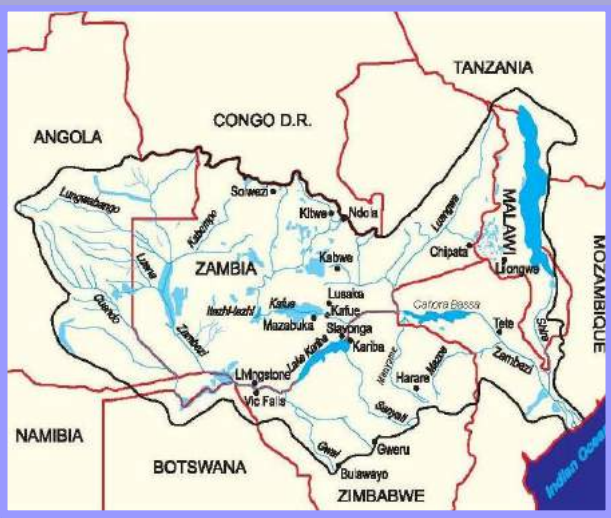
Transboundary Water Management in SADC
DAM SYNCHRONISATION AND FLOOD RELEASES IN THE ZAMBEZI RIVER BASIN PROJECT



Executive Summary

31 March 2011

On behalf of: Federal Republic of Germany, The Federal Government

UKaid from the Department for International Development

Australian Government, Aid Program

SWRSD Zambezi Basin Joint Venture

SSI A DHV COMPANY

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RANKIN

SEED

Deltares Enabling Delta Life

This report is part of the Dam Synchronisation and Flood Releases in the Zambezi River Basin project (2010-2011), which is part of the programme on Transboundary Water Management in SADC. To obtain further information on this project and/or progamme, please contact:

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List of Acronyms

AG	Advisory Group
ARA Zambeze	Regional Water Administration for Zambezi, Mozambique
ARS	Automatic Rainfall System
CBO	Community Based Organization
CDM	Clean Development Mechanism
CPC	Climate Prediction Centre
DANIDA	Danish International Development Assistance
DNA	Direcção Nacional de Águas (Department of Water Affairs in Mozambique)
DWA	Department of Water Affairs, Zambia
ECMWF	European Centre for Medium-Range Weather Forecasts
EDM	Electricity de Mozambique
EFR	Environmental Flow Requirements
ESCOM	Electricity Supply Commission of Malawi
EU	European Union
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (German International Cooperation)
HCB	Hidroeléctrica Cahora Bassa
HYCOS	Hydrological Cycle Observation Station
ICOLD	International Commission of Large Dams
ICP	International Cooperating Partner
IFR	Instream Flow Requirements
IFRC	International Federation of Red Cross and Red Crescent Societies
IPCC	Intergovernmental Panel on Climate Change
ISO	International Standard Organization
IUCN	International Union for Conservation of Nature
MAR	Mean Annual Runoff
METEOSAT	Meteorological Satellites
MoU	Memorandum of Understanding
MIWD	Ministry of Irrigation and Water Development, Malawi
NCAR	National Centre for Atmospheric Research
NCEP	National Centres for Environmental Prediction
NGO	Non Governmental Organization
NMC	National Meteorological Centre
NOAA	National Oceanic and Atmospheric Administration, USA
PC	Policy Committee
PMC	Project Management Committee
PMS	Performance Management System
PSC	Project Steering Committee
RBO	River Basin Organization
RSAP	Regional Strategic Action Plan
RSMC	Regional Specialized Meteorological Centre, Pretoria
SADC	Southern African Development Community
SAPP	Southern Africa Power Pool
SARCOF	Southern Africa Regional Climate Outlook Forum
SAWS	South African Weather Service
SIDA	Swedish International Development Agency
SWRSD JV	SSI, WRNA, Rankin, SEED, Deltares Joint Venture (the Joint Venture of Consulting Firms for this Project)
ToR	Terms of Reference
TRMM	Topical Rainfall Measuring Mission

TTWW	Think Tank Work Week
TWM	Transboundary Water Management
UNFCC	United Nations Framework Convention on Climate Change
UNZA	University of Zambia
USAID	United States Agency for International Development
USGS	US Geological Survey
UTIP	Inidade Técnica de Implementacáo de Projectos Hidroeléctricos
WB	World Bank
WMO	World Meteorological Organization
WWF	World Wide Fund for Nature
ZACPLAN	Zambezi Action Plan
ZAMCOM	Zambezi Watercourse Commission
ZAMWIS	Zambezi Water Information System
ZESA	Zimbabwe Electricity Supply Authority
ZESCO	Zambia Electricity Supply Company
ZINWA	Zimbabwe National Water Authority
ZMSD	Zimbabwe Meteorological Service Department
ZPC	Zimbabwe Power Company
ZRA	Zambezi River Authority

Executive Summary

GENERAL

This Executive Summary presents a synopsis of the overall challenges, findings and recommendations of the "Dam Synchronization and Flood Releases in the Zambezi River Basin" Project. The Project's purpose was to address the question, "How can dams and measures of water management in the whole Zambezi River Basin contribute to safeguarding lives, livelihoods and nature while giving room for further sustainable development with due regard for the costs?".

The Zambezi River, 2 650 kilometres in length from source to mouth, rises in the Kalene Hills of north-western Zambia and flows generally eastwards to the Indian Ocean. With a catchment area of some 1 350 000 Km^2, the River covers about 25% of the total land area of its eight riparian states of Angola, Namibia, Botswana, Zambia, Zimbabwe, Mozambique, Tanzania and Malawi. Figure 1 refers.

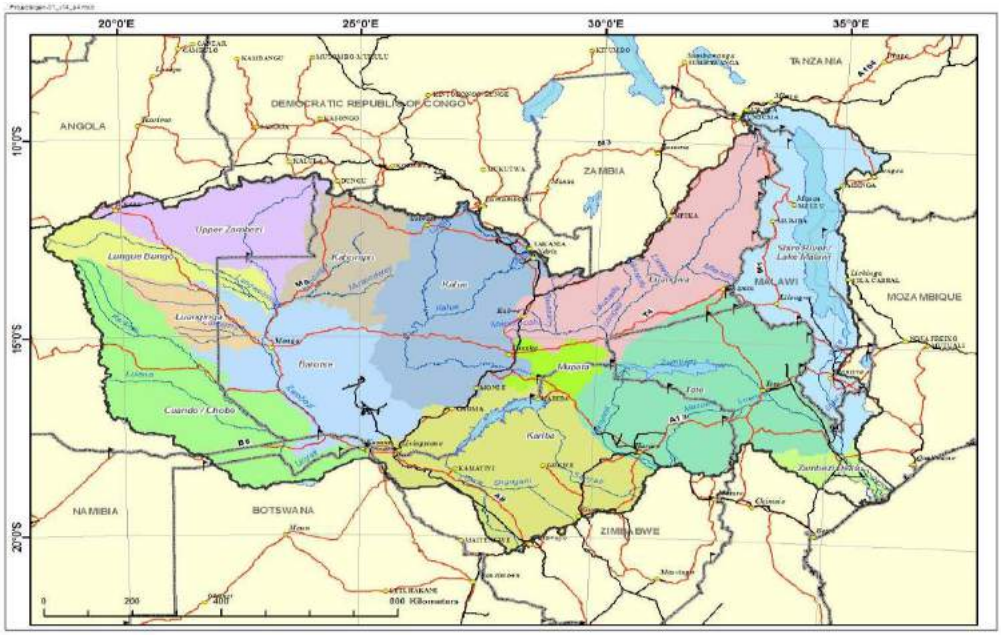


Figure 1: The Zambezi River Basin (Source: ZAMWIS)

The Zambezi River Basin's total population estimate for the year 2000 was 40 million persons with approximately a quarter residing in urban areas. The Basin is well endowed with mineral, water and energy resources, natural tourist attractions like the Victoria Falls, as well as being blessed with a wealth of wildlife.

The Zambezi River Basin is the largest in the Southern African Development Community (SADC) region and is shared by more riparian states than any of the other 14 shared watercourses of SADC. As such, the Basin provides a lot of challenges and opportunities in its development and management.

To date, the majority of the countries of the Zambezi River Basin have conducted water resources development and management on their portions of the river, more or less independently. Examples of such development projects are the Cahora Bassa on the Zambezi, the dams and hydroelectric schemes on the Kafue and Shire rivers; as well as the fisheries and other water based economic activities in the Basin. As the riparian countries establish and

operate such additional projects for various uses, the need for cooperation between the nations in the Basin, in the spirit of the SADC Treaty to which all Zambezi riparians are party to, has become more critical. Water development and management activities by an upstream country may pose serious risks or water shortages to another downstream. Similarly, downstream countries may pose serious developmental constraints on upstream countries by claiming prior use of and rights of water of a shared watercourse. The backflows of reservoir waters in downstream countries can affect communities and the environment of upstream countries. This is particularly so with respect to the operation of the dams and reservoirs in the Basin in light of the recent uncertainties associated with climate variability and possible climate change.

Currently, the major dams in the Zambezi River Basin are not operated together as a single unit to optimise their multiple uses and the overall system potential. The operation of these dams is not synchronised in any way. The dams are operated to satisfy their primary functions: to store water for further use for hydropower production, irrigation, institutional water supplies or for mining purposes. Spillways and flood gates are operated primarily for dam safety reasons to release excess water or floods, and not necessarily for environmental flows or nature. Itezhi-Tezhi Dam in Zambia is the only exception. As such, the operating rules of these dams do not generally incorporate the environmental and social needs downstream and upstream. Thus extreme events' impacts, precipitated by climate variability, lead to stakeholder complaints. Inadequate management of extreme events' impacts, such as those of the floods experienced in the 2000/2001 rainfall season, or during drought years when rivers run dry due to limited rainfall and dam release operations, have often led to significant criticism.

The population in the Zambezi River Basin floodplains is on one hand very vulnerable: people are poor and have little savings; it is difficult to warn people of impending disasters as communication facilities and systems are poor or non-existent; alternatives for shelter or refuge during extreme events are limited; transport is often not available; and people do not want to leave the few belongings and livestock that they have as this often constitutes all their possessions. On the other hand, the people are very resilient: some areas (Barotse Floodplains) have wet season and dry season settlements; houses are built with local material and rebuilt after the floods; the floods also bring fertile soils and therefore allow for winter cropping in the floodplains.

All too often, in some transboundary river basins of the world, inefficient use of water resources is experienced due to lack of cooperation among riparian states. With increased pressure from growing populations, urbanization and economic growth, the demands on scarce water resources are often heightened. Efficiency can be encouraged by establishing Transboundary Water Management (TWM) Protocols and Agreements, such as the Revised SADC Protocol on Shared Watercourses and the ZAMCOM Agreement. These should be founded on strategies developed from well informed studies that build confidence amongst all stakeholders. The "Dam Synchronization and Flood Releases in the Zambezi River Basin Project" is one such study.

The "Dam Synchronization and Flood Releases in the Zambezi River Basin Project" (hereafter referred to as the "Project"), investigated the extent to which the timing of water releases for electricity production, agricultural demands, environmental flow, dam safety, and flood protection from existing and proposed new dams can result in more collective win-win advantages. To effectively manage the inflows, storage and releases for these purposes, the Zambezi system requires forecast of flows at given key locations. Short term forecasts for floods and seasonal forecasts for environmental flows can be incorporated in reservoir operation decision-making as well. At present the predominant interest is on the multi-million dollar hydropower generation investment sector, and any new operational changes or re-allocation of

the water, has to earn the confidence of this sector. Forecasts and appropriate models can be used to reliably demonstrate that the power generating levels/storage will be sustainable whilst ensuring releases are made for environmental flows or flood protection.

Often, the environmental requirements are perceived as competing with other interests such as hydropower generation. During execution of the Project, effort was made to show that flood management and release of environmental flows can be achieved in tandem. This falls in line with the concept that environmental flow management should provide flows needed to sustain freshwater and estuarine ecosystems in coexistence with competing interests such as agriculture, hydropower production, public water supply and industries.

Studies that aim at finding ways to improve the dam operation rules and the development of a flow forecasting system can contribute to the transboundary management of the Zambezi River with due regard for all diverging interests, thereby reducing flooding whilst taking into account the needs of the environment. For a river basin that is as large and complex as the Zambezi, the development of such operation rules and flow forecasting system requires expert input with know-how of the whole catchment, dedicated models and tools and sufficient human resources. This Project thus aims to provide such expert input, amongst other objectives, by finding ways and means to address positively the water infrastructure management and development scenarios in the Zambezi River Basin in respect to flood management, improved livelihoods and water for the environment.

The findings and recommendations of this Project are presented in a six-volume Report structured as follows and as depicted in Figure 2 below:

a) Executive Summary (this Report);
b) Main Report: Concepts and recommendations for improved basin-wide management;
c) Annex 1: Summary report of compiled literature and existing studies, geodata, measuring/gauging stations and available data;
d) Annex 2: Concepts and recommendations for dam management;
e) Annex 3: Concepts and recommendations for precipitation and flow forecasting; and
f) Annex 4: Recommendations for investments

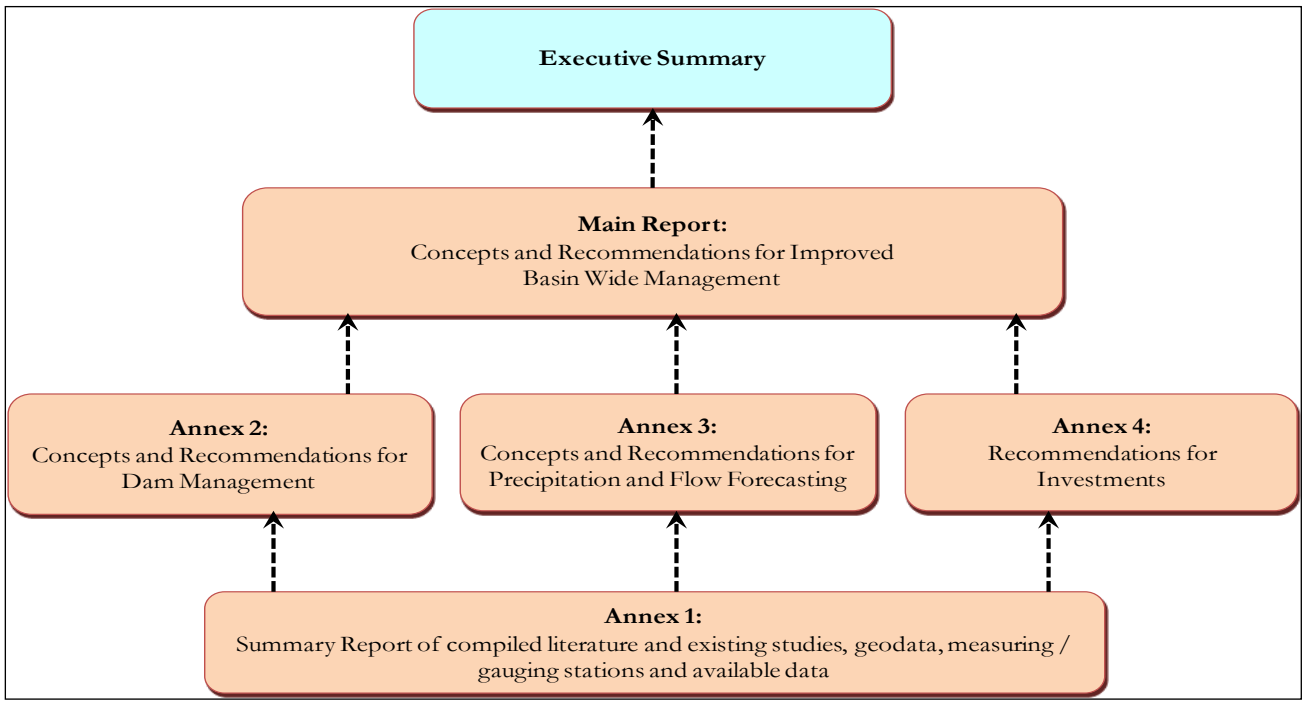


Figure 2: Final Project Reporting

Annex 1 presents available water resources and climatic data for the whole of the Zambezi River Basin as well as information on current management of the Basin that is relevant to the Project. A variety of institutions within the Basin were consulted for this information. The data and information was also analysed and used as reported in the other Annexes 2, 3 and 4.

Annex 2 presents Concepts and Recommendations for Dam Management, which aimed at attaining the following objectives:

- improving the modes of operation of the dams on the Zambezi in order to create a win-win balance amongst the interests of environmental flows, flood reduction, hydropower generation and agriculture; and
- improving cooperation between dam operators in the Basin by applying the latest analytical techniques to provide them with improved approaches to dam management

Annex 3 presents an analysis of the available data and information to derive Concepts and Recommendations for establishing a Precipitation and Flow Forecasting System for the whole Zambezi River Basin. The recommendations from this part of the Project were aimed at addressing the following objectives;

- to improve the reliability of seasonal forecasts, thereby providing Dam Operators with enhanced confidence for flow releases;
- to contribute to an archive of hydrological forecasted and measured information for enhanced dam operation, optimization of hydropower production, flood control and environmental flow releases; and
- to improve operational disaster management by providing Disaster Management/Civil Protection Units with reliable and targeted forecast information.

Annex 4 analyses the investment options that can be considered in the Zambezi River Basin. Different investments are being planned to improve the utilisation of the Zambezi River waters. The investments investigated focussed on improving flood protection and flow regulation. From this perspective, the different investment options were evaluated.

The Main Report of the Project presents the overall concepts and recommendations on ways and means of improving flood protection and providing environmental flows in the Zambezi River Basin. These concepts and recommendations are based on simultaneous consideration of all the various and divergent interests of the riparian states including the need to sacrifice some electricity generation capacity to provide for environmental flows in the rivers.

FINDINGS

Floods and droughts are part of the history of the Zambezi River Basin and have occurred in the situations with and without dams. Large floods and severe droughts are a fact of life in the Zambezi River system. Dams cannot entirely stop floods but can help manage them. In addition, while dams cannot restore the original river flow conditions, the operation of existing and new dams can minimize negative upstream and downstream impacts.

The major dams in the Zambezi River Basin are: Kariba, Cahora Bassa and Itezhi-Tezhi. These major dams, except for Kariba, will fill up and spill every year on average and cannot capture and store large floods. Unregulated tributaries on the Zambezi River System contribute significantly to flooding and they influence timing and magnitude of flood releases. "New" dams on the Zambezi main stem such as the Batoka and Mphanda Nkuwa and on the tributaries such as Kafue Lower, are unlikely to be larger than Kariba but can, if synchronised, reduce pressure on

the existing major dams, bringing flexibility in the operation of the existing major dams in the Zambezi River Basin and thus indirectly contributing to flood management. The conjunctive operation of Kariba Dam and others is thus very important for the management of floods in the Zambezi River system.

New "modes of operating" dams in the Basin that simultaneously address different objectives including dam safety, hydro power production, drought and flood management and the needs of the environment, have been identified and proposed by the Consultant. The new modes of dam operation consider operating rules for the dams which incorporate multiple objectives and span over a number of rainfall seasons while giving due consideration for hydrological cyclicity.

An analysis of historical annual rainfall data reveals cyclic behaviour in rainfall patterns. A number of previous climatology studies predict that the Zambezi River Basin will become drier in the future; the intensity of rainfall will increase and will likely contribute to increased sediment load with resultant negative effects on dam/reservoir usefulness; rainfall will decrease and evaporation will increase. However, most of these studies have focused on climate change and variability as a threat to water availability rather than on the frequency and magnitudes of floods. From the literature review undertaken on cyclone events, there is insufficient evidence to suggest an increase in the frequency of occurrence of cyclonic events but most research findings concur that the intensity of the cyclonic effects, when they occur, will increase.

An analysis of flood retention by wetlands for different seasons showed that the retention varied significantly, probably because the retention capacity largely depends on antecedent water levels in the wetland. Established methods for enhancing wetlands' retention capacity were interrogated and found to be unsuitable for application on the identified wetlands. However, climate change scenarios identified in this Project may have adverse impacts on wetland functioning. These need to be investigated further.

A review of the operating rules for the large existing dams on the Zambezi River system showed that these rules primarily consider dam safety and the provision of water and adequate head for hydropower production.

The current Joint Operations Technical Committee (JOTC) is made up of ARA Zambeze, HCB, ZESA/ZPC, ZESCO, ZINWA and ZRA, is an exclusive technical committee which does not include other key Zambezi River Basin stakeholders like ESCOM, the Disaster Management/Civil Protection Units, WWF and the Red Cross. To ensure the greatest possible benefit from the efficient utilisation of the Zambezi River, such stakeholders currently not in the JOTC, who deal with the effects of floods and droughts, want to be involved in a wider System Operating Forum. Cooperation that is perpetually sustainable can only thrive where costs, risks and benefits are shared, reviewed and updated when conditions change.

The major dams on the Zambezi River have 100% sediment trap efficiency during low floods. However the low Storage/MAR ratios of all current dams in the Zambezi River Basin, except for Kariba, suggest that they cannot store major floods. Essentially, the smaller dams will pass major floods together with their sediment load. As for medium floods, the storage condition just before a major flood (which is affected by the operating rule) may also affect the transport and distribution of sediments from the contributing rivers. Reservoir bottom outlets for sediment flushing are not effective for large dams. However, the new dams on the unregulated tributaries of the Zambezi River should ideally consider bottom outlets for release of minimum flows (contributing to environmental flows), sediment release and water quality management.

There is a clear need for establishing a basin-wide flow forecasting system in the Zambezi River Basin. Until now, flow forecasting has been limited to a national or bi-national focus and has been undertaken largely for the purpose of unilateral dam operational functions. However, the significant flooding that has occurred in the Lower Zambezi and the Chobe Swamps in recent years, the overall power deficit in the SADC region, the growing awareness of the environmental needs of the Basin and the potential gains to be achieved from synchronised and conjunctive operation of the large dams, all point to the importance of reliable and timely monitored and forecasted flow data for stakeholders. Existing models or forecasting/warning systems are available for parts of the Basin, but a comprehensive model or set of models does not currently exist.

It is important to distinguish short, medium and seasonal lead time forecasts. Short lead time forecasts are important for flood forecasting and this forecast timeframe therefore focuses primarily on flood prone areas in the Basin. Medium lead time forecast locations include existing hydropower plants (large and small), while seasonal lead time forecast locations include major hydropower plants and associated structures in the Basin; i.e. Itezhi-Tezhi, Kafue Gorge, Kariba, Cahora Bassa and Kamuzu Barrage. Most forecast locations require a combination of observed flows (or levels) and observed precipitation. For catchments that have a generally fast response, such as those of the Gwayi, Sanyati and Luangwa Rivers, precipitation forecasting will also be important to meet the required lead times. Similarly, below major reservoirs, such as Kariba and Cahora Bassa, observed and forecast reservoir releases will be important to provide accurate information to stakeholders downstream. Current flow gauge coverage in most parts of the Zambezi River Basin is generally adequate for flow forecasting purposes. The most notable deficiency is in the portion of the Zambezi River Basin within Angola, where only one flow gauge is currently operating. On the above basis, 51 candidate streamflow and water level gauges have been identified in the network design (Figure 3).

Most existing flow gauges in the Basin are manual gauges, the existing SADC-HYCOS network and part of the ZRA network are exceptions. For flow forecasting, real-time observations are generally needed; however, in the context of the relatively long travel times of flood peaks in the Zambezi River Basin, manual readings with daily transmission of data by phone or radio would be viable in cases where sub-daily readings are not required. Due to the significant increase in GSM (cell phone) coverage in the Zambezi River Basin in recent years, satellite transmission, which is currently used by gauges within the SADC-HYCOS and ZRA networks, is unlikely to be necessary except in very remote parts of the Basin. The sustainability of automatic flow gauges in the Basin is currently a significant challenge. Key sustainability factors include inadequate funding, vandalism, theft, limited availability of spare parts, loss of maintenance personnel and weather related risks, such as lightning and floods.

The existing density of precipitation gauges in the Basin is generally below what is needed for accurate flow forecasting. In some areas (mostly Zimbabwe, Malawi and parts of Mozambique) current coverage was found to be adequate, but upgrading of the existing manual gauges to automatic stations will be required. Detailed location of such existing manual gauges needing upgrading are given in Annex 3 of the Main Report. Analysis carried out on three case study areas indicates that Satellite Rainfall Estimation (SRE) would be a viable and significantly cheaper alternative to ground based measurement and establishment of an automated basin-wide system for SRE is therefore recommended. However, as ground based measurement is generally more reliable than SRE, upgrading of existing manual stations to real-time is still recommended as a long-term measure.

The establishment of a flow forecasting system for the Zambezi River Basin will require a number of interventions including the development of new models to fill in the gaps between existing models, and most importantly, the establishment of a centralised Flow Forecasting Centre. The proposed Flow Forecasting Centre will be a subsidiary of the ZAMCOM Secretariat, created to fulfil the mandate and obligations of the ZAMCOM Secretariat as per the provisions of Articles 6 and 15 of the ZAMCOM Agreement. The decision on the selection of the location of the Flow Forecasting Centre will be made by the Zambezi riparian states and should include consideration of key technical issues, such as internet connectivity, capital and operational costs, power supply reliability, human capacity, ground and air transport connectivity and potential links to universities and technical institutions.

Based on an approximate cost estimate using 2010 prices and available information, it is estimated that the capital investment cost for a Flow Forecasting Centre would be in the region of US$275 000, while the annual operating costs would be between US$800 000 and US$1.2 million. The major cost would be the annual operating cost and the largest component of this cost would be the salary bill for the required technical staff (60%). Costs would vary depending on the location of the Flow Forecasting Centre and the number of staff included. Possibilities for obtaining finance for a Flow Forecasting Centre include donor agencies, banks and organisations involved in the establishment of flow forecasting systems. However, given the volatility of donor funding, the operational costs of the proposed Flow Forecasting Centre should be met by the Zambezi riparian states.

In terms of infrastructure investments currently being considered, the planned hydropower dams such as Batoka, Kafue Lower and Mphanda Nkuwa, could contribute up to 4 000 MW towards reducing the power deficit in the SADC region. In comparison to normal reservoir power schemes, the reservoir size of run-of-river schemes is relatively small in comparison to the power generating capacity, which is positive for its impact on human settlements, greenhouse gasses (large reservoirs can increase greenhouse gas emissions) and evaporation losses. Designs and operating rules are recommended to sufficiently consider the environment to minimize negative impacts.

Tributaries with high flows generally have technically suitable sites for large dams that can have impact on flood management, but the question is to what extent such dams can contribute to other purposes than flood management, as flood management alone is not sufficient to attract funding. For instance, technically suitable sites for large dams to reduce flooding on the Luangwa river are in National Parks and will therefore be difficult to realize. Moreover, flood protection impacts of small and medium sized dams are limited, but the contribution to livelihoods may create alternative locations for resettlement of persons currently living in flood prone areas. Large scale structural measures for flood protection, such as dykes, require high capital input, high maintenance and operation requirements. Priority by most Zambezi riparian states is currently being given to other investments such as in health care, education and irrigation for poverty alleviation. Combining the advantages of improved public buildings such as schools with the need for refuge areas in terms of flood management, is a promising win-win situation.

Additional investments in existing hydropower stations can contribute to flow regulation. Extra turbines on existing dams will increase the capacity to generate hydropower if reservoir water levels are to be reduced before forecasted floods, as more water is able to pass through the turbines rather than spillways. Such projects are planned at Kariba, Itezhi-Tezhi and Cahora Bassa dams. An extra spillway is being considered as part of the extension of the Cahora Bassa North Bank Power station.

The Lake Malawi/Nyasa/Nyassa – Shire River system is regulated by the Kamuzu Barrage located at the outlet of the Lake. The existing operating rule is for downstream hydropower production requirements. For flood control purposes, the investment in the upgrading of Kamuzu Barrage will contribute to easier operation during flood conditions, but will not benefit extra flood management capacity. Realisation of the power interconnector between Malawi and Mozambique would add more options for flow management as the total dependency of Malawi on the Shire River hydropower generation would decrease.

Apart from the proposed new interconnectors between Malawi and Mozambique and between Zambia and Tanzania, other planned enhancements to the SAPP network, such as the strengthening of the Democratic Republic of Congo to Zambia and Mozambique to Zimbabwe interconnectors, will also improve the possibilities for power production in coordination with flood regulation. Such improvements will indirectly contribute to improved flood management and the introduction of environmental flows in the Zambezi River Basin as there will now be flexibility in the operation of the power plants in conjunction with the hydropower dams as it will be easier to import or export power within the SADC Region as demands and water availability dictate. However, it needs to be noted that importing power from other suppliers is currently far more expensive than producing one's electricity. There will therefore be hesitation to release water from the hydropower dams if there is uncertainty that there would be sufficient inflow into the dam to fill the reservoir afterwards. Combining investments in the Flow Forecasting Centre with a Dispatch Centre for coordinated power production and water management, would therefore increase the benefits further.

The Consultant identified a number of issues, gaps and constraints which could affect acceptance and successful implementation of synchronized operation of dams in the Zambezi River Basin. Table 1 gives a summary of the identified key issues, gaps and constraints.

Table 1: Summary of Issues, Gaps and Constraints affecting Dam Synchronization in the Zambezi River Basin

ISSUES	GAPS AND CONSTRAINTS
Zambezi riparian states' water sector Policies and Laws are not harmonized with each other's and/or with the SADC Regional water sector Protocols, Policies and Strategies and/or the ZAMCOM Agreement.	1. Domestication of the SADC Protocol on Shared Watercourses, Regional water sector Policy and Strategy, including the Zambezi Watercourse Agreement in the member states. 2. Harmonization of the Zambezi riparian states water sector Legislation, Policies and strategies.
Establishment of a permanent Zambezi Basin-wide management institution.	1. Signing and ratification of the 2004 ZAMCOM Agreement.
Institutional Capacity constraints.	1. Weak national water management institutional capacity to perform river basin management tasks. 2. Inadequate water resources knowledge base for basin-wide development and management. 3. Inadequate effective stakeholder participation in water resources planning, development and management. 4. Communication limitations in and amongst some Basin institutions. 5. Inadequate financial resources to attract and retain skilled staff and to facilitate operations. 6. Putting in place an effective Dam Operator MoU for data/information sharing, synchronized water infrastructure operation and management in the Zambezi River Basin.
Lack of Trust and Confidence.	1. Inculcating and nurturing trust between some Zambezi River Basin stakeholders. 2. Building confidence in a Regional/Basin Precipitation and Flow Forecasting System.
Lack of investments in water infrastructure.	1. Sourcing and securing financial resources to invest in water infrastructure. 2. Identifying sustainable long-term sources of funding. 3. Lack of capacity to prepare bankable projects in riparian states.

RECOMMENDATIONS

In coming up with the overall Recommendations for achieving improved Basin-wide Management of the Zambezi River Basin, the following assumptions were made as the issues under these assumptions are of fundamental importance if the recommendations are to be positively considered and eventually implemented:

1) An effective (Interim/Permanent) ZAMCOM Secretariat is established and operational;
2) The Zambezi riparian states National Water Sector Policies and Legislation have been harmonized with the SADC Protocols, Zambezi Watercourse Agreement, SADC Regional Water Policies and Strategies; and
3) Dam Operators have signed an effective and operational MoU for data/information exchange, conjunctive and synchronized dam operation and management.

It should be noted that the above assumptions deal with issues that will take a lot of resources, energy and time for their realization. Therefore, all stakeholders concerned should prioritize the attainment of these assumptions.

The Project's consolidated Recommendations which lead, if implemented, to the achievement of the Project's overall goal of safeguarding lives, enhancing livelihoods and providing environmental flows, while giving room for further sustainable development are given below. Brief explanations of each consolidated Recommendation are given in the Main Report. Table 2 gives the reference details and groups the Project's consolidated Recommendations into three Priority Lists, with Priority List 1 considered to have the highest priority and recommended to be on the interim/permanent ZAMCOM Secretariat's priority list for sourcing of funding and immediate implementation. These consolidated Recommendations summarise and aggregate the more specific Recommendations made and reported on in the Annexes 1 to 4 of the Main Report as summarised in Table 3 below with appropriate referencing for easy access in the relevant Annexes of the Main Report. These consolidated Recommendations are:

Project's consolidated Recommendations

1) Operationalise, upgrade, maintain and improve ZAMWIS;
2) Support capacity building to facilitate better understanding of dam synchronisation and new modes of dam operation;
3) Promote the establishment of a Zambezi River Basin System Operators' Forum;
4) Rehabilitate and extend SADC-HYCOS;
5) Establish and finance an effective Basin-wide Precipitation and Forecasting Centre;
6) Establish a Basin-wide flow forecasting system based on a real-time data acquisition network;
7) Implement a pilot project involving the Kariba, Itezhi-Tezhi and Kafue Dams with core activities such as dam synchronisation, conjunctive operation of dams, introduction of e-flows and flood management;
8) Carry out a financial assessment of the Project Recommendations and the implications for implementation;
9) Expand and improve the forecasting capabilities of the SADC Climate Services Centre;
10) Develop new flow forecasting models and integrate with existing models;
11) Develop and implement multi-objective dam operating rules;
12) Estimate and implement Zambezi Environmental Flows;
13) Introduce and implement flood risk zoning for regulation of settlements, land use, warning and rescue systems;

14) Improve the understanding of the hydrology and functioning of wetlands in the Zambezi River Basin;
15) Invest in new dams such as the Batoka and Mphanda Nkuwa and other water infrastructure to mitigate floods and droughts and provide freshets and water to enhance livelihoods; and
16) Support new SAPP interconnections such as the Malawi - Mozambique and Zambia - Tanzania.

Table 2: Consolidated Recommendations Matrix with prioritisation of the Recommendations

NUMBER	CONSOLIDATED RECOMMENDATION	INTERVENTION SHEET	PRIORITY LIST
1	Operationalise, upgrade, maintain and improve ZAMWIS	Annex 1 Sheet # 1.1 and Annex 3 Sheet # 3.13	
2	Support capacity building to facilitate better understanding of dam synchronisation and new modes of dam operation	Annex 2 Sheet # 2.2	
3	Promote the establishment of a Zambezi River Basin System Operators' Forum	Annex 2 Sheet # 2.1	
4	Rehabilitate and extend SADC-HYCOS	Annex 3 Sheet # 3.1	
5	Establish and finance an effective Basin-wide Precipitation and Forecasting Centre	Annex 3 Sheets # 3.14 & 3.15	***NUMBER 1***
6	Establish a Basin-wide flow forecasting system based on a real-time data acquisition network	Annex 3 Sheet # 3.16	
7	Implement a pilot project involving the Kariba, Itezhi-Tezhi, Kafue and Cahora Bassa dams with core activities such as dam synchronisation, conjunctive operation of dams, introduction of e-flows and flood management.	Annex 2 Sheet # 2.11	
8	Carry out a financial assessment of the Project recommendations and the implications for implementation	Annex 4 Sheet # 4.11	
9	Expand and improve the forecasting capabilities of the SADC Climate Services Centre	Annex 3 Sheet # 3.10	
10	Develop new flow forecasting models and integrate with existing models	Annex 3 Sheet # 3.8	
11	Develop and implement multi-objective dam operating rules	Annex 2 Sheet # 2.5	***NUMBER 2***
12	Estimate and implement Zambezi Environmental Flows	Annex 2 Sheet # 2.6	
13	Introduce and implement flood risk zoning for regulation of settlements, land use, warning and rescue systems	Annex 4 Sheet # 4.6	
14	Improve the understanding of the hydrology and functioning of wetlands in the Zambezi River Basin	Annex 2 Sheet # 2.10	
15	Invest in new dams such as Batoka and Mphanda Nkuwa and other water infrastructure to mitigate floods and droughts and provide freshets and water to enhance livelihoods	Annex 2 Sheet # 2.3 & Annex 4 Sheets # 4.6, 4.7 and 4.8	***NUMBER 3***
16	Support new SAPP interconnections (Malawi-Mozambique and Zambia-Tanzania)	Annex 4 Sheet # 4.9	

Figure 4 summarises the specific Project Recommendations extracted from the Annex Reports 1 to 4, linking these to the Project's objectives, outcomes and benefits whilst Figure 5 groups the Project's consolidated Recommendations in line with addressing the Project's question, "How can ***dams and measures of water management*** in the whole Zambezi River Basin ***contribute to safeguarding lives, livelihoods and nature*** while giving room for further sustainable development with due regard for the costs?".

IMPACTS

Some of the Project's interventions are studies and assessments, including pilot projects. It would thus be premature at this stage to give a comprehensive "if/then" analysis of all the Project's recommendations. The consolidated Recommendation number 8 proposes to make a financial assessment of all the Project's Recommendations in order to have an understanding in financial terms about the costs, risks and benefits of the proposed Recommendations. This financial assessment of the Project's Recommendations will facilitate the identification and better understanding of the anticipated impacts if the Recommendations are implemented. It is thus important and critical that this financial assessment is undertaken soonest. However, at this stage and in accordance with the findings of the Project, it is expected that the following positive impacts can be realised if the Project's consolidated Recommendations are implemented:

- Through establishment of the recommended stakeholder participatory fora, management institutions and capacity building programmes, good governance, communication and enhancement of dam operations in the Zambezi River Basin will be realised;
- Improved, regulated releases from the main reservoirs in the Zambezi River Basin for improved livelihoods and environmental flows will be achieved;
- Basin-wide flow forecasting and exchange of information between stakeholders will be attained resulting in improved management of the water resources and floods in the Zambezi River Basin, for the benefit of power production, dam safety, disaster management, the environment and livelihoods.

Whilst the urban and rural populations of the Zambezi River Basin are affected differently by the impacts of floods and droughts, the recommendations of the Project, if implemented, will benefit both urban and rural populations. The urban population has its own demands on the natural resources of the Zambezi River Basin which are quite different from those of the rural population. The rural population in itself, is also diverse, with different livelihoods. The benefits that the environment will accrue if the Project Recommendations are implemented and the resultant benefits to the livelihoods of the populations in the Basin, is another aspect as well. The overall Recommendations of the Project have wide ranging benefits and impacts if implemented, going beyond the Zambezi River Basin and thus affecting more than the Basin's estimated population as improved hydropower generation from dam synchronisation will support SAPP to the benefit of all SADC citizens. It is a complex task to assign Recommendations and associated benefits/impacts to sub-basin population sizes and their locations and this requires further in-depth study. However, if the Project's Recommendations are implemented, the resultant benefits and impacts will not only accrue and affect the Zambezi River Basin citizens, but will also contribute towards SADC's overall Agenda of regional integration, economic development, and poverty alleviation.

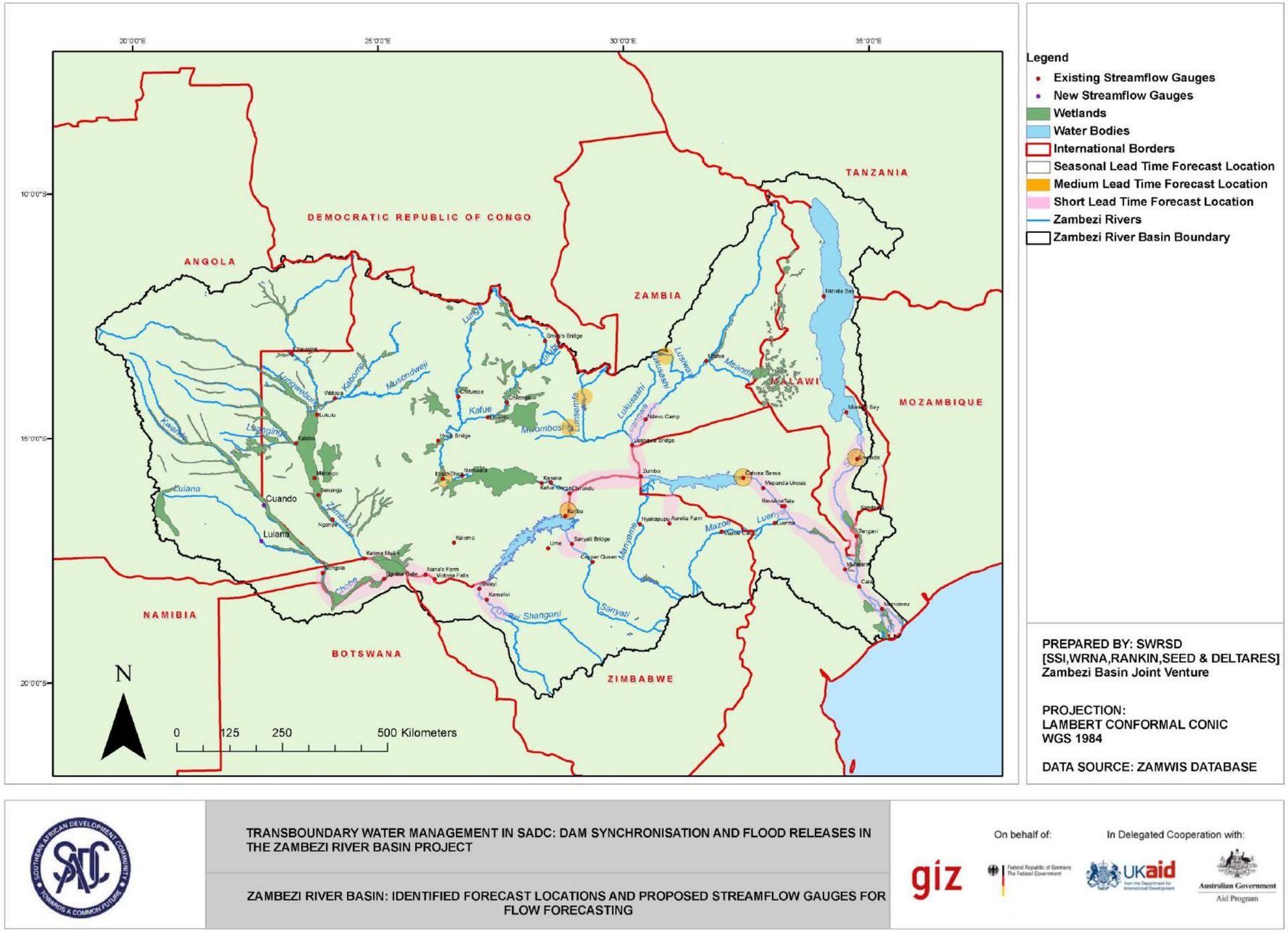


Figure 3: Map of identified forecasting locations across the Zambezi River Basin with lead time requirements and proposed streamflow gauges

Table 3: Project's Specific Recommendations leading to Recommendations for improved Basin-wide Management

REPORT/SECTOR	SPECIFIC RECOMMENDATIONS	INTERVENTION SHEET NUMBER
ANNEX 1: Data and Information	1) Operationalise and upgrade ZAMWIS to a fully operational hydrological database 2) Analyze and verify existing data in ZAMWIS	1) Annex 1 Sheet # 1.1 & Annex 3 Sheet # 3.13 2) Annex 1 Sheet # 1.2 & Annex 2 Sheet # 2.7
ANNEX 2: Dam Management	1) Promote the establishment of a Zambezi Basin System Operators' Forum and support existing stakeholder participatory fora. 2) Support capacity building to facilitate better understanding of dam synchronisation and new modes of dam operation 3) Establish and implement a basin-wide flood and drought risk management plan 4) Facilitate the adoption of new modes of dam operation 5) Develop operating rules for new dams 6) Estimate and implement Zambezi Environmental Flows 7) Improve the quality of observed flow data for application on dam management 8) Simulate flow time series for the Zambezi River System 9) Develop climate change scenarios for the Zambezi River Basin 10) Improve the understanding of the hydrology and functioning of wetlands in the Zambezi River Basin 11) Implement a pilot project involving the Kariba, Itezhi-Tezhi, Kafue and Cahora Bassa dams with core activities involving dam synchronisation, conjunctive operation of dams, introduction of e-flows and flood management.	1) Annex 2 Sheet # 2.1 2) Annex 2 Sheet # 2.2 3) Annex 2 Sheet # 2.3 4) Annex 2 Sheet # 2.4 5) Annex 2 Sheet # 2.5 6) Annex 2 Sheet # 2.6 7) Annex 2 Sheet # 2.7 8) Annex 2 Sheet # 2.8 9) Annex 2 Sheet # 2.9 10) Annex 2 Sheet # 2.10 11) Annex 2 Sheet # 2.11
ANNEX 3: Precipitation and Flow Forecasting	1) Rehabilitate the SADC-HYCOS Network 2) Extend network of real-time gauging stations 3) Establish Rating Curves for key gauges 4) Enhance procedures for collection of rainfall data 5) Upgrade rain gauge network for real-time capability 6) Implement approach for use of satellite rainfall estimation (SRE) 7) Integrate existing flow forecasting models into a Basin-wide flow forecasting system 8) Develop new flow forecasting models and integrate with existing models 9) Investigate new forecasting capabilities in collaboration with research institutions and universities 10) Expand precipitation forecasting capabilities of the SADC Climate Services Centre 11) Review forecast locations and requirements for stakeholders 12) Establish data sharing Agreement between Dam Operators and other stakeholders 13) Establish Basin-wide Forecasting Centre with training and research roles 14) Establish forecasting system using flexible operational platform	1) Annex 3 Sheet # 3.1 2) Annex 3 Sheet # 3.2 3) Annex 3 Sheet # 3.3 4) Annex 3 Sheet # 3.4 5) Annex 3 Sheet # 3.5 6) Annex 3 Sheet # 3.6 7) Annex 3 Sheet # 3.7 8) Annex 3 Sheet # 3.8 9) Annex 3 Sheet # 3.9 10) Annex 3 Sheet # 3.10 11) Annex 3 Sheet # 3.11 12) Annex 3 Sheet # 3.12 13) Annex 3 Sheets # 3.14 & 3.15 14) Annex 3 Sheet # 3.16
ANNEX 4: Investments	1) Assess Investments in the regulation of the Shire River and Lake Malawi 2) Assess Investments in multi-purpose dams on the mainstream Zambezi and Kafue Rivers 3) Facilitate the siting of new dams/reservoirs on the Zambezi River unregulated tributaries 4) Support the construction of an extra spillway at Cahora Bassa Dam 5) Provide adequate bottom outlets in new dams 6) Support the coordination of flood risk zoning initiatives 7) Support local multi-purpose measures which add to flood protection 8) Consider local structural flood protection measures or diversion of floods 9) Support new SAPP interconnections 10) Support Forecasting Centre and SAPP Dispatching Centre 11) Carry out a financial assessment of the Project recommendations and the implications for implementation	1) Annex 4 Sheet # 4.1 2) Annex 4 Sheet # 4.2 3) Annex 4 Sheet # 4.3 4) Annex 4 Sheet # 4.4 5) Annex 4 Sheet # 4.5 6) Annex 4 Sheet # 4.6 7) Annex 4 Sheet # 4.7 8) Annex 4 Sheet # 4.8 9) Annex 4 Sheet # 4.9 10) Annex 4 Sheet # 4.10 11) Annex 4 Sheet # 4.11

Dam Synchronisation and Flood Releases in the Zambezi River Basin Project

Current situation

As at end of 2010:

- Almost all the countries of the Zambezi River have conducted water resources development and management on their portion of the river, more or less independently.
- There is currently no basin-wide conjunctive operation of the major dams in the Zambezi River Basin to optimize their multiple uses and the overall system potential.
- The operation of the major dams in the Zambezi River Basin is not comprehensively synchronized.
- Spillways and flood gates are operated primarily for dam safety reasons to release excess water or floods, and not necessarily for the environment or for nature purposes. As such, the operating rules of these dams do not generally incorporate the environmental and social needs of the downstream and upstream environment. Itezhi-Tezhi Dam in Zambia is the only exception.
- All the Zambezi River Basin riparian states are party the Revised 2000 SADC Protocol on Shared Watercourses as well as the 2008 Zambezi River Basin Integrated Water Resources Management Strategy and Plan.
- The Joint Operations Technical Committee (JOTC) constituted by the Dam Operators of Mozambique ARA Zambeze, Zimbabwe Power Company (ZPC), Zambia Electricity Supply Corporation (ZESCO), Zambezi River Authority (ZRA) and Mozambique Hydro-Cahora Bassa (HCB) and Zimbabwe National Water Authority (ZINWA) often meet to discuss dam operations.
- The Dam Operators, Power Producers and other water management institutions in the Zambezi River Basin are sharing data and information, particularly during the rainfall season and flood situations, albeit in an informal manner.
- The Zambezi Water Management Information System (ZAMWIS) database has been developed and operated under the interim/permanent ZAMCOM Secretariat.

This Project

This Project investigated during 2010-2011 the extent to which the timing of water releases for electricity production, agricultural demands, environmental flow, dam safety, and flood protection from existing and proposed new dams in the Zambezi River Basin can result in more collective advantages. To effectively manage the river inflows, storage and releases for these purposes, the Zambezi river system requires forecast of flows at key locations. Short term forecasts for floods and seasonal forecasts for environmental flows can be incorporated in reservoir operation decision-making. Additionally, investments that could influence flood protection and flow regulation have been evaluated.

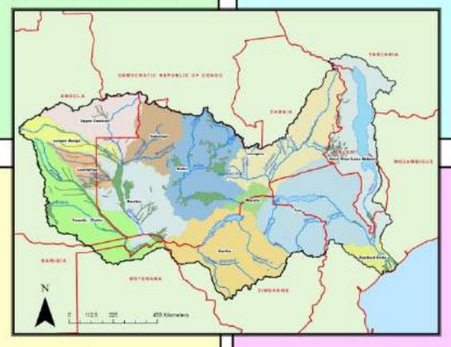
The Project Recommendations made are directed at and are for the attention of basin custodians – the Zambezi riparian states

Recommendations for Dam Management

- Establish Zambezi River Basin System Operators' Forum
- Develop and implement multi-objective dam operating rules
- Establish and implement a basin-wide flood and drought risk management plan
- Facilitate the adoption of the new modes of dam operation
- Improve the appreciation of the hydrology and functioning of wetlands in the Zambezi River Basin
- Develop climate change adaptation scenarios for the Zambezi River Basin
- Estimate and implement Zambezi Environmental Flows regulation obligations
- Improve the quality of river observed flow data and simulate associated flow time series
- Implement a pilot project involving the Kariba, Itezhi-tezhi, and Cahora Bassa Dams with core activities such as dam synchronisation, conjunctive operation of dams, introduction of e-flows and flood Management

Recommendations for Precipitation and Flow Forecasting

- Rehabilitate the SADC-HYCOS Network
- Extend network of real-time gauging stations
- Establish Rating Curves for key gauges
- Enhance procedures for collection of rainfall data
- Upgrade rain gauge network for real-time capability
- Implement approach for use of satellite rainfall estimation
- Integrate existing river flow forecast models into a basin-wide flow forecast system
- Develop additional river flow forecasting models and integrate with existing models
- Explore and expand precipitation forecasting capabilities of Climate Services Centre
- Establish Basin-wide river Flow Forecasting Centre
- Establish river flow forecasting system using a flexible operational platform



Recommendations for Information Management

- Support the operationalisation and upgrading of ZAMWIS
- Analyze and verify existing data

Recommendations for Investments

- Investment in the regulation of the Shire River and Lake Malawi/Nyasa/Nyassa
- Investments in multi-purpose dams on the mainstream Zambezi River and Kafue Tributary
- Investments on new dams on other Zambezi tributaries
- Additional spillway for Cahora Bassa Dam
- Reservoir bottom outlets for sediment management
- Establish flood risk zoning for regulation of settlements, land use, warning and rescue systems
- Structural flood protection measures/diversion of floods
- Support new SAPP interconnections
- Carry out a financial assessment of the Project recommendations and the implications for implementation

EFFECTIVE COLLABORATION

Dam Safety

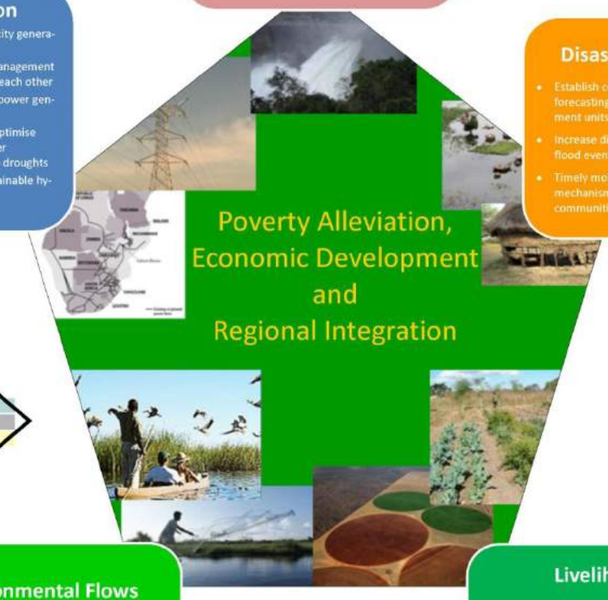
- Manage releases to keep dam water levels within a safe operating range
- Provide adequate storage volume to safely store and pass the maximum flood which the dam was designed for

Power Production

- Secure adequate water for electricity generation
- Coordinate storage and release management for hydropower plants to support each other
- Utilise high river inflows for extra power generation
- Utilise SAPP interconnectivity to optimise power production (hydro and other sources) and improve resilience to droughts
- Effectively operationalise the sustainable hydropower protocol

Disaster Management

- Establish communication protocol between forecasting agencies and disaster management units
- Increase disaster warning time for expected flood events
- Timely mobilisation of disaster management mechanisms, including warnings to affected communities



Environmental Flows

- Provide river flow with same characteristics as that of natural flow
- Provide quantity and quality of water required to maintain ecosystems and enable them to provide sustainable services

Livelihoods

- Plantation irrigation: Provide adequate water for agricultural production
- Dry season floodplain agriculture: Accommodate needs for harvest in water release management from dam for dry season cultivation requirements

SWRSD Zambezi Basin Joint Venture

Figure 4: Project's Specific Recommendations and Project Objectives/Outcomes/Benefits

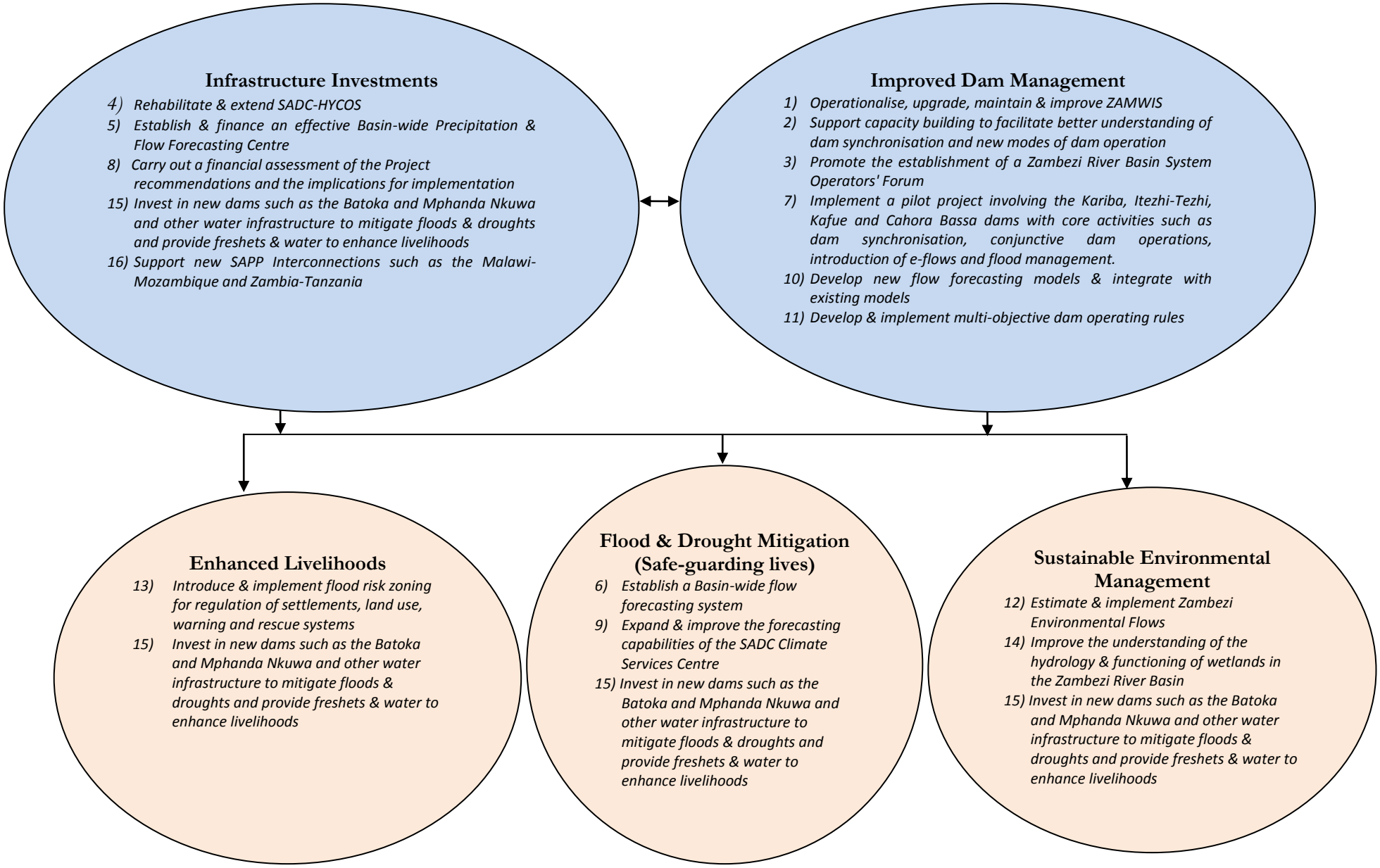


Figure 5: Grouping of Project's consolidated Recommendations for improved Basin-wide management