Rapid Assessment – Final Report

Integrated Water Resources Management Strategy for the Zambezi River Basin

SADC-WD/Zambezi River Authority
SIDA, DANIDA, Norwegian Embassy Lusaka

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List of abbreviations and acronyms

Ag	Silver
ARA	Regional Water Administration (Mozambique)
As	Arsenic
Au	Gold
BOD/ BOD5	Biological Oxygen Demand/ Biological Oxygen Demand, 5 days method
BRIC	Brazil, Russia, India, China
CBNRM	Community Based Natural Resources Management
CEO	Chief Executive Officer
Co	Cobalt
COD	Chemical Oxygen Demand
CP	Cooperating Partners (SIDA, DANIDA, NORAD)
CPNC	National Committee for Civil Protection (Angola)
Cr	Chromium
Cu	Copper
DANIDA	Danish International Development Agency
DMU	Disaster Management Unit (Malawi)
DNA	National Directorate of Water (Angola, Mozambique)
DPA	Provincial Directorate of Water (Angola)
DWA	Department of Water Affairs (Botswana, Zambia)
DWAF	Department of Water Affairs and Forestry (Namibia)
E_a	Actual evapotranspiration
ECZ	Environmental Council of Zambia
EFR	Environmental Flow Requirements
ET_0	Potential evapotranspiration
F	Fluorine
f (…)	Function of …
FAO	Food and Agriculture Organisation of the United Nations
Fe	Iron
FEWS Net	Famine Early Warning System Network
FFEM	Fonds Français pour l'Environnement Mondial
FRIEND	Flow Regimes from International Experimental and Network Data
GDP	Gross Domestic Product
GHCN	Global Historical Climatology Network
GIS	Geographical Information System
GPWv3	Griddled Population of the World, version 3
GRUMP	Global Rural-Urban Mapping Project
HCB	Hydroelectrica de Cahora Bassa
Hg	Mercury
HQ	Head Quarters

I	Water Imports
ICB	Institutional Capacity Building
ID	Identification
INGC	National Institute for Disaster Management (Mozambique)
IRR	Internal Rate of Return
IUCN	The World Conservation Union
IWRM	Integrated Water Resources Management
MAR	Mean Annual Runoff
MAWF	Ministry of Agriculture, Water and Forestry (Namibia)
MDG	Millennium Development Goal
MEA	Ministry of Energy and Water (Angola)
MEWD	Ministry of Energy and Water Development (Zambia)
MIWD	Ministry of Irrigation and Water Development (Malawi)
MMEWR	Ministry of Minerals, Energy and Water Resources (Botswana)
Mn	Manganese
Mo	Molybdenum
MOPH	Ministry of Public Works and Housing (Mozambique)
MoU	Memorandum of Understanding
MRD	Water Resources Department (Malawi)
NA	Not analysed
NDMO	National Disaster Management Office (Botswana)
NDVI	Normalized Difference Vegetation Index
NGO	Non-Governmental Organisation
Ni	Nickel
NO3	Nitrate
NORAD	Norwegian Agency for Development
NPK	Nitrogen, Phosphorus, Potassium
NSC	National Steering Committee
OPPPI	Office for Promoting Private Power Investment, MEWD (Zambia)
P	Precipitation
Pb	Lead
Pd	Palladium
PIU	Project Implementation Unit
PMC	Project Management Committee
PRB	Population Reference Bureau
PSC	Project Steering Committee
Pt	Platinum
R	Runoff
RSAP	Regional Strategic Action Programme
RWP	Regional Water Policy
SADC-WD	Southern Africa Development Community – Water Division
SARDC	Southern Africa Research and Documentation Centre
Sb	Antimony
SB	Sub Basin
SEBAL	Surface Energy Balance
SGAB	Swedish Geological AB
SIDA	Swedish International Development Agency
Sn	Tin

SP	Stakeholder Participation
SS	Suspended Solids
SWECO	Swedish Engineering Consultancy Company
Ta	Tantalum
TNTC	Too numerous to count
ToR	Terms of Reference
TSS	Total Suspended Solids
U	Uranium
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNZA	University of Zambia
USAID	United States Agency for International Development
USD	United States of America Dollar
V	Vanadium
W	Tungsten
WAP	Water Apportionment Board (Botswana)
WHO	World Health Organisation
WQC	Water Quality and Conservation Division of DWA (Botswana)
WRAP	Water Resources Action Programme (Zambia)
ZACPLAN	Zambezi River Action Plan
ZACPRO 6	ZACPLAN Project 6 (Phase 1 and 2)
ZACPRO 6.2	ZACPLAN Project 6 Phase 2
ZAMCOM	Zambezi Watercourse Commission
ZAMWIS	Zambezi Water Information System
ZESA	Zimbabwe Electricity Supply Authority
ZESCO	Zambia Electricity Supply Company
ZINWA	Zimbabwe National Water Authority
Zn	Zinc
ZRA	Zambezi River Authority

Executive Summary

This Rapid Assessment Report provides an overview of water resources availability, water utilization and environmental and water quality issues as they apply to the shared Zambezi River Basin. Where possible these parameters are analyzed at the level of the thirteen sub-basins that make up the Zambezi Basin.

The Zambezi River Basin is populated by an estimated 30 million people, of which approximately 7.5 million live in the urban centres. The population is expected to increase to 47 million by 2025 with urbanization steadily increasing. Most riparian countries have witnessed encouraging economic growth recently and there is a need to consolidate and sustain this, among others by the sustainable development of the water resources of the Zambezi Basin.

The Zambezi River Basin covers eight different Southern African countries[1] and has a catchment area of some 1.37 million square kilometres. The basin as a whole receives a mean annual rainfall of about 950 mm, with most concentrated in the summer period. The north and east of the basin experience significantly more precipitation than the south and west. The rainfall pattern is such that there are distinct wet and hot summer months and a dry period in the remainder of the year. Climate change may have an effect on evaporation from the reservoirs, on crop production and fish stocks.

Less than 10% of the mean annual rainfall in the basin contributes to the flow of the Zambezi River into the Indian Ocean. The major contributors to this runoff are the sub-basins in the upper part of the Zambezi, as well as the Kafue, Luangwa and Shire sub-basins. More than 90% of mean annual rainfall in the basin evaporates and returns to the earth's atmosphere. Given the relatively high rainfall in summer, it is a safe assumption that a significant part of the resulting water resource is temporarily stored in sub-soil aquifers. However, detailed information about the availability and use of these groundwater resources is as yet not available, though this resource can be expected to become more prominent over time.

The Zambezi is the eighth largest river in the world and carries an average run-off of 103,224 Mm^3. At present around 20% of this stream flow is used, but this could increase to 41% if the various ambitious plans by riparian states for irrigation and hydropower development are implemented in 2025. Given the high degree of seasonal and spatial variability in available water resources, and the possible effect of climate change this would bring water use in the critical zone. In addition there are a number of water quality issues that demand attention, in particular point pollution around manufacturing and mining centres, the spread of aquatic weeds and wetland degradation.

[1] Angola, Botswana, Malawi, Mozambique, Namibia, Tanzania, Zambia, Zimbabwe.

Regional cooperation on the Zambezi has made considerable progress, with the main accomplishment so far being the Zambezi Watercourse Commission (ZAMCOM) Agreement. There is a broad and important agenda for regional cooperation, in particular on synchronizing water resources development plans; revising reservoir operation so as to serve a wide variety of functions – such as flood control, support to flood plain agriculture, river and estuarine fishery and navigation; cooperation in the control of aquatic weeds; and the development of climate change adaptation strategies, appropriate to the Basin, among others through the use and recharge of groundwater. Further to enable the sharing of benefits cooperation should also focus on the basic elements, in particular the joint planning of electricity grids, road networks and navigation opportunities. There is a need for data information and data exchange, expanding on the Zambezi Water Information System (ZAMWIS) that was set up parallel to this assessment. The need for an effective Zambezi Watercourse Commission to come into being is considerable.

1 Introduction

1.1 Background

The Rapid Assessment of the Water Resources of the Zambezi River Basin has been prepared within the framework of the Zambezi River Action Plan (ZACPLAN) Project 6 Phase 2. ZACPLAN is an initiative of the Southern African Development Community (SADC) aimed at achieving environmentally sound planning and management of water and related resources in the Zambezi Basin. This action plan was originally adopted by the forerunner of SADC, the Southern African Development Co-ordination Conference in 1987 and consists of 19 projects aimed at development and management of the water resources of the Zambezi River Basin to achieve sustainable socio-economic development and environmental sustainability.

The ZACPLAN Project 6 (ZACPRO 6) titled “Development of an Integrated Water Management Plan for the Zambezi River Basin” has been implemented over two phases. Phase 1 was concerned with the development of a knowledge base of water and related information to provide a sound basis for the planning and development of water resources of the Zambezi River Basin. This was implemented over the period 1995 to 1999.

The next phase, ZACPRO 6 Phase 2, was designed to build up on the results of the previous phase and its objective was to establish an enabling institutional environment and management tools for integrated water resources management of the Zambezi River Basin. Phase 2 began in October 2001, and after experiencing inordinate delays in implementation, the project design was reformulated in 2003. The refocused project objective is “To improve integrated water resources management and to facilitate social and economic development and protection against floods, droughts, water resources pollution and environmental degradation in the Zambezi Basin”. The focus of the reformulated project was the development of the enabling institutional environment for basin-wide management of the water resources, and this reached fruition with the signing of the Agreement for the Zambezi Watercourse Commission (ZAMCOM) in July 2004, as an organization for coordinated planning, development and management of water resources of the Zambezi Basin as a whole. ZAMCOM Agreement is currently undergoing the ratification process by the basin states.

The objective of ZAMCOM is to promote the equitable and reasonable utilization of the water resources of the Zambezi basin as well as the efficient development and management thereof. This is a practical expression of the intents of the SADC states to “foster closer cooperation for judicious, sustainable and co-ordinated management, protection and utilisation of shared watercourses and advance the SADC agenda of regional integration and poverty alleviation" as stated in the Revised Protocol on Shared Watercourses.

The formulation of the integrated water resources management (IWRM) strategy for the Zambezi Basin provides the basin states with a vital management tool for effective management of the shared water resources of the basin. The Rapid Assessment of Water Resources is an important first step in the formulation of the IWRM strategy.

1.2 Objectives and Scope of Rapid Water Resources Assessment

The objective of the Rapid Assessment of Water Resources is to produce an update overview of current water availability in the Zambezi Basin, as well as an assessment of current and future demands on these resources so as to provide a sound basis for development of strategies for effective management of water resources of the basin. The Rapid Assessment aims to quantify, qualify and document water resources availability; existing and planned water resources infrastructure developments; present and future water demands; water resources threats including over-allocation, floods, droughts, environmental, ecological and water quality related issues. The assessment also included institutional, policy and legislative issues that affect the coordinated development and management of water resources for the entire Zambezi basin. Of importance in the assessment is the identification of hydrological, environmental and ecological, and institutional and policy issues that constrain effective management of the water resources of the basin, as well as assessment of opportunities for effective development and management of the water resources of the basin.

1.3 Rapid Assessment and Strategy Preparation Process

The IWRM Strategy is defined as a set of measures that the basin as a whole needs to undertake to achieve a desirable water future. It consists of medium to long term measures in support of integrated water resources management to meet socio-economic development including poverty eradication and environmental integrity. The strategies are predicated on an objective assessment, identification and quantification of the water resources issues, opportunities and challenges, and the formulation of specific measures to address the issues and challenges to effective water resources management while taking into account the identified opportunities.

The Rapid Assessment therefore forms an important first step towards the formulating of an IWRM strategy. It presents a comprehensive knowledge base on which to build upon specific medium to long term measures that will facilitate the achievement of coordinated, effective and sustainable integrated water resources management in the Zambezi Basin.

The process for the Rapid Assessment involved the following activities:

(i) Collection of hydro-meteorological data, socio-economic data as well as development plans from all the riparian states of the Zambezi Basin.

(ii) Assessment of available water resources – quantity, quality, spatial and temporary characteristics.

(iii) Assessment of present and future water demands across all sectors including the environment.

(iv) Matching available water resources with present and future water demands for different development scenarios.

(v) Identifying issues and challenges to the development and management of water resources to meet the projected water demands

The Rapid Assessment Report consists firstly of the description of the Zambezi Basin – its physical, hydrological, socio-economic characteristics. This is followed by a quantification and qualification of available water resources, water utilisation and water demand for all socio-economic sectors as well as the environment. This is followed by an assessment of institutional and policy characteristics. Finally, the issues and challenges to coordinated development and management of water resources in the basin are presented. These form the point of departure for the formulation of the IWRM strategy.

1.4 Data sources

The Rapid Assessment builds upon various assessments of water resources carried out by individual riparian countries of the Zambezi Basin or regional assessments already carried out under previous phases of ZACPRO 6. The assessment is regarded as “rapid” because it is based on existing data and information, published or available from the riparian countries, updated to a common timeframe; there was no collection of new or primary data.

To a large extent, the assessment consisted of updating the studies on water resources carried out under ZACPRO 6.1 (Sector Studies). The Sector Studies was completed in 1998 and consisted of seven studies covering water use (demand) for major uses, including, domestic and industrial water supply, agriculture, energy, tourism, wildlife, water transport, and environment. The database was up to the year 1995.

The Sector Studies were updated by using data collected from the Zambezi basin states by national staff of the water departments (seconded staff) and/or Consultant’s team. The collected data has been assembled into a database that forms an integral part of the Zambezi Water Information System (ZAMWIS) that is being developed as an independent component of the Strategy formulation assignment. ZAMWIS is a database of hydro-meteorological data integrated with a GIS platform and is currently still under development but will be completed at the end of the Strategy assignment.

The ZAMWIS will replace the Zambezi River Basin Information System (ZACBASE) that was developed in ZACPRO 6 Phase 1. This database was not recoverable following computer system failure after the completion of ZACPRO 6 Phase 1.

Other data was collected from global resources such as the Southern Africa FRIENDS database and the Global Historical Climatology Network (GHCN), literature resources and national and regional studies and reports provided by the member states. A list of all resources used in the assessment is given in the back of this report (References).

Other very important sources of information became available through the seconded national teams, consultative workshops organised through ZACPRO 6.2 with National Steering Committees (NSCs) and professional staff from water related departments in the basin, and the annual Zambezi basin stakeholders meetings. The recent Zambezi Basinwide Stakeholders Forum held during the last week of November 2007 in Victoria Falls, Zimbabwe, focussed on sharing experiences on IWRM issues and possible solutions. The Forum brought together more than 150 delegates from government ministries for environment, water, justice, finance, fisheries, forestry, agriculture and energy; as well as river basin organizations, local and international NGOs, traditional leaders, universities/research institutions, the media and the private sector. The key output was a rich compendium of experiences on issues in water resources management in the Zambezi basin and also from other international transboundary basins. The outputs from these consultative meetings helped provide valuable background on IWRM issues in the Zambezi basin as well possible solutions to such issues.

A number of photo captions used in the report have been sourced from the ZACPRO 6.2 photo files, or from stakeholder workshops, country presentations organized under the auspices of the project. We acknowledge all sources of photo.

1.5 Structure of this report

The structure of this report follows as much as possible the list of contents as was adopted by the Project Steering Committee in the Inception Report, Phase I.

This chapter, **Chapter 1**, describes the background, objectives and scope of this report.

Chapter 2 gives a detailed description of the Zambezi basin and the current institutional arrangements for water resources management.

Chapter 3 presents the water resources update by type of resource. The chapter also presents the flow, floods and drought regimes in the basin and flow regulation.

In **Chapter 4** the current and projected water demands are presented and discussed. The current water demands are compared to the available run-off and the projected water demand up to year 2025 is developed into several scenarios. In the last section of Chapter 4 the implications of the different future scenarios is discussed.

Chapter 5 gives an overview of the environmental and water quality situation and starts with the description of the environmental endowment of the basin. This is followed by sections on surface water quality and pollution, groundwater quality and pollution, the environmental threats in the basin and sections on the management of the water resources and related environmental issues. It has been decided during the development of this report to discuss the climate change issues in Chapter 7 of the report, as the adaptation towards climate change is clearly a strategic issue as well.

Institutional and policy issues on basin/ trans-boundary level are presented and discussed in **Chapter 6** of this report.

The last chapter, **Chapter 7**, presents a synopsis of all strategic issues arising from the assessments. The issues arise from the information given in the previous chapter and may therefore slightly differ from the previous adopted list. Chapter 7 will function as a starting point for the development of an IWRM strategy for the Zambezi basin.

All maps are presented in Annex 1 of the report.

2 Description of the Zambezi River Basin

2.1 The Zambezi River Basin

2.1.1 Location and Topography

The Zambezi River Basin is located between 9-20° South and 18-36° East in Southern Africa (see Map 1, Annex 1*). The Zambezi River, together with its tributaries, forms the fourth largest river basin in Africa after the Congo, Nile, and Niger River basins. It is the largest river basin in SADC. Its total basin area of 137 million hectares (1.37 million km^2) extends through Angola, Botswana, Malawi, Mozambique, Namibia, Tanzania, Zambia and Zimbabwe. The Zambezi Basin covers almost all of the territory of Malawi and the lion's share of Zambia; it covers also around half of Zimbabwe including the most densely populated areas. Very significant areas of both Mozambique and Angola are also covered, but only minor parts of Tanzania, Botswana and Namibia.

Most of the Zambezi Basin is high plateau land of the ancient Gondwana Continent, with elevations of the high plateau varying between 800 and 1,450m amsl (see Map 2, Annex 1), the most extensive areas being between 1,000 and 1,300m amsl. Only a very small portion of the basin is below 100m or above 1,500m. The fact that there are these elevation differences, and that most of the basin is above 1,000m, contributes to the high hydropower potential of the Basin.

2.1.2 Geology

Underlying geology (see Map 3, Annex 1) in the basin is mostly of hard impermeable crystalline basement metamorphic and igneous rocks and mostly indurated Palaeozoic sediments, and these lithologies are predominant in the areas downstream and to the east of Livingstone. Areas upstream and to the west of Livingstone are dominated by underlying materials of sandy lithologies, with areas of superficial riverine, lake and aeolian deposits also occurring in low-gradient areas close to the upper Zambezi and associated tributaries. These sandy and superficial sedimentary deposits dominate the lithologies of the Upper Zambezi (12), Lungwe Bungo River (11), Luanginga River (10), Cuando/ Chobe River (8) and Barotse (9) sub-basins. The most prominent of these sandy formations are Kalahari sands covering large areas of this part of the river basin.

* All the maps have been put in a single annex so that it can serve as a thematic atlas for the basin

A large area of Palaeozoic sedimentary rocks occurs in the north-central part of the basin covering the entire northern half of the Kafue Sub-Basin (7). This comprises dolomites, quartzites, and indurated shales and sandstones, and most of Zambia's copper and cobalt deposits are associated with the periphery of this area. Ultrabasic igneous materials are found in several parts of the Basin, most notably in Zimbabwe where chromium and nickel, which are associated with these, are mined in several areas. Gemstone minerals and gold are found in many small localised areas within some of the crystalline basement materials, and these support mostly small-scale mining activities. Appreciable deposits of coal are found in several parts of the Zambezi valley, and these are mined in a few of these locations. All mining activities have an appreciable environmental impact, and some of these are clearly detrimental over extensive areas and may adversely affect downstream water quality.

Although ancient volcanic materials are observed in several areas – most notably in a large expanse around Livingstone and in three major areas to the south and south east of the Caborra Bassa Dam - most of the area is tectonically stable. The exception to this is the Shire Valley and Lake Malawi areas which form part of the East African rift valley system and are subjected to occasional low- to moderate-intensity earth tremors.

A geological description of the Zambezi basin as a whole is confounded by lack of harmonization of geological descriptions – names and divisions of formations are country specific. Consequently even constructing a lithostratigraphic table, useful as it may be in aiding understanding of the geology of the basin, requires standardization of forms, divisions and structures adopted in different countries of the basin. Within the scope of this assignment it was not undertake such a task.

2.1.3 Climate

Average annual rainfall across the Basin (see Map 4, Annex 1) varies from about 500mm in a small part of the extreme south and south-west to more than 1,400mm in the Upper Zambezi and Kabompo sub-basins in small areas in the north-eastern shores of Lake Malawi within Tanzania, and in the southern border area between Malawi and Mozambique. In general, rainfall is greatest in the north, with an extensive area of over 1000mm, and declines towards the south, where most areas show less than 700mm. In general, there is only a single rainy season in the year. Rainy seasons are longer in the north and north east, and much shorter in the south-west.

Overall, mean annual rainfall across the Basin averages some 950mm (or 1,300 km3 of water). However, rainfall variability from year to year is considerable, and rainfall reliability for agricultural and livestock production is an over-riding issue. This leads to big differences in total run-off from year to year, estimates varying from some 500 km3 in the wettest years to only 100 km3 in the driest.

Temperature across the Basin varies according to elevation, and to a much lesser extent latitude. Mean monthly temperatures for the coldest month, July, (see Map 5, Annex 1) thus vary from just below 13° C for higher-elevation areas in the south of the Basin to some 23° C for the low elevation areas in the delta area in Mozambique. Mean monthly temperatures for the warmest month (November, normally the pre-rains month) vary from around 19° C in the highest elevation areas, to 31° C for the lower parts of the Zambezi valley (see Map 6, Annex 1).

Potential evapotranspiration (ET_o) varies greatly across the area, being determined by temperature, relative humidly, windpseed and sunshine. Annual (ET_o) (based on FAO CROPWAT data) values vary from 1,000mm to almost 2,000mm, with an average of some 1,600mm which is almost double the average annual rainfall. Irrigation is thus essential in most areas, both to grow perennial crops (e.g. sugarcane, bananas, citrus), and, in the drier areas, to guarantee crop yields for seasonal crops (e.g. maize, rice, cotton).

2.1.4 Basin Physiography and Morphology

The geology of the central southern Africa, characterised by oldest landscape on earth, tectonic movement and rift valley faulting, dominates the physical and geomorphologic characteristics of the Zambezi River basin. Within what is now the Zambezi River basin quite a large part was in existence already in the *proterozoic* era, some 550 million years ago. Prior to and since that time, the region also experienced excessive faulting, folding and metamorphosis with associated weathering and erosion that have led to land surfaces being eroded down to *peneplains*, while leaving only the most resistant parts of the old Gondwanaland in the plateaus and high grounds.

The original rock materials have been metamorphosed into granitic/gneissic basement complex, particularly where faulting has not been extensive. In fact the tectonic movements associated with rift faulting and uplifting have lifted up many old Gondwanaland plains with western part of the basin at an altitude of 1600-1800 m amsl and the eastern part having the low lying and wide stretches of flood plain valleys penetrating 350 to 450 km inland. The eastern part of the catchment and the river morphology have been shaped by the East African Rift Valley system. The narrow shaped Shire River-Lake Malawi sub-catchment lies and follows the middle southern part of the north-south Rift Valley system. The Luangwa River valley is also in the Rift Valley system while the Lower Zambezi River and its delta section lay in the southern part of the Rift Valley system or faulting zone associated with the rift faulting.

The geological processes summarised above have led to a mosaic terrain of the Zambezi River basin, encompassing deep and shallow valleys, steep and flat river profiles and extensive plateaus, sometimes with their sharp edges protruding, because of the enormous forces exerted including the formation of long bands of metamorphosed rocks. This also explains why the Zambezi River and its tributaries have relatively long reach stretches with weak slopes resulting in low velocities and of wide riverbeds and meandering stream channels. It also explains why there is the existence of canyon like gorges, many water rapids and falls of relatively old age (with Victoria Falls standing out as the highest and biggest of these falls), as a result of the dominance of hard, metamorphosed rock-plates, vertically dislocated. The long canyon-like river reach stretches of gorges are often extremely suitable for the construction of reservoirs for hydropower installations, allowing relatively small dams to form large storage with very big volumes of water and little surfaces to cause evaporation.

2.1.5 Land Cover / Use

The terms 'land cover' and 'land use' are often used synonymously. Land cover refers to the actual coverage of the surface of the earth with natural or man-made environment - forests, grass, crops, water bodies (lakes, rivers), marshes, rock, sand dunes, roads, urban settlement. 'Land use' on the other hand refers to the usage of the land cover. Commercial forestry, pastures, irrigated farming, rainfed cropping, recreational areas, game reserves, mining, urban areas, industrial estates etc. are examples of land use types. Land cover/use has a great impact on water resources – it affects how precipitation that falls on the ground eventually translates into runoff, infiltration, evaporation, and the quality of the water.

The main classes of land cover/use in the Zambezi River basin are summarised in Table 2.1 and shown on Map 7 in Annex 1.

Table 2.1 Land Cover/ Use in the Zambezi River Basin (2000)

Sub-Basin	Rainfed Farming	Forest	Bushland	Grassland	Barren & Built-up Land	Open Water	Marshes & Irrigated Areas
Barotse	2.6%	3.9%	11.5%	14.5%	0.0%	0.0%	9.4%
Cuando / Chobe	1.3%	7.4%	12.6%	30.5%	0.0%	0.0%	9.5%
Kabompo	0.1%	17.5%	2.5%	0.4%	0.0%	0.0%	0.0%
Kafue	10.8%	17.2%	11.4%	0.4%	33.0%	1.2%	10.5%
Kariba	25.4%	2.7%	13.8%	0.7%	21.8%	11.9%	0.0%
Luanginga	0.0%	6.2%	1.0%	7.1%	0.0%	0.0%	6.6%
Luangwa	10.5%	4.6%	15.5%	0.6%	1.5%	0.2%	0.0%
Lungue Bungo	0.0%	9.1%	1.0%	11.3%	0.0%	0.0%	8.0%
Mupata	3.2%	0.7%	1.5%	0.4%	0.0%	0.1%	0.0%
Shire River/ Lake Malawi	15.8%	9.4%	9.3%	2.6%	9.4%	79.0%	0.6%
Tete	30.3%	4.8%	16.3%	3.0%	31.8%	7.2%	1.5%
Upper Zambezi	0.0%	13.2%	2.6%	28.5%	0.0%	0.0%	16.6%
Zambezi Delta	0.0%	3.3%	0.9%	0.0%	2.6%	0.3%	37.3%
Grand Total	***100.0%***	***100.0%***	***100.0%***	***100.0%***	***100.0%***	***100.0%***	***100.0%***
Total Basin	***13.2%***	***20.6%***	***54.2%***	***7.7%***	***0.1%***	***2.8%***	***1.3%***

(*Source: ZAMWIS, 2007*)

Most parts of the basin are covered by forests and bush (almost 75% of the land area); cropped land (mostly rainfed agriculture) covers 13% of the land area, and grassland covers approximately 8% of the land area.

2.1.6 Flood plain agriculture

As written in the GWP Framework for Action for instance 'floods are not only a hazard but also provide a livelihood to some of the poorest people'. This very much applies to flood plain agriculture in the Zambezi basin.. The Zambezi Basin includes extensive flood plain areas (see Table 2.2)

Table 2.2 Selected flood plain areas in Zambezi Basin

	Area
Caprivi	
Barotse	9000 km2
Luangwa	2500 km2
Liuwa	3500 km2
Kafue Flats	6500 km2
Zambezi Delta	

(Source: Hirji et al, 2002)

In a context of low population density, flood plain agriculture is highly productive when measured in output per capita, though less in output per land unit. In large parts of the Zambezi Basin however land is however not necessarily the limiting factor. Flood recession resource systems moreover have several other benefits – such as recharging shallow wells; sediment deposits contributing to soil fertility; regenerating rangeland in outwash areas, sustaining fisheries and maintaining wetland functions. These should be carefully considered in making a comparison with perennial irrigation.

A detailed analysis* was done on the Lower Zambezi, assessing the costs and benefits of several artificial flood release scenarios from the Cahora Bassa Dam. Such controlled flood releases would restore flood plain functions that were undermined with the closure of the dam. The Cahora Bassa Dam, as well as the other main hydraulic structures in the Zambezi, i.e the Kariba and Kafue Dams are now operated to maximize hydro-power production. The conclusions from these analysis' are:

- Efforts to recreate the pre-dam historical flood hydrograph over a period of 2-4 months will only be possible at the cost of a substantial reduction in hydropower generation
- However an immediate improvement in the Lower Zambezi flow regime could be made with no impact on hydropower production. Over a long term period a two-week release in February of 4500 m3/s could be achieved in 98% of the years. With the present operational rules this event occurs only in 7% of the years. This outflow would be achieved with 97% power reliability and no reduction in hydropower generation.

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* R. Beilfuss and C. Brown (eds), 2006

- Several of the other options for annual flood level changes can be achieved with minimum or modest reductions in power generation. Even large flood level changes (over 10,000m^3/s) can be attained with reduction in power generation in the order of 7%. There is considerable scope to improve the integrated management of the Cahora Bassa reservoir over the current conventional operation.. The impact of such annual flooding on the different functions – especially rain fed farming, fisheries, control of invasive species, natural vegetation and groundwater recharge is significant, see Table 2.3.
- Flood change levels could be achieved with even less impact on hydropower generation through coordinated management with Kariba Dam outflows and power generation.

Table 2.3 Preferred flow regime changes for Zambezi Delta for several water-related functions, based on expert opinion

	Increase in low flows	Restore annual flood	Restore 1 in 5 year flood
Irrigated commercial agriculture	●●●	●	●●
Rain fed agriculture	●	●●	●●●
Naturally flooded rice	●	●●●	●●●
Coastal and estuarine fisheries	●	●●●	●●
Freshwater fisheries	●	●●●	●●
Livestock	●	●●●	●●
Large mammals	●●	●●●	●
Water birds	●	●●●	●●
Mangrove	●●●	●●	●
Riparian forest	●●	●●●	●●●
Papyrus and reeds	●	●●●	●●
Savanna vegetation	●	●●●	●●
Invasive aquatic plants control	●	●●	●●●
Sediment	●	●●	●●●
Effluent dispersal	●●●	●●	●
Eutrophication	●	●●●	●●
Salinization	●	●●	●●●
Groundwater recharge	●	●●●	●●
River navigation	●●●	●●	●
Most preferred	●●●		
Least preferred	●		

(Source: Beilfuss and Brown, 2006)

2.2 Sub-Basin Characteristics

The Zambezi River System covers a huge geographical area; it is a transboundary basin shared by eight out of 14 SADC member states. There are significant variations across the whole basin in terms of rainfall, temperature, physical characteristics, land use, economic development, and even cultural state of the riparian countries. Hence for purposes of analysis and management the Zambezi Basin is divided into 13 sub-basins, numbered from Sub-Basin 1 (Zambezi Delta) to 13 (Kabompo River). See Table 2.4 and Map 1 in Annex 1. It is evident that a number of these sub-basins also cut across national boundaries.

Table 2.4 Sub-basin characteristics

Sub-basin	Sub-basin	Area	Mean Annual Rainfall	Average Temperature in July	Average Temperature in November
	No.	km^2	mm	°C	°C
Kabompo	13	69 301	1159	16	22
Upper Zambezi	12	90 359	1225	17	22
Lungue Bungo	11	46 482	1120	16	22
Luanginga	10	33 931	972	16	22
Barotse	9	118 994	840	16	23
Cuando / Chobe	8	151 465	760	15	23
Kafue	7	157 629	1004	15	22
Kariba	6	163 202	707	14	23
Luangwa	5	148 286	987	16	23
Mupata	4	19 552	793	15	23
Shire River / Lake Malawi	3	158 043	1157	16	23
Tete	2	197 816	903	17	23
Zambezi Delta	1	23 653	1060	19	24
Total/Average		**1 378 713**		**16**	**23**

(Source: ZAMWIS, 2007)

A summary description of each of the sub-basins is given in Annex 3

2.3 Basin Social and Economic Profile

The economies in the Zambezi Basin have two faces: a fast growing and high income generating economy centered around the extraction of mineral resources – diamonds, oil, copper, cobalt, and a rural economy with high levels of poverty and low coverage of basic services, especially in Middle and Lower Zambezi. In most countries, though, positive progress has been made in economic terms. Annual growth in the last few years has been high and has exceeded population growth – around 6%, with Angola far exceeding this number (14%) and Zimbabwe being the exception at the other side. More general information on the basic economics of the riparian countries is given in Table 2.5.

The challenges for most economies is to diversify and improve the productivity and value-added of the sectors that provide the bulk of the employment, services and agriculture, and hence achieve sustainable development. At the current stage many of the countries are vulnerable to changing prices of mineral resources or to prolonged droughts. The food security crisis of the early part of this century is a reminder of this. At present food security is under control in most countries, yet with high food insecurity in some parts of Zimbabwe, as Figure 2.1 shows.

Table 2.5 Basic economic statistics of riparian countries

Angola	Botswana
Population ▪ 16.4 million (2006) ▪ 2.8 % annual population growth Economy ▪ Strong economic performance ▪ Increase of oil production, around 13% ▪ Increase of agricultural value of 8% ▪ Inflation fell from 19% to 12% in 2006 ▪ Medium term outlook is positive; GDP is expected to grow about 25% on average in the next two years and about 8% average in 2009-2010 driven by the oil sector. ▪ Fiscal deficit is projected to be sustainable in the medium and longer term Current GDP numbers ▪ 44 billion USD (2006) ▪ 14.6% annual growth (2006) ▪ 74% Industry (2005) ▪ 18.7% Service (2005) ▪ 7.2% agriculture (2005)	Population ▪ 1.8 million (2006) ▪ 1.2% annual population growth Economy ▪ Botswana's economy is dominated by the diamond mining industry ▪ GDP growth over the past years established around 5%. This trend is expected to continue in the medium-term ▪ Major challenge is to diversify economy and look for other engines of growth as the diamond growth begins to taper off Current GDP numbers (2006) ▪ 10,3 billion USD ▪ 53.5 % industry (38% accounts to diamond mining industry) ▪ 44.5% services ▪ 2% agriculture Water and sanitation ▪ 42% (period of 2005) of population has access to improved sanitation facilities ▪ 95% (period of 2005) of population has improved water source
Malawi	**Mozambique**
Population (2006) ▪ 13.2 million ▪ 2.1% annual growth rate Economy ▪ relatively small economy ▪ Agriculture is the mainstay, but vulnerable to weather shocks ▪ Unequal land distribution. Over 40% of smallholders households cultivate less than 0.5 hectares ▪ Export is dominated by tobacco, tea, cotton, coffee and sugar ▪ Improvement of macroeconomic performances Current GDP numbers (2006) ▪ 2.2 billion USD ▪ 8.4% annual growth rate ▪ 44.7% services ▪ 35.5% agriculture ▪ 19.8% industry	Population ▪ 20.1 million ▪ 1.2% annual population growth Economy ▪ Export commodities: aluminium, cashews, prawns, cotton, sugar, citrus, timber, bulk electricity, natural gas Current GDP numbers (2006) ▪ 7.6 billion USD ▪ 8.5% annual growth rate ▪ 49.3% services ▪ 29.0% industry ▪ 21.7% Agriculture

Namibia	Tanzania
Population ▪ 2.1 million (2006) ▪ 1.1% annual growth rate (2005) Economy ▪ Middle income country ▪ Among top 10 countries worldwide in share of GDP spent on education ▪ The generally good growth and macroeconomic picture is overshadowed by the lingering levels of poverty; high unemployment; and unequal distribution of wealth and income Current GDP numbers (2006) ▪ 6.4 billion USD ▪ 4.6% annual growth ▪ 57.7% Services ▪ 31.0% industry ▪ 11.3% agriculture	Population ▪ 39.5 million ▪ 2.6% annual population growth Economy ▪ Economic performances continue to be strong, despite the drought of 2006 Current GDP numbers (2006) ▪ 12.8 billion USD ▪ 5.9% annual growth rate ▪ 45.3% agriculture ▪ 37.3% services ▪ 17.4 % industry
Zambia	**Zimbabwe**
Population (2006) ▪ 11.9 million ▪ 1.6% annual population growth Economy ▪ Negative impact on economy by macroeconomic instability, resolved with debt cancellation. ▪ Income between 1974 and 1990 fell with 5% ▪ In 2002 Zambia was hit by a copper crisis and a severe drought Current GDP numbers (2006) ▪ 10.9 billion USD ▪ 6.0% annual growth rate ▪ 59.2% services ▪ 24.8% industry ▪ 16.1% agriculture	Population (2006) ▪ 13.6 million ▪ 0.6% annual growth rate Economy ▪ Decade after independence economic growth was strong, but in the late 1990 the growth began to slow ▪ In 2002 Zimbabwe's economy was severely constrained ▪ Overvalued exchange rate ▪ Unsustainable external debt burden Current GDP numbers (2006) ▪ 5.0 billion USD ▪ -4.8% annual growth ▪ 50.7% services ▪ 27.4% industry ▪ 21.9 % agriculture

(Source: World Bank, 2005)

Figure 2.1 Food security in some countries in the Zambezi Region in 2007

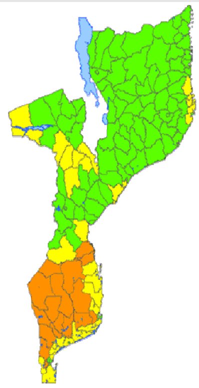
Angola

- Steady improvement in food security
- Good status of food security due to recent harvests of cereals, tubers and beans

Malawi

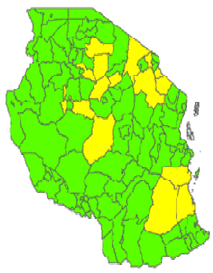
- Good household food stocks from bumper harvest
- Maize production will grow
- Some areas with high vulnerability, it is estimated that 519,000 people are at risk of food insecurity

Mozambique



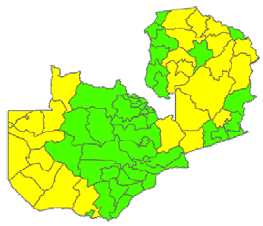
- Food prices continue to increase in South
- Immediate food distribution is necessary
- Flows of maize from central region to south are decreasing
- It is expected to meet the food requirement needs of 90% of population
- Rains are forecasted to be normal or above

Tanzania



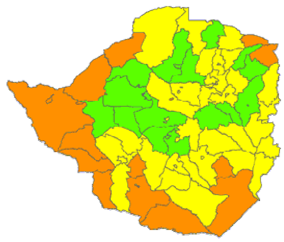
- In general: food access is good; seasonal outlook favourable
- Moderate food insecurity for poor net-produces households
- Harvests 2007 were good
- Seasonal rains are forecasted to be normal through December
- Upcoming cropping seasons are expected to be favourable
- Pasture and water availability remains good

Zambia



- Nationally, food security is good, but localized food insecurity is expected
- Food assistance is given to almost 441,000 people
- If rainy season is normal, food security improves after hunger season ends in Feb/March 2008
- In a worst case scenario, 13 additional districts face higher levels of food insecurity and require assistance

Zimbabwe



- Food security has deteriorated in most of the country
- Drought had a large impact
- Over the next six months the scenario is worsening
- Government imports and food aid will mitigate the worst consequences
- Most likely scenario: natural cereal deficit will be filled by commercial and food aid imports. 2007/08 will be a normal season
- Worst case scenario: Government and humanitarian agencies fail to import cereals and prices of staple increase

(Source: FEWS Net, USAID, 2007)

2.4 Water Resources Administration and Management

2.4.1 Water Management Arrangements in Countries

Institutional frameworks for each Zambezi basin state have been summarized and their outline organograms presented in Annex 2. A summary of institutional responsibilities for major water management functions is presented in Table 2.6 below.

Table 2.6 Institutional responsibilities for water management in the Zambezi Basin States

Country	Institution Responsible for			
	Water Allocation	Planning & Management	Water Supply and Sanitation	Irrigation
Angola	DNA	DNA	Utilities	Ministry of Agriculture
Botswana	Water Apportionment Board in MMEWR	Department of Water Affairs (DWA) in MMEWR Department of Geological Survey (DGS) in MMEWR	DWA and Water Utilities Corporation (WUC) in MMEWR Department of Local Government Technical Services (LGTS) in the Ministry of Local Government (MLG) Department of Waste Management and Pollution (DWM & PC) in the Ministry of Environment, Wildlife and Tourism	Department of Crop Production (DCP) in the Ministry of Agriculture
Malawi	Water Resources Board in MIWD	Water Resources Department, MIWD	Water Supply and Sanitation Dept., MIWD, and Utilities	Irrigation Department, MIWD
Mozambique	Regional Water Administrations (ARAs) / DNA	DNA	DWA, Ministry of Local Government (MLG) and Water Utilities Corporation	Ministry of Agriculture (MoA)
Namibia	Department of Water Affairs & Forestry, MAWF	Department of Water Affairs & Forestry, MAWF	DWAF (rural water supply) and Utilities	Department of Agriculture in MAWF
Tanzania	Basin Water Board	Ministry of Water	Utilities and Local Authorities	Ministry of Agriculture
Zambia	Water Board, MEWD ZRA*	Department of Water Affairs, MEWD	Utilities	Ministry of Agriculture and Cooperatives
Zimbabwe	Catchment Councils ZRA	Catchment Councils	ZINWA and Local Authorities	Ministry of Agriculture

**In Zambia and Zimbabwe, ZRA allocates water from Lake Kariba to the utilities ZESCO and ZESA for hydropower production*

From the presented outlines it becomes clear that there is no blueprint approach for institutional frameworks for water management in the region. The institutional structures vary greatly between the countries. Overall, the following observations can be made:

- Institutions responsible for water allocation (permits/water rights) are separate from those responsible for major water uses – agriculture and water supply and sanitation.
- Water allocation is still centralised (through a statutory body, e.g., water board). This is still the case even in countries where basin authorities have been established since these do not yet cover all basins or catchments in the country.
- In the majority of cases, water resources planning and management is a separate function and handled by a separate institution from that dealing with water allocation. However, invariably both institutions report to the same ministry, and there is technical cooperation between both institutions. In the case of Angola, Namibia and Zimbabwe water allocation and planning and management are carried out by one and the same organisation (national Directorate of Water in the case of Angola, Department Water Affairs and Forestry in the case of Namibia, and Catchment councils in the case of Zimbabwe).
- Except in the cases where basin or catchment management has been instituted, water resources planning and management, including data collection and processing, are centralised through a national department with regional/province (political boundaries) and/or district offices.
- In a few countries, the major water use sectors (irrigation/agriculture and water supply and sanitation) institutionally report to the same ministry responsible for water resources planning and management. At policy level there is no separation of institutional responsibility between users and regulators.

Over the last decade institutional frameworks for water resources management are being reviewed, revised and improved in most countries of the region and of the Zambezi basin. The driving force for such changes is the strong economic development that many of the countries' experience and that bring new challenges to the management of the important natural resource that water is. The major milestones for the changes are summarised in Table 2.7.

Table 2.7 Significant changes in institutional frameworks at country level in the last 5 – 10 years

Country	Major Change process
Angola	New water law adopted in 2002 that makes provision for the establishment of basin water authorities and the National Institute for Water Resources Management. Presently only one basin authority has been established, the Cunene River Basin Authority.
Botswana	The National Water Master Plan completed in 1992 initiated a critical review of policy, legislative and policy frameworks for water management. Proposed changes were not implemented. Following the national Water Master Plan Review completed in March 2006, far reaching changes to the legal and institutional frameworks have been proposed including establishment of National Water Resources Council to be responsible for water resources management, and the separation of water resources management functions from service delivery functions. Implementation of the reforms is

Country	Major Change process
	due to follow.
Malawi	National Water Resources Master Plan (1986). The first national water policy, the Water Resources Management Policy and Strategies was adopted in 1994. This was reviewed in 2000 and further in 2004. The Water Policy 2005 is aimed at strengthening water resources management in Malawi, including decentralization and adoption of basin management approach. The 1969 Water Resources Act is also being revised to conform to the new water policy
Mozambique	Reforms anchored by the National Water Policy of 1995 and the the Water Act (1995). A single apex institution, the National Directorate of Water (DNA) responsible for water resources management and promotion of urban and rural water supply and sanitation has been established. Formation of Regional Water Administrations (ARAs) in most of the country has been initiated and steps taken towards strengthened stakeholder participation in water management. Also the National Water Resources Management Strategy 2006.
Namibia	The Namibian Water Resources Management Review was launched in March 1998, and has led to a new Water Policy 2000, new Water Act of 2004 (being amended), water conservation strategy, and revised institutional arrangements for water resources management including establishment of basin management agencies on basins shared with neighbouring countries.
Tanzania	The revised National Water Policy 2002 and the National Water Sector Development Strategy initiated major reform programme for the water sector. This led to decentralization of water resources management through establishment of river basin organizations. Stakeholder participation became formally established through creation of catchment water committees and water user associations.
Zambia	Reforms started in 1994 with adoption of National Water Policy; but review of water resources management aspects were carried out more substantively from 2000 through the Water Resources Action Programme (WRAP). Proposals for new institutional framework for water resources management (including establishment of catchment management), new water bill of 2007, and revised draft national water policy strengthening integrated water resources management, and provisions for managing transboundary basins are ready for implementation.
Zimbabwe	The 1998 Water Act that came into effect in 2000 established the framework for significant reforms of the water sector in Zimbabwe – decentralized management of water resources, integrated management on basis of basin or catchment areas, and stakeholder participation. The reforms led to the creation of Zimbabwe National Water Authority (ZINWA) in 1998 with responsibilities including planning and development of national water resources; and strong institutional anchoring of stakeholder decision-making processes through the Catchment Councils made up of representatives of water users in each catchment

In general the water management policy throughout the region has moved away from centralized government-only planning and implementation of water management, towards decentralized water management with inclusion of stakeholders in the process. The decentralization and stakeholder participation policies are being implemented in different ways in the Zambezi countries. Most countries have adopted revised National Water Policies in the last 10 years, in which both decentralization and stakeholder participation have been adopted as explicit policy principles. Some countries have developed National Water Management Strategies that address the implementation of such policies at the national level. Table

2.8 highlights the policy documents which form the basis for the reforms in water management in the Zambezi basin.

Table 2.8 Policy documents

Country	Water Policy and Water Management Strategy documents
Angola	No formal water policy, but national water policies are implicit in the Water Law 6/02 of 2002 and the Water Sector Development Strategy 0f 2004
Botswana	No separate Water Policy, but policy principles included in the National Water Master Plan of 1992. The plan was reviewed in 2006 and plan implementation has started.
Malawi	National Water Policy adopted 2005; Water Resources Investment Strategy under preparation
Mozambique	National Water Policy adopted 1995, currently under revision; and the National Water Resources Management Strategy 2006
Namibia	Namibia National Water Policy adopted in 2000; Water Resources Management Act adopted 2004
Tanzania	Revised National Water Policy and the National Water Sector Development Strategy were adopted in 2002
Zambia*	National Water Policy adopted 1994; currently under revision. A new Water Resources Management Bill 2007 is awaiting enactment
Zimbabwe*	Water Act adopted 1998

Decentralization is probably most advanced in Mozambique in terms of the institutional model with reduced responsibility at the central level and more at the regional level. Operational water management in that country, previously the exclusive responsibility of the National Directorate of Water in Maputo, has been delegated to five multiple-basin regional water administrations or ARAs. One of these ARAs exclusively manages the national part of the Zambezi basin. Significant in this context is that the ARAs are semi-autonomous institutions under the Ministry of Public Works and Housing and enjoy autonomy in their administrative and financial processes as well as possess the right to own property. Income from water use licenses is retained by the ARA as a basis for sustaining its operations.

Stakeholder participation has found a unique and strongly pronounced form in the institutional framework of Zimbabwe. Whereas in other countries major powers of decision-making, in particular on water use licenses and water allocations, are retained by government structures, in Zimbabwe this power lies with the Catchment Councils that are made up exclusively of stakeholders. The Catchment Councils coordinate their actions with the regional delegations of the Zimbabwe National Water Authority ZINWA but are not dependent on it for their decision-making. In most of the other countries of the region the inclusion of stakeholders in management of water resources takes one form or other.

Both decentralization and stakeholder participation are important issues in relation to transboundary river basin management. Decentralization has the potential to strengthen the focus on operational water management, in particular the collection of hydro-meteorological data leading to an increased allocation of resources to the data collection process. This is important not only for the operational water management processes on national level (e.g. for flood management) but also at the transboundary level potentially leads to coordination processes based on better data. Stakeholder participation on the one hand has the potential to increase the focus on operational water management that delivers results, thereby potentially enhancing transboundary coordination mechanisms, motivating national water managers to seek international cooperation that will help them deliver at home. This holds true especially for downstream countries. Strong stakeholder participation can also lead to a tendency to emphasize national interests over transboundary cooperation. Stakeholders sometimes do not feel the weight of international obligations and cooperation, or even adherence to already agreed policy principles. Altogether, water management is always a balancing act between various different types of interests, both at the national as well as the international level. It's complexity is very high by nature.

2.4.2 National data management systems

Annex 2 described the institutional arrangements for hydro-meteorological data collection in all the basin countries. In some countries the collection of data is not implemented directly by the national water department, or some aspects of it are implemented by other institutions. This fragmentation of responsibility has meant that the complete set of hydro-meteorological data is not available from one authoritative source in the country.

Data collection systems in most basin countries are in a state of deterioration. Basin hydrologists[1] decry the decline in national networks – due to non-repair of gauging stations. In Zambia, for example, out of the 309 gauging stations only half (153) were operational in 2007. Hydrological agencies often have insufficient financial and human resources even to maintain regular data collection.

Also due to constraints in human resources and finances, in some countries there is a backlog of data which is not processed and archived. Another well known problem is the vandalism of hydro-meteorological data collection stations. For example, most Data Collection Platforms (DCPs) constructed under SADC-HYCOS were vandalised within one year of commissioning. This even increases the already existing problems in operation and maintenance.

Groundwater monitoring systems are sparse or do not exist in most countries in the basin.

Also water quality networks are not extensive or do not exist at all. On the main stem of the Zambezi River, a water quality network has been established and maintained by ZRA. Access to data from commercial organisations like ZRA is often restricted or relatively costly.

[1] As reported at the basin hydrologists' Pre-Season Meeting, November 2007

Poor data availability due to the deterioration of the national networks and or the non existence of a network is one of the major problems in data management. However, another problem is the use of different data management systems/ formats (HYDSTRA, HYDATA, and text for river flow data; even more formats for meteorological data) and models, which makes it even more difficult to exchange data.

2.4.3 Regional institutional framework

Regional Framework

In the SADC region, water resources management among member states is governed by the Revised Protocol on Shared Watercourses. A technical unit under the SADC Secretariat is responsible for water resources management in the region. SADC Water Division (WD) is a section of the Directorate of Infrastructure and Services of the SADC Secretariat, based in Gaborone, Botswana. SADC WD represents the basin states on specific issues for which the states have granted a mandate to the Division. Transboundary river basin management is one of those areas in which the Division has been active for a long time. One of the important highlights of the regional cooperation has been the signing and ratification by the SADC countries of the Protocol on Shared Watercourse Systems, first adopted in 1995 and revised in 2001.

Another area of intervention of SADC WD has been the negotiation of an agreement between the riparian countries of the Zambezi river basin on the establishment of the Zambezi Watercourse Commission (ZAMCOM). The ZAMCOM Agreement was signed in 2004 by seven out of the eight basin countries. At the time of writing this report the ratification process is ongoing. ZAMCOM will consists of three levels of authority.

- *ZAMCOM Council of Ministers* of the 8 Zambezi states is the highest level where ultimate decision-making takes place.
- *ZAMCOM Technical Committee*, consisting of Senior Official, is the second level of authority and responsible for technical advisory support to the Council of Ministers. This is an important intermediate level where the direct interaction with each country's national water department is guaranteed.
- *ZAMCOM Secretariat*. The Secretariat will manage ZAMCOM's daily affairs, in particular its programmes and projects.

Altogether, ZAMCOM is set to become an important part of the regional institutional framework for water management.

SADC WD has also facilitated the development of a regional water policy. A consultative and participatory process for the formulation of the Regional Water Policy (RWP) was adopted involving a diverse range of stakeholders at national and regional levels. The RWP is founded on the principles of regional cooperation and economic integration espoused by the SADC

Treaty and the SADC Protocol on Shared Watercourses, and incorporates principles of IWRM, and focuses on cooperative management of shared watercourses within the region, to promote regional integration and poverty eradication and environmental integrity within SADC. An accompanying Regional Water Strategy has been formulated to give effect to the policy.

Bilateral Institutions

Joint Water Commissions: The main bilateral arrangements on water resources management are established through Joint Water Commissions. Riparian countries have long been establishing joint water commissions that allow the countries to consult, negotiate and agree on interventions, utilization and usage of water resources common to both countries. These commissions include management of sub-basins of the Zambezi Basin, for example, the Joint Water Commission between Malawi and Mozambique signed in 2005, Mozambique and Zimbabwe signed in 2001. Besides, these, riparian states have Permanent Joint Commissions, for coordinated development and management of common assets, including water.

Zambezi River Authority (ZRA) is a bilateral institution of Zambia and Zimbabwe established in 1987 through parallel legislation in the two countries. ZRA is institutionally linked to the ministries responsible for energy in both countries. These are not necessarily the same as the ministries responsible for water. ZRA's main function is to manage water resources of Lake Kariba on the main stem of the Zambezi River common to both countries for the production of hydropower. ZRA allocates water from Lake Kariba to the electricity supply companies in both Zambia and Zimbabwe for hydropower generation. ZRA furthermore operates and maintains telemetry stations relevant to the operations of the Kariba Dam, and in consultations with the national electricity undertakings in Zambia and Zimbabwe, undertakes planning for new hydropower stations on the common stem of the Zambezi.

Lake Malawi/Niassa/Nyasa and Shire River Water Resources Management Initiative: Malawi, Mozambique and Tanzania, the three countries riparian to Lake Malawi/Niassa/Nyasa and Shire River signed a Memorandum of Understanding in 2005 for the management of shared water resources of this sub-basin of the Zambezi. The Initiative has proposals for development and adoption of a sub-basin agreement on common management and utilization for water resources of the sub-basin by the three riparian states, capacity building and training in integrated water resources management and strengthening water resources monitoring systems.

3 Water Resources Assessment

3.1 Available Surface Water Resources

3.1.1 Definition

The available surface water resource of a basin is the amount of water generated, through precipitation, over the entire basin. It is equivalent to the water flowing in a stream at a given terminus point over a specified time period. It is usually measured in volume of water over the period or an equivalent average depth of precipitation over the basin. The flow at a point on the river represents the integrated runoff for the entire basin above the point in question; if that point is the outlet of the basin (or sub-basin), then the amount represents the available water resources for the basin.

For the purposes of this study, the focus is on the annual available water resources; hence the interest is on the mean annual runoff for the basin.

3.1.2 Methodology

Mean annual runoff is estimated either from measured flows at a gauging station along the river, or from rainfall-runoff relations usually derived over sub-basins and integrated over the whole basin. Where flow measurements are short, monthly rainfall-runoff models have been used to extend the record or infill data to enable estimates of mean annual runoff. The Pitman model (Pitman, 1973), a monthly rainfall-runoff model requiring mainly rainfall and evaporation rates to estimate runoff, has been used widely in Southern Africa for extending or infilling missing flow data. Where catchments are ungauged, runoff estimates have been made from representative gauged catchments with similar catchment characteristics.

In most of the basin states, water resources assessments have been carried out over the past decade covering a number of sub-basins. A few countries have carried out nation-wide water resources assessments. By and large, the assessments have been based on measured flow data. For Zambia, a national water resources assessment, based mainly on measured stream flow data was carried out in 1995 as an integral component of the National Water Resources Master Plan; in Botswana similar assessment was done recently (early 2006) under the National Water Master Plan Review. On the other hand Zimbabwe has recently (October 2006) carried out a comprehensive surface water resources assessment over the entire country, and has derived rainfall rainfall-runoff relations for ungauged catchments in most parts of the country.

In the course of the Rapid Assessment study for the whole Zambezi Basin the assessment of available water resources was based on existing data. The scope of the assessment did not permit detailed modelling of rainfall-runoff to make estimates of mean annual runoff. Besides, the hydrometric network over the Zambezi Basin is space and poorly maintained, particularly in the upper sub-basins of the basin. Therefore deriving realistic rainfall-runoff relationships, particularly at monthly time periods is very challenging because of the paucity of data.

A simplified form of the water balance equation was used to estimate the annual volume and distribution of water resources in the basin. This simplified equation neglects change in storage, (assuming this to be constant over the period of a year), and percolation to groundwater, and is represented as follows:

$$P + (I) = R + Ea$$

where

P = precipitation

(I) = water imports (e.g. for irrigation from external water sources)

R = runoff ($R = R_s + R_s$)

R_s = surface runoff

R_u = groundwater runoff

E_a = actual evapotranspiration

and E_a = f (land use, area)

The estimates of rainfall, P, and runoff, R, were made from measured data in and near each of the sub-basins. The total actual evapotranspiration was estimated by subtracting runoff from rainfall, with the assumption that ground water percolation is zero. This was adjusted as a function of land use and coverage (area) and was distributed spatially according to the distribution of land cover / water use classes. A detailed description of the water balance model is presented in Annex 3.

The approach that was followed to develop these water balances is similar to the work that was done for the earlier ZACPLAN Sector Study No. 3, but an effort was made to update and improve the results of the earlier study by incorporating the following information:

- Updated river flow data provided by the country teams
- Detailed land cover information for the year 2000
- An updated and improved mean annual rainfall surface for the Zambezi basin using data for 657 Global Historical Climatology Network (GHCN) Version 2 stations. The GHCN Version 2 is global database, updated monthly, compiled from existing national, regional and global meteorological stations.

3.1.3 Runoff

Estimates of historical mean annual runoff for each of the sub-basins were made using measured daily flows provided by the country teams. The data provided by the country teams were in case of need supplemented by flow data from the Southern Africa FRIEND database. The actual runoff for each sub-basin was determined from flow differences between the nearest upstream and downstream gauging stations. In some cases, it was necessary to apply scale factors to compensate for stations that were located some distance from sub-basin inlets and outlets. The stations that were used in the assessment are listed in Table 3.1 and the computed runoff from each of the sub-basins is shown in Table 3.2 and Map 8.

Table 3.1 Flow Stations Used in Runoff Computation

Station	River	Station Number	FRIEND ID	Mean Annual Runoff [10^6 m^3/a]
Zambezi Pump House	Zambezi	1-150	60390050	19 075
Lukulu	Zambezi	2-030	60370030	24,430
Katima Mulilo	Zambezi	2300M01	64370001	37,263
Senanga	Zambezi	2-400	60370001	31,423
Kongola	Kwando	2400M01	0	1,032
Kafue Hook Bridge	Kafue	4-669	6033466	8 696
Chirundu Road Bridge	Zambezi	3-980	0	44,385
Great East Road Bridge	Luangwa	5-940	60332040	18,231
Chikwawa	Shire	1L12	0	17 850
Tete	Zambezi	E-320	58316087	77,741

(*Source: ZAMWIS, 2007 and Southern Africa FRIEND database*)

Table 3.2 Computed Sub-basin Runoff

Sub-basin	Area [km^2]	Scale Factor	Calculation	Mean Annual Runoff [Mm^3]	Mean Annual Runoff [mm]
Shire River / Lake Malawi	158 043	1.15	[1L12]	20 528	130
Luangwa	148 286	1.00	[5-940]	18 231	123
Kafue	157 629	1.20	1.2 x [4-669]	10 435	66
Cuando / Chobe	151 465	1.10	[2400M01]	1 135	7
Barotse	118 994	0.78	0.78 x ([2300M01] - [2-030])	9 986	84
Luanginga	33 931	0.22	0.22 x ([2300M01] - [2-030])	2 847	84
Lungue Bungo	46 482	0.40	0.40 x ([2-030] - [1-150])	2 150	46
Upper Zambezi	90 359	1.00	[1-150]	19 075	211
Kabompo	69 301	0.60	0.60 x ([2-030] - [1-150])	3 205	46
Zambezi Delta	23 653	1.00	Unit runoff similar to Tete	936	40
Kariba	163 202	1.00	[3-980] - [2300M01] - [2400M01]	6 090	37
Mupata	19 552	0.17	0.17 x ([E-320] - [5-940] - (1.2*[4-669]) - [3-980])	774	40
Tete	197 816	1.67	1.67 x ([E-320] - [5-940] - (1.2*[4-669]) - [3-980])	7 831	40
TOTAL/AVERAGE	1 378 713			103 224	75

(*Source: ZAMWIS, 2007 and Southern Africa FRIEND database*)

While the estimates of zero runoff from some of the catchments appears incorrect (because some of the limited rain has very high intensity and will create limited runoff whatever the mean annual value is), it shows that there is probably limited runoff in those areas. It demonstrates that, on an annual basis, local runoff is not sufficient to meet the demands for evapotranspiration.

3.1.4 Basin Water Balance

The surface water availability in each sub-basin is based on the computed runoff derived from historical stream flow measurements. The sub-basin, and Zambezi basin mean annual runoff are presented in Table 3.3 below.

Table 3.3 Zambezi Basin Water Balance

Sub-basin	Area	Rain		Runoff		E_a*	
	[km^2]	[mm]	[10^6 m^3]	[mm]	[10^6 m^3]	[mm]	[10^6 m^3]
Kabompo	69 301	1159	80 304	46	3 205	1113	77 099
Upper Zambezi	90 359	1225	110 722	211	19 075	1014	91 647
Lungue Bungo	46 482	1120	52 056	46	2 150	1074	49 906
Luanginga	33 931	972	32 991	84	2 847	888	30 144
Barotse	118 994	840	99 930	84	9 986	756	89 944
Cuando / Chobe	151 465	760	115 114	7	1 135	753	113 979
Kafue	157 629	1004	158 233	66	10 435	938	147 798
Kariba	163 202	707	115 440	37	6 090	670	109 350
Luangwa	148 286	987	146 414	123	18 231	864	128 183
Mupata	19 552	793	15 500	40	774	753	14 726
Shire River / Lake Malawi	158 043	1157	182 828	130	20 528	1027	162 300
Tete	197 816	903	178 533	40	7 831	863	170 701
Zambezi Delta	23 653	1060	25 063	40	936	1020	24 127
Total/ Average	***1 378 713***	***952***	***1 313 127***	***75***	***103 224***	***878***	***1 209 903***

* E_a is computed as the difference between rainfall and runoff volumes.
(*Source: ZAMWIS, 2007 and Southern Africa FRIEND database*)

According to the water balance, net runoff in the Shire River/Lake Malawi, Upper Zambezi and Luangwa sub-basins are highest, while actual evapotranspiration nearly equals rainfall in the Mupata, Tete and Zambezi Delta sub-basins.

The above analysis shows the Zambezi basin mean annual runoff of 103,224 Mm^3. This, in effect, is the available surface water resources in the basin. The Sector Studies estimated the basin mean annual runoff at 97,432 Mm^3. There is, therefore, an increase of around 15%. Estimates for individual sub-basin vary from those in the Sector Studies, some have reduced (e.g., Kafue) while others show an increase (e.g., Barotse).These differences may be attributed to differences in sub-basin areas, and probably also due to the manner of estimating the runoffs at the inlet and the outlet of each sub-basin.

3.1.5 Lakes and Reservoirs

There are three major lakes in the Zambezi Basin (see Map 9, Annex 1), Lake Malawi, Lake Kariba and Lake Cahora Bassa. The later two are man-made lakes created by the construction of dams on the Zambezi River. There are many other natural and man-made lakes that are smaller in size and associated with dams constructed for hydropower and or water supply for irrigation or domestic use. The key characteristics of the three major lakes are summarised in Table 3.4 below, and described in detail in Annex 4

Table 3.4 Characteristics of Major Lakes in the Zambezi Basin

	Malawi	Cahora Bassa	Kariba
Surface area [km^2]	28,750 **	2,739 *	5,400 *
Volume [km^3]	7,730 **	55.8 *	160 *
Maximum depth [m]	706 (2)	157	78
Mean depth [m]	292	20.9	31
Water level	Regulated	Regulated	Regulated
Normal range of annual water level fluctuation [m]	0.7-1.8	-	2.5
Length of shoreline [km]	245	246	2,164
Catchment area [km^2]	126,500 **	56,927	663,000
Lake Utilisation	Source of water, transportation, sight-seeing and tourism and fisheries.	Hydropower generation, source of water, transportation, fisheries	Hydropower generation, source of water, fisheries, recreation (water skiing, scuba diving, sport-fishing and yachting) and bird-watching, tourism

* Surface area and volume at mean depth.
** Source: Ministry of Irrigation and Water Development, Malawi
(Source: Database of International Lake Environment Committee, 2007 at www.ilec.or.jp/database, except for **)

All the major lakes are important in the assessment of renewable water resources of the basin and need to be considered in any water allocation decisions. However the two man-made lakes – Lakes Kariba and Cahora Bassa – were primarily designed for single purpose use, for hydropower. But it is now appreciated that they need to be integrated into any water resources management decisions for the basin. Thus their operational rules are being reviewed and revised to take into account other uses, in particular, flood control, environmental flows and tourism.

3.2 Available Groundwater Resources

3.2.1 The role of groundwater in the Zambezi River Basin

Groundwater is a major source that maintains the base flow in the Zambezi River during the dry period and it is also an important resource for large parts of rural Africa providing water for household use through natural springs and both rudimentary and advanced water intake structures (shallow wells and boreholes). National plans for water supply and sanitation indicate that in almost all the countries of the Zambezi River basin, groundwater is the main source of rural water supply. It is also an important source of urban and peri-urban water supply for rural towns and some major cities. For example, the city of Tete in Mozambique uses groundwater as the only sources for water supply; in Lusaka about 50% of its water supply is groundwater from boreholes drilled in the dolomite aquifer system. The achievement of MDGs in sanitation and water supply for rural and urban communities would to some extent, therefore, depend and would be based on groundwater development.

Groundwater is also and important contributor to the baseflow feeding streams and rivers during the dry season. This contribution, together with dam discharges, is responsible for the perennial flow regime in most the stretches of the river.

However, data and information to assess the ground water availability and its full role is fragmented and based on different set of standards and practices. It has, therefore, been difficult to assess the amount of groundwater available in the basin in the past studies as well as the current ones. Groundwater resources knowledge is not much different for the Zambezi River basin as compared to the rest of SADC region. For this reason SADC launched a project in early 1999 aiming at developing minimum groundwater development and management standards across the region. A subsequent project aiming at developing a regional hydrogeological map was less successful due to large disparity in level of information and existence of large areas without background information. In October 2007, SADC invited short listed consultant to submit a proposal to develop “Regional Groundwater Drought Management Support for SADC”. This study focuses on the regional importance and threats to the groundwater resources of the region. The main objective is to stimulate sound development and management of this key resource in the region and minimize or/and mitigate against the effect of groundwater drought.

The present section of the Report is developed in such a way that it gives a general overview of the groundwater resources of the Zambezi River basin and forms the basis for the consideration of the strategic options for a future conjunctive use of water resources of the basin. Geological, physiographic and climatic conditions of the region are determinant to groundwater potential of the area. The physiographic and climatic conditions of the basin are described elsewhere in this report; the present sections will concentrate on the geological features of the basin and on the hydrogeological features resulting from the combination of these three.

3.2.2 Hydrogeological Features of Zambezi River Basin

Major Types of Aquifers

The vast Zambezi River basin can be divided into three major lithological groups as shown in Map 3 in Annex 1: (i) the Kalahari Sands; (ii) the

Dolomites, quartzite, shales and sandstone and (iii) the Basement granites and gneisses.

An important aquifer type in the basin is the intergranular aquifer that is well represented by the Kalahari sand aquifer system in the western part of the basin that is found in Angola, Zambia, Namibia and Botswana. Alluvial aquifers are also found mainly along the margins of main river channels or in old channels as the river changed its course along the years. These are mostly high yielding systems with great potential for large scale use. Karoo deposits are also intergranular aquifers and occur mainly in the middle section of the basin between Zambia, Zimbabwe and Mozambique. These are mainly poor yielding aquifers that occasionally have high secondary porosity or faulting that confer the system moderate to high yields.

Dolomite, Sandstones and Limestones aquifers predominate in the Kafue sub-basin. These aquifers have good potential in the presence of extensive secondary porosity. These have been largely exploited in Zambia and Zimbabwe. The most prominent of these aquifers is the second main source of water for the City of Lusaka in Zambia and has prospect for becoming the main source of water supply of the city .

Large parts of the Zambezi River basin present aquifers where groundwater flows mainly in fissures, channels or discontinuities; these are crystalline formation or basement formation aquifers. They occupy most of the Shire River sub-basin, parts of Luangwa, Tete eastern parts of Kariba sub-basins

Apart from the main group given above there are other formations with local relevance to groundwater occurrence. In the lower sections of the basin, Zambezi delta, and along the main river channels and flood plains sedimentary formation of sands, silts and clays including lake beds are common.

Pockets of Sandstones, mudstones and Siltstones located in old valleys and depressions are found in the southern part of the basin specifically in the Kariba sub-basin; marine sandstones, shales; siltstones appear sporadically on the right bank of the Cahora Bassa lake and in the lower sections of the Tete valley in Mozambique.

Small sections of metasediments, igneous complexes and volcanic material are commonly found along the north eastern boundaries of the basin in Zambia in the Luangwa sub-basin and south eastern sections of the basin in Zimbabwe along the Kariba Sub-basin.

Ground Water Resources

A groundwater potential map of the Zambezi basin in given in Map 10 in Annex 1. This map was obtained from the FRIENDS report for the SADC region. There are considerable gaps in the map, for example, faults and other geological structures are not shown; the extension of the Kalahari system into Angola is not well represented resulting in difference in yields of the aquifer along the border with Zambia. Groundwater movement in the basin is not represented and no data was obtained to enable generation of basin wide maps. The existing country hydrogeological maps use different sets of legends and denomination and would required extensive work for generation of new map within the duration of present assignment.

The knowledge base on groundwater resources in the region is, therefore, very limited and would not be sufficient to support its planning and development at regional level. The information and data obtained in the course of the present study is only enough to give an overview of the resource potential. Overall most production boreholes records obtained for this study, are from basement aquifers with yields around 1 to 2 litres per second; alluvial aquifers, which can yield up to 10 to 15 litres per second and dolomite aquifers, which can yield up to 40 to 80 litres per second, such as those supplying water to Lusaka City.

The existing information, as shown in Map 10 in Annex 1, needs to be read with due care given the limitations discussed. In most of the Angolan portion of the basin, especially along the border with Zambia and Namibia where the Kalahari sands are present, the potential is higher than shown in the map and should be read as being in the range of 5 – 10 litres/s. In Malawi to the west of Lake Malawi/ Niassa/ Nyassa yields are expected to be in the range 1 – 3 litres/s.

Overall the groundwater potential of the Zambezi River basin, targeting large water use, i.e., irrigation, is moderate to low but occasionally high especially in alluvial aquifers along the main river stems and Karst aquifers with high secondary porosity. Other areas with considerable potential are located in basement aquifers with extensive faulting but these are localized system and only present in few areas across the basin.

3.3 Flow Regimes and Regulation

3.3.1 Floods

Floods and droughts are part of the hydrological features of the Zambezi river basin and occur almost cyclically. The majority of the population in rural areas across the Zambezi River basin practice subsistence agriculture along the flood plains, swamps, wetlands and margins of large water bodies. Although for large parts of the river basin the threats related to flooding are limited, the situation is different in some sections of the upper, middle and lower Zambezi where floods inundate extensive areas and result in serious infrastructure damage, people and property loss.

The floods in the Zambezi River basin can be characterized in two main types (i) floods in swamps, wetlands and flat areas along the extensive Barotse Flood Plains, Kafue Flats and Lower Zambezi Delta ; (ii) floods due to over bank flows along the upper Luangwa, Caprivi Strip, upstream of Cahora Bassa reservoir and Lower Tete. The main difference between the two main types is the recurrence and extent of flooding; while in type (i) floods occur every rainy season to some extent, type (ii) is usually associated with extreme rainy conditions in the basin.

The existing flood prone areas (see Map 11 in Annex 1) are located in areas with little river regulation. Even in the case of the Lower Tete and Zambezi delta, areas located downstream of the two major dams (Kariba and Cahora Bassa), the effect of regulation, within the current management scenario that mainly target hydropower generation, does not result in significant mitigation of large floods. Moreover, in the event of large floods, there are extensive portions of the basin contributing flows to these sections that are not regulated namely the Revúbuè, Luenha and Shire rivers further reducing the impact of upstream regulation.

Floods also have significant positive roles in culture and livelihoods of the people of the Zambezi basin. Floods bring sediments and nutrients that increase soil fertility, and increase spawning grounds for fish, especially in the Zambezi delta. The annual *Kuomboka Ceremony* of the Lozi people in Western Zambia marks the movement of the traditional chief (the Paramount Chief, the *Litunga)* and his peoples from the flooded Barotse plains to higher grounds. The colorful regatta of boats moving across the flood plains and the attendant cultural festivities is in effect a celebration of the benefits of the floods to the livelihoods of the people. Today this tourist attraction of world renown expresses to the world the links between the people and the Zambezi River.

The present hydraulic infrastructure development in forms of large dams, although it has impact in terms of river regulation and change of hydrological flow characteristics, does not contribute significantly to flood regulation especially in case of floods caused by large-scale atmospheric events such as cyclone spanning across extensive areas of the basin. For example during the floods of 2007 although Cahora Bassa dam in Mozambique was operated to reduce the flood peak in the main river stem the flows received from the unregulated rivers downstream of the dam, mainly Revubué, Shire and Luenha, resulted in extensive damage and loss of 30 lives, and displacement of 120,000 people, and also impacted the peoples economically in terms of huge losses of harvest. The 2007 February floods were the worst in 6 years; however the death toll was not higher owing to improved disaster management by the Mozambican authorities with support from regional and international community.

Improved reservoir operations for the main two man-made reservoirs in the basin will have considerable benefits for both ecology and some flood mitigation. However, given that large parts of the basin remain unregulated another important action that can contribute in reducing the negative impacts of floods in the Zambezi basin is flood management initiatives that are non-physical interventions like improved territorial planning and flood forecasting systems associated with strong disaster management systems.

3.3.2 Droughts

Unlike floods, droughts cover extensive geographic areas and have had large impact than floods. It is usually much more difficult to perceive the beginning and end of droughts as this is normally a result of accumulated deficit in soil moisture and rainfall.

Southern Africa region is known for its recurrent drought conditions that span across the entire region causing famine conditions and death. The most notorious droughts in recent history hit the region during the period 1991-1992 and 1994-1995. These droughts affected water supplies (both in rural as well as urban areas – evidenced by severe water rationing in urban centres), reduced crop harvests, The situation is likely to get worse as population increases put more pressure on the environment and increases vulnerability.

Drought Monitoring

One way of monitoring droughts is to keep track of the Normalized Difference Vegetation Index (NDVI) derived from satellite imagery. NDVI measures vegetation "greenness" or plant health based on the principle that plants prefer to use (absorb) visible red colors (wavelengths) of sunlight for photosynthesis during growth. For example, a healthy plant will absorb more visible red sunlight for photosynthesis and reflect less back to the atmosphere. A plant stressed by drought will photosynthesize less and reflect more sunlight back to space. A satellite can measure the amount of sunlight reflected in the red and near infrared spectrum and the NDVI can be computed to provide a relative measure of greenness or plant health that can be displayed as an image. These changes in vegetation patterns have implications for agriculture, livestock farming and vector borne disease outbreaks. Above normal vegetation conditions are an indicator of improved pasture conditions which boosts livestock production in these areas.

Today there are many sources of images that enable one to conduct such an analysis with relatively easy and at increasingly affordable cost. Over the period of 4 years between 1997 and 2000 NDVI anomalies for the Eastern and Southern Africa (Earth Observatory, 2002) indicate that SADC region enjoyed a rather good climatic conditions with most of the area showing less red and brown areas that express dryness in the NDVI anomaly analysis.

Although the NDVI gives a good way of monitoring droughts, it should however been mentioned that this index registers agricultural droughts (which might be caused by unwise human decisions, e.g., wrong crop variety, poorly developed/ managed infrastructure), and will therefore not always indicate hydrological droughts.

Drought Index

In the course of preparation of the Rapid Assessment a drought sensitivity map of the basin was prepared that will enable planning and implementation of measures to mitigate drought effects. In this methodology rainfall is in the centre of analysis over a period of time. Rainfall data was obtained from Global Historic Climatology Network (GHCN) database. The data is used to monitory rainfall anomalies over long period of time and thus establish the most drought sensitive areas. For this particular study the following analyses were carried out:

- computation of the 80% exceedence values of annual rainfall totals (driest year in 5) for each of 589 GHCN stations;
- interpolating the point values with ordinary kriging to produce a drought rainfall surface
- computation of a drought index, as the percentage deviation of the driest year in 5 from mean annual rainfall; the index being calculated as follows:

Index = ([Mean Annual Rainfall] - [Driest Rainfall amount in 5 years]) / [Mean Annual Rainfall]*100. The larger the index value, the more susceptible to droughts is the location.

The 80% rainfall exceedence map is shown in Map 12 in Annex 1. The basin can be split in mainly three sections: (i) the southern with relatively low rainfall conditions; (ii) the middle section, comprising southern parts of Zambia and north-western parts of Mozambique, with medium rainfall; and (iii) the upper Zambezi area covering Angola, northern and eastern parts of Zambia, and the surroundings of Lake Malawi/Niassa/Nyassa, and the Zambezi delta, with relatively higher rainfall values.

The resulting drought susceptibility map is given in Map 13 in Annex 1 and expresses well the relative high drought vulnerability of the basin, a common characteristic of the SADC region. Except the Upper Zambezi area near the source of the river the whole Zambezi basin is susceptible to droughts exposing most of its rural population to high vulnerability to climatic variability.

4 Water Utilisation and Demand

This section makes an assessment of current and future water demand in the Zambezi Basin. It does so by looking at domestic water demand, industrial water demand and demand for agriculture, hydropower and other uses such as navigation. This is the basis of a number of water utilisation scenarios, which are compared with the surface runoff in the Zambezi Basin in section 4.10.

4.1 Population in the Zambezi Basin

The division of the Zambezi River basin into 13 sub-basins cutting across international borders between the riparian countries and within the countries does in most cases not tally with the existing demographic records that use administrative rather than hydrological boundaries. In general, records present data by districts which often cut across more than one sub-basin and/or cover areas lying outside of the river basin. Moreover, the existing national sources of demographic data are not necessarily consistent with each other over time and space.

The source of demographic data is Griddled Population of the World, version 3 (GPWv3) and Global Rural-Urban Mapping Project (GRUMP), alpha version, available at http:/sedac.ciesin.org/gpw/documentation.jsp. GPWv3 relies on national statistical office estimates of population. This database has a GIS based facility for adjusting population densities to suit defined geographic areas, as is the case for sub-basin areas. The population in the sub-basins has been estimated on the basis of the proportion of the area falling in the sub-basin. Adjustments have been made for major towns.

The total number of people (2005/6) living in the Zambezi Basin is close to 30 million. Their distribution over the eight Zambezi Basin countries and over the 13 sub-basins is summarized in Table 4.1 and presented in Map 14 in Annex 1.

Table 4.1 Population ('000) in Zambezi River Basin, 2005/6

Sub-Basin	Ang	Nam	Bot	Zam	Zim	Mal	Tan	Moz	*Total*	%
1-13	4			279					***282***	0.9
1-12	200			71					***270***	0.9
1-11	99			43					***141***	0.5
1-10	66			56					***122***	0.4
1-09	7	66	0.3	679					***752***	2.5
1-08	156	46	16	70					***288***	1.0
1-07				3,852					***3,852***	12.9
1-06			0.3	406	4,481				***4,888***	16.3
1-05				1,765		40		12	***1,818***	6.1
1-04				113	111				***224***	0.7
1-03				13		10,059	1,240	614	***11,926***	39.8
1-02				221	3,011	182		1,641	***5,055***	16.9
1-01								349	***349***	1.2
Total	***531***	***112***	***17***	***7,567***	***7,604***	***10,282***	***1,240***	***2,617***	***29,969***	
%	1.8	0.4	0.1	25.2	25.4	34.3	4.1	8.7		100.0

(Source: GRUMP)

Table 4.1 highlights the uneven distribution of population over the basin. More than 85% of the basin population live in the three countries Malawi, Zimbabwe and Zambia. The sub-basins 1-03 (Shire River), 1-02 (Tete), 1-06 (Kariba) and 1-07 (Kafue) together contain more than 85% of the basin population. Population density in the sub-basins in the Upper Zambezi by contrast is very low.

Out of the total present population of about 30 million, approximately 7,60 million (equivalent to 25,3%) live in 21 main towns, i.e. in towns with 50,000 or more inhabitants. The total populations for these towns are presented per country and sub-basin in Table 4.2.

The large majority (75%) of the population in the Zambezi Basin lives in rural areas. The proportion of rural population varies from country to country, from over 50% in Zambia to around 85% in Malawi. This population split has a bearing on water demand since domestic water consumption in rural areas is smaller than in the urban areas.

Table 4.2 Population in Main Towns by Sub-basin and Country

Sub-catchment	Country	Town	Urban Population
Kabompo River (1-13)	Zambia/ Angola	None	
Upper Zambezi (1-12)	Angola/ Zambia	None	
Lungue Bungo (1-11)	Angola/ Zambia	None	
Luanginga River (1-10)	Angola/ Zambia	None	
Barotse (1-09)	Zambia/ Angola	None	
Cuando/Chobe (1-08)	Angola/ Namibia/ Botswana	None	
Kafue (1-07)	Total		2,578,000
	Zambia	Chililabombwe	60,900
		Chingola	164,600
		Mufulira	136,600
		Kitwe	406,100
		Luanshya	129,100
		Ndola	418,400
		Lusaka	1,211,100
		Kafue	51,200
Kariba (1-06)	Total		1,560,800
	Zambia	Livingstone	108,900
	Zimbabwe	Hwange	58,700
		Bulawayo	1,003,700
		Gweru	157,500
		Kwe Kwe	81,500
		Kadoma	110,300
		Chegutu	40.200
Luangwa (1-05)	Total		279,000
	Zambia	Chipata	81,600
		Kabwe	197,400
Mupata (1-04)	Zambia	None	0
Shire River (1-03)	Total		1,084,200
	Malawi	Lilongwe	521.800
		Blantyre	562,400
Tete (1-02)	Total		2,100,200
	Zimbabwe	Harare	1,976,400
	Mozambique	Tete	123,800
Zambezi Delta (1-01)	Mozambique	None	0
TOTAL			***7,602,200***

(Source: www.tageo.com)

4.2 Domestic Water Use

Part of the water used by domestic and urban users is derived from groundwater sources. As such it does not directly affect the Zambezi Watercourse and its tributaries, particularly as groundwater is not overused, and for large parts of the steep topography of Zambezi basin rivers do not contribute significantly to groundwater levels. This interaction is significant only along the flood plains and extensive flat areas such as Kafue with seasonal recharge and discharge from/to river/aquifer.

Within the context of this study it was not possible to obtain data to enable a quantitative distinction to be made regarding which users draw on groundwater and which are supplied with surface water. Quantification of water use by domestic, institutional and industrial users has been estimated, using the populations in the major town as the base. These estimates then provide the basis for further estimates on effluent generation.

Reliable data on domestic and institutional water use is not readily available from most urban centres in the Zambezi Basin. To estimate this water use it is assumed that current net urban water use per capita (taking into account return flows and water use by service businesses) is 85 litres/day/ capita. For rural water supply a norm of 20 litres/day/capita has been adopted. It is assumed that 90% of the urban water supply comes from surface water and 15% of rural water supply comes from surface water.

Under this projection urban and rural domestic water supply projections for 2005 are given in Table 4.3. They assume that 90% of urban water demand comes from surface water and 15% of rural water supply comes from surface water.

Table 4.3 Rural and urban water use 2005/2006

	Population 2005/6	Per capita consumption per day In litres	% from surface water	Total consumption In Mm3
Urban	7,602,200	70	90	175
Rural	22,366,800	20	15	24

4.3 Water Use for Industries and Mines

A number of urban centres in the Zambezi Basin have significant industrial and commercial activity other than mining (see Map 15 in Annex 1). These towns include Kitwe, Ndola, Lusaka, Kafue in Zambia, and Bulawayo, Gweru, Kwe Kwe, Harare in Zimbabwe. There is very little reliable data recorded for water use and wastewater discharges for these industries. The industrial water use therefore is estimated on the basis of a number of steps:

- A list of industries is used for each town (see Annex 6);
- Note has been taken of the wet industries, with a relatively high demand for water;
- An estimate has been made of the industrial water demand in each town as a percentage of demand from institutional and domestic users in that town;
- The estimated losses of abstraction, treatment and reticulation are estimated at 30%;
- The losses from the sewers are estimated as for domestic and institution use at 10%;

- The wastewater fraction returned to the watercourse after losses in treatment and irrigation of final effluent, and the fraction discharged to open drains have been estimated.

Table 4.4 Industrial water use for the main urban areas

Total Industrial Water Supply (m^3/d)	98,615
Net Industrial Water Use (m^3/d)	68,182

Industrial water use at less than 70,000 m^3/d (25 million m^3/ year) as part of the total supply is still rather insignificant. A major portion of the used industrial water is returned to the watercourse as (treated) wastewater.

4.4 Agriculture

4.4.1 Irrigated area

Agriculture in the Zambezi Basin is largely rain-fed or flood-dependent. An estimated 5.2 million ha is cultivated yearly in the Basin. Measured in ha of present total area under crop production Zimbabwe, Zambia and Malawi have together 85% of this total cultivated area.

Zimbabwe has 56% of its cultivated area in the country in the Basin, Zambia 76% and Malawi 90%. More than 60% of the total cultivation in the Basin is concentrated in two sub-basins Tete (sub-basin 1-02) and Shire River (sub-basin 1-03).

The areas used for irrigated agriculture in the basin are presented by sub-basin and country in Table 4.5, as based on the Sector Studies. The total area under irrigation in the Zambezi Basin is 171,621 ha in 1995. More than 90% of irrigated agriculture is concentrated in the four sub-basins Tete (sub-basin 1-02), Shire River (sub-basin 1-03), Kariba (sub-basin 1-06) and Kafue (sub-basin 1-07). Half of the total area under irrigation in the basin is in Zimbabwe.

Table 4.6 shows the use of water for irrigated agriculture, adjusted by the cropping pattern and evaporation requirements n the different basins. More than 90% is used in sub-basins Tete (sub-basin 1-02), Shire River (sub-basin 1-03), Kariba (sub-basin 1-06) and Kafue (sub-basin 1-07). Shire River sub-basin and Kafue sub-basin have large sugar schemes in them which account for as much as 60% of the irrigation water used. Kariba sub-basin and Tete sub-basin are dominated by the commercial farming sector in Zimbabwe, which accounts for 85% of the irrigation water used in these two sub-basins. The combined water use for irrigation is 1,477 Mm3.

Table 4.5 Irrigated Land by Sub-basin and Country (ha), 1995

Sub-bas	Ang	Nam	Bot	Zam	Zim	Mal	Tan	Moz	*Total*	%
1-13	5			320					***325***	0.2%
1-12	350			95					***445***	0.3%
1-11	160			40					***200***	0.1%
1-10	80			250					***330***	0.2%
1-09	10	170		1,500					***1,680***	1.0%
1-08	370	650	660	50					***1,730***	1.0%
1-07				32,500					***32,500***	18.9%
1-06			1	1,400	25,000				***26,401***	15.4%
1-05				4,300				10	***4,310***	2.5%
1-04				1,700	450				***2,150***	1.3%
1-03						36,500	150	120	***36,770***	21.4%
1-02				180	60,100			1,000	***61,280***	35.7%
1-01								3,500	***3,500***	2.0%
Total	***975***	***820***	***661***	***42,335***	***85,550***	***36,500***	***150***	***4,630***	***171,621***	
%	0.6%	0.5%	0.4%	24.7%	49.8%	21.3%	0.1%	2.7%		100.0%

(Source: Denconsult, 1998; Sector Study No. 2)

Table 4.6 Water Use for Irrigation and by Sub-basin and Country, (‘000m^3)

Sub-bas	Ang	Nam	Bot	Zam	Zim	Mal	Tan	Moz	*Total*	%
1-13	40			2,054					***2,094***	0.1%
1-12	2,250			618					***2,868***	0.2%
1-11	1,032			276					***1,308***	0.1%
1-10	507			1,626					***2,133***	0.1%
1-09	45	1,087		10,071					***11,203***	0.8%
1-08	2,405	4,167	6,635	316					***13,523***	0.9%
1-07				327,195					***327,195***	22.2%
1-06			21	9,168	174,715				***183,904***	12.5%
1-05				30,197	-			64	***30,261***	2.0%
1-04				14,702	2,916				***17,618***	1.2%
1-03						390,640	21,619	807	***413,066***	28.0%
1-02				1,255	425,130			6,922	***433,307***	29.3%
1-01								38,437	***38,437***	2.6%
Total	***6,279***	***5,254***	***6,656***	***397,478***	***602,761***	***390,640***	***21,619***	***46,230***	***1,476,917***	
%	0.4%	0.4%	0.5%	26.9%	40.8%	26.4%	1.5%	3.1%		100.0%

(Source: Denconsult, 1998; Sector Study No. 2)

4.4.2 Livestock

The bulk of livestock in the Zambezi basin consists of cattle. Cattle, therefore, is regarded as representing livestock with regard to the purpose of this study. The most recent distribution of cattle is presented in Table 4.7.

Table 4.7 Cattle by basin, category and country (heads) 1995

Country	Upper-basin	Middle-basin	Lower-basin	Zambezi	% of
Sub-basins	1-08 to 1-13	1-04 to 1-07	1-01 to 1-04	1-01 to 1-13	total
Angola	151,140			151,140	2%
Namibia	83,425			83,425	1%
Botswana	2,000			2,000	0.03%
Zambia	592,190	1,515,747	30,626	2,138,563	31%
Zimbabwe		1,557,593	1,245,153	2,802,746	41%
Malawi			1,252,566	1,252,566	18%
Tanzania			350,655	350,655	5%
Mozambique			115,170	115,170	2%
Total	828,755	3,073,340	2,994,170	6,896,265	
% of total	***12%***	***45%***	***43%***		***100%***

(Source: Denconsult, 1998; Sector Study No. 2)

Also concerning cattle, Zambia, Zimbabwe and Malawi altogether have 90% of the animals in the Basin. About 80% of the cattle population in the Basin is concentrated in 4 sub-basins Tete (sub-basin 1-02), Shire River (sub-basin 1-03), Kariba (sub-basin 1-06) and Kafue (sub-basin 1-07).

The use of drinking water by cattle is calculated at 45 litres per head per day for non-dairy cattle and 90 l/head/day for dairy cattle. This on the high side, which is probably on the high side, but no estimate has been included for other livestock like sheep and goats. Total drinking water for cattle amounts to some 113 Mm^3 /year for the Basin for 1995. It assumed that cattle population has increased with 2%/ annually in the period 1995-2005, which bring the total to 141 M m3.

4.5 Hydro-power

Hydropower production is an important sector in the Zambezi Basin. A number of hydropower plants in the Zambezi river basin are characterised as run-of-river plants with only a small reservoir or intake dam. Other plants have a reservoir with a storage capacity to save water from the rainy through the dry season. Very large reservoirs have capacity to save more than one year of rainfall, thus saving water from wet years for drier years.

Only three existing reservoirs in the Zambezi river basin have a regulating capacity of significance: Kariba, Cahora Bassa and Itezhi-Tezhi. All others show a regulating ratio (live storage as per cent of average annual inflow) close to zero.

Although only part of the hydropower potential of the Zambezi River basin has been developed, this sector is by far the largest water user because of the evaporation from hydropower reservoirs. The existing hydropower plans, their capacity, average power production, reservoirs and average evaporation is presented in Table 4.8.

Table 4.8 Existing hydro-power plants by sub-basin

Sub-basin	Power plant Reservoir	River	Installed capacity (MW)	Average annual generation		FSL	Surface area *	Annual Evaporation	
				[GWh]	[%]	[m]	[km^2]	[Mm^3]	[%]
1-02	Cahora Bassa	Zambezi	2,075	17,000	51.5	326	2,660	5,799	34.1
1-03	Nkula A	Shire	24	171	0.5	377	0.4	0.9	0.01
	Nkula B	Shire	100	411	1.2				
	Tedzani I+II	Shire	40	211	0.6	320	0.8	1.8	0.01
	Tedzani III	Shire	52	291	0.9				
	Kapichira I	Shire	64	9	0.0	147	2	4.4	0.03
	Wovwe	Wovwe	5		0.0				
1-05	Mulungushi	Mulungushi	20	80	0.2		31	49.6	0.3
	Lusemfwa	Lusemfwa	18	113	0.3		45	72	0.4
	Lusiwasi	Lusiwasi	12	105	0.3		3.4	5.4	0.03
1-06	Victoria Falls A	Zambezi	8	52	0.2				
	Victoria Falls B	Zambezi	60	390	1.2				
	Victoria Falls C	Zambezi	40	260	0.8				
	Kariba North	Zambezi	600	3,800	11.5	488.5	5,577	8,923	52.5
	Kariba South	Zambezi	666	4,200	12.7	488.5			
1-07	Itezhi-Tezhi	Kafue	900	5,900	17.9	1030.5	392	660.5	3.9
	Kafue Gorge	Kafue				977.2	800	1,472	8.7
Total			***4,684***	***32,993***	***100.0***		***9,490***	***16,989***	***100.0***

* Reservoir surface area is normally calculated at full supply level (FSL). However, this was not confirmed for all of the reservoirs.

(Source: Denconsult, 1998; Sector Study No. 5)

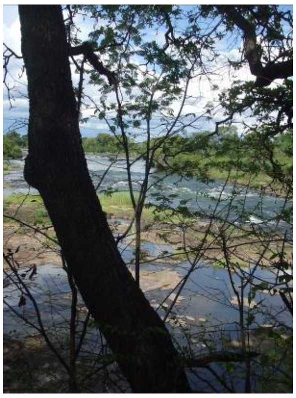
A total capacity of 4,684 MW has been developed in the Zambezi River basin, of which 75% is on the Zambezi River itself, producing an average of almost 33,000 GWh per year. Of the total developed capacity 5% is in Malawi, 45% in Mozambique, 36% in Zambia and 14% in Zimbabwe.

The Kariba and Cahora Bassa reservoirs totally dominate the picture of the present hydropower reservoirs within the Zambezi river basin in terms of surface area and evaporation. All other reservoirs are small compared with these two. The live storage of Kariba accounts for more than 50% of the total live storage of the existing reservoirs, while Kariba plus Cahora Bassa accounts for about 95%. Kariba alone has a surface area of 5,577 km^2 or almost 60% of the total surface area of the existing reservoirs, while Cahora

Bassa has a surface area of 2,660 km^2. Kariba plus Cahora Bassa account for more than 85% of the surface area. Itezhi-Tezhi, the third largest reservoir, has a live storage of about one tenth and a surface area of less than one third of the respective figures for Cahora Bassa.

The total annual evaporation from the existing hydropower reservoirs in the Zambezi River basin has been estimated at approximately 17 km^3 (17 billion m^3). This is by far the largest water use in the basin. The evaporation is dominated by Kariba, which accounts for more than half of the total evaporation, and Cahora Bassa which accounts for close to 35%. These two reservoirs thus account for about 85% of the present total evaporation from hydropower reservoirs in the basin. Kafue Gorge accounts for close to 9% and Itezhi-tezhi close to 4% of the evaporation. The remaining reservoirs are small with a limited evaporation.

4.6 Environmental Water Demand



Fisheries, fauna and flora need water of specific qualities and quantities to survive. The most important fish habitats in the basin (rivers, lakes, and wetlands), the aquatic ecosystem supporting variety of wildlife and birdlife, as well scenic beauty, all depend on sufficient quantities of water for survival. It is now widely recognised that the Environment has a legitimate demand on the available water resources in the basin. “Environmental flows” are defined as stream flow necessary to sustain habitats, encourage spawning and the migration of fauna species to previously unpopulated habitats, enable processes upon which succession and biodiversity depend and maintain the desired nutrient structure within rivers, lakes and wetlands when ecosystems are subject to flow regulation and competition from multiple users (defined in Botswana’s National Water Master Plan Review, 2006).

Large water resource developments or excessive abstraction of water from rivers affect their flow regimes water chemistry, and sediment and temperature regimes, consequently affecting their fauna and flora. Abstraction of water for hydropower production, for the mining and industrial sectors has affected the natural flood regime in some areas of the basin.

The Kafue Flats in Zambia, an area of 4,380 – 7,000 km^2 of floodplain on the Kafue River was once the most productive fishery in Zambia, and included some of the most spectacular concentrations and vulnerable species of mammals and birds in Africa (Bingham, 1978). In addition, floodplain grazing supported some 700,000 cattle, a quarter of the national herd (Ghirotti *et al.,* 1991). With the construction of the Kafue Gorge Dam in 1971 and its regulating reservoir at Itezhi-tezhi in 1978, river regulation was instituted. Since 1972, regulation has attenuated the flood peaks and raised base flows; drainage has been retarded, the area of floodplain reduced and unseasonable fluctuations in water level induced. The Itzehi-tezhi was the first reservoir in Africa with a provision for flood releases, amounting to 15% of its capacity. These releases are made in March. As there are problems with prior warning the flood releases do damage standing crops as they are not anticipated by farmers. Also the flood releases are made relatively late in the cultivation season. The construction of the Kafue dams has led to decline in fish production and fish biodiversity, and decline in flood plain pasture.

In the Lower Zambezi and Zambezi Delta in Mozambique, river regulation began with the closure of the dam at Kariba in 1958, but with the completion of Cahora Bassa in 1975, flows in the lower Zambezi dramatically changed. There is now little seasonal variation in river flow at Tete. The natural flood has been attenuated and the base flow increased; flood peaks are unpredictable and may occur at any time. Regulation has probably caused significant economic damage to both the freshwater and marine shrimp fisheries in the delta.

In Mozambique the elements of Environmental Flow Assessment for both rivers and estuaries have been reviewed. In Zambia, an environmental assessment of the Kafue River Basin was carried out in 2003. Different basin countries are at different stages of defining the Environmental Flow Requirements (EFR) for their different river systems. There have been several studies that have tried to map out the environmental flow requirement for different ecosystem within the basin. The status of EFR in different Zambezi River basin countries is as shown in Table 4.9.

Table 4.9 EFR in Different Portions of Zambezi River Basin

Country	River system and EFR Data
Angola	No available data
Botswana	No data available on rivers within the Zambezi basin, data for other basins:
	▪ Nata River: 2.9 m^3/s
	▪ Shashe River: 6 m^3/s
	▪ Okavango River: 390 m^3/s
Malawi	8-10% of average long term river flow
Mozambique[1]	Marromeu Complex of the Zambezi Delta : A two-week release in February to generate flows of 4,500 m^3/s
Namibia[2]	Lake Liambezi, Namibia: Maintain El. 935.8 m at the intake sill which occurs when discharge in the Cuando/ Linyanti/ Chobe/ River exceeds 2,500 – 3,000 m^3/s.
Tanzania	No available data
Zambia[3]	Itezhi-tezhi dam release: 400 m^3/s in February and 600 m^3/s in March and April is required
Zimbabwe	No data available

([1] *Source: Beilfuss et.al., 2006;* [2] *Source: Hughes, 2004;* [3] *Source*: *Scott Wilson Piésold, 2003).*

4.7 Navigational uses

Various sections of the Zambezi River have been used for navigation in the past. Testimony to the relatively low economic growth of the region in the last two decades, there has been little development of new navigation in the Zambezi Basin. There is considerable potential, however, and interest to improve navigability of the Zambezi River, including the lakes and impoundments. This concerns both international transport routes (Kazungula and Katima Mulilo - Sesheke), as well as major national routes like in the upper Zambezi River and Caia in Mozambique and on lake

Malawi. The National Water Resources Plan of Mozambique has a provision to undertake studies to improve navigability of the Lower Zambezi. The initiatives require improved berthing infrastructure, flow level regulation, aquatic weed control and, in selected places, dredging. The resurgence in mining may prompt navigational improvement. Also recently an agreement has been concluded between the Governments of Malawi and Mozambique to revitalize navigation on the Lower Shire. Improved navigation combined with regional road network planning could be a step forward towards closer cooperation between countries in the basin.

Below a short overview of the options for navigation in the Zambezi is given:

1 Upper Zambezi and Barotse: Navigation in the Upper Zambezi is difficult over larger sections due to rapids and due to shallow water. Potential exists in the Barotse Flood Plain, but below that there are further rapids. There are several crossings, Kazungula being the most important one, but shallow water at the landing site at times of the year causes problems. A further reduction in the water level in the upper Zambezi will have a detrimental impact on navigation.

2 Central Zambezi Impoundments: Navigation on Lake Kariba and Lake Cahora Bassa is developed. On Lake Kariba both Zambia and Zimbabwe utilise the lake for transport to create accessibility to settlements that are otherwise isolated. Low water levels hamper accessibility particularly on the Zimbabwean banks of Lake Kariba.

3 Central Zambezi: Ferry crossings such as between Luangwa (Zambia) and Kanyemba (Zimbabwe) shorten the transport distance between Malawi and Zimbabwe and South Africa and will promote regional economic integration. In Lake Cahora Bassa navigational use has increased with the return of peace in Mozambique and the development of productive fishery.

4 Kafue River: Agricultural development is likely to result in improved transport structure particularly on the Kafue Flats. More river crossings are to be established and/or some of the existing being replaced by a bridge. Shallow bottomed vessels can all navigate throughout the year.

5 Shire River (Lower Shire): The re-utilisation of navigation on the Shire River depends both on water flow regulation and dredging in some sections of the river, but even more on the effective removal of water weeds that are a major obstacle. In the past there was traffic between Nsanje/Chiromo (Malawi) and Chinde . This may be resumed with the development of (large-scale) farming in the area.

6 Lake Malawi: Lake transport – though earlier well developed – has been declining in Malawi. Improved road infrastructure appears to be a main reason. In some sections navigation has also reduced due to low water level. In the Mozambique section the picture is different, but the lack of road infrastructure places lake transport in a better position. In the development of the north western

province, Niassa lake transport, also for tourism, may get more attention. In Tanzania economic development may increase the demand for navigation services to some extent but some ports suffer from low water levels and would require dredging or extension of piers to become operational.

7 Lower Zambezi: The section has traditionally been the section where navigation has taken place. The section from the Indian Ocean and 570 km upstream to Mepanda Uncua is the longest navigable section and was used at times to transport coal, molasses and construction materials. At present, navigation only takes place at the crossings at Caia. There is scope to improve the section from Mepanda Uncua to Chinde. This requires a minimum depth and higher releases than the common 500-800 m^3/ sec from Cahora Bassa. A water depth of 3m for instance requires a release of 2,000 m^3/ sec. This may interfere with other water demands.

4.8 Comparing current demand with run-off

The water demand is calculated here as a composite of main anthropogenic water uses: domestic, livestock, industrial, agriculture and hydropower. Though navigation benefits from minimum levels, it does not consume water, and is not included in the equation. Environmental flows are released at present from the Itezhi-tezhi Dam only. Table 4.10 makes the comparison with run off in the Zambezi Basin.

Table 4.10 Current water utilization and run-off

	In Mm3	As % of run off
Available run off	103,224	100%
Rural domestic consumption	24	0.02
Urban domestic consumption	175	0.17
Industrial consumption	25	0.02
Mining	120	0.12
Environmental/ flood releases	1,202	1.16
Irrigated agriculture	1,478	1.43
Livestock	113	0.11
Hydropower (evaporation)	16,989	16.46
Total water demand	***20,126***	***19.49***

Total current water demand is 20% of the surface run-off. The major water consumption comes from the evaporation from storage reservoirs. Agricultural use comes a second, but is modest, because of the low proportion of irrigation currently (only 3% of cultivated land).

At present water consumption as a proportion of the total available run-off is modest over the year – but this may change in the future. Although there is no water shortage in the basin over the year there might be some conflicts between the different sectors in the dry season. For example, in Kafue sub basin the water allocation between the agricultural (irrigation) and power supply sectors has caused conflicts during the dry season.

It is proposed as a priority in the future to prepare water balances on a regional scale, using the surface energy balance method or SEBAL, rather than on composite uses. SEBAL is an algorithm that will process actual rather than theoretical evapotranspiration from land use. In the context of the Zambezi Basin this method has a number of advantages:

1. It measures actual evapotranspiration for all land uses, including environmental uses such as wetlands and savannah vegetation.
2. It makes it possible to assess water productivity in irrigation and compare different irrigation areas in this respect
3. It also measures actual evapotranspiration from the main reservoirs and lakes. As this is the largest single factor, accuracy in assessing actual evapotranspiration over the year will make a key contribution to water management in the Basin;
4. By comparing rainfall and evapotranspiration and stream flow, it is possible to make assessments on groundwater recharge.

4.9 Forward projections

This section presents forward projections using 2025 as the horizon. For the largest anthropogenic water uses, which will have the largest bearing on water utilization – i.e. hydropower and irrigated agriculture – different scenarios are used.

The assumptions in the different water utilization categories are summarized below.

1. Domestic demand affected by population growth and increased urbanization
2. Growth in the manufacturing and mining sector, in line with national growth projections
3. Development of new multi-purpose storage reservoirs in the Basin
4. Expansion of irrigated agriculture
5. Incorporation of managed floods and environmental flows

4.9.1 Assumption on domestic demand

Population projections for 2025 are given in Table 4.11. The population is expected to increase modestly, as it is unlikely that there will be substantial immigration into the Zambezi Basin. Population growth is moderate as the HIV/AIDS pandemic has particularly affected the reproductive age group. In general reproductive health coverage is expected to increase with increased population . Total Zambezi basin population is forecasted as about 47 million by 2025, an increase of 56% over the population in 2005/6.

Table 4.11 Population forecast 2025 by Country and sub-basin*

Sub-basin	Ang	Bots	Mal	Moz	Nam	Tan	Zam	Zim	Grand Total
Barotse	11,262	243	0	0	77,245	0	1,060,339	0	1,149,089
Cuando / Chobe	258,590	15,709	0	0	53,735	0	109,261	0	437,295
Kabompo	6,407	0	0	0	0	0	435,374	0	441,782
Kafue	0	0	0	0	0	0	6,020,065	0	6,020,065
Kariba	0	300	0	0	0	0	635,087	5,042,668	5,678,055
Luanginga	109,462	0	0	0	0	0	86,960	0	196,422
Luangwa	0	0	78,271	17,066	0	0	2,758,686	0	2,854,023
Lungue Bungo	163,378	0	0	0	0	0	66,774	0	230,152
Mupata	0	0	0	0	0	0	176,582	125,409	301,991
Shire River / Lake Malawi	0	0	19,563,982	839,859	0	1,732,527	19,900	0	22,156,268
Tete	0	0	354,416	2,244,612	0	0	345,232	3,388,892	6,333,152
Upper Zambezi	330,589	0	0	0	0	0	110,919	0	441,508
Zambezi Delta	0	0	0	477,481	0	0	0	0	477,481
Grand Total	***879,688***	***16,252***	***19,996,669***	***3,579,018***	***130,980***	***1,732,527***	***11,825,180***	***8,556,970***	***46,717,283***

* GRUMP population by country and sub-basin (revised basin boundaries) adjusted by PRB forecasts

A steady trend toward urbanization may be expected, associated with the growth of job opportunities in the manufacturing/ mining and services sector. In 2005/2006 the urban population was 7.6 million, equivalent to 25.8 % of the basin population. For the sake of this projection it is assumed urbanization will stand at 44% in 2025 in the basin. Hence the rural population and the urban population in the basin are projected at respectively 26,161,678 and 20,555,605 respectively.

As living standards may be expected to increase, so will water consumption. For the purpose of the projection it has been assumed that net urban water use per capita will increase to 100 litres/ capita/ day. No distinction in water consumption is made with institutional users. For rural water supply a norm of 30 litres /capita/ day is used for 2025, upward from the lower norms applied at the current time in some of the riparian countries.

Under this projection urban and rural domestic water supply projections for 2025 are given in Table 4.12. They assume that 90% of urban water demand comes from surface water, and 15% of rural water supply comes from surface water.

Table 4.12 Domestic water demand projections 2025

	Population 2025	Per capita consumption per day	% from surface water	Total consumption in Mm^3
Urban	20,555,605	100 litres	90	676
Rural	26,161,678	30 litres	15	43

4.9.2 Assumption on demand from industry and mining

The various National Development Plans project significant economic growth. The aspiration in the concerned national vision documents for among others Zambia, Tanzania, Mozambique and Malawi is to reach Middle Income Status by 2025-2030. Part of the growth is expected to derive from industrial development with concomitant growth in industrial water use. The Zambia Vision 2030 predicts that the share of industry in GDP will go up from 29 percent in 2006 to 38 percent in 2030. The Zambia Five Year National Development Plan projects a growth of water demand in manufacturing (industry and mining) to increase to 446,000m^3/day or 163 Mm^3 in 2015. At present high GDP growth in the Zambezi Region is mainly related to resource extraction and high commodity prices (copper, oil, and diamonds). For the sake of this projection and in line with the different riparian development plans we have assumed a growth in manufacturing and mining of 6% per annum and a concomitant increase in water consumption. Using the base year, this brings water consumption for mining and manufacturing in 2025 to 408 Mm^3 and 85 Mm^3 respectively. Possible reduction because of the future use of water-efficient production processes is not incorporated in this projection.

4.9.3 Assumption on demand from irrigation and livestock

Assumption on the potential for irrigation expansion must be linked to long term economic outlooks. During the 1970s and 1980s irrigated area grew rapidly in the region, in many instances driven by strategic and political rather than economic motivation. In response to market liberalisation and structural adjustment during the 1990s growth of irrigated area slowed dramatically. In some countries it even reversed, as a result of political instability.

The environment for agricultural development nowadays is different from what it was in 1970's and 1980's. For three decades since the early 1960s irrigation in the region was promoted and protected by Governments. In Malawi, Zambia, Zimbabwe and Mozambique numerous irrigation schemes were built for smallholders. Small and medium-size dams were built in Zimbabwe to store water, primarily, used by commercial farmers. A new economic reality has come in force. Governments in all the states of the region, under budgetary constraint, have retreated from substantial direct investment in irrigation. Instead in most countries, the reliance is on a greater degree of private financing in the development of water resources for irrigation – complemented by efforts of NGOs.

Increasingly subsidies are removed and markets opened up to foreign competition. This globalization provides opportunities too. The global outlook is that high fuel prices and the threat of energy shortage is causing a conversion of agricultural land to bio-fuels, thereby ending the overproduction of wheat in Northern America for instance. This may spell a gradual end to food support to countries in the Zambezi Basin in the long run. For agriculture in the region this requires a substantial effort to achieve regional food security but also to capitalize on the new opportunities, including the production of bio-fuels within the basin. In addition there are a number of other developments that will affect the demand for irrigated crops:

1 Rice has a potential large market demand in South Africa. Wheat demand is also forecast to grow substantially and could also drive irrigation growth to a lesser extent when combined with other crops.
2 Root crops have a good yield response to water, but they are bulky and perishable and hence their demand is limited to local and domestic markets
3 Cotton has significant potential for export to regional markets (South Africa) and world markets.

Most riparian countries have ambitious plans to develop agriculture. Zambia for instance has earmarked the farm sector as the 'engine of economic development'. To assess future demand current plans in the riparian countries are briefly reviewed below.

Angola

Angola, the second country area-wise in sub-Saharan Africa, has a huge mass of fertile land with considerable potential. The estimates vary between 5 and 8 million hectares, of which an estimated 2.5 million (around 32-50 per cent of the total) is cultivated, mainly in the lowlands. The National Water Resources Plan does not emphasize irrigation development. In the highlands land utilisation is low and rainfall is reliable. There is no strategic need for irrigation. In the next ten years emphasis is mainly on re-establishing estate type farms growing tree crops and particularly coffee. In the long run this may change. The possibility of at least one large sugar estate in the south in Cuando/Chobe sub-basin (sub-basin 1-08) cannot be ruled out.

Botswana

In Botswana, agriculture development, apart from mechanized rain-fed farming, irrigated horticulture is considered to hold considerable promise, as it may substitute current high-cost agricultural import. The possibility of diverting 400 Mm^3/year from the Zambezi was studied, as part of the National Master Plan for Agricultural Development (2000) and was found feasible. It was not incorporated in the Master Plan, which covers the period up to 2010, as this option would require extensive study. This diversion may be developed in the period post-2010 and has been updated by the Ministry of Agriculture to 714 Mm^3/year for irrigation, fish farming, poultry farming and agro-processing.

Namibia

The major irrigation development under study has been the Caprivi Farm, on the south east of the Caprivi. Under this plan 15,000 ha of sugar plantations is foreseen.

Malawi

The need for increasing agricultural intensity in Malawi is put in the context of achieving food security. More intense use of fertilizer is also expected to contribute to this. The National Irrigation Policy intends to achieve a utilization of 35% of irrigable land in the next 10 years.

The 2006-2011 Strategic Plan of the Ministry of Irrigation and Water Development has a target of 120,000 ha under manageable and effective irrigation schemes by 2011. Current irrigated area is 46,000 ha. The most promising area is the Lower Shire Valley. It is likely that within the next twenty years a very significant irrigation development will occur here when canals are built on the left and right banks of the Shire Valley to convey water under gravity from the vicinity of the hydro-electric power generating facilities.

Tanzania

Prospects for irrigation development in the Tanzanian sector of Shire basin (sub-basin 1-03) are moderate. The lake shore plain clearly has some scope but the problems associated with flash flooding from the short precipitous rivers which enter the lake in this region, poor communications and infrastructure are important impediments.

Mozambique

In all its sub-basins Mozambique has great potential for irrigation development. However, it is likely that in the next five to ten years poor infrastructure will retard development. It is anticipated that commercial and corporate farms will be established in the region between Sena and the delta and that others will occupy land adjacent to the central Malawi lake shore (sub-basin 1-03). The preparatory report for the First National Water Resources Project assumes a development of new irrigated areas of 2,000 ha per year in the Northern and Central parts of the country. In addition, 50,000 ha of damaged systems would be rehabilitated.

Zambia

About 12% of the total land area is estimated as suitable for arable use and only about 9% of the potential irrigable area is actually irrigated (Zambia Vision 2030). The recent Five Year National Development Plan for Zambia foresees an increase up to 2010 of irrigated area of 70,000 ha of which 10,000 ha among large scale commercial, 30,000 ha among emergent farmers and 30,000 ha among small scale farmers. Incremental production based on this irrigation hectarage would result in guaranteed food for strategic reserves, reduction in food imports, export of surplus food, export of high value cash crops and increased industrial outputs and employment.

The Zambia Vision 2030 foresees intensification of agricultural production on existing lands – the substantially higher yields of commercial farmers are testimony to the potential for production increase in the small-holders sector. However whereas in the current five year planning period the contribution of agriculture to GDP is expected to increase to 25% of GDP it is expected to decline to 10.1 percent in 2030.

Zimbabwe

Irrigation development in Zimbabwe in the last ten years has stagnated, even declined. Much of Zimbabwe's smallholder irrigation development is outside the Zambezi basin as are some of the large projects on the drawing board. Within the basin some relatively large schemes (e.g. Dande) have been prepared and may get off the ground in the next 10 years.

On the basis of the above, the maximum projected irrigation development within the basin is given in Table 4.13, using a number of assumptions, This is done for the sake of projecting future irrigation water demand only.

Table 4.13 Maximum projected new irrigation development by 2025 in the Zambezi Basin

	Assumption	New irrigation development by 2025 (in ha)
Angola	Development of sugar estates in southern region	20,000
Botswana	Diversion of 714 Mm^3 for irrigation, fish farming, poultry farming and agro-processing	40,000
Malawi	Development of 74,000 ha up to 2012 – continuing next at 50% of the pace 90% of national cultivated land in the Basin	163,400
Mozambique	New development at 2000 ha/year up to 2012 – accelerating with 50% subsequently and rehabilitation of 5000 ha	49,000
Namibia	Development of Caprivi Farm	15,000
Tanzania	Limited expansion within the basin	15,000
Zambia	Development of 70,000 ha up to 2011– continuing next at 50% of the pace 70% of national cultivated land in the Basin	117,600
Zimbabwe	Expansion of irrigated area with 3% annually on base figure of 84,000 ha	45,360
Total newly developed irrigated area		***467,385***

The maximum projected new irrigated area developed by 2025 would be 467,385 ha – in addition to the present 171,621 ha – bringing the total to 639,001 ha.

On the basis of this maximum projected irrigation development two scenario's are used to assess future irrigation water requirements. The first scenario is the full development scenario, based on these projections. The second scenario is a 50% achievement of the maximum projection of newly developed area. A number of reasons may trigger the second scenario:

1. The limited capacity to develop new irrigation system in the Basin at the level of professionals, technicians and equipment suppliers
2. Constraints in transport infrastructure, making a steep expansion in farm production non-feasible
3. Increased scarcity of feasible sites, making it more difficult to develop new irrigation systems at acceptable cost

In estimating water consumption for development of new irrigated areas we have assumed the same consumption as in the existing system.

However, it seems unlikely that irrigated agriculture could grow from the present level of about 172,000 to a significantly higher level without the development of significant storage of wet season stream flow, because dry season discharge on most of the Zambezi River tributaries is limited. evaporation losses from the irrigation reservoir would then need to be added to crop evaporation. For this reason an additional water consumption increment of 15% is added to full development scenario and 10% to partial (50%) development scenario. This translates in additional water demand of respectively 4,634 Mm^3 and 2,217 Mm^3 (Table 4.14)

Table 4.14 Additional water requirements under different Irrigation Development Scenarios

Scenario 2025	Additional area [ha]	Irrigation requirements [in Mm^3]	Reservoir evaporation increment [Mm^3]	Additional water demand [Mm^3]
Full development	467,385	4031	604	4635
50% development	233,693	2015	202	2217

In addition, the water requirements for livestock have been updated assuming a 2% growth in cattle population annually up to 2025. This brings livestock water requirements to 167 Mm^3 in 2025.

4.9.4 Assumptions on hydro-power development

The hydropower potential of the Zambezi river basin has been mapped through a number of studies, and some 40 schemes with a total potential of close to 13,500 MW have been identified and partly studied to pre-feasibility level. More than half of this potential is within Mozambique, about one fourth in Zambia and one sixth in Zimbabwe, see Table 4.15

In the past decade there has been no development of major new storage in the Zambezi Basin, though preparatory work was undertaken. There are several reasons why one would expect this trend to change and witness increased investment in hydro and thermal power generation in the coming two decades in the Zambezi Basin:

1 Political stability in the Zambezi Region, making investment in mega-projects less risky than in the recent past;
2 Increased demand for energy from the basin countries and the neighbouring countries;
3 Continued high global energy prices, related to fossil fuels scarcity;
4 Availability of long term investment capital from the emerging 'BRIC' states (Brasil, Russia, India China) following a first wave of investment in extractive industries, based on government underwriting.

Table 4.15 Hydro-power potential in the Zambezi Basin

Sub-basin	Power plant reservoir	River	Capacity (MW)	Mean annual generation		FSL ****	Surface area ****	Annual evaporation	
			(MW)	(GHh)	(%)	(m)	(km^2)	(Mm^3)	(%)
1-02	Cahora Bassa II	Zambezi	1,200	6,800	12.6				0.0
	Mepanda Unica	Zambezi	2,000	10,524	19.5	205	80	174	0.9
	Boroma	Zambezi	444	3,240	6.0	142	30	65	0.3
	Luapata	Zambezi	654	4,960	9.2	125	335	730	3.7
	Ancuaze-Sinjal I	Zambezi	330	2,230	4.1	98			0.0
	Ancuaze-Sinjal II	Zambezi	600	4,460	8.2				0.0
	Chemba	Zambezi	1,040	8,740	16.2	98	1,400	3,052	15.5
	5.8	Revubue	36	155	0.3	600	80	174	0.9
	5.9	Revubue	110	310	0.6	520	8	17	0.1
	5.13	Revubue	85	380	0.7	260	100	218	1.1
	7.6	Luia	267	600	1.1	300	100	218	1.1
	7.11	Capoche	60	250	0.5	440	220	480	2.4
1-03	Kapichira II	Shire	64		0.0				0.0
	Lower Fufu	S. Rukuru/ N. Rumphi	90	570	1.1	820	0.3	1	0.0
	Songwe	Songwe	150	930	1.7				0.0
	Masigira	N. Ruhuru	118	630	1.2	938			0.0
	Rumakali	Ruhuru	222	1,320	2.4		1.8	3	0.0
		Rumakali			0.0	2055	13	14	0.1
1-04	Mpata Gorge	Zambezi	640		0.0		1,190	2,380	12.1
1-05	Lusiwasi Ext.	Lusiwasi	40	49	0.1		7.5	12	0.1
1-06	Victoria Falls Ect.	Zambezi	390		0.0				0.0
	Victoria Falls (Zim)	Zambezi	300		0.0				0.0
	Kariba North** Ext.	Zambezi	300		0.0				0.0
	Kariba South*** Ext.	Zambezi	300		0.0				0.0
	Katombora	Zambezi			0.0	940	7,733	10,826	55.1
	Batoka Gorge	Zambezi	1,600	4,700	8.7	770	37.3	56	0.3
	Devil's Gorge	Zambezi	1,240 *		0.0	595	762	1,219	6.2
1-07	Lower Kafue	Kafue	600	3,000	5.5	582	0.3	1	0.0
	Itezhi- Tehzi	Kafue	80		0.0				0.0
1-12	1	Lumbage	1	11	0.0				0.0
	2	Zambezi	4	32	0.1				0.0
	3	Zambezi	2	19	0.0				0.0
	4	Luvua	1	10	0.0				0.0
	5	Luizavo	11	100	0.2				0.0
	6	Ludevu	3	26	0.0				0.0
	7	Lumache	1	5	0.0				0.0
	8	Lufuige	2	16	0.0				0.0
	9	Macondo	3	25	0.0				0.0
Total			***12,988***	***54,092***	***100***		***12,098***	***19,640***	***100***

*(Source: Denconsult, 1998; Sector Study No. 5, accept for *)*
* Personal Communication by ZRA
** Kariba North Bank is in the process op up rating its capacity to 720 MW
*** Kariba South Bank has already up rated its capacity to 750 MW
**** Surface area calculated on Full Supply Level (FSL)

The lead time to develop and finance a hydropower scheme is substantial with a design and construction period of 4 to 7 years as a minimum. For a sizeable hydropower project (upward of 100 MW) a period of 10-15 years before commissioning is normal. Given the analysis in Chapter 3 it is envisaged that the new reservoirs will be operated under multi-purpose objectives, maximizing the different purposes dependent on the reservoir (flood plain agriculture, navigation, control of invasive aquatic species, recharge, ecological function as well as power generation) in an integrated manner (see next section too).

For the period up to 2025 three hypothetical hydro-power scenarios are used to assess the possible impacts on possible future water demand. These scenarios are chosen as expressions of possible future developments only, unrelated to actual planning. The first scenario sees the development of the projects for which preparation has currently advanced. The second scenario adds to these pipelines projects of medium size distributed over the basin. The third scenario includes the pipeline projects and a selection of the new mega projects identified.

Table 4.16 Hypothetical Hydro-Power Development Scenarios

Scenario 2025	Description	New hydropower schemes	Additional capacity (MW)	Additional evaporation (Mm3)
Moderate	Pipeline projects	Cahora Bassa 2 Mepanda Uncua Lower Kafue	3,800	175
Medium	Pipeline projects Small and medium projects	Cahora Bassa 2 Mepanda Uncua Lower Kafue Boroma Lower Fufu Rumukali Revubue Projects 7.6 Luia Kapache Angola Projects	5,151	1,365
Accelerated	Pipeline projects Mega-projects	Cahora Bassa 2 Mepanda Uncua Lower Kafue Chemba Batoka Gorge Devils Gorge Luapata Mpata Gorge	9,334	7,609

Figures for reservoir surface area are available for about half of the identified possible new hydropower reservoirs. The potential plants in Angola are small with a potential capacity between 1 and 10 MW, and with small reservoirs. The Shire River power plants in Malawi are planned as run-of-river plants which normally have small reservoirs; nevertheless the

Kholombidzo reservoir will cover a substantial area. Ancuaze-Sinjal in Mozambique will probably also be a reservoir of considerable size.

The Katombora, on the Zambezi River upstream of Victoria Falls, is by far the largest reservoir among the possible new ones, with a surface area of 7,733 km^2. This mega project has been left out of the scenario', but may be expected to upset the water balance (see section 4.10). Chemba, Mpata Gorge and Devil's Gorge are also of mega-scale, while the remaining potential reservoirs are considerably smaller.

4.9.5 Assumption on managed flood releases

At present the managed flood releases are made from Itezhi-tezhi only. They fluctuate widely but average 464 Mm^3 for the March period or equivalent to 1,202 Mm^3. As described in chapter 3 the case has been made for managed flood releases from Cahora Bassa. Several scenarios have been analysed, but for this projection proposed artificial flood releases of 4,500 Mm^3 for a two week period are considered. This comes to 5,443 Mm^3 a year.

4.9.6 Inter-basin transfer

Several riparian countries have identified future projects for the transfer of water from or to the Zambezi basin to meet demands for various purposes. Botswana, for example, is planning to use water from the Zambezi basin for domestic and industrial use within and outside the basin. This project called the 'Zambezi Water Transfer Scheme' is however in the conceptual phase and will probably not be implemented before 2011. The Bulawayo – Matebeleland – Zambezi Water Supply Project in Zimbabwe is in its feasibility stage and although Bulawayo is within the basin, further water supply to a larger area of Matebeleland may become inter-basin transfer.

The inter-basin transfer in Zimbabwe is based on using water of the Zambezi for a water demand in other basins. In Namibia, however, the project involves water transfer from the Congo basin to the Zambezi basin to meet seasonal water deficits.

These proposed transfers, subject to social, financial and environmental feasibility, may be justified on account of the tremendous temporal and spatial variability in availability of water resources in the Zambezi basin. But on an annual basis alone, the previous analysis indicate that there is sufficient water for projected future demands

4.9.7 Future projection of water availability

The projections of future water demand need to be made against the background of future water resources availability in the basin. In the Zambezi basin, the key driver of water resources availability is rainfall. Thus possible changes in rainfall amounts, distribution and timing will impact the availability of water resources. These factors are invariably affected by climate change. An assessment of the vulnerability of key socio-economic sectors to climate change was made by IPCC in 1997. This study contains qualitative assessments of impact of climate change on African water resources. The results are illustrative of types and nature of impacts; but they underscore the complexity of regional climate modeling and the need for further and more detailed studies leading to more authoritative quantification of impacts.

The IPCC (1997) study reveals that rainfall is projected to increase over the continent except in Southern Africa and Horn of Africa where it will decrease; however seasonal changes in rainfall are not expected to be large. Climate change is expected to bring about higher surface temperatures with consequent increase in evaporation. This may be further exacerbated by rapid changes in land cover as a result of degradation of forests and vegetal cover due to increasing urbanization (including the increasing conversion of virgin land around large urban areas into cemeteries due to the HIV/AIDS pandemic), and higher demand for agricultural land. For Southern Africa this combination would be detrimental to the sustainability of the present hydrological balance with consequent decrease in surface runoff and availability of water resources. The quantification of changes is still tenuous, and there is no unanimity among hydrologists that the region is getting drier and that surface runoff is actually decreasing; some hydrologists attribute the decline in runoff in some basins in the region due to the natural variability inherent in a semi-arid environment that characterizes Southern Africa (Mazvimavi, 2007).

Given the lack of quantification of impacts of climate change on water resources availability, future projections of water availability will be based on historical trends. Thus the total available water resources in the Zambezi Basin in future will be as already determined in Section 3.1. The major challenge for water resources management in the basin is managing the observable variability in available water resources to meet the increasing water demand.

4.10 Implications under different future scenario's

The water requirements for 2025 – including the projects under the different irrigation and hydropower scenarios - are given in Table 4.17.

This overview of projected demands would need to be improved and with more reliable estimates, but has been produced on the best available data. In case of the high development scenario for hydropower and irrigated agriculture 41% of the run-off would be utilized. Sensitivity of the Zambezi River basin to changes in water consumption is moderate, but a combination of intense irrigation and hydropower development would jeopardize the sustainability of the various integrated uses, particularly if the effect of periodic droughts and climate change are taken into consideration.

Table 4.17 Future water demand (2025)

	Mm^3	As % of run off
Available run off	103,224	100%
Water demand		
Rural domestic consumption	43	0.04
Urban domestic consumption	676	0.65
Industrial consumption	85	0.08
Mining	408	0.40
Environmental/ flood releases	6,445	6.24
Irrigated agriculture (2005)	1,477	1.43
Additional under Full Scenario (100%)	4,635	4.49
Additional under Partial Scenario (50%)	2,217	2.15
Livestock	167	0.16
Hydropower	16,989	16.46
Additional under Moderate Scenario	175	0.17
Additional under Medium Scenario	1,365	1.32
Additional under Mega Scenario	7,609	7.37
Total	***42,291***	***40.96***

Most of the streamflow in the Zambezi River basin occurs in the single wet season, perhaps 90%, and rainfall is often erratic, unreliable and subject to frequent multi-year low rainfall cycles. The main stem of the river is controlled by the huge reservoirs at Kariba and Cahora Bassa, but the tributary rivers where the development potential is concentrated experience very low or no streamflow in the dry season (even in average years) when irrigation water demand is highest and other needs must also be met;

Equally important is that the extensive riverine wetlands and flood plain areas in the basin have high economic and social value in terms of agriculture, fisheries, wildlife and tourism as well as other environmental services, and these are already threatened by water pollution and uncontrolled and unmanaged water use including storage for hydropower generation. They may be served by managed floods from the new reservoirs, but this would also reflect on overall water use, as is clear from the managed floods currently released.

There is a scope for hydropower and irrigation development. Evaporation from reservoirs is however high and this needs to be taken into consideration when prioritising systems that are to be developed.

5 Environmental and Water Quality Situation

5.1 Environmental Endowment

5.1.1 Wetlands and Lakes

Large areas of important wetlands are found in several parts of the Zambezi basin (see Map 9 in Annex 1). The most important wetlands in the Zambezi basin are the Barotse Floodplains in Zambia, the Chobe-Linyanti Swamps in north-eastern Namibia and Botswana, the Busanga Swamps on the Lunga River (a tributary of the Kafue River), and the Lukanga Swamps and the Kafue Flats on the Kafue River. Smaller wetland areas are located on the lower reaches of the Luangwa River, as well as the Elephant Marsh near the town of Chiromo on the lower Shire River in Malawi and Mozambique. Wetlands, including the dambos that dominate the landscape of much of Zambia and Zimbabwe are an important aquatic ecosystem. Their importance derives from ecological /biodiversity, socio-economic value, and physical and/or hydrological significance.

Wetlands provide a wide range of goods and services of local, national and international importance. For local people, they provide a variety of benefits: drinking water and water for livestock; land for flood recession agriculture; pasture for dry season grazing; fish and bushmeat, and other foods in times of famine; plant material for house construction, mats and baskets, and clay for pottery and bricks. Several support wildlife, fisheries, irrigated agriculture, livestock production, and tourism of national importance, and there is growing recognition of their international importance for biodiversity conservation. Wetlands play a crucial role in maintaining water quality and regulating river flows. These wetlands absorb and attenuate flows from upstream catchment areas, releasing this “trapped” water slowly over a period of several months and maintaining flows during the dry winter months.

The number of wetlands of international importance in the river basin gazetted under the Ramsar Convention has increased from one in 1991 to six in 2007 and from 6,005 km^2 to 28,985 km^2 (Table 5.1).

The Zambezi basin also contains very large natural and man-made freshwater bodies. The largest natural freshwater lake is Lake Malawi/Nyasa/Niassa covering an area of 6,400 km^2 and containing 8,400 km^3 of water. Smaller lakes are found in various countries throughout the basin. Kariba Reservoir straddling the border between Zambia and Zimbabwe, and Cahora Bassa Reservoir further downstream in Mozambique are the largest man-made freshwater bodies in the basin. The

Kariba reservoir has with a mean depth of 31m a surface area of 5,400 km^2 and contains 160 km^3 of water, and Cahora Bassa covers with a mean depth of 20.9m an area of 2,739 km^2 and contains 55.8 km^3 of water (*Database of International Lake Environment Committee, 2007 at www.ilec.or.jp/database*). Both reservoirs are used primarily for power generation; but also for small quantities of irrigation. Natural and man-made lakes currently are important for hydropower, fisheries, tourism, and as source of water for domestic, agricultural and industrial water supply.

Table 5.1 Major wetlands (> 500 km^2) and Ramsar Sites (*i.e.* Wetlands of International Importance) in the River Basin

Country	Major Wetlands	Area (km^2)	Ramsar listed
Zambia	Nyamboma Swamp (Lungwe-Bungo River)	1,000	
Zambia	Barotse floodplain	9,000	2007
Zambia	Luena Flats	900	
	Nyengo Swamp (Lueti River)	700	
Namibia/Botswana	Chobe/Linyanti Swamp	2,160-3,800	
Zambia	Lukanga Swamp	2,600	2005
Zambia	Busanga Swamps (Lufupa River)	2000	2007
Zambia	Kafue Flats	6,000	1991
Zambia	Luangwa Floodplains	2,500	2007
Malawi/Mozambique	Shire Marshes	1,300	
Mozambique	Zambezi Delta	14,100	2004 (Marromeu Complex, 6,800 km2)

(Source: Hughes, R.H. and Hughes, J.S. 1992; www.ramsar.org/sitelist.doc)

5.1.2 Wildlife and Tourism

Major tourism attractions in the basin are closely related to aquatic ecosystems. These systems sustain a variety of wildlife, birdlife, fisheries as well as cultural assets.

Virtually all the major game parks or game management areas, bird sanctuaries, or sport fishing are associated with wetlands, or rivers and lakes. This includes the Kafue and Luangwa National Parks in Zambia and the Marromeu Complex in Mozambique. Many such areas are listed among the Ramsar sites in the basin. Other smaller aquatic ecosystems are of significant national and community value. Tourism, especially game viewing and sport hunting and fishing is an increasingly important economic sector in many of the riparian states in the Zambezi Basin. The sustainability of these aquatic ecosystems is therefore also of economic importance.

Other touristic 'crown jewels' in the Basin are water-related too: Victoria Falls on the main stem of the Zambezi between Zambia and Zimbabwe, and Lake Malawi/Nyasa/Niassa. Lake Malawi, is reported to have the largest diversity of fresh water fish, around 500 species, many of them unique to Malawi (Chenje, 2000).

5.1.3 Fisheries

The Zambezi River, its tributaries and its natural and artificial lakes constitutes one of southern Africa's most important fishery resources (see Map 16 in Annex 1) The river basin is a centre of endemism due to its vast terrestrial and aquatic biodiversity and the relatively untouched character of several of the sub-basin. Fish diversity is high in the Zambezi Basin, with a best estimate of 165 different freshwater species in the Zambezi basin in addition to more than 500 fish species in Lake Malawi/ Nyasa (Chenje, 2000).

Mean annual fish production from the most important fisheries in the river basin are shown in Table 5.2. The main fisheries in order of importance are Lake Malawi and Lake Kariba. The quality of the underlying data, years of collection and trend in catch are unknown. Generally, yield estimates from Zambia and Mozambique appear to be of doubtful accuracy (Douthwaite *et al.*, 2005, and Joint Venture, 2001).

Table 5.2 Mean annual production of the most important fisheries in the river basin

Fishery	Country	Mean Production (m.t.p.a.)
Lake Malawi	Malawi	50,000-64,000
Lake Kariba	Zambia/Zimbabwe	23,600-28,600
Lower Shire floodplains	Mozambique	4,000-17,000
Cahora Bassa*	Mozambique	13,500
Lake Malombe	Malawi	10,000
Zambezi Delta **	Mozambique	2,250 – 10,000
Barotse floodplains	Zambia	7,500
Kafue Flats	Zambia	7,000
Eastern Caprivi floodplains	Namibia	1,500
Lukanga swamp	Zambia	1,400
Lake Lusiwashi	Zambia	927
Lake Itezhi-tezhi	Zambia	640

* *Source: Lahmeyer International et. al, 2001; ** Sources: SWECO, 1982; and Turpie et al, 1998 (Source: Chenje, 2000, except for * and **)*

Fish production varies from year to year depending upon prior year and current flood levels and fishing effort. Overbank flooding is especially important for the productivity of floodplain fisheries such as those in the upper Zambezi floodplain, Kafue Flats, Lower Shire and Zambezi delta, while depth and fishing effort are strong predictors of fish yield in African lakes and reservoirs (Moyo, 1994). Some reports suggest that catches are declining in Lake Malawi, the Lower Shire, Lake Malombe and Kafue Flats (Scott Wilson Piesold, 2003). In particular, the catch on Lake Malawi fell from 70,771 m.t. in 1989 to 53,890 m.t. in 1995, reflecting a decline in key fish stocks (World Bank 2002; World Bank 2004). Several sources suggest that fishery potential in many areas – such as Cabora Bassa - is not exhausted yet. The potential for more intense fishery in a number of areas is large but would require appropriate storage and transport infrastructure.

Productivity of the Sofala Bank shrimp fishery, which lies off the Zambezi delta, is also related to Zambezi River flows. Catches are positively correlated with river discharge during the period December to March (Gammelsrod, 1992). Shrimp production has declined since 1974 from 10,000-12,000 m.t.p.a. to c. 8,000 m.t.p.a. in 1983 and 1998, probably due to river regulation at the Cahora Bassa dam.

5.2 Surface Water Quality and Pollution

5.2.1 Water Quality and Effluent Standards

Zambezi River Basin countries adopt national and international standards for water and wastewater quality. The most common standards used are the World Health Organization (WHO) standards and this is applied to compare or supplement the different national standards (FFEM, 2005). Table 5.3 shows the list of standards used in some of the basin countries.

Most countries in Zambezi basin do not maintain systematic water quality monitoring and databases in the same way as river discharge and water levels. The only water quality data available have usually been obtained on an adhoc basis. A ZRA initiated project to support the implementation of the water quality monitoring programme for Zambezi basin (FFEM, 2005) was carried out in 2005 covering the ZRA network of gauging stations for the upper catchment. Through this project water quality sampling points and monitoring protocols were established. Results of the one year monitoring showed that Kanzinze, Deka, Gwaii and Luangwa rivers are the most heavily loaded rivers in the basin. Luangwa River is the tributary which carries most heavy metals matter among the studied rivers with respect to its annual runoff. Some sampled points display higher concentration than WHO Water Quality Guideline for Pb, Mn, As, Cr especially at Kanzinze, Deka, Gwaii, and Luangwa rivers.

Table 5.3 Water and Effluent Quality in Some Basin Countries

Country	Water Quality/Effluent Standards
Botswana	▪ Botswana Bureau of Standards BOS 32: 2000, Water Quality – Drinking Water – Specification ▪ Botswana Bureau of Standards BOS 93: 2004: Standard to Discharge Waste Water into the Environment
Malawi*	▪ Malawi Bureau of Standards ▪ WHO Drinking Water Quality Guidelines, 1993;
Tanzania	▪ Second schedule of the Water Utilization (Control and Regulation) Act (1984) ▪ WHO Drinking Water Quality Guidelines, 1993;
Zambia*	▪ Quality of Trade Effluent into a Public Sewer, Local Administration Regulation Act (No. 161), 1985; ▪ Wastewater Regulations into an Aquatic Environment, 1993, prepared by the Environmental Council of Zambia; ▪ Zambian Standard Specification for Drinking Water Quality, prepared by the Zambia Bureau of Standards ▪ WHO Guidelines for Drinking Water Quality, 1993 ▪ Australian Summary Guidelines for Protection of Aquatic Ecosystems. ▪ ZRA Water Quality Guidelines, 2002
Zimbabwe	▪ ZRA Water Quality Guidelines, 2002

** (Source:SADC, 2004)*

5.2.2 Sources of Water Pollution

The increased amount of discharges and types of pollutants in the Zambezi basin is a result of population growth, intensive urbanization, increased industrial and a revival of mining activities. The sources of pollution arise from point source pollution namely: sewage effluent, industrial processes, power generation, and mining activities as well as non point source pollution namely natural pollution, storm water runoff, agricultural activities, leachate from landfills, soil erosion and gold panning (Chenje *et al.*, 2000).

Sewage discharge

The main type of pollution originating from urban areas is mostly sewage and to a lesser extent industrial wastewater. The urban population in the main cities and towns located in the Zambezi River Basin are shown in chapter 4. Domestic wastewater is handled using some form of sewage treatment works which consists of features such as septic tanks, oxidation ponds, conventional treatment works, and activated sludge types of works. Many cities and towns of the basin have sewage treatment works; however, these systems are largely inadequate in all urban centres and are a major source of water pollution in the Zambezi Basin (Chenje *et al.*, 2000). Important cities (Lusaka, Kafue, Livingstone) and smaller towns discharge their sewage into the Zambezi river and its tributaries partially treated or without any treatment. It is stated in *The State of the Environment, Zambezi Basin 2000* (Chenje *et al.*, 2000) that the total phosphates and total nitrogen in the final effluent at Victoria Falls, Livingstone, Kariba and Kasane exceeds any permissible level.

Table 5.4 represents typical effluent quality in the Copperbelt, Zambia. One notes the high levels of ortho-phosphate, turbidity, e-coli, and algae. Such pollutants contained in the effluent eventually reach the Kafue River, affecting downstream domestic water purification plants or causing proliferation of aquatic weeds as in Kafubu Reservoir serving the city of Ndola, Zambia.

Table 5.4 Typical sewage effluent quality from sewage ponds in Upper Kafue

Mine	Sample point	pH	Conduc-tivity µS/cm	Turbi-dity NTU	Sus-pend Solids mg/l	COD mg/l	Ortho-Phos-phate mg-P/l	E-coli No./100ml	Algae No./100ml
Chililabombwe	Golf course	7.7	39.6	17	26	48.6	15	TNTC	TNTC
Chingola	Lulamba	7.3	62	94	18		17.3	TNTC	TNTC
Mufulira	Kankoyo North	9.2	90	68	56	60	21.4	TNTC	TNTC
Luanshya	Mpatamatu	7.5	29.7	24.5				TNTC	TNTC
ECZ Specifications for outlet (1993)		6.0 - 9.0	4,300	15	100	90	6	0	1,000

(Source: Asset Holding Company - Mining Municipal Services, 2002
Note: "TNTC" - too numerous to count. Data for April 2002)

The eastern Kafue Flats host a number of major industrial enterprises including the Nakambala Sugar Estates; industries developed at Kafue town including chemical plants for fertiliser, leather, and an integrated pig and fish farm. Ironically the abstraction of water for Lusaka is further downstream of all these industries. Table 5.5 shows some data on surface and ground water quality of the Lower Kafue. It can be noted from the table that pollution of groundwater is a serious problem. Groundwater quality from Nakambala Sugar Estates and Kafue Fish Farm generally exceeded the threshold for BOD, COD, nitrates and phosphates which is the most important growth-limiting factor for aquatic plants.

Table 5.5 Water quality of surface water and groundwater, Lower Kafue

Parameter	ECZ Regul. Limits	Average values					
		Surface Water		Groundwater			
		Kafue river	Discharge	Nakambala Estates	Kafue Fish Farm	Kafue Sewage	Nitrogen Chemicals
Temperature(oC)	40	23.4	23.4	25.5	23.9	25.1	25.6
pH	6 – 9	7.12	7.71	7.11	7.00	6.69	6.80
Conductivity (µS)	4300	225	485	1613	2109	595	1791
D.O (mg/l)	5.0	2.32	3.90	1.52	1.60	0.75	1.30
Ammonia (mg/l)	10.0	0.31	0.61	0.50	1.60	0.27	0.50
Nitrates (mg/l)	50	11.1	36.0	51.0	73.8	15.6	30.2
Phosphorus (mg/l)	1.0	0.33	1.64	1.40	2.07	1.84	2.12
Potassium (mg/l)	NR	2.97	18.6	20.0	17.6	14.9	19.2
Calcium (mg/l)	NR	28.9	56.9	166	121	37.3	105
Magnesium (mg/l)	500	13.1	26.9	88.8	79.0	46.9	79.8
Iron (mg/l)	2	0.22	0.61	NA	NA	NA	NA
COD (mg/l)	90	75	137	113	1043	86	110
BOD (mg/l)	50	10	51	14	150	16	28

(Source: ECZ, 2000. Kafue River Nutrient Loading Study, Vol. I.
NR = No ECZ Regulations; NA = Not analysed)

The Ministry of Water Development in Malawi records since 1984 the levels of BOD5, nitrate and suspended solids in most of their rivers. The data for some of these rivers are fairly complete. Figures 5.1-5.3 show the trends for BOD, Nitrate and Suspended solids (SS) for three rivers, with the most complete data, draining the two largest urban centres in Malawi.

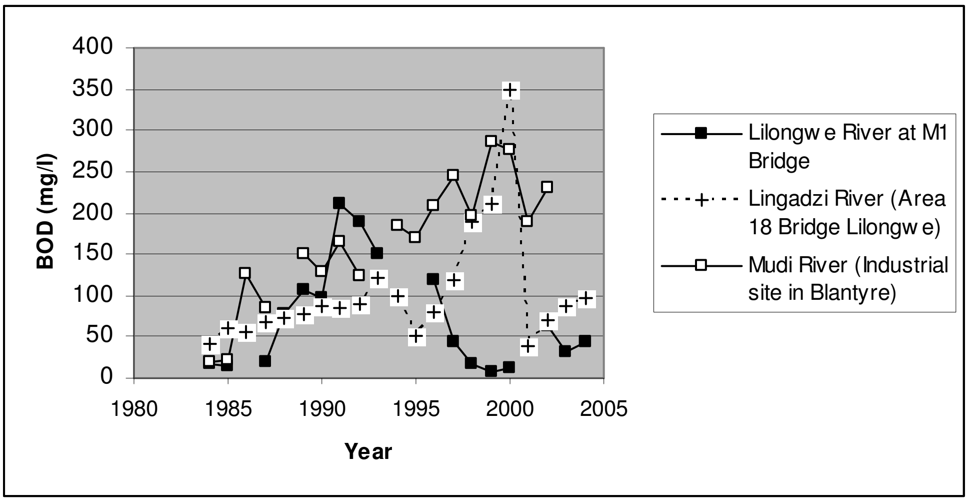


Figure 5.1: BOD$_5$ Trends in selected rivers in Malawi
Source: Ministry of Water Development, Malawi

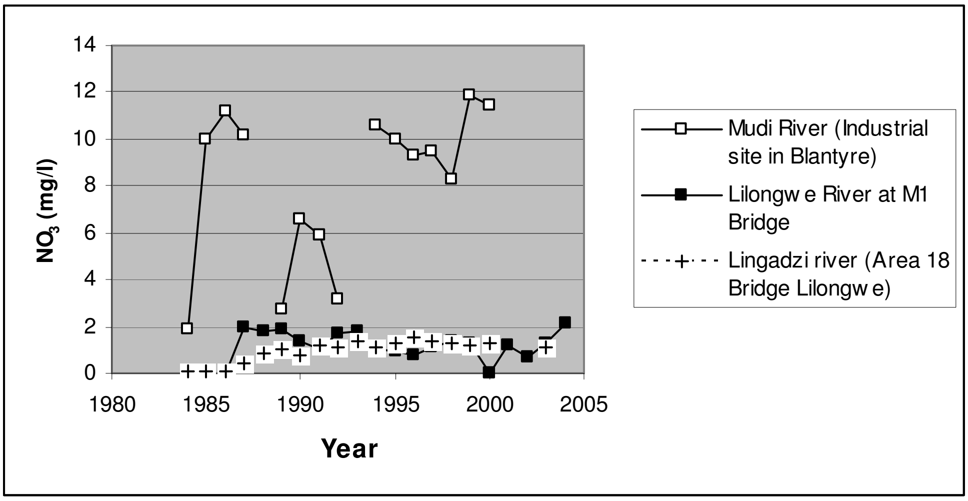


Figure 5.2: Nitrate trends in selected rivers in Malawi
Source: Ministry of Water Development, Malawi

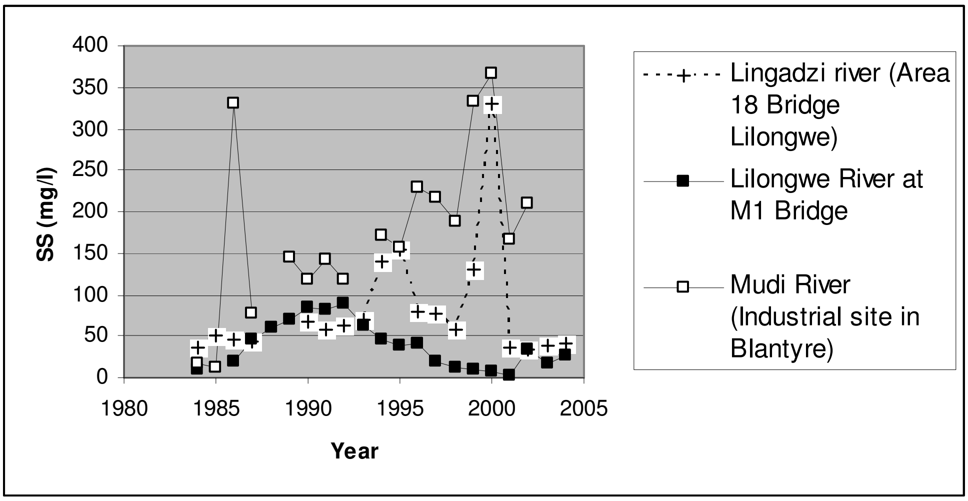
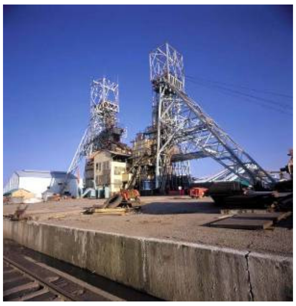


Figure 5.3: Suspended solids trends in selected rivers in Malawi
Source: Ministry of Water Development, Malawi

It can be seen in these figures that Mudi River, which drains the industrial sites in Blantyre, shows general increase in BOD5, TSS and NO3. Lilongwe River shows an increase in BOD and SS until around 1991/92 and thereafter there is a steady decline until year 2000 when another rise in the levels of BOD and SS is observed. Nitrate remained below 2 mg/l throughout the twenty year period. Lingadzi River showed increasing levels of BOD and SS until year 2000 when a sharp decline in levels of the two parameters is noticed. Nitrates increased gently but remained below 2 mg/l.

Industrial Activities



Industrial activities in the basin introduce various pollutants in the water system. These include metals, nutrients (phosphorous and nitrogen), organic compounds, anions (cyanides, sulphides, sulphites), acids, Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), suspended solids. The sub basins of Kariba and Kafue, being highly urbanised, host many industries, but there is a lack of studies and monitoring of waste discharges into the water systems. This makes it very difficult to assess how much pollution originating from industries reach Zambezi mainstream or tributaries. A summary of the main industries by sub basin is shown in Table 5.6.

Table 5.6 Listing of the main industries in the sub-basins of Zambezi River

District	Main Industries	Nature/Type of pollution
Zambezi Delta Sub basin (1-01)		
Marromeu	Sugar processing	BOD, nutrients, organic solvents
Shire River/ Lake Malawi sub-basin (1-03)		
Kyela	Coal Mining	Suspended solids, acidity
Mbeya Dwangwa	Cement factory Sugar manufacturing	dust BOD, nutrients
Nchalo	Sugar manufacturing	BOD, nutrients
Kariba Sub-basin (1-06)		
Livingstone	Textiles	BOD
Bulawayo	Sugar refineries, breweries, chemicals, oil processing, tanning	BOD, nutrients, chromium sludge, organic solvents
Gweru	Metallurgy	Metals
Kwekwe	Breweries, iron and steel, metallurgy	BOD, metals, nutrients
Kadoma Breweries	Breweries, textiles	BOD, nutrients
Kafue River Sub-basin (1-07)		
Kitwe	Breweries, oil processing, lead batteries, paint.	BOD, organic solvents, metals, petroleum waste
Ndola Paper mill	Paper mill, galvanization, breweries, oil processing	BOD, zinc sludge, petroleum waste, nutrients

Lusaka	Breweries, tannery, paper mill, chemicals, oil processing, textiles, slaughterhouses	BOD, chromium sludge, organic solvents, petroleum waste, nutrients
Kafue	Fertilizers, steam production	Acidic calcine slurry, boiler ash, nutrients
Mazabuka	Sugar production	BOD, nutrients
Kabwe	Oil processing	Petroleum waste

There is a likely decrease in water quality in the Zambezi delta associated with effluent discharge from Sena Sugar factory at Marromeu. Sugar industry produces high amounts of biodegradable waste, and the high organic loads of its wastewater represent a major environmental problem. Molasses produced from sugar waste is also spread on local roads, from where it runs off into local stream channels and eventually the Zambezi River during the rainy season. These effluents are likely to increase organic loading in the Zambezi River, therefore negatively affecting the aquatic ecosystem (Beilfuss, 2006). Near Marromeu, air pollution produced by the sugar factory and from the burning of cane fields result in high particulate matter that may contaminate local water bodies.

In Harare, the Mukuvisi River which drains into Manyame, is generally considered the most heavily polluted river system in Zimbabwe. The river flows through both industrial and residential areas of Harare (Chenje *et al.*, 2000).

In Tanzanian part of the basin, the quality of water in the basin is generally good except for the pollution of Kiwira River by Kiwira Coal Mine and Songwe river by Mbeya Cement (Ministry of Water, Energy and Minerals, 1992).

Mining

There are a large number and wide variety of mining and minerals processing operations in the Zambezi basin. Data on the type of mine, size, operational status and location of mining operations and their potential impacts in the Zambezi basin have been extensively reviewed by Ashton et al. (2001 in FEEM/ FAD, 2005)

Table 5.7 shows the major mining activity by sub basins in the Zambezi River Basin (FEEM/ FAD, 2005). It is clear from the Table 5.7 that the sub-basins of Luangwa River (1-05) Kariba (1-06), Kafue River (1-07) and Kabompo River (1-13) are the most active in mining activities and therefore potentially contributing significantly to the pollution of the Zambezi River basin.

Practically all streams draining the mining areas within the Copperbelt empty either into the Kafue River or its tributary the Kafubu River, which are the principal rivers draining the region, and which hold the chief source of drinking water for all of the towns of the Copperbelt. Table 5.8 shows the mining discharges and routes to Upper Kafue while Table 5.9 shows the status of water quality in the Kafue river compared to Australian guidelines.

Agriculture

In the Zambezi basin the most fertile soils are widely cultivated for crops such as maize, cassava, cotton and oil seeds (ZACPLAN, 1998). Zimbabwe, Zambia and Malawi have together 86 % of the estimated 5.2 million ha of the yearly cultivated area in the Basin. The major impact of agriculture on water quality results from contamination from agro-chemicals, siltation of rivers caused by soil erosion and impact from livestock. The use of fertilizer in commercial agriculture and erosion in communal lands in Zimbabwe, and in other parts of the Basin where soils are eroded and degraded, are the two most important factors for water quality in the area. Farming practices, especially in the Sanyati catchment area are reported to generate pollution especially during the rainy season when leaching of nutrients from the fields to the hydrographic system occur.

Overstocking is a problem in Mazowe valley. Attempts to enforce stock limiting procedures to safeguard the environment have not been very successful resulting in environmental degradation in many areas including Omay, Hurungwe, (Sub-Basin (SB) 1-06), Mukumbura (SB 1-02) in the Zambezi valley and, outside the sub-basin area, the Save basin (ZACPLAN, 1998).

Fertilizers

Fertilizers are the most commonly used chemicals in agriculture. The quantities of fertilizer and agro-chemicals used in the communal areas are much lower than those on commercial farms. The average application of fertilizer for maize, the staple food crop, is between 50 and 100 kg of Compound fertilizer and 50 to 100 kg of Ammonium Nitrate (AN) per Ha. On average, approximately 20% of farmers in communal areas purchase fertilizer. It is estimated that between 250,000 and 350,000 tonnes of fertilizer are used in Zimbabwe each year. It has been suggested that up to 50% of applied fertilizer can be washed off directly by runoff after a storm. Obviously only a proportion of the applied fertilizer will be leached into the surface water as much of that applied is either taken up by plants or bound into the soil and unable to be released (ZACPLAN, 1998).

In Marromeu (Beilfuss, 2006) there are currently 12,000 ha of irrigated agriculture, with sugar cane as the main crop (10,000 ha) and about 2000 ha other cash crops. The sugarcane fields can be increased to 20,000 ha with the current processing capacity. Use of fertilizers for sugar production may also be contributing to the eutrophication of floodplain waterbodies, especially abandoned channels, oxbow meanders, and shallow marshes. These problems are exacerbated by the lack of annual flushing from Zambezi flood flows. At Malingapans, people complain that the Micelo branch of the Zambezi River is now choked with reeds and other weeds because of reduced flushing flows and nutrient-rich runoff. These weeds have greatly reduced the potential for boat transportation upstream, thereby isolating the community from Marromeu.

Agrochemicals

Agro-chemicals required are expensive and out of the reach of most communal farmers. Herbicides are almost never used in the communal areas of Zambia and Zimbabwe where hand hoeing is the most common method of controlling weed growth. Agrochemicals are more used in commercial farming. The number of times chemicals are applied to a crop is determined by the type of season or the value of the crop. Different seasons bring different pests and control the rate and timing of weed growth. The higher the value of the crop the greater the number of chemical applications. Crops such as Paprika may require chemical applications on a weekly basis.

On average 2,300 tonnes and 900 tonnes of herbicide are applied each year in the Zimbabwe and Zambian sub-basins of the Zambezi respectively. The sub-basins involved are the Zimbabwean section of SB 1-02, the area around Lusaka in SB 1-04, the middle and Copper belt region of SB 1-07 and the lower portion of SB 1-05. The average annual application of pesticides in Zimbabwe is about 3,200 tonnes (Beilfuss, 2006).

Table 5.7 Status of mining activities in the Zambezi River Basin

Sub-basin	Status of mining/Type of mineral
Shire River/Lake Malawi, sub-basin (1-03)	Coal mining at Kiwira,
Luangwa River, Sub-basin (1-05)	▪ Mulungushi sub basin-several small Au Ag and Cu mines. The old Pb-Zn-V deposit at Kabwe is being re-examined with a view to re-working the tailings dumps with improved extraction technologies. The Kabwe deposit is known to be a problem because of acid mine drainage as well as sulphuric acid fumes from the old smelter. Minor seepage of cyanide is associated with the abandoned gold mining operations at the Lusemfwa Mine, especially from tailings dumps. ▪ In the Luangwa river sub basin, there are several small alluvial Au operations, with many artisan miners
Kariba, Sub-basin (1-06)	▪ Deka sub catchment: Coal, Pyrite (in Wankie) coking plant is present. ▪ Gwaii sub basin, gold mining in the Greenstone Belts in the south, the Shangani Nickel mine and, historically, Sn mining in the Kamativi-Dete Inlier in the north. There are several other mines in this area for Sb, Co, F, Au, Hg, Ni, Ag, Ta, Sn and W. There is considerable exploration taking place in the south of this area, mainly for Au, Ag and Ni. ▪ In Sebungwe and Sengwa sub basins fluorite and coal mining activities have been reported. ▪ In the Sanyati sub basin, the main mining activity is Au mining in the Greenstone Belts, Fe at Redcliff (historically) and Cr along the Great Dyke, but there are a lot of other heavy metal mining activities: Sb, Sn, Cr, Au, As, Fe, Mn Hg, Ni, Pd, Pt, W, Zn and Cu. There is exploration for Au, Ag, Cu, Pb, Zn, Ni, Co, Pt and As. Alluvial mining of gold is widespread, especially in the Sanyati, Munyati, Msweswe and Sebakwe Rivers. On the left side of Kariba Lake, the Maamba Colliery is the largest mining operation in this sub-catchment; In this area, the are several mines Chipepo (Coal), Maamba (Coal), Kabanga (Sn), Chisuki (Sn, Ta), Phoenix (Coal), Namakande (U), Nkandabwe (Coal), Siavonga (U). There has been considerable exploration in the area for Au, U, and coal. ▪ In the Chirundu sub basin, there are several small gold (Au) mines, new Cu prospects and a small Zn and Pb mine is starting operations to the north of Lusaka. In this sub basin, minor seepage of cyanide is associated with the gold mining operations, especially from tailings dumps. The zinc deposit is a sulphide ore so acid mine drainage is a potential problem.
Kafue River, Sub-basin (1-07)	▪ The Lunga River is the most important tributary of Kafue River. In its catchment, Cu, Co and Au deposits have been reported. Major deposits of copper, cobalt and gold at Kansanshi are being evaluated for their economic potential. Additional prospecting for copper and zinc is ongoing close to the junction of the Lunga River with the Kafue River, shortly after the Busanga Swamps. The most important sites are: Lunga Basin (Cu, Zn), Solwezi (Cu) Kansanshi – old (Cu, Co, Au), Kansanshi - new (Cu, Co, Au), Dumbwa (U, Cu), Lunga (Au, Cu), major Cu and Co deposits have been exploited for several years by both open pit and underground mining methods. There is a large copper smelter at the Nkana Operation in Kitwe and a cobalt refinery at Chambishi. The list of the metal mines is: Konkola (Cu, Co), Nchanga-open pit (Cu, Co), Nchanga-deep (Cu, Co), Chambishi (Cu, Co), Chambishi-COSAC (Cu, Co smelter), Chibuluma Cu), Chibuluma South (Cu), Mufulira – Main (Cu, Co), Mufulira – Mokambo (Cu), Nkana (Cu, Co), Nkana – Slag pile (Co, Cu), Luanshya (Cu), Baluba (Cu), Bwana Mkubwa (Cu), Ndola Lime (Limestone), Mwekera (Cu), Bob Zinc (Zn), Kabwe Division (Zn, Pb, Ag), Sakania (Au, Cu), Hippo (Cu), Silver King (Cu, Ag), Sable Antelope (Cu, Au). Most of the mines are large to very large. Some small to medium mining activities are located in the lower Kafue river sub basin (Chilanga (Limestone), Nampundwe (Fe, Cu), Matala (Au, Ag), Munali (Ni), Luwana (Cu), Luiri-

Sub-basin	Status of mining/Type of mineral
	Dunrobin (Au, Ag, Cu), Shimwyoka (Fe), Argosy (Cu), Chongwe (Cu), Kamiyobo (Cu, Fe), Nambala (Fe).
Cuando/Chobe River, Sub-basin (1-08)	▪ No mining and mineral operation no alluvial (small-scale) mining have been reported in the Chobe sub basin. In Cuando sub basin a diamond prospect (Lumbala Nguimbo) is under investigation.
Barotse, Sub-basin (1-09)	▪ Three small amethyst mines reported (Mulobezi, Njoko and Loazamba mines).
Luanginga River, Sub-basin (1-10)	▪ No known mining activities has been reported
Lungue Bungo River, Sub basin (1-11)	▪ One small coal deposit (Muangai mine) is reported
Upper Zambezi, Sub-basin (1-12)	▪ In the Luena River sub basin, the Macondo Copper Mine was abandoned several years ago as a result of the Angolan Civil War. The Alto Zambezi kimberlites show good prospects for diamonds. Anecdotal evidence for alluvial diamond mining in the headwaters of the Luena River is reported.
Kabompo River, Sub-basin (1-13)	▪ Copper (Cu), cobalt (Co), zinc (Zn) and uranium (U) deposits have been found at Lumwana and Kalumbila and a mine has started operating at Lumwana. ▪ The Kalengwa Copper Mine has closed down and there are good prospects for iron and nickel. The following mines have been reported: Macondo-C and Macondo-D ▪ (Fe), Kalengwa (Cu, Ag), Kalumbila (Cu, Co, Zn), Kabompo (Fe), Kalumbila (Ni, Cu), Lumwana (Cu, Co), Mwinilunga (Cu), Luamata (Cu), Kawanga (U), Mufumbwe (Cu), Lalafuta (Cu).

(Source: Zambia National Water Resources Master Plan, 1995)

Table 5.8 Mining discharges and routes to Upper Kafue

Mine	Infrastructure	Source of Discharge	Discharge to Environment
Konkola Division	Underground Mine, Crushers, Concentrators	Underground dewatering, Plant site	Lubengele Canal to Kafue
		Tails Effluent, Sewage Ponds, Underground water	Kakosa Stream to Kafue
Mufulira Division	Underground Mine, Crushers, Concentrator, Smelter, Refinery	Not specified	Mufulira Stream to Kafue
Nchanga Division	Underground Mine, Open Pit, Crushers, Concentrator, Tailings Leach Plant, Tank House	Not specified	Mushishima Stream to Kafue
		Block A-Dumps, tailings dam reclaim, tailings leach plant, Tank house	Kafue
		Muntimpa Tailings Dam	Muntimpa Stream to Mwambashi River to Kafue
Chambishi Mine (Nkana)	Roaster, Acid leach Plant, Copper & Cobalt Tank houses	Not specified	Musakashi Stream to Kafue
		Not specified	Chambishi Stream to Mwambashi to Kafue
Chibuluma (Nkana)	Underground Mine, Plant Site.	Underground water, Plant Site	Fikondo Stream to Mwambashi River to Kafue
Nkana Division	Underground Mine, Crushers, Concentrator, Acid Plant, Smelter, Refinery, Cobalt Plant, Tailings	Mindola Tailings Dam, Overburden Dumps	Icimpe Stream to Mwambishi to Kafue
		Underground Mine, Plant Site	Mindola Stream to Kafue
		Concentrator, Refinery, Cobalt Plant, Smelter	Uchi Stream to Kafue
		Underground Mine, Crushers, Concentrator, Acid Plants	Wusikili Stream to Kafue
		Tailings Dams 35 & 41, Runoff	Mululu Stream to Luanshimba to Kafue
Baluba	Underground Mine	Underground water	Baluba River to Kafue
Luanshya Division	Underground Mine, Smelter, Tailings Dams	Underground mine, Smelter, Concentrator	Luanshya Stream to Kafubu to Kafulafuta to Kafue
		Chonga and Musi Tailings Dams	Luanshya Stream Kafubu to Kafulafuta to Kafue
Ndola Lime	Open pit and lime kilns	Open pit dewatering / runoff from plant site	Kafubu dambo and river
Gem mine	Open pit and washing plant	Open pit dewatering and mineral washing plant	Kafue and tributary streams

(Source: ZCCM, Environmental Impacts, Emissions to the waterways – Kafue river basin, undated.)

Table 5.9 Water Quality in Kafue River

Parameter	Australian Guidelines	Upper Kafue	Middle Kafue	Lower Kafue
Dissolved Oxygen	>6mg/l (80% Saturation)	All high	All high	Often low
pH	6.5 – 9.0	Within range	Within range	Within range
Salinity	< 1000 mg/l	Low salinities	Low salinities	Low salinities
Turbidity	<10% change from seasonal mean	Low	High in wet season	High in wet season
Copper	2.0 – 5.0 µg/l	Within range	Within range	Within range
Iron	1000 µg/l	All low	All low	All low
Nitrate	Nitrate warning 35 – 260 µg/l	Beyond warning guidelines	Beyond warning guidelines	Beyond warning guidelines

(Source: as reported in Table 5.5, Zambia National Water Resources Master Plan, 1995)

5.2.3 Salinity intrusion

Salinity intrusion into the Zambezi Delta has been mentioned as one of the adverse impacts associated with Zambezi River impoundment at Cahora Bassa. Loxton Hunting and Associates et al. (1975) expressed early concerns about changes in salinity due to river impoundment. They stated that salinity intrusion is now widely reported from Malingapans to the coastal communities. Farmers at Malingapans, for example, note that Zambezi River water used for irrigation of rice crops is brackish and has resulted in the salinization of the floodplain, reducing crop yields. The historic influence of tides in the Zambezi River mainstream channels extended to Malingapans and further upstream during the dry season, and presumably turbine discharges during the dry season have reduced tidal influence upstream during the dry season. Loxton Hunting and Associates et al. (1975) claim that the control of regular annual flooding has affected the important function of flushing accumulated salts from the floodplains, leading to soil salinization; and halophytic vegetation has also replaced freshwater vegetation in the coastal region.

However a study by SWECO (1982), could not find evidence to substantiate the claim of salinity intrusion due to the river regulation by Cahora Bassa. This matter may need further investigation.

5.2.4 Sediment

Although sediment loading in rivers especially from human activities is considered an environmental problem, it is reported that significant reduction of the sediment load of the Zambezi River due to sediment trapping in reservoirs is causing geomorphological and ecological changes (Beilfuss *et al.*, 2006). Cahora Bassa Dam, in particular, captures the major source of sediments to the Zambezi River - runoff from the Luangwa River in Zambia. These changes include:

- degradation of the coastal shelf (and corresponding die-off of mangrove vegetation);

- highly eroded riverbanks through down cutting of the mainstream Zambezi River (for example, former water intake pipes for Sena Sugar factory at Luabo are now more than five meters above the mean annual Zambezi River water level and must all be replaced; the roots of old trees are also exposed on banks);
- decrease in micronutrient availability associated with sediment transport.
- lateral stabilization of channels and consolidation of sandbars into vegetation islands;

5.3 Groundwater Quality and Pollution

Generally there is very limited information on ground water quality in the Zambezi Basin. In this respect the situation is even worse than it is with respect to hydrogeology (section 3.2). In Mozambique the National Water Resources Strategy for instance has identified the following institutional issues and data availability problems/gaps hindering the development of groundwater protection zones: inadequate water quality monitoring data; limited capacity and divided responsibilities amongst government departments; poor coordination between government departments; under funding for groundwater protection issues; and limited enforcement of basic regulations. In this context the strategy recommended the production of a reconnaissance scale map of groundwater vulnerability as a first step to systematic groundwater protection.

The information in this section is collated from a variety of sources.

In Zambia, most groundwater in the Copperbelt is of good quality. However, within a number of active mining industrial areas, there is evident contamination of groundwater directly underneath and in the immediate surroundings of mineral/metallurgical plants or tailings deposits. Thus, infiltration of highly contaminated solutions occurs at Nkana due to leakages in the process. Somewhat similar impacts on the groundwater directly underneath tailings deposits occur at Chambishi and Bwana Mkubwa. However in these areas there is no indication of more widespread contamination. Mine water from most of the underground mines is usually of good quality, although usually with somewhat elevated concentrations of copper and cobalt. However, at Chibuluma, the Shaft 2 mine (now disused and the entrance plugged) has acid water and high concentrations of metals, particularly copper and cobalt, but even nickel and uranium. Further, the Mindola mine contains water with high concentrations of uranium. Mine water is sometimes pumped and used as municipal water, though usually after treatment. The quality of such mine water is usually good, but occasionally elevated concentrations of, for example, uranium may signify a certain hazard. It has been recommended that the use of mine water should be accompanied by strict analytical control in laboratories equipped to analyze even for such elements as uranium.

In major cities such as Lusaka and Maputo, that depend on groundwater for the water supply – including from individual wells, bacteriological contamination may be an issue due to poor sanitation and refuse dump run-off; for instance high levels of nitrates and e-coli bacteria in Maputo.

In Malawi, as in other countries in the Zambezi basin, information on groundwater quality is patchy. Yet there seems to be considerable variations even over short distances. One common problem, especially in the alluvial deposits in the Lower Shire area, is high salinity. It has been associated with evaporation and dissolution of evaporative minerals. This high salinity is less widespread in weathered basement and colluvium. Fluoride problems unlike elsewhere in the Rift Valley do not appear to be extensive. Some groundwater in the weathered basement have concentration in excess of the WHO norm of 1.5 mg/l; however, in a number of areas the water quality is below the WHO water quality guideline. In the Lower Shire several samples had fluoride concentration up to 15 mg/l (causing crippling fluorosis), probably related to active geothermal sources in this part of the Rift Valley. No indications of arsenic concentrations were found, but research has been limited. High iron content occurrence is common however, which does not lead to health problems as such, but reduces the potability of groundwater.

In Tanzania part of the Zambezi basin groundwater potential is distributed over a small area in the Basin. Test borehole drilling showed shallow groundwater potential in Kyela and few areas on the Lake shore namely Mbongo and Mbamba bay. There have been indications of high contents of chloride and sometimes fluoride in some of the boreholes drilled.

5.4 Environmental Threats

5.4.1 Waterborne Diseases

Water contamination from industrial and sewage pollution is widespread in the basin. Water borne and water related diseases such as typhoid, cholera, dysentery, gastroenteritis; hepatitis schistosomiasis and guinea worm are common. The incidence of malaria has continued to rise in Zambia (Chenje *et al.*, 2000). The Copperbelt which is almost synonymous to Upper Kafue, malaria incidence in 1999 of 322 per 1,000 population was higher than the national average of 314. Copperbelt ranked fifth of the provinces with the highest incidence of malaria (Chenje *et al.*, 2000).

Similar to the Copperbelt, malaria is the main cause of morbidity in Itezhi-tezhi District, which is traversed by the Kafue River, followed by non-pneumonia respiratory infections. The two diseases also top the morbidity list of the Zambia, suggesting that they are very widely spread and the Kafue basin has not been spared. The high incidence of malaria in the Kafue Flats sub-catchment, has been attributed to the large area covered by slow moving or stagnant waters.

The Itezhi-tezhi District Health Board attributes the high incidence of eye and skin infections, together with non-bloody diarrhoea, the fifth most common disease in the district, “to the low number of households with access to safe water supply and adequate sanitation facilities”. Only 28% of the population in Itezhi-tezhi had access to safe water supply in 2001 while 86.7% used bushes for their sanitation.

Faecal coliform is still the primary water quality issue in rivers in Zambezi basin, particularly in areas where animal and human waste is not adequately collected and treated. The high coliform count partly explains incidences of waterborne diseases such as cholera, and dysentery as experienced by Kariba and Siavonga throughout the 1990's.

Low functionality of existing systems water supply is another problem: in Malawi for instance 34% of the rural water supply systems are not functional.

5.4.2 Invasive aquatic species

There has been a build-up of aquatic weeds, mostly free-floating species such as Eichhornia (water hyacinth) and Azolla in the Zambezi River Basin. Many of the species (Eichhornia crassipes, Pistia stratiotes, Azolla filiculoides, Salvinia molesta) are introductions from other continents. These species reproduce rapidly and can cover the entire water surface, thus causing a number of problems including:-

- clogging up waterways hindering navigation;
- clogging intakes to power plants and water treatment plants; outlets (sewer outfalls) are equally affected;
- cutting out light so that submerged plants die out; and
- greatly increasing the biological oxygen demand of waters and modifying the aquatic environment so that various indigenous plants and animals (fish in particular) can't survive.

Though water hyacinth growth is a problem throughout the basin, areas that are particularly problematic are the Kafue Flats, Lower Shire and Lake Kariba.

Water hyacinth growth has been reported by the Environmental Council of Zambia to be one issue of concern affecting fisheries of Zambia. Kafue River is reported to be the most polluted river in Zambia. High levels of nitrogen and phosphorus are reported and are attributed to sewage effluents and runoff from NPK fertilizers and effluents detergent manufacturing companies. Proliferation of especially water hyacinth between Nakambala and Kafue Gorge is the most visible impact of pollution. Industries located in this area are Zambia Sugar Plc, Nitrogen Chemicals, Lee yeast, Kafue Chemicals, Kafue Bata Tannery, National Breweries and Kafue Township Sewage Treatment Works.

Water hyacinth is also a major hindrance to navigation in the Lower Shire. It is also reported for example that there was intense fish production in Bangula Lagoon of the Lower Shire marshes until it became choked by water hyacinth in the 1980s.

In Lake Kariba water hyacinth (*Eichhornia crassipes*) along-side hippo-grass (Vossia cuspidate) is found in the estuaries and along the shoreline. Table 5.10 shows the estimate of water hyacinth coverage on Kariba Lake from satellite data covering 1995-2001. The last column shows the result of weed coverage survey by boat that was carried out in 2001. It can be seen that the total weed coverage reached a peak of 1893.3 ha in 1997and since then a decline in total coverage is noticed. The observed distribution of water hyacinth, as observed during the ground truthing was in large mats (0.5 ha) split up into small floating mats (average 1-2 m in diameter) and individual plants, in open water and contained within areas of dead trees. The small mats are sensitive to fluctuating wind and wave action, and velocities were in the order of 10m/hr. Managing lake levels so as to avoid water hyacinth growth in shallow estuaries is reported to have an effect on the distribution of this invasive species. Biological controls are being used to control water hyacinth in Lake Chivero and 'salvinia' in Lake Kariba with some success.

ZRA has implemented several interventions on the control of water hyacinth on Lake Kariba, such as a herbicide control exercise in 1998, which marked a major turning point in weed populations on the Lake and the monitoring programme that is ongoing under ZRA. In Botswana, there is the Aquatic Weeds (Control) Act of 1971 and the Boat (Import, Registration and Movement) Regulations of 1968 that restrict movement of any aquatic weed from any point or place within Botswana to another point or place in Botswana. Allowance of boats or aquatic apparatus is zone specific in order to monitor inter-zonal movement and are also subjected to compulsory inspection and treatment when being brought in or moved between zones.

'Azolla Filliculoides' (red water fern) is the most common problem aquatic weed in the Mazowe Valley. It is a small free floating plant which can form multi-layered mats completely covering small ponds or slow flowing streams and canals. Water hyacinth is a problem in the eutrophic lakes of Chivero and Manyame in the Manyame catchment. Together with water hyacinth it causes a problem further down the Manyame and into the Zambezi.

Further, the small thorny bush Mimosa pigra which is associated with aquatic systems has become of environmental concern in the basin and is now considered as invasive. This is mainly a result of changes in the hydrological regime in some valleys which have thus become more hospitable to the plant. The main aquatic weeds of concern in the wetlands of the basin are the floating species Salvinia molesta, Pistia stratiotes, Eichhornia crassipes and Azolla filiculoides. Because they float and are not rooted in the substrate, all can move rapidly over water bodies. They also reproduce asexually and explosively under favourable conditions.

Kariba Weed (water fern) used to be widespread as well, but its spread has declined. This has been linked with the spread of predators, especially the grasshopper.

Table 5.10 Estimation of water hyacinth coverage on Lake Kariba from satellite data and boat survey, 1995 - 2001

Station	1995	1997	1999	2001	Boat survey 2001
	ha	ha	ha	ha	
Charara Bay	0	101	29	53	100
Gatche Gatche Bay	70	887	193	100	20
Hydro Bay	0	77	5	0	0
Kariba Dam Bay	0	2	1	2	-
Leisure Bay	1	44	29	34	70
Masango Bay	174	483	146	146	200
NW-Coastline	0	21	37	72	-
Sanyati East Bay	1	271	208	25	1
Sanyati West Bay	0	7	7	1	1
Total Weed	246	1893 3	653	433	392

5.4.3 Water Pollution Hotspots

Threats to water quality are siltation due to deforestation and resultant erosion, contamination of water from agro-chemicals used in intensive agriculture including irrigation, pollution from cities and industries. Water quality is also adversely affected by effluent discharge from mines, runoff from dumps and tailings dams and airborne pollution and effluent from smelters.

Large areas of Zambezi Basin are subject to erosion as more land is cleared and existing arable land is poorly managed. The areas near towns such as Luena, Cazombo and Lumbala in Angola have been reported to seriously suffer from soil erosion. The areas of Sucoma and Dwanga in Malawi and Nakambala in Zambia have been identified as threatened by high environmental impacts from agricultural activities associated with sugar estates. Industrial pollution impacts originate from the main mining areas such as the Copperbelt in Zambia and Hwange in Zimbabwe, around industrial towns and large cities such as Harare, Lusaka and Tete.

Other hot spots for water quality degradation are the Manyame and Kafue sub-catchments where effluent from urbanization and mining originate. Pollution from industrial and domestic sewage is increasing with the growing urban centres such as Mongu, Senanga, Katima Mulilo, Kasane-Kazungula, Sesheke, Livingstone, Victoria Falls, Kariba, Siavonga, Chirundu and Tete. Most of these urban centres including cities such as Blantyre, Bulawayo, Harare and Lusaka and the mushrooming tourist facilities along the river discharge poorly treated effluents into the river and its tributaries.

Pollution from mining activities on the Copperbelt is causing a marked decrease in aquatic biodiversity over a more than 150 km of the Kafue river [SGAB-SWECO-THOMRO-UNZA, 2005]. Changes in species composition indicate that the change is caused by mining-related contamination, and not by nutrient pollution and/or low oxygen events.

Sediment has been found to contain toxic amounts of metals. Laboratory bioassay tests on three species of fish found that samples from City of Kitwe on the Copperbelt in Zambia were approximately 90 times more toxic than samples from Lake Itezhi-tezhi at the beginning of the Kafue Flats, and ten times more toxic than samples from Kafue town further downstream [Ministry of Energy and Water Development OPPPI/ZESCO, 2003]. Another study on the Copperbelt established contamination of surface water related to siltation resulting from washout of fine particles from dumps and (often obsolete)ore-processing plants; from overflow of tailing facilities; leakage from tailing dams and from drainage of process water from smelters and acid plants. This resulted in:

1. High acidity of waste water from dressing plants (pH values of 2.0-3.6);
2. Toxic elements, especially Copper and Cobalt, in stream sediments in excess of norms – for instance Cu at 65460 ppm; Co 3660 ppm; Hg 6,47 ppm; Mo at 48 ppm; Pb at 360 ppm; Zn at 3590 ppm. This contamination is however

partly compensated by the acid neutralising capacity of the river sediment and contamination decreases as one proceeds downstream

A risk is that part of the contamination – also caused by air particles – will enter into the foodchain through fish and vegetables.

5.4.4 Wetland Degradation

Wetlands are among the most environmentally sensitive areas of the basin. Wetland resources are widely degraded and are threatened by further developments. Specific impacts vary from one location to the other depending on development, characteristics of the wetland and hydrological regime; but the observed impacts arise from:

1. river regulation, particularly for hydropower development, that does not mimic the natural hydrological regime of the river;
2. bunding and abstraction of water for irrigation, leading to reduced flows, particularly during the dry season;
3. abstraction of water for municipal supply;
4. impeded drainage due to infrastructural development in the wetland;
5. pollution from agriculture, mines, towns and industries;
6. overexploitation of natural resources, such as overgrazing, overfishing and poaching, reduction in vegetation cover; and
7. invasive weeds, such as water hyacinth.

These threats to these aquatic ecosystems have already been experienced on the:

- Kwando/Linyati/Chobe wetlands and the flood plains in the Eastern Caprivi (reduced flows due to drought; invasive aquatic weeds; pesticides (DDT) routinely used in to control malaria mosquitoes; overexploitation of resources – overpopulation leading to ever increasing use of natural resources, poverty and overgrazing; and intensive agriculture).
- Copperbelt Wetlands (“dambos”) in Zambia (effluent discharges form mining activities and industries; overexploitation of natural resources due to human activities – clearance of vegetation for farming, deforestation due to charcoal production and construction materials, and grazing).
- Kafue Flats in Zambia (river regulation of Lake Itezhi-tezhi for hydropower production at Kafue Gorge Dam; pollution from mining, industry agriculture and municipalities; competition for water supply; and over exploitation of wildlife resources – resulting from increasing human settlements).
- Zambezi Delta wetlands in Mozambique covering an area of 12,800 km^2 and comprising a range of wetland habitats including mangroves and floodplain grasslands (threats arise from reduced flow due to river regulation from Cahora Bassa; and saltwater intrusion in the delta on account of reduced freshwater flows and the lack of substantial seasonal floods)

5.5 Management of Water Resources and Related Environmental Issues

5.5.1 Water Quality Management

While most Zambezi basin states have policies, strategies and plans for managing water as an important resource, the focus has been primarily on the quantity of water. Water quality management has not received the same level of attention. An integrated approach to water quality management is still lacking. "Integrated water quality management is the planning, organisation, direction and monitoring of all aspects that have an effect on the quality (physical, chemical, biological, bacteriological, etc) of the water resources, incorporating and balancing the different requirements of relevant water users and water functions in order to enhance efficient and sustainable use of the resource" [Hirji, R., Maro, P. and Mackay, H., 2002].

Poor management of water quality in the Zambezi basin states is evident through lack of systematic water quality monitoring networks; inadequate knowledge of baseline water quality (thus making it difficult to define assimilative capacities of rivers and lakes), weak policy and legal frameworks relating to water and the environment (inadequate protection of watersheds and water sources, non-recognition of water requirements for environmental purposes, weak institutions – narrowly defined authority, inadequate staffing and funding). Legislation is often concentrated on the setting of effluent and water quality norms. Each of the Zambezi basin countries has legislative instruments in place to deal with pollution (Table 5.11), it is enforcement, however, that is often inadequate.

Table 5.11 Legal Instruments for Water Pollution Control in the Basin Countries

Country	Agency responsible	Instrument	Subsidiary legislation
Angola	Ministry of Energy and Water	Water Act-199	Water Regulations 1968
Botswana	Department of Water Affairs	Water Act of 1968 Aquatic Weeds (Control) Act 1971	Water Regulations 1968 Declaration of Infested Waters Order 1986 Boat (Import, registration and movement) regulations) 1986
	Department of Public Health	Public Health Act 1981	Public Health Regulations
Malawi	Ministry of Irrigation and Water Development	Water Resources Act 1969	Draft National Sanitation Policy 2007 Environmental Management Act 1996
Mozambique	National Water Council	Water Law Act No. 16 of 1991	WHO Guidelines
Namibia	Department of Water Affairs	Water Act No. 54 – 1956	
Tanzania	Ministry of Water	Water Utilisation (Control and Regulation) Amendment Act No.10 – 1981	Temporary Standards –1978
Zimbabwe	Zimbabwe National Water Authority	Water Act-1998	Water Pollution Control (Effluent and Wastewater) Regulations –1999
Zambia	Environmental Council of Zambia	Environmental Protection and Pollution Control Act No.12 – 1990	Pesticides and Toxic Substances Regulations –1994
			Water Pollution Control (Effluent and Wastewater) Regulations –1993
			Waste Management(Transport and Waste Disposal Site) Regulations – 1993

5.5.2 Mainstreaming Environment into Development Planning

In recent years almost all basin states have reformed their water management institutions, adopted environmental policies and strategies, ratified multilateral environmental agreements, and revised domestic legislation on the management of natural resources.

What is required is the effective implementation of these new institutional arrangements and the integration of water quality and environmental management. A framework of water quality management integrates the following:

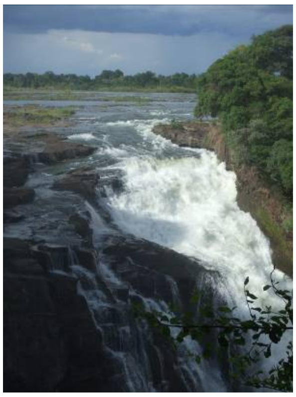
- legislative, including direct regulation;
- standards of effluent or water quality, and licensing;
- legal, including compensation for damage and fines for violation of laws; and
- economic incentives including effluent charges or tax subsidies and accelerated depreciation allowances
- integrating environmental concerns in land use planning, flow regulation and others.

Though administrative arrangements for environmental management vary between basin states, there is a risk to regard environmental management as a sectoral rather than cross-cutting activity and a conventional sectoral approach remains. It is now recognised that environmental sustainability and water security need to be mainstreamed into the broader development agenda. This also calls for promotion and support for water and environmental awareness amongst decision makers; an integrated rather than sectoral planning process; an open information/monitoring system; institutional capacity development; and a need to localise and shift power towards environment-dependent stakeholders.

Compared to other parts of the world, water resource use is not intensive in the Zambezi Basin. There is considerable scope for economic development and poverty alleviation in the Basin by a balanced development and management of its natural endowments. However there are also examples of water resources management issues or challenges that need to be addressed in order to pave way for more effective and sustainable management of this shared resource. These water management issues will be discusses in Chapter 7.

6 Institutional and Policy Issues

6.1 Basin Institutional Organization and Management



At present there is no single organisation with responsibility for water resources management of the Zambezi Basin as a whole. Institutional responsibility is exercised through national frameworks over the respective parts of the basin falling within each country. As discussed in section 2.5, there exist some significant differences in institutional frameworks among the riparian states of the Zambezi. The majority of the countries operate through centralised national institutions with delegated authority to sub-national organisations with jurisdiction over politically defined geographical area (province/region and district) rather than a basin or sub-basin. Therefore even at national level there are challenges in managing water resources effectively and in a coordinated manner over these areas. The challenge is therefore magnified at basin level since the basin as well as its sub-basins cut across national boundaries.

Though there is an overall policy and legal framework for water resources management in the SADC region – the Regional Water Policy and Strategy, as well as the Protocol on Shared Watercourses – coordinated development and management of water resources in the Zambezi basin will be more effective with existence of a formal institution to which the riparian states have acceded authority to manage the water resources of the basin as a single entity. The steps taken so far to establish the Zambezi Watercourse Commission (ZAMCOM) will go a long way to address this problem once the agreement has been ratified and come into force.

The opportunity for basin-wide management is strong because virtually all countries have in place policies and legal frameworks based on the concept of integrated water resources management (IWRM) including management on basis of a catchment or basin rather than political jurisdiction. These management principles are being implemented throughout the basin states. As may be expected, there is variation from one country to the other in the pace and scope of implementation of the reforms. It is therefore expected that translation of these management principles to the transboundary basin, that Zambezi is, will not pose insurmountable challenges.

6.2 Coordination of Trans-boundary Water Management Issues

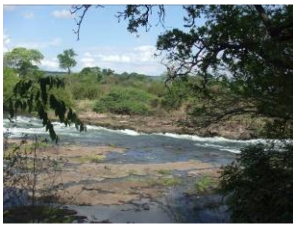
6.2.1 Hydro-meteorological data collection and exchange

The cooperation between the basin states in terms of the exchange of hydro-meteorological data has improved greatly in the past 10 years. Cooperation has benefited greatly from direct interaction between officials of the national water department in the context of regional meetings, many of which promoted by SADC Water Division. In practical terms requests for data from one country to the other are usually honoured. The provisions to this effect in the SADC Protocol on Shared Watercourse Systems have found firm rooting in that daily practice. Coordination is further enhanced by regular bi-annual meetings of the hydrological officers of the national water departments, to discuss issues related to hydrological and meteorological data collection, exchange and forecasting. These meetings are organized by the ZACPRO project.

Notwithstanding this improvement some difficulties remain. In some countries the collection of hydro-meteorological data is not implemented directly by the national water department, or some aspects of it are implemented by other institutions. This fragmentation can lead to obstacles, in particular in situations where payment is requested for the delivery of data.

The unification of available hydro-meteorological data in one single database is presently being undertaken by the ZACPRO 6 phase II project. This database, Zambezi Water Information System (ZAMWIS), will be in the custody of the ZACPRO project until the time that it can be handed over to the ZAMCOM Secretariat. The ZAMWIS database is fed with data from the riparian countries. Data integrity remains the responsibility of the countries.

6.2.2 Water rights and licenses



In most of the Zambezi countries the issuing of water use licenses or water rights is still centralized. Countries where decentralization has taken place with respect to the water allocation are Zimbabwe, Tanzania and Mozambique. In Angola and Namibia the national water department is responsible for the issuing of water use licenses. In Botswana, Malawi and Zambia this is done centrally as well but by dedicated Water Boards in which stakeholders participate. In most countries stakeholders are actively involved in the decision-making process on water use licenses. However, the level of involvement varies strongly. In Zimbabwe the stakeholders are in full control of the decision-making process, which is the responsibility of the Catchment Councils. In Malawi, Botswana and Tanzania stakeholders cooperate with government officials in water boards. In Mozambique the regional water administrations can consult stakeholders if they wish, but this is not mandatory.

The typology of institutional responsibilities for water allocation follows the two vectors of decentralization and stakeholder participation. The following matrix applies (Table 6.1).

Table 6.1 Typology of institutional responsibilities for water allocation

	Stakeholders involved in decision-making	Government department decides
Centralized	Malawi Botswana Zambia	Angola Namibia
Decentralized	Zimbabwe Tanzania	Mozambique

6.2.3 Water quality monitoring and management

The monitoring of surface water quality is in the hands of the same institutions that are responsible for hydro-meteorological data collection, albeit usually by a separate section of that institution focused on water quality.

Differences between the countries can be found at the level of measures to be taken in relation to water quality management, mostly pollution management. Botswana, Tanzania, Zambia and Zimbabwe have apex bodies for water quality management, such as the National Environmental Council in Tanzania or the National Environment Authority in Zimbabwe, which can prosecute polluters. By contrast, in Mozambique the ARAs themselves have the responsibility to take action against pollution.

It should be noted as well that in most countries water quality data collection is weak. Only in some of the countries are structural and regular sampling programs in place that are actually being implemented. Ad hoc monitoring takes place in most countries, mostly linked to pollution related problems.

Most water quality problems are related to the discharge of untreated sewage from the major cities and towns along the Zambezi river and its tributaries. As a result, eutrophication problems leading to large scale invasion of water bodies by floral species such as water hyacinth and hippo grass are widespread in the middle reaches of the Zambezi and its tributaries such as the Kafue.

Water quality issues are not being perceived as having international implications. No exchange of data on water quality or pollution takes place between the countries, nor has such exchange been requested for by any of the countries. It seems likely that in the future the transboundary aspect of water quality management will receive more attention, as the population pressure as well as agricultural and industrial production increase.

6.2.4 Flood management

Floods are probably the most pressing transboundary water management issue for the population living in the Zambezi river basin. The institutional responsibility for flood monitoring lies with the same bodies that are responsible for regular hydro-meteorological data collection. Rapid exchange of real time or near real time flow data is of the utmost importance in flooding situations and the mechanisms to make such real time data exchange possible are important practical tools that directly impact each country's ability to manage floods as effectively as possible under the circumstances.

As with hydro-meteorological data exchange in general, great improvements in the exchange of flood data have been achieved in the last 10 years. Equally, practical problems persist in cases where flood data collection is fragmented at the national level, in particular when payment is requested for flood data information, as still occurs in isolated cases.

Flood management at the national level is usually a shared responsibility between the water departments and a national disaster management apex body that has the power and mandate to mobilize the necessary resources to address flood problems and take the necessary measures. The national institutional frameworks, depicted in annex xxx, indicate the situation for each country.

The transboundary aspect of flood management is mostly linked to the way the major dams in the basin are being managed. Exchange of flood information to determine the optimum measures to limit the downstream impact of floods while maintaining safe and sound individual dam operations are of great importance. This coordination takes place between the two management bodies for the basin's major dams, Zambezi River Authority – managing the Kariba complex – and Hidroeléctrica de Cahora Bassa (HCB) that manages the Cahora Bassa dam and reservoir complex.

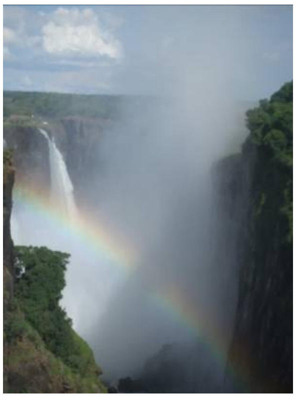
6.2.5 Groundwater monitoring and management

Groundwater monitoring is in the hands of the same institutions that are responsible for hydro-meteorological data collection, albeit usually by a separate section of that institution focused on groundwater.

It should be noted in this context that structural and regular groundwater monitoring only takes place in Botswana. Most other countries have a rudimentary groundwater monitoring program.

There are no known groundwater issues that have a transboundary aspect in the Zambezi basin.

7 Synopsis of Strategic Issues



The Zambezi Basin has considerable potential for development in agriculture, tourism, hydropower and mining. The Basin is rich in resources, but low in population. As global economies develop, this creates considerable opportunities for the Zambezi Basin. Water resources development and management will be a key factor in the socio-economic development and management of the SADC region as a whole and the Zambezi basin in particular. Increased food security, energy for industries and domestic use, increasing access to water supply and sanitation, protection against extremities of floods and droughts, and sustainability of the environment will invariably require the development and effective management of the water resources of the Zambezi Basin.

The strategy in the Zambezi should be to capitalize on these opportunities, while ensuring sustainable resource use, safeguarding its unique environmental assets and very importantly ensuring livelihood improvements for the basin population. While some of the riparian countries have achieved Middle Income Status or are fast moving towards it, the statistics of the countries that make up the largest part of the population and land area in the Basin (Malawi, Zambia and Zimbabwe) indicate high levels of poverty in these countries.

The past record of water resources management in the Basin needs to be significantly improved, as is evident from present uncoordinated and single-purpose operation of major hydraulic structures, from pollution around mining sites and urban centres and from the proliferation of invasive aquatic species. There needs to be a big leap forward and this requires effective regional cooperation in water resource management.

As the economies of the region develop, there is also a need for the essential infrastructure that allows the sharing of benefits. These are the basics of regional development and they include the coordinated planning of power grids and the linking of national road networks with navigation possibilities.

Finally, and very important, the various ambitions of riparian countries with respect to water resources development for hydro-power and agriculture needs to be effectively synchronized. While water resources in the Zambezi Basin are considerable, they are not limitless. Wasteful development in particular – with high evaporation and little return to water utilization – needs to be avoided.

This section discusses strategic issues for the Zambezi Basin in four essential areas:

- Coordinated Water Resources Development
- Environmental Managent
- Climate Change Adaptation
- Regional Cooperation and Integration

7.1 Coordinated Water Resources Development

7.1.1 Extreme Variability in Rainfall and Water Resources

The Zambezi River Basin covers eight different Southern African countries and has a catchment area of some 1.37 million square kilometres. The basin as a whole receives a mean annual rainfall of about 950 mm, with most of this concentrated in the summer period. Thereby, the North and East of the basin experience significantly more precipitation than the South and West. The rainfall pattern induces flooding around the summer months and drought periods in the remainder of the year.

There is tremendous variability in rainfall across the basin; some parts of the basin are arid or semi-arid while others receive large amounts of rainfall. Rainfall in the basin falls in a single season, the rest of the year is dry. If the sole rain season fails, the entire year has no precipitation to support growth and sustain hydrological processes.

The total average annual estimated run-off is around 100,000 Mm^3. Less than 10% of the mean annual rainfall in the basin contributes to the flow of the Zambezi River into the Indian Ocean. The major contributors to this runoff are the sub-basins in the upper part of the Zambezi, as well as the Kafue, Luangwa and Shire sub-basins. More than 90% of mean annual rainfall in the basin evaporates and returns to the earth's atmosphere.

The high temporal and spatial variability in available water resources, significantly impacts on reliability. This natural situation is exacerbated by the fact that areas of high water demand are not located in the same areas of high rainfall. The upper catchments have relatively low population, and the demand for water is equally low. The middle Zambezi in particular is an area of high population, it has more large urban centres, and irrigation schemes.

Ensuring water security is a major challenge in an area characterised by high variability in available water resources. Investments in storage dams, inter-basin (within the sub-basins in Zambezi basin itself or beyond) transfers and large scale water distribution networks are needed to ensure water security for multi-purpose uses under varying climatic and hydrological conditions.

7.1.2 High Demand for Infrastructure for Water Development

The Zambezi River Basin is populated by an estimated 30 million people, of which approximately 7.5 million live in the 20 main towns. Access to water supply and sanitation in the region is very low, particularly in the rural areas. There is widespread poverty in the region. UN and World Bank studies indicate that a number of SADC countries, particularly those in the Zambezi Basin, have the lowest human development indices – there is perennial food insecurity, frequent outbreaks in water and sanitation related diseases, low access to communication, electricity, and other social amenities.

The present demand for surface water resources is rather limited. Whereas the agricultural sector is often the largest water user in a semi-arid environment, the major water user in the Zambezi River Basin is the hydropower sector. The current estimated water use for irrigated agriculture and livestock does not exceed 2% of the mean annual stream flow in the Zambezi River. There are however ambitious plans in most of the riparian countries to expand the area under perennial irrigation.

Hydropower developments account for a use of about 15% of available run-off. This is mainly due to the evaporation of the two largest existing reservoirs, Kariba and Cahora Bassa. These two dams represent a generating capacity of 4,684 MW, According to estimates the unused hydro-power potential in the Zambezi Basin is 13,500 MW. Several of these projects have been studied at reconnaissance level. The evaporation requirements of the different reservoirs vary considerably. What is required is that the different plans for irrigation and hydro-power development are synchronized at Basin level, keeping in mind the annual fluctuation in water availability, the likely impact of climate change and the water requirements for other uses or purposes.

As the Zambezi basin countries improve their economies to meet the demands for higher social, health and economic well being – to eradicate poverty, and meet MDGs - , there will be need to increase the infrastructure necessary to harness and manage the water resources of the region, upon which the envisaged development depends.

7.1.3 Improved Operation of Major Dams in the Basin

The major dams now in place have had a significant effect on the Zambezi hydrology. Presently the operation of the current hydraulic infrastructure is exclusively focussed on the generation of hydro-power. The operation of the Cahora Bassa, Kafue and the Kariba Dams, however has a large bearing on flooding, particularly in the Lower Zambezi, where some of the tributaries are unregulated while others are regulated. There is much to gain with the coordinated and multi-purpose operation of the hydraulic infrastructure so as to maximize the positive benefits in terms of flood mitigation, navigation, fishery, flood plain agriculture and wetland and wild life while safeguarding power delivery. This again is an important area for basin-level cooperation.

7.1.4 Basin-wide Data Collection and Information Exchange Systems

The collection, processing and storage of hydrometric data is done by basin states primarily through various Government ministries and departments, many of whom are centralised. On the main stem of the Zambezi, ZRA is also involved in collecting hydrometric data. The power utilities in Zambia and Zimbabwe also collect data on stations of strategic importance to the operations of the utility. However this is done on an agency basis because the national departments are failing to sustain data collection, processing and archival. At present there is no basin specific strategic network, a legacy from the historical reality that network design has been done on a country basis and not reflecting basin-wide data requirements.

There are a number of issues, all related, pertaining to data collection and exchange.

- Data collection networks are declining, rather than increasing, in almost all basin states. Very few new stations are being established, and the existing ones are not maintained regularly. While the situation may be better with respect to surface water networks, groundwater monitoring networks are fewer and far in between, and water quality networks hardly exist. The main cause of this problem is inadequate funding of hydrological services in almost all countries; the other problem is declining human resources as government departments fail to attract and retain qualified staff due to unattractive conditions of service.

- Lack of basin specific strategic network for dealing with extreme events - floods and droughts. Given the transboundary nature of these events, lack of real time data (in the case of floods) or long term records (in the case of droughts) severely hampers flood management and drought mitigation measures.

- Poor information sharing and exchange. Though this has been improving lately, it has been hampered by lack of protocols for data sharing (what data can be shared, cost of data, levels of access); lack of common standards for data processing and storage. ZAMWIS, which is being developed as part of IWRM Strategy formulation, presents a real opportunity to address this problem. But its success depends on improved communication systems, the vital role of basin states in contributing and updating data and information to ZAMWIS. A related issue is that ZAMWIS requires an institutional base where its functions can be sustained.

7.1.5 Inadequate Financing of Water Resources Management

The water sector as a whole, particularly water resources development and management receives very little funding in national budgets of basin states, even in countries that are regarded as arid or same arid. A large part of investments have been supported by funding by cooperating partners. Funding is not only for capital investment, but for project preparation, institutional development (policy, strategy and legislation development), operation and maintenance of hydrometric systems, stakeholder participation, human resources development. Poor economic performance of the basin states may be responsible for constrained local funding; but there is also the question of low priority given to the water sector by government in the Zambezi Basin.

At basin level there is poor funding of projects of a transboundary nature. There is a large funding gap even for projects already approved by the various member states. SADC RSAP identified almost 20 projects, but few of them have been financed except with support of cooperating partners. The lack of a basin-wide organization with responsibility for managing the basin including planning, resource mobilization, and project implementation has continued to negatively impact cooperative development water resources in the basin.

7.2 Environmental Management

The Zambezi Basin is an area of considerable environmental value – as is clear from the extensive wetlands, natural lakes and numerous national parks. These areas do not only embody important environmental values, but also present significant economic opportunities – in local resource use and in regional and national tourism. There is a need to better manage the ecological assets and also to put the Zambezi Basin on the global map, as an area of pristine environments.

7.2.1 Wetland Management

The Zambezi Basin is host to some of the largest wetlands in Africa. Wetlands are potentially among the most productive ecosystems in the river basin, providing a wide range of goods and services of local, national and international importance. For example, these wetlands absorb and attenuate flows from upstream catchment areas, releasing this “trapped” water slowly over a period of several months and maintaining flows during the dry winter months. However, wetlands are also among the most environmentally sensitive areas of the basin and are often widely degraded.

Wetland management suffers from an institutional vacuum. In most riparian countries there is as yet no regulatory framework, to ensure the rights of local people to their traditionally-held natural resources. As a result, common property management of water and floodplain pasture, wildlife and fisheries regimes are often undermined. On the Kafue Flats, for example, the original access agreements between the Ila cattle herders, Tonga agro-pastoralists and BaTwa fishermen have been eroded: water is used for hydro-electricity, affecting productivity of pastures, fishery and wildlife, while outsiders from the towns, with more powerful technologies to hunt and fish, have gained access. In several countries there is little evidence of a successful generic management model emerging from community based natural resource management programmes for forest, water and aquatic resources, and efforts have often too scattered and not been sufficiently rewarding to the community economy. An innovative approach to CBNRM in a trans-boundary context has been started on the Okavango River in Angola, Botswana and Namibia. The ‘Every River Has Its People’ project is aimed at promoting sustainable management of natural resources along the river. The intention is to gather information and encourage exchange between people, to improve understanding between all major stakeholders of the problems local communities face and to develop joint solutions to the most urgent problems. The model is now undergoing transfer to the Zambezi River.

There is a need to strengthen wetland management with appropriate legislation on local resource access rights, effective community resource management programmes and regional cooperation and research on holistic wetland resource management in pursuit of optimising multiple uses.

7.2.2 Control of Point Pollution

Water quality is adversely affected by effluent discharge from mines, runoff from dumps and tailings dams and airborne pollution and effluent from smelters. Pollution from mining activities on the Copperbelt in Zambia is causing a marked decrease in aquatic biodiversity over a more than 150 km of the Kafue River (SGAB-SWECO-THOMRO-UNZA 2005). Changes in species composition indicate that the change is caused by mining-related contamination, and not by nutrient pollution and/or low oxygen events. Toxic amount of metals have also been found in sediments and in fish tissue (OPPPI/ZESCO Ltd, 2003). Urban sewage disposal add to water quality problems. The largest and closest settlement to Zambezi River is Livingstone, in Zambia. In Livingstone six wastewater oxidation ponds were commissioned in 1995. Some limited discharge into the river still occurs. Victoria Falls in Zimbabwe discharges 8,000 m3 of wastewater into the Zambezi River. The town's sewage treatment facilities are overloaded and subject to frequent breakdowns. Chitungwiza town, south of Harare, Zimbabwe has high level of pollution due to poor disposal of sewage. The town is a significant threat to the Manyame River. The water quality of Khami dam on Khami River in Zimbabwe is deteriorating to the extent that it can no longer be used to supply dinking water to the City of Bulawayo. Kabwe in the Kafue Basin in Zambia is now regarded as one of the ten most polluted cities in the world (http://www.blacksmithinstitute.org/site10j.php), This is all the more serious as a further intensification of mining and industrial operations can be expected to take place and larger population concentrations will develop in and around these urban centres.

The management of mining waste is an operational and long-term environmental imperative as is the improvement of urban waste water facilities – particularly as the countries in the Zambezi basin want to progress to higher standards of living.

With consumptive use increasing and the basin population growing, the pressure on water quality will continue to increase. The establishment of agreed water quality standards, a unified system of water quality monitoring, an action plan against pollution hotspot in the basin that addresses problems in their national context, are examples of issues that will become increasingly important in the near future and would benefit from regional cooperation.

7.2.3 Control of aquatic weeds

The invasion of aquatic species has become a problem in a number of basins. Water hyacinth, Kariba weed and Mimosa pigra are established on the Kafue Flats, adversely affecting wildlife populations and fishing activities. The former two species also affect hydropower generation at Kafue Gorge. Mimosa was first observed growing at Lochinvar National Park in 1983. It is now spreading rapidly, and covers some 29 km^2, displacing endangered wildlife beyond the boundaries of the protected area. Water hyacinth is also a serious problem on Lake Kariba, Lake Chivero, Kwando-Linyanti and other water bodies. Navigation on the Lower Shire is affected because of the extensive beds of aquatic weeds.

As the Zambezi Basin is an integrated water system, the control of aquatic weeds would benefit from a coordinated effort, supported by the Zambezi riparian countries, both at the level of joint action and at the level of jointly developing effective control mechanisms.

7.3 Climate change adaptation

Periodic, some times extensive droughts have long been a feature in the Zambezi Basin. There is now compelling evidence that an irreversible shift towards a new climatic state, driven by global warming, is underway (Lovelock, J. 2006).

Climate modelling exercises point to a complex range of possible outcomes as a result of climate change. However beyond this complexity, there are two recurrent themes. The first is that dry areas will get drier and wet areas wetter, with important consequences for the distribution of agricultural production. The second is that there will be an increase in the unpredictability of water flows, linked to more frequent and extreme weather events. Drought-prone countries in southern Africa face some of the gravest challenges in the world (John Ashton , ___).

The evidence on climate change effects for the Zambezi is necessarily tentative, but it includes:

- Recent data show that temperature in the Zambezi basin increased by 1-2^{o} C between 1970 and 2004 (IPCC WGII, 2006). So far, there is no evidence of long-term change in seasonal rainfall (December-April) or increased variability (Fauchereau et al, 2003).
- The Zambezi river has a low runoff efficiency (i.e. volume of runoff per unit of area) and the basin has a high dryness index (i.e. dryness of the vegetation based on remote sensing), indicating a high sensitivity to climate change. This sensitivity may have increased due to human-induced desertification over the past fifty years. Reduced runoff in recent years is now evident. At Victoria Falls, runoff (10 yr running mean) increased from 1907 to peak in the 1960s, but then declined (UTIP, 2001). Between the periods 1950-1980 and 1981-1997 there was a 50% decline in mean annual runoff from the upper catchment, compared with a 20% decline in mean annual rainfall

The predicted impact of climate change in the region concerns the evaporation from reservoirs, agricultural productivity and fish production:

- Reduced runoff may significantly affect the financial viability of existing and planned hydropower projects. Harrison and Whittington (Harrison and Whittington, 2002) examined the potential impact of climate change on financial performance of the Batoka Gorge project. Using three climate change scenarios, they assumed that by 2075 mean temperature will have risen by 4.4º – 5º C, and precipitation and river flow will have fallen by 2-18% and 10-35 % respectively. With a 10% discount rate, the project is no longer economically viable under two of the three climate change scenarios, with the mean internal rate of return (IRR) falling by 6-22%.
- Simulating the impact of climate change on crop yields and output has alarming results. Yields of wheat, rice and maize are estimated to fall by 10% for every 10º C rise in temperature. One simulation presented by UNDP (2006) shows cereal production falling by up to 25% over most of the river

basin between 2000 and 2080. However the report considers this outcome to be optimistic, partly because much of the agricultural land is already degraded, and partly because maize production is highly sensitive to the timing and amount of rainfall.

- The fisheries of Lake Malawi, Cahora Bassa and Kariba are susceptible to the same drivers of productivity as Lake Tanganyika. A recent study there found that regional warming and declining wind speed have reduced lake mixing, nutrient enrichment, and the primary productivity of surface waters (O'Reilly, 2003). The recorded 20% decline in primary productivity would indicate fish yield has already fallen by some 30%.

Irrespective of the direct effects of climate change, the region will be exposed indirectly to the impacts of changes elsewhere. Food availability is likely to become a global issue (Brown, 2005). Stocks of food could be declining and the reduction in grain production per person has been unusually steep in sub-Saharan Africa. From 1960 through 1981, this ranged from 140 – 160 kg/person compared to 120 – 140 kg/person from 1980 through 2001. Since 1981, Southern Africa has faced a periodic food security crisis (Kalibwani, F. 2005), and this could reoccur as global warming increases. There will be growing demands for water for irrigation and an urgent need for land reform to enable intensified agricultural production.

The issue on climate change is to further substantiate the early indications and their consequences and to develop effective program of climate change adaptation. Only seven scientific studies of the impact of climate change on Africa were made between 1990 and 2006 (IPCC WGII 2007). A recent policy brief by the International Research Institute for Climate Prediction has examined the implications of climate change for development and poverty alleviation in Africa (Hellmuth et al, 2007). Many of the report's findings and recommendations are relevant to a future response by the basin states. In general, the report found that climate should be recast as a 'development' issue. The economic implications of climate-related risks must be made clear. The potential of climate information and services to improve the management of risk should be established. Institutional innovation is to be encouraged, with. African 'centres of excellence' should create networking that can develop and implement innovative Climate Change Risk Management programmes. Meteorological services should be orientated towards pro-actively supporting development outcomes. Also needed is sector-specific research to improve sectoral decision making under climate uncertainty.

The impact of climate change will depend not only on the change in climate, but also on how water resources are managed. The adoption of flexible management approaches and policies which can cope with current climatic variability will reduce vulnerability to climate change. One practical implication is that water resource development proposals should consider the effects of climate change on the ability of the proposed schemes to deliver their objectives. Other important areas of climate change adaptations are:

- Better understanding of groundwater and groundwater recharge in the Zambezi Basin. As described in section 3 groundwater is the largest storage

in the Basin – resilient to temporarily weather fluctuations - but understanding of it is still fragmented.
- Crop adaptation, looking at crops and varieties better adjusted to generally higher temperatures and aridity.
- Revisiting the logistics of food supply, including storage and regional transport networks, so as to respond to local shortages or emergencies
- Revisiting the operational rules of the main reservoirs in the basin in general, and in particular, drought and structural and non-structural flood management procedures – to take into account possible larger fluctuations upward and downward in surface run-off.

7.4 Regional Cooperation and Integration

From the above it is clear that there are considerable gains to be made in effective regional cooperation on the management of the Zambezi Basin water resources.

7.4.1 Integrated Management of Zambezi Basin Water Resources

At present there is no single organisation with responsibility for water resources management of the Zambezi Basin as a whole. Institutional responsibility is exercised through national frameworks over the respective parts of the basin falling within each country. There exists some significant differences in institutional frameworks among the riparian states of the Zambezi. The majority of the countries operate through centralised national institutions with delegated authority to sub-national organisations with jurisdiction over politically defined geographical area (province/region and district) rather than a basin or sub-basin. Therefore even at national level there are challenges in managing water resources effectively and in a coordinated manner over these areas. The challenge is therefore magnified at basin level since the basin as well as its sub-basins cut across national boundaries.

Coordinated development and management of water resources in the Zambezi basin will be more effective with existence of a formal institution to which the riparian states have acceded authority to manage the water resources of the basin as a single entity. The steps taken so far to establish the Zambezi Watercourse Commission (ZAMCOM) will go a long way to address this problem once the agreement has been ratified and come into force. Delays in the formal establishment of ZAMCOM denies the riparian states an opportunity to embark on cooperative development and management of Zambezi basin water resources to the mutual benefit of all basin states in particular and the entire SADC region in general.

Important for the enhancement of the benefits from the water resources of the Zambezi is the cooperative planning of use. At present this concerns consultations on plans for large scale hydraulic works such as dams. In the (near) future consumptive water use (mostly by the agriculture sector) will increase throughout the basin, leading to an increased necessity of coordinated planning. A process of joint strategic planning in the basin in terms of consumptive use projects would be very beneficial in this context, providing not only a sound basis for such investment, but also creating transparency to the other basin countries. Eventually, with joint planning mechanisms being developed in the future, the need will arise to harmonize the licensing processes in the riparian states, or at least to verify water uses in the international context through basin hydrological models. Thus the following broad steps in the institutional cooperation mechanisms can be foreseen:

- Coordination and consultation on major hydraulic works
- Joint investment planning of consumptive water use
- Coordinated operational management
- Harmonization of water use licensing in the full basin context
- Promoting the development of basic infrastructure that allows the sharing of benefits, in particular regional electricity grids, road networks and improved navigation.

With such important issues on the horizon, the responsibility of ZAMCOM to address them is obvious. The development of the ZAMCOM Secretariat to be able to address issues such as these is of paramount importance. There are many gains to be made and a short and medium term agenda would need to be developed.

7.4.2 Weak Institutional Capacity of Water Management Institutions

Institutional capacity of the water management institutions, both at national level as well as at the regional level, is the Achilles heel of the sector. Water management institutions lack adequate financial resources not only for capital investment but even for normal operations. The staffing is often constrained due to poor conditions of service in the civil service. Furthermore, there are human resources deficiencies in multi-sectoral planning, environmental planning and management, assessment of floods and droughts, research methodologies, and economic analysis.

Great leaps forward have been made at all levels in the last 10 years, with very limited means in terms of institutional capacity (staff and financial resources being the most limiting factors) and thanks to dedicated regional leadership, effective regional water research programmes and capacity building networks. Achievements include the development of the regional institutional framework (SADC Protocol on Shared Watercourse Systems, the ZAMCOM Agreement), the revision of national institutional frameworks in most countries of the basin, including the establishment of some completely new sub-national institutions (e.g. ARA-Zambeze).

The deficiency of the existing institutional capacity however is still apparent when looking at the issue of hydro-meteorological monitoring. It is the reality of most countries that hydrological data collection networks are at present smaller than they have been in the past. In a number of countries flow measurements do not take place or only in an ad hoc manner. The same holds true for water quality monitoring with most countries not having the means to maintain a regular program for water quality sampling.

The problem of inadequate institutional capacity for hydro-meteorological monitoring is not limited to the Zambezi basin or to its basin countries. Addressing it in the basin context is one strategy that could be explored to mitigate its impact. A combination of investment in automated monitoring systems and the strengthening of the capacity of the involved institutions may be explored as one option to address the shortcomings and build larger mutual confidence in the process.

7.4.3 Poor Knowledge Base of Basin Water Resources

A sound basis for tackling the Zambezi basin water resources development and management issues lies in good knowledge of the resources, its people and services.

In general data availability to support an acceptable level of planning in the Zambezi basin is inadequate. In the course of the preparation of this Rapid Assessment (which was supposed to be based on existing datasets), it was found out that much of the data and information is fragmented and outdated. In addition to this there are issues of inconsistent standards, formats as well time frames. This obviously would be the first challenge for the ZAMCOM and its secretariat to establish more updated database and mechanisms for data sharing and information exchanges. A first step was taken during the course of this study to establish a web-based data and information system, ZAMWIS, in parallel with the Rapid Assessment. The remaining challenge is to keep ZAMWIS updated and to add more information to its database as well as improve its real time functionality.

In particular it is worth pointing out the paucity of data on groundwater – extent, types, distribution, and quality. In spite of its potential importance, it is least investigated in a systematic manner. In a number of countries even the exploitation of groundwater is unregulated, treated simply as a fugitive resource, subject to capture by whoever has the capacity to do so.

There is also inadequate knowledge on water demands, their locations, or valuations. An illustration of this is the poor state of knowledge on environmental flow requirements, or even baseline water quality in a number of streams in the region.

7.4.4 Vulnerability to Natural Disasters – Floods and Droughts

Floods are probably the most pressing transboundary water management issue for the population living in the Zambezi river basin. The institutional responsibility for flood monitoring lies with the same bodies that are responsible for regular hydro-meteorological data collection. Rapid exchange of real time or near real time flow data is of the utmost importance in flooding situations and the mechanisms to make such real time data exchange possible are important practical tools that directly impact each country's ability to manage floods as effectively as possible under the circumstances.

As with hydro-meteorological data exchange in general, great improvements in the exchange of flood data have been achieved in the last 10 years. Equally, practical problems persist in cases where flood data collection is fragmented at the national level, in particular when payment is requested for flood data information, as still occurs in isolated cases.

Flood management at the national level is usually a shared responsibility between the water departments and a national disaster management apex body that has the power and mandate to mobilize the necessary resources to address flood problems and take the necessary measures. The large number of institutions involved even at national level already presents challenges of coordination, and the challenges are amplified at regional level. There is need for improved coordination, reporting, and disaster management plans.

The transboundary aspect of flood management is mostly linked to the way the major dams in the basin are being managed. Exchange of flood information to determine the optimum measures to limit the downstream impact of floods while maintaining safe and sound individual dam operations are of great importance. This coordination takes place between the two management bodies for the basin's major dams, Zambezi River Authority – managing the Kariba complex – and Hidroeléctrica de Cahora Bassa (HCB) that manages the Cahora Bassa dam and reservoir complex.

Droughts are a common phenomenon in the region and predominantly affect the south-western parts of the basin. Unlike floods, droughts are not dramatic, they have slow onset with effects accumulating slowly over time. Though there is increasing body of knowledge in the basin, this is still inadequate, such that most states are almost invariably caught unaware by droughts.

The transboundary impacts of droughts involve primarily food security (decline in harvests, loss of livestock), but at national level there are further impacts on water supplies, especially in the rural areas.

There a number of challenges in dealing with droughts, including: poor data networks of climatic and hydrological variables (including water supply); poor information sharing and exchange among basin states; lack of integrated physical and socio-economic indicators that would facilitate a comprehensive understanding of the magnitude, spatial extent and impacts of droughts; and lack of sound drought management plan, and bureaucratic obstacles to efficient implementation.

7.4.5 Stakeholder Participation

Water resources management touches upon interests and views of different parties or interest groups. The stakeholders in water resources management include regional economic development communities (such as SADC), basin state governments (central, and local), river basin organisations, sub-basin organisations, local and international NGOs, community based organisations, the private sector (suppliers of goods and services - consultants, contractors and suppliers), and academic and research institutions. IWRM recognises the importance of stakeholder participation – stakeholders are the custodians of natural resources, they bring about multi-sectoral skills and experiences that are fundamental to integrated planning and management of water resources, and they confer legitimacy and validation of solutions.

Stakeholder participation in water resources management in the Zambezi basin is not yet well established. There are a number of issues, including:

- The institutional frameworks for stakeholder participation are still weak in a number of basin states, with the exception of Zimbabwe, where there already exists the legal and institutional framework (sub-catchment councils) for managing water resources at sub-basin level. Though virtually all countries have embraced IWRM, this is not yet fully supported by legislation, and there are no institutions for facilitating stakeholder participation. At basin level, there are as yet no clear institutional frameworks for stakeholder involvement in managing water resources.
- Inadequate knowledge sharing at all levels and between local, national and regional (basin) levels.
- Lack of effective representation of stakeholders at decision levels; this is often compounded by poorly defined roles, mandates of institutions and poor information flow.
- Stakeholder participation is a relatively new phenomenon among governments that, historically, have operated under a highly centralised governance structures – hence the often apparent misunderstandings between governments and civil society.
- Weak capacities of stakeholders, particularly at local levels, to understand and implement principles of IWRM.

There are several other challenges that are best addressed in the context of regional cooperation, described above, such as coordinated programmes on invasive aquatic species, exchange on wetland management activities and development of climate change adaptation mechanisms. All such activities will foster Basin cooperation in water management and move it from the political to the operational level.

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- *Geotechnical Issues*
- *Groundwater in the Copperbelt*
- *Luanshya*
- *Metal accumulation in vegetable*
- *Ndola Rural*
- *Re-vegetation of Mining Waste Dumps*
- *Socio-economic Consultations*
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Annex 1 Thematic Maps

Annex 2 Institutional Structures for Water Management

Annex 3 Sub-basin Profiles

Annex 4 Water Balance

Annex 5 Lakes in the Zambezi Basin

Annex 6 Industries in the Zambezi Basin