundary analysis would not be necessary. The economy of each country could be segregated into tradable and non-tradable sectors (or goods and services). Economic exchange across borders (i.e. trade) would take place between willing sellers and willing buyers at prices established on the international market. The private sector would invest in economic activities with attractive risk and rate of return profiles, taking into account the local market for non-tradables and the international market for tradables. These choices would be determined by a number of factors, including the natural resource endowment at hand in each country.

In the Okavango Basin, it is precisely the natural resource endowment that raises the need for a transboundary analysis. Each country has its own endowment of natural resources. Many of these resources are fixed and unchanging pending their transformation by humans, for example soil, minerals and trees. Some resources are mobile or migratory like wildlife, birds, fish or water. Each of these has it's own natural range. In the case of the Okavango Basin, the primary migratory resource is surface water. It starts in the headwaters of the Basin in Angola, travels downstream through a large portion of Angola, briefly transits Namibia and then spreads out across the Okavango Delta in Botswana, where it is stored as groundwater, evaporated from surface water bodies, or evapotranspired by plants, animals and human activities.

Over the course of geologic and human history the water resources of the Okavango Basin have been informally shared between the countries, based on the one hand on climate, geomorphology and vegetation, and on the other hand, the limited efforts to date by humans to use and develop the resource. From the perspective of its water resources the Okavango River is generally regarded as in about as pristine a condition as any found in Africa today (Milzow et al. 2009). In an arid environment increasing development pressure from the upstream riparian states, as well as new uses in Botswana is inevitable. In economic terms this shared water resource is a perfect example of a common pool resource. No one country can exclude the other from using the resource and the use of the resource by any one of the countries effectively to limit its consumption by another. The non-excludability of common pool resources is the source of market failure. In effect at present the Okavango River is largely used by Botswana, the downstream country to provide a variety of ecosystem goods and services that have local and international value. To the extent that the River really is congestible and therefore rival in consumption – i.e. that the use of water by an upstream riparian country will affect the downstream uses and values – then exercise of upstream location in the form of extraction of water or re-regulation of flow is an act with economic consequences, creating opportunity costs for Botswana, and those people outside of Botswana that visit the delta or care about its continued existence (in its present state).

The lack of an explicit and enforceable regime for managing the sharing of the waters of the Okavango River is a source of market failure and may impede its efficient allocation and the equitable sharing of its benefits. While resolving this dilemma is beyond the scope of the present work or the TDA, it is expected that clearly defining the present and potential allocations of the water resource and then estimating the associated values and their distribution across sectors and countries should serve to stimulate further discussion between the countries.

For example, one possibility for the future governance of the Okavango would be to make an explicit allocation of the water between states. In this case an understanding of the economic consequences of water resource development, would provide information to the states and the larger community of states about the values inherent in the allocation of shares. The tradeoffs between different uses of these allocations would thus be clear and open up a basis for negotiations between states and with the international community over how to share the benefits and costs of any master plan for the Okavango.

In order to shed light on the nature and extent of the choices that basin countries are presented a quantitative analysis of the potential costs and benefits of alternative future courses of action is presented below.

4. Quantitative Evaluation Framework: Costs, Benefits and Water Resource Withdrawal Alternatives

In its present allocation the Okavango River sustains the Okavango Delta in Botswana, an important environmental and economic asset for the country and the global community. The river and its derivative groundwater have also been "developed" by humans for a number of uses in each of the three countries. However, these uses remain minimal to date. Previous authors have noted that withdrawing more of the flow of the River for off-stream uses will at some point imply some loss of downstream economic benefits that exist today. This is expected to occur as changes to the flow regime downstream lead to a loss of the ecosystem goods and services provided by the river and its derivative groundwater in the Okavango Delta. These foregone net ecosystem benefits would be the opportunity cost of taking action to deploy the water resource to off-stream uses. In a similar vein, any decision not to develop the water resource potential in the upstream countries implies giving up the net economic benefits of hydropower, irrigation, and municipal and industrial (M&I) uses. These would be the opportunity costs of not withdrawing additional amounts of the water resource. The main components of any economic analysis of future states of the system are future changes in net ecosystem benefits and water withdrawal benefits, each with its component changes in costs and benefits. In this document alternative paths for developing the water resource are examined and therefore the economic gains from water withdrawals are contrasted with the losses in ecosystem goods and services.

4.1 Valuation of Basin Resources

The ToR call for a valuation of basin resources under current development and use patterns (ToR output #1). This valuation is to be disaggregated by sector and by country (ToR output #1), and this is to include not only direct, but indirect (including ecosystem services), contributions of basin resources to the national economies (TOR output #2). This analysis is not sought in and of itself but rather to set the stage to then analysis what changes in value occur as different water withdrawal alternatives are imposed on current conditions (TORs outputs #3 and #4). The analysis of alternatives is to include not only water resource development benefits but any costs in terms of the loss of ecosystem services.

Ultimately, then the valuation of basin resources is required for the purpose of evaluating the impacts of gains and losses in economic welfare associated with decisions to develop or not develop the water resources of the Okavango River (and its tributaries, distributaries and groundwater). For this reason the analysis of basin resources is best circumscribed to include only those resources and sectors that will be affected by changes in the timing and amount of the flow regime – either in terms of impacts from changes in flow and timing downstream or in terms of the development benefits and impacts from the changes in development and land use patterns that accompany the water resource developments themselves. The ensuing sub-section attempts to specify how such an analysis will be constructed, indicates what data will be needed to this effect, and reports on data already identified and in hand.

4.2 Formulation of the Alternatives Analysis

The analysis involves assessing the economic impacts on sectors in each country. In order to construct the matrices for each alternative the countries, alternatives and sectors are identified.

4.2.1 Countries

The three riparian states are Angola, Namibia and Botswana. Typically, the scale of an economic analysis needs to be at the level that incorporates all relevant welfare changes. An economic analysis of the Okavango that did not include the upstream (Angola) or downstream (Namibia) states, for example, would be of little use in decision-making. In the case of the Okavango River, the environmental asset represented by the Okavango Delta has value that is not realized only within the three states. Tourists travel from all around the world to experience and use the resource. The economic impacts of that travel are experienced well beyond the three countries. Further, as a Ramsar site and one of the world's few remaining pristine wetland areas, as well as the larger reservoir of biodiversity, the Okavango Delta has value to the international community that goes beyond mere travel and tourism. As such a comprehensive economic analysis would need to incorporate a fourth "country" or region, represented by these international stakeholders.

4.2.2 Alternatives

Three alternatives are analyzed in companion efforts by the TDA team. These alternatives (called "scenarios" in the IFA analysis) each involve a mix of additional hydropower, irrigation and M&I projects to those already in existence. The alternatives are identified as future possible combinations of these projects that yield low, medium and high water withdrawal levels. Each successive alternative includes the projects from the prior alternative and adds in more projects. Thus the high withdrawal alternative includes all the projects in the medium alternative (which in turn includes all the projects in the low alternative). These alternatives are thus not independent sets of projects. Rather the analysis of these alternatives investigates the impacts of a progression of projects that could be developed.

A reference case alternative is necessary to represent the valuation of basin resources under current development and use patterns, i.e. present day, extrapolated forward for the full duration of the analysis. Analysis of each successive alternative will lead to new valuations of basin resources. The difference between these outcomes and that of the reference case represent the net change in economic welfare (by sector and country) of each water withdrawal alternative, including the impacts on biodiversity and ecosystem goods and services. Positive results indicate that there is a net increase in economic welfare of the withdrawal alternative. Negative results indicate a net decrease. The choice of which alternative is preferable to a given stakeholder group should be informed by these results, but will likely incorporate other decision criteria.

4.2.3 Sectors

The variable that changes in each alternative is how the water of the Okavango River and its tributaries are used. Changes in flow lead to changes in economic welfare and, therefore, it is necessary to only examine those basin resources and sectors that are likely to respond to new water resources projects and the subsequent, downstream impacts of alterations in the timing and amounts of flows. On the water resources side the changes will occur in hydropower production, irrigated lands and production, and water supply for M&I. On the ecosystem side, changes in flows are expected to alter the production of natural resources, tourism, ecosystem services and nature conservation.

A brief characterization of each sector and discussion of issues that may need to be addressed is provided below.

- *Tourism*. Tourism is best understood as a result of biodiversity and ecosystem services. The surface water discharge of the Okavango River underpins the wetland ecosystems, the groundwater system and a rich oasis of biodiversity in the Delta. Thus, while tourists may visit to marvel at the wildlife, this wildlife is effectively reliant on the ecological function of the Delta which in turn depends in large part on the timing and availability of water. As a major service sector in the economy of Botswana this one sector is separated out from the other natural resource sectors for special attention and prominence.
- *Natural Resources*. Natural Resources is a catch all sector that will be used here to capture the impacts of changes in river flows on the direct use values of resources like water, food, fibre, timber, wildlife etc that can be categorized as components of local livelihoods for communities in the Basin. In the context “natural resources” are in effect ecosystem “goods.” The emphasis here is on distinguishing between the primary goods provided by new water resource projects. Water projects may increase water supply and food, for example, but the manner in which they do so oftentimes means that there are impacts on those communities previously relying on this water (or flow). New projects mean that these goods are provided through different economic production systems and, at times, to different groups of people. So, modern irrigated agriculture has often come at the expense of traditional, flood recession agriculture, for example. Thus, under the natural resources heading the impacts of changes in river flows and subsequent effects on the full variety of natural resources that enter into household production and consumption will be captured.
- *Ecosystem Services*. Ecosystem Services is used consonant with the interpretation provided in Turpie et al (2006) and thus refers to carbon sequestration, water supply, water purification, etc. In other words these are the natural hydrological and ecological functions that only indirectly enter into the economy. For example, boreholes support a variety of livestock and agricultural uses in and around
- the Delta. These uses of water may not be considered in the reference case as they do not reflect formal sector M&I water supply. As development proceeds these groundwater uses may be affected with knock-on impacts on livelihoods in the Delta. The value of the groundwater is derived from its end use in this case, and end use reflected in the natural resources produced (as above). A key consideration then with respect to natural resources and ecosystem services is to ensure that benefits, or the ensuing welfare

changes, are not double-counted. Thus, the analysis needs to be clear in this case as to whether the resource production based on groundwater extraction is classified under natural resources or ecosystem services (but not both). Priority is given to recording those services that lead to the production of direct use values as natural resources. Measuring the change in these direct use values under different flow regime could then be used to demonstrate the ecological value of the ecosystem services provided by the natural flow regime. However, these are not added back in to the analysis as that would be double counting.

- *Nature Conservation*. This sector is again not a typically recognized economic sector. However, this heading is used to reflect the economic importance of conserving the Okavango Delta as a Ramsar Site - a world renown wetland rich in biodiversity. In other words, this category is designed to capture the global willingness to pay to conserve nature, as represented in this case by the Delta. This value is separate from that reflected under Tourism, as an additional value above and beyond that which actual tourists engage in when they purchase tourism services. People who have never visited the Delta and never will may still be willing to pay to conserve this environmental asset. Similarly, people who have not visited the Delta may wish to preserve their option (and that of their children) to someday visit – and this value may be reflected in an option value for the delta. Probably most importantly, is that those who have visited the Delta may come away from the experience convinced of the importance of protecting this rare intact system and may be willing to contribute to efforts to implement such actions. So this sector is considered as global, which is not meant to say that only those outside the region value nature, but rather that any effort to capture this values would be global in scope.
- *Hydropower (HEP)*. The hydropower sector is a subsector of the national energy sector and changes in hydropower production will need to be placed in the context of their expected benefits to the national energy sector. However, the energy sector may also include biomass energy, which in the Basin may be a natural resource sector that is affected by changes in river flows and water availability (decrease in biomass if water is not available) or by water resources development (i.e. availability of agricultural or livestock wastes for use as fuel). In order to keep these impacts separated out, we will keep the hydropower designation separate from these other energy sector impacts.
- *Irrigation*. Irrigated agriculture or irrigation is likewise a sub sector of the agriculture sector and is defined here as such for similar reasons as for the hydropower/energy distinction, i.e. in order to keep any impacts on traditional agriculture separated out from the impacts of water resource development.
- *Water supply*. Water supply is used here to reflect large-scale infrastructure to provide M&I water to settlements, commerce and industry. Domestic water supply is used to refer to water supplied to homes and communities for the purpose of household use.

The resulting sectoral and country matrix that needs to be created for the current situation and each of the three alternatives is shown in Table 5.

Table 5: Alternatives Matrix

Country Sector	Botswana	Namibia	Angola	Global
Tourism				
Natural Resources				
Ecosystem Services				
Nature Conservation				
Hydropower				
Irrigated Agriculture				
Water Supply				

Table 6 below takes a very rough cut at stating where water is currently used and where it will be used based on information from the TDA team about each of the alternatives. For the three alternatives the new usage and change in absolute usage of water is compiled along with an indication of the percent of mean water available that is consumed by each use in each country. As hydropower uses are non-consumptive (except for some evaporation at two reservoir sites) and use and reuse the same water as it flows downstream they are included in terms of the Gwh of power produced.

In the reference scenario the bulk of the flow in the Okavango River is ultimately used in Botswana (in the Delta and outlying areas). As this water supports ecosystem function it is called “ecosystem use” even though a good portion of it probably indirectly supports human uses of water and water-related ecosystem goods and services. The physical use of the water in Botswana clearly supports global nature conservation values, although for simplicity sake the global scale is not included in the charts.

Table 6: Summary of Water Use and Availability

Table 6. Summary of Water Use and Availability

Water Withdrawals
(all figures in million m3 of water, except HEP is GWh)

Country / Sector	Botswana	Namibia	Angola
Ecosystem Uses	10,225		
Direct Human Use			
Hydropower	-	-	-
Irrigation	-	29	17
Water Supply	25	3	11

Total Water (million m3)	10,311

Withdrawals as % of Total Water

Sector	Botswana	Namibia	Angola
Ecosystem Uses	99.2%		
Direct Human Use			
Hydropower			
Irrigation		0.3%	0.2%
Water Supply	0.2%	0.0%	0.1%

Low Development Scenario

Country / Sector	Botswana	Namibia	Angola
Ecosystem Uses	9,800		
Direct Human Use			
Hydropower	-	-	228
Irrigation	-	36	431
Water Supply	26	4	13

Change from reference case (million m3)

Sector	Botswana	Namibia	Angola
Ecosystem Uses	(425)		
Direct Human Use			
Hydropower	-	-	228
Irrigation	-	6	414
Water Supply	1	1	2

Sector	Botswana	Namibia	Angola
Ecosystem Uses	95.1%		
Direct Human Use			
Hydropower			
Irrigation		0.3%	4.2%
Water Supply	0.3%	0.0%	0.1%

Country / Sector	Botswana	Namibia	Angola
Ecosystem Uses	9,116		
Direct Human Use			
Hydropower	-	-	257
Irrigation	-	112	1,017
Water Supply	30	21	14

Sector	Botswana	Namibia	Angola
Ecosystem Uses	(1,109)		
Direct Human Use			
Hydropower	-	-	257
Irrigation	-	83	1,000
Water Supply	5	18	3

Sector	Botswana	Namibia	Angola
Ecosystem Uses	88.4%		
Direct Human Use			
Hydropower			
Irrigation		1.1%	9.9%
Water Supply	0.3%	0.2%	0.1%

Country / Sector	Botswana	Namibia	Angola
Ecosystem Uses	6,646		
Direct Human Use			
Hydropower	-	97	367
Irrigation	-	210	3,296
Water Supply	37	104	18

Sector	Botswana	Namibia	Angola
Ecosystem Uses	(3,579)		
Direct Human Use			
Hydropower	-	97	367
Irrigation	-	181	3,279
Water Supply	12	102	7

Sector	Botswana	Namibia	Angola
Ecosystem Uses	64.5%		
Direct Human Use			
Hydropower		0.9%	
Irrigation		2.0%	32.0%
Water Supply	0.4%	1.0%	0.2%

Please note that the changes in water withdrawals in the middle portion of the table are calculated by subtracting current withdrawals of water in the reference case from the numbers for each alternative. This is not the same change in value that would occur under these alternatives against a negotiated allocation of the water resources of the Okavango River. Given, that any such negotiations would be unlikely to grant the downstream country more than the current use allocation of water these changes would be unlikely to increase in magnitude. Thus, as calculations in the table suggest it is the downstream state, Botswana, is currently consumptively using the vast majority of the flow of the Okavango river.

4.3 Economic Issues in Deriving Changes in Values

Quite a number of challenges exist in gathering, interpreting, compiling and aggregating the economic information that may be available for these different values, sectors and countries. These are too numerous to mention here, however, a number of basic challenges are discussed here along with the suggested approach to handing these.

4.3.1 Gross Value vs Net Value Added

In simple terms there are three concepts associated with value: production costs, price of market transactions, and consumer willingness to pay (WTP). The value to the economy represented by a market good is reflected by the total willingness to pay for goods traded in the marketplace. This total WTP will typically exceed the price paid by the consumer in the marketplace. The difference between these two is called consumer surplus and represent the economic gains received by the consumer. The difference between the total amount paid (quantity times price) by consumers and the total production costs represents the economic gains garnered by producers in the market, or the producer surplus. Production costs reflect payments for land, labor, equipment and capital made by the producer. Each of these payments is therefore part of the total payment made in other markets, i.e. the markets for land, labor, equipment and capital.

Gross value added in a particular market should be represented by total WTP. However, in practice WTP of consumers is not known and only market purchases are observed. Thus Gross Value Added typically reflects the value of purchased goods and services in the markets that make up a national economy. This gives the gross size of the economy but does not accurately reflect the true value added provided by the economy. This, as some of the items bought and sold in the economy are imported or exported. So, for example, the gross value of automobiles sold in a country may be quite large, but if the automobiles are imported attributing the full gross value to the country would not accurately measure economic value added in the country. In this case it the local economic contribution would simply be the set of services needed to import, distribute and market the vehicles, which would be just a portion of the purchase price. Net Value Added is therefore a more appropriate measure of the size of an economy. Net value for a given market is arrived at by taking the gross value and subtracting the costs of production. The net value added for the input costs are in turn valued in their respective markets. So for example local labor employed to bring imported automobiles to market is valued at what it is paid. Assuming labor has no cash costs then all labor contributed to the automobile market would represent net value added to the economy. Conversely, amounts paid by automobile importers to foreign vendors are imports and are not registered as national value added.

With regard to natural resources like timber, fish, wildlife and water it is often assumed in conventional economics that the resource has no cost. In the simplest case, hunters provide their time and equipment, harvest animals and sell them in meat, hide and other markets. Ultimately, in this case the amount paid for purchased products is the sum of all the different net value added associated with the wildlife markets. Even if it is assumed that there is some real opportunity cost associated with the resource it probably does not change this calculation as long as that opportunity cost is local. However, if this opportunity cost is borne by those outside the country then the situation will differ. In other words, if all external effects were compensated and an upstream country wished to use water already in use and, therefore, impose costs on its downstream riparian neighbors then implicitly the net value added associated with the upstream use of water would need to be reduced proportionately (i.e. as if the water was being imported).

4.3.2 Value Added and Alternatives Analysis

In evaluating policy or projects the analyst is not so much interest in static measures of gross value added for the entire economy, as in tracing through how shifts in particular markets will play out and what the net effect will be on the economy. In this regard it is important to be clear that economic measures are typically only reliable when the changes that are evaluated take place within the range of observed data. Quantities and prices in observed markets are always in flux, rising and falling, and in some cases are subject to large shocks. However, when it comes to large increases or decreases in supply or demand, these may push the analysis beyond the bounds of existing data making it hard to predict price and quantity response. For the analysis contemplated here this is an important point, both in terms of any large decrease in water and ecosystem services available in Botswana and any large increase in food production and hydropower in the upstream countries.

For cases where these responses can be estimated the question is whether they should be calculated as changes in gross value or net value added. For a specific change in a specific market the best metric would be the change in net value added. Ideally this would reflect both consumer and producer surplus, but at a minimum it would consist of producer surplus for the measurement reasons described in the prior sub-section. One rationale for not including any changes in production costs in the market is the assumption that markets are in equilibrium. For example, if tourism declined slightly in the Delta due to changes in water availability the change in the quantity and price of labor employed in tourism is reflected in the change in production costs. It is assumed that any labor freed up in tourism goes to its next best use in the economy and that the price of labor adjusts to keep labor “fully” employed. On this basis, the change in net value added is the best measure of the welfare changes resulting from the water withdrawal alternatives evaluated here. This said, once again it is clear that for marginal changes this assumption may hold, but for rapid and large changes that might accompany such projects there will clearly be volatility in these markets as labor may be constrained by location and wages may be “sticky.”

4.3.3 Direct vs. Indirect Economic Impacts

As suggested above an economic analysis of water withdrawal alternatives will involve examination of welfare changes in a number of sectors. Each of these sectors may involve a number of markets, i.e. so the irrigation sector will involve a range of crop and livestock markets depending on what plants and animals are grown in a given irrigation projects. As stated above estimating the change in net value added in each and every product market associated with each of the development projects associated with each alternative will yield the best measure of the economic impacts associated with that alternative (relative to the reference case).

However, the economic impacts from irrigation, for example, are not limited just to the market for wheat, beef or milk, but the markets for inputs to agricultural production, as well as those for further processing of agricultural products. So, for example, dramatic expansion in agricultural production in Angola may stimulate the market for fertilizer, tractors and farm labor. Similarly, the onset of milk production in the Okavango region may lead to new businesses for the processing and production of a variety of diary products for internal or external consumption. Recalling the discussion above this is the same as saying that the change in agricultural production may increase the gross value in agricultural production – which of course includes the wages and prices paid for agricultural inputs. It may also create or expand agricultural processing markets leading to new opportunities to create value for the economy. These impacts are secondary to the impacts in the markets for agricultural products per se. Oftentimes the primary impacts are refereed to as the direct economic impacts and the secondary impacts as the indirect economic impacts. These indirect economic impacts are what is being referred to when people talk of the “multiplier” impacts of a given project or action. This reflects the idea that the specific action in a given market generates economic benefits (direct), which are then multiplied through backward (inputs) or forward (processing) linkages to other markets. The idea being that $1 of direct benefit actually creates, for example, $1.5, of value as it circulates through the economy.

It is safe to say that there is some debate as to what role these indirect economic impacts should play in decision-making. From the perspective of positive economic analysis there are conditions under which these indirect economic benefits might be legitimately included along with the direct economic impacts in considering whether a given project (or alternative) will maximize economic efficiency. But generally it is recommended that they not be included (as explained further below) and that decisions be made on the basis of the direct benefits alone (Aylward et al. 2001; etc). The explanation for this mirrors that found above which is basically that in a well-functioning economy resources will be priced at their opportunity cost and as economic activity shifts will move from sector to sector. If resources to be devoted to a proposed project are priced at their opportunity cost the only thing that matters is whether it is worth dedicating these resources to the project – and that is only the case if net benefits are generated. In other words the inputs will generate more economic value to the economy in the new, proposed use than in their alternative use.

The crucial exception to this is, of course, if the resources will be un- or under-employed if the project does not go ahead. This argument has been used to tout large dam projects for a very long time. This is where the perspective of normative economics applies. Oftentimes considerations of political economy have driven the development of large water resource projects on the premise of employment and large multiplier benefits, the interests of the unemployed coincide with that of politicians seeking popular support. However, it needs to be clear that positive economic analysis does not support the contention that devoting idle resources to a project that generates net economic losses (and not net gains) is not an effective way to build a national economy. The question that needs to be answered is what other activity could be funded with the same development monies that would provide employment and generate net economic benefits.

A further difficulty is that once marginal economic projects are funded – and input and processing markets develop, the existence of these multipliers becomes a normative argument for continuing these projects and activities. For example, in developed countries where full employment of resources is largely taken as a given (subject to the ups and downs of economic cycles) the argument that restricting the use of water for agriculture and putting it to ecosystem uses will have adverse affects on local economies in rural areas is now a frequently heard argument. A recent review of the literature however, provides little support for the contention that these multipliers are of a significant magnitude (MacDonnell et al. 2009). The inclination to place undue importance on these indirect economic benefits, therefore, can be seen as a potential poverty trap – first lowering the bar to investment in unproductive activities and then raising the bar to abandoning these activities.

A final point with regard to indirect economic benefits is that these are often considered as unmitigated positives of water resource development activities. Implicitly this reflects the view that there is no opportunity cost to developing the water resource. But, as discussed in detail above, in the case of the Okavango it is clear that the resource is already being used for the production of tourism, ecosystem goods and services, and global existence value. In other words, an increase in agricultural production in Angola or Namibia may be accompanied by a decline in tourism in Botswana. These alternative economic uses of water also have indirect economic, as well as direct, benefits. The point being that if the indirect benefits are to be included on one side of the equation they may well need to be included on the other. This issue also, therefore, needs to be considered in the economic analysis. Indeed, this would be one argument for just focusing in the alternative analysis on the direct changes in net value added.

The approach taken in the analysis is therefore to focus on these direct impacts and leave the indirect impacts for future consideration. Predicting the multipliers associated with processing industries that may or may not emerge alongside irrigation projects would be haphazard at best in any case. The one exception here would be to explicitly consider potential employment multipliers from labor markets directly engaged in irrigation developments under the alternatives.

4.3.4 Financial vs. Economic Values

Prices and quantities appearing in national accounts are typically what can be observed by data collectors or what is reported by producers and consumers. As indicated above, in the first instance then these figures reflect prices of real market transactions. These are typically referred to as financial values. However, there are a large number of market and policy failures that may skew market quantities and prices away from what they would be in an efficient market that allocates goods and services to their highest and best use from an economic perspective (Anandarup 1984: ; Asian Development Bank 1997: ; Belli et al. 1998: ; Gittinger 1982: ; Jenkins and Harberger 1989). This underlying “true” economy and its associated economic values can be derived from market transaction data and knowledge of the distortions imposed by market failures and distortionary policies. This type of analysis is often undertaken in evaluating projects, although actual practice lags that recommended as best practice (Jenkins 1997). Thus, there would be a financial cost-benefit analysis carried out at market prices and quantities and an economic cost-benefit analysis carried out at so-called “shadow” market prices and quantities.

Where market and policy distortions are significant it is very useful to undertake an economic analysis, as otherwise a project that looks good in financial terms but is actually deleterious to the economy might be approved. Some of the typical issues that arise and are usefully dealt with through economic analysis include:

- transfers – i.e. where costs are not borne by the purchaser and thus do not appear in the financial accounts even though the resources deployed in the activity have an economic opportunity costs. Examples include free provision of inputs, lack of cost recovery on infrastructure and failure to account for opportunity costs of resources that can be extracted or harvested for "free."
- own labor – in particular small scale production oftentimes pays the owner in profits not in hourly wages and thus economic analysis involves specifying the labor hours and valuing them at the appropriate wage rate in order to accurately convey not just financial but economic profit
- wages – the true economic market-clearing price for labor of different categories may diverge from that observed in the market place, for example, in Botswana and Namibia the shadow price of unskilled labor is suggested to be 35 to 50% of market price due to high unemployment levels (Barnes 1994)
- trade barriers – i.e. where import or export subsidies or tariffs lead to under- or over-valuing the costs and benefits to the economy of resources
- taxes and subsidies – where the government partially subsidizes (or taxes) inputs, provides direct subsidies (taxes) to the production and sale of goods, or puts sales or other taxes on consumption or income appropriate discounts or increase in values may be needed
- price controls – i.e. where the government exerts direct control over the price of inputs or outputs
- opportunity cost of foreign exchange – i.e. manipulation or setting of foreign exchange rates, which will effectively have same impacts as trade barriers
- opportunity cost of capital – whereas financial analysis uses market lending and borrowing rates of interest, economic analysis should account for intragenerational equity (not penalize future generations) and therefore lower rates for the cost of capital are generally recommended although the range of views on this is large. This becomes an issue only where projects are likely to have costs and benefits that vary greatly over longer time horizons. In this case working with a future annual expected value may be sufficient to avoid this problem.

In gathering data for the quantitative analysis some studies and figures encountered will have applied shadow-pricing methods and in others this will not have been done. This poses a consistency problem that will be hard to eliminate. An effort will however be made to use economic values and not financial values where these are available. Where these are not available an effort will be made to indicate the likely net direction and magnitude of expected changes in any financial values. In this regard the paper by Barnes (1994) provides useful guidance for the region.

4.4 Data Collection

As alluded to in the discussion above a comprehensive and internally consistent (in terms of methods and results) quantitative analysis will not be possible within the frame of this consultancy. In large, part this is due to the scale of the alternatives that need to be analyzed, the sheer number of projects in each alternative, and the gaps in information that will be available regarding these projects. However, the analytical framework will be employed in making a first approximation at compiling and evaluating such data as is available and filling in the alternative matrices to the extent possible. Again, the interest is not in reaching some overarching conclusion about what should be done, but providing the riparian countries with formatted information that begins to indicate the values involved and the tradeoffs that need to be discussed in future negotiations. A further objective will to highlight which information remains to be gathered in order to attain a more comprehensive analysis going forward.

The discussion below presents the approach taken in gathering information to fill in the matrices with the efforts divided into those related to the ecosystem uses of water and those for the water resource developments themselves.

4.4.1 Ecosystem Values

This category covers the tourism, natural resource, ecosystem service and global nature conservation sectors. For the tourism, natural resource and ecosystem service sectors the socio-economic results from the IFA were extended by the TDA Team's Socio-Economist, in coordination with the author of the present study, and thus could be incorporated directly into the quantitative analysis.

For the global nature conservation values, no primary research exists on the existence values held by the global community with respect to the Okavango Delta. Nonetheless there is the assumption that the willingness to pay is significant in total. Literature review and where feasible benefits transfer could be used to see if at least a range in order of magnitude can be assigned to this value. Due to time and resource constraints, as well as the nature of the initial results for values within each countries, these were not pursued for this study. If as expected, a policy option to be considered would be having the global community engage with the three countries in a system of compensated payments for development rights foregone – based on a negotiated sharing of the waters of the Okavango River – carrying out such a review would be a useful exercise and could be included in the Strategic Action Programme.

4.4.2 Water Resource Projects

For each alternative and each project within each alternative there are a number of ways to arrive at alternative-level or project-by-project costs and benefits, or perhaps simply the net benefits of water use in irrigation, water supply and hydropower:

1. detailed project economic cost-benefit analysis
2. project-level cost-benefit analysis at some level of detail and precision in terms of reconnaissance through engineering/cost design proposal and financial/economic analysis
3. costs and benefits from similar projects already implemented (along the continuum of financial/economic cost-benefit analyses)
4. net values derived from larger evaluation datasets of similar projects (for example the World Commission on Dams case studies, cross-check analysis, and similar evaluation reports from development agencies such as the World Bank)

5. net values for irrigation, hydropower and water supply projects found in the grey and academic literature as selected for their likely applicability alternative

These sources are organized in order of preference. Project and site-specific numbers as indicated in items 1 and 2 above were not available or obtained under items 1-2. However, a range of information of the type mentioned in items 3 through 5 are available and were employed to identify likely cost, benefits or net values of these activities. Depending on the type of value some of the methodological issues mentioned above were dealt with, but it remains the case that the distinction between, for example, financial and economic values was not apparent in much of the literature. Where possible an economic as opposed to financial approach was taken but given the crude nature of the extrapolations required the lack of consistent economic data is probably not a major constraint.

It is also worth emphasizing that to some extent figures obtained from actual evaluation work or research are probably more reliable indicators that early stage reconnaissance project work. Indeed, one of the lessons learned from the World Commission on Dams process is that pre-project economic analysis has often understated project costs and overstated project benefits. For this reason, even if information was available under item 1, it might still need to be adjusted to account for this bias in pre-project analysis. In the end, the objective of the analysis was to ensure that rough orders of magnitude for the alternatives were first achieved knowing that this first approximation would probably clarify which projects would be worthy of further scrutiny with more site and project numbers.

5. Quantitative Evaluation

5.1 Model Development: General Parameters and Assumptions

The analysis is undertaken over a 40-year time horizon. In order to synchronize with a number of varying population estimates and water supply information the analysis begins with 2008 and extends to 2048. All costs and benefits are discounted at an 8% cost of capital. To evaluate the sensitivity of results to a lower discount rate, perhaps reflective of a lower social opportunity cost of capital, net present values are also calculated at a 4% discount rate. These rates are chosen to be consistent with those employed in the socio-economic analysis under the EPSMO project.

The projects that make up the alternatives are phased in over the first 20 years of the time horizon. Broadly speaking the projects set forth in the IFA for each of the three “scenarios” make up the alternatives. The low water withdrawal alternative assumes a limited set of developments that are completed in the first five years (i.e. by 2013); the medium water use alternative includes a more aggressive development schedule that includes additional projects that are implemented over the subsequent five years (to 2018); and the high water use alternative includes a further set of projects implemented over the next 10 years (to 2028); in years 20 through 40 projects are maintained but no increase in population or projects is assumed. This is done to allow the costs and benefits that result from the alternatives to play out over a time period sufficient to ensure that the long-lived benefits of the infrastructure projects, as well as their long-term costs, are adequately accounted for given the two different discount rates employed.

The reference case scenario against which these alternatives are compared simply incorporates population growth in the absence of any of these water resource development projects. The reference case is thus analogous to a “stagnation” alternative in which no further investment is made in these projects. The reference case thus includes the present value of current and projected future net benefits derived from ecosystem goods and services in each country. Based on the IFA and the subsequent results for changes in the tourism, natural resource values and ecosystem services from the socioeconomic report, the expected net benefits under each of the water withdrawal alternatives is also specified. Subtracting the reference case net benefits from those calculated for water resource developments, and ecosystem goods and services, yields the net benefits of selecting and pursuing each of the alternatives.
The specific parameters and assumptions employed in developing cost and benefit profiles for the water supply, hydropower, and irrigation, along with the sectoral outputs (improved water supply delivered to households, GWhs of electricity and lands irrrigated) are reviewed below, before proceeding to the results. The results are presented in terms of the present values of net benefits per sector and country, but also in terms of how the outputs translate into populations served.

5.2 Domestic Water Supply: Ecosystem Direct Use Values and Water Supply & Sanitation Values

5.2.1 Water Supply and Sanitation Overview

Access to improved water supply and sanitation varies between the riparian countries, the urban and rural areas within each country (see Table 7). The basin does have a number of towns and cities, but is generally remote from the population and governance hubs of each country. Actual, confirmed detail as to the level of water supply and sanitation for communities in the basin is scarce for Angola. Some, limited information is available for the other countries from EPSMO reports. As described further in the sub-sections below for each country, efforts are made to gather available data in order to portray what are at best imprecise estimates of source of water supply, level of improvements, and quantities withdrawn for the populations living in the basin.

Table 7: Access to Improved Water Supply and Sanitation, Okavango Riparian Countries

MDGs	Angola	Botswana	Namibia
Population Accessing Improved Drinking Water (% in 2004)			
Urban	75	100	98
Rural	40	90	81
Total	53	95	87
Population Accessing Improved Sanitation Systems (% in 2004)			
Urban	56	57	50
Rural	16	25	13
Total	31	42	25

Source: (WHO and UNICEF 2006)

5.2.2 Water Supply and Sanitation Benefits: Approach

Using the information for each country produced by EPSMO and that available from other secondary sources, the water supply and sanitation analysis is developed in four steps:

Step 1: Establish the value of present day use of water in the basin as part of the socioeconomics contribution to the valuation of basin resources:

- estimating present day populations, their level of current household service and current daily/annual volume of water use, and
    - estimating the water supply benefits garnered by populations from the ecosystem direct use values associated with domestic water supply under present day conditions and for the reference case.
    - Step 2: Establish the reference case and water withdrawal alternatives by:
- estimating expected growth in populations over the time horizon, and

- projecting improved service levels and changes in water use for the reference case and the three water withdrawal alternatives.
- Step 3: Establish the change in ecosystem direct use values
- by estimating the change in reliance on the river (or other untreated, natural sources) as opposed to improved water supply between the reference case and the different withdrawal alternatives
- Step 4: Establish the net benefits of improved service levels under the three withdrawal alternatives (as against the reference case) by:

- estimating the investment, and operations and maintenance (O&M) costs of improved water supply and sanitation for the withdrawal alternatives, based on World Health Organization (WHO) global studies, and
- estimating the benefits of improved water supply and sanitation, based on global WHO studies and country-by-country adjustments, and
- deducting costs from benefits for each year in the 40-year time horizon and discounting net benefits (and calculating internal rates of return where feasible, i.e. where non-negative)

The calculations for Step 3 provide the people served and water withdrawn for the reference case and alternatives. It is useful to note that one consequence of improved service levels is a higher withdrawal and use of water by households. This dynamic is not addressed in the IFA analysis, but is reported here. Also, as populations increase and coverage of populations by water supply schemes expands, the number of people who will rely on ecosystem direct use values for water will be reduced. Thus, even as increasing water withdrawal may impair these ecosystem values, the basis for these values will be reduced. In effect the reference case and water withdrawal alternatives will each vary in how they treat the latter two trends listed above. In order to evaluate this second dynamic, the domestic water supply analysis needed to compile an internally consistent picture of the populations in each country and how they are supplied with water over the 40-year time horizon of the economics analysis of the scenarios. Thus, the water withdrawal numbers here will diverge from those in the IFA. However, the numbers are generally lower as this analysis deals only with domestic water use by households and not the full range of water withdrawals for industrial, commercial, livestock, etc.

Another caveat is that modeling water supply while ignoring sanitation is not only difficult but largely meaningless. Providing improved water supply will increase water withdrawals. Without concurrent investments in sanitation improvements in water supply would just increase the scale of the sewage and effluent problem, most likely with negative impacts on water supply and treatment costs downstream. Perhaps indicative of this, the global WHO studies of the benefits of improved service exist for water supply and sanitation taken together not separately. Thus, while there is disaggregated information on costs of supply and sanitation to undertake the analysis only in terms of supply would not only be meaningless but would not be possible on the benefit side. For this reason the analysis considers improvements in water supply and sanitation jointly.

Each of the steps are reviewed below with the analysis for each country presented in turn. Botswana is the first country reviewed under each step as it served as the trial country for the purpose of developing the necessary estimates. More detail is thus provided for Botswana in order to show how the approach for the countries was developed and applied, particularly with respect to the direct ecosystem use values. For the other countries the data and parameters applied are simply summarized.

5.2.3 Step 1: Present Day

Botswana

Population. A number of sources provide information on populations in the study area:

- National Water Master Review of 2006 is cited as suggesting that in 2005 were are 133,000 people in Ngamiland region, although the language is not clear if this is rural and urban or just urban (Beuster et al. 2009)
- Central Statistics Office is cited as reporting a Ngamiland population of 138,654 for 2006 (Vanderpost 2009)
- Barnes (pers. com 2009) suggest a rural population in the study area of 14,000 households or 111,000 people
- population in Maun of around 50,000 people with household size of 4.4 (in 2001) (Vanderpost 2009)

The final population numbers employed by EPSMO are 157,690 for 2008, with a 1.5% population growth rate.

Household Water Sources/Service Levels. According to Central Statistical Office numbers for 2001, (shown in the table below) just 9% of Ngamiland Region households collect water directly from the river and 8% of households obtain their water from boreholes (Vanderpost 2009). Over two-thirds of the Region's households are connected to a water system that includes either a pipe to the yard or the house, or the use of a communal standpipe. The source of water use is not identified for 7% of the population.

Table 8: Household Access to Water Sources, Ngamiland, Botswana, 1991 and 2001

Type of Water Supply	% Households 1991	% Households 2001
Piped water in house or yard	15	23
Communal pipe	37	54
River	17	9
Borehole	8	7
Other	23	7
Total	100	100

Source: CSO, 2003 in Vanderpost (2009)

Trends between 1991 and 2001 suggest, that households using unimproved sources such as collection from the river and "other" sources are moved on to improved water supply, either in the form of piped water or communal pipe. The percentage of households using boreholes, on the other hand, remain roughly constant suggesting that these sources are improved boreholes (i.e. with surface protection) and provide adequate source of water given the remoteness of the location and distance to other sources.

Household Water Use/Demand. National Water Master Review of 2006 is cited in Beuster et al. (2009) as suggesting water demand for Ngamiland Region is 3,644 m3/yr. However, this amount of water demand is far too low for the region's population - about 300 l/c/yr as opposed to a daily minimum suggested for household needs by WHO of 20 l/c/d which is equal to 7,500 l/c/yr (see Table 9).

Table 9: Per Capita Requirements for Water Service Level to Promote Health

Service level	Access measure	Needs met	Level of health concern
No access (quantitycollected often below 5 l/c/d)	More than 1000m or 30 minutes total collection time	Consumption – cannot be assured Hygiene – not possible (unlesspractised at source)	Very high
Basic access (averagequantity unlikely toexceed 20 l/c/d)	Between 100 and 1000m or 5 to 30 minutes total collection time	Consumption – should be assured Hygiene – handwashing and basicfood hygiene possible; laundry/bathing difficult to assure unlesscarried out at source	High
Intermediate access (average quantityabout 50 l/c/d)	Water delivered throughone tap on-plot (orwithin 100m or 5 minutes total collection time	Consumption – assured Hygiene – all basic personal and foodhygiene assured; laundry and bathingshould also be assured	Low
Optimal access(average quantity100 l/c/d and above)	Water supplied through multiple tapscontinuously	Consumption – all needs met Hygiene – all needs should be met	Very low

Source: Howard and Bartram (2003)

Using the information provided above on populations and water sources it is possible to disaggregate between the Maun urban population and rural gazetted settlements, and use information on urban and rural household size and total regional population to work through and allocate population numbers by type of household access to water sources. WHO estimates for different service levels are used to estimate per capita water use. It is assumed that piped water to the house or yard results in use of 75 l/c/d (midway between intermediate and optimal access levels), communal pipe leads to use of 35 l/c/d (midway between basic and intermediate access levels), and that all others use 20 l/c/d (basic access). The end result is 2.14 million m3/yr of water use by households in Ngamiland Region. Water volumes can then be valued by applying an appropriate measure of the per unit economic value of water for domestic use. In this case a value of US$ 0.50/m3 is employed based on prior work in the Delta (Turpie et al. 2006). This suggests an annual current value of $1.07 million per year.

Table 10: Present Day Water Use, Botswana

Table 10.

% HH		Location	Population	HH Size	Households	Water Use	
Water Source						l/c/d	M m3/yr
Piped	23%	Urban	25,295	4.4	5,749	75	0.69

Water							
Communal Pipe	54%	Rural/Urban	86,979	6.4	13,497	35	1.11
Borehole	7%	Rural	13,822	7.9	1,750	20	0.10
River	9%	Rural	17,772	7.9	2,250	20	0.13
Other	7%	Rural	13,822	7.9	1,750	20	0.10
Total, of which			157,690		24,995		2.14
Urban	45%		50,000	4.4	11,364		
Rural	55%		107,690	7.9	13,632		

Note: HH = household, Urban population assumed based on Vanderpost (2009)

Ecosystem Direct Use Value. For water sourced from improved sources, particularly the treated water supplied to residences and communal pipes, the investment in infrastructure and water treatment effectively reduces the household's reliance on the river ecosystem. Given the emphasis on providing access to safe and secure water as a matter of global concern and national policy under the Millennium Development Goals the relatively low reliance on unimproved sources, i.e. the river, must be regarded as a positive development indicator – even if it lowers the extent to which humans are reliant on the ecosystem for their water supply. Based on the proportion of households and total population relying directly on the river, boreholes and other sources and using the water use under these categories, produces an estimate of 0.33 million m3/yr and $165,000 per year of present day direct ecosystem use value (valued at the same $0.50/m3).

Namibia

Population. The starting population for Namibia is 219,090 and a 1.7% growth rate used. The growth rate reflects the 2.5% growth rate for urban areas and the 1.5% for rural areas weighted for the relative share of population.

Household Water Sources/Service Levels and Demands. A range of estimates of which populations are served by what source and level of improvement are cited by the relevant EPSMO documents and these are employed to derive the assignment of populations to the different service levels (Nashipili 2009). Estimates for use by households that are on piped water systems are high for the region at 165 lcd, but appear to be substantiated by NAMWATER so are included in the analysis. Overall expected water use in 2008 for domestic purposes is 2.8 million m3.

Table 11: Estimated Water Use by Source, Namibia

Table 11.

Service Segments	2008 Population	% of Population	Water Use (l/c/d)	Water Use (m/yr)	Total Use (mill m3)
Rundu-Regulated Pipe	18,000	8%	165	60.225	1.08
StandPipe	46,668	21%	35	12.8	0.60
Namwater Boreholes	39,055	18%	20	7.3	0.29
River	115,367	53%	20	7.3	0.84
Totals	219,090				2.81
Of which Unimproved	154,422				

Ecosystem Direct Use Value. Based on water withdrawals of 1.13 million m3 by those households drawing from boreholes or the river the annual ecosystem direct use value of the river is $565,000.

Angola

Population. The Angolan population in the basin is estimated at 505,180 in 2008 with a 2.7% growth rate.

Household Water Sources/Service Levels. EPSMO information on service levels was not precise with respect to households or populations with improved standpipe or piped systems. It does appear that these systems do exist in the major towns, such as Menongue and Cuito Cuanavale. One source cited in an EPSMO report suggests that some 17.5%s (or 90,000) people may be receiving treated surface water (Saraiva et al. 2009). Another source, however, reports that just 0.2% of the population of Menongue receives water from the public grid and that 80% rely on water holes and wells, and another 14% rely on the river. No complete and reliable picture is therefore available for the source and level of improvement of the Angolan population in the basin. Moreover, it is likely that where improved, piped systems exist that these systems probably date back to 1975 or earlier. Nor is it likely that much investment was made since then given the war. In the absence of better information it was assumed that what systems are in place are likely to be antiquated and in poor repair, and likely would need replacing. For the purpose of this analysis it was therefore assumed that the entire population is on unimproved sources, with 25% on boreholes and 75% on the river as their source.

Household Water Use/Demand. Estimated using 20 lcd in consumption for river/borehole sources the total annual domestic water withdrawal would be 3.69 million m.3.

Ecosystem Direct Use Value. The total ecosystem direct use value would be $1.84 million given the assumptions above.

5.2.4 Step 2: Projecting Service Levels and Withdrawals

Future domestic water use is important to the economic analysis in two respects”

1. The degree to which domestic water use relies on unimproved sources and thus is subject to risk from future shortfalls or water quality impairment of flow and groundwater. These factors enable projection of the future direct ecosystem use value of water under the reference case and the water use scenarios
2. The extent to which improved water supply (and sanitation) is provided to the population. This motivates projection of the costs and benefits associated with existing or new populations receiving access to improved water supply (and sanitation) under the reference case and the water use scenarios.

In order to arrive at these figures it is necessary to (a) project future area population, (b) determine how the numbers of people reliant on unimproved and improved sources of water change over time, and (c) calculate the respective costs and benefits under the reference case (no change in water resource use) and the three water use scenario (low, medium and high). Comparing these values between each of the three scenarios and the reference case will provide the gain/loss in direct ecosystem use value and improved water supply and sanitation.

Thus, in Step 2 the present day domestic water sources, service level and withdrawals are combined with a series of assumptions about future investment levels in order to forecast the reference case (no further investment) and low, medium and high withdrawal alternatives. These alternatives represent increasing levels of investment in improved water supply and sanitation. The assumptions made are as follows:

- For the reference case it is assumed that there is no further provision of improved water supply and thus this additional population added each year collects water from the river (i.e. no further investment in improved water supply), with the exception of those rural populations using boreholes, which are assumed to increase at the rate of population growth. In other words, the bulk of the increase in population goes on the unimproved source that puts populations at risk from poor ecosystem management.
- For the low water use scenario, the additional population is served from the same set of improved and unimproved sources, with no change in the proportionate share of each source in the population (i.e. percentage shares by source are maintained). In other words, the population increase is spread across both improved and unimproved sources, but access to improved sources is limited. In the Angolan case standpipe water is supplied to the urban population over the twenty-year period to 2028.
- For the medium water use scenario access to improved sources is increased, with households using the river and “other” sources put on improved sources by 2018 (2028 for Angola given the larger number on unimproved sources at present). Borehole numbers remain the same as under the previous scenarios. For those households that receive access to improved sources, the existing proportion of piped (23%) vs communal pipe systems (77%) is maintained as the population grows. Proportionatley these are 23% and 28% for in house piped systems versus 77% and 72% for Botswana and Namibia respectively. In the case of Botswana these proportions are In other words, the bulk of the population is moved to the less costly improved source of water: communal standpipes. In the case of Angola the split between piped and communal pipe systems is 25% and 75% respectively.
- For the high water use scenario the same assumptions as the medium scenario, apply except that it is assumed that households on communal pipe systems are gradually upgraded, so that by 2028 all non-borehole users are on household pipe systems for their water supply. This moves the vast majority of the population to the highest level of improved water supply, in-house piped supply. In the Angolan case, with no households on piped or communal systems to start with all households (except those on boreholes) are gradually transitioned to piped systems by 2028.

Botswana

In the IFA model the numbers for Maun/Delta withdrawals for water supply vary from 25 million m^3/yr (2005) for the reference case to 36 million m^3 for the high water withdrawal scenario (i.e. in 2035) (Beuster et al. 2009). These water supply numbers actually come from total surface and ground water abstractions for 2005 (and 2025) as determined by the ODMP. These abstractions meet domestic water supply, livestock, game, small-scale irrigation and construction needs. These numbers apparently also include wild game water needs. They also may include water demand on the part of tourists. Background documentation suggests tourist demand of 32,000 m^3/yr in 2005, suggesting that this is minor in total quantity. Clearly the present day estimates of household water use (2.14 million m^3/yr) arrived at above are just a fraction (7.5%) of the 2005 water use employed in the IFA analysis. The numbers employed in the IFA analysis presumably do not affect the IFA scenario outputs for flows into the Delta as the water is withdrawn in or around the Delta. The difference between these two sets of numbers is therefore not of consequence, and the analysis below proceeds on the basis of the bottom-up calculation of domestic water use.

The results for the reference case and the water withdrawal alternatives are presented for Botswana in the table below. In sum:

- with a 1.5% growth rate the population increase of 35% over the 40-year time horizon, to just over 212,000
- in the reference case, annual water use increases by 20% to 2025 in the reference case, with a fourfold increase in the population reliant on the river.
- with each of the water withdrawal alternatives, the reliance on the river decreases and the numbers served by improved sources rises. As a consequence the volumes of water used also increase, from

2.14 million m^3/yr under present day to 5.44 million m^3/yr under the high water use alternative, a 150% increase. However, with increasing levels of improved water supply, the population relying on unimproved sources decreases.

Table 12: Population Served and Domestic Water Use, Botswana

Table 12.

Scenario	Present Day	Reference	Projections for 2028 Low	Medium	High
Population Served					
Pipe	25,295	25,295	34,069	43,656	193,769
Communal	86,979	86,979	117,148	150,113	-
Borehole	13,822	18,616	18,616	18,616	18,616
River	17,772	67,673	23,936	-	-
Other	13,822	13,822	18,616	-	-
Water Use in million m3/yr (present day value is 2.81 million m3/yr)					
2013		2.22	2.30	2.46	3.08
2018		2.32	2.48	2.80	4.05
2028		2.53	2.88	3.25	5.44

Namibia

The results for the reference case and the water withdrawal alternatives are presented for Namibia in the table below. In sum:

- with a 1.7% growth rate the population increase of 35% by 2028, to just over 295,000
- in the reference case, annual water use increases by 20% to 2028, with a 50% increase in the population reliant on the river.
- with each of the water withdrawal scenarios, the reliance on the river decreases and the numbers served by improved sources rises. As a consequence the volumes of water used also increase, from 2.81 million m^3/yr under present day to 14.99 million m^3/yr under the high water use scenario, a 430% increase. However, with increasing levels of improved water supply under the water use scenarios, the population relying on unimproved sources decreases.

Table 13: Population Served and Domestic Water Use, Namibia

Table 13.

Scenario	Present Day	Projections for 2028			
		Reference	Low	Medium	High
Population Served					
Pipe	18,000	18,000	24,243	67,493	242,479
Communal	46,668	46,668	62,855	174,987	-
Borehole	39,055	54,714	52,602	52,602	52,602
River	115,367	175,699	155,381	-	-
Water Use in million m^3/yr (present day value is 2.81 million m^3/yr)					
2013		2.93	3.03	4.27	7.27
2018		3.07	3.26	5.76	11.81
2028		3.36	3.78	6.69	14.99

Angola

The results for the reference case and the water withdrawal alternatives are presented for Angola in the table below. In sum:

- with a 2.7% growth rate the population increase of 70% by 2028, to just over 860,000
- in the reference case, annual water use increases by 70% to 2028, with an 80% increase in the population reliant on the river.
- with each of the water withdrawal scenarios, the reliance on the river decreases and the numbers served by improved sources rises. As a consequence the volumes of water used also increase, from 3.69 million m3/yr under present day to 20.0 million m3/yr under the high water use scenario, a 440% increase. However, with increasing levels of improved water supply under the water use scenarios, the population relying on unimproved sources decreases.

Table 14: Estimated Water Use by Source, Angola

Table 14.

Scenario	Present Day		Projections for 2028		
Reference			Low	Medium	High
Population Served					
Pipe	-	-	-	170,944	683,774
Communal	-	-	341,179	512,831	-
Borehole	126,295	176,932	176,932	176,932	176,932
River	378,885	683,774	342,595	-	-
Water Use in million m^3/yr (present day value is 3.69 million m^3/yr)					
2013		4.21	4.68	5.63	7.34
2018		4.81	5.75	7.74	11.25
2028		6.28	8.15	12.52	20.01

5.2.5 Step 3: Evaluation of Ecosystem Direct Use Values with the Alternatives

The analysis of potential changes in ecosystem direct use value with the water withdrawal alternatives is explored in full below for Botswana and only briefly summarized for the other two countries. Employing the figures for the population using borehole, river and other as their supply source, the ecosystem direct use value of water supplied is calculated for each scenario. The impact of changing mix of water supply sources on ecosystem direct use values is examined first. Then the impact from any degradation in ecosystem function due to changes in flow and water quality resulting from increased water resource development under the scenarios is examined.

The direct use values for the reference case and the three scenarios are presented in the table below, for the two values of the discount rates employed across the valuation studies. The 8% figure is the best estimate for the discount rate and values for this figure will be cited in the text. The 4% figures are presented for the reader's information. Under the reference case the net present value of the ecosystem direct use values is $3.1 million (reflecting the heavy reliance on unimproved sources and the calculation of a discounted value over the 40-year time horizon for the economic analysis of the scenarios). These figures decrease to $1.1 million for the medium and high scenarios, as households are switched to improved sources. The net result is that the water use scenarios result in a loss of ecosystem direct use value, rising to $2.0 million for the medium and high use scenarios, merely due to the switch in water supply source. As documented later these losses are balanced by the net benefits of moving households to improved sources.

Table 15: Ecosystem Direct Use Values, Changes due to Shift in Water Supply Sources, Botswana

Discount Rates		
(all figures US$ milliions)	8%	4%
Ecosystem Direct Use Values		
Reference Case	$3.1	$5.7
Low	$2.3	$4.0
Medium	$1.1	$1.7
High	$1.1	$1.7
Change in Values from Reference Case		
Low	($0.83)	($1.72)
Medium	($2.04)	($4.04)
High	($2.04)	($4.04)

Notes: Numbers in parentheses are negative values

The possible impacts of reductions in flow and water quality on unimproved domestic water supply was not explicitly included in the IFA analysis. Below a brief attempt is made to use the IFA analysis to assess the case that the water withdrawal alternatives would affect the ecosystem direct use values of domestic water supply, and then to simulate what these impacts might be in quantitative terms.

The first point to emphasize is that the decreasing reliance on unimproved domestic water supply sources will tend to limit the significance of any degradation of these ecosystem direct use values. With a maximum loss of value of $2 million under the low withdrawal alternative, such degradation may have an important and localized impact on human health, but would be of minor consequence in the overall economic analysis of the IFA scenarios, where changes in values are on the order of hundreds of millions, if not billions, of US dollars.

Changes in flow amounts and timing due to upstream changes in water use under the water withdrawal alternatives may lead to reductions in flow and water quality, with consequent negative impacts on households and the economy. A shortage in flow may lead to a shortage in water availability for collection from the river by the household for domestic uses. Households then face the choice of doing without (or with less) water or acquiring it from other, more costly sources. Typically water can always be purchased from entrepreneurs who abstract water in other locales (or from boreholes) and bring it by tanker for sale. In the case of boreholes, temporary deficits in flow are unlikely to cause shortages per se in groundwater. On a seasonal or long-term basis, flow deficits might result in a lowering of groundwater levels, leading to shortfalls or necessitating extra expenditure to deepen boreholes.

Reductions in flow may also negatively affect water quality by increasing the concentration of physical, chemical or biological contaminants. This imposes costs on households – either in the form of treating the water, finding an alternative source or using the water and suffering from consequent increases in morbidity or mortality.

In the case of the Botswana portion of the Okavango the results of the IFA analysis suggest the following conclusions with respect to ecosystem direct use values:

- while river inflows to Botswana are reduced, water remains available in the river throughout the year so no absolute shortages are foreseen (King et al. 2009)
- the reduction in river inflows to Botswana may affect groundwater levels in the Delta, however, information from the IFA does no provide explicit information about drops in the water table
- examination of impacts of scenarios on water quality parameters show no change under all three scenarios for PH and under the low and medium scenarios for all other variables; but for the high water use scenario show significant percentage increases for conductivity, temperature, dissolved oxygen, total nitrogen, phosphorus, chlorophyl and a decrease for turbidity.

In other words the IFA did not directly examine the issue of impacts on drinking water collected from streams and rivers. Moreover, the available proxy information suggests that while there might be some impacts at some times of year from water quality impacts, it would be hard to derive a quantitative estimate of these losses. Further, even if these had a significant impact on the direct ecosystem use values for water these would be quite small relative to those of other ecosystem values (and indeed the direct costs and benefits of the water supply and sanitation improvements envisioned). While, reductions in water quality or flow would remain a concern, there is not a need to include any such adjustment in the alternatives analysis.

Botswana and Angola

Given the difficulty of establishing any clear impact from low flows or degraded water quality on domestic water supply in the case of Botswana it is not pursued further for the other countries except to summarize that no severe impacts were expected in Namibia and that while there might be seasonal issues with water quality and flow availability in Angola, these are not well enough established to investigate further. The only point worth making is that in the reference case the reliance on the river in Angola as a water source would increase considerably, however, the lack of investment in increasing withdrawals would in effect mean that there is no threat from further development. In actuality, the threat would come from untreated human sewage finding its way back into the river. This, is of course, precisely the argument for moving populations onto improved water supply and sanitation (as explored further in Step 4).

Under the withdrawal scenarios there are changes in the ecosystem direct use value attributable to the shift from unimproved to improved sources. The present value of these changes are summarized for Botswana and Angola in the two tables below.

Table 16: Ecosystem Direct Use Values, Changes due to Shift in Water Supply Sources, Namibia

Discount Rates		
(all figures US$ milliions)	8%	4%
Ecosystem Direct Use Values		
Reference Case	$8.3	$14.5
Low	$7.9	$13.5
Medium	$3.4	$5.1
High	$3.4	$5.1
Change in Values from Reference Case		
Low	($0.48)	($0.99)
Medium	($4.90)	($9.45)
High	($4.90)	($9.45)

Notes: Numbers in parentheses are negative values

Table 17: Ecosystem Direct Use Values, Changes due to Shift in Water Supply Sources, Angola

Discount Rates		
(all figures US$ milliions)	8%	4%
Ecosystem Direct Use Values		
Reference Case	$29.3	$51.9
Low	$21.8	$36.4
Medium	$14.7	$21.5
High	$14.7	$21.5
Change in Values from Reference Case		
Low	($7.54)	($15.52)
Medium	($14.60)	($30.39)
High	($14.60)	($30.39)

Notes: Numbers in parentheses are negative values

5.2.6 Step 4: Net Benefits of Improved Service Levels

Step 2 provides the numbers of people moving on to improved water supply and sanitation. In order to complete the analysis the per capita costs and benefits off changing service levels is needed to obtain the total net benefits of undertaking any one of the alternative. Figures employed by a number of WHO global estimates for meeting the Millennium Development Goals provide the requisite cost and benefit estimates (Haller et al. 2007: ; Hutton and Haller 2004: ; Hutton et al. 2007). As with all the net benefit calculations a conservative and optimistic range of projections for the costs and benefits is employed based on expected variation in the key parameter values.

The cost data are for African countries and the benefit data are provided for a number of regions in Africa. Angola is classified in one region and Namibia and Botswana in another. These benefit levels are based largely on the time savings from avoiding morbidity and mortality and thus are very sensitive to the value placed on time. To confront the likelihood that the WHO figures are over-estimates the per capita benefits from improvements are adjusted downward in a conservative projection. Shadow water rate adjustments are made to these benefit levels based on country information provided by Barnes (pers. com. 2009) for unskilled labor at 20% for Angola, 30% for Namibia, and 50% for Botswana. The shadow wage rate in effect compensates for the potential effect of overstating the value of wage labor, given the varying degrees of unemployment and underemployment in the countries. While these reductions are severe and lead to negative net present values under the conservative projection they are the best that can be done to reflect the possibility that the WHO numbers may vastly overstate the economic benefits of time savings.

In the case of Namibia withdrawals of 17 and 100 million m^3 for the Eastern National Carrier project are forecasted for the medium and high water withdrawal alternatives respectively. This project will simply connect water from the Okavango into the existing NAMWATER network at Grootfontein. The costs of the project are thus the installation and maintenance of the required diversion and conveyance facilities. The benefits of the project are simply provision of additional water to the grid which services households in the major population centers of the country. Rather than make assumptions about the potential costs of the project the approach taken here is simply to assume that additional water provided to the system is valued at $0.50/$m^3$ as elaborated above. Cost figures are then chosen that generate 15% (conservative projection) and 25% (optimistic scenario) rates of return. These are purely assumptions taken in the interest of the time available for this report and should not be taken to suggest that the project is, or is not, a beneficial use of economic resources. Rather the intent was to neutralize the potential impact that the project would have on the overall basin-wide analysis by assuming a reasonable set of positive returns to the project.

The parameters employed are provided in the table below. The results are provided by country in Section
5.5.

Table 18: Cost and Benefit Parameter Values for Domestic Water Supply

Value Parameters by Projection	Conservative	Optimistic
Investment Cost ($/c/served)		
Piped and Sewer	$222	$222
Standpipe	$48	$48
ENC-Medium ($/m3)	$3.80	$2.50
ENC-High ($/m3)	$2.10	$1.10
Maintenance Cost ($/c/served)		
Piped and Sewer	$13.88	$13.88
Standpipe	$0.31	$0.31
Benefits ($/c/yr)		
Angola		
Piped and Sewer	$10.63	$53.17
Standpipe	$2.05	$10.24
Namibia		
Piped and Sewer	$24.34	$81.12
Standpipe	$3.40	$11.33
Botswana		
Piped and Sewer	$40.56	$81.12
Standpipe	$5.66	$11.33

Notes: c stands for capita or per person

5.3 Hydropower

Currently there are no hydropower schemes in operation in the basin (Table 6). Each of the water withdrawal scenarios envisions a number of largely run-of-river hydropower projects as described further in the IFA (Beuster et al. 2009). These projects and their key parameters are summarized in Table 19). Power capacities were determined based on flow rate and height. As with the other projects the low withdrawal alternatives are developed from 2008 to 2013, the medium from 2013 to 2018, and the high from 2018 to 2028. Capacities and generation figures are taken as end of period figures and are considered to be phased in over the relevant period.

Investment costs, O&M costs and power benefits are the determinants of economic profitability (see Table 20). With no experience in the basin to pull from, not detailed feasibility work on each project, and with the site specific nature of any individual hydropower project industry figures for costs and benefits are employed as likely parameters for all projects, again employing a conservative and optimistic projection. The economic profitability of any individual project will depend on the site characteristics and, thus, the evaluation of alternatives merely provides an indication of how much net benefits the projects might generate. It is important to note that the investment costs employed do not include transmission and distribution systems for the power. Again, any particular site may be close to or far from conveyances and may serve populations that have or do not have an existing grid. For this reason the positive nature of economic returns under each of the two projections must be regarded as an upper bound. Clearly, having site feasibility studies and placing such project in the context of a power development plan would be ideal to further investigate the pros and cons of each project. But for the purposes of the basin-wide analysis the projections illustrate the potential order of magnitude that a set of such projects might have. The results are provided by country in Section 5.5.

Table 19: Hydropower Projects

Table 19.

Project	Power Generation (GWH/yr) Low	Medium	High	Qa (m3/s)	Height (m)	Capacity (MWs)
Angola						
Cuvango_HP	8.40	8.30	8.30	4	40	1.37
Liapeca_HP	21.60	21.50	21.50	24	16	3.76
Maculungungu	35.90	35.10	36.00	24	22	5.17
Malobas_HP	2.40	2.20	2.20	3	14	0.41
Mucundi_HP	159.10	148.50	155.50	70	40	27.44
Chamavera_HP	0.00	0.00	38.10	100	6	5.88
Cuito_HP	0.00	40.90	40.90	90	7	6.17
Cutato_HP	0.00	0.00	12.00	6	30	1.76
MPupa_HP	0.00	0.00	33.60	100	5	4.90
Menongue_HP	0.00	0.00	6.60	12	8	0.94
Rapides do Cuelei HP	0.00	0.00	11.50	8	22	1.72
Namibia						
Popa Site 2	0.00	0.00	96.70	280	8	20.58

Table 20: Hydropower Cost and Benefit Parameters

	Conservative	Optimistic
Price ($per Kwh)	$0.08	$0.10
Investment Cost ($/MW)	$3,000	$2,500
Maintenance Cost (% of IC)	5%	3%

5.4 Irrigation

At present there are just a few irrigation projects that withdraw water from the Okavango and its tributaries for irrigation. A large number of additional projects were identified as part of the IFA consultations. These can be classified by location, their extent in hectares, and the amount of water they are likely to withdraw (see Table 21 and

Table 22). If the full extent of the projects were developed then the extent of irrigation would go from 3,251 hectares to 352,981 hectares, a 100-fold increase. Water withdrawals under present conditions are estimated at just less than 50 million m3/yr. This would increase ten-fold to under 500 million m3 under the low water withdrawal scenario (by 2013), double again to 1,100 million m3 under the medium withdrawal alternative (by 2018), and increase another three times to 3,500 million m3/yr under the high withdrawal alternative (by 2028). As the IFA emphasizes these projects are not part of an approved development plan, but rather represent the compiling of a number of possible projects for the purpose of examining the impacts of changes to the flow regime on the social, economic and environmental conditions and values in the basin. This, as unlike, the water supply and sanitation projects, and the hydropower projects, large-scale development of the water resource for irrigation is at a scale that is significant relevant to the total overall basin yield. At peak development, the irrigation projects schemes listed here would withdraw 38% of mean annual volume for the basin of 9,209 million m3/yr.

Table 21: Irrigation Projects, Area

Table 21.

Project Name				Area Irrigated (Has)
	Present Day	Low (2013)	Medium (2018)	High (2028)
Angola				
Missombo	1,000	1,000	1,000	1,000
Kahenge	300	700	900	900
Cuchi		15,000	150,000	150,000
Ebritex		17,000	17,000	17,000
Menongue		10,000	10,000	10,000
Cuvango		-	10,000	10,000
Longa		-	10,000	10,000
Calai Dirico		-	-	35,000
Calais Dirico B		-	-	60,000
Cuangar Calai		-	-	45,000
Namibia				
Mukwe	560	560	560	560
Ndiyona	870	1,270	1,270	1,270
Rundu Mashare	521	551	551	551
Mukwe Future		-	4,000	10,600
Rundu Future		-	1,100	1,100
Totals	3,251	46,081	206,381	352,981

Table 22: Irrigation Projects, Water Withdrawals
Table 22.

Project Name	Water Withdrawn (million m3)			
	Present Day	Low (2013)	Medium (2018)	High (2028)
Angola				
Missombo	12.96	11.12	11.12	11.11
Kahenge	4.50	10.50	13.50	13.50
Cuchi	0.00	109.59	554.41	1020.34
Ebritex	0.00	189.06	188.99	188.82
Menongue	0.00	111.21	111.17	111.07
Cuvango	0.00	0.00	74.42	74.42
Longa	0.00	0.00	63.40	63.40
Calai Dirico	0.00	0.00	0.00	453.20
Calais Dirico B	0.00	0.00	0.00	776.91
Cuangar Calai	0.00	0.00	0.00	583.20
Namibia				
Mukwe	8.34	8.34	8.34	8.34
Ndiyona	13.05	19.05	19.05	19.05
Rundu Mashare	7.82	8.27	8.27	8.27
Mukwe Future	0.00	0.00	60.00	157.78
Rundu Future	0.00	0.00	16.50	16.50
Totals	46.67	467.14	1,129.17	3,505.91

Assessing the costs and benefits of these developments is fraught with the same difficulties – in terms of site specific assessment - expressed above for water supply and sanitation, and hydropower projects. As with hydropower projects, irrigation projects are prone to considerable potential variability in economic returns. With hydropower the upside potential is, however, more considerable. Large irrigation projects built in areas remote from major markets do not have this upside potential as they will typically end up producing food for local markets. Basic grains and foodstuffs tend to be the least profitable crops, in part because they are not as perishable as high value fruits and vegetables, and are well-commodified. Instead, irrigation projects have considerable downside potential, particularly if the works involved prove expensive compared to the net value of crops produced, or if large works (particularly dams) are built and the command area set aside for irrigation is not developed, or takes much longer than anticipated to development. The World Commission on Dams report suggests that irrigation projects in developing countries are particularly vulnerable to these problems, and hence, often produce economic returns that are far less than expected and that often do not even cover the cost of capital (WCD 2000).

In order to evaluate the possible direction and magnitude of these returns conservative and optimistic projections are developed for the projects (see

Given the above discussion the parameters employed here do not attempt to rely on farm models or project appraisal work. Rather – in a related FAO-funded venture – data was gathered from the academic and grey literature of economic studies of the net returns to water employed in irrigated agriculture. The global literature was reviewed, but with an emphasis on developing countries, and particularly those in Africa. A total of 52 datapoints suggested an average annual return of $0.24/m3. However, there is extreme variation between high value and low value crops. In the sample, nine datapoints for basic grains suggested an average of $0.02/m3, whereas fourteen studies of high value crops and rice came in at just over $0.30/m3. Breaking these out by region, lowers these values in the case of Asia and Africa. For Asia, nine datapoints for a mix of crops averaged $0.15/m3, while seven studies of rice and other grains came in at $0.07/m3. For Africa, fewer studies were found but seven studies of mixed crops averaged $0.15/m3. Based on this review a floor of $0.05/m3 was chosen for the conservative scenario and $0.15 for the optimistic scenario. In all likelihood, these are high estimates for the full expansion under the high water use withdrawal alternative.

The investment costs required for construction will vary with size of the project and distance from the river. Figures cited in EPSMO work and appraisal of recent projects in Africa were used to establish a range of these costs. An EPSMO document from Angola suggests these costs will vary from $15,000 to $25,000 per hectare depending on the type of project, with construction of projects greater than 100 hectares expected to cost $15,000 (EPSMO 2009). A couple of donor project appraisals in southern Africa suggest costs on the order of $7,000 to $10,000 per hectare. A range of $10,000/ha to $15,000/ha is used to capture this range. On the one hand the Angolan numbers seem quite high, but on the other it is typical for donor projects to understate project costs at appraisal (WCD 2000). The results of the analysis are presented by country in the next section.

Table 24). The parameters employed are net returns to the agricultural activity and the investment costs for developing the irrigation schemes. Review of similar projects in the region suggest that irrigation schemes are conceptualized in terms of two steps, the first being the construction of the scheme and the second being the recruitment of farmers to prepare the ground and then conduct annual farming operations. A quick review of available donor appraisal documents suggests that farming models are often used to evaluate the potential returns to irrigated agriculture. The models often indicate reasonable rates of return to the farmers. Similarly, academic studies of the net value of water in agricultural production typically show positive returns. These findings are not surprising as farmers would presumably not engage in irrigated farming if they could not produce net farm income with the help of the irrigation water.

The difficulty with using the results of farm models is that they assume that farmers will choose specific crops and will all operate at some pre-specified level of efficiency. Reality of course does not often run to plan, and irrigation schemes that fail to reach their full command area and farms that are abandoned are part of the history of irrigation expansion globally, but certainly in Africa. As referred to above, ex post (after the fact) evaluation work by major donor agencies shows that actual returns for irrigation are typically much lower than projected at appraisal (WCD 2000). A further issue is whether the farm models incorporate the associated costs of the project component in which the irrigation scheme is engineered and built. As, the irrigation water pricing literature pretty much assumes that the best that can be hoped is for irrigators to cover project O&M costs, this does not suggest that their are sizeable returns to cover both capital costs of the works and still provide necessary returns to the farm operation.

Given the above discussion the parameters employed here do not attempt to rely on farm models or project appraisal work. Rather – in a related FAO-funded venture – data was gathered from the academic and grey literature of economic studies of the net returns to water employed in irrigated agriculture. The global literature was reviewed, but with an emphasis on developing countries, and particularly those in Africa. A total of 52 datapoints suggested an average annual return of $0.24/m3. However, there is extreme variation between high value and low value crops. In the sample, nine datapoints for basic grains suggested an average of $0.02/m3, whereas fourteen studies of high value crops and rice came in at just over $0.30/m3. Breaking these out by region, lowers these values in the case of Asia and Africa. For Asia, nine datapoints for a mix of crops averaged $0.15/m3, while seven studies of rice and other grains came in at $0.07/m3. For Africa, fewer studies were found but seven studies of mixed crops averaged $0.15/m3. Based on this review a floor of $0.05/m3 was chosen for the conservative scenario and $0.15 for the optimistic scenario. In all likelihood, these are high estimates for the full expansion under the high water use withdrawal alternative.

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Table 23: Irrigation Project Cost and Benefit Parameters

Table 24. Irrigation Project Cost and Benefit Parameters		
	Conservative	Optimistic
Net Operating Benefits ($/m3)	$0.05	$0.15
Investment Cost ($/ha)	$15,000	$10,000

5.5 Summary of Economic Results

5.5.1 The Trade-off Analysis

The information and analyses explained in the prior section were then used to evaluate the potential economic consequences of future water withdrawals in the Basin under the different alternatives for water withdrawals. A summary of the parameters, data and assumptions is provide in This involved setting off the potential economic net benefits of increased water withdrawals – for municipal and domestic water supply, hydropower and irrigation – with the net change in economic benefits that results from the response to flow changes of ecosystem goods and services.

In this fashion the economic tradeoffs for each country of different levels of water withdrawals are made explicit. This is a preliminary analysis given the rudimentary information available on many of the water resource projects involved. Further work at the level of individual projects would provide a better basis for actually choosing beneficial projects to include in alternatives for water development and use. In order to cope with this limitation, conservative and optimistic projections regarding the economic profitability of water in each of the three levels of water withdrawals were employed based on literature review and secondary sources.

In the tradeoff analysis, the existing natural resource and tourism benefits garnered from the basin are denoted as ecosystem goods and services and the water supply and sanitation, irrigation and hydropower values are grouped as water resource developments.

Box 1. Summary of Macroeconomic Parameters and Assumptions

The analysis builds on where the IFA scenarios left off and develops an integrated set of costs and benefits over 40 years, as follows:

- the expected changes in direct economic contributions of natural resources in the Basin found in the IFA analysis are used to project future streams of costs and benefits over 40 years for different water withdrawal alternatives
- data from each country on population, population growth and existing sources of domestic water supply are used to develop low, medium and high intervention levels that reflect progressive
- implementation of improved water supply and sanitation (as opposed to the use of raw water from the river and boreholes).
- data from the IFA analysis on hydropower and irrigation projects is used to develop low, medium and high levels of infrastructure development for power production irrigation; existing sources of water supply are derived from available data and incremental improvements to water supply and sanitation are projected for low, medium and high levels of infrastructure development.
- the resulting low water withdrawal alternative assumes a limited set of developments that are completed in the first five years (i.e. by 2013); the medium water withdrawal alternative includes a more aggressive development schedule that includes additional projects that are implemented over the next five years (to 2018); and the high water withdrawal alternative includes a further set of projects implemented over the next 10 years (to 2028); in years 20 – 40, projects are maintained but no increase in population or projects is assumed
- benefit and costs were based on literature and project data from the region (and elsewhere as necessary) choosing conservative and optimistic projections for economic profitability as follows: (a) irrigation - net operating income of \$0.05 to \$0.015/m^3 for irrigation water and investment cost of \$15,000 to \$10,000/ha, (b) hydropower – revenue at \$0.08 to \$0.10/KwH, investment cost at \$3,000 to \$2,500/MW, and O&M costs at 5% to 3% of investment costs, (c) water supply and sanitation – benefits and costs for improvements are based on WHO studies.
- the streams of costs and benefits are discounted at 8% to arrive at present values for each sector by country (with 4% used for a low discount rate sensitivity analysis

5.5.2 Angola

For Angola, the analysis suggests the following outcomes:

Under the conservative projection, large and increasing economic losses of from $250 to $1,600 million are generated by the water resource developments. Hydropower generates increasing but modest net benefits of $60 to $100 million, and water supply and sanitation imposes net costs on the economy of from $5 to $85 million as the level of improved access is increased. Irrigation is a major drain on the economy posting $300 million in losses for the low water withdrawal alternative, growing to $1.6 billion under the high water withdrawal alternative. The conservative projection demonstrates the risk of investing in costly irrigation infrastructure – a likely prospect in an area remote from major markets and with poor soils.

Under the optimistic projection, water supply and sanitation generate increasing net economic benefits from low to high alternatives (in the $10 to $85 million range); the net benefits of hydropower double in value and irrigation benefits generate positive ranging from $300 million to $950 million, with the exception of the medium water withdrawal alternative where the large Cuchi scheme (at 150,000 has) reaches only half its proposed command area. Such failures to complete very large irrigation schemes, leaving stranded infrastructure costs are often observed. In this case under the medium water withdrawal alternative net benefits of just $38 million are generated on the back of $1.2 billion in investment.

The impacts of water withdrawal on Angolans reliant on the river for ecosystem goods and services is on the order of a loss of $30 to $50 million, reflecting the relatively small change in ecosystem function expected for upstream inhabitants of the basin (compared to that lower in the basin)

Investment costs for the water resource development projects can be expected to range widely from one alternative to the next (and with the projections), with investment costs for the low water withdrawal alternative of from $400 to $600 million and for the high withdrawal alternative from $1.7 to $2.6 billion.

Figure 5-1: Macro-economic trade-offs for different water withdrawals according to quantity of water diverted for Angola[1]

a) Conservative projection

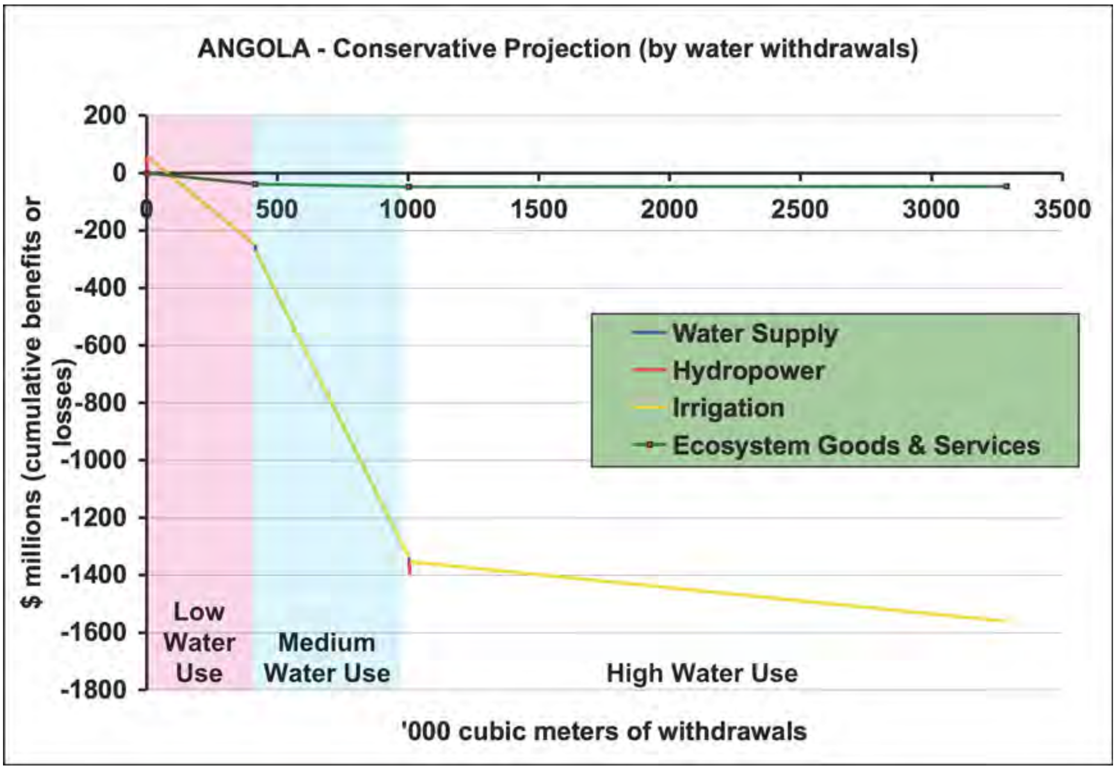
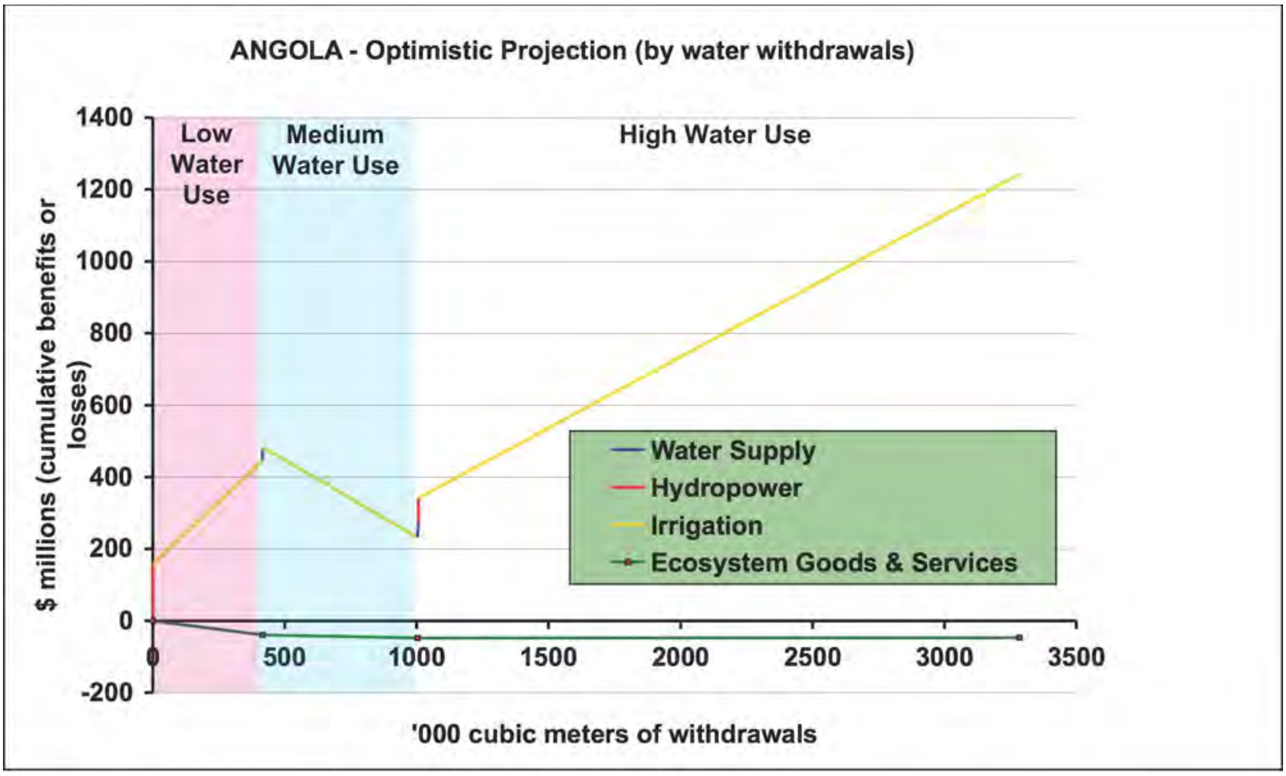


Figure 5- 1

Notes: Given that the analysis envisions further development that subsequently cause losses of ecosystem goods and 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, i.e. below the x-axis.

b) Optimistic projection



For Angola, the net benefits vary considerably by level of water withdrawal. Under the conservative projection net losses to the economy of $290 million for the low water withdrawal alternative are far exceeded for the medium and high alternatives at $1.4 and $1.6 billion respectively. The net losses are cut in half for the low alternative under the sensitivity analysis, but for the medium and high alternatives little change is noted in the large losses.

Under optimistic assumptions the picture improves substantially with net benefits ranging from $184 million to $1.2 billion. Prospects for economic returns from large areas devoted to irrigation are the principal drivers behind the differences for Angola between the conservative and optimistic projections. Employing the lower discount rate drastically increases these net benefits due to the large up front investment costs and the sizeable returns through year 40 of the analysis.

As the Angolan loss in ecosystem goods and services varies only slightly (around $10 million), between the levels of water withdrawal, the net benefits of water development would drive the choice of alternative projects. The wide range of potential benefits from the water developments highlights the importance of studying these projects more closely, as the economic risk of the proposed irrigation is significant.

5.5.3 Namibia

For Namibia, the analysis suggests the following outcomes:

Under the conservative projection, Namibia sees positive net benefits under the medium and high levels of water withdrawal for water supply and sanitation, with just minor losses and gains for the limited hydropower and irrigation efforts – overall the water developments provide little economic return under the low level of water withdrawal, growing to $60 million under the high level.

Under the optimistic projection, Namibia benefits even more greatly from improvements in water supply and sanitation – up to $230 million under the high level of water withdrawal, with hydropower and irrigation net benefits ranging from $6 to $90 million depending on the alternative.

The impacts of water withdrawal on the Namibian economy is considerable, particularly in terms of the loss of tourism revenues – losses of from $150 million to $190 million accrue as levels of water withdrawal proceed from low to high.

Investment costs for the water resource development projects will range widely from one alternative to the next, with maximum investment costs for low water withdrawal development of just $5 million and for the high withdrawal alternative up to $300 million (a large part of which would be associated with the ENC project).

Figure 5-2: Macro-economic trade-offs for different water withdrawals according to quantity of water diverted fro Namibia

a) Conservative projection

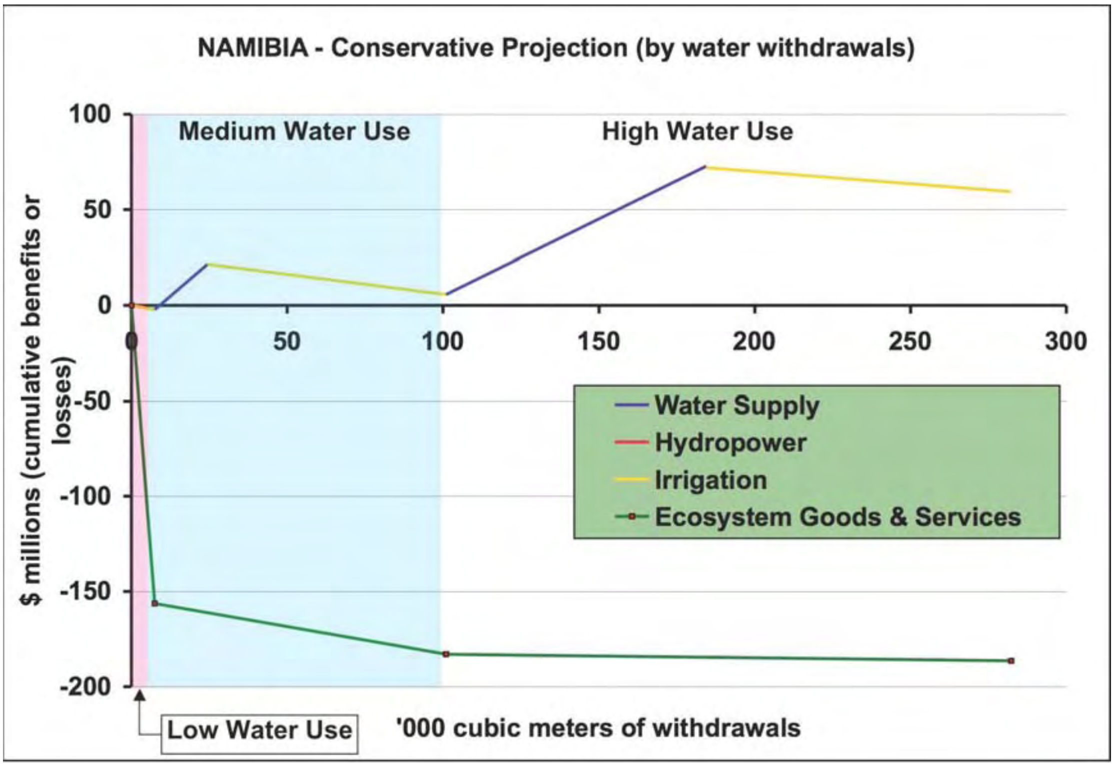
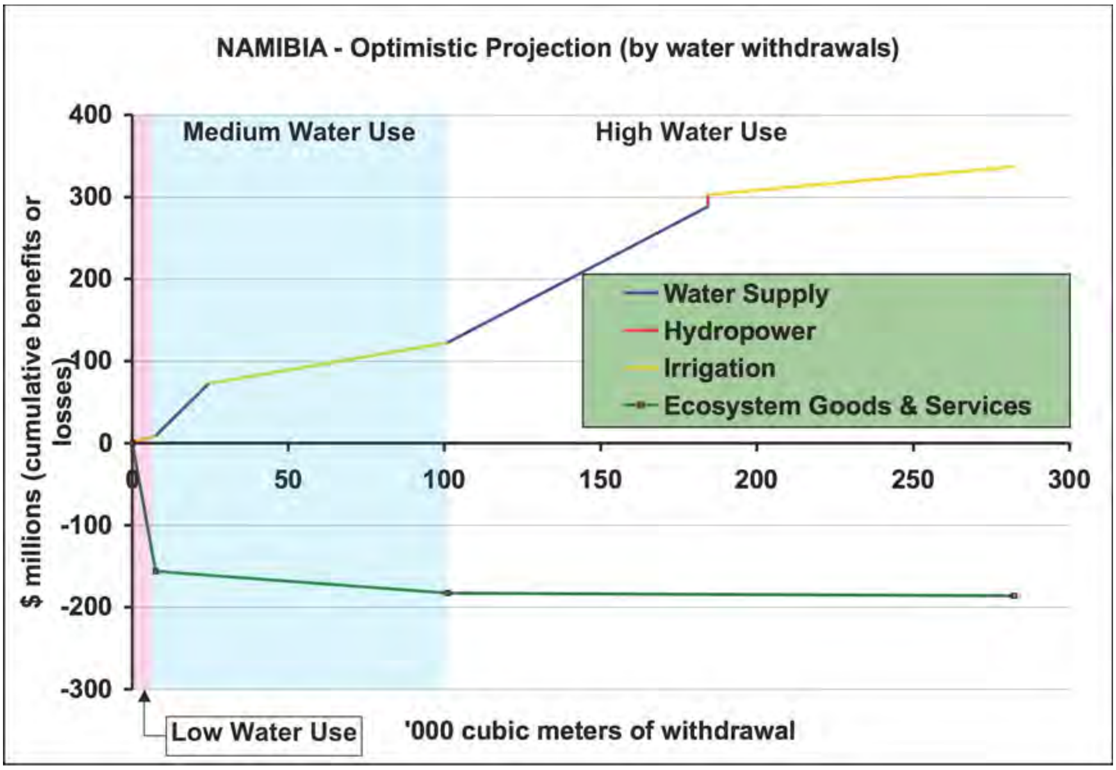


Figure 5- 2

b) Optimistic projection



Totaling up gains and losses, under the conservative projection all the alternatives generate large economic losses for the Namibian economy, of the order of $125 million to $175 million. The only bright spot are the water supply and sanitation benefits.

Under the low discount sensitivity analysis the water supply benefits and ecosystem losses increase significantly from the low to high levels, exaggerating the net losses under the low and medium levels of water withdrawal and exaggerating the positive water supply and sanitation returns under the high withdrawal alternative – leading this alternative to be break even at the 4% discount rate.

Under the optimistic projection net benefits remain negative under the low (-$150 million) and medium (-$60 million) alternatives, but positive returns for the country's economy are seen for high withdrawal levels (from $150 with the 8% discount rate to $530 million, with the lower rate).

Practically all the positive sectoral benefits in Namibia come from the water supply and sanitation, which is a negligible factor in causing the large ecosystem losses. Other things being equal, the optimal choice for Namibia would be to avoid the ecosystem losses and economic risks associated with major water withdrawals for irrigation, but move forward with improvements in water supply and sanitation.

5.5.4 Botswana

For Botswana, the alternatives analysis suggest the following outcomes

Under both conservative and optimistic projections Botswana sees positive net benefits from water supply and sanitation, implementation of the low water withdrawal alternative generates net benefits of the order of a few million dollars, while providing improved water supply and sanitation for all under the high water withdrawal alternative generates up to $55 million in net benefits (under the optimistic projection)

Ecosystem losses due to changes in harvesting and use of natural resources is of the order of $4 to $8 million, while losses from a precipitous decline in tourism revenues generates $500 million in losses under low water withdrawal on up to over $1,150 million in losses under the medium and high levels of water withdrawal.

Under the low discount sensitivity analysis, the water supply and sanitation net benefits and the ecosystem losses practically double in size exaggerating the net losses under all water withdrawal alternatives

Investment costs in the case of Botswana are limited to that of water supply and sanitation and vary from a million dollars through $25 million depending on the level of improvements and the population served.

For Botswana, then, the impacts of all three levels of water withdrawal is hugely negative, from a loss of $500 million for the low water withdrawal to a loss of the order of $1,150 for the medium and high water withdrawal. Botswana would clearly be better off without the upstream development of irrigation, which the IFA analysis shows will have devastating impacts on tourism in the Delta and the Delta economy.

Figure 5-3: Macro-economic trade-offs for different water withdrawals according to quantity of water diverted for Botswana

a) Conservative projection

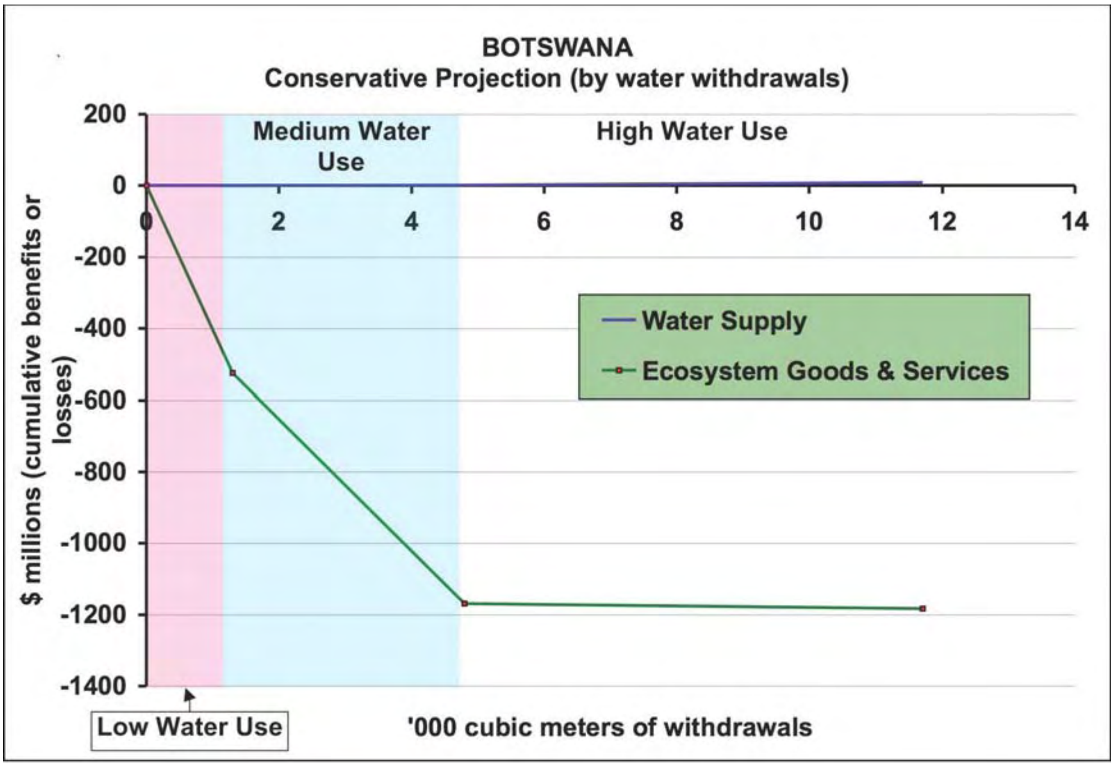
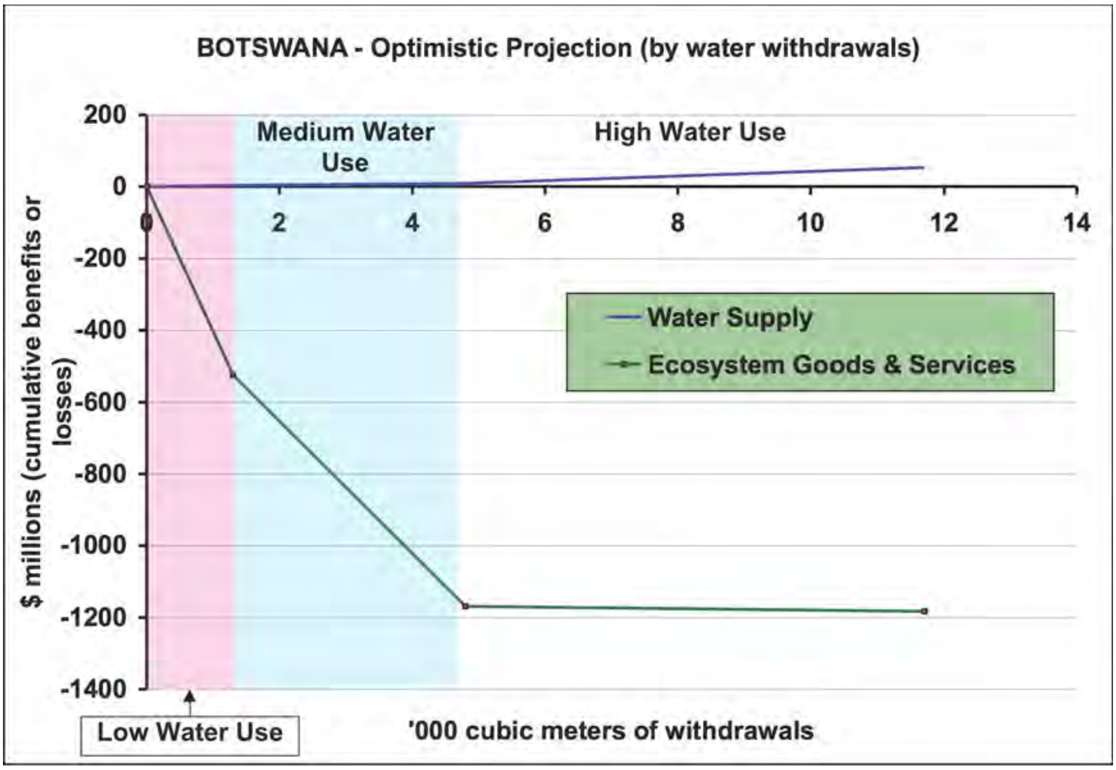


Figure 5- 3

b) Optimistic Projection



5.5.5 A Basin Perspective

The analysis above suggests that the potential large ecosystem losses faced by the downstream riparian countries are from $700 million for the low levels of water withdrawal through $1.4 billion for the medium and high water withdrawal levels. Under conservative assumptions regarding the profitability of irrigated agriculture these losses may double in size under the large expansion of irrigated area expected under the medium and high water withdrawal alternatives. Under optimistic assumptions the net returns remain negative under the low (-$260 million) and medium (-$1 billion) alternatives. Only, with the full implementation of the large Cuchi irrigation scheme do net returns generate positive returns (of $215 million) under the optimistic projection. However 60% of the positive returns under this alternative come from water supply and sanitation, and hydropower. Measured in terms of net benefits to irrigation and the resulting ecosystem losses from the large increase in water consumed, the net impact of irrigation may be a loss of half a billion dollars to the basin. These results occur prior to taking into account any willingness to pay for the continued existence of the Okavango Delta as a Ramsar Site.

Figure 5-4: Macro-economic trade-offs for different water withdrawal alternatives from a Basin Perspective

a) Conservative Projection (by water withdrawal)

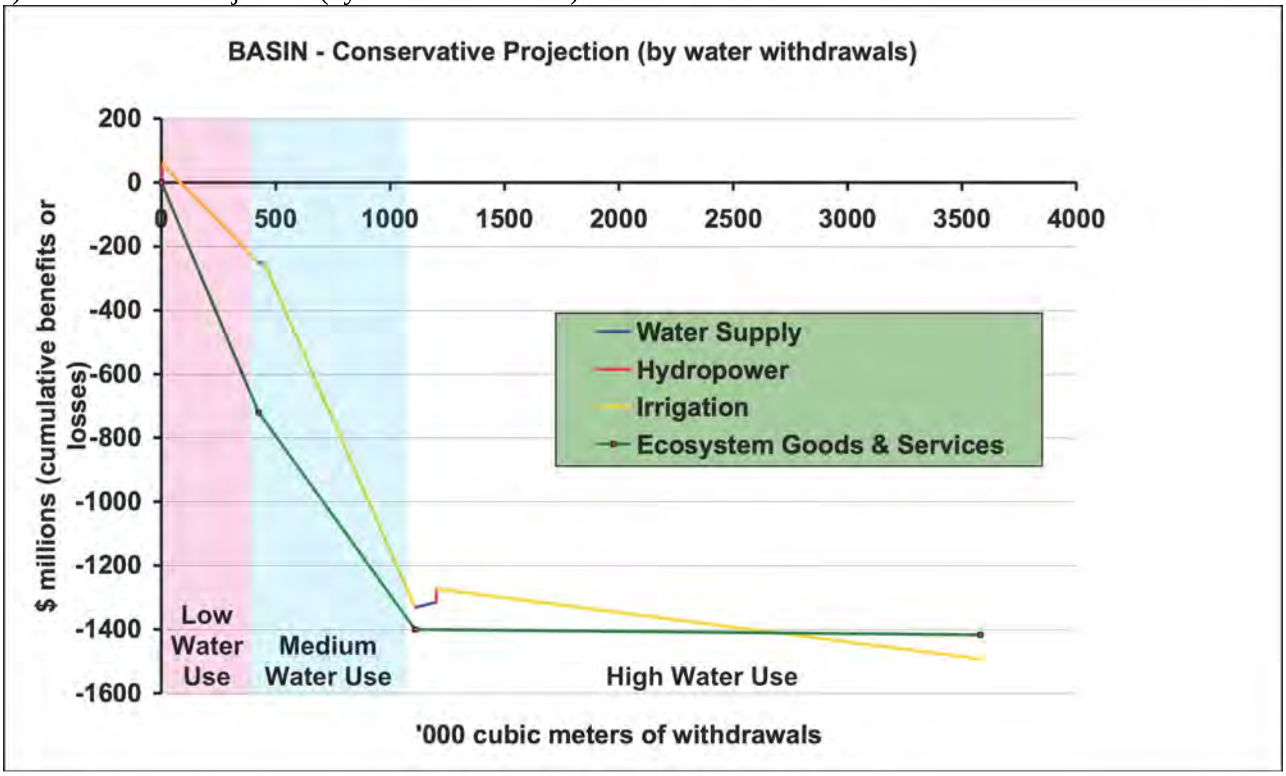
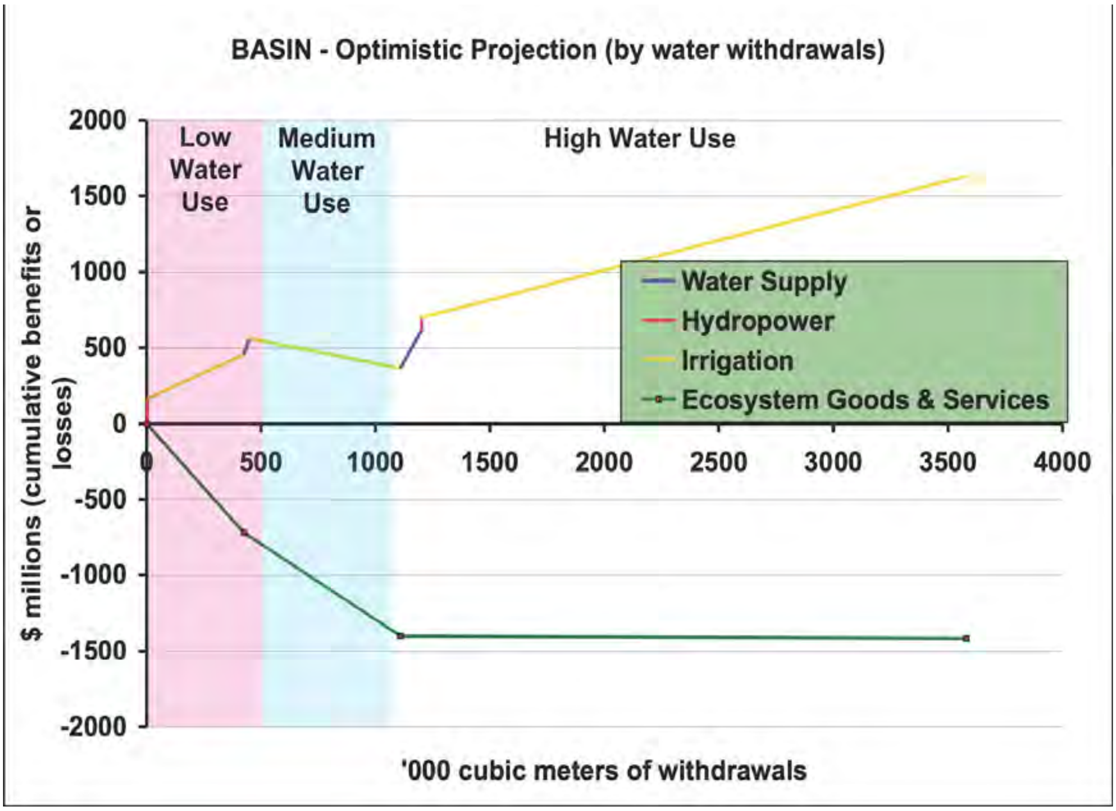
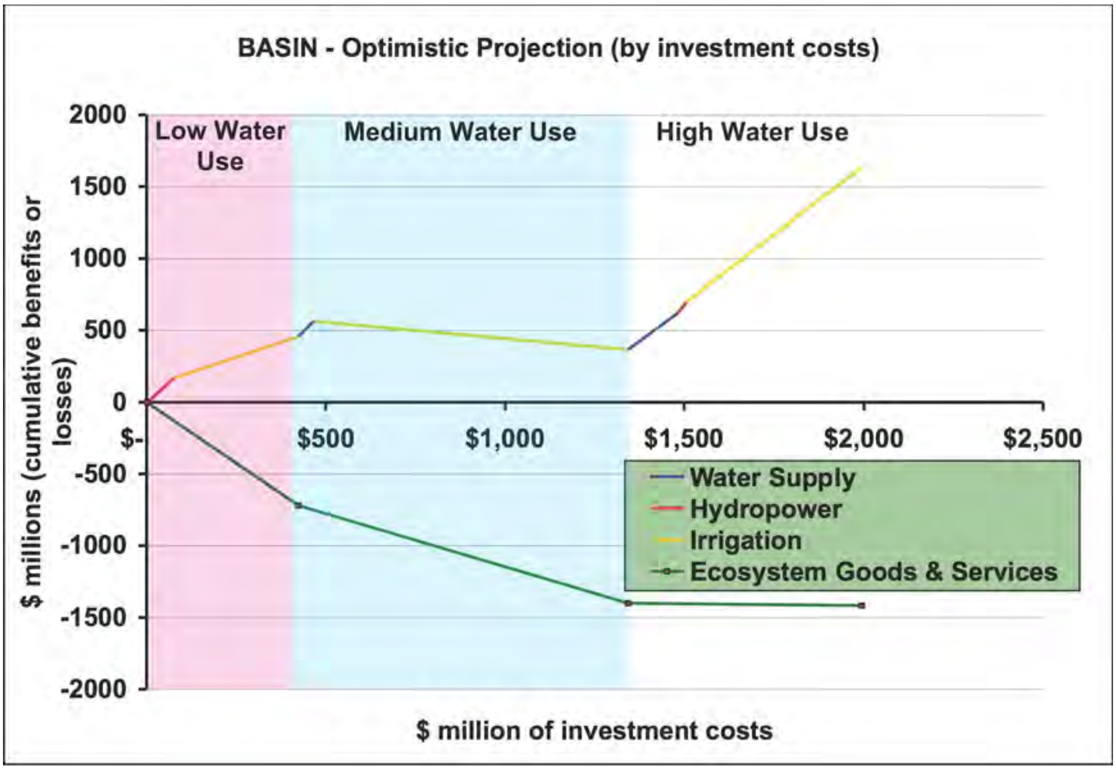


Figure 5- 4

b) Optimistic Projection (by water withdrawal)



b) Optimistic Projection (by investment costs)



In sum, prospective water withdrawals generate an order of magnitude of economic losses and risk such that they overwhelm the potential benefits of the full suite of water resource developments as implemented across all three countries.. From a basin-wide perspective then, caution and further study is called for before proceeding with the alternative projects given that these developments might not produce "optimistic" results (collectively or individually) and given the now-documented risk that such developments might result in substantial economic loss of ecosystem goods and services.

Despite the overall note of caution, the analysis above does clarify a few key findings that should be considered in future development planning:

- the provision of improved water supply and sanitation requires relatively small amounts of water to be extracted from the system and therefore may be judged and promoted based on its contribution to human well-being and socio-economic development (and not linked to the loss of ecosystem goods and services) within the scope of national development plans and budgets
- the hydropower schemes considered here are run of river schemes and will also not have a significant impact on downstream ecosystems and, therefore, may be considered purely within the context of the planned development of the Angolan and Namibian power sector plans (and not linked to the loss of ecosystem goods and services). Sediment discharge through such schemes would be a major issue to be resolved.
- the cumulative impact of the irrigation schemes suggested under the medium and high levels of water withdrawal generate the vast majority of the economic losses in terms of ecosystem goods and services. For this reason it may be best to contemplate only limited development of economically sound irrigation projects while simultaneously exploring further development of realistic alternative sources of income generation that have low water withdrawals – such as wildlife and tourism

The next step in planning is to consider how the existing water economy – one producing important ecosystem goods and services – can work to ensure its continued existence. That the most promising future economic path for the basin is one of low water withdrawal does not resolve the current asymmetry in levels of development and economic opportunity between riparian countries. One potential tool in this regard would be to leverage the considerable international goodwill that would be generated by assuring the protection of the Okavango Delta as a functioning (if not pristine) wetland of international importance under the Ramsar Convention. While not explicitly covered in the analysis above, studies have shown significant willingness to pay on behalf of the international (and local) community for the conservation of unique ecosystems, including wetlands. Arguably, the Okavango Delta is not just a jewel of the Kalahari but a gem of great value to people around the world.

5.5.6 Comparing sustainable development, stagnation and high water withdrawal paths

The alternatives considered above, assume a continued progress of economic development. However, under an economic stagnation scenario, such as may be envisaged with continued global recession, populations in the basin continue to grow but investment resources to pursue low water withdrawal 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. As populations are projected to continue growing this leaves increasing numbers of people in the basin without access to improved water supply; and the basin will have to import or find alternative sources of food and electric power to underpin basin development.

This situation compares poorly with indicators derived from the high levels of water withdrawal.

Presents extent of water developments through 2028. In the high water withdrawal alternative substantial gains are made in these indicators, particularly in Angola and Namibia. For example, new hydropower projects in these two countries could supply up to 2.4 million Angolans and 62,000 Namibians with electric power (at current national average consumption levels). If projections for 2028 were made at current national average consumption levels for South Africa (considerably higher than current levels in the basin) these hydropower projects would produce enough power for 100,000 people or 7% of the basin's expected population in 2028. The large extent of irrigation development contemplated under the high water withdrawal alternative would likewise greatly improve food production in Angola and Namibia. For low meat diets (roughly approximating consumption levels for sub-Saharan Africa) these irrigation schemes would make Angolan and Namibian portions of the basin self-sustaining in caloric terms. Even if the proportion of meat shifted by 2028 to reflect higher meat diets, these projects might greatly increase food self-sufficiency. Again, these projections are limited by significant assumptions about the uptake and profitability of these schemes. If they do not perform well, these benefits would be greatly reduced.

The stagnation and high water withdrawal alternatives may also be compared to a sustainable development alternative. Under this alternative the linkages between water withdrawal and the triple bottom line is recognized and a more discerning, moderate level of water withdrawal is pursued. In this case, the medium water withdrawal alternative for domestic water supply and hydropower is combined with the low water withdrawal alternative for irrigation. The results suggest that significant gains in social and economic development can occur in the basin without the need to put the Okavango Delta and the Namibian and Botswana basin economies at risk. Under the sustainable development alternative some 82% of the population receives access to improved water supply as compared to 13% under a stagnation scenario (Table 27). The difference between the two scenarios would simply be that a much larger proportion would be on the less expensive community standpipe systems – which in turn would lead to lower water withdrawals (40% less in fact).

With the sustainable development alternative, less hydropower and irrigated food would be produced in Namibia and Angola, however the tradeoff would be the maintenance of the sizeable wildlife tourism economies in Namibia and Botswana.

Hydropower production would be constrained but still provide Angolans with twice the national average consumption (down from almost three times under the high water withdrawal alternative). If per capita consumption levels are assumed for the basin in 2028 that match today's consumption levels for South Africa the percent of basin consumption supplied under these two alternatives are 7% (high withdrawal) and 4% (sustainable development) respectively. In other words, even under the high water withdrawal alternative the amount of power provided from the river is fairly limited in absolute terms.

It is with respect to food production that the two alternatives show the most difference. Using the low meat consumption figures, moving to the sustainable development alternative lowers the percent of basin food requirements provided by irrigation from 400% to 53%. While this is a large drop it still indicates that with only limited irrigation expansion (and limited water withdrawal) irrigation can provide almost half of basin requirements. This is a significant improvement over the status quo where irrigation meets only 5% of the need. Obviously, rain-fed agriculture and imports to the basin provide the bulk of current food supply and would maintain an important role under a sustainable development alternative..

Table 24: Comparison of Per Capita Indicators for Different Basin Development Alternatives

Table 24. Comparison of Per Capita Indicators for different Basin Development Alternatives

Country	Angola	Namibia	Botswana	Totals
Basin Population - 2005	505,180	219,090	157,690	881,960
Basin Population - 2025	860,706	295,081	212,385	1,368,172
Growth Rate	2.7%	1.7%	1.5%	
Status Quo – Stagnation Alternative				
Water Supply				
People Accessing Improved Water Supply	-	64,668	112,274	176,942
Hydropower				
People Served	-	-	-	-
Irrigation				
Lands Irrigated (has)	1,300	1,951	-	3,251
Water Withdrawals (m m3)	17	29	-	47
People Fed (low meat)	27,282	45,635	-	72,917
People Fed (high meat)	13,431	22,466	-	35,898
High Water Withdrawal Alternative				
Domestic Water Supply				
Water Withdrawn	20	15	5	40
People Accessing Improved Water Supply	683,774	242,479	193,769	1,120,023
Hydropower				
Annual Production (GWh)	367	97	-	464
People Served (at current consumption)	2,404,145	62,589	-	2,466,734
People Served (at current RSA levels)	76,362	20,104	-	96,466
Irrigation				
Lands Irrigated (has)	338,900	14,081	-	352,981
Water Withdrawals (m m3)	3,296	210	-	3,506
People Fed (low meat)	5,149,959	328,021	-	5,477,980
People Fed (high meat)	2,535,364	161,487	-	2,696,852
Sustainable Development Alternative				
Domestic Water Supply				
Water Withdrawn	13	7	3	22
People Accessing Improved Water Supply	683,774	242,479	193,769	1,120,023
Hydropower				
Annual Production (GWh)	257	-	-	
People Served (at current consumption)	1,680,873	-	-	1,680,873
People Served (at current RSA levels)	53,389	-	-	53,389
Irrigation				
Lands Irrigated (has)	43,700	2,381	-	46,081
Water Withdrawals (m m3)	431	36	-	467
People Fed (low meat)	674,186	55,713	-	729,899
People Fed (high meat)	331,907	27,428	-	359,335

Note: People served with electric power is based on national averages, with Namibia and Botswana at 10 times the Angolan level and RSA (South Africa) at 3 times the Namibian and Botswana levels.

Table 25: Percentage of the population served under different Basin Development Alternatives

Population Served (as percent of total population)				
Country	Angola	Namibia	Botswana	Totals
Satus Quo - Stagnation				
Improved Domestic Water Supply	0%	22%	53%	13%
Hydropower - Electric Power	0%	0%	0%	0%
Irrigation - Food Production (low meat)	3%	15%	0%	5%
Irrigation - Food Production (high meat)	2%	8%	0%	3%
High Water Withdrawal Alternative				
Improved Domestic Water Supply	79%	82%	91%	82%
Hydropower - Electric Power (current levels)	279%	21%	0%	180%
Hydropower - Electric Power (RSA levels)	9%	7%	0%	7%
Irrigation - Food Production (low meat)	598%	111%	0%	400%
Irrigation - Food Production (high meat)	295%	55%	0%	197%
Sustainable Development Alternative				
Improved Domestic Water Supply	79%	82%	91%	82%
Hydropower - Electric Power (current levels)	195%	0%	0%	123%
Hydropower - Electric Power (RSA levels)	6%	0%	0%	4%
Irrigation - Food Production (low meat)	78%	19%	0%	53%
Irrigation - Food Production (high meat)	39%	9%	0%	26%

6. Investment in the Presence of Uncertainty, Irreversibility and Choice of Timing

6.1 Analytical Framework

While the development of water resources can be positive for a country's socio-economic development it is important to heed the advice of the World Commission on Dams (see Box 1) and other major assessments that suggest caution and forethought before moving forward with such developments – given the potential of failing to realize hoped for economic benefits and incurring negative social and environmental impacts.

It is therefore useful to create an overarching framework into which the information about the alternatives for water resource development can be placed for comparison and evaluation. As experienced in the evaluation above, information on the economic costs and benefits of these options will be partial in nature due to a lack of data on some values and the imprecise nature of some of the estimated impacts that can be provided. As an example, the understanding of the relationship between changes in flow timing and volume, and ecosystem net benefits can only be approximately judged and is anyway based on alternatives that consist of large intervals in water use. While these serve the purposes of broadly illustrating the economic choices that confront the riparian countries over the long-term for the purposes of the TDA, they may not be wholly satisfactory as the basin continues to grapple with how it should develop.

In other words, the quantitative assessment will be useful in providing what information there is on the economic costs and benefits but will leave a number of questions unanswered. One way to address this problem is to take this information and incorporate it into a more qualitative analysis that directly addresses the uncertainties in the data and the missing information. In standard economic cost-benefit analysis sensitivity and risk analysis can be used to determine how the results of a project analysis respond to a number of key variables. While this is useful it remains reliant on the quantitative estimates, and therefore cannot really move much beyond the data limitations, particularly when these are significant.

For this reason a second, qualitative, framework could be applied to the information generated in the course of conducting the quantitative analysis. Beyond standard project appraisal methods there exists a more robust consideration of the investment environment, an environment that includes not only uncertainty, but the potential irreversibility of financial investment and its consequences (e.g. social and environmental impacts). Further, real world decisions are not "now or never" but involve a choice of timing of investment. Dixit and Pindyck (1994) provide an innovative and comprehensive application of the use of modern options theory to investment decisions involving issues of uncertainty, irreversibility and timing. The intent of the remainder of this section is to reiterate the general theory and arguments advanced by these authors and indicate the potential relevance of the theory and methods to water resources development as first laid out in the Economics Thematic of the World Commission on Dams (Aylward et al. 2001). So first material from Aylward et al. (2001) is repeated below to lay out the theoretical framework and then a rough sketch of how the approach could be applied to the Okavango case is provided. Bear in mind that the reference to NPV (or net present value) is roughly equal to the metric of net value added employed above for the quantitative analysis. The latter is more relevant to calculations of national income but is effectively the same as NPV as it emerges from microeconomic project analysis.

6.2 The Theory and Argument: The Incompleteness of CBA in the Presence of Uncertainty, Irreversibility and Choice of Timing

According to conventional theory and practice, a positive expected net present value (NPV) returned by economic or financial CBA tells the investor to go ahead with an investment. Dixit and Pindyck (1994) describe two hidden assumptions that underpin this approach. The NPV rule assumes that one of two cases apply. In the first case, the investment is reversible insofar as the investor can exit from the investment and recover the expenditure if the future (i.e. market conditions) turns out worse than expected. In the second case, the NPV rule assumes that if the investment is irreversible that there is no choice of timing, i.e. the investment is a “now or never” proposition. Not only do most investment decisions of course not fulfil either of these assumptions, but irreversibility and the possibility of postponing investment are very important characteristics of investments faced by firms and by society.

As indicated above the “simple” net present value rule does not account for the ability to delay an irreversible investment. The value of delaying investment is equivalent to holding an “option” to invest – the right but not the obligation to invest – and, thus, can be called an option value (analogous to a financial call option). When an irreversible investment is made the investor exercises the option, or, in so many words “kills” the option. At this point the investor has effectively given up the opportunity to wait for additional information, i.e. to reduce the uncertainty over the present worth or timing of the expenditure. The central point made by Dixit and Pindyck (1994) is that the decision to go ahead with the investment implies the loss of this option value. This is an opportunity cost of the decision to proceed with the project that standard CBA does not count. Thus the NPV rule needs to be reworked so that the decision to invest is taken only when the benefits of the investment exceed the standard costs of investment plus the value of keeping the option alive.

Dixit and Pindyck (1994) suggest that the opportunity cost represented by the value of an option to invest will be very sensitive to uncertainties, such as the risk and uncertainty of realizing future cash flows. Given that the growing literature on these options values shows that they can “profoundly affect” the decision to invest, they argue that these uncertainties may therefore be better at explaining variation in investment behavior than variables such as interest rates. They also find that this may explain the large gap between private sector “hurdle rates” and the cost of riskless capital – thus explaining why firms tend not to invest until prices are well over long-run average costs (as conventionally measured) and why they do not exit immediately upon prices falling under this level. Instead, there is an area of profitability the upper and lower threshold of which must be exceeded for entry and exit, respectively, to occur. This phenomenon, whereby investment decisions fail to reverse themselves when the underlying causes are fully reversed is called economic hysteresis (Dixit and Pindyck 1994).

Dixit and Pindyck (1994) suggest that this advance in thinking undermines the theoretical foundation of standard neoclassical investment models. The authors, however, do not seek to overturn the analysis of costs and benefits of a decision, but rather to expand the notion of costs and benefits to include the option value associated with uncertainty and irreversibility. In other words this is another case of standard CBA omitting another type of value. Indeed, there is a somewhat parallel stream of thought in the environmental economics literature which posits the existence of a “quasi-option value” that is associated with the irreversible decision to develop an environmental resource under uncertainty. The general methodological implications of this are as follows:

> . . . the implication, however is *not* the overthrow of marginal analysis. Just because and action is irreversible does not mean that it should not be undertaken. Rather, the effect of irreversibility is to reduce the benefits, which are then balanced against costs in the usual way . . . the point is that the expected benefits of an irreversible decision should be adjusted to reflect the loss of options it entails (Arrow and Fisher 1974: 319).

In terms of the application of these ideas it should be clear that they are not only useful in evaluating a particular investment but in comparing alternative investments or, more simply, alternative courses of action. Clearly, the characteristics of a given alternative in terms of its flexibility of timing, its degree of reversibility and its level of uncertainty will affect the option value associated with the decision to invest or not at the present time.

Both types of literature – the financial investment literature and the environmental economics literature on quasi-option value – emphasize the dynamic nature of uncertainty and information. For the purposes of valuation it is not simply the degree of uncertainty that is important but how it will change over time. Other things equal the more uncertainty associated with an alternative, the more it will pay to postpone the decision. However, if uncertainty is unlikely to be resolved over the relevant decision period then this will also affect the value of the option. In the case of a financial option one of the determinants of the value of the option is the expected volatility of the price of the underlying asset (such as a stock). If there will be no “news” that will affect the stock price during the option period then there is, implicitly, no expected volatility and the value of the option will be zero. Thus, if there is no additional information expected over the relevant period about the timing of the decision that will “reduce” the uncertainty then the value of postponing the decision over that period will be marginal. On the other hand, the theory suggests that where additional information will become available as to the profitability of the intended course of action, the most economically sound strategy may be to “wait and see.”

6.3 Application to Water Resource Development

The fairly obvious first point to make regarding how relevant these ideas are to water resources development is that large infrastructure projects such as dams, irrigation schemes, hydropower projects and water supply and sanitation systems, are a case of an irreversible financial investment. Dixit and Pindyck (1994) indicate that investment expenditures are sunk costs – and hence irreversible – when they are firm or industry specific. In other words, once infrastructure is built it has little value for alternative uses or in terms of salvage value. For example, as physical structures and equipment, a large dam that cannot fulfill its purpose will have a very low salvage value. Further consideration is required in the case of dams that are multi-purpose or that have the potential for multi-purpose use. A hydroelectric reservoir built in an area with little to no irrigation potential could be said to be industry specific. However, in the case of a multi-purpose facility a fall in the price of agricultural prices leading to a decline in irrigation demand may lead to a switch in water use from irrigation to power generation. Thus, reversibility must be carefully interpreted with respect to the financial investment in the specific type of infrastructure, but many of these investments will certainly have strong characteristics of irreversibility in this regard.

In addition to the infrastructure itself, it should also be clear that there are a series of social and environmental impacts of construction and operation of water projects that exhibit irreversibility. For example, in the case of a dam, the negative impacts of resettlement, flooding of reservoir land, biodiversity and upstream/downstream ecosystems will be regarded as having irreversible characteristics. An irreversible decision can be characterized as one that "significantly reduces for a long time the variety of choices that would be possible in the future" (Henry 1974). Whether the same statement can be made of the environmental and social benefits generated by water projects like massive extraction of water for irrigation requires further consideration. Key questions would be to what extent do the benefits and costs disappear or persist once the project is removed. Relevant here is that ecosystems are not easily or quickly regenerated, nor is social cohesion.

With regard to decommissioning of projects it is also worth pointing out that the implications of the hysteresis argument. Once the irreversible decision is taken and investment made, the activity may have to fall to a lower than expected profitability before the investment is abandoned. Here again the option to exit carries with it an option value that reflects the benefit of waiting. In this case the option to "sell" is analogous to a put option in financial terms. Decommissioning of a dam, for example, is irreversible and is characterized by a high degree of uncertainty. The debate over the likelihood that the decommissioning of the Lower Snake dams (in the US) will bring back the salmon runs is indicative of this uncertainty. Thus, even if a dam is unprofitable the operator may wish to wait before exiting the activity as waiting may provide additional information that resolves uncertainty regarding the future profitability of the enterprise. In this case then, the option value provides an extra incentive (above and beyond the standard CBA result) not to exit the activity. The possibility of being stuck in an unproductive investment may need to be worked into the decision to invest in the first place. How these issues play out for different types of water infrastructure projects is unexplored.

So the construction of large water infrastructure projects may involve both a large financial investment and a significant divestiture of environmental and social assets. In terms of uncertainty, there are clearly uncertainties and risks associated with the financial investment as highlighted in previous sections of this paper, but it is probably fair to say that the uncertainties are significantly larger when it comes to the social and environmental divestiture. Thus, it is clear that the argument made by Dixit and Pindyck (1994) warrants further exploration in the case of these projects. It may therefore be valuable to apply this framework in a qualitative fashion to the Okavango case. It is expected that such an approach to explicit consideration of the uncertainties, irreversibilities and timing issues involved will sharpen and quite possibly greatly expand on the conclusions that are drawn from the quantitative analysis.

As is stated in Aylward et al (2001):

> The application of the theory of investment under uncertainty and irreversibility to dams, and to water resources development more generally is novel at this stage. Further investigation is needed to determine the applicability of these ideas to the project planning and evaluation process. Still, it seems likely that at least the insertion of a qualitative discussion and analysis of different alternatives in this regard may be useful at an early stage in the screening and ranking of projects.

Indeed, it is possible to argue that stakeholder discussion of different scenarios for water and energy resources development should include these issues in an explicit fashion, given that they may have significant bearing on the CBA outcomes.

In terms of specific areas for further investigation, it would be worth considering the extent to which, in practice, the passage of time is likely to significantly reduce the uncertainty about future values of the irreversible investments and divestitures associated with different options, particularly the environmental and social impacts. Attention should examine how the costs and benefits of investments may differ in terms of irreversibility, uncertainty and timing. The objective here would be to see if the different components of the alternatives under consideration are likely to have the same characteristics in this regard and, thus, can be bypassed or whether important differences between alternatives are expected and should be accounted for in the decision process.

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The Okavango River Basin Transboundary Diagnostic Analysis Technical Reports

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

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

Final Study Reports	**Reports integrating findings from all country and background reports, and covering the entire basin.**		
		Aylward, B.	*Economic Valuation of Basin Resources: Final Report to EPSMO Project of the UN Food & Agriculture Organization as an Input to the Okavango River Basin Transboundary Diagnostic Analysis*
		Barnes, J. et al.	*Okavango River Basin Transboundary Diagnostic Analysis: Socio-Economic Assessment Final Report*
		King, J.M. and Brown, C.A.	*Okavango River Basin Environmental Flow Assessment Project Initiation Report (Report No: 01/2009)*
		King, J.M. and Brown, C.A.	*Okavango River Basin Environmental Flow Assessment EFA Process Report (Report No: 02/2009)*
		King, J.M. and Brown, C.A.	*Okavango River Basin Environmental Flow Assessment Guidelines for Data Collection, Analysis and Scenario Creation (Report No: 03/2009)*
		Bethune, S. Mazvimavi, D. and Quintino, M.	*Okavango River Basin Environmental Flow Assessment Delineation Report (Report No: 04/2009)*
		Beuster, H.	*Okavango River Basin Environmental Flow Assessment Hydrology Report: Data And Models(Report No: 05/2009)*
		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*
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Tel +267 680 0023 Fax +267 680 0024 Email okasec@okacom.org www.okacom.org
PO Box 35, Airport Industrial, Maun, Botswana