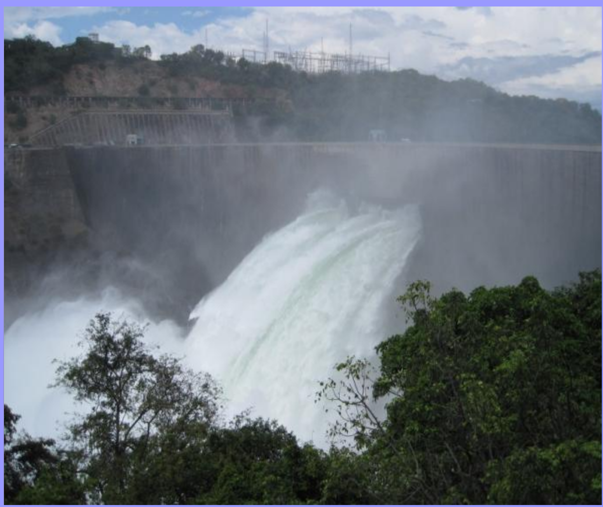
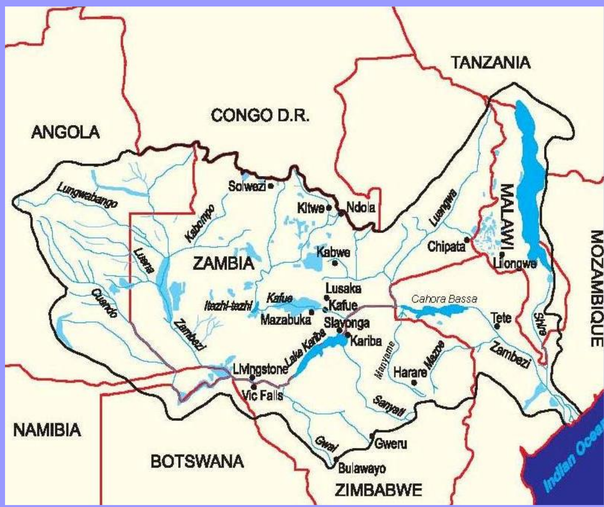
Transboundary Water Management in SADC

DAM SYNCHRONISATION AND FLOOD RELEASES IN THE ZAMBEZI RIVER BASIN PROJECT





Main Report

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 | WRNA W R Nyabeze and Associates | RANKIN | SEED Sociedade de Engenharia e Desenvolvimento, Lda. GRUPO DHV | 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
CBO	Community Based Organization
CPC	Climate Prediction Centre
DANIDA	Danish International Development Assistance
DNA	Direcção Nacional de Águas (Department of Water Affairs in Mozambique)
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
IWRM	Integrated Water Resources Management
Lake Malawi	Also known as Lake Malawi/Nyasa/Nyassa or Lago Niassa/Nhiassa
m.a.s.l.	metres above sea level
METEOSAT	Meteorological Satellites
MoU	Memorandum of Understanding
NCAR	National Centre for Atmospheric Research
NCEP	National Centres for Environmental Prediction
NGO	Non Governmental Organization
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
SADC	Southern African Development Community
SAPP	Southern Africa Power Pool
SARCOF	Southern Africa Regional Climate Outlook Forum
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
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
ZACBASE	Zambezi Action Plan Database
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 Services Department
ZPC	Zimbabwe Power Company
ZRA	Zambezi River Authority

Executive Summary

This Main Report contains primarily the Concepts, Principles, Findings and Recommendations that are a result of the implementation of the SADC Project, Dam Synchronisation and Flood Releases in the Zambezi River Basin. The overall goal of the Project was to provide appropriate answers to 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?".

Some issues, gaps and constraints were identified during the execution of the Project which can affect the acceptance and implementation of dam synchronisation and conjunctive operation of dams in the Zambezi River Basin. These issues, gaps and constraints are given in Table 3.2 below. Figures 7.1 and 7.2 give the Project's summarised Concept and Recommendations respectively.

In coming up with the consolidated 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 however be noted that the above assumptions deal with issues that will take a lot of resources, energy and time for their realization and therefore all stakeholders concerned should prioritize the realization of these assumptions.

Bearing in mind the assumptions, Principles, Findings, Concepts and specific Recommendations made during the Project's execution, the following are the Project's consolidated Recommendations, which if implemented, would address the Project's question and overall goal of achieving the Zambezi River Basin's sustained economic development whilst safeguarding lives, livelihoods and providing freshets:

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, Kafue an d Cahora Bassa 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.

The Annexes 1 through 4 contains the details of these Recommendations together with the justifications, suggested key implementation players, timeframes and estimated implementation costs.

The Project's consolidated Recommendation list above has been grouped 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 Priority Lists are given in Table 7.2 below.

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:
1) 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;
2) Improved, regulated releases from the main reservoirs in the Zambezi River Basin for improved livelihoods and environmental flows will be achieved;
3) 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.

1 Introduction

1.1 Brief description of the Project

1.1.1 Project Area

The Zambezi River, approximately 2 650 kilometres in length from source to mouth, rises in the Kalene Hills of north-western Zambia at altitude 1 585 m above sea level and flows generally eastwards to the Indian Ocean. Its Basin is located between Latitude 8° and 20° South and Longitude 16.5° and 36° East. The Zambezi River, with a catchment area of some 1 350 000 Km^2 , covers about 25% of the total land area of its eight riparian states of Angola, Namibia, Botswana, Zambia, Zimbabwe, Mozambique, Tanzania and Malawi, Figure 1.1 refers.

The Zambezi River Basin is home to some 40 million people (2000) who speak Bantu-lineage local languages with English and Portuguese being the main official languages in the eight riparian states. 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.

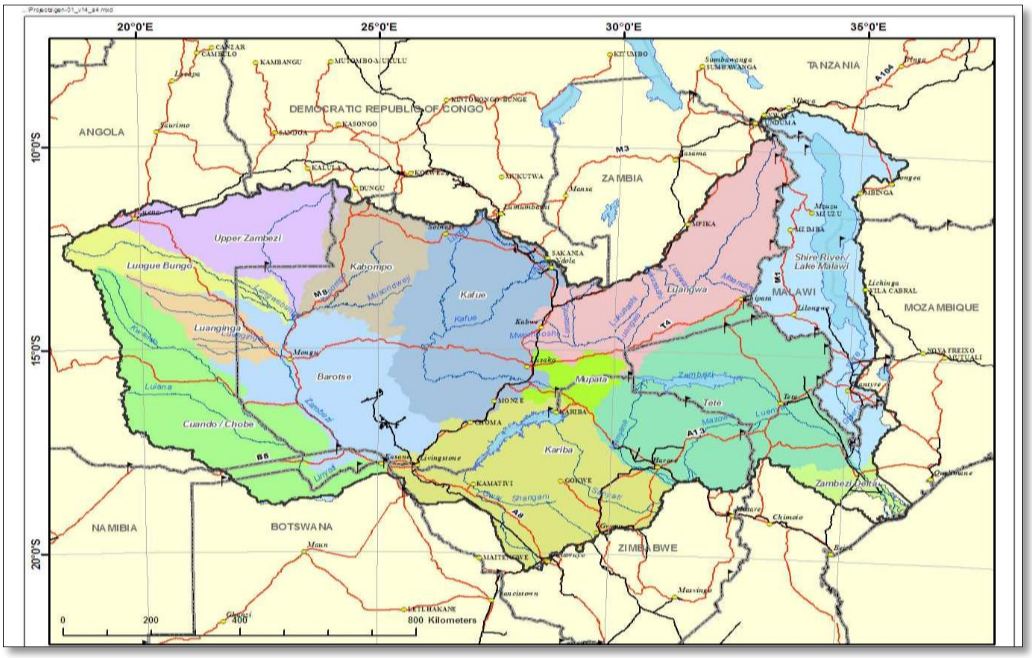

Figure 1.1: The Zambezi River Basin (Source: ZAMWIS)

1.1.2 Project Objectives

The developments that have taken place in southern Africa over the past few decades are significant, and the potential for further economic growth is clear. Predictions of water scarcity and electricity shortages have already been made and this has a direct bearing on the demands being placed on the Zambezi River Basin. Transboundary Water Management (TWM) of this water resource is therefore of critical concern to the Southern African Development Community (SADC) and the riparian states.

The concept of integrated water resources management (IWRM) in river basins has been a key field in GIZ cooperation for many years. In its efforts to improve transboundary water management in the SADC region, the German, British and Australian Governments, through GIZ, supported the Project "Dam Synchronization and Flood Releases in the Zambezi River Basin" under the Transboundary Water Management Programme in SADC. The Contract for the Project was signed on the 17th November 2009 between GIZ and the SWRSD Zambezi Joint Venture (SSI, WRNA, Rankin, SEED, Deltares Joint Venture) – hereinafter referred to as 'the Consultant'. The duration of the Project was 14 months.

The outcome of the Project was to provide a comprehensive response to the following 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?" This question forms the basis for the elaboration of the layout of this Main Report, the Annexes 1 through 4 and definition of the Project results.

To achieve the Project's overall outcome, the Consultant prepared a set of consolidated Recommendations focusing on ways and means of improving flood protection, improving livelihoods and provision of environmental flows, taking into account the various and divergent interests of the Zambezi riparian states. These consolidated Recommendations provide an overview of all of the outcomes of the Project, and highlight all aspects of the studies which have been conducted throughout the life of the Project.

The final Project Reports produced are schematically shown in Figure 1.2 below.

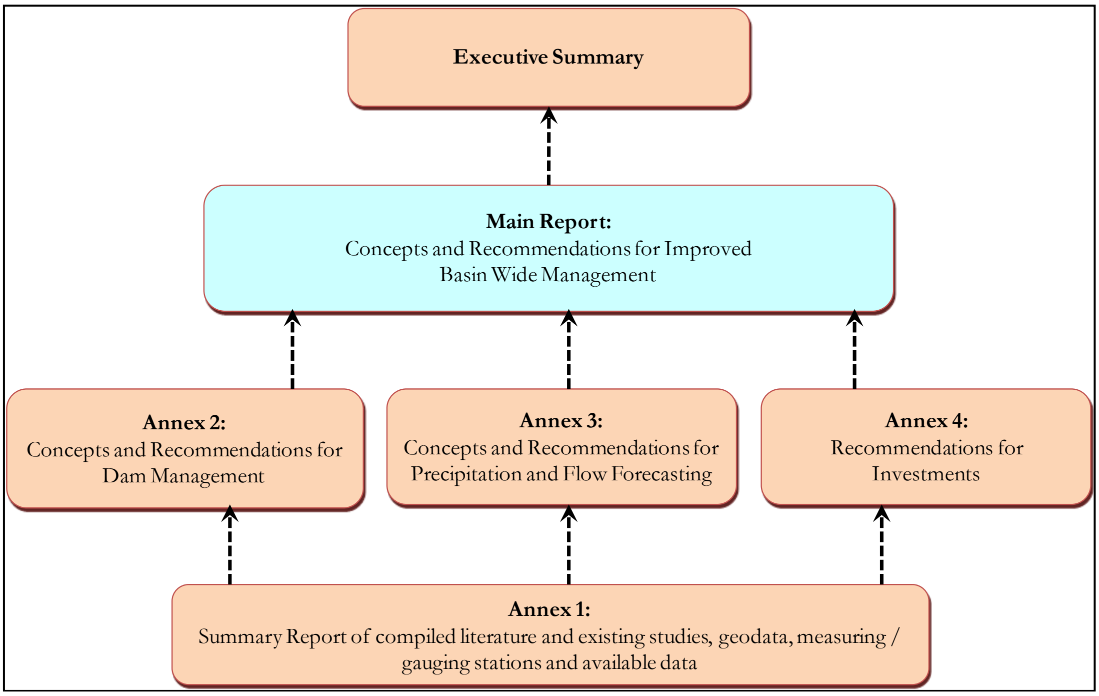

Figure 1.2: Final Project Reporting

The Project was divided into five Output areas as follows:

- Output 1, included in the Main Report as Annex 1, deals with Data and Information;
- Output 2, included in the Main Report as Annex 2, deals with Concepts and Recommendations for Dam Management;

- Output 3, included in the Main Report as Annex 3, deals with Concepts and Recommendations for Precipitation and Flow Forecasting;
- Output 4, included in the Main Report as Annex 4, deals with Recommendations for Investments, and
- Output 5 which is the Main Report, synthesizes and links Outputs 1 to 4 to give the consolidated Recommendations for improved Basin-wide Management.

To come up with the Concepts and Recommendations that would address the Project's overall objective; the Consultant had to undertake a total of eleven main Tasks. The linkages between the Tasks and the Project Output areas are given in Table 1.1 below. Figure 1.3 further illustrates how each of these Outputs and their Tasks link to the Project objectives.

Table 1.1: Linkage between Tasks and Outputs

Task	Description	Reported in Annex	Output 1	Output 2	Output 3	Output 4	Output 5
1	Data and Information Management	1	■				■
2	Long Cycles and Climate Change	2		■			■
3	Precipitation and River Flow Forecasting System	3			■		■
4	Wetland retention and enhancement	2		■			■
5	Regulation of Existing Large Reservoirs	2		■			■
6	Regulation of Shire River and Lake Malawi	2 & 4		■		■	■
7	New Multipurpose Dams on the Zambezi and its Tributaries	2 & 4		■		■	■
8	Synchronization of Dams for Flood Release	2 & 4		■		■	■
9	Potential of New Flood Protection Measures and Risk Zoning	4				■	■
10	Sediments	2 & 4		■		■	■
11	Diversification of the Electric Power Pool	4				■	■

1.1.3 Scope of Works

This Project investigated the extent to which the timing of releases for electricity production, agricultural demands, environmental flow, dam safety and flood protection by both existing and proposed new dams can result in more overall sustainable advantages. The Zambezi system requires forecast of flows at key locations in order to manage the inflows, storage and releases for these purposes. 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 sector, and any new operating paradigm has to earn the confidence of this sector. Forecasts and appropriate models can be used to show the probability that the power generating levels/storage will be sustained when 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 this Project, effort was made to show that flood management and release of environmental flows can be achieved synergistically. 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, public water supply and industries.

The Outputs of this Project constitute six major documents as depicted in Figure 1.2. Chapters 4 and 5 of this Main Report give the summary of the work carried out and the results of the Output Areas in detail.

1.2 Project Outputs' approval and validation processes

The Consultant held meetings and Think Tank Work Weeks with relevant staff to discuss the various aspects of the Project and assess Project progress. The data/information, results and recommendations that the Consultant had to use and analyse, had to be collected, verified and validated by the respective stakeholders. As such, it was imperative that the Project set up structures to achieve this. The structures included the Project Steering Committee (PSC) and an Advisory Group (AG). The Consultant also undertook visits within the Zambezi River Basin and interacted with some key stakeholders whilst also collecting data and information.

1.2.1 Project Steering Committee Meetings

The Project Steering Committee (PSC) comprised the SADC Water Division and GIZ. The Interim or Permanent ZAMCOM Secretariat would have been a member of the PSC had it been established during the life of the Project. The Consultant was in attendance at all PSC Meetings and provided secretarial services.

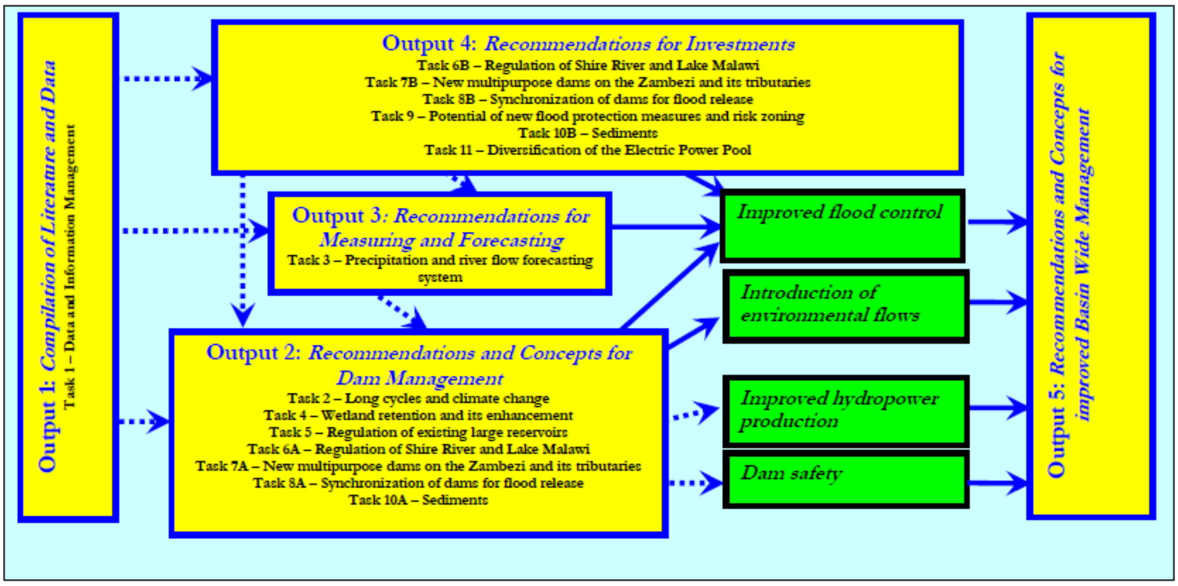

Figure 1.3: Project Outputs and Objective linkages

The purpose of the PSC was to provide the overall direction to the Project, ensure close communication and interaction between the Consultant and the Advisory Group (AG), approve Project deliverables and Outputs and facilitate associated payments to the Consultant. Eight PSC Meetings were held during the Project's execution. Besides the formal PSC Meetings, regular contact was maintained via email and telephone between the Consultant's office and the SADC Water Division and GIZ.

1.2.2 Advisory Group Meetings

According to the Terms of Reference (ToR) of the Project and the policies of SADC and GIZ, regular stakeholder consultation was required during the execution of the Project. SADC, in consultation with GIZ, prepared the ToR for the Advisory Group (AG) which were presented and adopted at the first AG Meeting held in Gaborone on 24 March 2010. The AG was made up of forty three Zambezi stakeholder members. The AG members were informed of the plans of the Project and reacted positively. Their main concern, however, was the tight timeline for Project execution.

One important aspect of constituting and having an effective AG was Project Ownership. The results/outputs of this important Project needed to have a "home" for future implementation. The AG constituted such a "home". The AG further provided the overall strategic guidance to the Project and played a key role in the validation of the Project Outputs.

Three AG Meetings were held during the life of the Project; 24 March 2010 in Gaborone, 11 October 2010 in Maun and 14 to 16 February 2011 in Livingstone.

1.2.3 Visits, stakeholder Meetings and Workshops

As part of the Project consultation process, data and information collection, consolidation and validation process, the Consultant undertook visits, held Meetings and attended Workshops with some of the key stakeholders of the Zambezi River Basin.

Meetings were held with the Joint Operating Technical Committee [(JOTC) which is made up of the technical staff of ZRA, ZESCO, ZPC, ZINWA, HCB and ARA-Zambeze], SAPP, WWF (Zambia Office), ZINWA, ZPC, ARA Zambeze, HCB, ZRA, ESCOM, ZESCO, Department of Water Affairs (Zambia), ZMSD, Department of Water Development (Malawi), Department of Water (DNA Mozambique) and the International Federation of the Red Cross and Red Crescent Societies (IFRC).

The Consultant also attended the 4th SADC River Basin Organisation (RBO) Workshop on benefit sharing held in Gaborone, the Sida Workshop on increasing benefits from transboundary water management for people living in poverty which was held in Nairobi, the 4th SADC Multi-stakeholder Water Dialogue (MWD) held in Maun with a focus on building resilience to climate variability/change impacts in the SADC Region, and the 3rd Africa Water Week (AWW) held in Addis Ababa focussing on climate change adaptation and resilience. The Consultant made Project presentations at the 4th SADC RBO Workshop, the 4th SADC MWD and the 3rd AWW.

1.2.4 Telephone interviews and Questionnaires

Further Project consultations and data/information collection and validation was carried out through telephone interviews and administration of Questionnaires. For example, the Consultant conducted a telephone interview with SADC-HYCOS (South Africa Office).

For the Forecasting System, a number of key questions were posed to AG members through a Questionnaire process, and the results of this process assisted in identifying forecasting requirements. Separate Questionnaires were prepared for Disaster Management Agencies, Water Ministries, Energy Ministries, Power Utilities and environmental interest agencies and these were emailed directly to AG members, with follow-up telephone calls to ensure receipt and to encourage early responses. These processes provided extremely useful information, particularly with respect to forecast locations and required lead times.

Figure 1.4: Participants of the 1st Advisory Group Meeting in Gaborone

Figure 1.5: Participants of the 2nd Advisory Group Meeting in Maun

Figure 1.6: Participants of the 3rd Advisory Group Meeting in Livingstone

2 Summary of Existing Situation

2.1 Literature Review

The SADC Directorate for Infrastructure and Services through its Water Division has been instrumental in spearheading IWRM practices in the fifteen SADC mainland shared watercourses. The launching of the Guidelines for Strengthening River Basin Organisations in June 2010 was a significant milestone in this regard. The following documents contain valuable details of the ZAMCOM Agreement and the SADC policies, principles and strategies that are key and fundamental to managing dams and other water infrastructure in the Zambezi River Basin in a synchronised and sustainable manner.

- The SADC Revised Protocol on Shared Watercourses (SADC 2000);
- The ZAMCOM Agreement (2004);
- The SADC Regional Water Policy (SADC 2006);
- The SADC Regional Water Strategy (SADC 2006); and
- The SADC Guidelines for Strengthening River Basin Organisations (SADC 2010).

The Zambezi River Basin has an IWRM Strategy and Implementation Plan (SADC 2008) which identified four major Basin challenges and issues related to:

- Integrated and Coordinated Water Resources Development and Management;
- Environmental Management and Sustainable Development;
- Adaptation to Climate Variability and Climate Change; and
- Basin-wide Cooperation and Integration.

Strategies to address the above challenges and issues as well as an implementation plan for their mitigation were proposed in the Zambezi River Basin IWRM Strategy and Implementation Plan. Some of the proposed strategies are relevant to this Project. The preliminary analysis on regulation and synchronisation of dam operations for environmental flows (Klaassen 2008) also gives some excellent inputs into this current Project.

In early December 2009, WMO and USAID facilitated a Regional Consultation Meeting on the Zambezi River Basin Flood Forecasting and Early Warning Strategy which was held in Maputo, Mozambique. During this meeting, the WMO Information System (WIS) and the WIGOS Pilot Project were demonstrated to the participants. The outcomes of the meeting are summarised as:

- A Regional consensus for the development of a flood forecasting and early warning system for the Zambezi River Basin based on an agreed strategy was arrived at;
- The process of confidence building among countries of the Zambezi River Basin for real time flood information sharing was initiated; and
- A road map for activities to be implemented under an agreed Project up to 2012 was established.

The Consultative Meeting took note of the SADC Zambezi River Basin Dam Synchronisation and Flood Releases Project which had just commenced and the Project's potential contribution to the initiatives of the WMO proposed Project. The Proceedings of this Regional Consultation Meeting are contained in the WMO Final Report on the Zambezi River Basin (2009) which can be retrieved from www.whycos.org/WMO/hwrp/Zambezi/FinalReportBasin.pdf

The World Bank's Zambezi River Basin Multi-sector Investment Opportunities Analysis (WB 2010) is another valuable source of information for this and other future projects/studies in the Zambezi River Basin.

Annex 1 of the Main Report also gives details of all sources of information used for this Project.

2.2 Zambezi River Basin Situation Analysis

2.2.1 Data and Information sharing

Hydro-meteorological data collection in the Zambezi riparian states is primarily carried out by:

- Dam Operators;
- Departments of Water;
- Meteorological Services Departments; and
- National Agencies like ARA Zambeze and ZINWA.

These institutions collect the hydro-meteorological data at their own expense and have varying missions for disseminating the data and information they collect. Most of these organisations now charge a fee for supplying the data or information, unless it is part of their obligation to do so to their stakeholders. Members of staff in some of the organisations above have and still publish technical papers in reputable international journals utilising this data and information which builds on the knowledge base of the Zambezi River Basin. In other cases where data and information is obtained by others, such data and information has been used for research or educational purposes and subsequently published.

The SADC Zambezi Action Programme 6 (ZACPRO 6) aimed at establishing a database for the Zambezi River Basin that would be accessible to all stakeholders in the eight Zambezi riparian states. Phase I of the ZACPRO 6 Project established ZACBASE which unfortunately never benefited the Zambezi stakeholders as the hard drives containing the information crashed on re-installation of the server when it was relocated from Maseru, Lesotho to ZRA offices in Lusaka, Zambia. This system was never resuscitated. In Phase II of the ZACPRO 6 Project, a new database, the Zambezi Water Resources Information System (ZAMWIS), was established. This was operational until April 2009 when once again, ZAMWIS had to be re-installed in Gaborone, Botswana where the ZAMCOM Interim Secretariat has since been established. The process of establishing the ZAMCOM Interim Secretariat has taken long and thus ZAMWIS, like its predecessor ZACBASE, was not operational as at 31 March 2011. However, the information uploaded to April 2009 is available and accessible on DVD.

At present, limited data and information sharing takes place in the Zambezi River Basin, partly due to a reluctance in sharing the costs associated with data collection and information dissemination. The Dam Operators, Power Producers and some water management institutions in the Zambezi River Basin are sharing data and information to a limited extent, particularly during the rainfall season and flood situations, albeit in an informal manner.

2.2.2 Forecasting Systems

2.2.2.1 Southern Africa Regional Climate Outlook Forum

At a regional level, the Southern Africa Regional Climate Outlook Forum (SARCOF) meets annually to develop and reach a consensus climate outlook for each rainfall season for the SADC member states. By the end of August 2010, SARCOF had held 14 annual meetings in total. Each SARCOF meeting also suggests potential impacts arising from the consensus seasonal climate outlook for that rainfall season thus providing a platform for Dam Operators and Disaster Management Units/Agents to plan and make operational decisions for the forth-coming rainfall season. SARCOF provides a forum for stakeholder participation and a mutually beneficial interface between climate information/prediction service practitioners and those that need to use the products.

The major issues with regards to SARCOF are:

- SARCOF outputs, (the consensus climate outlooks for each rainfall season), are general. They divide the SADC region into rainfall percentage zones classified as "above normal", "normal" or "below normal". These consensus climate outlooks will thus need to be domesticated if they are to be of more practical use for the various users at local level;
- SARCOF is a forum and cannot be held responsible for the quality of its outputs;
- SARCOF is currently financially viable due to the ICP support it receives. It is important that the SADC Climate Services Centre looks into the future sustainability of SARCOF;
- The proper interpretation of the seasonal climate forecasts and their application across the various socio-economic decision making processes at local level still remain challenging in the SADC region;
- The effects of Climate Change/Variability affect long-term forecasts thus reducing the confidence in the consensus climate outlooks for each rainfall season issued by SARCOF; and
- Whilst SARCOF is a useful forum for networking, it uses simplistic methods which have been largely superseded by new technology available in the SADC region. It appears that improved precipitation forecasting is more likely to come from the Regional Specialised Meteorological Centre (RMSC) in Tshwane, South Africa than from SARCOF.

2.2.2.2 SADC HYCOS PROJECT

The World Meteorological Organization (WMO) and the World Bank initiated the World Hydrological Observing System (WHYCOS) in 1993. The main objective was to strengthen National Hydrological Services (NHS). WHYCOS subsequently spearheaded regional initiatives in various parts of the world including SADC. This resulted in the setting up of the SADC-HYCOS Phase I stream flow gauging network in 1998, which allowed for the installation of 50 Data Collection Platforms (DCPs), the establishment of a Pilot Regional Centre (PRC) in Tshwane, South Africa, the development of an Internet based Information System (http://sadchycos.dwaf.gov.za/) operated by the PRC and the training of regional personnel from participating countries. Installation and setup for Phase I was completed by 31 August 2001 (only 43 DCPs out of the planned 50 were eventually installed for a range of reasons). The SADC-HYCOS Phase II Project commenced in 2006 and was designed to consolidate and expand on the Project activities that were initiated during Phase I. These included further development of the regional and national water resources information systems, identification and development of hydrological products of regional interest and further capacity building of the SADC participating institutions. An additional 41 DCPs are planned under Phase II. Phase II is still underway and to date civil works for the required gauges are now almost complete.

2.2.2.3 Zambezi riparian states National Forecasting Agencies

All the Zambezi riparian states have national forecasting organisations that are primarily the Meteorological Services Departments. These organisations are capacitated to carry out their mandates to different levels. The national forecasting organisations form the core of SARCOF and have the mandate to domesticate and disseminate the SARCOF consensus climate outlooks for each rainfall season for more direct use by their national stakeholders. The SADC-HYCOS Projects are meant to primarily benefit the Meteorological Services Departments as well as other national hydro-meteorological service providers. As the WMO's Southern Africa Regional Centre, the South African Weather Service (SAWS) can provide daily forecasting information to all Meteorological Services Departments in the Zambezi River Basin. The Consultant understands that this information is based on much improved technology and the National Meteorological Services Departments can use this information for national forecasts if they choose to do so.

Figure 2.1: Typical SADC-HYCOS Station

2.2.2.4 Dam Operators and Disaster Management Units/Agencies

Dam Operators and Disaster Management Units/Agents rely heavily on SARCOF for the overall rainfall seasonal climate outlook forecasts. Their planning and decision making usually starts after the SARCOF Meetings and is informed by the SARCOF forecasts. The Dam Operators and Disaster Management Units/Agents participate in SARCOF fora and thus form part of the consensus seasonal climate outlook forecasting process. However, since the SARCOF seasonal forecast is "general", the Dam Operators and Disaster Management Units/Agencies have to further rely on the domestication of these forecasts by their national forecasting agencies like the Meteorological Services Departments.

Dam Operators require reliable and timely rainfall forecasts that they can confidently use for their operational decisions. General information that emanates from SARCOF is not adequate to ensure dam safety, viability and the reduction of risks of losses in power production. Dam Operators in the Zambezi River Basin can reasonably deal with runoff and have built up models to predict lead times and inflows into their water infrastructure. As no individual or agency can predict the future, and without further investments in state-of-the-art rainfall forecasting systems, accurate and reliable forecasts will remain part of a wish list for the Dam Operators and other similar stakeholders, leaving them with no option but to take conservative action. However, improved technology is currently available to National Meteorological Services Departments through the SAWS – if Dam Operators could make use of this improved forecasting technology, a significant improvement in the SARCOF predictions would be possible.

2.2.3 Dam Operations

The major dams in the Zambezi River Basin are: Kariba, Cahora Bassa and Itezhi-Tezhi. These major dams in the Zambezi River Basin were originally built as single-purpose dams, be it for hydropower generation, irrigation, institutional water supply or mining purposes. Except for Kariba Dam which is co-owned by Zambia and Zimbabwe, all the other major dams in the Zambezi River Basin are nationally or privately owned and are operated to the best interests of the owners.

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.

2.2.4 "Soft" Project/Studies Output implementation

The Zambezi River Basin has suffered from the syndrome of "Soft Project/Study shelving". Several examples can be given of "Soft" Projects and Studies in the water sector that have been carried out successfully to final report stage but their outputs and recommendations, which needed active follow-up for implementation, have remained on the shelves of the water sector decision makers' offices in the Zambezi riparian states. The following can be postulated as some of the reasons for this situation:

- The absence of a Basin-wide management institution like ZAMCOM;
- In many cases, the Project/Studies' participants from the Zambezi riparian states are not senior enough to pass onto the political level the outputs and recommendations for adoption/implementation;
- Lack of Project/Study ownership by the intended beneficiaries;
- Where Basin-wide or regional recommendations are made, national priorities supersede such recommendations;
- Limited national financial and human resource capacity for follow-up action or implementation; and
- Lack of sustainable Project/Study exit strategy.

This Project will not end up on the shelves for the following reasons:

- the ZAMCOM Interim Secretariat will be established in Gaborone on 1 April 2011 and will take up the various recommendations made for implementation, with due consultations with the Zambezi riparians states;
- with the creation of the ZAMCOM Interim Secretariat, there will be more buy-in from the Zambzi River Basin stakeholders to view, address and implement projects and programmes at basin level, slowly moving away from national considerations;
- there is strong goodwill from the ICPs to assist the young ZAMCOM Interim Secretariat get off its feet;
- the AG, which consists of a diverse stakeholder base, is willing to be transformed into the Zambezi River Basin System Operators' Forum thus providing continuity to the Project's activities;

- there is strong goodwill between the Zambezi riparian states to cooperate; and
- the threats and challenges being brought by climate change/variability will make the Zambezi River Basin stakeholders close ranks facilitating coorporation.

Figure 2.2: Cahora Bassa Dam

Figure 2.3: Kariba Dam

3 Issues, Gaps and Constraints affecting Dam Synchronisation

The Consultant, during the execution of this Project, identified some issues, gaps and constraints pertinent to dam synchronisation, management of flood releases and the introduction of environmental flows in the Zambezi River Basin. The following are some of the issues identified, along with the associated gaps and constraints, as they relate to effective dam synchronisation, management of flood releases and introduction of environmental flows in the Zambezi River Basin.

3.1 Riparian states water sector Policies and Laws

Whilst the SADC region has the ratified Revised Protocol on Shared Watercourses and the Regional Water Policy and Strategy is in place, the provisions of these key water governance instruments and tools still need to be domesticated in the Zambezi riparian states. The water governance laws and policies in the Zambezi riparian states need to be harmonised not only with the SADC water governance instruments, but also with those amongst the Zambezi riparian states. This will now be easier achieved with the ZAMCOM Interim Secretariat in place to facilitate the harmonisation process and provide a focussed platform for dialogue amongst the Zambezi riparian states and the Zambezi River Basin stakeholders. Table 3.1 gives some details of the main water sector legal instruments as well as the shared watercourses and institutions of the Zambezi riparian states.

3.2 Institutions and Governance structures

Whilst the ZAMCOM Agreement was signed by 7 of the 8 Zambezi riparian states on 13 July 2004 in Kasane, Botswana, the Agreement, as of 31 March 2011, is yet to be ratified by at least two-thirds of the Zambezi riparian states as provided for within the Agreement. The ZAMCOM Secretariat has thus been established initially as an interim secretariat in Gaborone, Botswana on 1 April 2011, despite the fact that the Zambezi riparian states' agreed on the establishment of this ZAMCOM Interim Secretariat in February 2009. Therefore, when the final outputs of this Project are handed over at the end of March 2011 to the ZAMCOM Interim Secretariat for consideration for implementation, the ZAMCOM Interim Secretariat will still be finding its feet and will therefore need the immediate unwavering support of the Zambezi riparian states, the SADC Water Division and the ICPs.

The national or bi-national institutions' governance structures vary from country to country. For example:

- The ZRA was established by Zambia and Zimbabwe in 1987 and operates on the ZRA Acts of 1987 which give ZRA the mandate to manage the water resources of the common Zambezi River between Zambia and Zimbabwe;
- The ARA Zambeze was established in 2002 in Mozambique to manage the water resources of the Zambezi River in Mozambique;
- ZESCO Limited, which is a Zambian national electricity utility established as a corporation, is mandated to manage the water resources of the Kafue River, a major tributary of the Zambezi River;
- ZINWA, the national water authority in Zimbabwe established by an Act of Parliament in 2000, is mandated to manage all the water resources of Zimbabwe which include the major tributaries of the Zambezi emanating from Zimbabwe;.

- HCB is mandated to manage the hydrology of, and operate the Cahora Bassa Dam, for hydropower generation in Mozambique;.
- ESCOM, a Commission established by the Malawian Government, is mandated to manage the water resources of Lake Malawi and the Shire River, a major tributary of the Zambezi River, for hydropower generation: and
- Each of the eight Zambezi riparian states has a national Government Department with various responsibilities to manage the water resources nationally and internationally which include the water resources of the Zambezi River Basin. Some of these Government institutions still use inherited colonial legal instruments and water laws.

It should be noted here that the Zambezi riparian states have adopted the SADC Revised Protocol on Shared Watercourses (2003), the SADC Regional Water Policy (2006), the SADC Regional Water Strategy (2006) and seven of the eight Zambezi riparian states signed the ZAMCOM Agreement in July 2004. However, some Zambezi riparian states are yet to harmonise their national water sector policies, laws and strategies with those of SADC. The above scenario is not conducive and poses challenges for Zambezi basin-wide dam synchronisation.

3.3 Institutional capacities

Capacities within the various Zambezi River Basin water resources management institutions for hydro-meteorological data collection, data analysis, information dissemination, dam monitoring, operation and management, vary from institution to institution. The 2008 Zambezi IWRM Strategy and Implementation Plan (SADC 2008) observed that:

- the capacity of national water management institutions is weak to perform river basin management tasks;
- there is an inadequate water resources knowledge base for basin-wide development and management;
- there is inadequate effective stakeholder participation in water resources planning, development and management; and
- there are inadequate financial resources to attract and retain skilled staff and to facilitate operations.

The Consultant has also noted that some Zambezi riparian institutions have operational constraints like communication limitations such as lack of internet facilities. The above scenarios will definitely pose challenges for dam synchronisation in the Zambezi River Basin.

3.4 Trust and Confidence

Dam Operators need to have better confidence in the forecasting system that is available in the Zambezi River Basin for them to consider changing their current dam operating rules to facilitate environmental flows and release of water to enhance livelihoods. As mentioned earlier, the major dams in the Zambezi River Basin were designed for single purpose use with none designed to operate to provide water for nature, except for minimum river flows. Where humanly possible, the Dam Operators will need a forecasting system that will predict the forthcoming rainfall season as close to actual as is possible.

Apart from having confidence in the forecasting system itself, the Zambezi River Basin stakeholders need to have trust and confidence between themselves as institutions and in their related operations. This is of paramount importance if dam synchronisation is to be successfully introduced.

Table 3.1: Zambezi Riparian States Main Water Sector Legal Instruments and Shared Watercourses

COUNTRY	MAIN WATER SECTOR LEGAL INSTRUMENTS & POLICIES	SHARED WATERCOURSES/INSTITUTIONS
Angola	1. Environment Act (1998) 2. Water Act (2002) 3. National Water Resources Management Policy (2003) 4. Zambezi/ZAMCOM	1. Cunene/ Permanent Joint Technical Commission 2 Okavango/ OKACOM
Botswana	1. Boreholes Act (1956) 2. Water Act (1968) 3. Water Utilities Corporation Act (1970) 4. Public Health Act (1981) 5. National Water Conservation Policy (2004) 6. Draft Water Bill (2005) to repeal the 1956 Boreholes Act and the 1968 Water Act	1. Okavango/OKACOM 2. Zambezi/ZAMCOM 3. Orange-Senqu/ORASECOM 4. Limpopo/LIMCOM
Malawi	1. Water Resources Act (1969) 2. Water Works Act (1995) 3. Irrigation Act (2001) 4. National Water Policy (2005)	1. Zambezi/ZAMCOM 2. Songwe/Malawi-Tanzania Joint Technical Committee
Mozambique	1. Water Act (1919) 2. Water Act (1991) repealing the 1919 Water Act 3. National Water Policy (2007)	1. Zambezi/ZAMCOM 2. Zambezi/ARA Zambeze 3. Limpopo/LIMCOM 4. Pungwe/Pungwe Basin Commission 5. Ruvuma/Ruvuma Joint Water Commission 6. Inkomati-Maputo/Inco-Maputo Tripartite Permanent Technical Committee
Namibia	1. Water Act (1956) 2. Water Resources Management Act (2004) 3. Water Supply & Sanitation Policy (2008)	1. Zambezi/ZAMCOM 2. Orange-Senqu/ORASECOM 3. Okavango/OKACOM 4. Cunene/Permanent Joint Technical Commission
Tanzania	1. Water Utilisation Act (1974) 2. National Water Policy (2002) 3. Water Resources Management Act (2009) 4. Water Supply and Sanitation Act (2009)	1. Ruvuma/Ruvuma Joint Water Commission 2. Nile/NBI 3. Zambezi/ZAMCOM 4. Lake Tanganyika/Convention for Management of Lake Tanganyika
Zambia	1. Water Act (1948) 2. Bureau of Standards Act (1982) 3. Zambezi River Authority Act (1987) 4. Environment Protection and Pollution Control Act (1990) 5. Local Government Act (1991) 6. Public Health Act (1995) 7. Water Supply and Sanitation Act (1997) 8. Draft Water Bill (2006) to repeal the 1948 Water Act 9. Draft National Water Policy (2007)	1. Zambezi/ZAMCOM 2. Lake Tanganyika/Convention for Management of Lake Tanganyika 3. Zambezi/ZRA
Zimbabwe	1. Water Act (1976) 2. Zambezi River Authority Act (1987) 3. Water Act (1998) repealing the 1976 Water Act 4. ZINWA Act (2000) 5. National Water Policy (2000) 6. Environmental Management Agency Act (2003)	1. Zambezi/ZAMCOM 2. Zambezi/ZRA 3. Pungwe/ Pungwe Basin Commission 4. Limpopo/LIMCOM

Trust and confidence between institutions is usually established and nourished through implementing joint sustainable projects and programmes of mutual benefit and not just by signing Protocols, Agreements or MoUs.

3.5 Summary of issues gaps and constraints affecting dam synchronisation

Table 3.2 below summarises the identified issues, gaps and constraints that are likely to affect conjunctive and synchronised operation of the water infrastructure in the Zambezi River Basin for optimum utilisation and for the benefit of livelihoods and the environment.

The gaps and constraints identified may be considered as the "underlying risks" that need to be addressed and mitigated by the Zambezi riparian states, key Zambezi River Basin stakeholders and SADC for successful dam synchronization in the Zambezi River Basin. Every effort should thus be made by all Zambezi River Basin stakeholders to prioritise the elimination of these "underlying risks".

Table 3.2: Summary of Issues, Gaps and Constraints affecting Dam Synchronisation 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.

4 Execution of Project Tasks

To come up with the Recommendations that would address the Project's overall objective; the Consultant had to undertake a total of eleven main Tasks. The details of the work done under each of the eleven Tasks are contained in Annexes 1 to 4 of the Main Report and are summarized below as follows;

Task 1 sought to collect and collate **data and information** to serve the objectives of this Project and ensure that the collected data and information was stored in a way that was available and accessible during the Project to other team members and for use after this Project. Task 1 was carried out in the Inception Phase of the Project. On completion of the exercise, the Draft Final Output 1 Report was submitted to the Client on 8th April 2010. Further data and other information were obtained, analyzed and compiled as the Project progressed and the complete finalized list is presented in Annex 1 of the Main Report. This additional data and information were obtained from the consultation meetings referred to above, telephone contacts and questionnaire surveys, which were conducted between April and October 2010. The consulted Zambezi River Basin key stakeholders also committed specific staff members to attend to any additional requests. The meeting notes of these consultations were circulated to all stakeholders.

Task 2 focused on **"Long cycles and climate change".** The main purpose of this Task was to provide insight into the effects of climate change on dam operations in the Zambezi River Basin. The work undertaken under this Task captures the cyclic behaviour in annual rainfall and the consequent periods of wet and dry years as reported by many authors, but the studies differ on the duration of the cycle periods mainly because of the limitations in the length of time series data considered in the analysis. Due to limited time series, it is not clear if the rainfall patterns depicted are indeed cyclic behaviour in annual rainfall or autocorrelation in annual rainfall in combination with the intra-annual influence of wetlands and groundwater levels.

Task 3, whose objective was to provide **insights and recommendations for improved precipitation and flow forecasting in the Zambezi River Basin**, was sub-divided into five parts as follows:

- Task 3A – Identification of the requirements for flow forecasts;
- Task 3B – Evaluation of the existing weather/gauging station network and recommendations for improvement;
- Task 3C – Design of a forecasting system for precipitation and flows for the Zambezi River Basin;
- Task 3D – Advantages, costs, locations and financing options of an improved flow forecasting system; and
- Task 3E – Demonstration of a pilot model of the Zambezi River Basin precipitation and flow forecasting system using the Deltares FEWS software.

Task 3A focused on the ***"Identification of preliminary requirements for flow forecasting by stakeholders".*** Flow forecasts are required by a wide range of authorities and organisations including dam operators, power companies, disaster management agencies, water related state agencies, and tourism and wildlife agencies. The forecast requirements which were identified in Task 3A included lead times, locations, timeframes (short-term, medium-term, seasonal) and data requirements (input parameters for forecasting, such as flow and precipitation).

Data requirements for each forecast location were derived – these include observed precipitation, observed flows and levels, observed releases from reservoirs, forecast precipitation and forecast releases. Annex 3 gives more information on data requirements for each forecast location and corresponding forecast timeframes.

Task 3B focused on the ***"Evaluation of the existing weather and stream flow gauging networks in the Zambezi River Basin and identification of requirements for upgrading and extension of these networks to meet improved forecasting requirements in the entire Basin".*** The main purpose of this Task was to evaluate the existing weather and flow monitoring networks and compare the coverage and capability of these networks with that needed for forecasting at the identified forecasting locations at the required timescales. The evaluation was based on data obtained both from ZAMWIS and directly from stakeholders, such as Dam Operators and Meteorological Services Departments. The evaluation was based on the following main criteria: coverage, reliability, transmission of data and sustainability. The evaluation of the precipitation network included consideration of the possibility of using existing satellite rainfall technology as an alternative to ground based measurement. With respect to the flow monitoring network, the main outcome of this Task was a list of proposed gauges for basin-wide monitoring. Evaluation of the weather monitoring network resulted in a proposal for the establishment of SRE in certain areas.

Task 3C focused on the ***"Design of a forecasting system for precipitation and flows in the Zambezi River Basin".*** This Task looked at the following key issues:

- *Capabilities in the SADC region*: this sub-task included an evaluation of the current expertise and capability in precipitation forecasting in the SADC region and whether this would be adequate for a basin-wide operational flow forecasting system.
- *Design of a forecasting system for flow*: this sub-task focused on data and model requirements for each of the identified forecast locations (Task 3A) integrated into a single forecasting system.
- *Current capabilities in flow forecasting*: this focused on a preliminary evaluation of existing forecasting models and methods in the Basin, based on information from a number of sources.
- *Recommendations for improvements in integrated forecasting*: this sub-task focused on a comparison of the existing capabilities in forecasting with the needs of a basin-wide forecasting system, including requirements for the development of new models.

Task 3D dealt with ***"Investigating the advantages, costs, possible locations and financing options so as to come up with recommendations for establishing a Flow Forecasting Centre for anchoring an improved flow forecasting system in the Zambezi River Basin".*** The prerequisites for a good flow forecasting system is that it should be reliable, cover the short and medium term as well as seasonal time scales, easily transmit data and information to other users and be convertible by different users for their needs. As an example, the flow forecast should allow Dam Operators to better anticipate future inflows, allowing them to optimise the use of hydropower generating capabilities and allowing them to implement environmental flows. The flow information should also allow Disaster Management Units to respond to flood and drought events timeously and effectively.

There is therefore need to establish a Flow Forecasting Centre that will be the custodian of a basin-wide flow forecasting system that integrates hydrological and meteorological data to predict future flows and water levels. The Centre would also be responsible for sharing the information to all stakeholders. The Flow Forecasting Centre can be established as part of ZAMCOM. Additionally, a Flow Forecasting Centre can serve as a centre of excellence in operational management of the Zambezi River Basin, providing a facility that not only supports exchange of data, but also exchange of experts between stakeholders, and to facilitate research on improvement of water resource management in the Basin.

Approximate costs for establishment of a Flow Forecasting Centre based on 2010 prices were estimated. These were divided into capital (investment) costs (Table 5.6) and operating costs (Table 5.7). Further information is provided in Section 5.3 of this report and in Chapter 8 of the Annex 3 Report.

Task 3E focused on the ***"Development of a demonstrative pilot forecasting system for the Zambezi River Basin".*** The objective of this demonstration pilot forecasting system was to show how the stakeholders within the Basin could use information to improve the coordinated response to the management of water resources and flood/drought events. A selected past flood event was used for demonstration purposes showing what information could have been provided by such a forecasting system, and how this could have helped in decision making on synchronised release strategies in the major reservoirs in the Zambezi. The 1999-2000 flood event was selected which was primarily caused by Cyclone "Eline". The pilot system was configured using the forecasting shell Delft-FEWS. Annex 3 provides further details.

Task 4 investigated the **"Retention capabilities of wetlands on the Zambezi River Basin, potential impacts of climate change scenarios on the wetlands and the establishment of environmental concepts for incorporation in dam management".** The three wetlands of the Zambezi River Basin investigated were the Barotse Flood Plains, Chobe Swamps and Kafue Flats. These wetlands, apart from flood retention, have important ecosystem functions. Both human and wildlife have historically depended on these wetlands besides their hydrological functions in regulating flows and attenuating floods. The attenuation capacities and lag times are important for flow forecast information for Dam Operators. The effects of land use and water resource management practices on the wetlands have been enormous and these can affect the attenuation rates.

Task 5 was concerned with the **"Regulation and operation of existing large reservoirs in the Zambezi River Basin".** This Task investigated the possible improvements or changes in the current operations of the existing dams in the Basin in order to improve the control of flood releases and releases for the environment. The main Dam Operators of the Zambezi River Basin are the Zambezi River Authority (ZRA) for Kariba, Hidroeléctrica Cahora Bassa (HCB) for Cahora Bassa, Zambia Electricity Supply Company (ZESCO) for Kafue and Itezhi-Tezhi, Zimbabwe National Water Authority (ZINWA) for dams on Zambezi tributaries in Zimbabwe, the Electricity Corporation of Malawi (ESCOM) for barrages and diversion weirs/dams in Malawi and various other individual operators. Three major reservoirs in the Zambezi River Basin were considered, namely; Kariba, Cahora Bassa and Itezhi-Tezhi/Kafue Gorge. These dams have been operated in isolation, without regard to other stakeholders in the Basin, the environment, downstream or upstream riparian countries and other users. To accommodate all stakeholders and concerns, the dams have to be operated differently with new operating rules. Operating rules can be used to specify the amount of water to be released/abstracted/stored over a given period. Operating rules have to consider the storage at the time of making the decision, probability of occurrence of certain inflow being received and losses from the reservoir. Major challenges are posed by high variability in precipitation and hence inflow, as well as evaporation from the reservoir, changing water demands and climate change/variability.

One of the objectives of Task 5 was to review the current Dam Operators' joint "Operational Rules or Regulations". The main concerns in any cooperation arrangement are around risk, cost and benefit sharing. Changes in modes of dam operations require sharing of costs, risks and benefits as all organisations want to benefit and minimise risks and additional costs. For a lasting cooperation, a system has to be developed where costs, risks and benefits are shared, reviewed and updated when conditions change.

Task 6, **"Regulation of the Shire River and Lake Malawi"**, was split into two parts, Task 6A and Task 6B.

Task 6A investigated the ***"Regulation of the Shire River and Lake Malawi"*** by considering the possible rehabilitation of Liwonde Weir (Kamuzu Barrage) to regulate the Shire River and Lake Malawi more efficiently. Lake Malawi is of fundamental importance to Malawi, Tanzania and Mozambique and for Malawi, the Shire River and Lake Malawi together represent the country's single most important natural resource system. Lake Malawi supports fishing and navigation industries. Hydropower plants located in the Lower Shire produce about 95% of Malawi's electricity requirements. In addition, agriculture, tourism and recreational activities are dependent on the system.

The discharge from Lake Malawi into the Shire River is presently regulated by the Kamuzu Barrage. The operating rule produces almost a constant flow (annual wave) in the Shire River to satisfy hydropower generation requirements. The firm flow downstream of the Shire River to satisfy hydropower production is 170m^3/s but 300m^3/s is required to accommodate transmission losses.

Task 6B investigated the ***"Interventions to improve the operation of the Lake Malawi/Shire River subsystem"*** . The proposed investments for Shire flow regulation identified in the ToRs are the upgrading of the Kamuzu Barrage which would increase the operating level of the Kamuzu Barrage and improve possibilities for operation, and a pumping scheme at Mponda that would allow for pumping water from Lake Malawi whenever the lake levels are too low to allow adequate outflow for power generation. It was concluded that the Kamuzu Barrage was never designed for flood control. Therefore the flood control advantage of the upgrading is only in the improved possibilities for operation during floods.

The ToR asked for an assessment of the impact of floods on the hydropower generation on the Shire. In the past, debris was not removed efficiently around the intakes, thereby damaging the Tedzani stations. Monitoring of pressure differences at the intake and adjusting intake structures has improved the risk of failing power production during floods.

The alternative investment of building Kholombidzo Reservoir was investigated and potential benefits and points of concern were highlighted. During the execution of the Project, it became clear that investments in the Malawi – Mozambique interconnector would result in less power dependency on the Lake Malawi/Shire River system. Additionally alternative investments in diversion of floods on tributaries (Ruo in particular, via Elephant Marshes) were identified.

Task 7 focused on the **"Identification of new Multipurpose Dams on the Zambezi River and its tributaries"** which would contribute to flood mitigation whilst serving other purposes like enhancing livelihoods. Possible worst case scenarios for flooding were identified. The potential contribution of the proposed multi-purpose dams to improved dam management and addressing basin-wide objectives was also evaluated. The study identified a number of possible interventions comprising of new dams, new power plants and extensions to existing power plants.

Task 8, **"Synchronization of Dams for flood releases",** was split into two parts, Task 8A and Task 8B.

Task 8A focused on arriving at ***"Concepts and recommendations for synchronization of dam operations that would improve the management of flood releases and environmental flows".*** Synchronization and conjunctive operation of dams are two terms which have become associated with water resource system management interventions to achieve these goals. Synchronization relates to timing of actions (near real time) in order to achieve or avoid an outcome which is certain to occur at a known position in space and time. Conjunctive operation on the other hand relates to getting different parts of a system to support each other or to support other systems in order to meet requirements such as quantity and/or quality of water.

In the current practice, the main issues have been that each Dam Operator wants to have as much water as possible stored in their dams for annual hydropower generation commitments as this is their revenue base. In order to protect the walls and stilling pools of the dams, certain storage levels cannot be exceeded and in the past, this has resulted in emergency releases. For efficient hydropower generation, dams are operated at high water levels and unpredictable inflows have caused unplanned flood releases. If the flood releases from Kariba, Luangwa and Kafue peak at the same time along the Zambezi, serious flooding can occur. Emergency flood releases from Cahora Bassa can also cause flooding. Task 8A thus focussed on how to synchronize operation of the dams in order to avoid these situations whilst optimizing operations for hydropower generation as well as reviewing the current MoU being used by the Dam Operators with a view of suggesting any improvements.

Task 8B focused on ***"Evaluating the need for an additional spillway at Cahora Bassa Dam".*** The additional spillway planned in conjunction with the North Bank Power Station Extension of Cahora Bassa makes it possible to adjust to a flat flood rule curve for the reservoir. The existing rule curve lowers the water level before the flood season, as the current spillway cannot accommodate the full design flood. Maintaining a flat rule contributes to power generation, but increases the size of the maximum flood that can pass the reservoir. Both the upstream and downstream impacts on the environment were evaluated.

Task 9, "Potential of New Flood Protection Measures and Risk Zoning", focused on flood risk zoning methods and constructive flood protection measures. Flood risk zoning is, in contrast to most other investments in this Project, not a structural investment. To undertake flood risk zoning is however an investment. The vulnerability of the Zambezi River Basin with respect to flood risk has three different aspects; the vulnerability of the population, the vulnerability of capital investments and the vulnerability of wildlife. As per the ToR, two case studies were conducted, one in the Chobe River floodplain in the Caprivi Strip and the other in the area around Caia in Mozambique. For these case studies, maps were created to demonstrate what zoning classification could be used. This is detailed in Annex 4 of the Main Report.

The risk zoning methods investigated related to the different approaches for flood protection:

- Prevention: zoning to set rules for new developments;
- Preparedness: zoning to give advice or set rules for land use practices and for awareness raising among current inhabitants;
- Preparedness: zoning to inform insurances; and
- Warning and rescue: risk zoning to use during emerging flood events to set priorities.

Task 10, **"Sediments",** was split into two parts, Task 10A and Task 10B.

Task 10A was concerned with ***"Sediments for nature, the impact of existing dam operations on sediments and sedimentation"***. The fertility of the floodplain areas is dependent on the organic suspended solids that are deposited during floods. The fertility of floodplains is what draws people into these areas to the extent that they risk flooding in order to crop on fertile soils. The amount of organic soil deposited on the flood plains has been reduced significantly following the damming of the Zambezi and its major tributaries. The sediment now deposited by the Zambezi is perceived by the locals as sandy, 'non-fertile'. Sandy sediments are not necessarily caused by the construction of dams, but are also due to local soil erosion and conditions. The transportation of nutrients as sediments was investigated under concepts and the purpose of environmental flows in Task 5 where the impact of historical releases on flow requirements for the environment and availability of sediments was also discussed. Improvements in environmental flow management can improve availability of sediments for fisheries, agriculture and growth of vegetation to support wildlife.

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 Zambezi River Basin, except for Kariba, suggest that they cannot store major floods. The smaller dams will pass major floods together with their sediment load and 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. Bottom outlets for sediment flushing are not desirable for large dams. However, the new dams on the unregulated tributaries of the Zambezi should consider bottom outlets for release of minimum flows (contributing to environmental flows), sediment release and water quality management

The tributaries downstream of the major dams carry fine sediments to the main stem of the Zambezi River, but deposition of these fine sediments on the floodplains can only happen when the floods in the tributaries coincide with floods in the main stem of the Zambezi River. Increase in the intensity of rainfall due to climate change, as discussed in detail in Annex 2, will result in increased sediment loads with resultant negative impacts on reservoirs.

Task 10B focused on ***"Bottom outlets in new dams: their benefits, costs and usefulness".*** Bottom outlets are useful and are specified as a requirement in Zimbabwean dams. Bottom outlets are designed to prevent full siltation of the dam in order to maintain a live storage (and therewith release some sediment during the flood season), reduce the turbidity of the water for potable water supply, provide for environmental releases, and allow for the lowering of the lake water level in the dam if this is necessary for dam safety purposes. The use of bottom outlets as a means of flushing sediment from reservoirs created by new dams was explored for the Zambezi River Basin. Complications of flushing for the benefit of the environment downstream have been identified.

Task 11 focused on the **"Diversification of the Electric Power Pool"** with particular reference to investments in the energy grid, power plants and coordination of power generation. During the wet season, tributaries downstream of the hydropower producing dams may be in flood. In such cases the release of dam water for hydropower generation is undesirable. Thermal power plants could help in generating additional energy at such times to compensate for the times when it may become desirable to shut down the hydropower turbines to keep flows downstream to a minimum. This task thus dealt with possible alternate energy options in order that hydropower plants can be considered for use in flood control. The operational costs of buying and selling were compared. The constraints and possibilities of the SAPP network were identified.

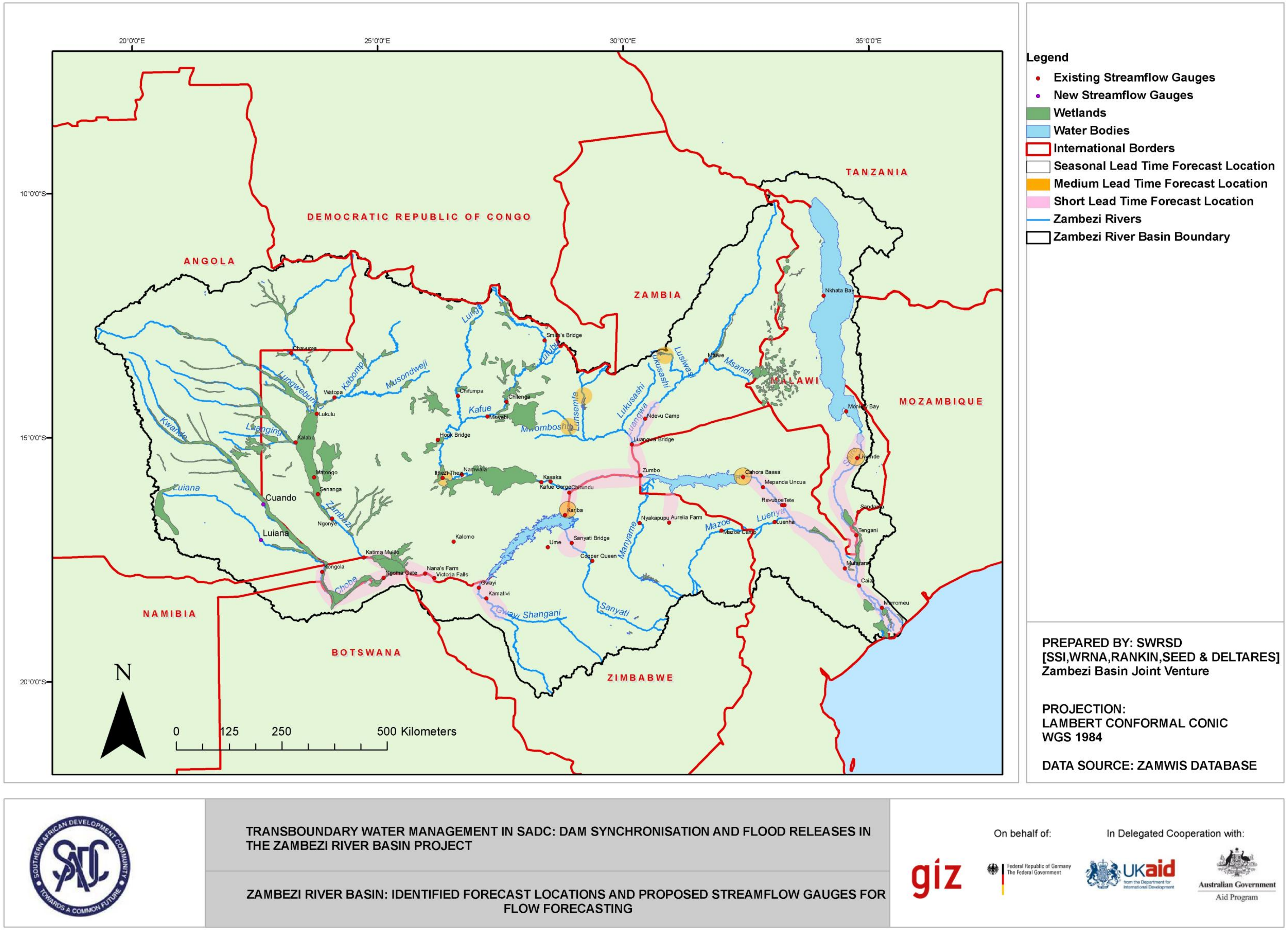

Figure 4.1: Map of identified forecasting locations across the Zambezi River Basin with lead time requirements and proposed streamflow gauges

5 Project's Consolidated Findings

This section presents the major Findings of the Project that drive or trigger study/research to enable various specific Recommendations to be reached. The Project's Findings have been grouped into the four output areas of: Data and Information sharing, Dam Management, Precipitation and Flow Forecasting and Investments.

5.1 Data and information sharing

Several attempts have been made in the past to compile data and information related to the Zambezi River Basin. This includes the Zambezi River Basin Information System (ZACBASE) developed under ZACPRO 6.1 project, which was lost due to hardware complications. Its successor, the Zambezi Water Information System (ZAMWIS) was formalized in the 2nd Phase of the ZACPRO 6 Project. ZAMWIS has been dormant from April 2009 until 31 March 2011 as it awaited the establishment of its host, the ZAMCOM Interim Secretariat. The Zambezi River Basin data and information as at end of March 2009 is however, available on DVD. The literature, data and maps which ZAMWIS contains, were carefully reviewed during execution of the Project. Strengths and deficiencies within the ZAMWIS database were identified and are presented in detail in Annex 1 of the Main Report. In addition, supplementary literature, data and maps, which were obtained or produced during the execution of this Project, were compiled and are included in Annex 1 of the Main Report.

To ensure that data is effectively managed and systems are in place for its collection, storage and sharing, a centralized system should be adopted by the Zambezi riparian states. ZAMWIS is the most recent information management system prepared for basin-wide data storage and sharing. It should be resuscitated, improved and integrated into the operations of all stakeholders, with mechanisms put in place to regularly update it with data, literature and reports, as well as maps, and any other relevant information.

To resuscitate ZAMWIS, the interim ZAMCOM secretariat needs only to pay the necessary fees for hosting the server-hosted database's website domain. Once these fees are paid, ZAMWIS will be up and running again and accessible to the Zambezi Basin stakeholders. Improvements can be made to upgrade ZAMWIS by enhancing the current windows-based interface of ZAMWIS, allowing for ease of access to data and updating of information. The data contained in ZAMWIS should also be cleaned and patched whilst extending the available observed data and carrying out statistical analyses of stream flows to inform dam operations. ZAMWIS should also be linked to other regional databases like the SADC-HYCOS. The ZAMCOM Secretariat (interim/permanent) should put in place the mechanism to regularly update ZAMWIS with data, and reports, as well as maps, etc.

5.2 Dam management

5.2.1 Objectives

The main objective of Output 2 (Dam Management), as detailed in Annex 2 of the Main Report, was to provide "Concepts and Recommendations for Dam Management" which seek to achieve the following:

- Improve the modes of operation of the dams on the Zambezi River in order to contribute to the balancing between the interests of environmental flows, flood reduction, hydropower generation and agriculture; and

- Improve cooperation between Dam Operators by providing them with new insights, methods and tools that improve confidence in their operations.

5.2.2 Consolidated Findings

Floods and droughts

The low storage to mean annual runoff ratios of most existing dams in the Zambezi River Basin, except for Kariba, suggests that such dams cannot store major floods. Flood-plain farmers have resettled close to the main-stem Zambezi to cultivate crops in the narrow band of alluvium that is inundated each year. The near elimination of medium-sized flooding events has resulted in farmers moving further into the flood plain under the perception that the large dams can control large floods. This has contributed to increased flood damage when large floods occur. Flood-plain agriculture is also practiced on some of the tributaries of the Zambezi River and it is also affected by rises in water levels during flooding. The risks can be mitigated by education and awareness campaigns, regulation and enforcement of flood zoning. This is the concept of "living with floods".

The record of reservoir outflows versus inflows dispels the notion that the frequency of floods and magnitude of flows have increased because of dam operations. The timing of releases and lack of appropriate responses have increased the risk of flooding and the social and economic severity of large flooding events. Improving the timing of releases and monitoring response would help.

The history of floods in the Zambezi River system shows that flooding is experienced throughout the Zambezi but the frequency and severity depends on local conditions. In the Upper Zambezi, the Kabompo River and the Zambezi tributaries between Senanga and Katima Mulilo contribute significant flows. In the Middle Zambezi, tributaries between Kariba and Victoria Falls, mainly Kalomo, Gwayi, Ume and Sanyati Rivers, and downstream of Kariba, the Kafue, Luangwa, Msengezi, Manyame and Machanga, discharge very high flows. The lower Zambezi has the Shire, Luia (two tributaries called Luia), Revubué, Mazowe/Luenya, Muira and Pompue tributaries which can also discharge very high flood flows. Even floods that are moderate by historical standards such as the 1989 and 1997 floods (about 10,000 m^3/s at Mutarara) resulted in extensive flood damage. Some of the serious flooding emanated from tributaries which do not have large dams. The construction of new dams on the unregulated tributaries would help to alleviate this impact.

For the unregulated tributaries, construction of new dams provides important points for flood monitoring as well as for local flood mitigation, providing opportunities for agricultural production and enhancement of livelihoods. The main purpose of most of the dams is not flood control, but for other water management objectives:

- The Gwayi-Shangani dam is for water supply to Bulawayo and for irrigation;
- The Kudu dam is designed for irrigation and domestic water supply;
- The dams on the Luangwa River may have negative economic and environmental impacts because of the flooding of nature parks. The dams can contribute to hydropower generation for local consumption but will have very positive flood attenuating effects for Cahora Bassa;
- The dam sites identified on the Luia and Revubué Rivers have positive local flood control impacts, but there is a need for irrigation water as well. Optimizing irrigation could require other additional dams; and
- The dams on the Mazowe would be primarily for irrigation purposes.

In terms of flood protection, measures on the Shire River tributaries and improved flow forecasting will be more promising than infrastructural works on the main Shire River itself. Apart from flood protection and hydropower production, flow regulation will enhance the functioning of the Shire River as a waterway. These are both important considerations for Malawi.

Proposed power station extensions can allow operators to better manage incoming high flows by releasing flows through turbines thus avoiding loss of water for power generation. ZESCO has planned investments in extra hydropower capacity for Kariba North (360 MW) and Itezhi-Tezhi Hydroelectric Project (120 MW). ZESA has planned extra hydropower capacity for Kariba South (300MW). For Cahora Bassa, HCB has planned a North Bank Extension (1200MW).

The newly planned dams on the Zambezi and Kafue Rivers are designed for power generation. The Batoka Gorge dam (1600 MW), the Mphanda Nkuwa dam (1800 MW) and Kafue Gorge Lower (600 MW) are furthest in the decision making process and are technically feasible. Effort to ensure financial viability of these dams may lead to operating rule curves which are not optimal from a flood control perspective, even though every new dam within the Basin may provide improved ability for flood control and allow operators better management of incoming high flows. New dams on the Zambezi main stem such as the Batoka and Mphanda Nkuwa and on the tributaries such as the 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.

New modes of dam operation

The most serious risk to flooding is the lack of appreciation that floods have not disappeared with the construction of the major dams. Floods and droughts will always occur but patterns and magnitude may differ. The upstream and downstream impacts of floods and droughts can be minimised by the development and implementation of appropriate modes of dam operation.

The Zambezi River Basin is a complex system which supports various economic activities including hydropower, irrigation, fisheries, navigation and tourism. In addition, the system experiences hydrological cyclicity; floods and droughts. Infrastructure on the system such as dams and barrages makes the system amenable to regulation. However, the existing infrastructure has largely been operated in a stand-alone mode with narrow objectives and a consideration of a single hydrological year. This operating mode is undesirable because it increases system vulnerability to threats from variability in climate. This Project proposes new modes of dam operation in the Basin that simultaneously address different objectives including dam safety, hydropower production, drought and flood management and the needs of the environment with due consideration for hydrological cyclicity.

The current operation rule curve of the Kariba Dam specifies the need to reserve sufficient storage space at the beginning of the rainy season to store peak flows (floods) and to avoid peak discharges through the floodgates. Opening the Kariba floodgates is extremely undesirable because of the following:

- For hydropower generation, the rise of the tail-water level associated with the opening of one floodgate reduces the net head by about 5 m, and thereafter by 3 m for every additional gate opened;
- For dam safety reasons, the vibrations caused by very high discharges through the floodgates should be avoided;

- Extremely high releases may endanger the populations living downstream and create operational problems at the Cahora Bassa Dam; and
- The plunge pool, which is the energy dissipater for the spilling waters, is currently only stable with three floodgates open. Opening more than three floodgates for prolonged periods may cause further erosion of the plunge pool necessitating very expensive underwater rehabilitation/maintenance works.

The objective of the existing Cahora Bassa rule curve is to ensure sufficient storage space for flood water and release of water for maximal hydropower production. This rule curve does not take environmental flow releases into consideration. Incorporation of environmental flow releases in the operating rule curve of Cahora Bassa was first proposed by SWECO in 1982 (SWECO, 1982) by creating storage in the months of December to June as compensation for the release of freshets in February. But these proposals have not been implemented to date.

The aim of the original operating rule curve for the Kafue Gorge and Itezhi-Tezhi dams, developed by SWECO, were to maintain maximum storage levels for both reservoirs in order to maximize hydropower production. The drought of 1991 resulted in low water levels in both reservoirs and resulted in power failures. The operation rules were then revised in 1994 through the SADC AAA 3.4 project to avert such power failures during dry years. The operation rule curve was later fine-tuned in 2004 through a WWF study with a view to achieving better congruence with the ecological requirements of the Kafue Flats located between the two reservoirs. Current practice at Kafue Gorge reservoir is to maintain a constant high water level for hydropower generation. The existing operating rule also considers drawing down the water level at Kafue Gorge, which reduces dam surface area and hence evaporation, minimizing early releases from Itezhi-Tezhi to preserve water for freshets to be discharged from Itezhi-Tezhi into the Kafue Flats. The Itezhi-Tezhi/Kafue Flats/Kafue Gorge system is unique in that it is located within one country and as such, dam operating rules of this system can be implemented more easily. However, lessons from operating this system, if successful, can later be adapted for replication on the Kariba/Mana Pools/Cahora Bassa system.

Table 5.1: Existing models considered in this study and their limitations

Model	Description	Identified Limitations
HEC-3	A reservoir operation model developed by NIRAS-BRL for the World Bank.	The model was incomplete and a complete description of the set up was not available.
WEAP	A water balance model available in the ZAMWIS database.	The model is for a water balance assessment and the time-step is not suitable for flood studies. It is also a work in progress. Updating and configuring the model to address the objective of management of flood and environmental flows would require detailed studies.
ZRA Flow Forecasting	This comprises a regression equation (wet season) and an exponential equation (dry season) to estimate flows at Victoria Falls. The wet season equation uses observed flow at upstream gauge stations namely: Chavuma, Matongo Platform, Watopa and Kalabo whereas the dry season equation uses the flow observed during the previous month as input.	The model algorithms are limited to estimating flows at Victoria Falls but it is not clear how the inflow from the Kariba sub-basin are incorporated into the Lake Kariba water balance.

A major limitation of the dam operating rules described above is that they have narrow objectives (primarily dam safety and hydropower production) and only consider a single hydrological operation year. This is inadequate considering the multiple purposes of the dams/reservoirs and cyclicity of the Zambezi River Basin hydrology. A shift towards multi-objective and multi-year operating modes is therefore logical. However, multi-objective operating modes will inevitably result in trade-offs while the high climate variability of the Basin, limited forecasting capabilities, and poor historical data, pose a challenge to adopting a longer operating window. There is also limited understanding and use of statistical tools for estimating reservoir trajectories. Such statistical tools can be used to define desirable trajectories for periods exceeding one year.

The models reviewed for reservoir operation and flood management are incomplete and significant effort is required to update them. The models considered for application on this study and their limitations are shown in Table 5.1 above.

The application of other models such as the Hugo Model and the HDAM has been limited to the developers only.

The operation of existing dams on the Zambezi River System places high priority on dam safety and provision of water for hydropower generation. This Project has shown the need to incorporate flood protection, environmental requirements and other uses which contribute to the improvement of socio-economic conditions. However, each of these other water uses has different links to the water resource system which needs to be kept in balance through a multi-objective procedure. Multi-objective operating rules would provide an answer on how dam management can incorporate the other uses. Table 5.2 includes six new objectives identified in this Project.

Table 5.2: Operating objectives of the Zambezi River System.

Objective	Description
Objective 1	Dam Safety: Manage releases to avoid the reservoir reaching unsafe levels. Provide adequate capacity to safely storing and pass the design flood.
Objective 2	Hydropower: Provide adequate head and firm yield for electricity generation. Failure of Hydropower has severe socio-economic consequences beyond the Zambezi basin riparians.
Objective 3	Flood management: Avoid loss of life and reduce socio-economic impacts.
Objective 4	Environmental management: Maintain flow characteristics. Provide quantity and quality of water required to maintain ecosystems and enable them to provide sustainable services and good quality water.
Objective 5	Dry season floodplain agriculture: Accommodate harvest period in flow release management.
Objective 6	Plantation irrigation: Provide adequate yield for crop production.
Objective 7	Navigation: Provide adequate flow for large ferry boats.
Objective 8	Other water users: These can also have their own sets of priorities according social considerations such as elimination of poverty and economic benefits.

The major dams on the Zambezi River system are currently only being operated to fulfil objectives 1 and 2 in Table 5.2 above, except on the Kafue sub-system where environmental releases for the Kafue Flats have been considered. This is because objective 1 supersedes all other objectives while objective 2 currently provides the highest economic benefits for the riparian countries in respect of hydropower production. The extent of inclusion of the remainder of the other objectives requires an appropriate weighting system to be agreed upon by the affected stakeholders to facilitate trade-offs and win-win solutions.

The incorporation of all the objectives in Table 5.2 in dam operations allows stakeholders to engage on how Dam Operators make decisions during floods and droughts and dispel the suspicions in current operations. A preliminary indication of the impact of implementing these objectives was obtained by trying to address the expectations of some of the eight potential water uses in Table 5.2 while not compromising safety of dams and minimizing the reduction of hydropower output and based on the historical operations of the major dams on the Zambezi. This informed the scope to accommodate the "new" modes of operation which incorporate flood and environmental management and other uses.

This study shows that it is possible to develop "new" modes of dam management from a flood protection perspective to address the timing of releases through the following actions:

- Managing releases to provide early warning (e.g. an early minor release, say only one gate opening) to warn downstream riparian communities of the onset of flooding;
- Adopting a downstream to upstream dam draw-down sequence (e.g. downstream dams draw down first and provide storage space for floods) to allow dams immediately upstream of floodplains to capture floods; and
- Draw down levels should minimize loss in hydropower generation capacity. The upstream dams could be operated for optimum hydropower generation so as to replace lost power generation of downstream dams. This ultimately means that upstream dams would generate more hydropower at the expense of downstream dams, necessitating compromises and trade-offs.

The current negative impacts of dam operations could be mitigated by operating existing dams considering some of the following water demand characteristics of the various users:

- Adjusting flood release patterns to accommodate the harvest period for floodplain agriculture;
- Providing specific flood releases, of size and timing, to achieve E-flows; for example floods released from dams can be timed to augment each other thereby providing much needed (but naturally rare) larger floods. These are generally called prescribed floods. These floods are required for management of salt intrusion on the delta coastline for instance;
- Providing adequate flow for navigation in the rivers; and
- Providing adequate water for commercial agricultural needs.

However more detailed studies are recommended to inform the practical application of these "new" modes of operation. These recommended studies are detailed in Annex 2 of the Main Report.

Cooperation Protocol between Dam Operators

At present, the major Dam Operators and Power Producers on the Zambezi river namely: ZRA, HCB, ZESA and ZESCO have a technical platform for cooperation called the Joint Operation Technical Committee (JOTC). ZINWA and ARA Zambeze are also part of the JOTC. This corporation arrangement also includes an MoU to provide for executive decisions to consider recommendations from this technical committee. The JOTC is focused on the operations of the Kariba, Kafue and Cahora Bassa dams and excludes the Lake Malawi/Shire River system.

The JOTC has held scheduled meetings on cooperation. This existing cooperation arrangement is guided by a Draft Memorandum of Understanding (MoU) which was reviewed in Table 5.3 below. The purpose of the review of this Draft MoU was to provide comments and recommendations on the following parameters: representation, vision, objectives, action plan, obligations, enforcement, financing, and communication strategy to ensure that the concepts of cost, benefit and risk sharing are adequately embedded. The realization of the new modes for reservoir operation proposed in this Project will require a revised Cooperation Protocol for the Dam Operators and Power Producers.

Table 5.3: Review of existing Draft MoU of the JOTC and recommendations for improvements

Parameter	How the parameter is addressed	Comments and recommendations on cost sharing	Comments and recommendations on risk sharing	Comments and recommendations on benefit sharing
Vision	To ensure the greatest possible benefit from the efficient utilisation of the Zambezi River.	Cost sharing not explicitly mentioned.	Risks sharing not explicitly mentioned.	Benefits to be recognized through provision of water to meet socio-economic and hydropower requirements.
Objectives	To set a framework for collaboration and information exchange between members to ensure informed management of the water resources.	Cost sharing not explicitly mentioned. Collaboration and information exchange can open up discussions on benefit sharing.	Risks to safety of dams, hydropower supply and flooding are recognized. Timely sharing of information can enable different stakeholders to manage their risks. The JOTC should consider how dam operations can meet system-wide objectives.	Clear objectives and procedures on benefit creation and sharing can open up stakeholders to collaborate and exchange information. System-wide objectives should be considered.
Representation	To qualify for membership of the JOTC, an institution should be a water manager or large dam operator in the Zambezi River Basin. Presently the following organizations constitute the JOTC: ZRA, ARA-Zambeze, ZESCO, HCB, and ZPC.	The parties represented in the JOTC are primarily the Power Producers and Dam Operators on the Zambezi main stem. The current focus is clearly on water management for hydropower production and dam safety.	It is not clear how operators of dams and collectors of hydrological and rainfall data on the tributaries such as Water Authorities/Managers and Meteorological Departments are engaged. Disaster Management Agencies are not represented which presents challenges in implementing risk management interventions. Other fora are required to address these issues.	Environmental Management Agencies are not represented. Environmental requirements may not be implemented or monitored. The vision cannot be realized with the current stakeholders alone.
Obligations	1. Timely information exchange in agreed format and frequency. 2. Regularly update each other on the reservoir operation schedules 3. Sharing of expertise in implementation of tools for reservoir operation and environmental protection 4. Regular sharing of expertise and experiences in dam safety monitoring and analysis 5. Agreement on special working provisions in case of floods, droughts and any other emergency situations.	Data collection carries a cost. The obligations will ensure knowledge exchange and may eventually result in standardization of dam operations and response to emergency situations.	The time frames are not defined and type of information to be shared is not defined. There is no reference to a shared risk management framework. Responsibilities for actions need to be negotiated and agreed. Obligations on other stakeholders such as Water Authorities/Managers and Meteorological Departments on collection and sharing of climatic and flow data are not clear. The MOU should recognize other relevant fora and provide for formal linkages.	Obligations on knowledge sharing can result in benefits to all parties.

Parameter	How the parameter is addressed	Comments and recommendations on cost sharing	Comments and recommendations on risk sharing	Comments and recommendations on benefit sharing
Enforcement	The Member Institutions will work together with reasonableness and honesty of purpose to establish and maintain a relationship of mutual benefit based on goodwill, cooperation and partnerships.	Members are able to engage and enforce collection of funds for shared items/activities.	The MOU is entirely dependent on the goodwill of Members. Moreover the Members are free to withdraw upon giving notice. As such, a Member is likely to implement only the resolutions which are beneficial to them. The vision may be difficult to achieve.	Enforcement of benefit sharing can make stakeholders more accountable to each other and to the achievement of system-wide objectives.
Financing	Member Institutions shall meet their own expenses.	This is rather a limited view possibly focused to participation in JOTC only. Upstream and downstream movements of costs need to be monitored as the costs may unevenly burden the JOTC Members.	A desirable decision beneficial in a system context may disadvantage others. A framework to assess the financial implications is essential.	A mechanism for monitoring movement of costs is essential.

The JOTC is essentially a technical committee with representation drawn primarily from Power Producers and Dam Operators. The management of the Zambezi River Basin in a system-wide context will entail the accommodation of other uses of the river such as flood protection, agriculture and the environment. This study identified the need for a broader forum of stakeholders to address the extended dam operating objectives, and recommends the establishment of a System Operating Forum (SOF). This includes organizations responsible for Disaster Management, NGOs, ESCOM, Water Management, Environmental Management, Local Government and the Civic Society. Most of these other stakeholders, currently excluded from the JOTC, are the ones that deal with the effects, impacts and consequences of flood and drought events as well as with the impacts of flow releases from the Zambezi River Basin dams. This broader forum, whilst not replacing the JOTC which should continue as a technical committee, will enhance sharing of data between operators and other stakeholders. It will facilitate closer liaison with different ongoing programs by various organizations as well as updating the ZAMWIS database. The second and third Advisory Group meetings deliberated on the continuation of the AG meetings to take the form of the SOF. Most of the members of the AG are in support of the SOF and can see its benefits, therefore the transformation of the AG into a fully operational SOF can be achieved within a very short time. The SOF will provide a platform for interested and affected stakeholders to contribute to the effective management of the Zambezi River System and improve communication. The ZAMCOM Interim Secretariat, with inputs from the Zambezi River Basin stakeholders, needs the draw up the ToR for this proposed Zambezi System Operators' Forum.

In the past, Hydrologists working in the Zambezi River Basin met once a year following the SARCOF meeting. This Hydrologist meeting allowed these specialists to engage and interpret recommendations from SARCOF into practical forecasts. These meetings have since stopped, and should be resuscitated.

The increasing complexity of dam and hydropower operations while meeting other objectives requires strengthening of the draft MoU for the JOTC in the areas identified in Table 5.3 above. The vision as presented in the Draft MoU of the JOTC can be strengthened by providing for formal links to the SOF while the obligations require links with the SARCOF and the regional meetings of the Hydrologists. The existing Draft MoU for the JOTC should be strengthened to facilitate risk, cost and benefit sharing as a result of improved dam operation. Its vision is very wide and cannot be realized with the current limited range of participants.

Synchronisation of dam operations

Synchronisation relates to timing of actions (near real time) in order to achieve or avoid an outcome which is certain to occur at a known position in space and time. For example, two hydropower dams in series can be synchronised such that spillway discharge is minimized and as much water as possible goes through the turbines. To achieve this, the storage in the downstream dam is drawn down first. When it reaches a certain level the upper dam starts generating power or increases its releases for power generation in order to benefit the downstream dam. Similarly, if the downstream dam receives runoff from incremental catchments and its level rises, at a certain level, releases from the upstream dam are stopped or reduced to retain water in storage in the upper dam for later use. The releases also account for abstractions and losses between the two dams. Thus timing of releases and discharge rates are very important. Dam synchronisation is a tool that can be used to manage flood releases. Concepts for synchronization of dam operations to manage flood releases considered in this study include (1) **delaying**, (2) **reducing**, and (3) **delaying and reducing** flood peaks for flood protection The following options can be considered on the Zambezi River Basin in order to implement these synchronisation scenarios:

Scenario 1: Management of releases to delay arrival of peak of flood flows especially for early warning:

(a) managing releases from Kariba to allow the peak flow from Kafue Gorge to pass the Kafue/Zambezi confluence.
(b) managing releases from Kariba to allow peak flow from Angwa, Luangwa, Machanga, Manyame and Msengezi to reach Cahora Bassa.

Scenario 2: Management of releases to reduce peak of flood flow resulting in a consequent reduction in the impact of the flood:

(a) managing releases from Kariba when dam levels are within a specific range. Historical flows indicate that this has happened in the past.
(b) managing release from Cahora Bassa when dam levels are within a specific range.
(c) implementing the operating rule for Kamuzu Barrage to release flows close to the pattern of the inflow hydrograph when lake levels are within a specific range. Flood risk increases significantly as the Lake levels increase and as the response time required becomes less.

Scenario 3: Management of releases to reduce and delay peak of flood flow to achieve both benefits of Scenarios 1 and 2:

(a) managing releases from Kariba when dam levels are within a specific range to retain some of the water in storage for current and future hydropower generation and other uses that depend on storage. Historical flows indicate that this has happened in the past.
(b) managing releases from Cahora Bassa when dam levels are within a specific range to retain some of the water in storage for current and future hydropower generation and other uses that depend on storage. Historical flows indicate that this has happened in the past.

Considering the variability and uncertainty in the hydrology of the Zambezi River Basin, these concepts form a sound basis for engagement on synchronization of dam operations. However to get to a level of implementation would require detailed modelling, monitoring and evaluation on an on-going basis. The setting up of modelling and monitoring systems to support dam synchronisation through the implementation of a pilot project involving the Kariba, Itezhi-Tezhi and Cahora Bassa Dams is therefore recommended.

Bottom Outlets and Sedimentation

Kariba Dam has a maximum length of about 280 km and a capacity of 185.6 km^3, while Cahora Bassa has a maximum length of about 292 km and a capacity of 55.8 km^3 at full supply level. Both these dams do not have bottom outlets to flush out sediments. Although the spillways for both dams are openings under water, it is currently impractical to release sediments from these reservoirs as both reservoirs are very long and most of sediment load settles in the upstream parts of the reservoirs and on the edges. Their sediment trap efficiency is 100%. It is already evident that bottom outlets will have negligible value for sediment flushing for such major dams and the need for bottom outlets for dams of this size is debatable. Itezhi-Itezhi Dam has a bottom outlet, but most sediments settle well upstream of the dam wall. The storage condition of the dams just before a major flood, which is affected by the dam operating rule, affects the distribution of sediments from the contributing rivers.

The tributaries downstream of the major dams carry fine sediments to the main stem of the Zambezi River, but deposition of these fine sediments on the floodplains can only happen when the floods in the tributaries coincide with floods in the main stem Zambezi River.

Bottom outlets are included in a dam either as diversion works during dam construction or to facilitate the management of the reservoir thereafter. Bottom outlets or floodgates also allow for drawing down the water level below crest level if spillways are placed higher in the dam body. When bottom outlets are present in small and medium sized dams, it is possible to release not only flow, but also sediment, allowing for sediment management in the reservoir.

For the new dams that have been identified for construction on the tributaries of the Zambezi River, bottom outlets will be included in the designs. For example, a bottom outlet has been provided for on the new Gwayi-Shangani Dam, and will release sediments especially if significant floods are experienced at the start of the rainfall season coinciding with low dam levels. This could be beneficial to the ecology possibly limited to the extent of Kariba Dam only.

New large dams on the unregulated tributaries of the Zambezi should consider bottom outlets for multi-purpose uses such as the release of minimum flows (contributing to environmental flows), and water quality management. For new small and medium sized dams, bottom outlets will also be used for sediment releases. The predicted increase in intensity of rainfall due to climate change means that rivers will carry more sediment load. If deposited in small and medium size dams, these sediments will significantly reduce their live capacity, design life and usefulness. Dredging and flushing of sediments is carried out on farm dams but is an expensive exercise.

Investment in bottom outlets for the purpose of flushing sediments only should consider the following:

- Flushing can have detrimental environmental impacts both in the reservoir and downstream. This is particularly true when the releases are made in the absence of a large flood, when deoxygenated sludge is potentially released;
- Releasing water using bottom outlets requires experienced Dam Operators, as the bottom water needs to be mixed with water from other levels, to prevent only cold, nutrient-rich (hypolimnion) waters from the bottom of the reservoir being released downstream; and
- For large reservoirs, flushing is not an option as sediment will settle upstream of the dam wall.

Floodplains/wetlands

It is important for dam management that floodplains and wetlands in the Zambezi River Basin should retain their hydrological functions.

The floods from the Barotse and Chobe take 30 to 40 days to travel to the Victoria Falls, however in periods following a drought season, the floods take almost 90 days before they arrive in the Victoria Falls area. It is therefore recommended that instead of flood retention 'enhancement', dam releases be operated in synchrony with the flooding of wetlands so that releases are done much earlier to accommodate huge floods and that way, huge and sudden impacts downstream can be averted.

The Barotse Floodplains can achieve a 20% reduction in peak flood on average. For the Barotse and Chobe, inflow and outflow hydrographs show that absolute flood volumes retained by the wetlands only constitute a small percentage of the total volume of the floods.

The Kafue Flats give a considerable reduction in peak flow (a 40% reduction in peak flows is achievable) but the retained volume of water is a very small percentage of the total volume of floods. The Kafue Flats are therefore not significant for flood retention. The vast extent of shallow floodwaters across the Kafue Flats results in very high evaporative water losses. Potential evaporation exceeds rainfall in all months except the peak rainfall months. Net evaporation over the annual hydrological cycle for the Kafue Flats on average is about 1050 mm/annum. Evaporation losses for the Barotse Floodplains and Kafue Flats are considerable in absolute volume terms. The Kafue system floods should be managed in conjunction with the releases from the Cahora Bassa. The storage characteristics of the wetlands can be determined using satellite images, ground based observations and modelling. This is important for dam and disaster management.

The Luangwa River has a big influence on operations at Cahora Bassa and contributes about 70% of the floods for the reservoir. The Luangwa River is not regulated and the Luangwa wetlands are reportedly quite degraded. To halt further degradation, there is need to institute a wetlands management program for maintenance of the integrity of the Luangwa wetlands. Apart from the wetlands, it is also recommended that considerations for regulating the Luangwa River be studied especially for flood control. These recommendations are made in Intervention Sheet 2.10 of Annex 2 of the Main Report.

A number of reasons make it impractical to enhance the retention capacity of the wetlands of the Zambezi River Basin. The wetlands on the Zambezi are huge and are also designated Ramsar sites, thus restricting any modification of the wetlands. Even if it were possible to enlarge the size of the wetlands, this would increase the evapo-transpiration rates tremendously, thus also negatively affecting the water demands during dry seasons.

There are other possible interventions for improvement of retention capacity that are carried out as 'restoration and rehabilitation' of degraded wetlands. These interventions have attained variable success in particular with regard to the hydrological regime. So far it is not known to what extent these interventions have succeeded in attaining the original state or desired state of the wetlands. On the other hand, restoration work for successional marsh and reed swamps has been recorded as successful. It still has to be emphasized that this has been done on small size wetlands.

The available methods for analysis of hydrologic behaviour of wetlands have not been fully tested on the wetlands of the Zambezi River Basin which means that reliable estimates of the attenuation period, volume and the reduction in peak flow cannot be made especially with the limited data. There is an opportunity to set up new studies to improve available data and to better understand the hydrological functioning of the wetlands.

The ecology in wetlands and the delta downstream of the existing dams will significantly benefit if dam operations implement the following suggestions:

- Restoring the difference between wet and dry season low flows as much as possible (i.e. wet season low flows should be higher than dry season low flows);
- Making a flood release as early as possible in the natural flood season, 'piggy-backed' on natural floods from tributaries or on pre-arranged releases from other dams to maximise their effects and to reduce the amount needed from any one dam. This would assist in flushing out the pollution, bilharzia snails, and mosquitoes and resets the river for wet season conditions;
- Releasing single long flood pulse as early as possible in the flood season on the main stem; on tributaries with flashy hydrographs single floods should be released in their entirety and others captured in their entirety, with one of the first floods of the flood season released;
- Recognizing/forecasting dry and wet years (or dry and wet cycles of years), and amending operating rules accordingly so that the river, as well as people, do not suffer years of drought and abundance. In wet cycles/years release more of the flows than in dry years – in other words there should not be one set of rules for all years;
- Varying releases at a daily, or at least weekly level, linked to the flow pattern of an un-impacted headwater reach and in accordance with the wet/dry year arrangement. The rate of change of releases should be no greater than the natural rate of change in flow in that river. Hydro-electric power dams should not create unnatural surges of water or unnatural de-watering of the downstream river;
- Using outflow gates at different levels to mix and match water quality and temperature of released water, in order to approximate that of inflowing water as much as possible; and
- Monitoring should focus on whether or not the agreed pattern of flows is being released and achieving the predicted river condition. Such monitoring could be funded from the dam sales of water or hydropower production, and should include a facility of adaptive management to respond to monitoring results.

Climate Change

Climate Change and Variability research globally and in respect to the Zambezi River Basin in particular, is ongoing. An extensive literature review on Climate Change and Variability in respect to the impacts on the Zambezi River Basin shows that scientists seem to concur that the Zambezi River Basin's average temperatures are rising and that the north east of the SADC Region will become wetter whilst the south west will become drier. What will happen in-between is still unclear. The following are the findings related to Climate Change/Variability:

- Most of the available studies are consistently predicting that the Zambezi River Basin will become drier. However, most have focused on investigating climate change as a threat to water availability rather than frequency and magnitude of floods which limits their applicability for this study;
- Rainfall changes are predicted over the whole basin, with a decrease of approximately 10-15% by 2050. However, as this region experiences tropical cyclones which are yet to be simulated in Global Climate Models, the frequency of wet extremes from the model results is quite uncertain;
- 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;

- The intensity of rainfall will increase and will likely contribute to increased sediment load with resultant negative effects on dam/reservoir usefulness;
- Evaporation is estimated to increase 10-25% by 2050. A general consensus of warming is projected for the Zambezi River Basin, with results showing an increase in temperature in the range of 0.3-0.6°C per decade. A maximum increase of 0.8°C is projected for the summer months;
- It is projected that runoff will significantly decrease in the Basin, with the projected range being between 26-40% by 2050; and

Table 5.4: Project's Climate Change Findings

THEMATIC AREA	FINDINGS
Temperature and Evaporation	Available studies predict that; 1. The Zambezi River Basin's temperatures will increase in the range of +0,3°C to +0,6°C per decade 2. Summer temperatures will increase by a maximum of +0,8°C per decade 3. Evaporation is estimated to increase by 10% to 25% by 2050
Rainfall and Runoff	Available studies predict that; 1. The Zambezi River Basin will become overall drier 2. Rainfall pattern changes over the whole Zambezi River Basin will occur 3. Increase in rainfall intensity is likely to result in increased sediment loads with resultant negative effects on dam/reservoir usefulness. 4. Rainfall over the whole Zambezi River Basin will overall decrease by 10% to 15% by 2050 5. Runoff will significantly decrease in the Zambezi River Basin in the range of 26% to 40% by 2050 6. There will be drier droughts and wetter wet years 7. A shift in the wet season is also expected
Dam Management	1. Existing dam operating rules in the Zambezi River Basin consider one year rule curves. A shift to a longer operating window, which is desirable because dam operations will be able to better deal with hydrological cyclicity, brings major challenges to Dam Operators because of the expected higher weather variability caused by climate change 2. The low storage/MAR ratios of all current dams in the Zambezi River Basin, except for Kariba, suggests that these dams cannot store major floods 3. Due to high weather variability, perceptions regards dam operations are that there will be incremental, unpredictable increases in flow discharges resulting in flooding with losses of lives, livelihoods, etc

- Four plausible scenarios for 2030-2050 were generated based on conclusions drawn from the literature review:
  - "very dry" (+2 degrees Celsius, -15% rainfall);
  - "dry" (+2 degrees Celsius, + 0% change in rainfall);
  - "wet" (+1 degree Celsius, +15% change in rainfall); and
  - "Higher Variability" for Lake Kariba, as well as for Cahora Bassa Dams, for the purpose of sensitivity analyses on dam operations. The "Higher Variability" scenario was to address the expectation that climate change would give drier droughts and wetter wet years and was simulated using input from the other scenarios.

The "wet" scenario is recommended as worst case for floods and the "very dry" scenario as worst case for droughts. The "Higher Variability" scenario can be used as a moderate situation for multiyear events, though having the full impact on variability of flows. The climate change experts also expect that a shift in the timing of the wet season. A renowned hydrologist, Professor D. Hughes, in his review of this Task, pointed out that while a shift in the seasonal distribution due to climate change effect has been noted by some studies, it is by no means a confirmed effect and may have very little impact on the general conclusions reached on this investigation.

Table 5.4 above summarises the Project's Findings in respect to Climate Change and Variability. Some of the Project's Recommendations made are to address these Findings.

The Lake Malawi/Shire River System

The outflow from Lake Malawi into the Shire River at lake levels between 473.22 and 475.32 masl is regulated by the Kamuzu Barrage which is located at Liwonde immediately downstream of Liwonde National Park. It is the only point where flow is currently being regulated in the sub-system. Above 475.32 masl, the Barrage has no flow control function. Therefore during floods, outflows from Lake Malawi cannot be reduced or delayed and the hydropower plants and the downstream riparian zones will receive the full flood flows from Lake Malawi. These high floods carry a lot of debris. It is therefore necessary to prevent debris from blocking intakes of the power plants particularly during floods.

Economic, social and environmental activities/functions on Lake Malawi are affected by high and low lake levels. Negative impacts start from 475.5 masl going upwards. However, the current operation of the Kamuzu Barrage does not consider avoidance of high lake levels. There is need to monitor and review the implementation of the operating rule as emergency releases may cause flooding downstream. High lake levels also cause flooding in the lakeshore areas.

The most serious and most frequent flooding takes place in the Lower Shire where the hydropower plants are located. The flooding in this region is mainly caused by the tributaries of the Shire River especially the events in the Ruo River, the Elephant Marsh areas and backwater from the Zambezi. These floods cannot be managed through the regulation functions at Kamuzu Barrage. A combination of high outflows from Lake Malawi and the high flows from the tributaries on the Shire can result in very high floods. Flooding in the lower Shire caused by unregulated tributaries could be mitigated/reduced by infrastructure development and implementation of an early warning and communication system. If the operation of the Kamuzu Barrage (within its effective range to reduce outflow from the Lake) also considers the flood hydrographs and concentration times of downstream tributaries, it is possible that the extent of downstream flooding could be reduced.

5.3 Precipitation and flow forecasting

5.3.1 Objectives

The Objectives of Output 3 (Precipitation and Flow Forecasting), as detailed in Annex 3 of the Main Report, were to:

- Improve the reliability of the seasonal forecasts in order for Dam Operators to take a more informed decision on releases from their dams, including releases for environmental flows;
- Contribute to a knowledge management database of hydrological forecasted and measured information to allow for better informed changes to the present operation of the dams that

will result in an optimization of hydropower production, flood control and environmental flow releases; and

- Provide Disaster Management/Civil Protection Units and Dam Operators with reliable and targeted forecast information timeously, so that operational disaster management is improved.

5.3.2 Consolidated Findings

The main outcome of Output 3 were the detailed Recommendations for the establishment of an effective Basin-wide Flow Forecasting System (FFS) that would improve disaster management, dam operation, optimisation of hydropower production, environmental flow management and flood control. Within this context, the essential Findings developed from Output 3 are:

Forecasting Requirements

Table 5.5 summarises the Findings for forecast lead times informed by consultations with the key users of the information. The identified forecast locations for each of the forecast lead times are shown in Figure 4.1 above.

Short lead time forecasts are important for flood forecasting and this forecast timeframe therefore focuses primarily on flood prone areas in the Zambezi River Basin. Medium lead time forecast locations are important for existing hydropower plants (large and small). Seasonal lead time forecast locations cover major hydropower plants and associated infrastructure in the Basin; i.e. Itezhi-Tezhi, Kafue, Kariba, Cahora Bassa and Kamuzu Barrage.

Table 5.5: Forecast Lead Times and User Requirements

Forecast	Timeframe	Required for/by:
Short	1-10 days	Dam Operation, Disaster Management, Tourism and Wildlife Agencies
Medium	10 days – 3 months	Dam Operation, Power Generation
Seasonal	>3 months	Dam Operation, Power Generation, Water Supply

The Findings show in general that 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, gauges are necessary for keeping track of observed and forecast dam releases.

Flow and Precipitation Monitoring Networks

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 Basin within Angola, where only one flow gauge is currently operating. In developing the flow gauge network design, the following approach was generally used for the selection of gauges at required sites:

- Preference of existing real-time gauges against manual gauges;
- An existing manual gauge where real-time gauge was not available; and
- Identification of an approximate site for a new gauge where none existed (this was the only case for two proposed gauges in Angola).

It became clear in the course of this study that the SADC-HYCOS network within the Zambezi Basin, as the only basin-wide real-time flow gauging network, should form the starting point for design of a flow monitoring network for flow forecasting. This conclusion was based on the following important findings:

- Gauges within the SADC-HYCOS network were selected through a comprehensive participatory and transparent process that included representatives from all of the basin states.
- Development of the SADC-HYCOS Project followed a process with similar objectives to those of this Project. These objectives included institutional strengthening and information sharing between the riparian Member States, education and training and the improvement of data collection for integrated water resources management.
- There is already an agreement between the Member States, SADC Water Division and the SADC-HYCOS Project that SADC-HYCOS network stations are owned by the Member States and therefore the operation and maintenance costs are borne by the Member States. Most of the Member States currently have a budget allocation in their respective Treasuries for the SADC-HYCOS Project.
- The SADC-HYCOS Project already has a data transmission arrangement with WMO and EUMETSAT, as well as data transmission facilities and a regional database at the Project Regional Centre in Tshwane, South Africa. These arrangements have reduced both capital and operating costs substantially from what would have been required had the assistance and cooperation of the WMO not been obtained.
- Establishment of new gauging stations outside the SADC-HYCOS network will entail:
    - Extra costs for the construction and upgrading of the selected stations and for procurement and installation of new equipment;
    - Commitment and agreements will also have to be made by the Basin States to support the system. However, the institutional arrangements already established as part of the SADC-HYCOS project could form a foundation for this process; and
    - Issues such as site access (for installation and maintenance of gauging and transmission equipment), historical reliability (length of historical record available and record quality), and stability of the rating curve for the site (for natural control sections) have already been addressed for gauges in the SADC-HYCOS network.

Following the approach and principles outlined above, fifty one (51 no.) candidate stream flow and water level gauges were identified in the network design (Figure 4.1).

Most existing flow gauges in the Zambezi River Basin are manual gauges – the existing SADC-HYCOS and ZRA networks and a few other gauges are the exception. 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 used by gauges within the SADC-HYCOS and ZRA networks, is unlikely to be necessary except in very remote parts of the Basin. GSM transmission is significantly cheaper than satellite transmission and has added advantages due to a lower risk of theft or vandalism and easier maintenance. The use of GSM technology is therefore generally recommended where coverage is available.

The sustainability of automatic flow gauges in the Zambezi River Basin is currently a significant challenge. Ageing equipment, lack of spare parts, loss of trained personnel, theft/vandalism, damage due to floods and lightning, and a general lack of funds are some of the main issues currently being faced. For sustainability continuous flow of funds, political and institutional support and the selection of appropriate equipment are necessary.

The existing density of rainfall gauges in the required sub-basins is generally below what is needed for accurate flow forecasting. In some areas (mostly Zimbabwe, Malawi and parts of Mozambique) coverage is adequate, but upgrading of the existing manual gauges to automatic stations will be required to cover the entire Basin. A comparison of rain gauge density in the Rhine, Mekong and Zambezi River Basins indicates that the density of the Zambezi is generally significantly below those of the Rhine and Mekong.

A detailed investigation of currently available remote sensing technologies was undertaken, and revealed that this method would be feasible for the Zambezi River Basin. On this basis, it is recommended that satellite rainfall estimation (SRE) (remote sensing) is used in the following situations:

- In areas with insufficient rain gauge coverage where the cost of upgrading existing stations or installing new stations is not justified or feasible.
  - As a short to medium term interim measure for areas which have adequate gauge density, but which still require upgrading of manual stations to real-time for operational forecasting (in the long-term, ground observation is still recommended over SRE as it is generally more reliable).

As one of the goals of this Project was to retain existing forecasting expertise by integrating existing flow forecasting models rather than replacing them, an important consideration in the network design was the inclusion of flow gauging stations that are currently used by forecasting authorities (forecasting models are currently used by ZRA and ARA Zambeze). The required flow and precipitation monitoring networks design is thus in accordance with the principle that:

- existing measurement and communication equipment should be utilised wherever possible (i.e. cognisance should be taken of past investment to maximise long-term reliability and sustainability while minimising costs);
- equipment and technology that offers the highest reliability and sustainability within the Zambezi River Basin, taking due consideration of costs, should be utilised; and
- where significant investment would be required to achieve the required density for ground based precipitation stations, consideration should be given to the use of other measurement technology, such as remote sensing.

Forecasting Models

A number of existing models are currently in use in the basin by a range of forecasting authorities. These include:

- ZRA Regression and recession models for inflow forecasts at Lake Kariba (SADC/ZRA);
- MIKE-11 model upstream of Cahora Bassa to the mouth of the Zambezi River (ARA Zambeze);
- WRSM2000 model (currently a component of Kafriba) for rainfall-runoff upstream of Itezhi-Tezhi and the Kafue Gorge (ZESCO);
- New InfoWorks model of the Kafue Flats (ZESCO, under development); and
- Trigger based warning system on Shire and Ruo Rivers (Ministry of Water Development and Irrigation, Malawi).

Prior to acceptance of the above models, an evaluation of their capabilities and accuracy will be required. While it is likely that the existing models will form the backbone of the forecasting system, additional new models will be required. In particular rainfall runoff models and reservoir/water balance models are still lacking in many parts of the basin. Any new model development should be accompanied by human capacity building in the use of the model. To this end, it is recommended that new models are established in close collaboration with the authority that will be responsible for their maintenance.

Based on a preliminary assessment of model requirements using the forecast requirements identified in this study, the following new models are likely to be required. The models are listed with the expected forecast lead time for which they will be used.

- Routing models for the Gwayi, Sanyati, Luangwa, Manyame and Luenya rivers (short);
- Hydrodynamic routing model from Katima Mulilo to Victoria Falls (short);
- Hydrodynamic routing model from the outlet of Kariba to Cahora Bassa (short);
- Rainfall-runoff model for Sanyati and Gwayi (short);
- Rainfall-runoff model for Luangwa based on concepts of the research model developed by Winsemius (2009);
- Rainfall runoff model for Manyame and Luenya rivers (short - medium);
- Flash Flood Guidance procedures for the Gwayi/Sanyati, and Shire catchments linked to the Regional Flash-Flood Guidance System – Southern Africa project by WMO (short);
- Reservoir models for operation of Itezhi-Tezhi and Kafue Gorge, Kariba and Cahora Bassa (medium); and
- Reservoir routing model for Lake Malawi including wind effects (medium lead time).

Precipitation Forecasting

In areas where the (natural) lag times upstream of a forecast location are shorter than the desired flow forecast lead time (fast responding catchments), precipitation forecasts will be required. An evaluation of the current precipitation forecasting capability in the SADC Region indicates that there are currently sufficient forecasting capabilities to provide the required inputs for flow forecasting in the Zambezi River Basin at the Short, Medium, and Extended to Seasonal Range time scales. The WMO Regional Specialised Meteorological Centre for southern Africa (RSMC), based in Tshwane, South Africa, as well as the National Meteorological Centres (NMCs) in most countries within the Zambezi River Basin have an established cooperation and these centres are additionally actively pursuing the continued improvement of forecasting capabilities.

Proposed Flow Forecasting Centre

A proposed Forecasting Centre would receive, archive and distribute monitoring data from flow and precipitation gauges within the forecasting network, to relevant authorities. The ZAMCOM Agreement mandates and obligates the ZAMCOM secretariat to be the central data and information depository and disseminator, as provided for in Articles 6 and 15 of the ZAMCOM Agreement. The Forecasting Centre could thus be situated at the same location as the permanent ZAMCOM secretariat, or at an entirely independent location as an extension of the ZAMCOM secretariat. As the success of the Flow Forecasting Centre will depend to a large degree on a range of important technical criteria, it is recommended that the location is chosen on the basis of such criteria in consultation with the Zambezi riparian states. Some of the more important issues are listed below:

1) *Practical Issues:*
    - Internet speed and reliability;
    - Security of power supply;
    - Existing ICT infrastructure and staff;
    - Transport/connectivity; and
    - Cost of living.

2) *Political Issues*
   - Independency of the Flow Forecasting Centre;
   - Institutional mandate (recognition); and
   - Legal status/liability/immunities.
3) *Capacity Issues*
   - Attractiveness of location for human capacity retention; and
   - Connections with knowledge institutes/universities.

Locating the forecasting centre in the same building as the ZAMCOM secretariat would greatly facilitate communication and could also result in cost savings with respect to rent and ICT infrastructure. However, at the same time, this arrangement could unnecessarily delay establishment of the Flow Forecasting Centre as ratification of the ZAMCOM Agreement by all riparian states is a political process without any fixed timeframe. In addition, situating the Flow Forecasting Centre and the ZAMCOM Secretariat at the same location would concentrate the risks of responsibilities of these two significant entities in one country, while splitting them would spread these risks and responsibilities.

Before the Flow Forecasting Centre is fully established, it may still be possible to obtain some benefits through implementation of the following interim measures:

- Augmentation of the role of the Joint Operating Technical Committee for Dam Operators to include information sharing between important stakeholders; and
- Establishment of an Agreement and Protocol for upgrading of ZAMWIS to an operational archive under the auspices of the interim ZAMCOM secretariat.

Generally, a Forecasting Centre requires:

- A flow forecasting system that integrates all information and establishes new information, for instance by running hydrological and hydraulic models. Information is typically stored in an operational database as well as an accumulating historical digital archive;
- Staff to run the forecasting system 24/7, upgrade and improve it, and provide database and hardware maintenance of the systems in place; and
- Dedicated staff with the required experience and qualifications to run and maintain the Forecasting Centre.

The financial resources presented in Tables 5.6 and 5.7 will be required for the establishment of the Flow Forecasting Centre. These tables do not include costs for the establishment/upgrading of the measurement and data collection networks, but do include the operational costs of the Flow Forecasting Centre. Various financing options were investigated and a range of ICPs were identified as detailed in Annex 3 of the Main Report. In the long term, the most realistic option would be to seek financial assistance from funding organisations for the capital investment costs while the operating costs should be planned for and be financed by the Zambezi riparian states and other beneficiary stakeholders. Tables 5.6 and 5.7 give the required Capital Investment and Operational Costs respectively.

There are pre-conditions, advantages and risks associated with the establishment of the flow forecasting system and Flow Forecasting Centre. The pre-conditions are:

- The willingness to cooperate and to share information is a prerequisite to the success of a Flow Forecasting Centre. Zambezi riparian states and other stakeholders have to come to agreement on the manner that this information sharing will take place; and

- Experience with the SADC-HYCOS Project indicates that it is important to recognize the need for operation and maintenance costs. To ensure a sustainable operational network, Agreements should be set up on responsibilities and financing between Member States. Such Agreements should include responsibilities for maintaining stations, updating rating curves and replacing faulty station equipment.

Advantages:

- The primary advantage of an operational Flow Forecasting Centre is that hydrological and meteorological data from across the Basin is integrated and shared amongst stakeholders and that the Centre would process this data using the latest hydrological forecasting tools to predict future flows and water levels;
- The sharing of data and other information will lead to trust and confidence between the stakeholders leading ultimately to improved management of the Basin's water resources;
- Real-time flow forecasting enables better synchronized operation of reservoirs, enhanced hydropower production, environmental flow planning and timely flood/drought warning;
- Improved management of the Basin's water resources facilitates dam synchronisation, improves hydropower revenues, ecosystem services will increase and DMUs will be able to mobilize resources more effectively and timely during floods and drought events; and
- Increased protection of stakeholders against the effects of floods and droughts in the Basin through improved and synchronized dam operations using integrated and shared information as well as real-time forecasting.

Risks:

- Measurement networks need to be operated and maintained. Without sufficient funding and commitment to operation and maintenance, these networks will not provide the required input data for reliable flow forecasts to be established;
- There is a risk that stakeholders who own forecasting models will not be willing to cooperate and share their models for the benefit of the flow forecasting system unless a data/information sharing agreement is signed and implemented. If this is the case and an alternative model is made use of in the forecasting system, there is an additional risk that the same stakeholders will not be willing to embrace the Flow Forecasting Centre because their own models will not be part of it. This risk can be reduced by ensuring that all stakeholders, in particular those that have developed data acquisition and modelling infrastructure, fully support the development of a centralized flow forecasting system by demonstrating the benefits and advantages of this basin-wide flow forecasting system. Buy-in of those that have developed data acquisition and modelling infrastructure should be obtained by undertaking specific and comprehensive consultation with all relevant stakeholders. Again such commitment may be agreed upon as an addendum to the ZAMCOM Agreement;
- It is well known that human capacity is often lost to foreign countries because of job opportunities and potential to further develop capacity abroad. To avoid this from happening, the Flow Forecasting Centre, along with the 'Centre of Excellence', should provide an attractive environment for both research and operational work; and
- The non-availability of continuous ICP funding is another risk factor. For this reason, it is proposed that operation and maintenance funding for the proposed Flow Forecasting Centre be provided by the Member States (funding of operating costs by an ICP would be possible, provided such funding could be guaranteed in the long-term, thereby minimising the risk of a loss of sustainability).

Table 5.6: Flow Forecasting Centre Capital Investment Costs

Item	Number	Indicative Price (USD)	Amount (USD)
Office furniture	Lump Sum	$30,000	30,000
Central Server	1	$13,800	13,800
Model Server	1	$12,000	12,000
Database Server	1	$16,300	16,300
Mass storage with redundant backup facilities	1	$25,800	25,800
Rack system	1	$4,300	4,300
Operator Terminals	3	$2,600	7,800
Backup/Remote Laptops	3	$3,000	9,000
Operator Terminals	15	$1,800	27,000
Printers	2	$16,300	32,600
Plotter	1	$17,200	17,200
Fax machine	1	$1,200	1,200
Overhead projector	2	$2,600	5,200
Training room clients	10	$1,500	15,000
Backup generator	1	$20,000	20,000
UPS Systems	3	$12,900	38,700
Total Capital Investment Cost			**$275,900**

Table 5.7: Flow Forecasting Centre Operating Costs

Item	Number	Indicative Cost per Year (USD)	Remarks
Wages		$550,000 – $890,000	Bracket for minimum and maximum staffing. Excluding cost of 2-3 junior hydrologists coming from member states institutions
Office Rentals	1	$12,000 – $60,000 Average*: $47,000	For a 250 m² office space. Extremely variable between different locations.
Power		$6,000	
Insurance		$13,000	Insurance for office content
Lease of photocopier, plotter, fax, telephone (+consumables)		$28,000	Possibility to buy instead of leasing
Cleaning materials and teas		$3,000	
Cell phones	5	$9,000	5 contract cellular phones/lines with 120 USD airtime/month
Telephone	4	$12,000	
Internet connection	1	$12,000	
Backup satellite internet connection	1	$12,000	
Real-time data access		$10,000	To precipitation forecast models
Postage and courier		$6,000	
Travel		$20,000	
Depreciation		$59,000	Based on 4 years for IT material, 10 years for office furniture.
Miscellaneous		$15,000	
Total operating cost		**798,000 – 1,138,000**	

5.4 Considerations for investments in the Zambezi River Basin

5.4.1 Objectives

The main objective of Output 4 (Investments), as detailed in Annex 4 of the Main Report, was the assessment of potential capital investments in the Zambezi River Basin which would have the most positive impacts and benefits for flood protection and flow regulation as well as providing water for nature and enhanced livelihoods. This means:

- Recommendations on identified investment options that deserve further feasibility analysis with emphasis on flood protection; and
- Recommendations on the considerations for further decision making.

5.4.2 Consolidated Findings

The Zambezi River and its tributaries are important to the economies of the Zambezi riparian states through the provision of hydropower, irrigation water, fisheries, water transport and other uses. Different investments are being planned by the Zambezi riparian states to maximise the utilisation of the water resources of the Zambezi River Basin for the provision of one or more of these uses. These investments, if implemented, will have an impact on the flow regime of the Zambezi River and its tributaries. The investments were thus investigated with a focus on their role in flood protection and impact on provision of environmental flows.

Regulation of the Shire River and Lake Malawi

The challenges of effective and efficient investments in the Shire River flow regulation infrastructure lies in maximizing the conservation of Lake Malawi water resources, maintenance of vital ecosystems within the Lake Malawi/Shire River system, minimizing the likelihood of flooding around the Lake and Shire River valley as well as minimizing the occurrence of low flows for hydropower production and environmental management. Decisions on upgrading the Kamuzu Barrage have been made and work will commence in the immediate future. This upgrading of the Kamuzu Barrage will improve the operations and management of the Barrage. The Barrage is not, and has never been, intended for flood control. When the power interconnector between Malawi and Mozambique is realized, reliance on the Lake Malawi/Shire River for hydropower production will be reduced, giving opportunities to re-allocate the available water resources to the provision of E-flows and enhancement of livelihoods. Additionally, the need for an investment in a pumping scheme at Mponda to maintain minimum flows for power generation would become redundant. Another investment option is the Kholombidzo Reservoir. Both options for Kholombidzo Reservoir, High and Low, will need further study before decisive conclusions can be made. As the flooding of riparian zones is most critical in the lower Shire, the option of diverting flows of the Ruo tributary through the Elephant Marsh has been identified as an option that would need further investigation.

Multipurpose dams on the Zambezi and Kafue Rivers

Investments in multipurpose new dams on the main stem Zambezi and Kafue Rivers are being planned whilst existing dams are being retrofitted for hydropower production. Additional hydropower turbines are planned at Kariba South Bank and Cahora Bassa North Bank whilst work has commenced in adding hydropower turbines at Kariba North Bank and at Itezhi-Tezhi dam. The advantage of additional hydropower turbines for flood control is that power generators will be more willing to release water by producing power than to release it over the spillway, in preparation of a forecasted but uncertain flood. However, the possibility to sell this power also relies on investments in the SAPP network. The large power deficit in the SADC region makes decision processes on new hydropower dams progress faster. Financial viability of these dams will dictate their mode of operation, which will most likely not be optimal from a flood management perspective, despite the fact that the construction of every new dam adds to flood control. It is recommended to consider the Hydropower Sustainability Assessment Protocol (IHA, 2010) provisions during the design and development of operating rules of all new hydropower dams.

New dams on unregulated tributaries

As for new multipurpose dams on the tributaries of the Zambezi River, stakeholders in Zimbabwe, Zambia and Mozambique indicated that new dams in their countries for flood control purposes have low priority. In Zambia and Mozambique in particular, the usefulness of dams for irrigation purposes is emphasized. The identified planned dams for multipurpose use on tributaries generally have little storage capacity in comparison to the flows coming from the Zambezi main stem but they will contribute in local flood management. From an environmental viewpoint, the identified dam sites which are assessed as technically suitable on the Luangwa and Lusemfwa Rivers are not recommended as these dam sites are located in nature parks.

Construction of an extra spillway at Cahora Bassa dam

Final conclusions and recommendations on the additional spillway at Cahora Bassa will have to await the results of an on-going study commissioned by HCB which is due for completion in 2011. The benefits of the additional spillway are in relation to operating Cahora Bassa reservoir at higher lake levels thus maximising hydropower production. Additionally, a flat rule curve would be good for the ecology of the upstream Cahora Bassa Lake as it would prevent unnatural drawdown before the wet season. Also, downstream flows will be more natural. However, the impact of the increased maximum flood capacity needs further investigation.

Flood risk zoning

Investments in flood risk zoning were assessed in respect to insurances, for regulation of new settlements, for regulating current land use and for warning and rescue purposes. Flood risk zoning for flood insurance is not a viable option in the Zambezi River Basin at present. Flood risk zoning for regulation of new settlements and for regulation of current land use and for the raising of awareness makes sense as an investment if further local research can show that such a system will be locally accepted and respected. Flood risk zoning for warning and rescue is already taking place; flood mapping during floods has been done by UNOSAT for example. Flood Risk Vulnerability has been assessed for some villages by the International Federation of the Red Cross and Red Crescent. UN Habitat has also commissioned different flood mapping studies. Coordination between current mapping activities in the Zambezi River Basin is a first and useful step in flood risk zoning that will benefit flood forecasting and the involvement of local and international relief organisations during flood events as well as the understanding between neighbouring countries. This coordination is therefore recommended. Current developments in remote sensing will contribute significantly to improved and less costly flood risk zoning.

Structural flood protection measures and diversion of floods

The purpose of infrastructural flood protection measures is to provide direct flood protection of livelihoods or capital investments by either keeping the water levels low at these locations or by offering possibilities to flee to higher ground. In general, few existing flood protection measures in the Zambezi River Basin exist. Infrastructure investments should concentrate on making roads and bridges less vulnerable to flooding and raising roads to make them usable during floods, rather than large scale investments in flood protection measures.

Dykes (or levees) are the oldest and most frequent type of flood control measure. Dykes form an embankment which protects land with elevations lower than the high-water surface level. Dykes however, may create a false sense of security about the degree of protection provided. A dyke provides protection only up to the level it was designed for, if well maintained. Floods exceeding the design levels can cause disastrous loss of life and property. Moreover, monitoring of dyke conditions and maintenance of dykes is costly. The construction costs of dykes range from USD570,000 to USD1.8 million per kilometre for a dyke heights of between 2 to 4 m.

School buildings or other public buildings can also be built with an elevated floor which provides a safe refuge above most flood waters, although for extreme events, roof areas can also be used for refuge. Elevated school or public buildings and topographically higher refuge areas are easier to maintain than dyke protection systems, although they can only provide protection against loss of life and not against economic damage. The win-win situation of improving public buildings and at the same time providing flood protection, seems a cost effective contribution to the economy.

The concept of flood diversion is to divert a portion of the flood towards the less valuable parts of the floodplain in order to protect the more valuable land parts. This kind of structural solution can involve the construction of dykes, channels or diverting structures (spillways, etc.) and options for such diversion that would need further investigation have been identified in the Shire sub-system and in the Zambezi Delta.

Diversification of the Electric Power Pool

When good meteorological forecasting systems are available, hydropower plant operators can match their power production with optimal control of the dams. In this case, they have better control of reservoirs and river flows downstream. Under drought conditions, energy could be bought from other non-hydro sources due to a shortage of water. The turbines would be used to maintain minimum flows for ecological reasons downstream of the power plants.

If substitution of hydropower is considered for the benefit of flood control, the most needed investment above all else is an efficient flow forecasting system within the basin. Such a system can assist in determining if substitution of hydropower can contribute to flood control and can help to optimize hydropower production.

Investments in the energy grid, power plants and the coordination of power generation by a Forecasting and Dispatch Centre, would be very beneficial for more efficient power production in the SADC Region as it is then possible to coordinate power production with water availability or based on forecasted flows to come. This is particularly beneficial in drought situations and is an added advantage of these investments. The main benefits of such investments are therefore a maximization of power production on present and predicted water availability.

Overview of all investments

Various possible investments were investigated and evaluated to shed light at a Zambezi River Basin Scale of investments that can contribute to flood protection or flow regulation for the environment. This evaluation will help ZAMCOM to find its role in reacting to or the initiation of investments. Overviews are given below of the scores of the different investments and details of their location in Figure 5.3. The stage of project preparation of the investments are given in Annex 4 of the Main Report.

Table 5.8 gives the legend for the type of investment and colour coding given to each investment considered and the explanation for arriving at the scores allocated in Table 5.9. Table 5.9, which should be read in conjunction with Table 5.8, gives the overall assessment of the proposed investments whilst Figure 5.3 gives the location of the assessed investments.

Figure 5.1: Kariba Dam Power Stations' Tailrace Outfalls

Figure 5.2: Kamuzu Barrage

Table 5.8: Legend for scorecard and Figure 5.3

LEGEND Scorecard

Scores criteria and explanation criteria

	Unlikely to very unlikely / difficult / unsuitable / strongly not recommended / probably high negative impact
	Possibly (suitable) / uncertain / moderate to negative assessment / pros and cons
	Probable to very probably / probably suitable to very suitable / (limited) positive impact
	Not relevant criterion for this investment option / might be a relevant criterion but not part of this study

A	**Technical and legal feasibility:** Is the investment physically and legally feasible?
B	**Contribution to flood protection:** Does the investment contribute to flood protection?
C	**Impact on ecosystems:** Does the investment have impact on the river and its associated ecosystem?
D	**Cost effectiveness:** Is the investment cost effective for flood protection and/or flow regulation?
E	**Impact on human use**: Does the investment have impact on resource economic objectives and other human use?
F	**Biophysical impact**: Does the investment otherwise have impact on the biophysical behaviour of the river basin? (i.e. greenhouse gass emissions, evaporation losses, sediment transport)
G	**Likelihood of realization**: Is the realization likely?
H	**Impact on more than one country**: Does the investment benefit more than one country?

Scores progress financing

	Not yet started
	Financiers identified, but still to commit (or withdrawn for 12.1 and 12.3)
	Financiers committed
	Not applicable (for forecasting system see Annex 3)

Type of investment

16	New Dam
19	Upgrade of Existing Dam
2	Other Structural Measure
23	Non Structural Measure

Table 5.9: Assessment of proposed investments (read in conjunction with Table 5.8)

		MW (capacity)	Mm^3	A Technical and legal feasibility	B Contribution to flood protection	C Impact on Ecosystems	D Cost effectiveness	E Impact on human use	F Biophysical impact	G Likelihood of realization	H Impact on more than one country	Progress on financing	Estimated Project Cost (M USD)	Overall score
	Shire River and Lake Malawi												Norconsult (2003)	
1	Upgrading Kamuzu Barrage	+		green	yellow	yellow	yellow	green	grey	green	red	blue	9	yellow
2	Mponda Pumping Scheme	+		green	grey	red	yellow	green	grey	red	red	light cyan	35	red
3	Kholombidzo Reservoir High	180		green	yellow	red	yellow	green	yellow	red	red	light cyan	293	red
4	Kholombidzo Reservoir Low	170		green	yellow	red	yellow	green	yellow	yellow	yellow	light cyan	293	yellow
	Multipurpose dams on the Zambezi and Kafue												SAPP (2008)	
5	Batoka Gorge	1600		yellow	yellow	red	yellow	yellow	green	green	green	cyan	2400	yellow
6	Mphanda Nkuwa	1800		yellow	yellow	yellow	yellow	green	green	green	red	blue	2000	yellow
7	Itezhitezhi Extension	120		red	yellow	yellow	green	green	green	yellow	red	blue	142	green
8	Kafue Gorge Lower	600		green	yellow	red	green	green	green	green	yellow	blue	600	yellow
9	Kariba Extension	600		green	yellow	yellow	green	green	green	green	green	blue	392	green
10	Boroma	444		green	yellow	yellow	yellow	green	green	yellow	yellow	cyan	-	yellow
11	Lupata	654		green	yellow	yellow	yellow	green	green	yellow	yellow	cyan	-	yellow
	Multipurpose dams on unregulated tributaries													
12	***Gwayi dams***												ZINWA (2007?)	
	1. Gwayi Shangani		635	green	yellow	yellow	yellow	green	yellow	yellow	yellow	blue	107	yellow
	2. Gway Umguza		195	green	red	yellow	yellow	green	yellow	yellow	yellow	light cyan	83	yellow
	3. Bupi Lupane		40	green	red	yellow	yellow	green	yellow	yellow	yellow	blue	11	yellow
13	***Sanyati dams*** (Kudu dam)		160	green	red	yellow	yellow	green	yellow	yellow	yellow	light cyan	160	yellow
14	***Luangwa dams***													
	1. Lusemfwa Lower	35	500	red	red	red	yellow	red	yellow	red	green	light cyan	-	red
	2. Luangwa	40	2500	red	green	red	yellow	red	yellow	red	green	light cyan	-	red
15	***Luia dams***													
	1. Luia 1			yellow	yellow	red	yellow	yellow	yellow	yellow	red	light cyan		yellow
	2. Luia 2			yellow	yellow	red	yellow	yellow	yellow	yellow	red	light cyan	-	yellow
	3. Luia 3			yellow	yellow	red	yellow	yellow	yellow	yellow	red	light cyan	-	yellow
16	***Revubue dam***		8000	yellow	yellow	red	yellow	yellow	yellow	yellow	red	light cyan	-	yellow
17	***Mazowe/Luenha dams***													
	1. Chitse		290	yellow	yellow	red	yellow	yellow	yellow	red	yellow	cyan	141	yellow
	2. Silver Stroom		140	yellow	yellow	red	yellow	yellow	yellow	red	yellow	light cyan	193	yellow
	3. Bindura		87	yellow	yellow	red	yellow	yellow	yellow	red	yellow	light cyan	90	yellow
	4. Kunzvi		146	yellow	yellow	red	yellow	yellow	yellow	red	yellow	light cyan	147	yellow
	5. Luenha 1		11000	yellow	yellow	red	yellow	yellow	yellow	red	yellow	light cyan	-	yellow
	6. Luenha 2		4000	yellow	yellow	red	yellow	yellow	yellow	red	yellow	light cyan	-	yellow
18	***Muira dam***		2000	yellow	yellow	red	yellow	yellow	yellow	yellow	red	light cyan	-	yellow
	Dams for livelihoods			green	yellow	yellow	yellow	green	yellow	green	red	cyan	-	green
	Investments in Cahora Bassa Reservoir													
19	Additional Spillway Cahora Bassa	1200		green	red	green	yellow	green	grey	green	green	cyan		green
20	**Flood Risk Zoning**													
	- Flood risk zoning for rules for new settlements			green	yellow	green	yellow	red	grey	yellow	green	light cyan		green
	- Flood risk zoning for current land use and awareness raising			green	yellow	green	yellow	red	grey	yellow	green	light cyan		green
	- Flood risk zoning for insurances			red	grey	grey	grey	grey	grey	grey	grey	light cyan		red
	- Flood risk zoning for rescue and warning			green	green	yellow	yellow	green	grey	green	grey	light cyan		green
21	**Structural flood protection**													
	- Dykes			yellow	yellow	red	red	yellow	red	red	grey	light cyan	0.5-1.9 /km	red
	- Elevated schools / public buildings			green	green	grey	green	green	grey	yellow	grey	light cyan	0.8-1.6 /ha	green
	- Construction of higher areas for refuge			green	green	grey	yellow	yellow	grey	yellow	grey	light cyan		green
	- Diversion of flood waters			yellow	yellow	yellow	yellow	yellow	grey	yellow	grey	light cyan		yellow
	Sediment management													
22	- Investments in bottom outlets			red	green	yellow	yellow	yellow	grey	green	yellow	grey	15-20% of total capital cost	yellow
	Diversification Power Pool													
23	- Operational costs of temporarily shutting down hydropower			green	yellow	grey	red	red	grey	yellow	red	grey		red
24	- Dispatching combined with flow forecasting System	+		green	green	grey	green	green	grey	yellow	green	light cyan		green
25	- Extra Thermal Power Plants	+		yellow	yellow	grey	yellow	yellow	grey	green	green	grey		yellow
	- New or enhanced interconnectors	+		green	green	grey	grey	green	grey	green	green	cyan		green

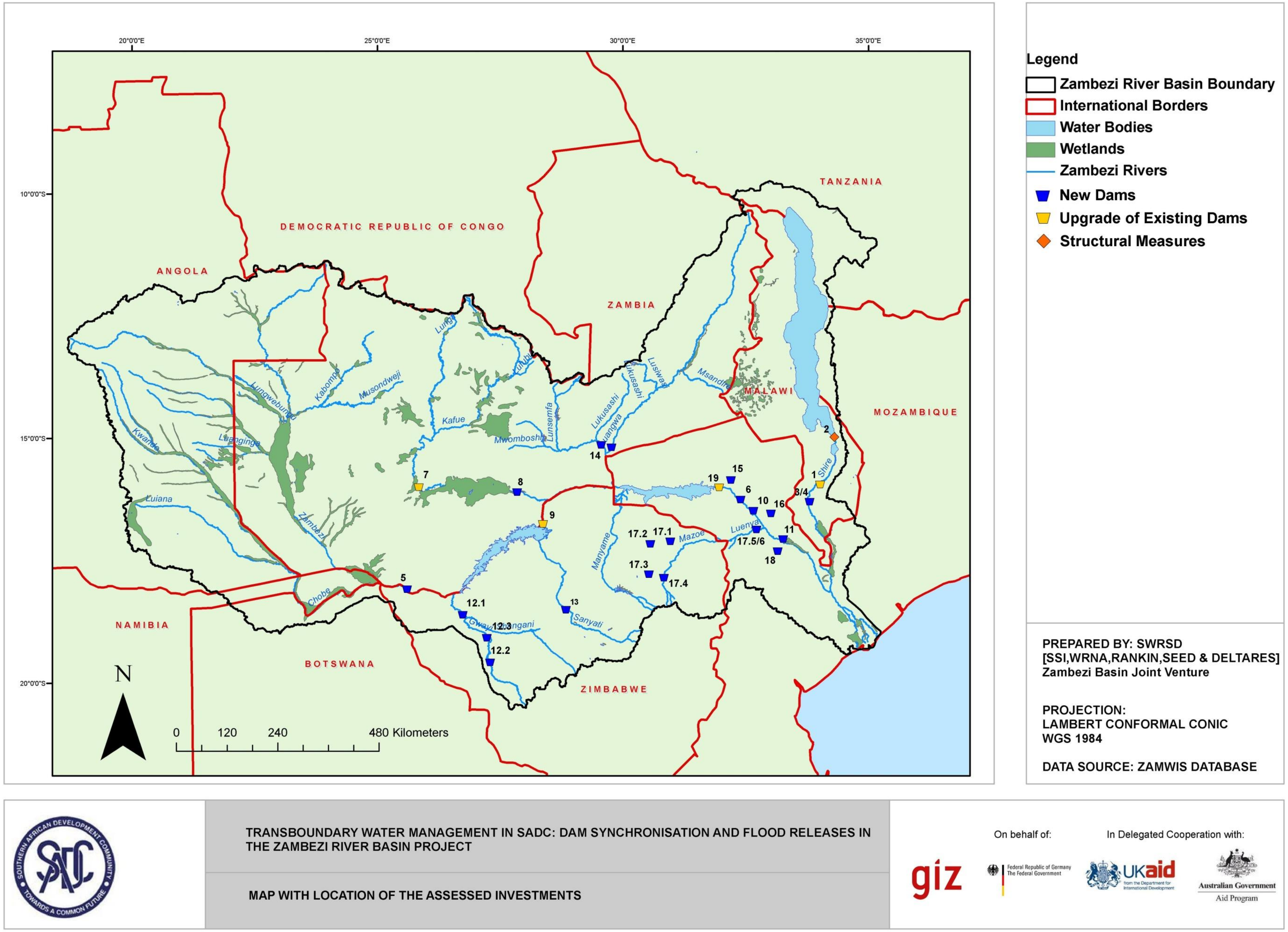

Figure 5.3: Map with locations of the assessed investments

6 Project's specific Recommendations

The Consultant proposes the following specific Recommendations for each Output area extracted from Annexes 1 to 4 of the Main Report. It should be highlighted here that these specific Recommendations were discussed, amended, validated and consolidated by the three AG Meetings which were held during the life of the Project and by other Zambezi River Basin stakeholders through the consultative process undertaken by the Consultant. Table 6.1 summarizes these specific recommendations leading to the consolidated recommendations for improved Basin-wide Management of the Zambezi River Basin given in Section 7 of this Main Report. The following are the detailed specific Recommendations.

6.1 Governance Issues

The governance issues were identified in Section 3 of this Report and are summarised in Table 3.2 above. The timely resolution of these governance related issues is fundamental in the realisation of conjunctive and synchronised dam operations in the Zambezi River Basin that will minimise flooding, mitigate droughts whilst enhancing livelihoods and providing water for the environment. As these are national and institutional issues, they will need time and resources and continued goodwill whilst negotiations are being undertaken. The ZAMCOM Secretariat and SADC have a major role to play in the realisation of the solutions to these governance issues.

6.2 Data and information sharing

The following specific recommendations, detailed in Annexes 1 and 2 of the Main Report, relate to data and information sharing:

1) ***Operationalise and upgrade ZAMWIS to a fully operational hydrological database*** (Annex 1 Intervention Sheet # 1.1 & Annex 3 Intervention Sheet 3.13). To operationalise ZAMWIS, the interim ZAMCOM secretariat needs only to pay the necessary fees for hosting the server-hosted database's website domain. Once these fees are paid, ZAMWIS will be up and running again and accessible to the Zambezi Basin stakeholders. Improvements can be made to upgrade ZAMWIS by enhancing the current windows-based interface of ZAMWIS, allowing for ease of access to data and updating of information. The data contained in ZAMWIS should also be cleaned and patched whilst extending the available observed data and carrying out statistical analyses of stream flows to inform dam operations. ZAMWIS should also be linked to other regional databases like the SADC-HYCOS. The interim/permanent ZAMCOM secretariat should put in place the mechanism to regularly update ZAMWIS with geodata, and reports, as well as maps, etc.

2) ***Analyze and verify existing data in ZAMWIS*** (Annex 1 Intervention Sheet # 1.2 & Annex 2 Intervention Sheet 2.7)). Many of the years in which data has been reported are incomplete. In addition, rating curves used in certain gauging stations are insufficient to translate stage information into discharge. Data from many different sources, representing the same river basin, requires evaluation to ensure consistency and provide for confidence in the basin-wide users that rely on this information. This will improve the quality of the observed flow data for stations used in the operation of dams on the Zambezi River Basin.

6.3 Dam management

The Consultant has provided the following specific recommendations, detailed in Annex 2 of the Main Report, related to dam management:

1) ***Promote the establishment of a Zambezi Basin System Operators' Forum and support existing stakeholder participatory fora*** (Annex 2 Intervention Sheet # 2.1). The major Dam Operators and Power Producers in the Zambezi River Basin namely: ZRA, HCB, ZESA and ZESCO have a platform for cooperation called the Joint Operation Technical Committee (JOTC). ZINWA and ARA Zambeze are also part of the committee. The JOTC is focused on the operations of the Kariba, Kafue and Cahora Bassa dams. In the past hydrologists working on the Zambezi Basin met once a year following the SARCOF meeting. This meeting allowed these specialists to engage and interpret recommendations from SARCOF into practical forecasts. These meetings have since stopped.

   The management of the Zambezi River Basin in a system-wide context will entail the accommodation of other uses of the river such as flood protection, agriculture and the environment. This study identified the need for a broader forum of stakeholders to address the extended dam operating objectives, and recommends the establishment of a System Operating Forum (SOF). This includes organizations responsible for Disaster Management, NGOs, ESCOM, Water Management, Environmental Management, Local Government and the Civic Society. Most of these other stakeholders, currently excluded from the JOTC, are the ones that deal with the effects, impacts and consequences of flood and drought events as well as with the impacts of flow releases from the Zambezi River Basin dams. This broader forum, whilst not replacing the JOTC which should continue as a technical committee, will enhance sharing of data between operators and other stakeholders. It will facilitate closer liaison with different ongoing programs by various organizations as well as updating the ZAMWIS database.
2) ***Support capacity building to facilitate better understanding of dam synchronisation and new modes of dam operation*** (Annex 2 Intervention Sheet # 2.2). The Zambezi River System has important socio-economic and environmental functions and it is resident to over 40 million people. There is growing recognition that the development and operation of water resources in this system needs to consider diverse uses. Synchronisation of dam operations and adoption of new modes of operation can contribute to this objective. The capacity building of the Basin's Hydrologists, JOTC and SOF will facilitate the better understanding and benefits of synchronisation of dam operations and adoption of new modes of operation. This better understanding is important for monitoring the implementation of recommended interventions, sharing of information and to get early buy-in of these concepts. This capacity building should consider the requirements of different stakeholders.
3) ***Establish and implement a basin-wide flood and drought risk management plan*** (Annex 2 Intervention Sheet # 2.3). A review of the current practice/operation and institutional set-up of the Zambezi River system shows that there is scope to incorporate flood and drought mitigation measures in policy and planning in order to reduce the vulnerability of the system to floods and droughts..Mitigation measures and policies in riparian states need to be harmonized into a basin-wide action plan. Key strategies for reducing vulnerability include increasing resilience through preparedness, adaptation and advance knowledge of flood/drought onset and severity. This can be achieved by establishing and implementing a flood and drought risk management plan.
4) ***Facilitate the adoption of new modes of dam operation*** (Annex 2 Intervention Sheet # 2.4). Current dam operations leave some other important user objectives and are typically for one year. Apart from dam safety and hydropower generation, other user objectives to be considered include flood management, environmental requirements, irrigation, and flood-plain agriculture, among others. The fulfilment of multi-purpose operating objectives will require improved information, development of multi-objective, multi-year operating rules and synchronization of dam operations. Improved operation of dams and barrages contribute to the maintenance of the ecological integrity of Zambezi River system and

mitigation of flooding. Monitoring of implementation of the operating rules will result in progressive realization of benefits and adjustments where necessary.

5) ***Develop operating rules for new dams*** (Annex 2 Intervention Sheet # 2.5). This would involve reviewing and updating guidelines for operation of dams of low live storage/MAR ratio that may be developed on the Zambezi River and its tributaries to incorporate basin-wide objectives as well as ensuring that the designs of new dams incorporate the new modes of dam operation.

6) ***Estimate and implement Zambezi Environmental Flows*** (Annex 2 Intervention Sheet # 2.6). Data and information on environmental flow requirements is generally unavailable and there is need to implement a process to obtain the data and information so as to be better informed in introducing and implementing environmental flows in the Zambezi River Basin. The WWF is supporting a project to establish environmental flow requirements for parts of the Zambezi River Basin. Establishment of environmental flows for the rest of the Basin will complement this effort.

7) ***Improve the quality of observed flow data for application on dam management*** (Annex 2 Intervention Sheet # 2.7). The available historical flow records in the ZAMWIS database have a lot of gaps. Some of the stage data has not been converted to flow and is still presented as stage readings. There are no rating curves for some of these gauge stations and there is need to develop them. Some of the data has gaps which can be filled using scientific patching methods. The usefulness of the ZAMWIS database as a source of flow data can only be realized if this data is improved and the database is continuously updated and maintained.

8) ***Simulate flow time series for the Zambezi River System*** (Annex 2 Intervention Sheet # 2.8). The stochastic nature of rainfall brings uncertainty and variability and as such risks associated with use of stochastic analyses need to be established and minimized. This will entail developing models and undertaking rainfall-runoff analyses and flow routing for important stations identified in the study using methods that accommodate heterogeneity and allow comparison across the Basin.

9) ***Develop climate change scenarios for the Zambezi River Basin*** (Annex 2 Intervention Sheet # 2.9). This exercise is important as the results will improve understanding of possible future changes in the climate of the Zambezi River Basin and the implications on dam and wetland management. This will entail developing new climate change scenarios relevant to dam management and wetland hydrology for the Zambezi River Basin for a period of 20 to 50 years.

10) ***Improve the understanding of the hydrology and functioning of wetlands in the Zambezi River Basin*** (Annex 2 Intervention Sheet # 2.10). The Zambezi River Basin has a number of significant wetlands. The Barotse and Lower Shire wetlands are important for management of floods and they also perform very important socio-economic and environmental functions. The wetlands in the Zambezi River Basin are likely to be impacted on by land use patterns and climate change. The wetlands face a number of threats rooted in poverty and high demographic growth rates. The degradation of the wetland functions may continue into the future unless the impacts are quantified and appropriate interventions are identified and implemented.

11) ***Implement a pilot project involving the Kariba, Itezhi-Tezhi, Kafue and Cahora Bassa dams on synchronisation, conjunctive operation of dams for introduction of e-flows and flood release management*** (Annex 2 Intervention Sheet # 2.11).The major dams of the Basin have, to date, been operated more of less independently, without regard to the requirements of other stakeholders.. Similarly, all dams have been managed without any provision for environmental flows and other socio-economic considerations for downstream or other riparian users. Floods and droughts are part of the history of the Zambezi with and without dams. Large floods and severe droughts are a fact of life in the Zambezi system. Dams impound floods and modify downstream flows and the lake environment. However releases can be managed to minimize upstream and downstream

impacts. The need to widen the range of possible flow regimes in the Zambezi River system downstream and upstream of major dams in order to provide for more uses/users was established in this study. The goals of system optimization, water security and benefit sharing were also discussed in detail. Synchronisation and conjunctive operation are two terms which are very closely associated with modern scientific trends in dam management to achieve these goals. There is need to demonstrate or otherwise that dam synchronisation, conjunctive operation of dams and introduction of environmental flows in the Zambezi River Basin is achievable. Dam Operators and other stakeholders require support to set up and implement a practical pilot project which builds confidence in synchronised and conjunctive operation of dams whilst providing valuable lessons and experiences for improvements and future replication in other SADC River Basins..

6.4 Precipitation and flow forecasting

A comprehensive forecasting system is almost a pre-requisite to establishing confidence in the weather and flow forecasts if early buy-in from riparian states and dam operators to take operational risks based on reliable data and information is to be obtained. A Basin-wide flow forecasting system would also play an essential role in integrating the Basin states by providing a strong platform for cooperation and sharing of information between the various stakeholders. The following are the specific recommendations made under Precipitation and Flow Forecasting and detailed in Annex 3 of the Main Report:

1) ***Rehabilitate SADC-HYCOS Network*** (Annex 3 Intervention Sheet # 3.1). The SADC-HYCOS network is the only basin-wide, real-time flow gauging network in the Zambezi River Basin. While some gauges are no longer operational due to breakdown or theft of equipment, a considerable investment in the identification of suitable sites and establishment of gauge infrastructure (civil works and gauge equipment) has already been made. By applying important lessons and experiences from the SADC-HYCOS Phase I and II, the risk of future theft, vandalism and damage will be minimised.
2) ***Extend network of real-time gauging stations*** (Annex 3 Intervention Sheet # 3.2). Although the SADC-HYCOS network provides good coverage in most key areas of the Zambezi River Basin, approximately 23 additional flow gauges, which do not currently have real-time equipment, were identified in the network design for establishment of a basin-wide flow gauging network. This includes existing manual and real-time (non-SADC-HYCOS) gauges used by basin based forecasting authorities such as ZRA, ZESCO, Namibia DWAF and ARA Zambeze, as well as other locations where additional coverage is considered necessary.
3) ***Establish Rating Curves for key gauges*** (Annex 3 Intervention Sheet # 3.3). An essential aspect of managing a flow-gauging network is the establishment and regular updating of rating curves for the conversion of water level readings into flows. This has been an on-going issue with some SADC-HYCOS stations, for which accurate rating curves have never been established. Most stations within the Zambezi River Basin are located at natural control sections, which often change with each flood season, necessitating that rating curves are updated after significant floods and at least annually.
4) ***Enhance procedures for collection of rainfall data*** (Annex 3 Intervention Sheet # 3.4). Currently, most precipitation measurement stations, which are owned by the respective NMSs in the Basin, are read manually. Most measurements are transmitted by phone or sent by post on a monthly basis to the central NMS office in each country. For real time forecasting, measurements should arrive at the central forecast location as soon as possible after the measurement has been taken. To this end, a procedure needs to be agreed upon between the ZAMCOM secretariat and the responsible National Meteorological Services (NMS's) to ensure timely delivery of data to the proposed flow forecasting centre.

5) ***Upgrade rain gauge network for real-time capability*** (Annex 3 Intervention Sheet # 3.5). Upgrading of the precipitation gauge coverage will result in sufficiently accurate rainfall estimates over sub-basins where rainfall-runoff models need to be run in order to establish flow forecasts. This intervention will require close cooperation with NMSs, as well as their broad support.
6) ***Implement approach for use of satellite rainfall estimation (SRE)*** (Annex 3 Intervention Sheet # 3.6). SRE is accurate enough to provide rainfall estimates in remote areas, where operation and maintenance of an extensive rain gauge network is not feasible. It would also require relatively little investment to establish SRE as a short to medium term observation mechanism in areas which have sufficient existing rain gauge density, but which require conversion of manual gauges to real-time for timely ground based measurement of precipitation. Furthermore, selected SRE products have operational status and are made available with little delay between acquiring satellite information and availability of the product on the internet. This intervention could be implemented as a short term measure through the SADC Climate Services Centre, which would allow Zambezi riparian states to start receiving and benefitting from SRE data prior to the full establishment of either the Flow Forecasting Centre or ZAMCOM.
7) ***Integrate existing flow forecasting models into a Basin-wide flow forecasting system*** (Annex 3 Intervention Sheet # 3.7). There are currently a number of flow routing or forecasting models available for the Zambezi Basin, which are likely to be suitable for use in a basin-wide flow forecasting system. These models contain local knowledge and are known to the authorities that own and use them. By integrating these existing models into a flow forecasting system, these authorities will recognize and understand the functionality of such a system. As a result, the sustainability of the forecasting system will increase, as it will be easier for the authorities to operate and enhance the underlying models. Furthermore, by integration, models can be connected together.
8) ***Develop new flow forecasting models and integrate with existing models*** (Annex 3 Intervention Sheet # 3.8). The strengthening of existing model capabilities in the proposed flow forecasting system will ensure that the forecast requirements of Dam Operators, energy producers and disaster management units are met. The required new models serve forecasts with different lead times. These models include rainfall-runoff models, flash flood guidance, hydrodynamic and river routing models for short lead times; reservoir models for medium-range and seasonal lead times; and water balance models for seasonal lead times.
9) ***Investigate new forecasting capabilities in collaboration with research institutions and universities*** (Annex 3 Intervention Sheet # 3.9). Hydrological and hydraulic models, precipitation forecasting and satellite information are rapidly evolving. New developments can improve the accuracy and versatility of the proposed flow forecasting system. To keep track of such new developments and ensure implementation in the flow forecasting system, strong links with research institutes and universities are needed. In particular WaterNet (regional network of universities and research institutes in Southern Africa) can offer a strong link with universities and positions for MSc and PhD research.
10) ***Expand precipitation forecasting capabilities of the SADC Climate Services Centre*** (Annex 3 Intervention Sheet # 3.10) There is need to integrate existing capabilities in precipitation forecasting through the SADC Climate Services Centre (former Drought Monitoring Centre) in collaboration with RSMC Tshwane (or other regional centres with similar capabilities), and National Meteorological Services. Current capabilities in precipitation forecasting are well established in the SADC region. The National Meteorological Services in the region, and in particular the WMO Regional Specialised Meteorological Centre in Tshwane has well developed precipitation forecasting capabilities. Within SADC, the annual SARCOF has an acknowledged role in establishing seasonal forecasts, with the Climate Services Centre updating and disseminating the seasonal outlooks made by SARCOF on a regular basis.

11) ***Review forecast locations and requirements for stakeholders*** (Annex 3 Intervention Sheet # 3.11). A basin-wide flow forecasting system will provide key information to stakeholders across the Zambezi River basin. Each stakeholder requires information tailored to meet specific needs. To utilise these forecasts in such a way that they provide maximum benefit to the stakeholder, the information provided by the forecast system should be fine-tuned to meet the requirements. Procedures need to be developed with regard to when critical information is conveyed from the forecast system to the stakeholders, as well as how these stakeholders will use the information to guide and improve their operational process.
12) ***Establish data sharing Agreement between Dam Operators and other stakeholders*** (Annex 3 Intervention Sheet # 3.12). Establishment of a basin-wide flow forecasting system will require the sharing of real-time hydrological and meteorological data and information between National Hydrological Services (NHSs), National Meteorological Services, forecasting agencies, Dam Operators and the ZAMCOM Secretariat. At present, there are no formal agreements for the sharing of data between these parties, except between the Namibia DWA and ZRA. This situation is currently of greatest concern for downstream countries which need information on upstream rainfall and flows for their forecasting. The Agreement should include a protocol on how the data will be shared and in what format and any agreed charges for the data or agreed contributions for the collection of this data etc.
13) ***Establish Basin-wide Flow Forecasting Centre with training and research roles*** (Annex 3 Intervention Sheet # 3.14 & 3.15). To allow sustainable operation of a basin- wide foresting system providing information to all stakeholders in the Zambezi River Basin, an operational Flow Forecasting Centre is required. This Flow Forecasting Centre should have adequate capabilities in terms of human resources and infrastructure to ensure that high quality forecasts can be produced. The Flow Forecasting Centre for the Zambezi River Basin should be a key activity of the interim/permanent ZAMCOM secretariat as mandated and obligated in Articles 6 and 15 of the ZAMCOM Agreement. The operation of the Flow Forecasting Centre, as well as the continued development of the forecasting methods used can be sustained by extending the role of the Flow Forecasting Centre to establish it as a "Centre of Excellence" for this field. Staff from different stakeholders (Dam Operators, Disaster Management Units) can be seconded to the Centre for short periods of time to ensure the involvement of stakeholders and the recognition of their needs, as well as facilitating the incorporation of new forecasting methods into the operational domain. The Centre of Excellence would also provide training of staff from stakeholders across the basin, so that the anticipated benefits of the use of forecasts are sustained.
14) ***Establish forecasting system using flexible operational platform*** (Annex 3 Intervention Sheet # 3.16). Requirements for operational forecasting by the stakeholders will change over time. Additionally the models and methods available for precipitation forecasting are a subject of continued research and development. The software that is used for the operational forecasting system should be flexible enough to allow for incorporation of these changes by the staff at the proposed Flow Forecasting Centre.

6.5 Investments

The Consultant has provided specific recommendations for capital investments to build additional dams as well as other infrastructure related to water resources management, with a focus on improving flood protection and environmental flows. The capital investments will be evaluated for their impact on flood protection and flow regulation and have been recommended for further feasibility study, if technically and financially viable. The following are the specific recommendations as detailed in Annex 4 of the Main Report:

1) ***Assess Investments in the regulation of the Shire River and Lake Malawi*** (Annex 4 Intervention Sheet # 4.1). Three investments are being considered: upgrading of Kamuzu Barrage, the pumping scheme at Mponda and the Kholombidzo (High or Low) Reservoir.

Malawi, Mozambique and Tanzania need to be aware of the potential impacts of changes in the regulation of the Shire in the Lake Malawi/Shire system. Upgrading of Kamuzu barrage contributes to extra hydropower generation and easier operation during floods. Kholombidzo (High or Low) Reservoir contributes considerably to extra hydropower production whilst the proposed pumping scheme at Mponda would facilitate pumping water out of Lake Malawi during periods of low lake levels.

2) ***Assess Investments in multi-purpose dams on the mainstream Zambezi and Kafue Rivers*** (Annex 4 Intervention Sheet # 4.2). Changes in the operation of the large reservoirs and the building of new large reservoirs will have international impacts on floods, the environment and economic development. The planned run-of-river dams: Kafue Gorge Lower, Mphanda Nkuwa and Batoka Gorge as well as Lupata and Boroma would contribute considerably to solving the power deficit in the SADC region and to flood control giving flexibility in the management of the existing dams. Mphanda Nkuwa, Lupata and Boroma would also contribute additional flow releases for the environmental and for the Zambezi River Delta.
3) ***Facilitate the siting of new dams/reservoirs on the Zambezi River unregulated tributaries*** (Annex 4 Intervention Sheet # 4.3). The siting of the new dams are a prerequisite to informing investments in small and medium sized dams for enhanced livelihoods, local flood management and provision of environmental flows.
4) ***Support the construction of an extra spillway at Cahora Bassa Dam*** (Annex 4 Intervention Sheet # 4.4). The benefits of the additional spillway are in relation to operating Cahora Bassa reservoir at higher lake levels thus maximising hydropower production with possibilities of storing additional water for the environment.
5) ***Provide adequate bottom outlets in new dams*** (Annex 4 Intervention Sheet # 4.5). New large dams on the unregulated tributaries of the Zambezi should consider bottom outlets for multi-purpose uses such as the release of minimum flows (contributing to environmental flows), and water quality management. For new small and medium sized dams, bottom outlets will also be used for sediment releases. The predicted increase in intensity of rainfall due to climate change means that rivers will carry more sediment load. If deposited in small and medium size dams, these sediments will significantly reduce their live capacity, design life and usefulness
6) ***Support the coordination of flood risk zoning initiatives*** (Annex 4 Intervention Sheet # 4.6). Coordination between current mapping activities in the Zambezi River Basin is a first and useful step in flood risk zoning that will benefit flood forecasting and the involvement of local and international relief organisations during flood events as well as the understanding between neighbouring countries.
7) ***Support local multi-purpose measures which add to flood protection*** (Annex 4 Intervention Sheet # 4.7). The purpose of infrastructural flood protection measures is to provide direct flood protection of livelihoods or capital investments by either keeping the water levels low at these locations or by offering possibilities to flee to higher ground. In general, little information exists on flood protection measures in the Zambezi River Basin.
8) ***Consider local structural flood protection measures or diversion of floods*** (Annex 4 Intervention Sheet # 4.8). The concept of flood diversion is to divert a portion of the flood towards the less valuable parts of the floodplain in order to protect the more valuable land parts. This kind of structural solution can involve the construction of dykes, channels or diverting structures (spillways).
9) ***Support new SAPP interconnections*** (Annex 4 Intervention Sheet # 4.9). Improved interaction of energy and water management and its role in flood protection and environmental releases is assisted through investments in the SAPP network. Establishment of SAPP interconnections between countries releases the pressure on optimal power production at the hydropower sites in the Zambezi River Basin. Angola, Malawi and Tanzania are not yet connected to the SAPP network. The limited transmission capacity of

the SAPP network is a bottleneck to energy trade between the Zambezi riparian states and SADC as a whole

10) ***Support Flow Forecasting Centre and SAPP Dispatching Centre*** (Annex 4 Intervention Sheet # 4.10). Investments in the energy grid, power plants and the coordination of power generation by a Forecasting and Dispatch Centre, would be very beneficial for more efficient power production in the SADC Region as it is then possible to coordinate power production with water availability or based on forecasted flows to come. This is particularly beneficial in drought situations and is an added advantage of these investments. The main benefits of such investments are therefore a maximization of power production on present and predicted water availability.

11) ***Carry out a financial assessment of the Project recommendations and the implications for implementation.*** (Annex 4 Intervention Sheet 4.11). 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. This recommendation thus 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.

Table 6.1: 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

7 Project's Overall Outcome

7.1 Linkages between the SADC's strategic objectives, regional water policy and strategy with project's recommendations

The SADC Regional Water Policy (SADC 2006) and the SADC Regional Water Strategy (SADC 2006) are divided into nine thematic areas which give reference to each thematic area's Strategic Objectives, the proposed Strategies and relevant Policy statements. It is therefore necessary to link some of the Recommendations of the Project with these Objectives, Strategies and Policies. Tables 7.1 gives these linkages.

Table 7.1: Linkages between the SADC's strategic objectives, regional water strategy and regional water policy with the project's recommendations

SADC STRATEGIC OBJECTVES	RELEVANT SADC REGIONAL WATER SECTOR STRATEGY	RELEVANT SADC WATER SECTOR POLICY STATEMENT	RELEVANT ZAMBEZI DAM SYNCHRONISATION PROJECT RECOMMENDATION	RELEVANT COMPLEMENTARY SADC ZAMBEZI PROJECT
To promote regional economic integration through the integrated management of water resources.	3.1 (b) Strengthen regional governance through the establishment and enhancement of shared watercourse institutions to enable effective, appropriate and incorporate management of water resources within shared watercourses.	9.2.2 A shared watercourse institution shall be established in each watercourse to advise and coordinate the sustainable development and equitable utilisation of the associated water resources for mutual benefit and integration.	(a) Consider role of Dam Operators and provide support to basin-wide Zambezi River System Operators' Forum (Annex 2 Intervention Sheet # 2.1) (b) Extend the role of the SADC Climate Services Centre to coordinate short, medium and long range seasonal precipitation forecasting in the SADC Region. (Anne 3 Intervention Sheet # 3.10) (c) Establish a Basin-wide Flow Forecasting Centre as part of the interim/permanent ZAMCOM Secretariat (Annex 3 Intervention Sheet # 3.14 and 3.15)	Signing and ratification of the ZAMCOM Agreement.
	3.1(c) Identify water infrastructure projects that have regional significance and hence develop and implement a regional strategic water infrastructure programme to change the lives of the region's people and meet the MDGs.	8.5.1 Integrated planning development and management of dams will be promoted so as to optimize the use of water resources, maximise derived benefits (such as hydropower, tourism, flood control, irrigation and water supply) and take both positive and negative externalities into account for both upstream and downstream countries.	(a) Improve operation of existing water infrastructure to take a longer term view in order to incorporate new objectives without compromising safety. (Annex 2 Intervention Sheet # 2.5) (b) Focus on development of small and medium sized dams or barrages on tributaries to enhance livelihoods, local flood protection and provision of water for the environment. (Annex 4 Intervention Sheet # 4.3)	Dam Synchronization and Flood Releases in the Zambezi River Basin Project.
To manage water resources within SADC in a manner that builds trust, understanding	3.2 (b) Develop a common water resources information data base and agreed analytical	3.2.2 Watercourse states shall participate and cooperate in the planning, development,	(a) Use the Precipitation and Flow Forecasting Centre for database management and analysis in order to make better informed decisions in the future. (Annex 3 Intervention Sheet # 3.14 and 3.15)	Consolidation and Expansion of SADC HYCOS.

SADC STRATEGIC OBJECTVES	RELEVANT SADC REGIONAL WATER SECTOR STRATEGY	RELEVANT SADC WATER SECTOR POLICY STATEMENT	RELEVANT ZAMBEZI DAM SYNCHRONISATION PROJECT RECOMMENDATION	RELEVANT COMPLEMENTARY SADC ZAMBEZI PROJECT
and cooperation between Member States based on mutual benefit and equitable use.	methods to further strengthen and consolidate trust and support cooperation among Member States	management, utilisation and protection of water resources in the shared watercourses	(b) Extend SADC-HYCOS and link SADC-HYCOS to the ZAMWIS initiative. (Annex 1 Intervention Sheet # 1.1, Annex 3 Intervention Sheet # 3.1 and 3.13) (c) Start with improved exchange of information on flow forecasting as a first step in preparing a joint flow forecasting centre, which can be a bridge for further collaboration. (Annex 3 Intervention Sheet # 3.12) (d) Improve information dissemination on dam operations, possible and actual impacts through a basin-wide Zambezi River System Operators' Forum. (Annex 2 Intervention Sheet # 2.1) (f) Resuscitate and maintain an up-to-date ZAMWIS and undertake periodic reviews (there is a huge disappointment among stakeholders on the current status of the ZAMWIS database) (Annex 1 Intervention Sheet # 1.1 and Annex 3 Intervention Sheet 3.13)	
To promote the harmonization of all Member States' national water sector policy, legislation and strategy with those of other Member States, the regional policy and strategy and relevant international conventions and protocols.	3.4(a) Promote and support the harmonization of national policy and legislation within SADC.	3.4.1 Member States shall promote the harmonization of their water policies and legislation with the water policy. 3.4.2 National water policy and legislation shall take into account any international regional conventions.	(a) Establish and implement a basin-wide flood and drought risk management plan. Annex 2 intervention Sheet # 2.3) (b) Harmonise decision making by Dam Operators through review of their mandates, policies etc to align with basin-wide protocols and strategies. (Annex 2 Intervention Sheet # 2.1 and Annex 3 Intervention Sheet # 3.12)	Dam Synchronisation and Flood Releases in the Zambezi River Basin Project.
To mainstream the environment in water resource development and management	5.1(b) Facilitate the development and implementation of reasonable measures, minimum requirement and guidelines for determining and meeting environmental water requirements in all watercourses.	5.1.2 Allocate sufficient water to maintain ecosystem integrity and biodiversity.	(a) Provide adequate bottom outlets in new dams. (Annex 4 Intervention Sheet # 4.5) (b) Estimate and implement Zambezi Environmental Flows. (Annex 2 Intervention Sheet # 2.6)	Dam Synchronisation and Flood Releases in the Zambezi River Basin Project.

SADC STRATEGIC OBJECTVES	RELEVANT SADC REGIONAL WATER SECTOR STRATEGY	RELEVANT SADC WATER SECTOR POLICY STATEMENT	RELEVANT ZAMBEZI DAM SYNCHRONISATION PROJECT RECOMMENDATION	RELEVANT COMPLEMENTARY SADC ZAMBEZI PROJECT
To provide framework for fair compensation of adversely affected communities	8.6(a) Develop and promote guidelines for relocation, rehabilitation and benefit sharing by genuinely affected communities	8.6.2 Legislation to provide for equitable compensation of affected communities so that they will not be worse-off as a result of the project	Support the coordination of flood risk zoning initiatives. (Annex 4 Intervention Sheet # 4.6)	(a) InWent/GIZ Sustainable Major Water Infrastructure Development Training (b) Dam Synchronisation and Flood Releases in the Zambezi River Basin Project.
To minimise the loss of human life that occurs as a result of water-related disasters in the SADC region.	6.1(a) Facilitate the development, ratification and implementation of agreements that commit to joint efforts to minimise water related disasters.	6.1.1 Protection of human life, livestock, property and the environment against the effects of water - related natural and human – induced disasters.	Support the coordination of flood risk zoning initiatives. (Annex 4 Intervention Sheet # 4.6)	Dam Synchronisation and Flood releases in the Zambezi River Basin Project.
To establish and manage effective and efficient disaster management plans and structures at appropriate levels within the region.	6.2(a) Strengthen and encourage collaboration of existing international, regional (e.g. DMC, Early Warning Unit, Famine Early Warning System and HYCOS) and national early warning institutions to enable them to stay prepared for disasters and coordinate efforts when disasters occur	6.2.1 Improving the region's capacity in predicting water-related disasters associated with floods and droughts 6.2.2 Develop and implement integrated and coherent watercourse level management plans and procedures for the management of natural disasters and emergency situation	a) Establish a basin-wide Flow Forecasting Centre with training and research roles. (Annex 3 Intervention Sheet # 3.14 and 3.15) (b) Support Flow Forecasting Centre and SAPP Dispatching Centre. (Annex 4 Intervention Sheet # 4.10) (c) A Start with improved exchange of information on flow forecasting as a first step in preparing a joint flow forecasting centre, which can be a bridge for further collaboration. (Annex 3 Intervention Sheet # 3.12) (d) Develop climate change scenarios for the Zambezi River Basin. (Annex 2 Intervention Sheet # 2.9) (e) Establish and implement a basin-wide flood and drought risk management plan. (Annex 2 Intervention Sheet # 2.5)	1) Dam Synchronization and Flood Releases in Zambezi River Basin Project 2) Consolidation and Expansion of SADC HYCOS
	6.2(b) Facilitate formalization and commitments to share information that is relevant to management of water-related disasters and diseases in any of the watercourses in the region	6.2.4 Each Member State has an obligation to notify and share knowledge and information with affected watercourse states in the event of actual impending water related disasters	(a) Establish a basin-wide Flow Forecasting Centre with training and research roles. (Annex 3 Intervention Sheet # 3.14 and 3.15) (b) Support the coordination of flood risk zoning initiatives. (Annex 4 Intervention Sheet # 4.6) (c) Establish and implement a basin-wide flood and drought risk management plan. (Annex 2 Intervention Sheet # 2.5)	

SADC STRATEGIC OBJECTVES	RELEVANT SADC REGIONAL WATER SECTOR STRATEGY	RELEVANT SADC WATER SECTOR POLICY STATEMENT	RELEVANT ZAMBEZI DAM SYNCHRONISATION PROJECT RECOMMENDATION	RELEVANT COMPLEMENTARY SADC ZAMBEZI PROJECT
To provide sustainable water resources data and information systems at national and trans-boundary basin levels to meet the needs for effective planning and management of water resources	7.1(a) Promote and support the establishment of an appropriate hydro-meteorological data and information archival and dissemination systems in the SADC region 7.1(b) Extend, rehabilitate and upgrade hydro-meteorological networks to meet data and information requirements for planning, management and monitoring of water resources 7.1(c) Support the strengthening of national hydro-meteorological institutions including development and retention of human resources capacities at professional and technical levels	7. 1.1 Member states shall establish water resources data and information systems in their territories in an integrated manner at regional, river basin and national levels to meet all water resources management needs 7.1.2 Member States shall adopt compatible systems for data and information acquisition and management	(a) Operationalise and upgrade ZAMWIS. (Annex 1 Intervention Sheet 1.1, Annex 3 Intervention Sheet # 3.13) (b) Establish a basin-wide Flow Forecasting Centre with training and research roles. (Annex 3 Intervention Sheet # 3.14 and 3.15) (c) Supplement existing forecasting networks with remote sensing. (Annex 3 Intervention Sheet # 3.6) (d) Establish basin-wide forecasting system using flexible operational platform. (Annex 3 Intervention Sheet # 3.16)	1) ZACPRO 6.2 ZAMWIS 2) Consolidation and Expansion of SADC HYCOS 3) Dam Synchronization and Flood Releases in Zambezi River Basin Project
To improve access to water resources data and information to all stakeholders	7.1 (d) Develop awareness programmes for the importance of water resources data and information systems. 7.2(a) Establish protocols for processing and exchange of water resources, data and information.	7.2.3 Establish mechanisms for regular interpretation and dissemination of essential information on water resources so that the public is regularly informed. 7.2.1 Member States shall share timeously relevant available information and data regarding the hydrological, hydro-geological, water quality, meteorological and environmental condition of shared watercourses.	(a) Operationalise and upgrade ZAMWIS. (Annex 1 Intervention Sheet 1.1, Annex 3 Intervention Sheet # 3.13) (b) Establish a basin-wide Flow Forecasting Centre with training and research roles. (Annex 3 Intervention Sheet # 3.14 and 3.15)	1)SARCOF 2) Consolidation and Expansion of SADC HYCOS 3) ZACPRO 6.2 ZAMWIS 4) Dam Synchronization and Flood Releases in Zambezi River Basin Project

7.2 The Project's Concept for improved Basin-wide Management

The Project presents new insights into the operation of the Zambezi River as a system for arriving at the overall **"Concepts and Recommendations for improved Basin-wide Management"** considering among other issues:

- Emerging climate patterns;
- The role of wetlands in flood management;
- The importance of establishing a basin-wide flow forecasting system with a supporting Flow Forecasting Centre;
- The potential of establishing flood protection measures and risk zoning; and
- The advantages that synchronized and conjunctive operation of dams would give to the management of the water resources of the Zambezi River Basin whilst improving livelihoods and providing environmental flows.

Several arguments are presented on the need to move dam operations from focusing on dam safety and hydropower generation to a situation where dams are able to accommodate other interests. This involved defining additional objectives and proposing new modes of operation and cooperation, which provide additional benefits. However, there will be need to quantify these additional benefits in order to demonstrate the advantages of operating dams encompassing the multiple objectives.

To contribute towards achievement of the desired balance in meeting the different stakeholder objectives, the following Concept as depicted in Figure 7.2 was developed as a summary of the various contributions from the various Project Tasks undertaken.

The overall "Concept" is that if Investments into improving Precipitation and Flow Forecasting (rehabilitation of DCPs, new DCPs and the establishment of a Basin-wide Precipitation and Flow Forecasting Centre) are made at both Basin and Regional levels, it will result in confidence in the inputs for dam management, operations and dam safety. If the governance issues listed in Table 3.2 are addressed, they will lead into improvements in dam management, operations and overall dam safety through inculcated trust and confidence being built between and amongst Dam Operators and other stakeholders. Investments in new water infrastructure are also required for various purposes but will also overall improve the management and operation of the dams in the Zambezi River Basin as there will be increased options for Dam Operators and other stakeholders.

With confidence in the Precipitation and Flow Forecasting System, appropriate governance issues having been resolved and new water infrastructure put in place, Dam Operators will be more amenable to accepting to operate their water infrastructure conjunctively and in a synchronised manner resulting in them realising several benefits for themselves and for other various stakeholders. "New water" will be realised from conjunctive operation of dams. Flood and drought protection measures will be easier to put in place to protect and improve the environment, to save lives and enhance livelihoods. This will overally result in an improved Basin-wide management of the Zambezi River which safeguards lives, livelihoods and the environment whilst taking due regards to the costs.

The various components of the Concept are associated with the consolidated recommendations for achieving improved Basin-wide Management of the Zambezi River Basin. In coming up with the consolidated recommendations for achieving improved Basin-wide Management of the Zambezi River Basin, the following assumptions have been made as the issues under these assumptions are of fundamental importance if the consolidated recommendations are to be positively considered and eventually implemented:

1) An effective (Interim/Permanent) ZAMCOM has been established;
2) The Zambezi riparian states National Water Sector Policies and Legislation have been harmonized with the SADC Protocols, 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 however be noted that the above assumptions deal with issues that will take a lot of resources, energy and time for their realization and therefore all stakeholders concerned should prioritize the realization of these assumptions.

Table 6.1 and Figure 7.3 summarize the specific recommendations that lead to achieving improved Basin-wide Management of the Zambezi River Basin. These specific recommendations are made under the Sector/Output Areas of; Data and Information, Dam Management, Precipitation and Flow Forecasting and Investments. The specific recommendations in Table 6.1 are also referenced for easy access in the relevant Annexes of the Main Report.

7.3 The project's consolidated recommendations for improved basin-wide management

With the specific recommendations made through the various Project Tasks as detailed in Table 6.1, the following are the Project's consolidated recommendations that if implemented, would address the Project's overall goal of safeguarding lives, livelihoods and providing environmental flows. These consolidated Recommendations summarise and aggregate the more specific Recommendations made and reported on in the four Annexes 1 to 4 of the Main Report.

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, Kafue and Cahora Bassa 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 7.2 below 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 ZAMCOM Secretariat's priority list for sourcing of funding and immediate implementation.

Table 7.2: Consolidated Recommendations Matrix with prioritisation of the consolidated 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	***NUMBER 1***
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	
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	***NUMBER 2***
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	
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	***NUMBER 3***
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	
16	Support new SAPP interconnections (Malawi-Mozambique and Zambia-Tanzania)	Annex 4 Sheet # 4.9	

Figure 7.1 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?".

7.4 The project's 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:

1) 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;
2) Improved, regulated releases from the main reservoirs in the Zambezi River Basin for improved livelihoods and environmental flows will be achieved; and
3) 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.

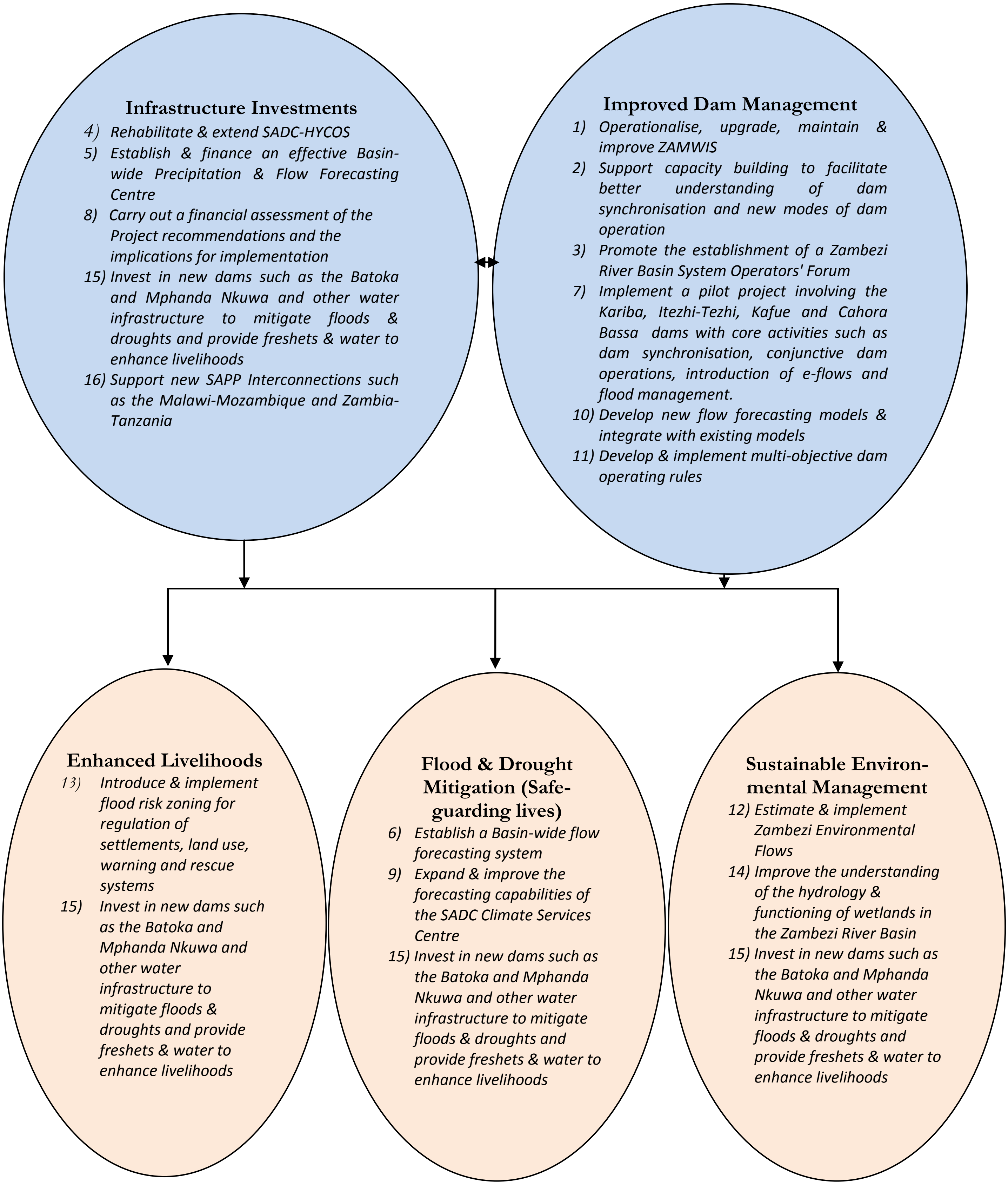

Figure 7.1: Grouping of Project's consolidated Recommendations for improved Basin-wide management

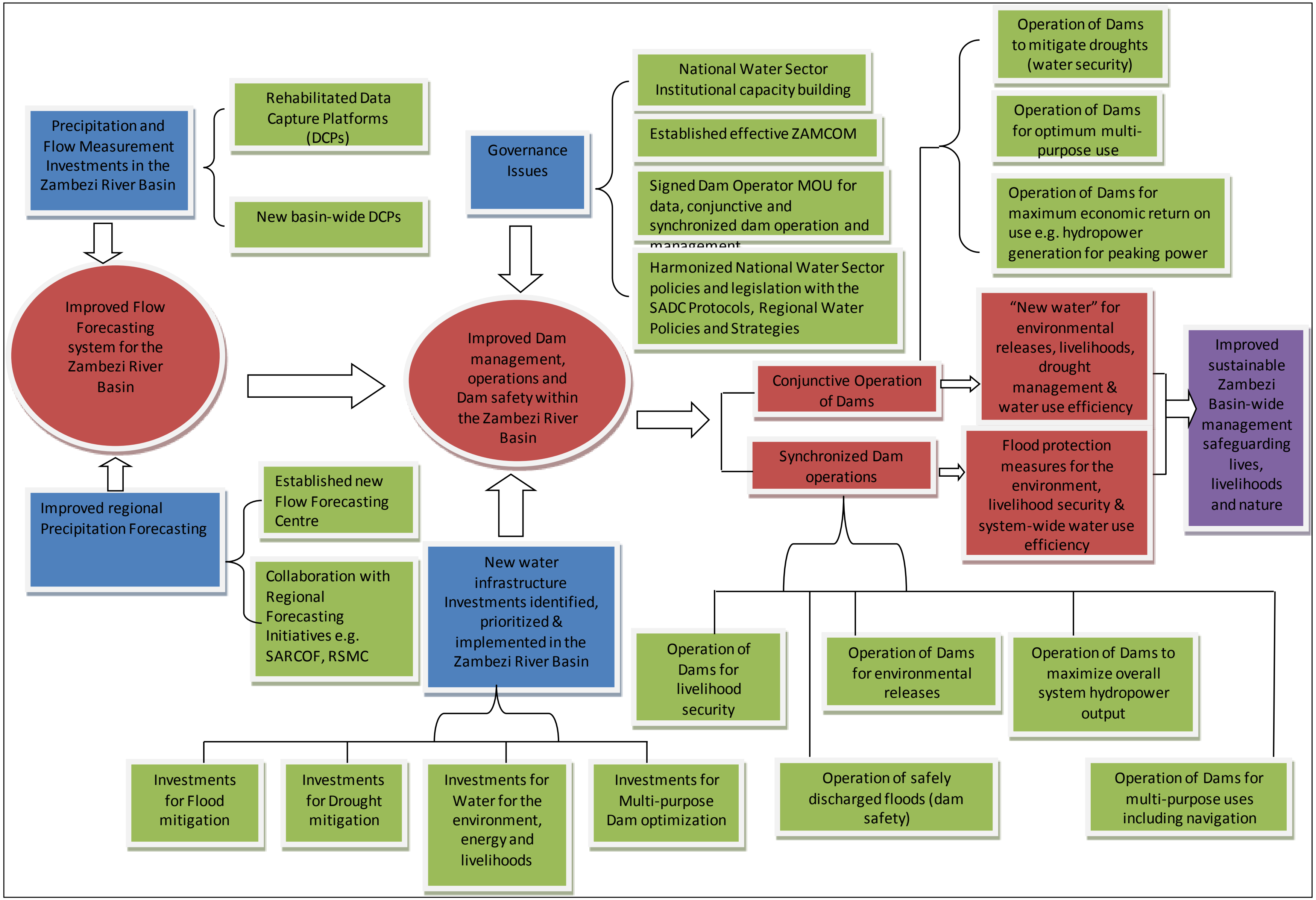

Figure 7.2: Concept for Improved Sustainable Zambezi River Basin-wide Management

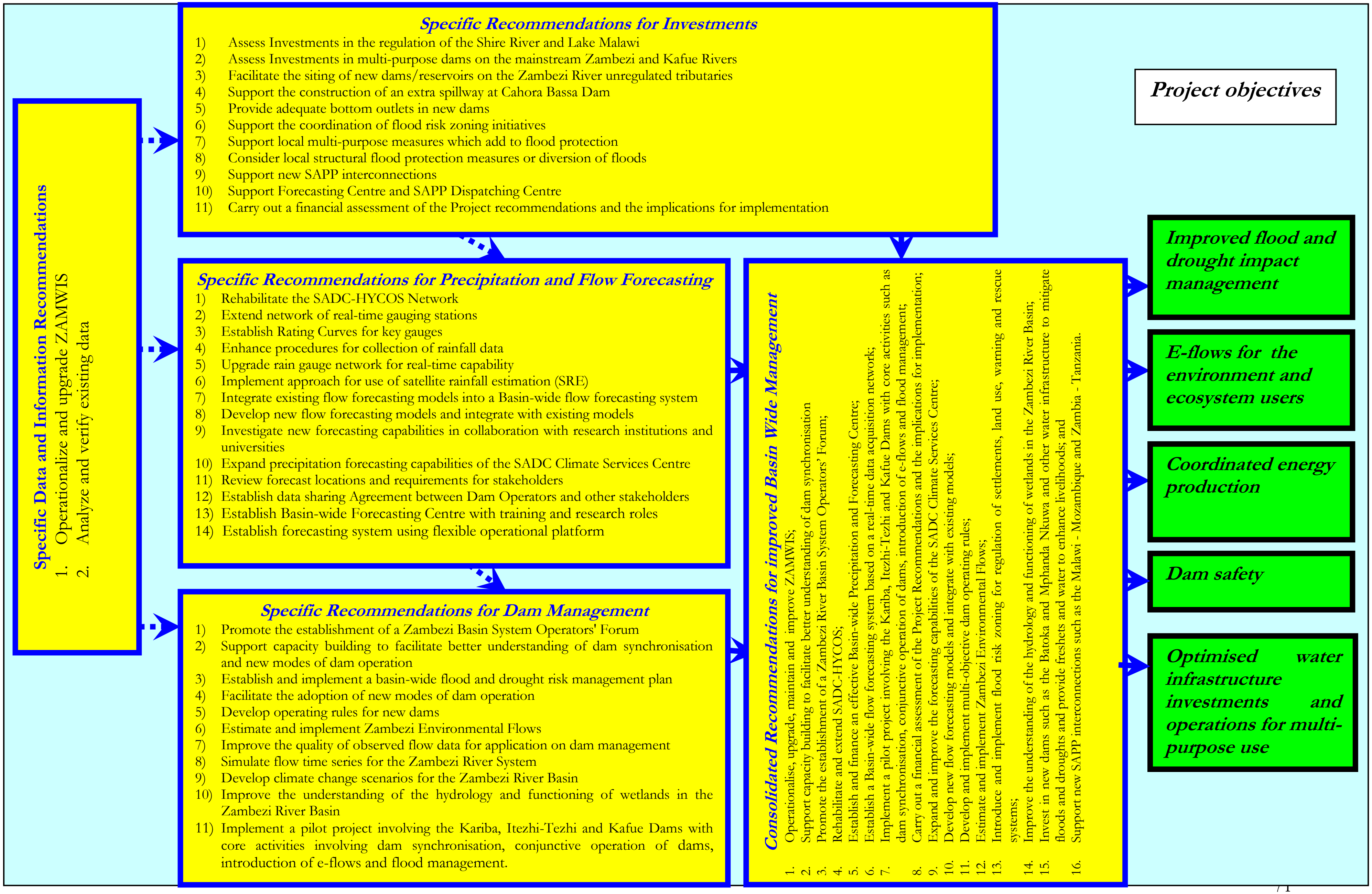

Figure 7.3: Road Map and Linkages between Project Recommendations and Project Objectives/Outcomes

References

Klaassen G. J., (2008), Regulation and Synchronisation of Dam Operations for Environmental Flows in the Zambezi River Basin – Preliminary Analysis, WWF Netherlands/ Mozambique

SADC, (2000), Revised Protocol on Shared Watercourses, Gaborone

SADC, (2006), Regional Water Policy, Gaborone

SADC, (2006), Regional Water Strategy, Gaborone

SADC, (2008), Integrated Water Resources Management Strategy and Implementation Plan for the Zambezi River Basin, Sida/DANIDA/Norwegian Embassy, Lusaka

SADC, (2010), Guidelines for Strengthening River Basin Organisations, Gaborone

WMO, (2009), WMO Final Report Zambezi Basin, Maputo retrieved 1 September 2010 www.whycos.org/WMO/hwrp/Zambezi/FinalReportBasin.pdf

World Bank, (2010), Zambezi River Basin Multi-sector Investment Opportunities Analysis, World Bank

Annexes

Annex 1: Summary Report of compiled literature and existing studies, geodata, measuring/ gauging stations and available data

Annex 2: Concepts and Recommendations for Dam Management

Annex 3: Concepts and Recommendations for Precipitation and Flow Forecasting

Annex 4: Recommendations for Investments