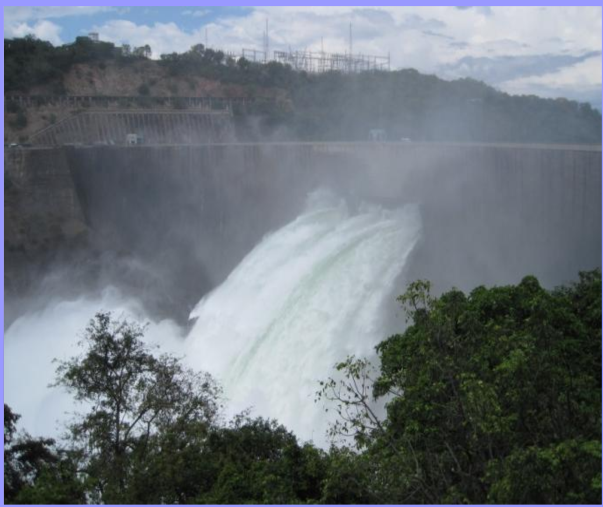
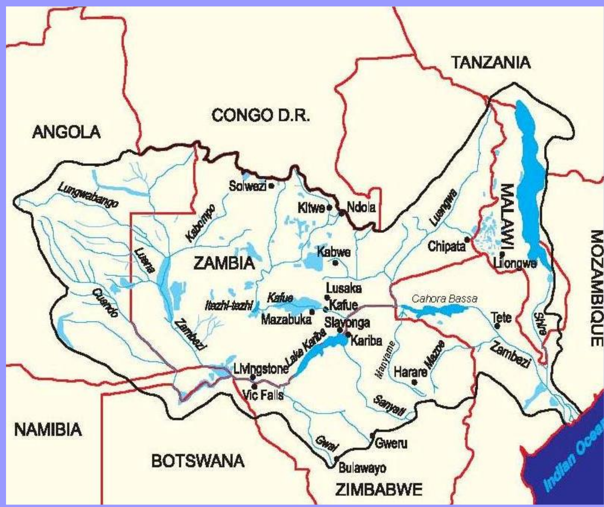
Transboundary Water Management in SADC

DAM SYNCHRONISATION AND FLOOD RELEASES IN THE ZAMBEZI RIVER BASIN PROJECT





Annex 4

Recommendations for Investments

31 March 2011

On behalf of:
Federal Republic of Germany
The Federal Government

giz

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:

Mr. Phera Ramoeli
Senior Programme Officer (Water)
Directorate of Infrastructure and Services
SADC Secretariat
Private Bag 0095
Gaborone
Botswana
Tel: +267 395-1863
Email: water@sadc.int

Mr. Michael Mutale
Executive Secretary
Interim ZAMCOM Secretariat
Private Bag 180
Gaborone
Botswana
Tel: +267 365-6670 or +267 365-6661/2/3/4
Email: secretariat@zamcom.org

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List of Acronyms

AG	Advisory Group
AfDB	African Development Bank
ARA Zambeze	Regional Water Administration for Zambezi
CDM	Clean Development Mechanism
DNA	Direcção Nacional de Águas (Department of Water Affairs Mozambique)
DWA	Department of Water Affairs, Zambia
EDM	Electricité de Moçambique
EIA	Environmental Impact Assessment
ESCOM	Electricity Supply Commission of Malawi
HCB	Hidroeléctrica Cahora Bassa
IFRC	International Federation of Red Cross and Red Crescent Societies
Lake Malawi	also known as Lake Nyasa, Lake Nyassa, Lake Niassa, or Lago Niassa or Nhiassa
M.A.R.	Mean Annual Runoff
m.a.s.l	Meters above sea level
MIWD	Ministry of Irrigation and Water Development of Malawi
RSWIDP	Regional Strategic Water Infrastructure Development Programme
SADC	Southern African Development Community
SAPP	Southern African Power Pool
ToR	Terms of Reference
UTIP	Unidade Téchnica de Implementação dos Projectos Hidroeléctricos (Technical unit for Implementation of Hydropower Projects), Republic of Mozambique
WB	World Bank
WWF	World Wide Fund for Nature
ZAMCOM	Zambezi Watercourse Commission
ZAMWIS	Zambezi Water Information System
ZESA	Zimbabwe Electricity Supply Authority
ZESCO	Zambia Electricity Supply Company
ZINWA	Zimbabwe National Water Authority
ZPC	Zimbabwe Power Company
ZRA	Zambezi River Authority

Executive Summary

The Zambezi and its tributaries are important to the economies of the southern African states through the provision of hydropower, irrigation water, fisheries, water transport and many other uses. Different investments are being planned to improve one or more of these uses. These investments may impact on the flows or may change the impact of floods.

The document is presented as “Recommendations for Investments” which seek to achieve the following:

- Identify investment options which support the flood management and flow regulation that is the overall topic of this study; and
- Identify investment options that are counterproductive in this respect.

A full evaluation of different investment options would have very limited value within the scope of this study, as (i) almost all the possible investments have other main objectives (ii) the investments impact on different areas of the Zambezi River Basin and are different in their nature and (iii) criteria for investing by possible investors differ and may use national priorities.

To be able to compare the various investment options and weigh their suitability, a set of criteria was used. Each criterion is explained by a question:

- Technical and legal feasibility;
- Contribution to flood protection;
- Impact on ecosystems;
- Cost effectiveness;
- Impact on human use;
- Biophysical impact;
- Likelihood of realization; and
- Impact on more than one country.

The investment options which have been analyzed are grouped in the following eight topics:

1. Regulation of Shire River and Lake Malawi;
2. Investments in Multipurpose Dams on the Zambezi and Kafue;
3. New Multipurpose Dams on the Tributaries;
4. Investments in Cahora Bassa reservoir;
5. Flood risk zoning;
6. Structural flood protection and diversion of floods;
7. Sediment Management; and
8. Diversification of the Electric Power Pool.

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 and minimizing the likelihood of flooding around the Lake and Shire Valley as well as minimizing too low flows for hydropower production and environmental management. The upgrading of Kamuzu Barrage is almost certain and will contribute to the operating possibilities of the barrage. The barrage is not, and has never been intended for flood control.

The pumping scheme near Mponda is not likely to happen in the near future. When the power interconnector between Malawi and Mozambique is realized, it should seriously be considered to rely on power supply from Mozambique, rather than drawing down Lake Malawi water levels beyond the natural levels. Both options for Kholombidzo Reservoir, High and Low, will need further study before decisive conclusions can be made. There will be a contribution to flood control and a considerable contribution to hydropower production, which has to be weighed against environmental impacts.

Investments in multipurpose dams on the Zambezi and Kafue Rivers are being planned and implemented; existing dams are being adapted and new dams are being planned. Hydropower turbines that are being added at existing dams will not only contribute to power generation, but will also increase the capacity to generate hydropower if reservoir water levels are reduced before forecasted floods, as more water is able to pass through the turbines rather than spillways. Such projects are planned for Kariba, Itezhi-Tezhi and Cahora Bassa dams. The newly planned dams on the Zambezi and Kafue Rivers are designed for power generation and are or have been debated from an environmental perspective. The large power deficit in the region makes decision processes on new dams progress faster. Financial viability of these dams will dictate their mode of operation, which will most likely not be optimal from a flood control 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) for further design and development of operating rules.

As for new multipurpose dams on tributaries, stakeholders in Zimbabwe, Zambia and Mozambique indicated that new dams in their own country for flood control purposes only, have low priority. In Zambia and Mozambique in particular, the usefulness of dams for irrigation purposes is emphasized. The identified 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 making floods more predictable. A considerable number of dams need to be developed, to have a significant impact. From a technical perspective, several dam sites were identified that could contribute to flood protection. In Zimbabwe, there is a list of technically suitable dam sites available which could be developed. Of these dams, the Gwayi-Shangani dam (635 Mm^3) and the Kudu dam (1550 Mm^3) on the Sanyati can have some positive impact in respect to flood control. Technically suitable dam sites have been found on the Luia and the Revubué rivers. However, it is pointed out that to develop dams which will contribute to economic activity, the technical suitability of a dam site is less of a determining factor, and socio-economic, institutional, financial, political and environmental considerations often outweigh physical site advantages. From an environmental viewpoint, the identified dam sites on the Luangwa and Lusemfwa are strongly not recommended. Dam sites on the Sanyati (Kudu) will affect spawning of Tiger fish. For dam sites of tributaries downstream of Cahora Bassa, the impact on sediment is of major importance.

Final conclusions and recommendations on the investments at Cahora Bassa will have to await the results of on-going studies commissioned by HCB which are due for completion in 2011. The benefits of the spillway in combination with the flat rule curve are for power generation and the environment. Both for the ecosystem of Cahora Bassa reservoir as for the downstream ecosystem, the adjusted flat rule curve will be beneficial. Flooding can increase downstream, but the impact depends on the operation of the dam and the coordination with floods at tributaries from downstream. This flooding impact will need attention when evaluating different options of spillway and operating rule curve. Coordination with tributaries downstream require a good flow forecasting system.

Investments in flood risk zoning were evaluated in respect to insurances, for regulation of new settlements and current land use and for warning and rescue. 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 raising of awareness only makes sense as an investment if further local research can show that such a system will be respected and if local inhabitants are not sufficiently aware of risks at present. 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 for Red Cross. 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 Risk Zoning that will benefit flood forecasting and the involvement of international relief organisations during floods as well as the understanding between neighbouring countries. This coordination is therefore recommended. Data availability in the region for flood risk zoning limits the possibilities, but the current developments in remote sensing will contribute significantly to improved and less costly flood risk zoning in the near future.

Structural flood protection measures and diversion of floods was evaluated. First and foremost adjusting existing and new infrastructure to minimize remaining damages after floods is important. Roads, bridges, sanitation infrastructure which are damaged require big new investments and derail life for a long time. Therefore such infrastructure investments have priority. Additionally, building new schools or public buildings on elevated grounds seems to be the most promising option, as it would benefit both education and flood protection and costs are reasonable. Moreover, some refuge areas could be created. Dykes are only recommended at a local scale to protect high capital investments, as dyke failure is a serious concern for communities protected by dykes. Diversion of floods to flooding areas is a measure on which few conclusions can be drawn at this stage, as the viability of this option is highly dependent on site specific factors, but options have been identified for the Ruo River (Shire subsystem) as well as for the Zambezi Delta.

Bottom outlets in dams are often required for other reasons than sediment management: preventing siltation of the dam, reducing turbidity of the released water to downstream users of the water, being able to maintain minimum environmental flow releases, being able to lower the water level in the dam in a certain period of time if this becomes necessary for dam safety purposes. The usefulness of bottom outlets for large dams (> 15 m and/or larger than 3 Mm^3) in the Zambezi River Basin for flushing sediments is doubtful because (1) flushing can have detrimental environmental impacts both in the reservoir and downstream; (2) flushing implies emptying the reservoirs at the beginning of the flood season, which is only an option for small and medium sized dams that do not generate hydropower; (3) for large reservoirs flushing is not an option as sediment has already settled upstream. Flushing of sediment will, in any case, require very experienced dam operators. Also releasing water from bottom outlets requires experienced dam operators, as water needs to be mixed with water from other levels, to prevent only cold, nutrient-rich (hypolimnion) waters from the bottom of the reservoir flowing downstream. Environmental considerations could be added to design standards for dams. Alternatively, dam siting and the choice for different sizes of dams can better take into consideration the possible downstream impacts on sediment transport, before site specific designs are made. The construction costs of dams are higher with higher flow capacities of bottom outlets. This financial consideration also has to be taken into account.

The diversification of the Electric Power Pool and its interconnection with water management depends on the possibilities of the international grid and the coordination between water management and dispatching of power. The effect of shutting down hydropower stations for the benefit of flood control is very limited, because to shut down the turbine flows for flood protection only makes sense at times when this has a considerable impact on flood flows downstream and cannot cause problems upstream. Operational costs to buy power from other sources or to generate power at thermal power stations in times when releases from hydropower stations are unwelcome, are far higher than generating power at the hydropower station itself. Power to substitute hydropower is also not always available either, because there is no surplus of power available on the grid or because there is no connection to the international grid. Adding connections or improving existing connections in the SAPP grid will therefore assist not only hydropower production, but also the options for water management. The interconnector between Malawi and Mozambique will make it possible for Malawi to import and export power. The connection between Zambia and Tanzania will connect the Southern African Power Pool to the Eastern African Power Pool. The exchange of power generated on the Zambezi now depends considerably on the capacity of the interconnections through Zimbabwe. Several planned new and enhanced interconnections will improve this situation (Zimbabwe-Zambia-Botswana, DRC-Zambia-Zimbabwe-South Africa, Mozambique-South Africa). 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.

On the basis of the analysis, investment options were grouped into three categories, from the perspective of flood control and flow regulation: investments not to be promoted, investments to be recommended under certain conditions and promising investments. Structural investments not to be promoted are Mponda Pumping Scheme and large scale constructive flood protection, such as dykes. A fund for taking the costs of decreasing hydropower production during floods also is not an investment option to be promoted. Investments to be recommended under certain conditions are the upgrading of Kamuzu Barrage, the Kholombidzo Reservoir on Shire, large run-of-river dam developments, bottom outlets and flood risk zoning. Although still with some risks, investments that seem promising are: an improved flow forecasting system coupled with Dispatching Centre for SAPP, extra hydropower generation on existing dams, an electricity interconnector between Malawi and Mozambique, small and medium sized dams on tributaries, an extra spillway for Cahora Bassa and elevated schools and public buildings.

The main recommendations from this part of the study can be summarized as follows:

1. Assess investments in the regulation of the Shire River and Lake Malawi;
2. Assess investments in multipurpose dams on the Zambezi and Kafue;
3. Assess siting of new reservoirs on unregulated tributaries;
4. Support the construction of an extra spillway on Cahora Bassa reservoir;
5. Ascertain sufficient large size of bottom outlets in new dams;
6. Support the coordination of flood risk zoning initiatives;
7. Support local multipurpose measures which add to flood protection;
8. Consider locally structural flood protection measures or diversion of floods;
9. Support additional and enhanced SAPP interconnections between countries; and
10. Support flow forecasting centre coupled with a dispatching centre for SAPP.

For each recommendation, an Intervention Sheet was produced.

Apart from presenting the evaluation of the investment options, the learning lessons of the analysis were summarized for planning for investments in general. For each phase of the planning cycle, as developed by the Infrastructure Consortium Africa (ICA), recommendations were made.

1 Introduction

This document is referred to as Annex 4 and it is one of six documents that make up the report "Dam Synchronisation and Flood Releases in the Zambezi Basin". The six documents are as follows:
 Executive Summary;

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

The relationships and linkages between these six documents are illustrated in Figure 1.1.

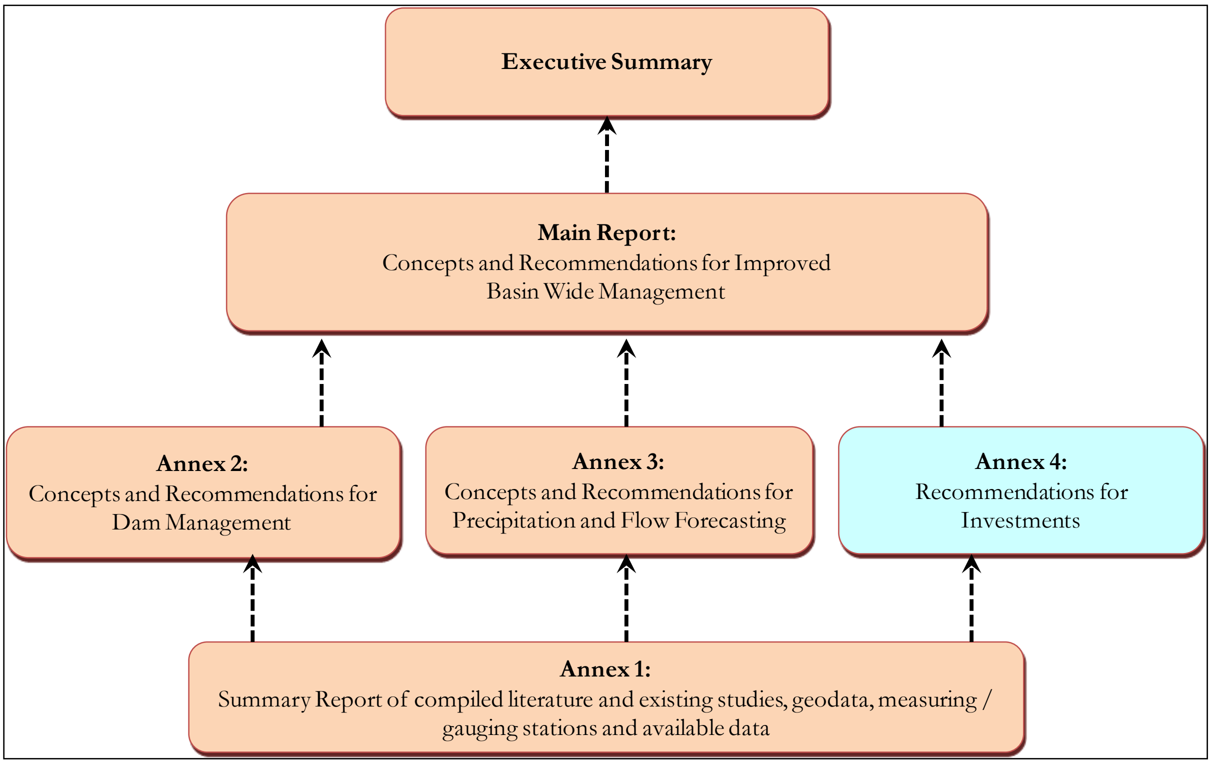


Figure 1.1: Alignment of project reports

1.1 Purpose and Structure of this report

The Zambezi and its tributaries are important to the economies of the southern Africa states through the provision of hydropower, irrigation water, fisheries, water transport and many other uses. Different investments are being planned to improve one or more of these uses. These investments may impact on the flows or may change the impact of floods. From this perspective different investments are evaluated. A full evaluation of different investment options would have very limited value within the scope of this study, as (i) almost all the possible investments have other main objectives (ii) the investments impact on different areas of the Zambezi River Basin and are different in their nature and (iii) criteria for investing by possible investors differ and may use national priorities. The intention is rather to identify investment options which support the flood management and flow regulation that is the overall topic of this study. The intention is also to identify investment options that are counterproductive in this respect.

This Chapter (Chapter 1) presents the purpose and layout of the document as well as the general approach. Chapters 2 -9 provide evaluations of various investment options, most of which were identified in the ToRs. Each chapter covers a certain topic:

- Regulation of Shire River and Lake Malawi (Chapter 2):
  - Upgrading of Kamuzu Barrage (Liwonde Weir);
  - Pumping barrage at Mponda; and
  - Kholombidzo Reservoir.

- Investments in Multipurpose Dams on the Zambezi and Kafue (Chapter 3):
  - Design adaptations for large new dams on the Zambezi river basin to serve dam synchronisation and flood releases; and
  - Evaluation of already identified changes to dams or new dams on the Middle and Lower Zambezi.

- New Multipurpose Dams on the Tributaries (Chapter 4):
  - New potential dams in Zambia on Luangwa;
  - New potential dams in Zimbabwe on Gwayi, Sanyati, Mazowe;
  - New potential dams in Mozambique on Luia, Revubúe, Luenha, Muira; and
  - Small and medium dams for improvements of livelihoods in general.

- Investments in Cahora Bassa reservoir (Chapter 5):
  - An additional spillway at Cahora Bassa Dam.

- Flood risk zoning (Chapter 6):
  - Flood risk zoning for rules for new settlements;
  - Flood risk zoning for current land use and awareness raising;
  - Flood risk zoning for insurances; and
  - Flood risk zoning for rescue and warning.

- Structural flood protection (Chapter 7):
  - Dykes;
  - Elevated schools / public buildings;
  - Construction of higher areas for refuge; and
  - Diversion of flood waters.

- Sediment Management (Chapter 8):
  - Investments in bottom outlets.

- Diversification of the Electric Power Pool (Chapter 9):
  - Funds for operational costs for temporarily shutting down hydropower;
  - Forecasting system combined with dispatch center; and
  - Extra thermal power plants contributing to diversification of power supply.

Chapter 10 gives the overall evaluation of all investments and Chapter 11 concludes with recommendations for follow up after this study. Figure 1.2 illustrates the inter-relationship between these different topics.

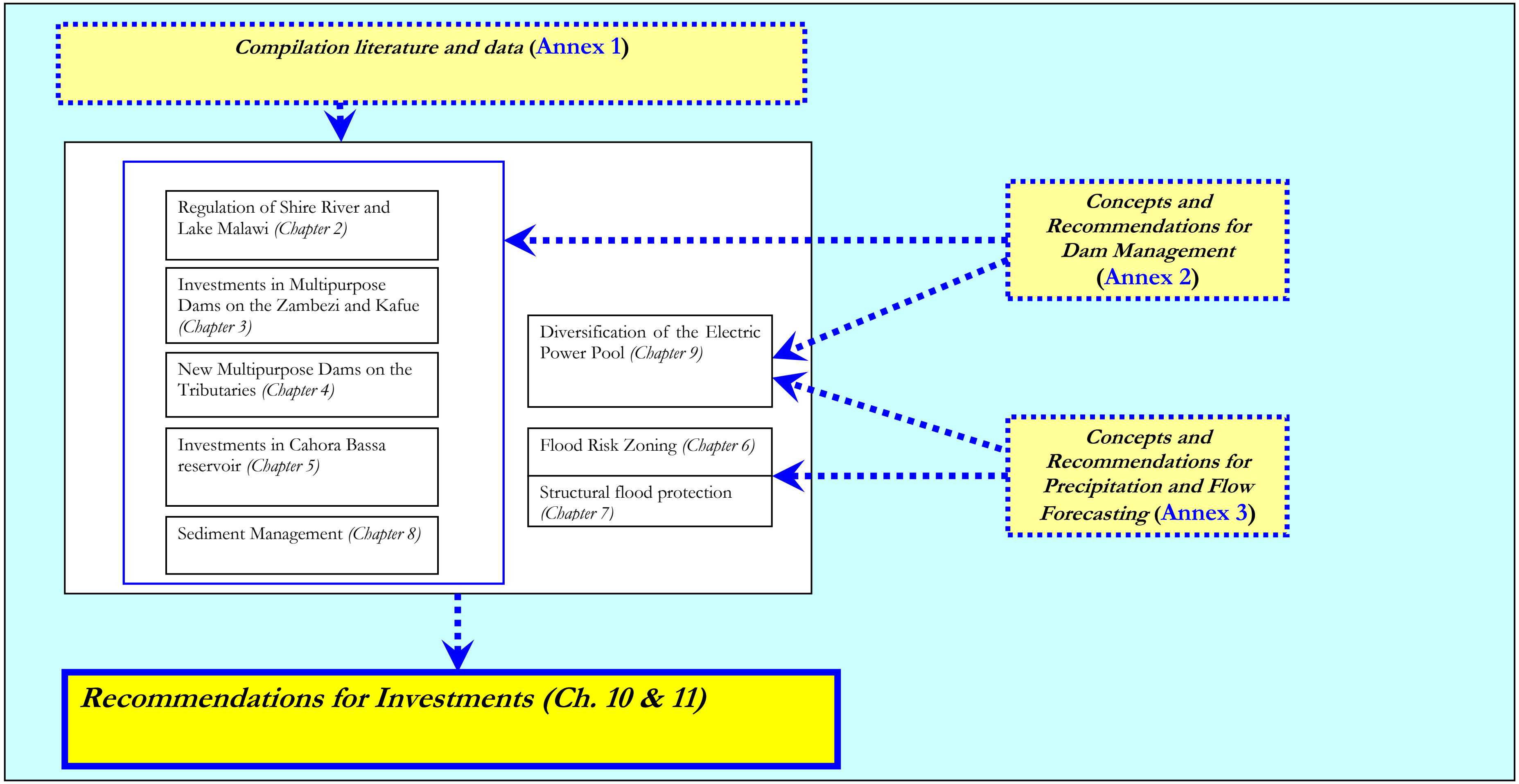


Figure 1.2: Structure of this report and the inter-relationship between the topics covered as well as the other components of this study

1.2 General approach

To be able to compare the various investment options and weigh their suitability, a set of criteria was used. Each criterion is explained by a question. The criteria have been ordered as a selection process such that, if the first criteria are not answered positively, further analysis is not necessary. For each criterion, a set of aspects is given that have to be taken into consideration when preparing answers. The criteria set is presented in Chapter 10 in the form of a Scorecard.

The set of criteria is as follows:

A **Technical and legal feasibility:** Is the investment physically and legally feasible?

- geologically suitable sites for construction of dams;
- other physical restrictions (for example from the electrical grid); and
- impact on, for example, RAMSAR sites.

B **Contribution to flood protection:** Does the investment contribute to flood protection?

- impact on flood flow regime;
- impact on lead time;
- livelihoods protected; and
- capital investment protected.

C **Impact on ecosystems:** Does the investment have impact on the river and its associated ecosystem?

- impact on the flow regime and particularly the ecologically relevant summary statistics (floods, high flow pulses, low flows);
- impact on the sediment regime for the environment;
- impact the thermal and chemical regime of the river; and
- impact on the biological component of the system.

D **Cost effectiveness:** Is the investment cost effective for flood protection and/or flow regulation?

- capital costs;
- operation and maintenance costs;
- costs of negative impacts; and
- costs of additional institutional requirements.

E **Impact on human use**: Does the investment have impact on resource economic objectives and other human use?

- Hydropower;
- Nature;
- Fisheries;
- Agriculture; and
- impact on other resource economic and human uses (how people use the river and its associated ecosystem).

F **Biophysical impact**: Does the investment otherwise have impact on the biophysical behaviour of the river basin?

- greenhouse gasses emission reduction;
- evaporation losses; and
- sediment deposition.

G **Likelihood of realization**: Is the realization likely?

- time necessary for realization

- possibilities for financing including Clean Development Mechanism;
- political will (as far as reported); and
- possible local protests.

H **Impact on more than one country**: Does the investment benefit more than one country?

- countries impacted positively; and
- countries impacted negatively.

This criterion is relevant for different financing schemes and for deciding if the decisions require ZAMCOM input.

For each investment the criteria are evaluated and color coded. The color coding of the evaluation criteria is presented in Figure 1.3. Because the investments are so different and the criteria cannot be made measurable in this identification stage, the color scoring is subjective. The scoring should be used as a key to reading the evaluation and identifying aspects that need attention, rather than as an absolute scores to be used in a multi criteria analysis.

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

Figure 1.3: Legend for scoring of criteria

2 Regulation of Shire River and Lake Malawi

2.1 Introduction to the investments

The regulation or blocking of the Shire River flows changes the regimes of downstream flows and water levels as well as the upstream lake levels. This could have positive or negative impacts which may influence the occurrence of floods as well as the conservation and utilization of ecosystem and the utilization of water by different water users. This has been the topic of study in Annex 2 Concepts and Recommendations for Dam Management and for further detail reference is made to this Annex.

The proposed investments for Shire River flow regulation identified in the ToRs are:

- the upgrading of Kamuzu Barrage which would increase the operating level of the Kamuzu barrage and improve possibilities for operation; and
- the pumping scheme at Mponda, that would allow for pumping water from Lake Malawi whenever the lake levels are too low to allow adequate outflow.

Besides, there are additional plans for:

- Kholombidzo on the Shire River, which will also be discussed in this Chapter.

In January 2011 a call for interest for an integrated flood and drought risk management plan for the Shire basin in Malawi has been advertised. This plan will study in more detail different options available for flood protection. An environmental impact assessment on the upgrading of the Kamuzu Barrage is currently being carried out.

2.2 Situation assessment: stakeholders views and expert views

The Ministry of Water in Malawi (interview August 2010) has a few strongly held views with regards to the regulation of the Shire River and Lake Malawi:

- Kamuzu Barrage was never designed for flood control and therefore evaluation of the Upgrading of Kamuzu Barrage should not concentrate on flood control; flood regulation from the main tributaries is more important to prevent flood damage in the lower Shire;
- Subsistence farming in the floodplains appears to have increased erosion and siltation of the Shire River and has also increased flood risks because of the presence of people and their livelihood in the floodplain. However, subsistence farming in the flood plains is something which should be accommodated due to scarcity of arable land and assistance should be provided to make it sustainable; and
- Improved flow forecasting, in particular from the Zambezi and from the Shire tributaries, can help in flood risk management in the Shire system.

ESCOM Malawi (interview and site visits, August 2010) also made clear that:

- Floods do not damage the Shire power stations, but water hammering due to late switching off of power stations can cause damage. Tedzani I and II power stations (40 MW) were out of commission from 2001 till 2007 due to the water hammer related damages to the turbines. The rehabilitation of these power stations started in 2006 and was completed end of 2007, at a cost of US$12.24 million (estimate 2005). Better monitoring and forecasting of weed clogging is being implemented and this prevents damage. (See for further detail Annex 2, Chapter 6);

- Hydropower generation on the Shire faces challenges due to silting and floating weeds problems as well as operation and maintenance of machines. Most of these challenges are associated with old age equipment. Hydropower generation needs clean water and ESCOM is spending significant resources to regularly dredge the pond at Nkula in an effort to get rid of silt problems. There are plans to rehabilitate the Nkula power plant with assistance from Millennium Challenge Account, MCA Malawi, which will include a weed diversion wall and eliminating the problems of floating weeds. Under this programme there are also plans to improve Lake Level forecasts and flood warning for better Shire River flow regulation and weed and sediment flashing; and
- Malawi is in serious need of extra power development investments to increase the generation capacity which can satisfy present demand of electricity.

Malawi is currently for more than 90% of its power supply dependent on the power generation by the power stations on the Shire. The available annual reports and consultations with ESCOM indicate that installed capacity of 287 MW was only available over about 80% of the year. The incidences of individual machines shutting down for maintenance, repairs or rehabilitation after damages are being experiences frequently, particularly in recent years. Millennium Challenge Account – Malawi , MCA –Malawi, studied the effects of black outs from inadequate power generations caused by machine shut downs. It was estimated that on average Malawi was losing some MK 2 billion (US $ 1.330 million) a day due to power disruptions (Personal communication MCA office Malawi).

The detailed financial costs of non-production of hydropower for ESCOM are not readily available but financial losses are huge considering costs of power at US$0.06 per watt-hour and loss of electricity by almost 20% from installed capacity of 287 MW. The financial cost of non production of hydropower for users of power is also reflected in use of expensive diesel generators at sites such as the Kayerekera Uranium mines (15 MW) and coal mines. Mchenga coal mines is spending MK 1.3 million (US $8,660) on diesel every month.

The impact of power failure on the economy of Malawi is significant and has been exacerbated by the continuous increase in electricity demand. There is more than 200 MW power needed over and above current installed capacity to satisfy existing and planned investments in mining and mineral processing in the country.

When evaluating the investments in the perspective of this study, it is important to be aware of other investments currently planned for the Shire River (See Figure 2.1 for locations).

Malawi – Mozambique interconnector

This power interconnector is in its financing phase and will decrease the dependency of Malawi on hydropower generation in the Shire river as Malawi is currently isolated from the SAPP network.

Shire Valley Irrigation Project (Green Belt Programme)

Malawi is planning to construct a 55 m^3/s intake works and gravity canal to divert water from Shire River and irrigate some 42,000 hectares. The irrigation project is downstream of the power stations but upstream of the most floodprone areas.

Shire-Zambezi Waterway

Mozambique has asked for an elaborate EIA before it will give approval to the Shire-Zambezi Waterway. Malawi is already constructing Nsanje Inland port due to be commissioned in 2010. Minimum depths of 2 meters have been mentioned as requirements for navigability of the river. The Shire River has been reported to have lower depths than these in the late 1990s when the Lake Malawi experienced lowest lake levels since 1932 or thereabouts. From these experiences, it can be estimated that Shire River flows of at least 250 m^3/s are required to maintain navigability of Shire Zambezi Waterway, less than the current request for flow by the hydropower stations of upto 360 m^3/s.

2.3 Description of investments

The Integrated Water Resources Development Plan for Lake Malawi and the Shire River System (Norconsult *et al.*, 2003a) recommends the upgrading of Kamuzu Barrage, a pumping scheme to pump water out of Lake Malawi into the Shire (originally at Samama, but during feasibility stage relocated to Mponda) and considered a new dam at Kholombidzo worth further investigation.

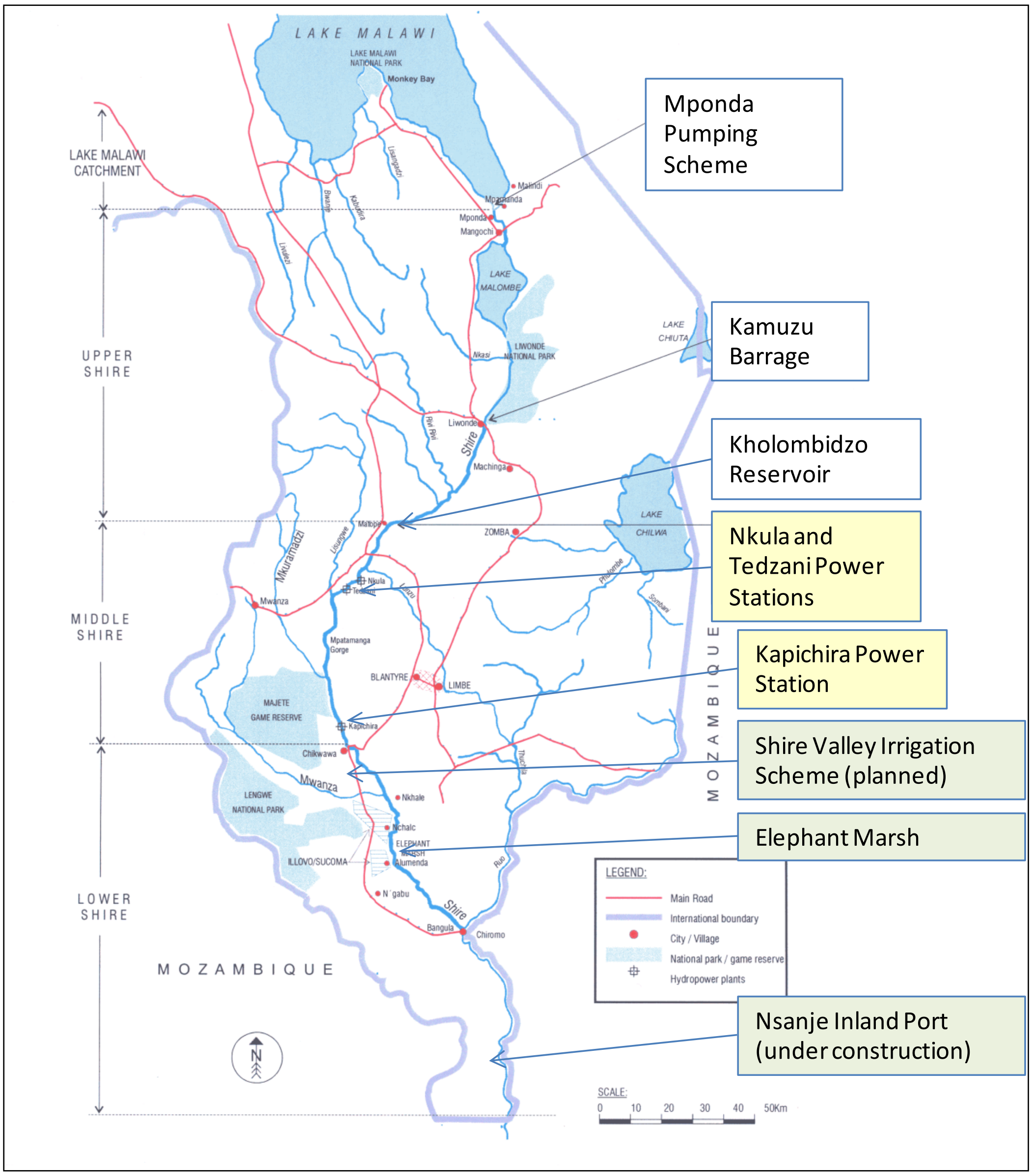


Figure 2.1: Map of Lake Malawi and Shire subsystem (adopted from Norconsult, 2003a)

Upgrading of Kamuzu Barrage

A new, gated structure is to be constructed immediately upstream and adjacent to the present Kamuzu Barrage structure with the old steel gates strengthened and moved to the new structure (See Figure 2.2). The Kamuzu Barrage is planned to be upgraded and rehabilitated to replace the old gates that have surpassed their designed lifespan. Also the traffic over the barrage has been heavier than planned for. The upgraded Kamuzu Barrage will have gates that can operate 0.2 m higher than the existing ones which implies that more water can be conserved in Lake Malawi but that also Lake Malawi levels are further affected. The upgrading of the barrage brings the operating level from 475.3 m.a.s.l. to 475.5 m.a.s.l. An extra 0.2 m increase of operating level thanks to the upgrading of Kamuzu Barrage would translate in a rise of 0.14 m lake level; over the whole lake this would translate into 4000 Mm^3, which is a gross estimate through multiplying by the lake area of 29600 km^2. Currently one of the 14 gates of the barrage is stuck, making the barrage an obstruction during floods.

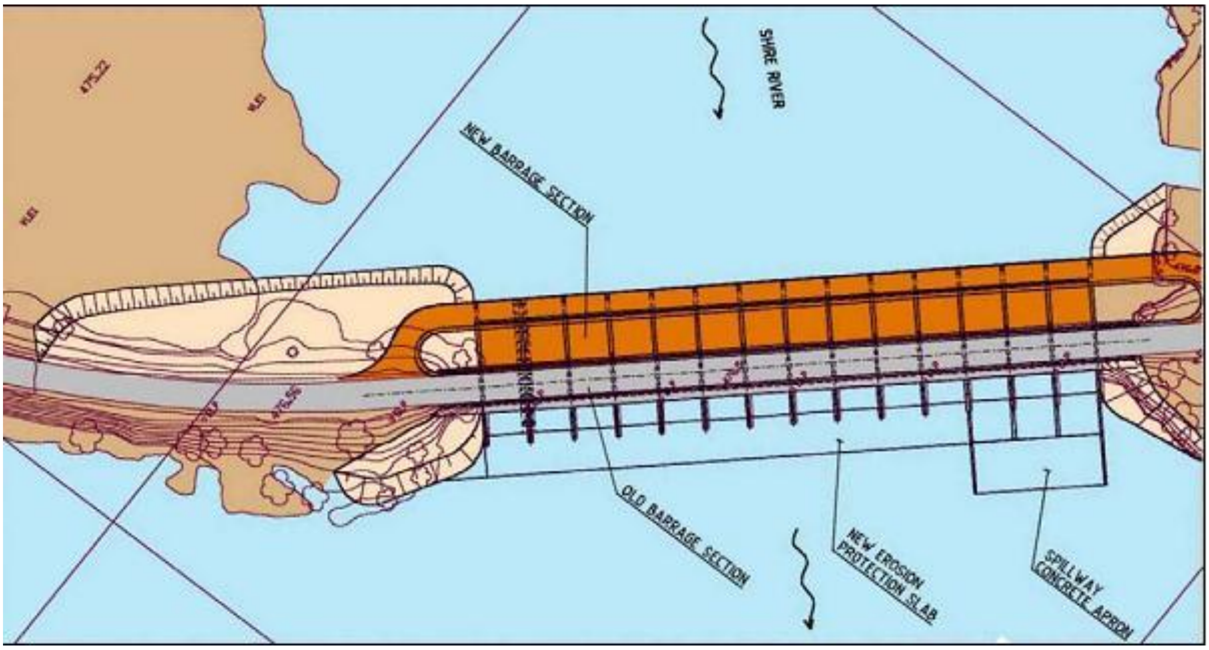


Figure 2.2: Plan View of the upgraded Kamuzu Barrage (as in feasibility study 2003; detailed design being carried out in 2010)

Pumping scheme at Mponda

The pumps to be installed at Mponda would be used to lift water from Lake Malawi over the natural barrier, to enable the water to flowdownstream under gravity into the Shire River. The purpose is to supply water to the power stations. The total pumping head is about 6 m and has a design capacity of 200 m^3/s.

Kholombidzo Reservoir

The Kholombidzo Reservoir involves construction of a regulating dam at Kholombidzo Falls, 50 km downstream of the Kamuzu Barrage on the Shire River. Two alternatives are available under this option namely a high dam cresting and a low dam. The high dam would regulate the water at the same height as the Kamuzu Barrage (475.3 m), and a low dam would be about 4 meters lower (471 m.a.s.l.). Kholombidzo Reservoir is upstream of the existing power plants and just at the beginning of the rapids of the Middle Shire.

The High Kholombidzo HPP has an assessed average continuous generation potential of 157 MW from its own turbines and will provide an additional average continuous production of 22 MW in the downstream cascade (Norconsult, 2003). The Kholombidzo Low can provide some 170 MW of power generation in total (Norconsult, 2003). The real power generation depends on the operating rules chosen.

Alternative investment: Tomaninjobi Stilling Basin for the Ruo Floods

Devastating floods in Lower Shire Valley are influenced by high flows on the Ruo River. The flood peaks could be attenuated with Tomaninjobi pools in Elephant marsh being used as flood stilling basins. Flood waters from the Ruo river could be diverted with a diversion weir that can discharge the flood water into Tomaninjobi pools. The Tomaninjobi pools are large (more than 10 km^2). The diversion through the pools is meant to attenuate flood peaks and reduce flooding around and downstream of Shire Ruo confluence.

The Department of Disaster Management Affairs has expressed interest in further examining the feasibility of such a scheme. Preliminary cost estimates have not been established yet. The idea is not further investigated in this study, but could well become an alternative option for flood protection in a later stage. Sufficient flooding in Elephant Marsh is also important from an ecosystems point of view (Annex 2, Chapter 6).

2.4 Decision stage of investments

Upgrading of Kamuzu Barrage

The Government of Malawi is currently carrying out detailed design and Environmental Impact Assessment of the Upgraded Kamuzu Barrage. The designs and EIAs are expected to be completed in 2012 and will include a bill of quantities, an environmental management plan and tender documentation of the upgrading, rehabilitation and refurbishing the Kamuzu Barrage. The control rule curve for the operation of the Upgraded Kamuzu Barrage will also be included in the design and environmental impact assessment report. The World Bank has committed to funding the detailed design and EIA. A project concept note of the Worldbank (P117617, Version June 2010) makes mention of reserve of budget finances for rehabilitation of Kamuzu Barrage.

Pumping scheme at Mponda

The plans for a pumping barrage at Mponda (originally at Samama but relocated to Mponda during the feasibility studies) have been shelved according to ESCOM and Ministry of Irrigation and Water Development of Malawi (MIWD, interviews August 2010). The low lake levels of late 1990s and the high reliance of Malawi on power generated in the Shire, prompted the Government to initiate the pumping scheme. The Lake Levels have increased substantially from less than 473 to 474.5 m.a.s.l. since then. For this reason there are currently no further studies on the Pumping Scheme. The Norconsult study (2003) already recommended leaving the plan dormant until the Lake Level is extremely low again. According to MIWD (interview August 2010) the pumping scheme is environmentally and technically viable and will be reconsidered once the need arises. The pumping scheme would only be essential for power supply to Malawi in the event of the electricity interconnection Malawi-Mozambique not being implemented. Recent reports (Chikwawa, August 2010) explain that the World Bank, the lead financier, has initiated renewed negotiations with the Malawi government to kick-start the project.

Kholombidzo reservoir

According to MIWD (interview August 2010) Kholombidzo Reservoir (High or Low) would be an option which required further studies, but no action plan has been provided or decided for the implementation of such studies. ESCOM mentioned that a Chinese delegation had expressed interest for a site visit, but further details were not known (ESCOM interview, August 2010).

2.5 Evaluation of the criteria of this study

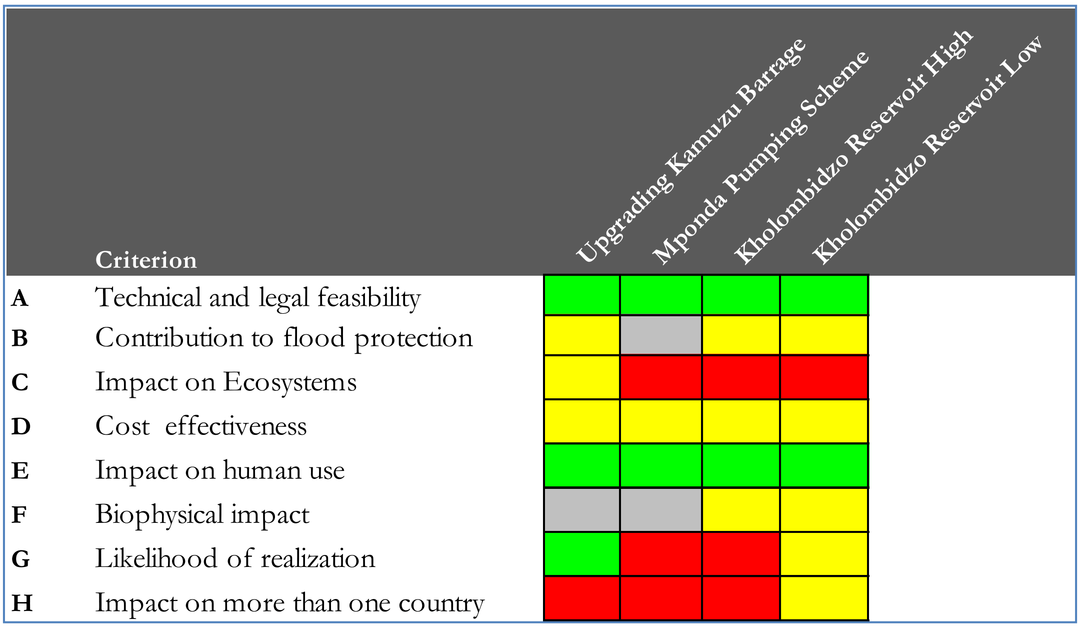


Figure 2.3: Assessment of Shire flow regulation options (see Fig. 1.2 for legend)

Technical and legal feasibility

The Upgraded Kamuzu Barrage and the pumping barrage at Mponda have passed feasibility stage. The Kholombidzo Reservoir Low and High are also physically and legally feasible although there is still discussion about the socio-economic and environmental impacts.

Contribution to flood protection

The different impacts on flood protection are as follows:

- an upgraded Kamuzu Barrage will not help in flood control, other than removing the obstruction of the currently stuck flood gate and improving the conditions under which the operation of the dam can be done;
- a pumping scheme at Mponda will not contribute to flood protection, as it is meant for low water levels; and
- a new Kholombidzo Reservoir (high or low) could contribute to flood protection downstream, unless it is kept at its optimal level for hydropower production and little storage remains for flood attenuation. However, the reservoir itself would also flood some area. For a Kholombidzo high reservoir this area extends upto Kamuzu Barrage and may even influence Lake Malawi levels.

For further explanation, reference is made to Annex 2 Concepts and Recommendations for Dam Management, Chapter 6.

Other investment options

It is clear that downstream tributaries have a large impact on flooding in the lower Shire, so new dams on these unregulated tributaries are likely to enhance flood control on the Lower Shire.

The alternative idea of a Tomaninjobi Stilling Basin for the Ruo Floods would need further investigation to be compared with the investment options presented here.

Impact on ecosystems

For evaluation of the impact on ecosystems, the upstream impact on Lake Malawi was decisive in the experts evaluation, as the downstream effects would depend on the operation of the investment rather than the realization of the investment, as described in Annex 2, Chapter 6. Lake Malawi was classified conservation priority 1 (globally outstanding and highly threatened) by dozens of specialists brought together in 2005 to classify the bioregions and freshwater eco-regions of Africa. Conservation priority 1 means that modifying such an eco-region is considered 'unacceptable' by these specialists.

From these three options:

- The upgrading of Kamuzu barrage is considered the least destructive and is scored 'moderate to low impact';
- A pumping scheme at Mponda can result in more frequent low levels of Lake Malawi and is scored 'high impact'; and
- The Kholombidzo Reservoir High will not only lead to further flow regulation but also connect Lake Malawi with the reservoir. The Kholombizo dam is therefore 'strongly not recommended'. A lower dam, which should be lower than the current proposed Low Kholombidzo alternative, would have a score 'high negative impact'.

Upgrading of Kamuzu Barrage

Over the past century the Lake level changed by 7 m and fish (cichlids) have evolved with the changes in Lake levels. The effect of a higher maximum operating level of 0.2 m will translate into 0.14 cm higher lake levels, which mean that the chances of extra flooding of the Lake shores increase. Annex 2, Chapter 6, shows computations suggest that with an upgraded Barrage the critical level of 476.0 m will be exceeded 3% of the time. The Upgraded Liwonde Barrage will therefore not have any major impact on the long-term natural variation in lake levels. Rocky areas are quite prominent in the southern part of Lake Malawi which is most affected by the increased operating level, and these rocky areas provide breeding grounds for fish (Norconsult, 2003d). During the high water levels of the 1980s there has been reported wide spread breeding and abundance of fish. The EIA on the upgrading of Kamuzu Barrage currently being carried out will be more conclusive in this regard.

Pumping scheme at Mponda

With use of the Mponda pumps the highest levels of Lake Malawi will stay the same but the lowest levels will go down. The low levels may dry out vital habitats and exposed habitats that have not been exposed before. A larger 'dead' zone around the lake will be created. Erosion may occur at the mouth of small perennial rivers entering the Lake. There is possibility of some streams being cut-off from the lake, when the Lake level is lower, but the Consultant expects that the rivers and streams flowing into the lake have enough gradient to deposit their run-off into the lake. This may further increase the drawdown of Lake Malawi. When in a cycle of dry years, impacts may extend over longer than usual periods. In the Norconsult report (2003d) it was mentioned that the negative impact on cichlid species was most pronounced. If Lake levels continue to be drawn down below 370 m.a.s.l., the ground water levels may drop in sympathy, with consequent negative environmental impacts.

However, it should be realized a pumping release of 200 m^3/s during a day decreases lake level by 0.6 mm/day (averaged over the whole Lake). About 5 to 6 mm/day is the evaporation loss when no rain occurs. Therefore, the pumping time required for a 10 cm additional dropdown due to pumping alone is 170 days. If pumping is necessary for only one dry season, the pumping causing 10 cm extra drawdown has limited impact. If pumping is continuous over consecutive years the impacts can be more severe.

Kholombidzo Reservoir

A Kholombidzo Reservoir High would influence Lake Malawi water levels which the ecology specialists do not consider acceptable. A lower dam (lower then what is currently proposed as the lower alternative) that can store water but not affect Lake Malawi levels, could be acceptable, the ecologists reckon from the Lake Malawi point of view. The impact on the ecosystems functioning downstream depends on the extent to which downstream tributaries stay natural and the operating regime of the Kholombidzo dam.

Other investment options

The Consultant points out that the proposed Shire-Zambezi River dredging project is potentially much more damaging than a single dam project. The dredging project as proposed would attempt to allow for large-scale barging from Lake Malawi to the Indian Ocean. A prefeasibility has been carried out (Hydroplan Ingenieur, 2006). Depending on which scenario will be chosen, both the Shire and Zambezi will be dredged. Dredging causes turbidity which damages the ecosystem. Mozambique has requested for a full Environmental Impact Assessment to be carried out before further approval of the waterway will be granted.

Cost effectiveness

Cost effectiveness for flood protection and flow regulation is difficult to assess. All options have to be financed from benefits of power production and the added benefits for flood protection are therefore secondary.

Upgrading of Kamuzu Barrage

Costs were estimated for the Upgraded Kamuzu Barrage, including refurbishment of the roadway, improved reed island management capabilities, and excluding environmental cost. The 2003 estimates (Norconsult *et al.*, 2003a) were:

- 8.56 million USD in construction cost invested over a 27-month implementation period;
- 0.05 million USD in annual operation and maintenance costs over 30 years; and
- 0.5 million USD in refurbishment costs on mechanical/electrical components after 30 years.

From a flood protection, cost effectiveness cannot be confirmed, as the project is evaluated based on a different set of benefits (hydropower, traffic, damage) and it is explained above that the contribution to flood management is limited. The repair of one of the flood gates which is now blocked and improving the ease of operating the gates in times of emergency can add to flood security with little investment.

The Norconsult (2003) report assumes a higher maximum operating level of 20 cm and some environmental flows, and with this scenario of operation power production would improve on average by about 15 MW. In that case, the Benefit/Cost ratio in excess of 5, an Economic Internal Rate of Return of 50 as assessed in Norconsult (2003) may still be valid.

Pumping scheme at Mponda

Capital costs for Mponda Pumping Scheme were estimated in 2003 in the range of 30-40 million USD, depending on the selected pumping capacity. Operational costs depend very much on the frequency of use. With the interconnector for the electricity grid between Mozambique and Malawi in sight, the investment is not considered cost effective.

Kholombidzo Reservoir

The costs of the High Kholombidzo hydropower plant and Low Kholombidzo are in the same range (Norconsult 2003):

- 230 million USD in construction cost invested over a 39-month implementation period;
- 16 million USD(Low) and 25 Million USD (High) for environmental costs during the construction phase;
- 2.3 million USD in annual operation and maintenance costs over 30 years and addiitonally 1.8 million USD environmental costs over the first 20 years; and
- 14 million USD in refurbishment costs on mechanical/electrical components after 30 years.

As Norconsult concluded, both the High and the Low Kholombidzo reservoir are highly viable projects in pure power economic terms. To make it cost effective for flood protection, the operating of the dam has to be adjusted, which will affect power generation.

Impact on human use

The main purpose of the investments is extra storage capacity or extra flow regulation for the benefit of hydropower production, however there are also agricultural impacts and impacts on navigability. See for further detail also Annex 2, Chapter 6.

Upgrading of Kamuzu Barrage

Apart from the hydropower benefits, upgrading of Kamuzu Barrage is beneficial for traffic over the barrage.

Pumping scheme at Mponda

Without the power interconnector Malawi-Mozambique, the pumping scheme may be the life line in very dry years for electricity supply in Malawi. However, the additional drawdown of lake Malawi levels may have a negative impact on lake transport infrastructure and fisheries (Norconsult, 2003).

Kholombidzo Reservoir

In terms of hydropower production, the Kholombidzo reservoir is most beneficial. However, this reservoir is also most debated on the other impacts it may have on flooding of residential area. The High Kholombidzo reservoir is most negatively assessed, as it impacts on Lake Malawi levels.

Likelihood of realization

An assessment of political and financial feasibility is as follows:

Upgrading of Kamuzu Barrage

The upgrading of Kamuzu Barrage is likely; the upgrading is in its design stage and an EIA is currently being done (www.norplan.com september 2010).

As the design was financed by the Worldbank and a reservation is made in the Shire River Basin Management Project (P117617, June 2010) for the rehabiliaton itself as well, financing through the Worldbank is most probable. Other financing possibilities that have expressed interest in investing in the Shire River Basin include Japanese and Chinese bilateral aid and the EU African Water Facility at AfDB.

If the institutional set up for an Upgraded Kamuzu Barrage remains as it is for the current Kamuzu Barrage, the Department of Water Affairs is owner and maintainer of infrastructure, the Water Resources Board is operator and collects revenue, and ESCOM is the actual operator at work and the main beneficiary. Currently ESCOM is paying for the operation, but is not willing to pay for maintenance and investments. The Department has done little maintenance in the past. Whether revenue collected is sufficient for future maintenance is yet unknown (Interview MIWD, August 2010).

Pumping scheme at Mponda

The Pumping scheme at Mponda is unlikely in the medium term, see section 2.4.

Kholombidzo reservoir

The Kholombidzo Reservoir still needs further investigation before a decision will be made, see section 2.4.

Impact on more than one country

The regulation of Shire River and Lake Malawi levels also affect Mozambique and Tanzania. The high lake levels promoted by regulation of the Shire River benefit navigation on the Lake affect all the riparian countries. The impacts of high lake level flooding also affect all the three countries, with Tanzania and Malawi having worse impacts. The upgraded Kamuzu Barrage and a High Reservoir at Kholombidzo can influence high lake levels.

The impacts on Mozambique are limited. The Mponda pumps and the Kholombidzo high dam will increase minimum flows so will probably be welcomed. The Kholombidzo reservoir could have some effect on floods in Mozambique, but this will also be limited.

2.6 Conclusions and recommendations

The challenges of effective and efficient investments in Shire River flow regulation infrastructure lies in maximizing the conservation of Lake Malawi water resources, maintenance of vital ecosystems and minimizing the likelihood of flooding around the Lake and Shire Valley as well as minimizing too low flows for hydropower production and environmental management.

The upgrading of Kamuzu Barrage is almost certain and will contribute to the operating possibilities of the barrage. The barrage is not and has never been intended for flood control.

The pumping scheme near Mponda is not likely to happen in the near future. When the power interconnector between Malawi and Mozambique is realized, it should seriously be considered to rely on power supply from Mozambique, rather than drawing down lake levels beyond the natural level.

Both options for Kholombidzo Reservoir, High and Low, will need further study before decisive conclusions can be made. There will be a contribution to flood control and a considerable contribution to hydropower production, which has to be weighed against environmental impacts.

Alternative options addressing the Shire tributaries also need further investigation, as much of the flood flows come from these tributaries.

3 Investments in Multipurpose Dams on the Zambezi and Kafue Rivers

3.1 Introduction to the investments

Multipurpose dams, in addition to providing for hydropower production, can be operated to reduce damages associated with large floods and to maintain or enhance ecosystem services in the river basin. Investments can be made by modifying the design of planned new dams in the Zambezi in order to improve contribution to flood control and flow regulation. Additionally, investment projects in existing dams in hydropower capacity influence the flow regime downstream. These three aspects related to investments in multipurpose dams on the Zambezi and Kafue are evaluated in this Chapter.

The evaluation in this report will have limited influence on the decision making processes, but adds to the complete review of the investments that change dam management and flood releases in the catchments. During the course of this study, progress has been made in the decision making on dams in the Zambezi River Basin, with Kafue Gorge Lower and Mphanda Nkuwa obtaining the green light for construction.

3.2 Situation assessment: stakeholders views

SADC is recognizes the essential need for and benefits of dams and their inevitable role to the development in Southern Africa. Taking into account the existence of other alternatives, the development of dams will need to be considered from a holistic perspective, within the framework of Integrated Water Resources Management (SADC, 2006).

The South African Power Pool (interview April 2010) pointed out that this is the time to develop hydropower in the Zambezi River Basin. Hydropower is viewed as clean energy and is now more favourable for investors. New coal based power plants are less favourable because of pollution concerns.

The Zimbabwe power company ZPC (interview April 2010) acknowledges that discussions are ongoing around Batoka Gorge. The ZPC pointed out that additional power generation capacity is not only expected from hydropower. Hwange thermal power plant can be extended with 1500 MW (2x300 MW and 3 x 300 MW). Extension of Kariba South by 300 MW is mentioned as an option. This extension would use the current storage capacity of Kariba Reservoir.

The Zambian power company ZESCO (interview June 2010) mentioned the value of Batoka Gorge for contributing to cover the demands in Southern Africa and for increasing the value of Zambezi water for power generation.

ARA Zambeze (interview 28 April 2010) pointed out that Mphanda Nkuwa, Boroma and Lupata are considered future possible hydropower locations. ARA Zambeze mentioned that these dams would help in flood protection. Their reservoir capacities are limited in comparison to Cahora Bassa, but some of the tributaries downstream of Cahora Bassa can be ‘caught’ by the new proposed reservoirs, thereby reducing their effects on flooding.

3.3 Description of investments

All planned dams and extensions of current dams on the main stem of the Zambezi and the Kafue are for hydropower production and therefore have operational limitations in terms of flood control and flow regulation for the environment. The following investment options are discussed in this Chapter:

- Batoka Gorge;
- Kariba Extension;
- Itezhi-Tezhi Extension;
- Kafue Gorge Lower;
- Mphanda Nkuwa
- Boroma; and
- Lupata.

Locations of all investment are shown in Figure 10.2 and further details are given in the table that summarizes the evaluation, Table 3.1. Batoka Gorge and Mphanda Nkuwa are each evaluated for all criteria of this study because of their size and the decision stage.

Reflection on general design considerations

Spillways can be designed either by flood gates in the dam wall (currently in Kariba and Cahora Bassa) or by crest gates. Crest gates have the advantage that any flood can pass; for radial crest gates (turning around an axis) gates can eventually be fully opened. Upstream flooding is generally less with crest gates than with flood gates in the dam wall. Spillway gates generally need to be maintained and operated. As such, they are typically not recommended for medium and small dams in Southern Africa.

Design criteria to size the bottom outlets are often defined by the period of time it would take to empty a dam, which instead of the environmental flows required. A discussion on investment in bottom outlets is done in Chapter 8.

Reflection on Batoka Gorge design

For Batoka Gorge (Batoka Joint Venture Consultants, 1993) crest gates are designed, limiting the floods upstream. For the design the Regional Maximum Flood of 20 000 m^3/s has been used, far larger than the maximum of Kariba dam of 16 000 m^3/s. The Regional Maximum Flood is a normal design criterion. The Possible Maximum Flood is normally 2-4 times higher. The use of the crest gates allows this Possible Maximum Flood to pass the dam without destabilizing the dam wall. The crest gates are radial (around an axis), which helps in the regulation of flow through each individual gate. Therefore no changes in basic design are recommended for the spillway gates.

With regard to bottom outles for Batoka Gorge dam; sediment load expected to enter this dam from Victoria Falls and the upstream wetlands is very low (Batoka Joint Venture Consultants, 1993). Therefore the design of the bottom outlet is not critical for sediment management. The dam was designed with a discharge capacity of the outlet is 1600 m^3/s at a normal reservoir level, which is more than the annual mean average of about 1200 m^3/s. Therefore the capacity is high enough for minimum environmental flows during dry periods.

Reflection on Mphanda Nkuwa design

The Mphanda Nkuwa dam, located on the Zambezi river, downstream of Cabora Bassa dam was the designed with a spillway consisting of 13 radial crest gates (Lahmeyer International *et al.*, 2003), and a discharge capacity of 31 000 m^3/s while a 10 000 year flood at this site is 33 000 m^3/s. The spillway capacity is therefore slightly below this extreme event. Because of the radial crests this dam is associated with the same advantages as for Batoka Gorge in terms of backwater effects.

The bottom outlet accommodates 2290 m^3/s and the combined turbine outflow is 2200 m^3/s. This combined flow, including additional contributions downstream from tributaries, is expected to be sufficient to provide for existing proposals to release freshets of 2900 m^3/s annually from Cahora Bassa (Lahmeyer International *et al.*, 2003). Further studies will need to be carried out to ensure that the freshet requirements can be met. Otherwise, larger bottom outlets would be recommended.

Reflection on additional hydropower production using existing reservoirs

Investment projects on the main dams in the catchment not only imply new dams but also additional power generating capacity making use of existing reservoirs. Extension of hydropower capacity is planned for Kariba North (currently being built), Itezhi-Tezhi Hydroelectric Project, Kafue Gorge Lower and Cahora Bassa Extension. Such extensions do not create extra storage capacity for flood control, but increase the possibility to release water through turbines when floods are forecasted and during floods. This adds considerably to hydropower production and the possibility to lower dam levels before extreme floods.

3.4 Decision stage of investments

The proposed extensions to the current hydropower schemes have reached advanced stages in the decision making process. Kariba North is currently being executed. A final impact assessment is currently being done for Cahora Bassa Extension. A recent publication also indicated that the Kafue Gorge Lower run-of-river scheme will be implemented (www.hydropower.com August 2010).

There are no official statements of what is next in terms of plans for Batoka Gorge, but the stakeholder views summarized in section 3.2 indicates that this will soon, or is already in, a final decision making stage.

It was recently publicly announced in the press that Mozambique's government has approved the construction of the Mphanda Nkuwa (www.hydropower.com August 2010 and signing of concession contract December 2010). Its construction is planned to begin in 2011 and is estimated to take five to six years.

It was also announced that Zambia has signed an agreement with two Chinese firms to build the Kafue Lower Gorge hydropower plant (www.hydropower.com August 2010). The project is planned to start in April 2011 and be completed in 2017.

The Boroma and Lupata dam are under pre-feasibility phase and are selected for feasibility study. The Ministry of Energy of Mozambique announced in 2009 that a socio-economic study was to be carried out for the construction of the Boroma dam and the feasibility study for the two sites was initiated in 2010 with request for proposal for the hydrological measurement at the two locations.

3.5 Evaluation of the criteria of this study

In Table 4.1 the most feasible dams which have been planned are summarized with regards to their impact on flood control, as well as technical and environmental feasibility. In Appendix A, a full overview is given of all plans on dams in Zambezi River Basin, with details of the considerations and references used. Further details on operation of the dams are given in the Report on Dam Management.

In general, the main constraints preventing construction of the potential dams stems from environmental considerations. The identified dams range from 180 m high to less than 40 m high. The locations vary between steep rocky gorges to flat river valleys. The sizes of the reservoirs are generally not impressive when compared to the size of the big existing reservoirs in the basin Kariba and Cahora Bassa.

It is important to bear in mind that, for most dams, hydropower is the main economic driver of the project. Therefore, in order for a dam to top the priority list as a development project in the Basin, flood control should interact well with hydropower generation.

Minimal environmental releases, flood releases and sediment transport are important to the ecology of the Basin. In terms of flow regulation, although the minimum environmental release is part of the standard design practice in the region, environmental flows have only been agreed upon for existing dams in the Kafue river basin. Flood releases for the environment will impact on hydropower production and will have to be “negotiated” at design stage. Since the main motivation for the dam projects is hydropower generation, which is directly related to the available head, most of the identified potential dams are not conceptualized on releasing sediments freely as this would require free flow during floods.

Table 3.1: Identified potential dam sites on the main Zambezi, their contributions to flood protection and hydropower production and their technical and environmental feasibility.

Project, location & proposed usage	Contribution to flood control	Planned power production	Technical Feasibility	Environmental considerations	Other considerations and overall conclusion
Middle Zambezi Basin					
Batoka Gorge Between Victoria Falls and Kariba, 54 km downstream of Victoria Falls, 160 m high. For hydropower production.	Contribution to flood control by this project is very limited due to small size of the reservoir. (1680 Mm³)	1,600 MW maximum. In average years the spillway is assumed operational several months a year, meaning that maximum power production is quite reliable.	This is considered to be a high dam, built in a narrow gorge. The feasibility study of 1993 has shown that this project is technically a viable scheme.	Conjunctive operation of Batoka and Kariba dams is being proposed to maximise hydropower generation and minimise environmental impacts. A lower level outlet will be incorporated on the dam to enable environmental releases.	A second EIA done in 1998 was apparently more positive than the 1993 EIA, but was not sourced in time for this study. Tourist activity of white water rafting will be affected as the rapids will disappear.
Kariba Extension	Contribution to flood control by this project is very limited due to its location as an extension in hydropower of the current plants at lake Kariba. The extra turbines create extra capacity to release flows, adding to dam safety.	600 MW; the extra turbines make it possible to create extra energy when dams are emptied in advance of forecasted floods and during floods.		The impacts of extra flow to meet peak demand are likely to be more severe than with present operation, due to downstream fluctuations that destabilize banks and economic activity.	North Bank currently being executed. South Bank more difficult.
Kafue Basin					
Itezhi-Tezhi Hydroelectric Project at Itezhi-Tezhi dam on the Kafue river	Will utilise existing regulatory storage at Itezhi-Tezhi reservoir for hydropower production. Firm energy at both Itezhi-Tezhi and Kafue Gorge increases as the regulatory storage	120 MW	There is no new dam proposed on this site. Raising of the existing dam is being considered, but foundation suitability may pose a problem.	If the operation will not change and the hydropower plant will make use of the releases currently being made for the Kafue Gorge, the	

Project, location & proposed usage	Contribution to flood control	Planned power production	Technical Feasibility	Environmental considerations	Other considerations and overall conclusion
	increases.			impact would be low to moderate. However, it is unlikely that operation rules will not change. The EIA that was done for the Itezhi-tezhi hydropower generation (Itezhi tezhi Hydroelectric Project, Vol IV EIA. Prepared by Harza Engineering Co.) was criticized by several independent reviews (for example, Douthwaite 2000) as inadequately accounting for changes in operation with the installation of power generation at Itezhitezhi.	
Kafue Gorge Lower, 65 km upstream of confluence of Kafue river and Zambezi river, and about 10 km downstream of existing Upper Kafue Gorge Hydro Project	Contribution to flood control by this project is very limited due to small size of the reservoir. From 3.8 to 54.5 Mm^3 depending on which site is chosen (Phiri *et al.*, 2009).	600 MW	Technical feasibility passed.	The rapid and frequent fluctuations in discharge (and hence water levels) caused by the peaking power generation at the proposed lower power station has the potential to seriously impact on the ecological functioning of the upper part of the 40-odd km stretch of alluvial channel from the bottom of the gorge to the Zambezi confluence as	Agreement signed between Zambia and two Chinese firms (www.hydroworld.com). Construction should start in April 2011.

Project, location & proposed usage	Contribution to flood control	Planned power production	Technical Feasibility	Environmental considerations	Other considerations and overall conclusion
				well as causing serious bank slumping and erosion and prejudice to the riparian farmers and those who rely on the river (fisheries).	
Lower Zambezi Basin					
Cahora Bassa Extension	Use of existing reservoir capacity, but with extra spillway. The storage capacity for floods will be decreased contributing to extra floods downstream.	1,200 MW maximum. Reliability is considered high.	Pre-feasibility studies indicate that technically the project is feasible.	Additional spillway and new operation of Cahora Bassa could, if well applied, contribute to environment downstream. Also, lake levels are more stable.	Probably feasible (final feasibility currently being executed).
Mphanda Nkuwa 61 km downstream of Cahora Bassa on Zambezi main stem. Run-of-river scheme benefiting from releases from the Cahora Bassa dam.	Mphanda Nkuwa is downstream of tributaries of Luia and Revubué but has a limited storage capacity of 2500 Mm^3.	1,800 MW	The Mphanda Nkuwa has passed technical feasibility stage.	Downstream environmental damage feared due to daily fluctuations in river levels, and reduction of the natural flow of river sediments, critical to the delta's health. (JA! *et al.*, undated). Impact feared on fishery activities downstream of the dam (WWF *et al.* 2006). Will reduce natural flow variability and sediment contribution from Luià	Construction has been approved by the government and should start in 2011 (www.hydropower.com August 2010).

Project, location & proposed usage	Contribution to flood control	Planned power production	Technical Feasibility	Environmental considerations	Other considerations and overall conclusion
Boroma 21 km upstream of Tete on Zambezi main stem.	Run-of-river scheme with limited storage capacity, but could potentially reduce flood problem at Tambara	444 MW or 160 MW	Prefeasibility phase	Designed to reduce the impacts of water level fluctuations due to peaking power operation at Mphanda Nkuwa.	
Lupata 84 km downstream of Tete, 21 km upstream of Tambara	Run-of-river scheme with limited storage capacity, but could potentially reduce flood problem at Tambara	654 MW	Prefeasibility phase	Will reduce natural flow variability and sediment contribution from Luenha and Revubué contribution from Luenha and Revubué	

The evaluation of Batoka Gorge and Mphanda Nkuwa is shown in Figure 3.1 and discussed in more detail than the other options in the sections below.

	Criterion	Batoka Gorge	Mphanda Nkuwa
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		

Figure 3.1: Assessment Batoka Gorge and Mphanda Nkuwa Reservoirs (see Fig. 1.2 for legend)

3.5.1 Batoka Gorge Hydro Electric Scheme

Technical and legal feasibility

The Batoka Gorge Hydro Electric Scheme was the subject of a feasibility study conducted in 1993 with positive outcome at the time (Batoka Joint Venture Consultants, 1993).

Figure 3.2: Picture of Batoka Gorge Dam Site (New Zimbabwe, 2010

Contribution to flood protection

The installation of crest gates which is planned for Batoka Gorge (Batoka JV Consultants, 1993) is positive to minimise flooding on the upstream side of a dam by keeping the water level more or less constant once it is overflowing through the spillway. However, it is reported in the feasibility study that the water levels downstream of Victoria Falls are still affected.

The Batoka Gorge dam will operate as a run-of-the-river scheme and its live storage capacity is 570 Mm^3 (Batoka JV Consultants, 1993) which is not sufficient to provide a significant flood attenuation effect on its downstream side. As an indication; this storage capacity is filled by the mean daily flow within three days. If the flood peak storage in Kariba dam can be reserved as aconsequence of Batoka Gorge extra power generation, then Kariba can attenuate floods better. With the current power deficit in the region this is not a very probable scenario in the near future. Chapter 7 and 8 in Annex 2 discuss the different operation options.

Batoka Gorge could be used to enhance the flood attenuation effect of Kariba dam, if the extra hydropower capacity could offset production and facilitate a drop in levels at Kariba dam before a flood, or by adjusting the operating rule curve that is the flood rule curve for more storage capacity before the wet season. This is however highly dependent on the operating rules to be developed, knowing that the feasibility of the dam relies on almost optimum power production and the demand of energy in southern Africa does not yet have sufficient supply.

Impact on ecosystems

Little could be found in the existing literature on the impact of the dam on environmental flow. However, the NGO Birdlife International reported that the new lake created in the Batoka Gorge would severely constrain the breeding opportunities for cliff-nesting raptors among which the Taita Falcon, a species listed as Near Threatened (BirdLife International, 2009).

A second EIA done in 1998 was not sourced in time for this study. This EIA could have shed more light on the consequences of Batoka Gorge on the environment. Reference to Devil's Gorge as an alternative site, previously discarded on economic grounds, is still found in recent reports and/or presentations (Mhlanga, 2006; Sisala, 2008) as an alternative with possibly less environmental negative impacts.

Impact on human use

The contribution of Batoka Gorge to other water resource management issues is the additional 1600 MW (2 x 800 MW) it adds to the hydropower generating capacity of Zambia and Zimbabwe. Reliability of power production is high, judging from the assessment that in an average year the spillway will be used for several months (Batoka Gorge Joint Venture, 1993). Extra power generation capacity is of major importance to the economies in the region.

However, the reported impact of Batoka Gorge on the white water rafting, downstream of the Victoria Falls, may negatively affect the tourist activities of Victoria Falls, on the Zimbabwean side, and Livingstone, on the Zambian side. Rafting accounts for about 10 Million US$ each year (Worldbank, 2010 refering to EIA 1993).

Cost effectiveness

As mentioned, the flood protection and flow regulation effects are limited, unless the flood operating rules of Kariba dam can be adjusted as a consequence of Batoka Gorge extra power generation. The power schemes should be viable from a hydropower generation perspective. Batoka Gorge has been deemed more economical than Devil's Gorge however information for the selection criteria was not available from the report. It may be the location where constructing a dam is cheapest (because of small width of the gorge) or it may present the location with highest energy head but Devil's Gorge may be an alternative with a better overall balance when all costs (including environmental and social costs) are taken into account.

Biophysical impact

As a run-of-river scheme, the evaporation losses are limited in comparison to the electricity generated. Also, the possible negative impacts on greenhouse gasses are limited as a relatively small reservoir is used. Further discussion on greenhouse gas emissions is explained in Appendix D.

Likelihood of realization

Although the project has reached the feasibility study stage, the likelihood of this investment is still uncertain. Zimbabwe has always shown a strong commitment in the implementation of the scheme and seems to have been the driving force for the progress made so far. Talks between Zambia and Zimbabwe were to be resumed in early 2010 to discuss issues that would give direction on the implementation of the project according to several web-based articles published in January 2010 which quoted Zimbabwe Energy and Power Development Permanent Secretary, Mr. Justin Mupamhanga (New Zimbabwe, 2010).

Impact on more than one country

The project would benefit power production for the two riparian countries, Zambia and Zimbabwe, and the SADC region through trade in SAPP.

3.5.2 Mphanda Nkuwa Hydropower Project

Technical and legal feasibility

A two-phase feasibility study for the Mphanda Nkuwa hydropower project was conducted in 1999-2002 and confirmed the project to be feasible. The project is now at an advanced stage of financing.

Figure 3.3: Artistic Layout of the Mphanda Nkuwa Dam and Hydropower Plant (Lahmeyer International et al., 2003)

Contribution to flood protection

Mphanda Nkuwa is also a run-of-the-river scheme and its storage capacity will only be approximately 2500 Mm^3 (Lahmeyer International *et al.*, 2003). This volume is not enough to provide a significant flood control effect for the downstream of the river: 2500 Mm^3 can store as little as 1000 m^3/s about three days. A similar approach can be applied to operating mode of the nearby (some 40 km upstream) dam of Cahora Bassa to enhance its flood attenuation potential by compensating the loss in power generation with the production of the new dam.

Similar to the Batoka Gorge dam, crest gates will be installed at the Mphanda Nkuwa dam (Lahmeyer International *et al.*, 2003) and will therefore provide minimal impact in upstream flooding caused by back-water effect.

Mphanda Nkuwa has received many criticisms for its negative impacts on the environment. It is feared that the dam would exacerbate the downstream impacts on people and the environment from reduced fisheries production, which has already been caused by Cahora Bassa (WWF *et al.*, 2006). It is also feared that the dam could add to downstream environmental damage by introducing daily fluctuations in river levels, as well as reducing the natural flow of river sediments, which are critical to the delta's health. (JA! *et al.*, 2006).

Impact on ecosystems

The Zambezi Delta is a Wetland of International Importance under the Ramsar Convention and the Provincial authorities support extending the Ramsar site to include the north bank of the delta, and the entire delta is proposed for designation as a World Heritage Site. The impacts of the damming of the Zambezi on the Delta have been described in Annex 2.

There has been an investigation of operating rules of Cahora Bassa and Mphanda Nkuwa to enhance the condition of the Delta (verbal communication Beilfuss 2010). It is not clear whether this dam will compromise these new operation rules or whether it could be synchronized so as to still allow the rehabilitation of the Delta to some extent.

Short –duration environmental flow releases ranging from 2750-9200 m^3/s have been considered by stakeholders in the lower Zambezi (Beilfuss and Brown, 2010). Such discharges would be accommodated by a combination of turbine outlets (2200 m^3/s) and spillways. Also, the bottom outlet has a capacity of discharging (2290 m^3/s, Lahmeyer International *et al.*, 2003).

Mphanda Nkuwa Dam is located downstream of the confluence of the Luia River, thereby reducing the natural flow variability and sediments contributed by the Luia to the Zambezi Delta. Sediment delivery from the Shire River to the Lower Zambezi River and Delta is not affected, but the addition of a new dam on the main Zambezi will mean an increased dependence on Shire runoff and sediment.

Cost effectiveness

Due to a limited contribution to flood protection, the investment is not considered to be very cost effective for flood protection.

The project can be financially feasible through selling of power. The total capital to be financed is about 3 Billion US$ of which 30% is equity from project sponsors and 70% is debt. The debt is 50% from commercial banks. The financial project feasibility depends on the selling of power to Electricidade de Mozambique and the South African Power supplier Eskom. To supply the power to the users also depends on the extension of the electrical grid. (Mphanda Nkuwa, 2010)

Impact on human use

The main contribution from the dam to other water resource management issue is the additional hydropower capacity of 1500 MW. Another anticipated benefit stated by the feasibility study report is the potential for developing a fishery industry around the new lake with an estimated annual yield of 500 – 1000 tons per year (Lahmeyer International *et al.*, 2003).

If environmental releases are fully respected, some water will flow via spillways. Increased turbine outlet capacity would be required to increase hydropower generation during environmental flow releases.

Biophysical impact

As a run-of-river scheme, the evaporation losses are limited in comparison to the electricity generated. Also, the possible negative impacts on greenhouse gasses are limited as a relatively small reservoir is used. Further discussion on greenhouse gas emissions is explained in Appendix D.

Likelihood of realization

The realization is almost definite, see decision stage described in section 3.4.

Impact on more than one country

The project is located in Mozambique and would not impact on any other Zambezi riparian State. However it is reported that 90% of the produced power would be exported to South Africa which is a major importer of the region. In the long term the power is likely to be available to other countries in the region through the SAPP.

3.6 Conclusions and recommendations

Hydropower turbines that are added at existing dams will not only contribute to power generation, but will also increase the capacity to generate hydropower if reservoir water levels are reduced before forecasted floods, as more water is able to pass through the turbines rather than spillways. Such projects are planned for Kariba North, Itezhi-Tezhi Hydroelectric Project and Cahora Bassa Extension.

Spillways can be designed either by flood gates in the dam wall or by crest gates on top of the dam. Crest gates have the advantage that any flood can pass and upstream flooding is generally less. Such gates have already been incorporated in the designs of Batoka Gorge and Mphanda Nkuwa. No changes in the design are therefore proposed.

The newly planned dams on the Zambezi and Kafue are designed for power generation and are or have been debated from an environmental perspective. The large power deficit in the region, makes that decision processes on new dams are currently fast progressing. Financial viability of these dams will dictate their mode of operation, which will most likely not be optimal from a flood control 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) for further design and development of operating rules.

4 New Multipurpose Dams on the Tributaries

4.1 Introduction to the investments

New dams on unregulated tributaries which contribute to flood flows could be regulated with multi-purpose dams and thereby help to improve flood control. These dams are not necessarily designed for flood control only, but may serve other purposes like hydropower production or irrigation. In this Chapter both dam sites that have been identified before as well as dam sites that are identified in this study are evaluated.

4.2 Situation assessment: stakeholders views

As mentioned in the previous chapter, SADC recognizes the essential need for and benefits of dams and their inevitable role to the development in Southern Africa. Taking into account the existence of other alternatives, the development of dams will need to be considered from a holistic perspective, within the framework of Integrated Water Resources Management (SADC, 2006). In this chapter it is important to add that SADC had explicit reservations to the World Commission on Dams and Development report: "There is a perceived danger that if dams are not accepted where appropriately needed, the regional peoples could be confined to under development, resulting in perpetual poverty. In practice, compromise will be inevitable if development is to continue." "Efforts on the use of small dams for multi-purposes would be encouraged since these would contribute significantly to ensuring reliable domestic and livestock water supply in rural areas, support small scale irrigation, promote tourism, and regulate seasonal flows to provide reliable all-year round flows." (SADC, 2006)

This situation assessment focuses mainly on stakeholders' opinions regarding the feasibility of development of new dams for flood regulation and flow regulation in general.

The unregulated tributaries identified at Inception stage are the Kalomo and Luangwa Rivers in Zambia, the Gwayi and Sanyati Rivers in Zimbabwe and the Luia River in Mozambique. The opinion of the three countries in which these tributaries are situated is important. The Kalomo tributary was not mentioned during the interviews in Zambia. In Mozambique the Revubué and Luenha were added as important tributaries that cause flooding. The Shire tributary in Malawi is dealt with under "Regulation of Shire River and Lake Malawi", Task 6.

Zambia (Luangwa)
The Department of Water Affairs (interview 14 June 2010) pointed out that priorities of the Zambian government have been education and health care. The priorities of the Department of Water Affairs dictate that making water available for irrigation and water supply supersedes new infrastructure for flood protection. The Department does not know of any dams planned in Zambia that could contribute to flood management. Some small dams on tributaries of the Luangwa could be used for irrigation, but, by virtue of their small sizes, they would hardly contribute to flood protection.

The Department noted that dams proposed for flood protection should also have other benefits if they are to be considered. Indications of flood prone areas within Zambia are mainly on tributaries to the Zambezi. The Barotse floodplains experience flooding, but would not be considered as a flooding problem that requires addressing. Traditional systems that sound drums as a means of flood warning are in place and are not in need of urgent improvement. The

Sesheke area has flooding problems. Namibia is very much interested in solving flooding problems in this area.

ZESCO (interview 15 June 2010) mentioned that the main Luangwa river was not of specific interest for dam construction as there are no hydropower sites that ZESCO is aware of. Also, high sediment transport levels in the Luangwa River would result in rapid filling of the reservoir.

Zimbabwe (Gwayi, Sanyati)

The Zimbabwe National Water Authority (ZINWA, interview 20 April 2010 and meeting 2 August 2010) explained how floods occur in the Mzarabani and Angwa areas as a result of backflows from Cahora Bassa rather than from flows from upstream. ZINWA provided a list of priority dams in Zimbabwe, mainly for irrigation purposes. ZINWA recognizes the value of two potential dams for flood protection; the Gwayi Shangaani Dam on the confluence of the Gwayi and the Shangaani rivers, which construction has started but is being held up because of financial problems and the planned Kudu dam, on the Sanyati, which could contribute to flood protection and which is at design stage. There are no prioritized dams on the Msengezi River.

Mozambique (Luia, Revubué, Luenha)

The regional Water Administration (ARA Zambeze, interview 28 April 2010) explained significant contributions to flooding comes from a number of the unregulated tributaries of the Zambezi. Annex 2 gives further insight in the contribution of different tributaries to flooding.

ARA Zambeze emphasized the need for dams on the Zambezi tributaries as opportunities for alternative livelihoods, rather than as means for flood protection. In this regard the dams wold provide vide water for agriculture, fisheries and other economic activities which could address current local problems of poverty. ARA Zambeze also mentioned that Mozambique has started a "green" revolution campaign to ensure food security. In that regard, new projects and programs, like dams and irrigation, are required to support this initiative. On the issue of environmental protection, ARA Zambeze also mentioned that the environmental impact of new dams and dam operation is important to be further investigated, not only in terms of flows but also in terms of water quality. The preservation of wetlands especially those demarcated as Ramsar sites is considered important.

HCB (interview 29 April 2010) indicated that its main flood concerns were related mainly with flows from the Luangwa and the main stem Zambezi.

4.3 Description of investments

4.3.1 Zambia (Luangwa)

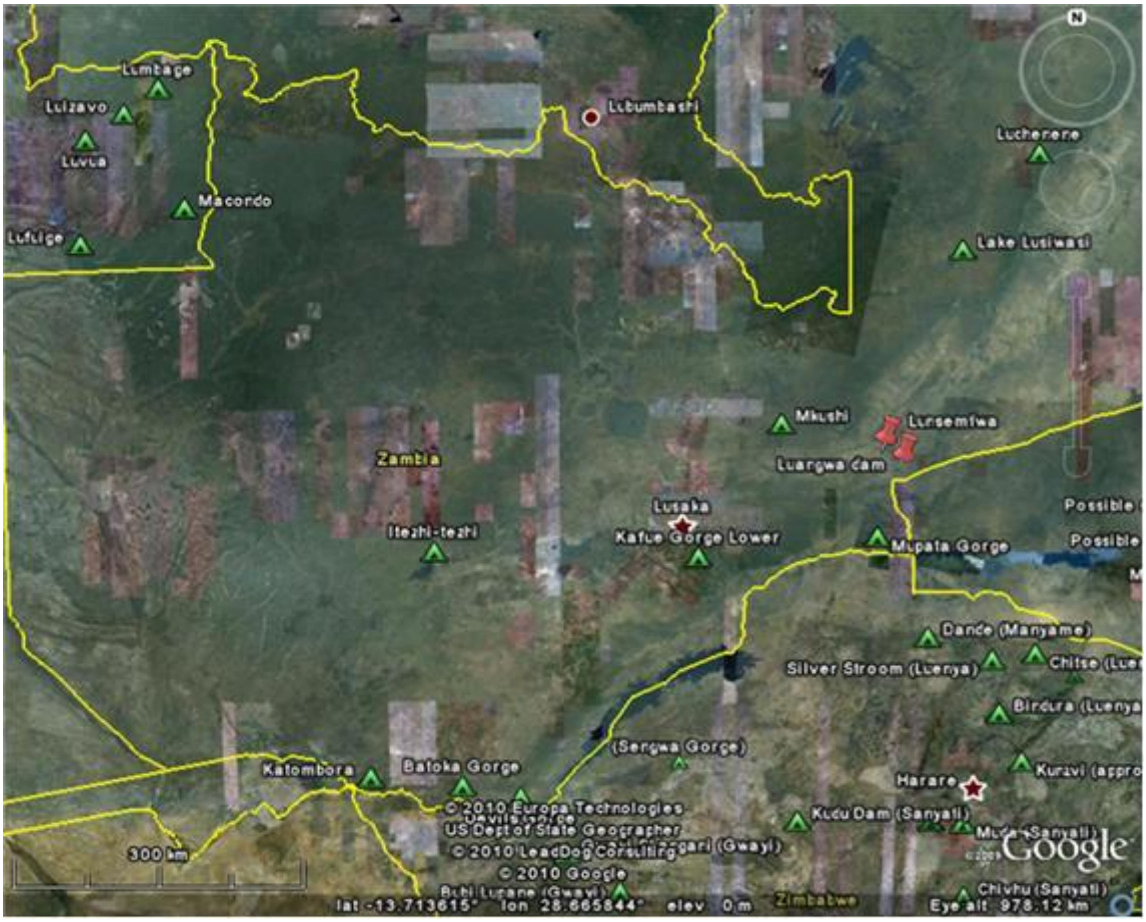


Figure 4.1: Potential dam investment projects on unregulated tributaries in Zambia (green triangles indicating potential new dam sites or possible extensions of hydropower generation as identified in literature, red drawing pins indicating potential dam sites identified in this study)

The Muchinga Escarpment, which cuts across the Luangwa Basin, with the available head across in the region of 600 m over a 15 km distance, provides technically suitable opportunities for dam construction for hydro power generation.

Over the past few years, there has been a renewed interest on the power generation in the private sector in Zambia. At present, there are three existing hydro power generation dams in the upper Luangwa basin; namely, Mulungwishi, Lunsemfwa and Lusiwasi. Each of these schemes has a small dam for flow regulation and a power plant some distance downstream of the dam for power generation. Several new dam projects have been identified which can contribute positively to the SADC power pool, but most of these projects have small impact on flood control as they have a limited storage capacity and focus on the upper Luangwa river basin. Two projects have been identified, one of which is at planning stage, namely Mkushi and the other has been identified during this study as a site having hydropower potential, namely Luchenene. Both dams have very limited influence on flood control.

The whole of the Lower Luangwa catchment falls in Zambia and a vast area is covered by North and South Luangwa game Parks (respectively 4600 km^2 and 9050 km^2) and their associated game management areas which are environmentally protected. Population density is generally low, in total less than 10 persons per square km.

By use of topographical maps and regional knowhow, two dam sites were identified, as presented in Table 4.1. Storage capacity during the flood season could be used for power generation in Cahora Bassa Power Station as well as the proposed dam sites. However, water availability is generally not the limiting factor of power production in Cahora Bassa (HCB interview, 29 April 2010). Also, the valley is part of the game management areas that are environmentally protected and which also contribute to tourism. Power unit costs on the Luangwa would be high, therefore the dam would not be on the priority list of ZESCO. The main use of this dam, as indicated, would be regulating the flow of Luangwa River for the benefit of other users. The reservoirs have to be sufficiently long to catch the high sediment load of the Luangwa River.

Table 4.1: Newly identified dams on Luangwa tributary which contribute to flood control

Sub-Project	Tributary	Dam Characteristics			
		Longitude / Latitude	Reservoir Capacity (Mm^3)	Height (m)	Possible extra hydropower generation (MW)
Luangwa					
Lusemfwa Lower	Lusemfwa	14.724 º S, 30.110 º E	500	60	35
Luangwa	Luangwa	14.877 º S, 30.274 º E	2500	70	40

Lusemfwa

The Lusemfwa Lower dam site is located 20 km upstream of confluence of Lusemfwa and Luangwa rivers. This would regulate the peak flood flow on Lusemfwa River by storing on a major portion of game management areas around South Luangwa Park. Contribution to flood control can be considered as promising, with added advantage of extra power generation in the range of 35 MW. This is considered a medium size dam 60 m high with medium size reservoir of about 500 Mm^3. The location is not environmentally favorable as it floods game management areas and protected lands.

Luangwa

A technically suitable dam site on the Luangwa is 10 km upstream from the confluence of Lunsemfwa and Luangwa Rivers. This is considered a medium size dam 70 m high with a large reservoir of 2500 Mm^3. Similar to a dam on the Lusemfwa, a dam could contribute to hydropower production in the order of 40 MW.

However, ZESCO (interview 15 June 2010) sees the main Luangwa as unsuitable for dam development for hydropower generation because of the regular dry period and the high sediment load. The power generation potential would be achieved at the proposed dam as well as Cahora Bassa. For this report, the generations shown are for the installed capacity at the dam sites only.

Two additional possible dam developments are identified that do not directly contribute to flood control. These are the Mkushi dam (Coordinates 14.607 º S, 29.187 º E) that is planned by a private developer for power generation (40 MW). It will be a medium size dam built on steep slopes of Muchinga Escarpment with height of 55 m. Another possible dam site on the Lunchenene tributary (Coordinates 12.066 º S, 31.594 º E), which would also be suitable for power generation (35 MW, 40 m). Contribution to flood control by these dams are limited due to small reservoir sizes.

4.3.2 Zimbabwe (Gwayi, Sanyati and Mazowe)

Figure 4.2: Potential dam sites on unregulated tributaries in Zimbabwe as identified by the Department of Water Affairs of Zimbabwe (green triangles)

The Zimbabwe National Water Authority has identified a number of dam sites that are technically suitable for development on the Gwayi and Sanyati rivers that flow into Lake Kariba. The Luenha is identified to be contributing to floods in Mozambique. On the Zimbabwean side, Luenha is called the Mazowe River. New dam developments planned for the Mazowe are shown in Figure 4.2.

Table 4.2: Possible dam sites in Gwayi and Shangani catchment (ZINWA, 2010)

Sub-Project	Tributary	Dam Characteristics					Estimated Cost (2005) (Million US$)
		H	Lat.	Long.	Live Storage Capacity (Mm^3)	Expected Yield (Mm^3/annum)	
		(m)	° S	° E			
Gwayi							
Gwayi Shangani	Gwayi	70.0	18.551	27.219	635	57	
Gwayi Umguza	Gwayi		19.498	27.768	195	30	83
Bubi Lupane	Bubi	20.0	18.922	27.719	40	11	10
Sanyati							
Kudu	Munyati	72.7	18.262	29.383	1,550	380	160

Table 4.3: Possible dam sites in Mazowe catchment, contributing to diminished flows in the Luenha (ZINWA, 2010)

Sub-Project	Tributary	Dam Characteristics					Estimated Cost (2005) (Million US$)
		H	Lat.	Long.	Live Storage Capacity (Mm^3)	Expected Yield (Mm^3/annum)	
		(m)	° S	° E			
Mazowe							
Chitse	Ruya	unknown	16.707	31.611	290	140	140
Silver Stroom	Msengezi	47.0	16.762	31.196	140	33	190
Bindura	Mazowe	44.0	17.263	31.281	87	36	90
Kunzvi	Mazowe				146	100	67

Gwayi

Gwayi Shangani

ZINWA has indicated that for the Gwayi, the Gwayi Shangani dam with a storage capacity of 635 Mm^3 seems most feasible and will contribute to flood control (interview 28 April 2010). Located at the confluence of the Shangani with the Gwayi, it controls an important part of the Gwayi catchment (nearly 39 000 km^2). ZINWA indicated that dam construction is in progress at this site, with the contractor already on site for construction of the scheme. but unfortunately the project is currently suspended due to financial reasons. Its sizeable live storage capacity of 635 Mm^3 will provide a significant flood attenuation effect. The main purpose of this dam is to supply water to Bulawayo, some 270 km south west of the dam site. The hydropower capacity of this dam is a mere 2 MW and would be primarily used to supply power to the pumping station required to convey the water to Bulawayo. A possibility of doubling the hydropower capacity through some redesign was also mentioned. Thus, the dam would combine water supply and hydropower generation. To serve for flood protection also, would need an additional objective in the operating of the dams and has to be weighed against the disadvantages for water supply and hydropower.

Gwayi Umguza

The Gwayi Umgasi scheme is located at the confluence of the Umguzi River with the Gwayi, some 115 km north west of Bulawayo, controlling a catchment of 8 000 km^2. According to the *Large Dam Site Data* record from the Ministry of Water Development in Zimbabwe (last updated in 1981), some prefeasibility investigation have been carried out. However no further information has been found on this scheme.

Bupi Lupane

Bupi Lupane is a dam located near Lupane, along the A8 road between Bulawayo and Victoria Falls. It is currently under construction and nearly completed. The dam will control a large catchment on the Gwayi River upstream of the Gwayi Shangani dam. Its live capacity is approximately 40 Mm^3 which will provide some, albeit minor, flood attenuation effect.

Sanyati

Kudu dam, on the Sanyati river has potential to make a considerable contribution to flood protectionith a storage capacity of 1550 Mm^3. Only preliminary designs of the dam have been carried out to date.

Other dams planned by ZINWA in the Sanyati catchment are the Muda, Mhondoro, Chivhu and Shavi dam. The Muda dam is located 50 km south of Harare for irrigation. The catchment that it controls is fairly small and very little flood attenuation effect can be expected for the scheme. It is therefore not a cost effective investment with respect to flood protection. The Mhondoro dam has a fairly large storage capacity of 450 Mm^3. This dam located about 30 km downstream from the Muda dam site was the subject of a feasibility study. However, because of the limited upstream catchment area, this dam is also not suitable for flood control. The Mhondoro dam has a larger catchment area (3500 km2) than the Muda dam (950 km2) and a larger storage capacity, therefore would have more impact on flood control. Chivhu and Shavi dam are too small for meaningful flood control purposes with respectively 23 and 5 Mm^3 live storage capacity.

Mazowe

The Mazowe River flowing from the north eastern part of Zimbabwe into Mozambique, where its name changes to the Luenha, discharging into the Zambezi between the site of the proposed Boroma and Lupata dams.

Chitse

There is no detailed information availableon this site

Silverstroom

This dam is planned for construction on the Msengezi river which discharges directly into the Cabora Basa. With a design capacity of 140 Mm^3 this dam has been planned primarily for irrigation purposes.

Bindura

At the time of writing this report, the Bindura dam under construction and has a capacity of 87 Mm^3. It is intended primarily for irrigation and water supply.

Kunzvi

The proposed Kunzvi, with a storage capacity of 146 Mm^3, will be constructed on a tributary for the Mazowe river, 40 km east of Harare, for the sole purpose of supplying water to Harare. Its capacity of will provide an appreciable but limited potential flood attenuation. It is already under construction although construction is proceeding intermittently due to erratic funding.

4.3.3 Mozambique (Luia, Revubué, Muira)

Several tributaries flowing in Mozambique have been identified by ARA-Zambeze. For this study possible dam sites were investigated using satellite imagery and dam engineering expertise. The knowledge that flow gauges are generally stationed at sites that are technically suitable for dams, added to a first selection. The possible dam sites are listed in Figure 4.3 and dam characteristics are given in Table 4.4.

Table 4.4 Possible dam sites on unregulated tributaries in Mozambique identified in this study

Sub-Project	Tributary	Dam Characteristics			
		Long.	Lat.	Reservoir Capacity (Mm^3)	H (m)
Luia	Luia 1	32.977 º	15.543 º	5600	120
	Luia 2	32.929 º	15.439 º	2700	90
	Luia 3	32.842 º	15.341 º	300	50
Revubué					
	Revubué	33.788 º	15.878 º	8000	90
Luenha					
	Luenha 1	33.715 º	16.428 º	2000	50
				11000	80
	Luenha 2	33.437 º	16.527 º	4400	50
Muira		18.843	34.107	2000	50

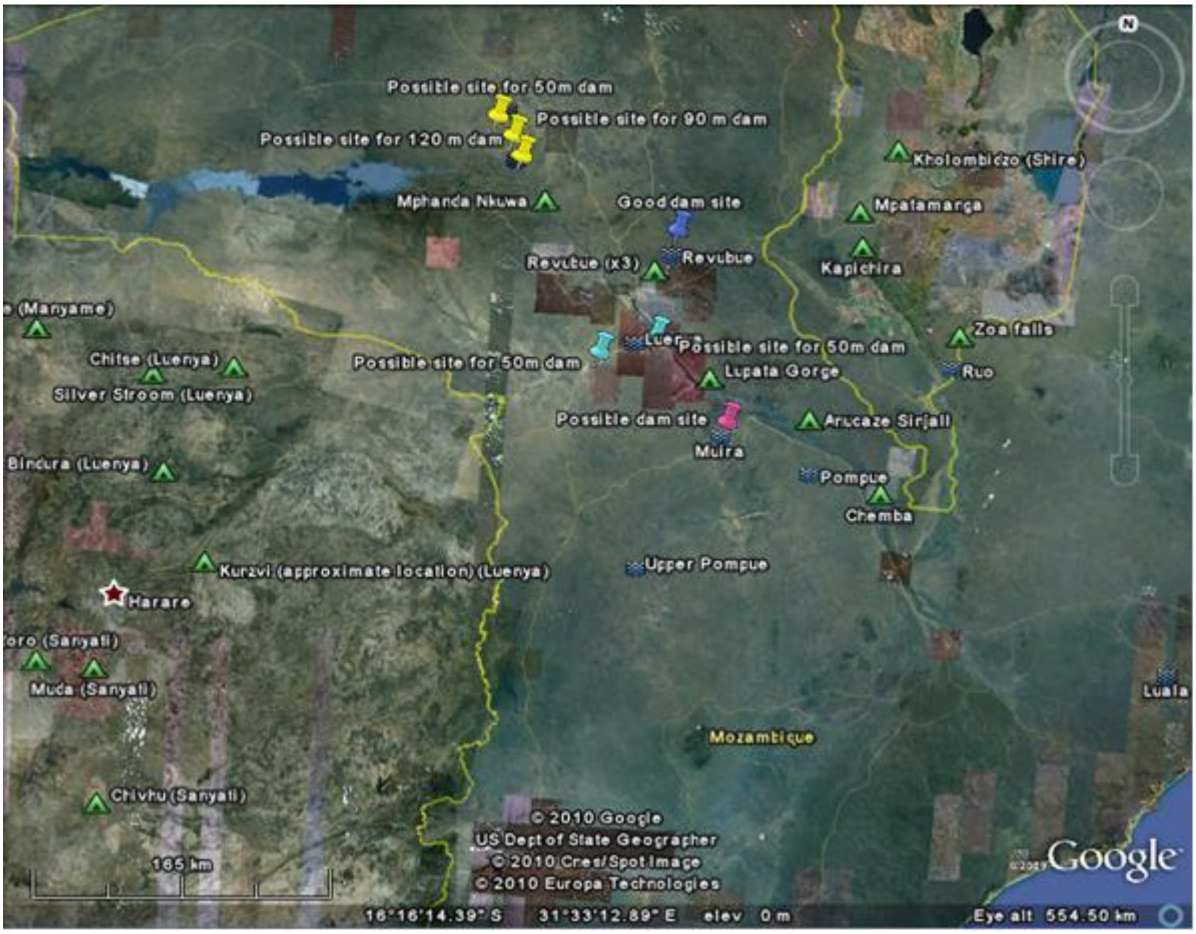


Figure 4.3: Potential dam sites on unregulated tributaries in Mozambique

Luia

The Luia flowing into the Zambezi on the left bank, just downstream of Cahora Bassa is reported as a tributary contributing to flood flows. Three potential dam sites have been identified. A general feature of the sites on the Luia is the narrow nature of the gorges all along its course, such that and none of the identified dam sites could provide a significant storage capacity.

Luia dam site no.1

This site is located approximately 4.8 km upstream of the confluence with the Zambezi. It would be suitable for a 120 m high wall. This dam would catch the water of nearly the whole catchment. This site is within the area of influence of the backwater curve of the Mphanda Nkuwa.

Luia dam site no.2

This site is located approximately 17.6 km upstream of the confluence with the Zambezi and 2.3 km downstream of the confluence of the Cherisse with the Luia. This site would be suitable for a 90 m high wall. This site would also catch the run-off of nearly the whole catchment.

Luia dam site no.3

This site is located approximately 33 km of the confluence of the Luia with the Zambezi and 3 km of the confluence of the Nhimbe with the Luia. A 50 m high wall could be built there and would catch approximately 85% of the run-off of the Luia.

Revubué

The Revubué was identified as a tributary contributing to flood flows. It is known that three dams are planned on the river (Niras and BRL Ingénierie, 2009), but the literature does not indicate specific locations. Investigations revealed one technically suitable dam site on the Revubué. It is located 1.5 km downstream of the confluence of the Condedezi with the Revubué. A 90 m high dam could be built on this site and would present a significant storage capacity as well as cover the major part of the catchment area.

Luenha

The Luenha is one of the bigger tributaries flowing downstream of Cahora Bassa. It has a very large catchment which starts in Zimbabwe, where the river is called the Mazowe, as discussed above. A number of dam sites have been identified in Zimbabwe by the Ministry of Water Development. Two sites have been identified in the Mozambican part of the catchment.

Luenha dam site no.1

The site is located approximately 9.5 km upstream of the confluence of the Luenha with the Zambezi. A 50 m high dam could be built on this site. It would catch runoff from nearly the whole catchment and would present a good storage capacity. It would however require a saddle dam in the southern part of the lake to achieve full potential capacity.

Luenha dam site no.2

The site is located approximately 12.5 km upstream of Mandie, just downstream of the confluence of the Upper Luenha with the Luenha/Mazowe. A 50 m high dam could be built in this site. However, two bridges of the road 108 would be flooded.

Muíra

The Muíra was identified as a tributary contributing to flood flows and no dams are known to be planned on this river. A dam site could be found 4.5 km downstream of Lunda. It could accommodate a 50 m high dam however the settlement of Lunda and a portion of the road nearby would be flooded.

Small to medium dams to provide water for livelihoods

Different stakeholders have expressed interest in dams to provide water for livelihoods rather than for flood protection only (See Section 4.2). Therefore, to compare with the dams mentioned above which have an impact on flood protection, Box 4-1 gives an indication of costs and yields and benefits.

4.3.4 Box 4-1 Dams to provide water for livelihoods

To give an indication of costs and reservoirs yields of small to medium dams for provision of water to livelihoods, the data of ten promising dam sites in the Pungwe River Basin (south of the Zambezi) have been converted to graphs that relate the water to the yield (SSI/SEED, 2010), see Figure 5.4. Reservoir yields and capital costs give an indication of the benefits and costs for the main purpose of the reservoir. Reservoir capacities and Mean Annual Runoff axes of the graphs indicate the added value for flood control.

These small and medium dams of less than 7 Mm^3 are not so much for flood control of the main Zambezi but could contribute to keeping water (and sediment) upstream and contributing to livelihoods there. The lines give an indication what kind of relations can be expected, but exact costs, yields and storage capacities will differ locally.

As an example, Dam 2 is a dam which costs about 2 Million US$ (Capital Costs) and provides a yield of 2500 * 10^3 m^3/year (10% probability of failure). Further computation with a lifespan of 20 years and 7% interest and 0.5% for interest gives a price 82 US$ per 1000 m^3. Dams 4,5,6 and 8 are expensive with costs ranging between 270 – 1100 US$/1000 m^3. However, these were sites with very high needs for water and for 4 and 8 relatively low total capital investment.

Irrigation water costs (at the dam - capital and maintenance) could be as low as US $10 per 1000 m^3 and as high as US $ 100 per 1000 m^3. Typically it would need between 5 and 10 Ml per hectare (irrigation of between 500 mm and 1000 mm per crop). This translates to a cost of water of between US $ 50 and US $ 1000 per ha. As an example a winter wheat crop needs 7Ml per hectare and with an average yield of 4 tonnes per hectare has a value of about US $800 per hectare. A maximum of US $ 200 per hectare for the dam and all the other irrigation costs would be feasible. Coffee would give you a return of US $ 3,000 – 5,000 a hectare and bananas US $ 5,000 to 20,000. The cost of irrigation could be proportionally higher.

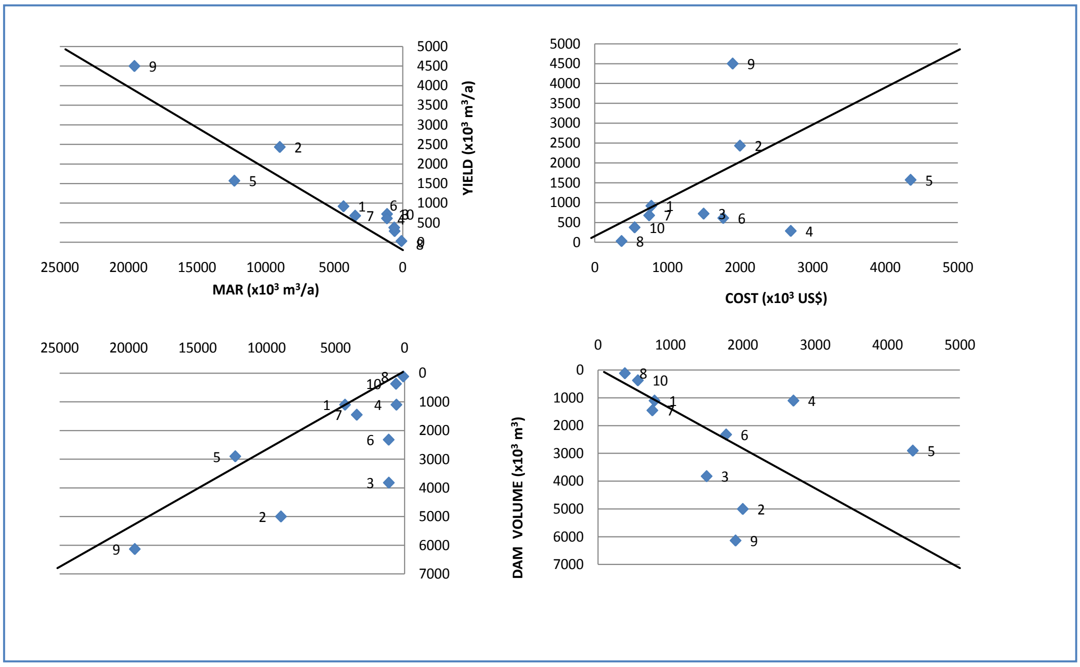


Figure 4.4 Indication of Dam Volume, Dam Costs, Dam Yield, Mean Annual Runoff through dam (on the basis of data SSI/SEED, 2010)

4.4 Evaluation of the criteria of this study

An assessment of evaluation criteria is shown in Figure 4.5.

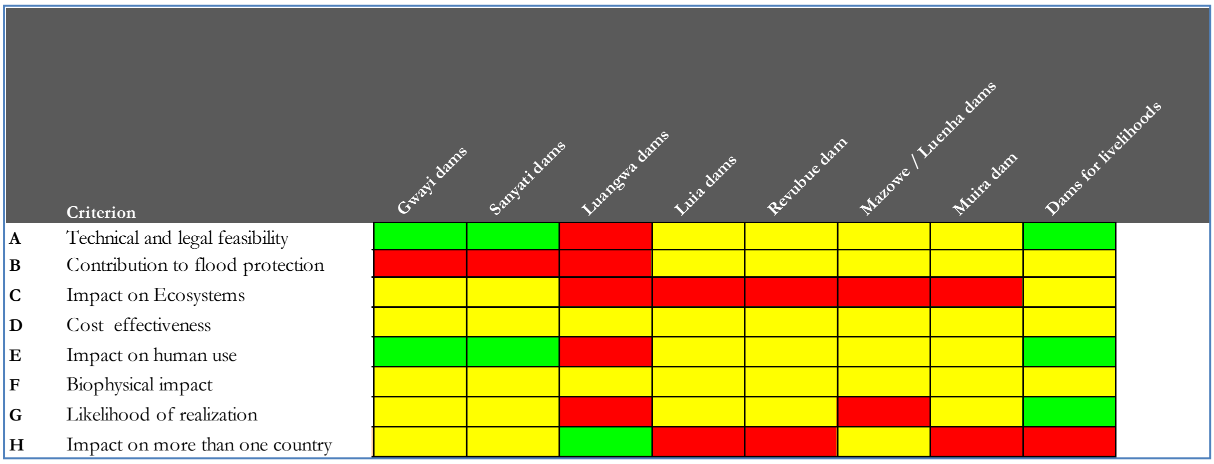


Figure 4.5 Assessment dams on tributaries (see Fig. 1.2 for legend)

Technical and legal feasibility

The dam sites identified in Zimbabwe on the Gwayi and Sanyati are considered physical feasible dam sites by the dam engineers of ZINWA. The Shangani-Gwayi dam has undergone a feasibility study as far back as 1992.

For dam sites identified in Zambia on the Luangwa it is pointed out that the location in nature parks may be a legal (and of course environmental) constraint.

For al dam sites identified in this study in Zambia (Luangwa) and Mozambique (Luia, Revubué, Muíra), these are suitable dam sites, judging from topography and location in the basin and type of geology expected. Physical and legal feasibility is not further studied.

Contribution to flood protection

For the Sanyati and Gwayi, the dams can contribute to diminished peak flows into Kariba. The peak flows of these rivers have a shorter forecasting time than the flows coming from Victoria Falls via the upstream wetlands. The maximum observed monthly flow of the Gwayi is 722 Mm3/month while the maximum observed peak flow is 894 m^3/s. The maximum observed monthly flow of the Sanyati is 988 Mm3/month while the maximum observed peak flow is 3470 m^3/s. Therefore, building the Gwayi Shangani and Kudu dam can have a significant impact on the inflows to Kariba coming from these tributaries.

To withhold water in the Gwayi Shangani and Kudu dam will have limited effect on Kariba reservoir flood outflows. If all dams listed would be built (2500 Mm^3) and the full live storage capacity could be used for flood attenuation, this would make a (temporary) difference of about 50 cm on the 5400 km^2 large Kariba reservoir. Maximum annual monthly flow totals into Lake Kariba (Vic Falls plus tributaries) are on average 7500 Mm^3/month (April), with peak months (1:50 or so) of in between 21000 Mm^3/month (April) to 25000 Mm^3/month (March). If full live storage capacity would be used, this could delay the opening of spillways during floods by about maximum four days, in the extreme floods mentioned.

Dam sites identified in the Mozambique in the Luia and Revubué could contribute to considerable flood reduction, although the peak flows of the Luia and Revubué are small in comparison to the Zambezi flows. The average maximum monthly flow is more than 900 m^3/s for the Luia (2300 Mm^3/month) and more than 725 m^3/s (1750 Mm^3/month) for the Revubué in February (Beilfuss *et al.*, 2001). Average total monthly flows in the flood season are respectively 970 Mm^3/month for the Luia and 700 Mm^3/ for the Revubué (Beilfuss *et al.*, 2001). More recent discharge data were not available for this study. The data from 2001-2010 would reflect a wetter period when average monthly wet season discharges have been higher from these rivers—very high in some years like 2001.

The live storage capacity of all four dams identified on the Mazowe is 377 Mm^3. The report from Beilfuss *et al.* (2001) gives a mean monthly runoff of approx 450m^3/s for January and February, which is the annual peak of the mean monthly runoff. The total volume for these months is therefore 1 170 Mm^3/month for the downstream Luenha. Therefore the dam capacity is only a quarter of the maximum mean monthly runoff which is suggesting the dam capacity is rather limited for flood control.

Probably none of the dams to be developed on the possible dam sites will have flood control as a main purpose. Dams that are operated for hydropower or (irrigation) water supply purposes sometimes contribute to flood control, but this depends on whether the dams have storage reservoirs or are operated as run-of-river. Many dams that are operated to maintain water levels near full supply level for hydropower production have very limited value for flood storage, or can increase the severity of large floods in some cases.

Impact on ecosystems

From an environmental point of view 'living with the floods' is much more encouraged than trying to prevent floods, because of the various beneficial impacts of natural flooding of floodplains and wetlands. A combination of small dams and alternative measures to reduce flood damage is preferred over development of large dams or flood regulation by large dams.

The Luangwa and Lusemfwa sub-basins are important areas for national parks and game reserves. Developments in these areas are therefore strongly not recommended. The Luangwa has large population of many species and is a major location for many birds to spent the winter. It may be possible to reduce some of these areas, but this should not happen at all locations. At some point whole populations may collapse. Luangwa still has an important sediment regime that would be disrupted by dams. As with the Shire, these are the dams for which designs should include latest technology for flushing sediments. Luangwa is also vital as an unregulated inflow to the Zambezi River---it is as important as the runoff entering Kariba (each controls about the same amount of MAR). So, Luangwa is very important for environmental flows given that Zambezi is already fully regulated at Kariba, and the other major tributary Kafue is also regulated. The hydrographs of Luangwa clearly indicates its importance. Significant development of the Luangwa for hydropower (if possible) would reduce or eliminate the opportunity for meaningful environmental flows in the lower Zambezi. Luangwa also has many important protected areas, including two of the most important national parks in southern Africa and is a basin with huge biodiversity importance.

In the Sanyati it is known that the migratory tiger fish spawns. The Kudu dam would stop fish migration along that part of the river with unknown impacts on the overall survival of the species in that river.

Dams on the Luia, the Muira and the Luenha Rivers will block sediment inflows into the Zambezi.

Cost effectiveness

New dams on tributaries are in the context of the Zambezi River Basin very expensive if they are only used for flood control purposes. The dams only become viable from the point of view of hydropower generation, irrigation, or urban water supply. For example, ZESCO will not give priority to dams on the Luangwa on the basis of power generation only, as unit production costs for power will be quite expensive. The costs of keeping the water level low for flood control purposes further renders the dams less viable.

Impact on human use

The main purpose of most dams is not flood control, but another water management objective:

- The Gwayi-Shangani dam has as a main purpose the water supply to Bulawayo;
- The Kudu dam is designed for irrigation water supply;
- The dams on the Luangwa may have negative economic and environmental impact, because of the flooding of nature parks. The dams can contribute to hydropower generation on location and in Cahora Bassa;
- The dam sites identified on the Luia and Revubué are identified to cover as much flood control as possible, but there is a need for irrigation water as well. Optimizing irrigation could require other dam sites and smaller dams;
- The dams on the Mazowe are for irrigation purposes. If there is need for irrigation dams on the Luenha is unknown; and
- The Muíra dam may flood a settlement and therefore not be viable.

Biophysical impact

As is explained in Appendix D, the decrease in greenhouse gas emissions thanks to hydropower generation is currently under discussion. In the case of dams for which hydropower generation is a major purpose, it will have to be recalled that due to the larger the surface area of the reservoir, there will be a hightened release of greenhouse gases than in a natural river. However, this needs to be compared to greenhouse gass releases of fossil fuels

Likelihood of realization

Dam development on tributaries in Zambia is heavily dependent of private developers (interview DWA Zambia, 14 June 2010), since the Zambian government is not giving them high priority.

Dam development on tributaries in Mozambique, will be supported by national policies for an agricultural ‘revolution’ (interview ARA Zambeze, 28 April 2010), with some consideration to environmental issues.

New dam development in Zimbabwe is not expected in the short term as existing dams are currently under-utilised and priorities in water infrastructure of the Government of Zimbabwe are more focus on drinking water supply and sanitation.

Feasibility will also depend on whether capital is available for investing in new dam sites. Most sites that will be used for rural development will probably not attract private capital for the full amount. Dam development is not sufficient for rural development; and additional infrastructure and institutional support will be required (see for Pungwe River Basin, SSI/SEED, 2010).

As is explained in Appendix D, the Clean Development Mechanism can only be used as an additional source of financing for hydropower reservoirs, if it can be sufficiently demonstrated that the new reservoir decreases the amount of greenhouse gas emissions and that without financial support from the Clean Development Mechanism the project would not be feasible.

Impact on more than one country

Dams on the Luangwa for flood control purposes would be built in Zambia, but mainly serve Mozambique.

Dams on the Mazowe would contribute to flood protection in Mozambique, but this is limited because of limited storage capacities.

4.5 Conclusions and recommendations

Stakeholders in Zimbabwe, Zambia and Mozambique indicated that new dams in their own country for flood control purposes only have no priority. In Zambia and Mozambique in particular, the usefulness of dams for irrigation purposes is emphasized.

The identified 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 making floods more predictable. A considerable number of dams need to be developed, to have a significant impact.

From a technical perspective, several dam sites were identified that could contribute to flood protection. In Zimbabwe, there is a list of technically suitable dam sites available which could be developed. Of these dams, the Gwayi-Shangani dam (635 Mm^3) and the Kudu dam (1550 Mm^3) on the Sanyati can have some impact. Technically suitable dam sites have been found on the Luia and the Revubué. However, it is pointed out that to develop dams which will contribute to economic activity, the technical suitability of a dam site is less of a determining factor, and socio-economic, institutional, financial, political and environmental considerations often outweigh physical site advantages.

From an environmental viewpoint the identified dam sites on the Luangwa and Lusemfwa are strongly not recommended. Dam sites on the Sanyati (Kudu) will affect spawn of Tiger fish. For dam sites of tributaries downstream of Cahora Bassa the impact on sediment is of main importance.

5 Investments in Cahora Bassa reservoir

5.1 Introduction to the investments

There are plans for an extension of Cahora Bassa North Bank, as an extension of the existing hydropower station. This new power station is not intended for continuous power generation, but to be used to generate extra power during peak demands, which are a better economic and financial value and help to reduce the stresses on the system during these demands.

As part of the development, an additional spillway is deemed necessary. The additional hydropower generation requires the storage to be maintained at a higher level than at present in order to secure continuous supply of water to the turbines at an adequate head (interview HCB, 29 April 2010). The current flood rule curve required lowering the lake before the high-flow period. The designed flat flood rule curve will be at a constant level of 326 m.a.s.l., while the current flood rule cure is between 320 and 329 m.a.s.l., dependent on the season. This flat rule curve will reduce storage capacity required for dam protection during floods which the additional spillway will take care of. The additional spillway thus makes it possible to increase hydropower production. However, it will also impact downstream flood flows.

5.2 Situation assessment: stakeholder views

HCB has strongly recommended that strong conclusions on the extra spillway be left for determination by studies that are currently in progress for the final evaluation on the extension of Cahora Bassa North Bank. This chapter was therefore based on available literature up to 2003 and did not have the benefit of results from the current studies. Thus, the proposals made here will need to be reevaluated in the light of information and data currently under production.

5.3 Description of investment

In Phase 1 of the feasibility study for the North-bank Extension, an additional bottom spillway was designed for Cahora Bassa, which had a design discharge of 3,600 m^3/s. During phase 2 of this feasibility study, it was decided not to pursue the additional spillway up to a feasibility study level, but rather to make a preliminary design, adjusting it to a discharge of 5,000 m^3/s. This is about 20% of the inflow design flood of 23,400 m^3/s and is in addition to the existing spillway. (Li-EDF-KP, 2001).

An overview provided by HCB mentioned that an update of the feasibility study for the Cahora Bassa North Bank Power Station was conducted by Hidrotécnica Portuguesa with a final report produced in April 2002. In a paper by Salvador Fernandes *et al.* (2003) results of the study were described, for three design capacities: 2200 m^3/s, 3600 m^3/s and 4400 m^3/s. This study showed that a design capacity of 2200 m^3/s was economically most beneficial. However, this discharge capacity is insufficient to accommodate the design flood and a Design Flood Rule Curve would still be required.

The different designs are presented in Table 5.1.

Table 5.1: Different design options described by Fernandes et al. (2003) and Li-EDF-KP (2001)

Additional discharge capacity	**Description of investment**
2200 m^3/s	Tunnel with a 15 m diameter horseshoe cross-section, with an entrance structure and an outlet in the form of a ski-jump structure controlled by two segment gates, with two protection flat gates for maintenance works on the main gates.
3600 m^3/s	Two tunnels of 13.6 m^3/s and similar design as the design for 2200 m^3/s; second tunnel starts some 80 m upstream.
4400 m^3/s	Tunnel with a 30 m diameter and similar design as the design for 2200 m^3/s.
5000 m^3/s	Two pressure concrete tunnels of internal diameter 15 m (length 285 and 375 m). Downstream of gate chambers two free-flow concrete lined tunnels (length 295 m). Entrance at 285 m.a.s.l.

It is argued by Beilfuss (2001) that a minimum discharge capacity of 3600 m^3/s is necessary to apply the flat rule curve. The 3600 m^3/s extra spillway capacity (in addition to the current spillway) makes it possible to fully pass a 1:10,000 flood. According to Salvador Fernandes *et al.* (2003) ICOLD instructions for large dams such as Cahora Bassa with a similar downstream environment are to pass a 1:5,000 floods only. This can explain the smaller design capacity.

5.4 Decision stage of investments

A final decisive feasibility study is planned for 2010-2011.

5.5 Evaluation of the criteria in this study

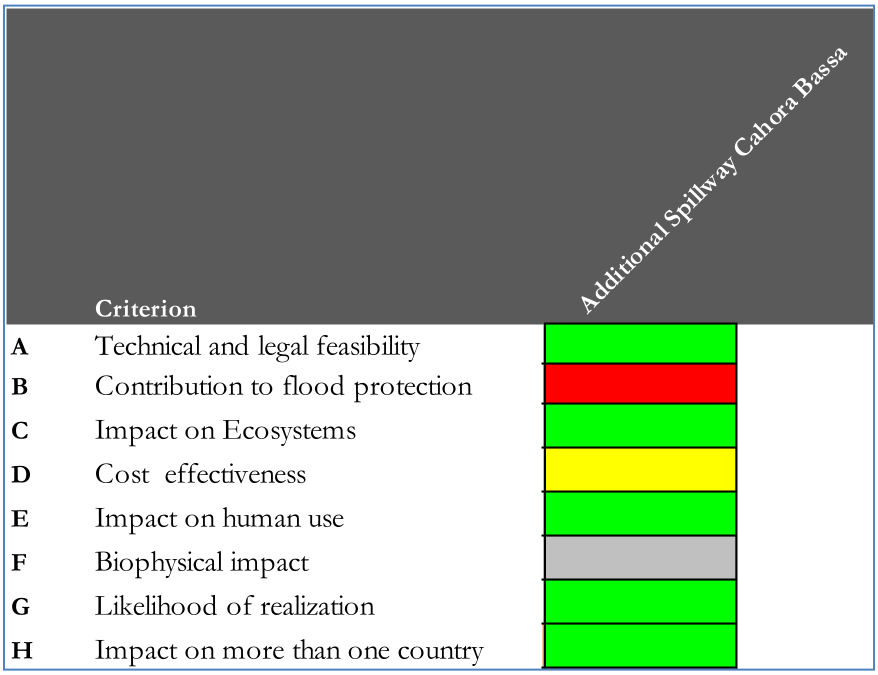


Figure 5.1: Assessment of extra spillway for Cahora Bassa (see Fig. 1.2 for legend)

Technical and legal feasibility

Positive; different previous feasibility studies already confirmed this.

Contribution to flood protection

Increased spillway capacity can increase the peak flood discharge downstream of the dam and thereby increase the flood risk in the floodplain. It is the purpose of the additional spillway to accommodate larger design floods to pass the dam during the flood season. In that sense the extra spillway decreases flood protection. If the design capacity is increased the risk management plan for the downstream area may have to be adjusted if the hydrological study indicates increased peak floods.

The impact of a flat rule curve and extra spillway was studied by Beilfuss (2001) using 91-year time series. The consequences on the probability of exceedence of certain high flows are shown in Figure 5.2. It is shown that the probabilities of exceedence are higher than in case of the current flood curve, but still better than for a situation without dams. The maximum monthly regulated inflow to Cahora Bassa during the simulated period (1907-1998) was about 13,700 m^3/s in February 1958. Operation according to the current flood rule curve reduced the maximum discharge by 24.5% to about 10,300 m^3/s. Maximum discharge following the Flat Rule Curve was reduced by 7.0% to 12,800 m^3/s.

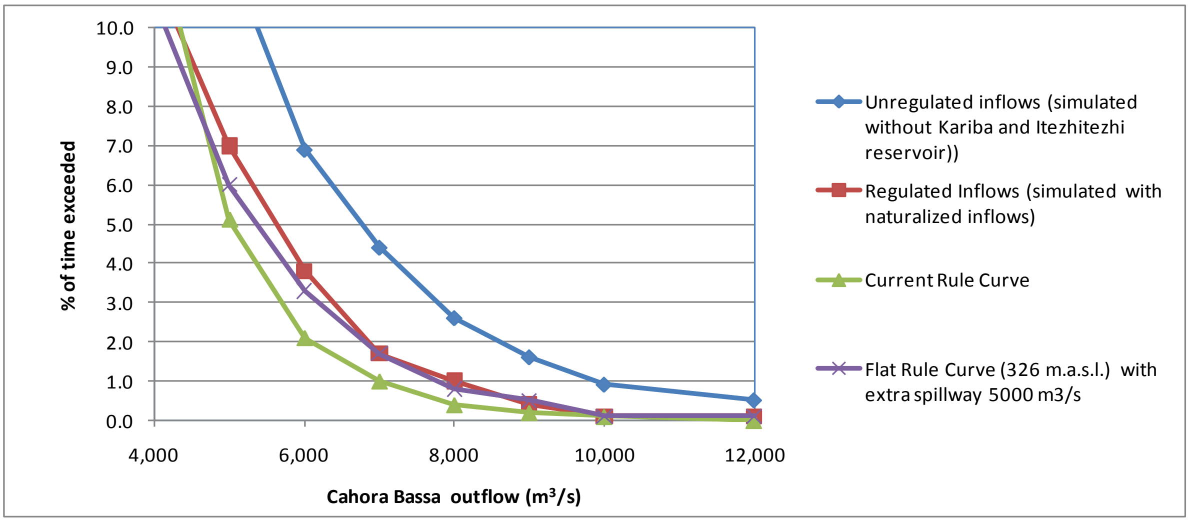


Figure 5.2: Different probabilities of exceedance for different high floods from Cahora Bassa (based on figures mentioned in Beilfuss, 2001)

It has been discussed in Annex 2 of this report that floods that cause damage in the lower Zambezi plains are not entirely attributable to releases from Cahora Bassa. The 326 m.a.s.l. for the flat rule curve is below the maximum level in the Cahora Bassa dam. By convention, reservoir elevations may temporarily exceed this threshold for short-duration, extreme flooding events (up to 329 m a.s.l.), but may not exceed this level during regular reservoir operations (personal communication, Beilfuss 2010). This still leaves some storage capacity for extreme floods.

Impact on ecosystems

The extra spillway makes it possible to maintain a flat flood rule curve. The flat flood rule curve prevents the drawdown of the water level from November to December, which is positive for the ecology in Cahora Bassa reservoir, and it gives more natural flows downstrwam. According to Beilfuss (2001) outflow during this period were greatly in excess of more natural inflows. The reservoir water level according to the current flood rule curve fluctuated by more than 8 m, which is not good for the ecology in the lake.

If the environment is prioritized, the extra spillway can also contribute to enable a freshet release in February of about 2900 m^3/s for the benefit of the environment (Li-EDF-KP, 2001), although this would considerably affect hydropower production, of 8% for the firm and average hydropower production, see Table 5.2.. Beilfuss (2001) researched the option without North Bank extension and with short prescribed floods of 14 days of 8,000 m^3/s in January using the flat rule curve. In comparison to a longer prescribed flood release for the environment, such a shorter more intensive release is said to have less negative impact on hydropower production. Such releases would be possible in 92% of the years of simulation (1907-1998) with only a 3.8% reduction in total power generation in comparison to the current situation (providing 94.5% firm power reliability at 1370 MW).

The design of the prescribed floods (freshets) needs further study, as different sources give different options (long constant February flood release of 3900 m^3/s or 14-day January flood release of 8000 m^3/s) and the timing of the flood releases with expected high floods from the tributaries can have a significant impact on the effect of the environmental floods and the peak releases that are necessary. To make such coordinated releases possible also needs a good flow forecasting system.

Cost effectiveness

Salvador Fernandes *et al.* (2003) computed economic indicators for the additional spillway capacities of 2200 m^3/s, 3600 m^3/s and 4400 m^3/s. Their computations assumed no freshet releases, an energy price of 0.02 €/KWh and an actualization rate of 8%. For a hydropower capacity of the North Bank of 3 * 415 MW (maximum capacity) the payback period, purely on the basis of energy generation, was 15 to 16 years for all configurations.

Additional flood protection and flow regulation (freshet) advantages, may not optimize hydropower production anymore, and therewith may increase the payback period, but the return on investment seems sufficient and considerably increases in comparison to no additional spillway (from about 7% to about 12%) (see also next criteria on hydrology used).

Impact on human use

For the UTIP feasibility study operating analysis were done comparing Cahora Bassa North Bank and Mphanda Nkuwa, with and without extra spill way (Li-EDF-KP, 2001). The results are summarized in Table 5.2, which shows that the spillway and also Cahora Bassa North have limited effect on the firm energy production and the average energy production. However, the main purpose of the North Bank Extension is to generate for peak power demands. The spillway as such does not seem to have much effects; its main purpose is to contribute to dam safety in the case a flat rule curve is used. Table 5.3 is based on the later study (Fernandes *et al.*, 2003), which does not consider freshet releases and produces more power and more benefit from an additional spillway. The difference in conclusion can (at least partly) be explained by the differences in hydrological time series used, in addition to the different assumptions on freshet releases. Where Li-EDF-KP used time series of available data of 1907-1997, Fernandes *et al.* generated stochastic time series to extend the time series as from 1931 up to 2071, without consideration of possible climate change effects and with the note that 1980 to 1998 was an extremely dry period, not repeated after 2001. Also, the underlying assumptions on freshet releases have considerable impact, as Beilfuss (2001) showed; curtailing freshet releases when there were water levels below 316 m.a.s.l. would considerably increase power production.

Table 5.2: Differences in hydropower production for different configurations of Cahora Bassa, with and without an additional spillway of 5000 m3/s and with or without freshet releases (on the basis of Li-EDF-KP, 2001)

	Cahora Bassa			Mphanda Nkuwa		
GWh/mth	Current	With SWECO FRC and additional spillway	With Flat rule curve and additional spillway	Current	With SWECO FRC and additional spillway	With Flat rule curve and additional spillway
Additional spillway capacity (m³/s)	**0**	**5000**	**5000**	**0**	**5000**	**5000**
Without Cahora Bassa North						
Firm energy production (95%)						
Without freshet releases	1100			630		
With freshet releases	979	1012	1012	586	586	580
Average energy production						
Without freshet releases	1200			730		
With freshet releases	1068	1104	1104	679	679	672
With Cahora Bassa North (884 MW)						
Firm energy production (95%)						
Without freshet releases	1120			660		
With freshet releases	941	963	974	607	601	601
Average energy production						
Without freshet releases	1380			770		
With freshet releases	1159	1187	1201	708	701	701

Table 5.3: Differences in hydropower production for different configurations of Cahora Bassa, with and without additional spillways of different sizes (on the basis of Salvador Fernandes et al., 2003)

GWh/mth average energy production	**Current**		**Extra spillway**	
Additional spillway capacity (m³/s)	**0**	**2200**	**3600**	**4400**
Without Cahora Bassa North (5 * 415 MW)				
Without freshet releases	1239	1307	1314	1319
With Cahora Bassa North				
Without freshet releases and extra capacity CBN:				
2 * 415 MW	1342	1462	1485	1484
2 * 305 MW	1317	1425	1444	1443
3 * 415 MW	1388	1526	1554	1555
3 * 305 MW	1351	1476	1500	1500

Likelihood of realization

The investments in a new feasibility study and the opinions ventilated by HCB (interview April 2010) and SAPP (interview April 2010) indicate that Cahora Bassa North, including the new spillway, are considered feasible options for realization.

Impact on more than one country

Most (upto 1300 MW) of the hydropower from HCB is currently sold to South Africa's ESKOM and an additional part to Zimbabwe (upto 200 MW) of its maximum of 2300 MW capacity. Although Malawi and Tanzania are not yet connected to obtain hydropower from Cahora Bassa, the investment in Cahora Bassa North is said to make it possible to have peak power available for these countries. However, at the moment only 13% of the population in Mozambique is served with electricity. (Fauvet, 2008)

5.6 Conclusions and recommendations

The production of final conclusions and recommendations will have to await the results of on-going studies commissioned by HCB which are due for completion in 2011.

The benefits of the spillway in combination with the flat rule curve are for power generation and the environment. Both for the ecosystem of Cahora Bassa reservoir as for the downstream ecosystem, the adjusted flat rule curve will be beneficial.

Flooding can increase downstream, but the impact depends on the operating of the dam and the coordination with floods at tributaries from downstream. This flooding impact will need attention when evaluating different options of spillway and operating rule curve. Coordination with tributaries downstream require a good flow forecasting system. If the design capacity is increased the risk management plan for the downstream area may have to be adjusted if the hydrological study indicates increased peak floods.

6 Flood Risk Zoning

6.1 Introduction to the investments

Flood risk zoning is the delineating on maps or in the floodplain itself of areas with different flood risks.

The investment of clearly mapping areas that are floodprone and using these zones for different purposes, is not an infrastructural investment like the other investment options in this report. Flood risk zoning is nevertheless evaluated in this report, because it is an alternative to other flood protection or dam management investments, and because the implementation requires research and institutional investments.

The purposes of risk zoning, which will be further explained in this chapter, are 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: zoning to use during emerging flood events to set priorities.

This chapter is supported by Annex E Insurances, Annex F Case study Chobe Plains and Annex G Case study downstream of Caia.

6.2 Situation assessment: stakeholders views

Zambia
The Department of Water Affairs (interview June 2010) indicated that regulations do exist for flood zoning. Permanent structures are not allowed in flood zones. However, the experience is that it is very difficult to enforce these regulations. Of the 72 districts in Zambia, there are 38 prone to flooding.

ZESCO (interview June 2010) indicated that there is no risk zoning downstream of Itezhi-tezhi dam, although regulations in terms of permanent structures are adhered to. Campsites are mentioned as vulnerable. Together with WWF, ZESCO is in the process of obtaining better maps for flood risks which will inform flood risk zoning. ZESCO is planning to have a more structured process for informing stakeholders downstream of Itezhi-tezhi dam.

Zimbabwe
There is a law that prevents cropping and livelihoods close to the river bed. This law is not monitored under the Ministry of Water but under the Ministry of Environment, as its purpose was mainly river protection rather than flood protection. A distance to the river bed of about 30 m is prohibited for activities.

In 2004, (Madamombe, 2004) it was announced that the Civil Protection Act [Chapter 20:06] for disaster management would be revised to become the Emergency Preparedness and Disaster Management Act. The revisions would give more emphasis on localized decision making with the local authority being expected to take a leading role in preparedness and response with the support of the provincial and national government. It is unclear to the Consultant if this planned revision has been finalized. This would probably also give a lot of responsibility in flood risk zoning to local authorities.

Zimbabwe / Zambia around Kariba
The Zambezi River Authority has marked all risk zones upstream and downstream of Kariba Dam; zones for seasonal cropping only, zones for multi-annual cropping but no permanent structures and zones where no permanent structures are allowed. To what extent the local population respects this zoning is unknown to the Consultant.

Namibia and Botswana
In the Chobe Swamps area within Namibia and Botswana, floods are influenced by water levels in the main Zambezi River. In the case study area of the Chobe Swamps (Appendix F), permanent structures appear to be mainly built on naturally higher ground. The Disaster Risk Management unit of Namibia pointed out (questionnaire this study) that the lead time currently given by the flood alert system is sufficient for effective reaction, but the effectiveness is heavily dependent on the attitude and risk perception of the vulnerable communities. Sensitization work is expected to improve this situation.

Mozambique
In Mozambique, cultivation within 50 m of the normal bank of a river and 250 m of the normal bank of a dam is prohibited. However, this regulation is not being enforced. The reason for this is that the different government agencies involved have other priorities (interview ARA Zambeze, April 2010).

ARA Zambeze indicated that warning levels and physical and visible pegs may be useful and that currently emergency agencies are warned by alerting them to which areas are likely to be flooded. (interview April 2010 and follow up August 2010).

ARA Zambeze mentioned the need to improve communication between dam operators and water users on flood risks. For example, there is the perception of persons downstream that whenever there are floods, these would have been caused by the opening of flood gates at Cahora Bassa. Meanwhile there is a significant contribution to this flooding by tributaries downstream of the dam. Beilfuss *et al.* (2002) confirmed that downstream stakeholders do not necessarily see that things can be done about the size of the floods, but the sudden rise of the water levels is the issue, which is associated with the sudden opening of flood gates. If the opening of flood gates could be done in stages, the corresponding staged rise in water levels could provide some warning.

In an article entitled “Co-existing With Floods” by Marshall Patsanza (22 April 2010, IPS), various water decision makers in Mozambique were interviewed. This article indicated several views on flood risk zoning. These included the idea that floods will always be there and that instead of fighting against floods, Mozambique could adapt its approach to try living with floods and focusing on the benefits they provide (fertile soils and fishery opportunities). To ensure that people who have settled on floodplains in river basins are aware of the pros and cons of their location, the country has set up disaster management committees at local level to provide education to local people on how to protect themselves while taking advantage of the benefits. This includes innovative approaches such as encouraging villagers to have two homes - one in the floodplain near their agricultural land or their fishing post at the river's edge, and another settlement on higher ground above the high water mark. In other areas where flooding is not as severe, inhabitants are encouraged to build elevated houses which will allow water to flow beneath them without being swept away.

Obstacles to effective flood risk zoning that are recognized by those interviewed include:

- cultural reasons and beliefs leading to people staying in flood prone areas;
- most settlers view their livestock as a symbol of economic wealth, and they do not move to higher ground during floods because their animals are not be able climb the steep slopes; and
- inhabitants who have lived in flood plains and have survived previous floods consider themselves invincible and therefore not inclined to react to warning systems.

These are practical considerations from persons in the Water and/or Disaster Management Sectors in Mozambique. In addition, Mozambique is continuing efforts to resettle previous flood victims to less flood prone areas with funding from donors such as GTZ (INGC website 2010). Since 2001 temporary refuge areas for floods have been converted to more permanent resettlement areas (Mozambican government *et al.*, 2007).

Malawi
In Malawi there are bylaws that prevent farming within 50 m of a river, but these are difficult to implement (interview MIWD, August 2010).

The Ministry of Irrigation and Water Development (Interview August 2010) explained that attempts to move people out of flood prone areas would have little or no chance of success as these are highly preferred areas for settlement for obvious reasons related to the high agricultural potential of floodplain areas. It could be preferable to improve safety and assist people living within or close to floodplains. There is conflict between the objectives of hunger and poverty eradication versus environment and flood management. The flood plains are fertile and are less drought prone; which contrasts with upland settlement areas which lack these basic livelihood necessities. It was mentioned that the strategies of the government in this regard were to promote sustainable livelihoods close to the river but away from the high risk flood prone areas. However, this may not provide a total solution from a flood protection point of view. Current practice shows that after June of every year, when there is no risk of flooding, people build huts in the floodplains and start tilling. This cultivation of the floodplains also leads to serious soil erosion in the flood season.

6.3 Description of investments

Figure 6.2 explains the concept of flood risk zoning, with further explanation in the text in this section. The concept is illustrated by the Case Studies in Chobe plains and downstream of Caia (Annex F and G). There are many different ways of Flood Risk Zoning. Box 6-1 illustrates how the necessary mapping is done in other countries.

6.3.1 Box 6-1 Different ways of flood risk mapping

Different ways of flood risk mapping for flood risk zoning can be applied. An important institute that deals among others with flood risk and insurance issues in developing countries is ICHARM (International Centre for Water Hazard and Risk Management), that operates under the auspices of UNESCO and has its main office in Japan. Recently a project has started that aims at providing technical assistance with flood issues to India, Bangladesh, Indonesia and the Lower Mekong region. They use the map descriptions:

A – Historical flood map
B – Flood extent map
C – Flood depth map
D – Flood danger map
E – Qualitative risk map
F – Quantitative risk (damage) map

In Asia especially, flood risk mapping is currently being introduced in many countries. Apart from the ICHARM initiatives, there is hardly any exchange of methodologies and there are no examples of successful transboundary flood risk mapping. In the United States most areas have classified flood risks. In the European Union an attempt is made to oblige countries to put in place flood risk management and methods may differ between different countries, although in transboundary river basins some coordination is needed (See Appendix E). In Asia, the dissemination of flood risk maps is recognized to be problematic due to a lack of sufficient access to the internet of the general public in the villages along the main rivers.

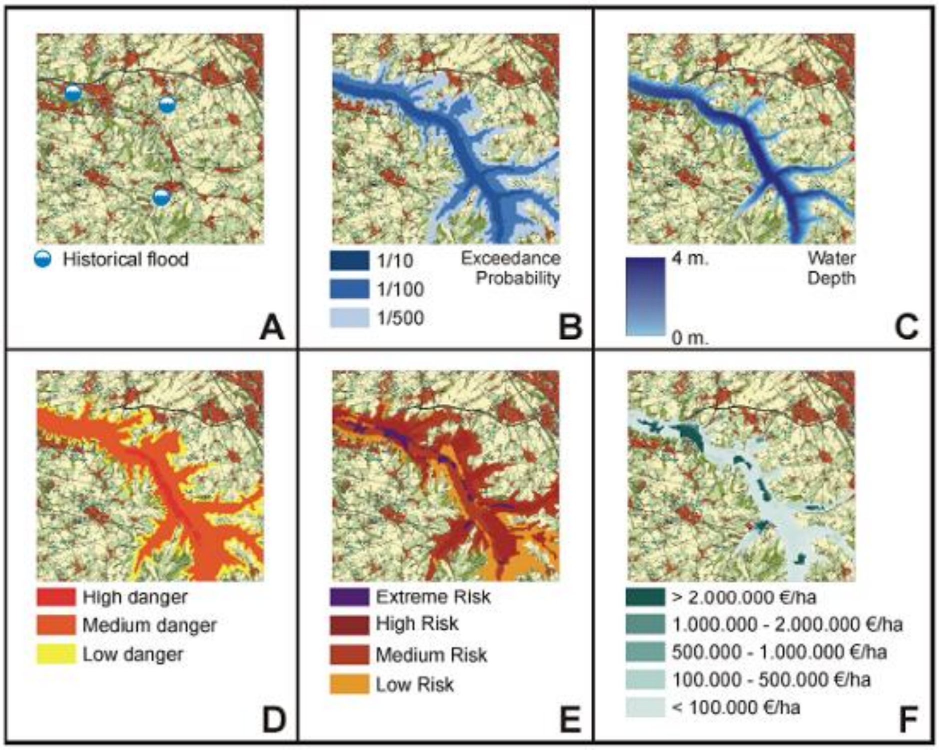


Figure 6.1: Different types of flood maps for an imaginary river basin (Moel, de, et al., 2009)

Risk Assessment

Risks are dependent on the flood hazard and on the vulnerability of the area being flooded. The 'risks' and 'vulnerability' are defined in different ways in different studies, but in general; the higher the vulnerability and the higher the flood hazard potential, the higher the risk.

The flood hazard potential is dependent on the extent of the flooded area, the frequency of the flooding, the depth of flooding, the lead time (time to evacuate or take measures), the duration of the flooding, the velocity of the water, and the presence of hazardous industries. This all together determines how 'dangerous' the flood is. In the Zambezi River Basin, there are extensive areas that tend to be flooded on an annual basis, making the awareness high without flood risk zoning being applied. However, the long drier period experienced in the 1980s and the beginning of the 1990s made people less aware of the flood hazard. In the areas downstream of the major dams, the sudden rise of water levels is experienced as a major problem.

Annex 2 describes the impact historic floods have had on livelihoods, infrastructure and wildlife and therewith gives an impression of the vulnerability in the Zambezi River Basin. Vulnerability Assessments for flood risk zoning would need very specific areal descriptions of flood vulnerability. The International Federation of Red Cross has carried out some vulnerability assessments for villages in the Zambezi River Basin (interview September 2010).

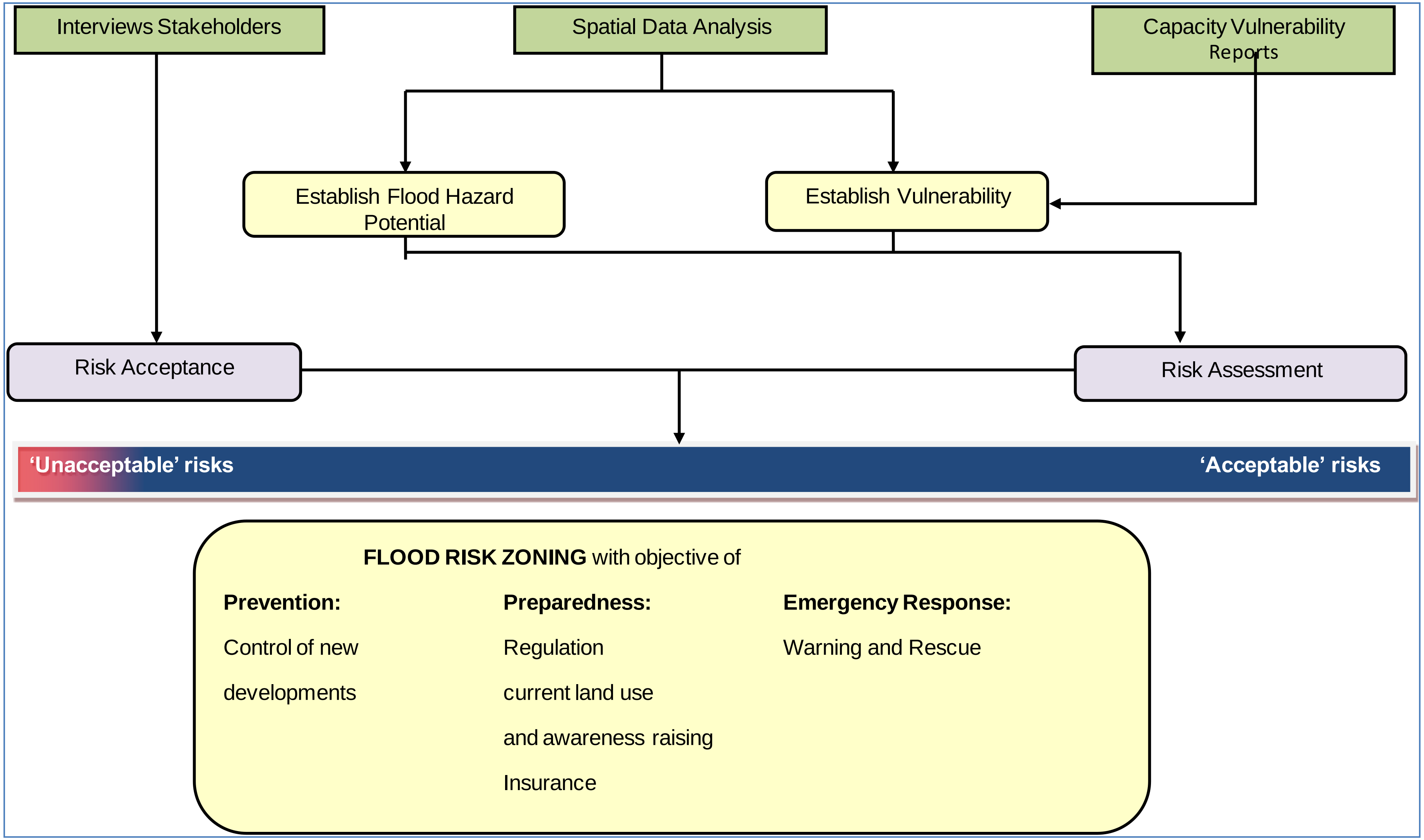


Figure 6.2: Concepts of flood risk zoning and steps to attain it as used in this study

Risk acceptance

The extent and purpose for which risk zones should be established also depends on the acceptance of the risks. People might prefer to live with the risk, knowing that floods also provide benefits. Governments may accept risks for people and may not see a priority for flood risk zoning, as is evident from the situation analysis from opinions expressed in Malawi and Mozambique. The encroaching of population into the floodplains in Mozambique, continuing after the large floods at the end of the nineties and beginning of this millennium, shows that some people do not consider themselves to have other viable options. In terms of acceptance, only social surveys and stakeholder interviews can show the need for risk zoning. From the stakeholder perspectives in the section above, the use of flood risk zoning for regulation of new settlements and land use is considered difficult to implement.

Flood risk zoning for regulation of new settlements

A map of maximum flood extents can be useful and is a limited investment. Accurate probabilities of flooding are not currently possible, except that areas with flood frequencies higher than 1:10 years are normally locally known. Digital elevation maps and hydraulic models are generally not available, but local knowledge of historical flood levels exists and can be obtained through oral surveys.

Flood risk zoning for current land use and awareness raising

The example of pegging flood zones around Kariba, where a distinction is made of zones for multi-year crops and seasonally crops, can be established in different areas of the Zambezi River Basin. It needs to be noted that people have already adapted such approaches without any official flood risk zoning. Figure 7.3 shows how historical water levels are evident in the Chobe region. Flood referencing is a way of involving local communities in marking historical floods and predicting oncoming floods. In Mozambique, the locally established Flood Risk Committees (See example in Fig. 7.3) already provide the institutional set up necessary for such an approach.

Figure 6.3: Caprivi strip October 2010 photos show local evidence of past floods, already marking the flood levels.

Flood risk zoning for insurances

Flood risk zoning for insurances requires a high level of accuracy of the frequency of floods and the flood levels. Insurances would like to estimate their risk of insurance on the basis of the zoning, which will also determine the premium to be paid by the insured. This is further explained in Appendix E.

Flood risk zoning for rescue and warning

Maps are important in disaster management planning and need to be updated during disasters. UNOSAT in this respect delivered on the spot mapping during the floods of 2005 to 2009, using satellite imagery of real-time flood extents. Additional information on refuge routes, hospitals, higher areas could have helped to prioritize and plan rescue operations. If this is combined with flood referencing, where persons at community level are trained to forecast flooding impacts on the basis of gauge readings and information from a flood forecasting centre (ADPC, 2005), this could contribute to decreasing vulnerability. In Mozambique already committees at the local level are being trained for this purpose (Figure 6.4 and 6.5).

Figure 6.4: Example of Local Risk Committee in Mozambique, established by INGC (Malo, 2009)

Figure 6.5: Participatory mapping of flood risks by INGC and UN Habitat in Mozambique (Cani, 2009/2010)

6.4 Decision stage of investments

Investigations carried out as part of this study have shown that, apart from some ad hoc activities on mapping of historical floods (UNOSAT, UN Habitat), no flood hazard and vulnerability mapping has taken place along the Zambezi River or its major tributaries.

Some flood risk zoning has been implemented along sections of the Zambezi river, upstream and downstream of Kariba dam. In Mozambique resettlement is being implemented for some areas in accordance with flood risk. Also, in Mozambique, local risk committees have been established to offer an effective institutional set up for flood referencing, for adjusting current land use and for rescue and warning.

An the scale of the Zambezi River Basin there is not yet a regional initiative, although FEWS-NET offers some insights region wide, mainly focused on warning and food security.

A river basin or regional approach like that applied in the Mekong River Basin or in the European Union (See Box 6 - 2) has not yet started.

6.4.1 Box 6-2 Example of the European Union Flood Directive

The EU Flood Directive is a guideline for the nationwide implementation of flood zone mapping and the development of flood risk management plans.

The process starts with a preliminary flood risk assessment in which the various countries make an overview of the flood risk in terms of sources of flooding and the potential areas under risk of flooding. Once this is done and reported to the EU, two types of flood maps are produced:

1. flood hazard maps
2. flood risk maps

The flood hazard maps identify areas of "medium likely hood of flooding" and "extreme events" and the depth of flooding that can be expected. No precise values are given for the return periods, although 1 in 100 years is suggested, and only three probabilities of flooding are distinguished: high, medium and low. The flood risk maps are made for those areas that are identified in step 1 and indicate e.g. the number of inhabitants at risk, the economic activity and the environment damage potential.

Subsequently, for the same zones, flood risk management plans need to be drawn. These plans need to indicate the potential measures that will limit the potential of flooding and the associated flood risk. The plans focus on prevention of flooding and damage, e.g. through rules that avoid building in flood-prone areas. It is explicitly mentioned that climate change should be taken into account in the process. The whole cycle of flood risk mapping and development of flood risk management plans need to be renewed every six years.

An important aspect of the EU directive is the approach in international (transboundary) rivers. For those river basins, the countries sharing the river need to coordinate their efforts and, very importantly, no measures shall be proposed that may negatively influence the flood risk in a downstream country.

Although in general application of the EU Flood Directive is indicated as being expensive, only for Switzerland is an estimate available and that is in the order of Euro 2,000 / km^2 (UNECE, 2009) which is very high in the context of the Zambezi River Basin.

Evidently the level of data availability in most of EU countries is much higher than along the Zambezi River. The time frame for implementation would have to be much more lenient than is now the case for European countries (six years). The actual process of coordinating a transboundary mapping process and the subsequent design of a basin-wide flood risk management plan will need much more effort than the mapping process itself. An excellent guideline for the process of implementation of transboundary flood risk management is available in UNECE, 2009.

6.5 Evaluation of the criteria of this study

	Criterion	Flood risk zoning for rules for new settlements	Flood risk zoning for current land use and awareness raising	Flood risk zoning for insurances	Flood risk zoning for rescue and warning
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				

Figure 6.6: Assessment Flood Risk Zoning

Technical and legal feasibility

The technical feasibility depends also on the data availability in the Zambezi region. Lack of data and frequencies of flooding limit the possibilities. The tables in Appendices explain the limitations.

For flood risk assessment (and for flood forecasting) digital elevation data are important and the flood prone areas are generally the flattest areas in the basin. Remote Sensing techniques are improving and decreasing in cost, but for good digital elevation data considerable ground truthing is still necessary. Techniques for this (using GPS receivers) have also improved significantly in recent years.

Vulnerability assessments can be improved with use of better data on population (number, poverty, livelihood), land use (annual cropping / multi-year cropping), infrastructure (condition of roads, culverts, bridges, water and sanitation, available refuge areas and clinics and hospitals, accessibility / possibilities to escape, communication options). For particular flood events those data have been collated, mainly for the Lower Zambezi. Population is the only statistic that is available in most countries, but censuses only take place once in ten years (last census in Namibia- 2001, Zambia -2000, Zimbabwe -2002, Malawi - 2008, Mozambique - 2007). Vulnerability capacity assessments have been done for about ten individual villages by the IFRC, which give an indication of livelihoods and further vulnerabilities.

For insurance purposes with respect to the Zambezi River Basin, the problems that are being met by re-insurance companies in developing and developed countries (See Appendix E) show that the introduction of a flood insurance program for the Zambezi River at a basin-wide scale would be a major undertaking that lacks for the time being the essential elements such as a comprehensive set of flood hazard maps and preferably more advanced types of maps. The frequency of floods may also be too high for insurance purposes. Legally, flood insurance may be difficult for property on communally owned land.

Contribution to flood protection

It needs to be assessed at a local level to what extent people are already aware of flood hazard potential whether they have and adjusted their settlement and land use activities accordingly or whether they are just accepting the risk. Only then, applied specifically for each area, does it make sense to invest in flood risk zoning to contribute to flood protection.

From the rescue and warning side, the need for flood risk maps requires further investigation through disaster management centers. Their immediate need seems to be improved forecasting rather than flood risk zoning. A report on the flood of 2007 (Mozambican government *et al.*, 2007) shows how organized rescue and warning procedures already are and the additional value of flood risk zoning should therefore be evaluated.

Reports on the flood of 2007 (Mozambican Government, 2007) also indicate that people from areas outside flood risk zones seek to benefit from the services and assistance provided to people displaced by flooding. Mapping can contribute by benefiting only those that are really affected, although it still may be difficult to identify where displaced people come from.

An investment could be done in coordinating different flood risk initiatives as illustrated in the Case Studies (Appendices F and G). The greatest value for the Zambezi region in coordinated flood risk mapping seems to be mostly in rescue and warning for international relief agencies to have similar information in the different countries. There is also value in coupling the mapping techniques used with a basin-wide flow forecasting model and additionally in informing downstream and upstream countries in ways that are familiar to these countries.

Impact on ecosystems

Preventing or decreasing human activity in the floodplain, based on flood risk zoning for new settlements and current land use, will be beneficial for the river ecosystem because anything that allows natural floods, and natural flooding of floodplains, to continue will enhance ecosystem functioning. There will be benefits not only to the aquatic fauna and flora, but also to the physical and chemical health of the system, as floodplains recharge groundwater, cleanse polluted water and store floods for slow release through the dry season. Offstream ecosystem benefits can also include improved floodplain grazing lands, flood-recession agriculture (if controlled wisely) fish stocks, and higher numbers of wildlife, all of which benefit from naturally functioning floodplains.

The vulnerability of wildlife for floods, for the purpose of flood risk zoning, is difficult to evaluate. Chapter 5 in the recommendations for dam management explains that wildlife is on the one hand very dependent on flooding and on the other hand vulnerable, dependent on species and on circumstances. Rescue and warning for wildlife has been limited so far. In the extensive floods of 2001, almost 40% of the buffalos in the Zambezi Delta died, partly because most of the herd had withdrawn into a very wet area (to avoid landmines). Rescueing such herds seem to need real time knowledge of the location and not so much mapping flood risk zoning in advance.

Impact on human use

If flood risk zoning contributes to diminishing vulnerability of inhabitants, by timely warning or by modified settlements and land use, it will be beneficial. However, if flood risk zoning is stringently put in place it may prevent human activities which are necessary for livelihoods to survive in spite of the flood risk. Caution should therefore be made to assess the carrying capacity of local livelihoods. In Mozambique, resettlement initiatives take place in which possible flood victims are offered material for resettling on safe ground on a voluntary basis.

Cost effectiveness

Operational flood mapping during flood events helps to improve flood forecasts (real time calibration), helps warning and rescue (real time information) and helps future flood risk zoning (mapping historical floods). In that sense the monitoring of floods during flood events is a cost effective investment. Ground truthing and Remote Sensing (by Radar images) should then be planned to happen simultaneously. The Department of Water Affairs of Namibia already intends working in that way during new flood events, mobilizing their team in Katima Mulilo. The Zimbabwean government used to have an operational team that measured water levels during flood events, but this team is currently dysfunctional. Such ground truthing teams also need to assess flows during floods, as most flow gauges are not calibrated or do not have the capacity to measure flood flows.

The challenge is to introduce flood risk zoning in a way that is cost effective for flood protection, staging it from priority areas and simple historical flood extent mapping to more elaborate flood risk zoning. Implementing a system like the EU Flood Directive, is in the EU generally indicated as being expensive. (For Switzerland an estimate is available, which is in the order of 2,000 €/km^2 (UNECE, 2009). For the Zambezi Region such a high order of costs would definitely not be a cost effective investment.

What can be learned from the EU Flood Directive (See Appendix E.2) is that the directive does not enforce any strict rules on which areas need to be included and for which.

Likelihood of realization

The Consultant considers that the present flood risk mapping activities that are underway in various countries aton different levels and scales are at a preliminary stage for implementation of basin-wide flood hazard and flood risk mapping. Inthe future, effort will need to be placed on establishing ZAMCOM as the coordinating agency for bringing together the many relevant international agencies and organizations in order tomove towards a basin-wide approach.

Impact on more than one country

If the initiative is implemented at a Zambezi River Basin scale, this would indeed benefit two or more countries. As is clear from the flow forecasting report of this study, information exchange between countries on floods is a major issue and if flood hazard mapping can contribute to improved forecasting as well as better information exchange, this will be beneficial. In the stakeholder interview with the Ministry of Irrigation and Water Development in Malawi (interview August 2010), it was clearly mentioned that more knowhow on flood risk in Mozambique flood risks would improve disaster management in the lower Shire basin. Another example is the Chobe River floodplains, where coordination between Namibia and Botswana is essential.

6.6 Conclusions and recommendations

Flood risk zoning for flood insurance is not a viable option in the Zambezi Region at present.

Flood risk zoning for regulation of new settlements and for regulation of current land use and raising of awareness only makes sense as an investment if further local research can show that such a system will be respected and that local inhabitants are not sufficiently aware of risks at present.

Flood risk zoning for warning and rescue is already taking place; flood mapping during floods had been done by UNOSAT for example. Flood Risk Vulnerability has been assessed for some villages by the International Federation for Red Cross. 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 Risk Zoning that benefit flood forecasting and involvement of international relief organisations during floods as well as the understanding between neighbouring countries. This coordination is therefore recommended.

Data availability in the region for flood risk zoning, limits the possibilities. A map of maximum flood extents can be useful and is a limited investment, but mapping flood frequencies is more difficult. The example of the flood risk zoning around Kariba, where a distinction is made of zones for multi-year crops and seasonal crops, can be established in different areas in the Zambezi river basin, but it needs to be noted that in many areas people may have already adapted such approaches without any official flood risk zoning.

The current developments in remote sensing will contribute significantly to improved and less costly flood risk zoning in the near future.

7 Structural Flood Protection

7.1 Introduction to the investments

Structural flood protection measures can 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. The type of investments that will be discussed in this chapter are dykes, elevated schools of public buildings, structural measures to divert flood waters.

7.2 Situation assessment

In general, little information could be found on existing flood protection measures in the Zambezi River basin.

There are some dykes near Marromeu and Luabo that were built in 1926 to protect the sugar estates in the Zambezi Delta. The dykes at Marromeu are maintained above the maximum observed flood level and prevent flooding of the Marromeu Municipality and the surrounding sugar production fields. The dykes at Luabo have not been maintained and are over-topped during large floods. There are also dykes associated with roads and railroads in the Zambezi Delta region that block the movement of floodwaters from the river to the floodplain.

There used to be dykes in the Kafue area in Zambia (interview Department of Water Affairs Zambia June 2010), built in the 1950s in Sanyanja. However, maintenance of these dykes was discontinued.

The different countries do not seem to place a high priority on structural flood protection measures. The Ministry of Water Affairs in Zambia (interview June, 2010) pointed out that investments in livelihoods (education, health, small dams) seem to be more cost effective than structural flood protection measures.

Current infrastructure investments rather concentrate on making roads and bridges less vulnerable to flooding and raising roads to make them useful during floods. In Zambia, Namibia and Mozambique it is confirmed that investments have taken place in recent years in this regard and have priority. An example is shown in Figure 7.1.

Figure 7.1: Recently improved roads and culverts in Caprivi strip (photo visit October 2010)

7.3 Description of possible investments

Dykes

Dykes (or levees) are the oldest and most frequently used type of flood control measure. Dykes form an embankment which protects land with elevations lower than the high-water surface level.

An indicative cost estimate for the construction of low dykes (<4m) based on cost of civil work in South Africa was made using the following assumptions:

- The dyke has a homogenous profile,
- Suitable material can be found within a 3 km distance from the dyke,
- Grassing is done by hydro-seeding.

The construction cost of dyke would range from 570,000 to 1.8 million USD per kilometre for a dyke height of between 2 and 4 m as shown in Table 7.1. It should be realized that inspection and maintenance costs are not included. These costs are considerable for dykes.

Table 7.1: Cost estimate of 1 km dyke in US$ (Based on SA Rands and conversion rate of 1 US$ is 7 SA Rand)

Height of dyke	2m	3m	4m
Clearing and grubbing	5,200	7,300	9,500
Tree cutting	3,300	4,700	6,000
Removing and stockpiling topsoil	15,000	22,000	28,200
Transport of material	71,000	145,000	244,000
Compaction soft material	442,000	897,000	1,508,000
Top-soiling	27,000	39,000	50,000
Grassing	6,300	9,300	12,400
Total Cost per km	**$ 569,800**	**$ 1,124,300**	**$ 1,858,100**

Elevated schools / public buildings

Elevated schools and public buildings have been built in Mozambique, in the Limpopo River Basin, see Figure 7.2 for an example. As a result, school conditions in normal times have improved considerably. School buildings are made 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. The Mozambican disaster management authority (INGC) with support of UN Habitat has been implementing these schools (Malo, 2010).

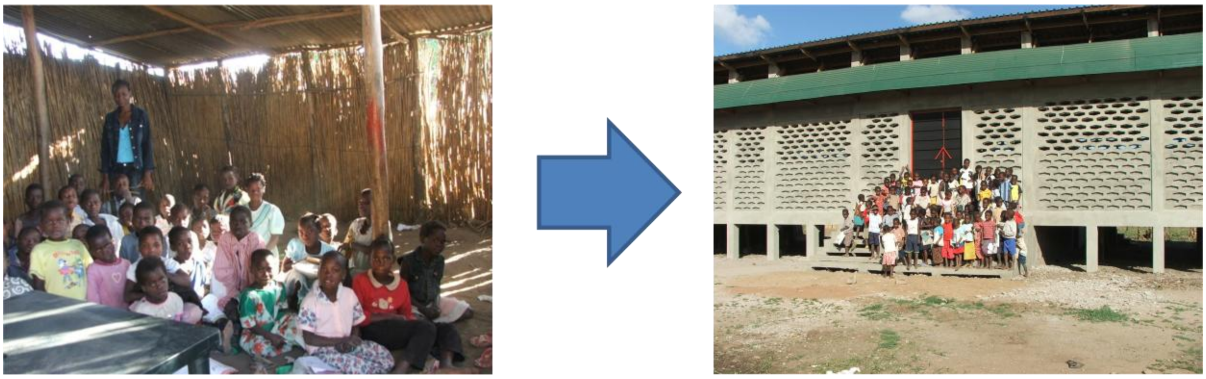


Figure 7.2: School that is safe haven in terms of flooding, including water tanks and sanitation (Maniquenique primary school Limpopo; photos M. Masiyandima)

For Tete Province (Inhangoma), a multifunctional building has been designed that is adapted for flood conditions (Caia, 2009/2010, See Fig. 8.3 and 8.4).

Figure 7.3: Multifunctional building designed for floods in Zambezi for Inhangoma (Caia, 2009/2010)

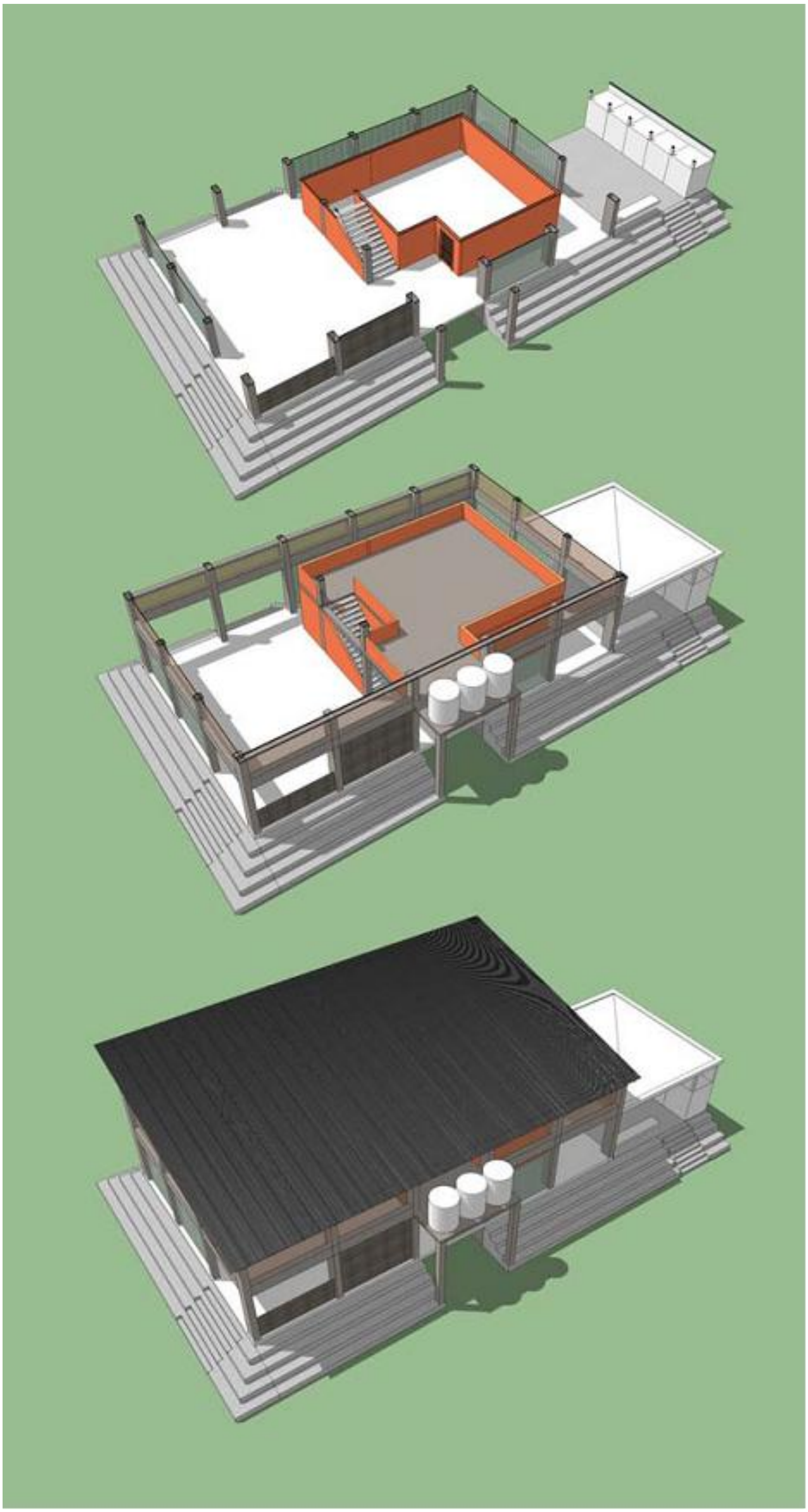


Figure 7.4: Design of building in Inhangoma; elevation, rain water harvesting, first floor level, additional sanitation (Caia, 2009/2010)

Construction of higher areas for refuge

Locally higher refuge areas can also be created, as illustrated in Figure 7.5. In Mozambique, these ideas are being investigated but ground works have not yet taken place. A cost estimate is given below for a platform of 1 ha, which is a large platform for temporary refuge.

Table 7.2: Cost estimate of platform of 1 ha in US$ (Based on SA Rands and conversion rate of 1 US$ is 7 SA Rand)

Cost Estimate for 1 ha of platform based on prices in SA (1 US$ = 7 SA Rand)	2m high	3m high	4m high
	Amount	Amount	Amount
Clearing and grubbing	$ 4,500	5,000	5,500
Tree cutting	$ 3,000	3,200	3,500
Removing and stockpiling topsoil	$ 13,000	15,000	16,400
Transport of material	$ 95,000	151,000	213,000
Compacting soft material	$ 586,000	933,000	1,320,000
Top-soiling	$ 23,000	25,000	28,200
Grassing	$ 1,400	2,100	2,700
Total Cost for 1 ha platform	**$ 725,900**	**$ 1,134,300**	**$ 1,589,300**

Figure 7.5: Sketch of refuge area to be created in village (As cited in Malo, 2007, from Manual "Aprender a Viver com as Cheias", UN-HABITAT & MICOA)

Diversion of flood water towards flooding areas

The concept of flooding areas is to divert a portion of a flood towards the less valuable part of the floodplain in order to protect the more valuable land downstream. This kind of structural solution can involve the construction of dykes, channels and diverting structures (spillway, gates, etc.). Professor Carmo Vaz (2004) points out that there are large areas in Mozambique which are normally flooded and not occupied for any particular use. These areas could be investigated and, if suitable, some could be defined as flooding areas whose use would be limited to activities with low economic value. When a flood wave comes, the peak is reduced by diverting some of the flood waters away from the channel into a local depression. An example, of diversion of floods can be found at Marromeu where flood waters are diverted into Marromeu Buffalo Reserve of the Zambezi Delta would improve the ecological conditions in the marsh and reduce the impact of flooding in surrounding areas of the delta that are populated. Costing of this measure is very site specific and cannot be done here. In this regard it is also worthwhile mentioning the idea of diverting the Ruo River flood through the Elephant Marsh on the Shire River, as discussed in Chapter 3.

Storage reservoirs

Storage reservoirs can be used in flood control. To this end, some of (or all) the reservoir effective storage capacity is allocated to flood control in order to decrease and delay the flood peak in the river reach downstream of the reservoir. This option has been discussed in Chapter 5.

Site specific for Chobe plains; adjustment of Ngoma bridge

The Department of Water Affairs in Namibia (2004) identified a possibility of flood protection measures at the bridge of Ngoma Gate to avoid back water of the Zambezi coming up the Chobe. The idea would be to control flow by means of gates under the bridge and to partly retain floodwater in order to form an artificial open water body. Besides flood control for the downstream area, this would provide continued opportunities for fishing at the time when Lake Liambezi is drying out, and also be beneficial for wildlife and tourism. Moreover the measure would benefit both riparian countries (Botswana and Namibia) according to the report. Further details of this idea are unknown and it is therefore not further discussed here.

7.4 Decision stage of investments

In literature examined and interviews conducted, it emerged that none of the governments of the region have any plans for structural flood protection measures, apart from an elevated school near Marromeu.

For Malawi a new study will start on a flood and drought management plan for the Shire River Basin subsystem, comprising but not limited to infrastructure development (Call for expressions of interest advertised January 2011 on UN Development Business).

7.5 Evaluation of the criteria of this study

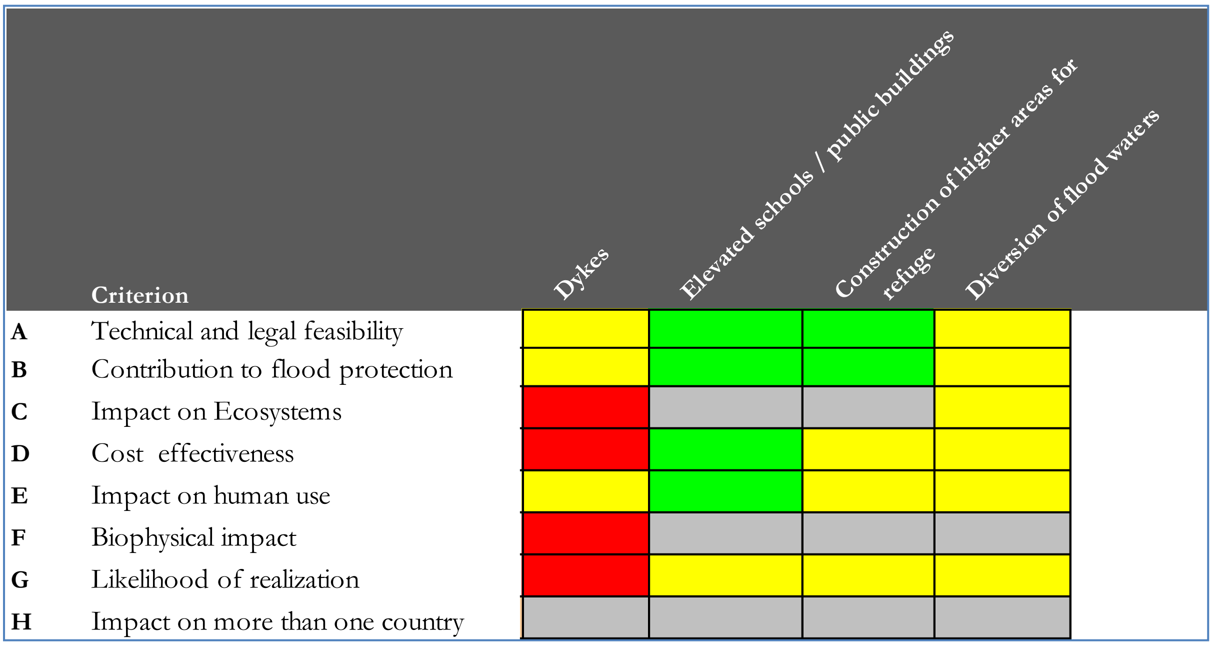


Figure 7.6: Assessment of structural flood protection measures

Technical and legal feasibility

DWA Namibia (2004) mentions that dykes are not considered to be a suitable solution due to unsuitable terrain: very flat areas, long river banks and wide areas to be protected and no rock strata for foundations. These arguments are valid in most of the Zambezi river floodplain.

The diversion of flood waters into flooding areas only contributes to flood protection if sufficiently large areas can be found that can really hold the flood peaks. This has not been further investigated in this study.

Contribution to flood protection

Dykes 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. Floods exceeding the design levels can cause disastrous loss of life and property. Dykes may increase flooding in other areas and should therefore mostly be designed to form part of a comprehensive programme.

Effective maintenance of structural flood protection structures is essential for their continued performance. Dykes for example settle by an amount which can reach 10 to 15 % of their original height. The cost and capacity required for this maintenance can be an issue in some parts of the basin. When inappropriately maintained, structures such as dykes can actually increase flood risk as the rapid influx of a flood wave could be more dangerous for people and habitats than slowly rising water. In France, for example, dykes which are not maintained by the French Department of Water Affairs are considered nonexistent when establishing flood hazard zones.

The other potential problem with flood protection structures is that local populations can lose access to water for irrigation of crops, as well as the fertile sediment brought by annual floods. During a meeting with the IFRC (October 2010), a case was cited from Kenya where a farmer installed pipes through a dyke to channel water to a field, resulting in failure of the dyke system.

For these reasons, such measures should only be implemented after careful study to incorporate all stakeholder interests.
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 economic damage.

Impact on ecosystems

Dykes prevent water and sediments from reaching floodplains. Flooding of floodplains is essential (See Output 2 Report Dam Management) among other reasons for storing floodwaters, groundwater recharge, cleansing of polluted water, spawning and the provision of nursery areas for fish, providing grazing for livestock and other large herbivores, and generally to sustain areas of outstanding productivity and biodiversity. Sediments are essential for nutrition of the soils and for elevating floodplains naturally.

Cost effectiveness

Cost indications are given in the description of investments. Dykes are only cost effective where high capital investments are protected, because of the high capital costs and maintenance necessary to protect larger areas. For schools / public buildings built on higher grounds, the added costs for raising the structure are limited and this seems cost effective. Also, constructing elevated land platforms for refuge are evaluated positively as these only have to be constructed at locations where fleeing from the floodplain to naturally higher grounds is not possible.

Impact on human use

Because of their impact on nutrients in soils dykes are evaluated as negative. However, it needs to be pointed out that in some cases dykes and roads can be combined, where new improved transport routes are required in the same direction as the dykes would be needed.

Combining schools or other public buildings with flood refuge areas is evaluated as very positive. School conditions in most of the Zambezi River Basin are very poor. Schools of this type that have been built in Mozambique have involved the local community in the construction (Caia, 2009/2010).

Likelihood of realization

As explained before, there seems little priority for construction of flood protection measures unless these contribute to improving living conditions, such as school buildings.

Impact on more than one country

Dykes may have a negative impact in particular in locations where one side of a river is in one country and the other side of the river in another (e.g. Chobe plains). Several examples exist of conflict between countries where dykes were raised on one side without consultation with the other. The new EU Directive prohibits in the European Union measures that affect other countries negatively. The other structural measures mentioned in the EU Directive would affect only the host country. The use of flooding areas can benefit downstream countries as well, if applied at a sufficiently large scale.

7.6 Conclusions and recommendations

First and foremost adjusting existing and new infrastructure to minimize remaining damages after floods is important. Roads, bridges, sanitation infrastructure which are damaged require big new investments and derail life for a long time. Therefore such infrastructure investments have priority. Additionally, building new schools or public buildings on elevated grounds seems to be the most promising option, as it would benefit both education and flood protection and costs are reasonable. Moreover, some refuge areas could be created. Dykes are only recommended at a local scale to protect high capital investments, as dyke failure is a serious concern for communities protected by dykes. Diversion of floods to flooding areas is a measure on which few conclusions can be drawn at this stage, as the viability of this option is highly dependent on site specific factors, but options have been identified for the Ruo River (Shire subsystem) as well as for the Zambezi Delta.

8 Sediment management with bottom outlets

8.1 Introduction to the investments

In this Study, the investment in bottom outlets is evaluated on its impact on sedimentation and erosion in the Zambezi River Basin. It is emphasized that this is not the only purpose and impact of bottom outlets, as will be explained in the description of the investment. The following explains to what extent sediment management is crucial for the Zambezi River Basin.

This Chapter is supplemented by Appendix A and Appendix C. Appendix B contains an analysis of the sedimentation impacts of dams and an analysis of impacts on livelihoods and the environment. Appendix C contains cost estimates of bottom outlets.

Impacts of the dams on sedimentation and erosion

Guy (1981) and Ronco *et al*. (2010) conclude that the sedimentation and erosion influence of the Kariba and Cahora Bassa dams on sediment transport is decreasing over decades. Davies *et al*. (2000) describe the impacts of damming the Zambezi downstream of Cahora Bassa and conclude that very large impacts on sedimentation and erosion and sediment transport are likely to occur. All references do not make a distinction between organic suspended solids and other types of sediment. For further information, see Appendix A.

Need for investment from agricultural perspective

The fertility of the floodplain areas, thanks to the organic suspended solids, is of major importance for the livelihoods of local peasants, to the extent that they prefer risking flooding than cropping on less fertile upland soils. There is less deposited organic suspended solids on the flood plains at present compared to the period before the dams on the Zambezi according to local sources. The sediment now deposited by the Zambezi is perceived by the locals as sandy, 'non-fertile'. Not all fertility problems are due to changes in the Zambezi, but also due to local soil erosion. Some of the problems of cropping near the river bed after construction of the dams have nothing to do with sediments and fertility as such but with (a) the unexpected rapid rise of flood levels since the construction of the dams, making riverbed farming dangerous, (b) the disruption of the seasonal cycle of flooding, making cropping in a seasonal pattern more difficult. For further information, see Appendix A.

Need for investment from fisheries perspective

Fisheries are also affected by a decrease in organic solids. However, there are other explanations possible for the occurrence of smaller number of fish species and smaller sizes, such as: (a) reduced fisheries productivity due to lack of exchange between the river and floodplain spawning grounds (b) irregular floods that wash away fish eggs in the river channel.

Need for investment from environmental perspective

The impacts of the dams on sediment transport and on the environment have been large. The dams reduced sediment load in the Zambezi River below Kariba, particularly the coarse sand fraction. This starved the unconsolidated coast of adequate sand supply. There has been extensive death of mangroves, although there are little data to prove this, with some experts suggesting that the observed death or reduction of mangrove areas has to do with sediment transport (although also the flow regime has changed).

Alluvial terraces in areas such as Mana Pools are eroding as a result of the loss of sediments that once maintained them but that are now trapped within the reservoir. Elsewhere it has been suggested that decreased low flows and a reduced frequency of flushing by floods due to impoundments have led to an increased retention of nutrients and fine sediment, resulting in conditions favourable for the growth of filamentous algae and biofilm that is unpalatable for macro invertebrates, leading to increased armoring of the stream bed and a reduction in habitat availability and quality for macro invertebrates and small fish.

8.2 Description of investment

When designing dams, always bottom outlets are considered to be part of the design.

Historically most design considerations for sediment control and water transport focused on:

a) Preventing the siltation of the dam in order to maintain the live storage capacity to its maximum;
b) Reducing the turbidity of the released water to the downstream users who use sprinkler or other pumped water for agricultural or domestic use.

Additional design considerations for bottom outlets are:

c) Being able to maintain minimum environmental releases
d) Being able to lower the water level in the dam in a certain period of time, should this be necessary for dam safety purposes.

For these reasons, the bottom outlets are normally designed above the dead storage level of the dam which is expected to be filled with silt over a design period – typically some 10 to 20% of the total storage capacity. This practice has kept the released water clear of silts, which has also been observed downstream of Kariba as well as Cahora Bassa Dams.

8.3 Evaluation of the criteria of this study

	Criterion	Bottom outlets in new dams
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	

Figure 8.1: Assessment of Bottom Outlets for sediment management (see Fig. 1.2 for legend)

Technical and legal feasibility

Sometimes bottom outlets are used for sediment flushing. For free flow flushing, the water level of the reservoir has to be lowered to the bottom outlet, in order for the river water to cut its way through the sediment; keeping the water level at full capacity would not give sufficient speed for sediment to be taken down. The free flow flushing of sediments with bottom outlets is a complicated exercise which may result in too much sediments going down the river. Lowering the water level to that extent also has environmentally negative impacts. Other methods of flushing keep the water level higher, but can only be used to bring very fine sediment downstream. The use of bottom outlets for sediment flushing requires experienced operators.

The following considerations play an important role in understanding the function of bottom outlet design and operation for large dams (Morris *et al.*, 1997 and experts opinions):

For a successful operation of a bottom outlet, the water level in the reservoir should be lowered before the flood season, gates are opened and flushing of some sediments downstream is controlled. This operation is highly complicated and risky, and almost completely avoided by most Dam Operators. The operation also needs a forecasting system of high quality, with many gauges to be maintained upstream. Dependent on the high size of peak flow the bottom outlets can accommodate, the sediment can be scoured to a certain river bed. In general, bottom outlets that can accommodate a 1:20 year flood are already very large, requiring high investments. When the dam is emptied for flushing, the sudden drop in the water level also may have detrimental effect on the integrity of dams or create undesirable geological movement under the dam reservoirs.

Even with the above operation, the sediment composition carried downstream is vastly different than the sediments that would be carried downstream naturally by the natural river regime.

When flushing was done without emptying the dam, the effective result downstream has been negligible. Supplying downstream with fine sediments would be the only positive outcome of this practice.

Another way to get sediment out of the dam to the downstream is by dry excavation or dredging the reservoir. Dry excavation is only possible when the dam is empty during the dry season. Dredging is an expensive exercise, which has been applied a few times in South Africa, but only when dams were silted up far earlier than their design life.

In light of the above, big dams such as Kariba and Cahora Bassa, with a long and deep reservoir, will have all sediment trapped some distance before the dam wall and bottom outlets do not provide a viable solution for increasing the sediment transport capacity of the dams.

For new run-of-the-river hydropower dams like the Mphanda Nkuwa and the Batoka Gorge, the reservoirs are not as large as Kariba and Cahora Bassa. Therefore during floods some of finer sediments will pass the dams.

For new reservoirs, due regard needs to be taken of the risk of the dam silting up with sediment. Considerations when designing a dam is to ensure dam capacities that are not too small in comparison to the mean annual runoff expected into the dam, especially when the upstream catchment can erode easily. Sediment yields from the catchment can be of the order of 100 to 200 ton/km^2/annum and the yields will give a first approximation of the reservoir volume loss over a 50 year life of the reservoir. There are many examples in the world and in Southern Africa of too optimistic designs, with dams being filled up by sediment.

As for suspended (organic) solids, the dam experts mention the phenomenon of Density Currents in reservoirs. These density currents are due to the differences in density between water with suspended solids or silts and water without. The currents travel along the bottom of the reservoir and rise up the dam wall, through the gates. Whether this is applicable in the Zambezi reservoirs is not known, but it would have a beneficial impact on the suspended solids content downstream.

The conclusion of this criterion is that flushing of reservoirs that are built for hydropower generation is not an option. Only when dams are designed to be empty at the beginning of the wet season (small or medium sized irrigation dams or dams for flood prevention) can flush gates for free flow flushing be considered an option.

Smaller dams are in terms of sediment management preferable to larger dams where possible, as sediment passage is especially difficult with large reservoirs that trap sediments far upstream from the dam wall. For smaller dams, in particular weirs/barrages, there are flood gates available to pass sediments, such as automatic Top gates (www.amanziflow.co.za). Scouring bottom outlets for smaller dams will have more effect than bottom outlets for large dams.

Contribution to flood protection

Current design requirements in Zimbabwe and South Africa are such that it is possible to lower the water level in the dam in a certain period of time, in case this seems necessary for example for reasons of dam safety. This implies bottom outlets also serve flood regulation, in terms of risks of dam break.

Impact on ecosystems

A natural sediment regime is an important component of a river ecosystem. Dams trap sediment leading to erosion downstream and to a reduction of deposition of fertile sediments in the floodplain. However, it is realized that it may be unavoidable to build some of the dams.

Although the available information is inconclusive with regards to the environmental impact of flushing sediments downstream by opening a bottom outlet, the little that is known swings both in negative and positive directions. In addition, those in favor of flushing emphasize that this operation should be done in a very measured and controlled manner, which is almost impossible to accomplish in case of the dams in the Zambezi River Basin, as explained under the criterion of physical feasibility. If bottom releases can be made that include sediments, the releases are preferably made during a natural flood, so that sediments are dispersed and oxygenated. Naturally, fine sediments will then end up on the floodplain and heavier sands in the Delta, etc.

The negative environmental impact of bottom outlet flushing on the dam reservoir has been observed as the sudden drop in the water level which certainly would cause damage to flora and fauna as well as natural habitat of the wildlife. If the release is made without a large flood, there is a chance that the releases consist of a deoxygenated sludge that could negatively affect the downstream ecosystem.

Bottom outlets do not just serve the purpose of sediment management. For environmental flows in extreme dry years, there needs to be an outlet quite low in the dam to provide minimum environmental flows. The disadvantage associated with releases from bottom outlets is that they release cold, nutrient-rich (hypolimnion) waters from the bottom of the reservoir, which can have a negative impact on water quality and some fish life immediately downstream of the dam. Therefore for environmental flows, water needs to be mixed with water from higher in the dam.

From an ecological point of view, for the impact of sediment management on the ecosystem, consideration should not only be given introducing bottom outlets, but also to adjusting the size of dams. Sediment management is less difficult to realize in smaller dams rather than bigger dams. For barrages, flood gates are possible that can pass almost all sediments. Given the difficulties with flushing sediments from dams, it is also important that any new dams in the river basin are sited in such a way as to ensure that some river reaches are able to transport sediments for ecosystem services downstream. Careful consideration should be given to key river reaches with no dam development, by focusing development on other reaches where the environmental and social costs are lower.

There is no information obtained on organic suspended solids in the Zambezi specifically. In general, for dams which have upper spillways, floods basically flow over the spillway and are expected to take along organic suspended solids. The designs of Batoka Gorge and Mphanda Nkuwa have upper spillways.

Cost effectiveness

Capital costs of bottom outlets depend on the type of dam, the head of water and the maximum flow to be accommodated. Costs are generally lower for Concrete Arch and Concrete Gravity dams than for Rockfill and Earthfill dams. As explained above, the investment may be required in terms of design specifications for being able to control the lake level and the discharge downstream. The additional costs for sediment management are in the fact that a larger flow has to be accommodated, which requires larger gates and other forces on the dam wall.

To have an impression of the costs of bottom outlets, the construction costs data of different dams in Southern Africa were collated and on the basis of the design a percentage was estimated to be the costs of the bottom outlets. The costs provided are the actual construction costs in the year of completion taking escalation during construction into account. The costs are very site specific. Three recently built dams in South Africa had construction costs for bottom outlets between 12 and 20% of the total construction of the dams, for dams that catch 1:10 year floods. Further details are given in Appendix C. To increase the capacity, to be able to scour a 1:5 year or 1:20 year river bed in the upstream sediment, would seriously increase the costs of the bottom outlets.

However, although difficult to quantify, the costs of ecosystems deterioration and its impact on society, may be more detrimental than the additional costs of bottom outlets.

Impact on human use

Through their impact on sedimentation, dams have had a large impact on fisheries and agriculture. For smaller dams, bottom outlets could contribute in preventing this damage.

The reason to flush sediment through bottom outlets is usually because of increasing the storage capacity and therewith the lifetime of the reservoir for human use. However, as mentioned under the criterion of physical feasibility, this is not an easy exercise.

8.4 Conclusions and recommendations

Bottom outlets are often required for other reasons than sediment management: preventing siltation of the dam, reducing turbidity of the released water to downstream users of the water, being able to maintain minimum environmental flow releases, being able to lower the water level in the dam in a certain period of time, may this be necessary for dam safety purposes.

The usefulness of bottom outlets for large dams (> 15 m and/or larger than 3 Mm^3) in the Zambezi River Basin for flushing sediments is doubtful because of the following reasons:

- flushing can have detrimental environmental impacts both in the reservoir and downstream;
- flushing implies emptying the reservoirs at the beginning of the flood season, which is only an option for small and medium sized dams that do not generate hydropower; and
- for large reservoirs flushing is not an option as sediment has already settled upstream.

Flushing of sediment will in any case require very experienced dam operators. Also releasing water from bottom outlets requires experienced dam operators, as water needs to be mixed with water from other levels, to prevent that only cold, nutrient-rich (hypolimnion) water from the bottom of the reservoir flows downstream.

Environmental considerations could be added to design standards for dams. Alternatively, dam siting and the choice for different sizes of dams can better take into consideration the possible downstream impacts on sediment transport, before site specific designs are made. The construction costs of dams are higher with higher flow capacities of bottom outlets. This financial consideration also has to be taken into account.

9 Diversification of the Electric Power Pool – Thermal and Hydropower Plants

9.1 Introduction to the investments

During the wet season, tributaries downstream of a major dam may be discharging large volumes of water into the main river. In such situations, the release of dam water for hydropower generation increases risk of flooding downstream of the tributary and is unwelcome. The units of power generation could be taken out of service to the extent that such action will not contribute to flooding upstream of the power plant and the damage of stopping power generation is acceptable. Thermal power plants could help in generating additional energy at such times when hydropower turbines are need to be shut, to keep flows downstream to a minimum.

Figure 9.1 is a schematic illustration of the above processes. If the tributary peak flow (*y*) is far larger than the maximum turbine flow (*x*) then shutting down of the turbines will not contribute to flood protection.

This Chapter discusses possible alternate energy options in order that hydropower plants can be considered for use in flood control.

When good meteorological forecasting systems are available, hydropower plant operators can match their power production with optimal control of the dams. In this manner they have better control of reservoirs and river flows downstream. To combine flow forecasting with power generation coordination is an investment option which is also discussed in this chapter.

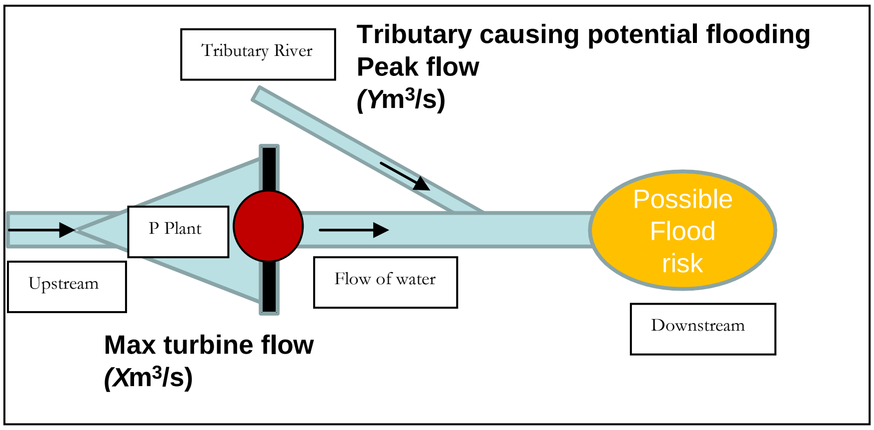


Figure 9.1: Conceptual diagram showing control of flooding contribution using hydropower plants.

9.2 Situation Assessment: expert views

In the process of replacing hydropower plants with thermal power, the criterion that is mostly used is m^3/MWh. This coefficient relates to the water that is used to produce energy. It is used to reflect the amount of energy to be substituted for any volume of water that will not pass through the turbine. As an example, for the North extension of Kariba Dam, the flow through each turbine of 180 MW is about 230 m^3/s. This means that for every MWh needed, 4600 m^3 of water will be used.

In power generation, daily power requirements are usually represented as a load curve as shown in Figure 9.2. The load curve shows the energy needs over a time period and how these are met by hydropower, thermal power plant and other sources. In many countries around the world the base load is provided from thermal power plants. Thermal power plants take long to start up, and are not easy to manipulate, hence they are best used for base load applications. On the other hand hydropower plants are easy to start-up and mostly used for chasing peak load. In the Zambezi basin however, hydropower is a dominant source of energy production as shown in Figure 9.2 b.

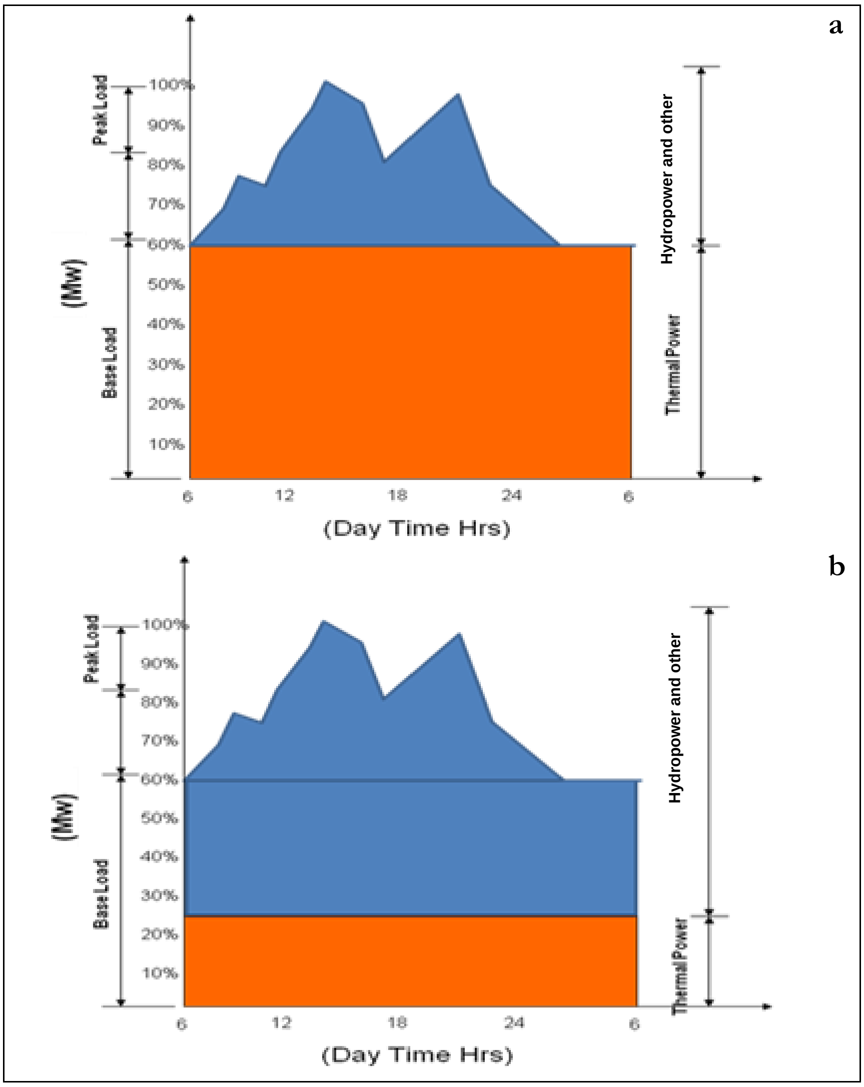


Figure 9.2: Illustration to show the difference between (a) a normal electricity load curve and (b) the Zambezi River Basin load curve

Table 9.1: Capacities installed in the different Zambezi river basin states (Tumbare, 2010 and www.mbendi.com)

No.	Country	Utility	Installed capacity Hydro + Thermal MW	of which Hydro power in Zambezi River Basin MW	Available capacity MW	Installed minus available MW	Peak demand MW
1	Malawi	ESCOM	287	229	267	20	260
2	Mozambique	Cahora Bassa		2075	2075	2075	416
3	Zambia	ZESCO	1812	1600	1200	612	1604
4	Zimbabwe	ZESA	2045	660	1080	965	1397

Table 9.1 shows the comparison between peak demand and installed capacity and the capacity that comes from hydropower. The individual countries that have hydropower stations in the Zambezi River Basin are discussed below.

Malawi

Malawi's current installed capacity is 287 MW; most of this power comes from hydropower plants. The existing hydropower plants on the Shire are Kapichira (64MW), Nkula A (24 MW), Nkula B (100 MW) and Tedzani Falls (40 MW). Malawi is isolated from the Southern African Power Pool; therefore pressures are high to keep on producing energy from the hydropower stations on the Shire River, even if water releases are not desired. Peak demand in 2009 reached 260 MW. With an available power producing capacity of 267 MW, there is no energy safety margin in the country. Malawi's Government is looking forward to increase capacity through additional hydro units and transmission lines connecting to Mozambique in the near future. Substitution of hydropower with thermal power should be 229 MW which is not available.

Mozambique

The main hydropower station in Mozambique is Hidroelectrica de Cahora Bassa with a capacity of 2075 MW. Most of Cahora Bassa's energy is sold to South Africa, while the south of Mozambique again imports energy from South Africa. With South Africa having a high demand for energy and with a high amount of MW coming from Cahora Bassa, it will be difficult to substitute hydropower generation from Cahora Bassa with power generation from elsewhere. Bilateral agreements between Mozambique and South Africa show that there is little possibility for Zambia or Zimbabwe to buy electricity from Cahora Bassa (ZESCO interview, 15 June 2010).

Electricidade de Mozambique (EDM) is responsible for generation, transmission and distribution in Mozambique. Electricidade de Mozambique has had a peak demand in 2009 of 416 MW far from the available capacity of 174 MW. Electricidade de Mozambique has 100 MW thermal power plants but this is not additional capacity that can substitute hydropower in the Zambezi River Basin as it is fully in use. In the coming years three of the hydropower plants of EDM will be rehabilitated, during which it is even less probable that thermal power can replace hydropower. The government intends to invest in thermal power plants and improvements of the grid. The Brazilian mining giant Vale de Rio Dolce is planning to build a coal fired power station of 1800 MW on the Moatize coal fields close to Tete, which could theoretically be used for hydropower substitution.

Zambia

Zambia has an installed power capacity of 1,812 MW, with an available capacity of 1,200 MW. Of this capacity, 600 MW is from the Kariba Power Plants, 900 MW in Kafue Gorge and 108 MW in Victoria Falls. The Zambian power provider ZESCO is a net exporter of electricity to the neighboring countries Botswana and Zimbabwe and to South Africa. Imports from South Africa also occur. The peak demand reached 1,604 MW in 2009 while the internal available capacity was only 1,200 MW. Due to the fact that there is very limited thermal power producing capacity, the substitution of hydropower plant is by wheeling through the grid.

Zimbabwe

Zimbabwe's power company, ZESA imports 35% of its power needs from Eskom (South Africa), Hidroelectrica Cahora Bassa (Mozambique) and the SNEL (Democratic Republic of Congo). Zimbabwe has huge potential for hydropower generation but it is not developing rapidly. Kariba South has a maximum capacity of about 660 MW. The power producing capacity which is operationally available is estimated in April 2009 to be 1,080 MW for the whole of Zimbabwe. The total of installed capacity is far higher, around 2,045 MW. The peak demand reached in 2009 was 1,397 MW. Once more of the installed capacity becomes operationally available for generation of power, it may become possible to substitute hydropower by thermal power temporarily internally. In other cases it is possible to obtain power from the SAPP grid.

Zimbabwe has Hwange I (480 MW) and Hwange II (440 MW) thermal power plants, that need rehabilitation. The required substitution on hydro power plants is 660 MW. This can be achieved through rehabilitation of the two thermal power plants above or by wheeling through the SAPP grid.

9.3 Description of investments

To make it possible to shift from hydropower to thermal power when water releases are not desired, for the countries that are on the SAPP grid, operational costs can be made to buy power. For the major hydropower dams in the Zambezi, this is only valid for Zambia, Zimbabwe and Mozambique. As an illustration the table below shows the energy that would need to be wheeled through the grid if the total hydropower installed per country in the basin is replaced. This is the worst case scenario, as it replaces all hydropower. The energy is on the basis of 12 hours of operation. This example uses an average of Eskom's WEPS Tariff (Wholesale Energy Pricing) in standard hours in the flood season in the Zambezi River Basin (0.04 US$cent/kWh or 0.30 Rand/KWh). The real costs for trading via confidential bilateral agreements will probably be lower but this illustrates the worst case scenario.

Table 9.2: Comparison of operational costs of buying power to substitute hydropower (Based on SA Rands and conversion rate of 1 US$ is 7 SA Rand)

Country	Hydro Power capacity in Zambezi River Basin MW	If total Hydro Power Energy to be Substituted in 12 Hours (kWh)	Operational Cost for Hydro 0.00015 cUS$/kWh	Probable wheeling charges from the Grid
				Sept to May cUS$/kWh = 4.3
Mozambique	2,075	24,900,000	3,913	1,067,143
Zambia	1,600	19,200,000	3,017	822,857
Zimbabwe	660	7,920,000	1,245	339,429

To make it possible to optimize on diversification of the power pool operationally, an improved flow forecasting system is very much required. This can be a consideration in Annex 3 Concepts and Recommendations for Precipitation and Flood Forecasting. For coordination of power generation, a forecasting can inform the Dispatch Center, which is a control room for energy power generation and transmission. The Dispatch Center then combines information of the flow forecasting system, energy prices on the market, the grid electricity demands and the energy coefficients of m^3/MWh. Where flood inflows into the reservoirs are forecasted, hydropower production can be maximized to bring down the water levels in advance and at the same time generate maximum power. Examples of combined flow forecasting and dispatch centres are along the Powell and Campbell Rivers in British Columbia and in North Carolina. Case studies for designs have been published for Three Gorges and Gezhouba in China.

To build new thermal power plants can only be done where fuel is available. For countries not connected to the Southern African Power Pool grid, building a new thermal power plant will have a cost of 3160 US$/kW (conversion from R 22,100/kW and 7 Rand/US$) and in case of rehabilitation will of the order of 1830 US$/ kW (R 12,800/kW). As an example Zimbabwe has also the option to rehabilitate two thermal power plants as mentioned above, i.e. Hwange I and II together 920 MW. The typical rehabilitation cost will be of the order of 1830 US$/ kW, with the total in the order of 1700 MUS$ (based on R 11 776 000 000) for both stations. In case of a new thermal power plant of the same capacity, the capital investment will be in the order of 3000 MUS$ (based on R 20 332 000 000).

The operation and maintenance costs for a thermal coal fired power plant is in the order of 3 cUS$/kWh (21,6 cR/kWh), which is also considerably higher than 0.00015 cUS$/kWh (0.0011 cR/kWh) for operational costs for hydropower generation.

Alternative investment in the SAPP network

The current grid of the Southern African Power Pool limits the exchange of Power. For example, as discussed in Chapter 2, Malawi is not connected to the SAPP network and therefore dependent on power generation in its own country. Therefore the SAPP has planned new interconnectors and enhancement of current interconnectors. These plans are depicted in (Tumbare, 2010). The Tanzania-Zambia interconnection is of particular importance as it will connect SAPP to the Eastern African Power Pool. The SAPP exchange of energy now also heavily depends on the interconnections through Zimbabwe. An additional line straight from Mozambique to South Africa and strenghtening the interconnector DRC – Zambia – Zimbabwe – South Africa, will also be of major importance. The total costs of all planned interconnections was assessed as 5.6 Billion USD (Mutale, 2010).

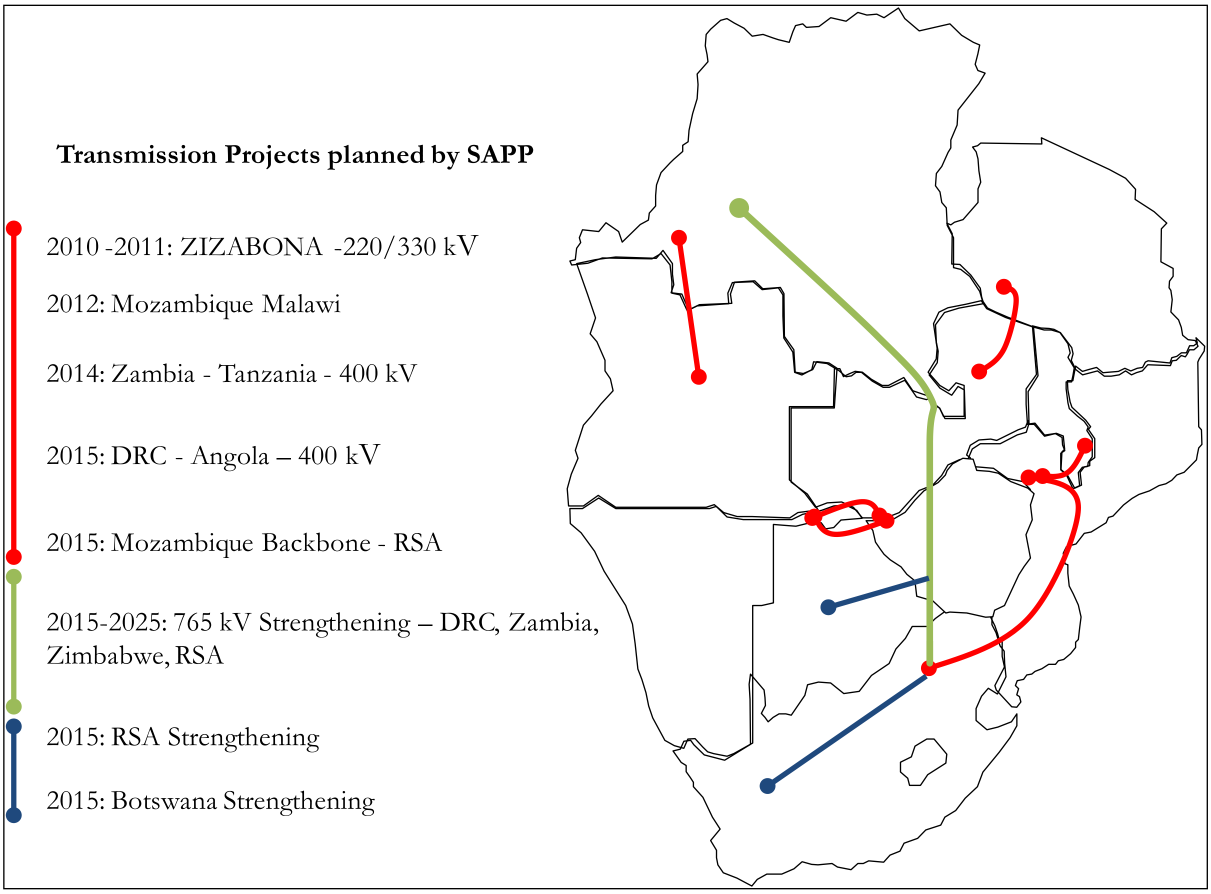


Figure 9.3: Planned SAPP new interconnections and enhanced interconnections (after Tumbare, 2010)

9.4 Evaluation of criteria of this study

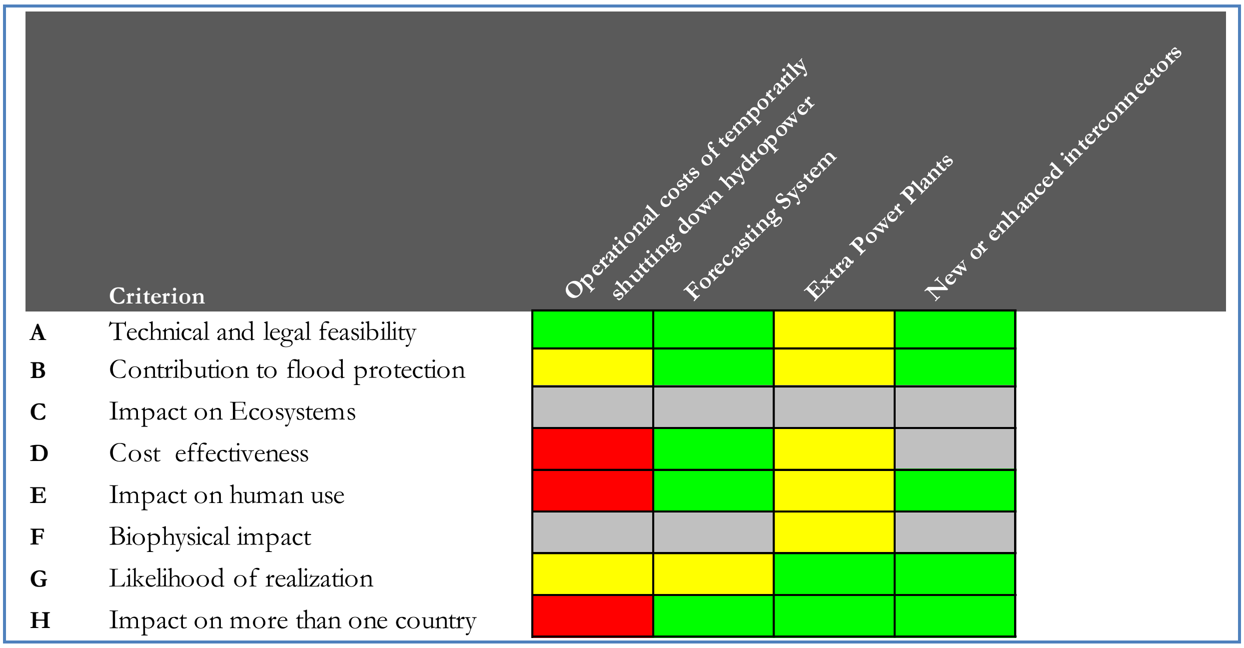


Figure 9.3: Assessment diversification of the electrical power pool (see Fig. 1.2 for legend)

Technical and legal feasibility

Operational activities (rather than investments) to wheel power through the grid, is possible for countries connected to the regional grid, although currently the existing grid has its limitations. As explained above, the Southern African Power Pool has investments planned up to 2025 to increase grid capacities and to connect countries currently not connected.

Investments related to new power plants will be subject to environmental impact assessments and other feasibility tests.

Contribution to flood protection

The impact of shutting down hydropower plants during floods in tributaries downstream on flooding impacts is limited.

The temporary shutting down of turbines in Kariba to minimize flood risks downstream, could theoretically help if a flood is expected from the Luangwa. It needs to be pointed out that the current total outflow from the turbines in Kariba is presently maximum 2200 m^3/s and new turbines are being built which will add 455 m^3/s (ZESCO interview, June 2010). Peak flows of Luangwa River are in the order of 9 000 m^3/s, so the influence of shutting down turbines in Kariba during these peak flows will be a maximum of about 30%, assuming Luangwa flows are in peak. The probability of Zambezi and Luangwa peaking at the same time also needs to be taken into account, in assessing the usefulness of using thermal power to replace hydropower.

The temporary shutting down of turbines in Cahora Bassa to minimize flood risks downstream, could theoretically help if floods from the Luia, Revubué, Luenha and/or Shire are expected. The maximum flow that goes through the turbines at Cahora Bassa is approximately 1660 m^3/s, as normally four of the five turbines of each 415 m^3/s are operated. Each of the lower flood gates of Cahora Bassa can discharge 1650 m^3/s. The eight flood gates together can together discharge 13 200 m^3/s (Annex 2). The scenario of Cahora Bassa having to shut down to prevent downstream flooding from tributaries only, seems highly theoretical.

The temporary shutting down of turbines on the Shire river, to minimize the impact of tributaries downstream causing flooding, is only possible when the water can remain behind Kamuzu Barrage which is highly unlikely (See Annex 2). Additionally, because of the dependency of Malawi on hydropower generated in the country itself, the shutting down of turbines will be unlikely.

Impact on ecosystems

Better coordination of power generation can contribute to storing water in dams during dry periods, while supplying power from other hydropower or thermal power sources. Theoretically it is then possible to create a more natural flow regime with freshets, if the coordination is not used for optimization of power only. However, as this mainly depends on operating rules, rather than on the investment, the criterion is here judged as ‘not evaluated’.

Cost effectiveness

Flood protection effects are expected to be very limited. The operational costs of buying power from the grid are much higher than generating power at the hydropower stations. Flood control or flow regulation will not be reasons to invest in power generation and the electricity grid. Benefits and costs are compared for energy production only. The flow forecasting system is cost effective for flood protection, but the main reason being the warning, not the shutting down of turbines.

Impact on human use

Hydropower production can be optimized making use of power diversification. Through timely forecasting more water can be released via turbines. Closing down turbines because of downstream flooding can temporarily and locally decrease power production. The investment in forecasting systems and new power plants will benefit power production.

Likelihood of realization

Currently the electricity demands in the Southern African Power Pool are often higher than the available electricity. As long as this is the situation, the substitution of hydropower with thermal power or with hydropower from sources where power generation is possible is very limited even if new power plants are built. There are many plans to increase power generation capacities, but it is expected that hydropower will still cover much of the base load in the Zambezi River Basin countries. Therefore substitution of hydropower where water releases are not welcome, will mostly depend on hydropower available elsewhere. The possibility to exchange this power is again dependent on the interconnections in the SAPP grid, which are planned to be extended and enhanced.

Impact on more than one country

The operational costs of shutting down of hydropower plants will negatively affect the countries dependent on the power. Investments that contribute to generating power within the Southern African Power Pool can benefit more than one country. Current bottlenecks are the missing interconnector between Malawi and Mozambique and the limited capacity of the network through Zimbabwe.

9.5 Conclusions and recommendations

The effect of shutting down hydropower stations for the benefit of flood control is very limited, because to shut down the turbine flows for flood protection only makes sense at times when this has a considerable impact on flood flows downstream and cannot cause problems upstream. Operational costs to buy power from other sources or to generate power at thermal power stations in times when releases from hydropower stations are unwelcome, are far higher than generating power at the hydropower station itself. Power to substitute hydropower is also not always available either, because there is no surplus of power available on the grid or because there is no connection to the international grid. Adding connections or improving existing connections in the SAPP grid will therefore assist not only hydropower production but also the options for water management. The interconnector between Malawi and Mozambique will make it possible for Malawi to import and export power. The connection between Zambia and

Tanzania will connect the Southern African Power Pool to the Eastern African Power Pool. The exchange of power generated on the Zambezi now depends considerably on the capacity of the interconnections through Zimbabwe. Several planned new and enhanced interconnections will improve this situation (Zimbabwe-Zambia-Botswana, DRC-Zambia-Zimbabwe-South Africa, Mozambique-South Africa).

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.

10 Evaluation of investments

10.1 Overview of all investments

This chapter presents the overall findings on investments. In interpreting this chapter it is important to take note of the following.

This study evaluated investments which the Terms of Reference of this Study required to be evaluated (See Introduction). However, during the course of the project, alternative investment options became apparent. In the respective chapters and in the intervention sheets these alternative investments are mentioned. Although these alternative investments may have not be evaluated to the same extent, it is important that alternative promising investments will remain to be considered.

This study has no intention to make definitive conclusions about investments that are initiated for different reasons by different actors and have values of millions of US dollar. Some of these investment options are at a final stage of decision making. The evaluation is meant to shed light at a Zambezi River Basin Scale of investments that can contribute to flood protection or flow regulation for the environment.

The recommendations as a follow up of this project are different for different investments and not so much a decision framework for all investments together, although some insight is gained by making it explicit how the different investments compare. This evaluation will help ZAMCOM to find its role in reacting to or the initiation of investments. In the next chapter this is further explained and discussed in the context of recommendations for the decision making process. Overviews are given below of the scores of the different investments, of their location on the map, of the stage of decision making / project implementation they are in. In the next sections the promising and not recommended investments are mentioned.

Table 3.1 gives an overall assessment of all investment options investigated and can be used as a key to reading the previous chapters. The scoring in red, green yellow for each criterion, should be considered a first assessment. It is emphasized that a red score should be interpreted as a warning, not as a definite ‘no’ to the proposed investment, as this is beyond the scope of this study. In a similar way, a green score may still require further study. Figure 10.1 gives a legend to the explanations in this table.

Figure 10.2 shows where the investment options are located in the Zambezi river basin. In the next sections the investment options are sorted into ‘investments not to be promoted’, ‘onvestments to be recommended under certain conditions’ and ‘promising investments’ after which Chapter 11 will present recommendations for after this study.

LEGEND Scorecard

Scores criteria and explanation of 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

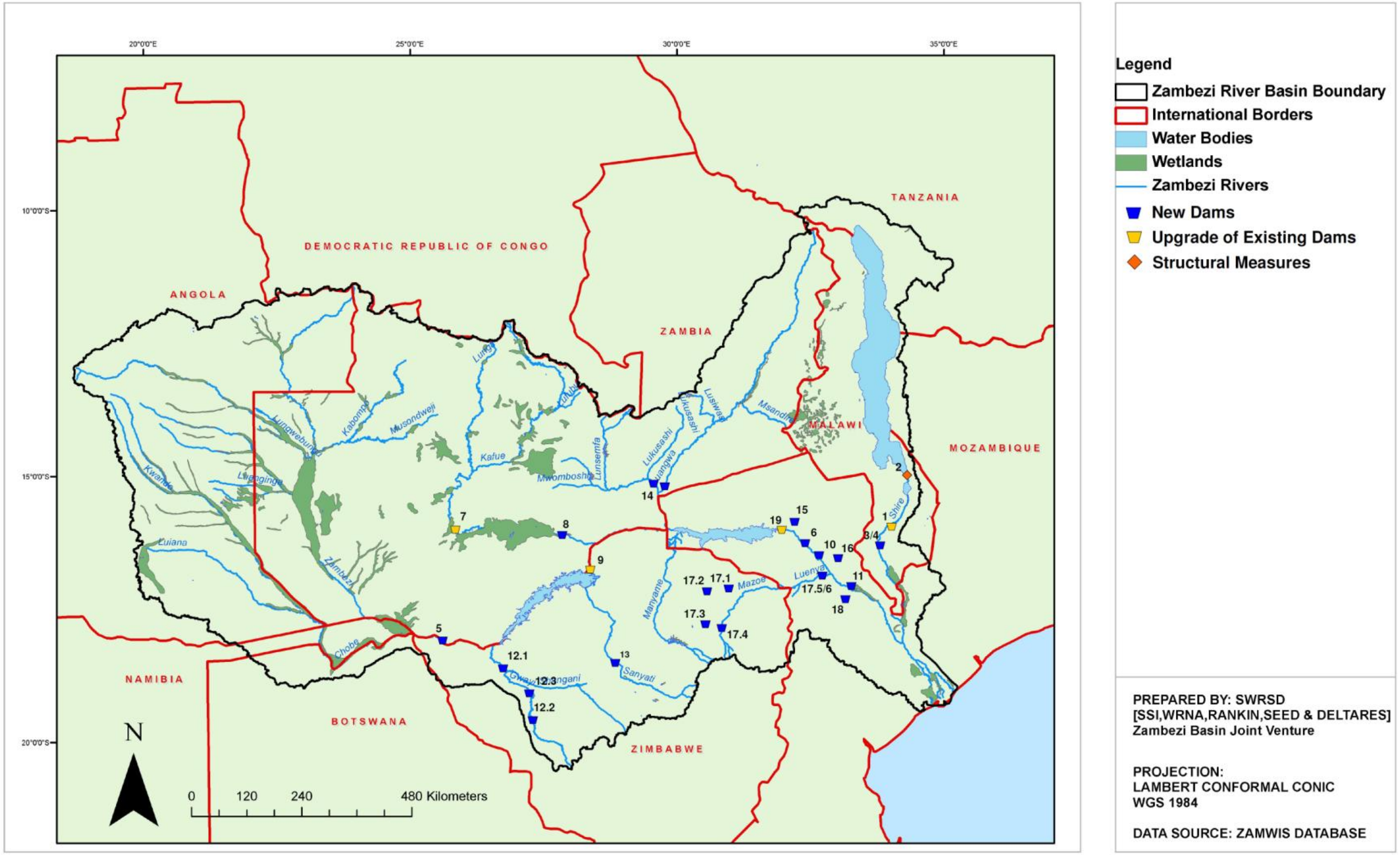
2 Other Structural Measure

23 Non Structural Measure

Figure 10.1: Legend for scorecard and map

Table 10.1: Assessment proposed investments

		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	+											9	
2	Mponda Pumping Scheme	+											35	
3	Kholombidzo Reservoir High	180											293	
4	Kholombidzo Reservoir Low	170											293	
	Multipurpose dams on the Zambezi and Kafue												SAPP (2008)	
5	Batoka Gorge	1600											2400	
6	Mphanda Nkuwa	1800											2000	
7	Itezhitezhi Extension	120											142	
8	Kafue Gorge Lower	600											600	
9	Kariba Extension	600											392	
10	Boroma	444											-	
11	Lupata	654											-	
	Multipurpose dams on unregulated tributaries													
12	***Gwayi dams***												ZINWA (2007?)	
	1. Gwayi Shangani		635										107	
	2. Gway Umguza		195										83	
	3. Bupi Lupane		40										11	
13	***Sanyati dams*** (Kudu dam)		160										160	
14	***Luangwa dams***													
	1. Lusemfwa Lower	35	500										-	
	2. Luangwa	40	2500										-	
15	***Luia dams***													
	1. Luia 1													
	2. Luia 2												-	
	3. Luia 3												-	
16	***Revubue dam***		8000										-	
17	***Mazowe/Luenha dams***													
	1. Chitse		290										141	
	2. Silver Stroom		140										193	
	3. Bindura		87										90	
	4. Kunzvi		146										147	
	5. Luenha 1		11000										-	
	6. Luenha 2		4000										-	
18	***Muira dam***		2000										-	
	Dams for livelhoods												-	
	Investments in Cahora Bassa Reservoir													
19	Additional Spillway Cahora Bassa	1200												
20	**Flood Risk Zoning**													
	- Flood risk zoning for rules for new settlements													
	- Flood risk zoning for current land use and awareness raising													
	- Flood risk zoning for insurances													
	- Flood risk zoning for rescue and warning													
21	**Structural flood protection**													
	- Dykes												0.5-1.9 /km	
	- Elevated schools / public buildings												0.8-1.6 /ha	
	- Construction of higher areas for refuge													
	- Diversion of flood waters													
	Sediment management													
22	- Investments in bottom outlets												15-20% of total capital cost	
	Diversification Power Pool													
23	- Operational costs of temporarily shutting down hydropower													
24	- Dispatching combined with flow forecasting System	+												
25	- Extra Thermal Power Plants	+												
	- New or enhanced interconnectors	+												



SOUTHERN AFRICAN DEVELOPMENT COMMUNITY — SADC — TOWARDS A COMMON FUTURE

TRANSBOUNDARY WATER MANAGEMENT IN SADC: DAM SYNCHRONISATION AND FLOOD RELEASES IN THE ZAMBEZI RIVER BASIN PROJECT

FIGURE 10.2 : MAP WITH LOCATION OF THE ASSESSED INVESTMENTS

giz

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

In Delegated Cooperation with: UKaid from the Department for International Development; Australian Government Aid Program

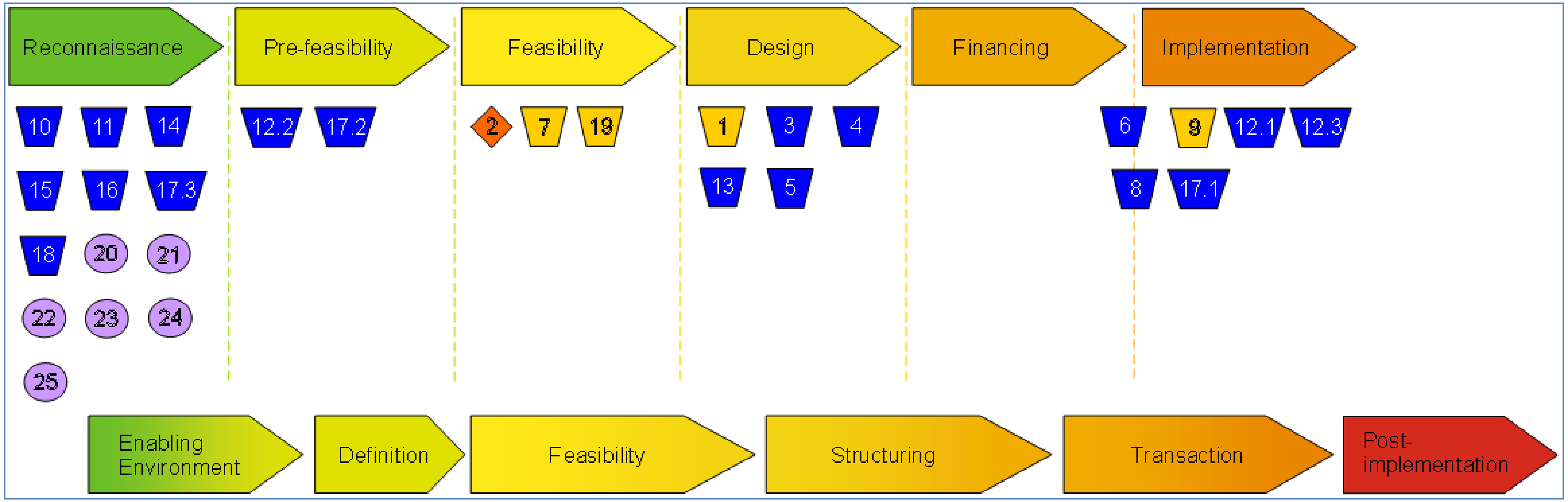


Figure 10.3: Stages of decision making for the different investments. Phases at top refer to more common project phases, phases at bottom are the phases of Infrastructure Consortium Africa.

10.2 Investments not to be promoted

The following investments are not recommended, in the context of this Study. The Intervention Sheets are part of Chapter 11.

Table 10.2: Investments not to be promoted

Investment	Comment	Chapter	Intervention Sheet
Mponda pumping scheme	The need for the Mponda pumping scheme is very limited if the interconnector Mozambique Malawi is realized. The possible further drawdown of Lake Malawi is also not recommended, although if only used for one season, the impact is limited. Currently the project is 'shelved' until the need arises when Lake Malawi levels are again low.	3	4.1
Large scale constructive flood protection, such as dykes	To implement dykes on a large scale (not just to protect high capital investments) will require immense capital costs as well as inspection and maintenance capacity and costs. In many areas the subsoils will require additional – expensive – engineering adjustments. There is little interest from stakeholders. Dykes also prevent sediments and water on the floodplains, essential for ecosystems.	5	4.8
Decreasing hydropower production to accommodate flood peaks of downstream tributaries and diminish flooding downstream of these tributaries	Stopping of hydropower production for the benefit if preventing downstream flooding is only useful if tributary downstream contributes flows that are not far higher than the turbine flows and the large reservoirs do still have storage capacity. For example the peak flows of the Luangwa are larger than the flow through the Kariba turbines, therefore stopping production at Kariba would have limited impact. Cahora Bassa and Kariba are connected to the SAPP grid, but buying thermal power to replace hydropower is operationally very expensive. In the Shire system there is no alternative power available.	11	N/A

10.3 Investments to be recommended under certain conditions

The following promising investments can only be recommended under certain conditions, which are specified below.

Table 10.3: Investments under certain conditions

Investment	Comment	Chapter	Intervention Sheet
Upgrading of Kamuzu Barrage	For flood control purposes this investment has little influence apart from making the barrage easier to operate during flood conditions. The upgrading also creates 14 cm higher Lake Malawi levels, adding to storage capacity for extra hydropower production. If Kholombidzo High Reservoir is realized the Upgrading of Kamuzu Barrage becomes redundant. One gate is currently stuck and if upgrading takes too long is recommended to be repaired independently. The structure is over its lifespan.	3	4.1
Kholombidzo Reservoir on Shire	The advantages for hydropower generation are clear but create again more dependency of Malawi power on Shire flows. The advantages and disadvantages for flood control, flow regulation and the environmental impact need to be studied in more detail before conclusive recommendations can be made.	3	4.1
Large run-of-river dam developments	The planned run-of-river dams contribute considerably to solving the power deficit in the region. Their reservoirs are relatively limited for storage of peak flows in comparison to the existing reservoirs of Kariba and Cahora Bassa, but additional power capacity can make it technically possible to release flood storage capacity in Kariba and Cahora Bassa. From an environmental viewpoint, large dams are not welcomed although the run-of-river schemes in the already regulated Zambezi do not have as large negative impacts as large new reservoirs. In comparison to normal reservoir power schemes, the reservoir size is relatively small in comparison to the power generating capacity, which is positive for its impact on human settlements, greenhouse gasses (large reservoirs can increase greenhouse gas emissions) and evaporation losses. Designs and operating rules are recommended to sufficiently consider the environment to minimize negative impacts. The use of the Hydropower Sustainability Assessment Protocol (IHA, 2010) can assist in further decision stages. If the operating of dams is indeed considered together with upstream downstream (i.e. Kariba for Batoka Gorge and Cahora Bassa for Mphanda Nkuwa as well as Lupata and Boroma) reservoirs, and the run-of-river schemes can replace some of the power production at these reservoirs during floods, the	4	4.2

Investment	Comment	Chapter	Intervention Sheet
	run-of-river dams can contribute to flood protection. However, their financial viability and the deficit of power in the region, may put pressure on optimal hydropower production.		
Bottom outlets	Bottom outlets are required on all dams to decrease water levels in times of emergency and to maintain environmental flow releases. The use for scouring of sediment in large dams to supply sediment downstream should be cautiously approached, because of the following reasons: (a) flushing can have detrimental environmental impacts both in the reservoir and downstream; (b) flushing implies emptying the reservoirs at the beginning of the flood season, which is only an option for small and medium sized dams that do not generate hydropower; (c) for large reservoirs flushing is not an option as sediment has already settled upstream. For environmental flow releases, also the operation of the bottom outlets should be done with care, as often mixing with water from the top of the reservoir is necessary to prevent downstream water quality problems.	9	4.5
Flood risk zoning	A staged approach is recommended to coordinate flood hazard mapping, which can serve for warning and rescue, for informing new developments and for awareness raising. Floodprone zones mapping is not urgent in most areas, as local floodrisks are known. Flood risk zoning for insurance purposes is not considered feasible.	7	4.6

10.4 Promising investments

The investments below are recommended to be supported by ZAMCOM / SADC.

Table 10.4: Promising investments

Investment	Comment	Chapter	Intervention Sheet
Improved flow forecasting system coupled with dispatching Centre SAPP	An integrated forecasting system is indicated by different stakeholders as top priority and further explained in Annex 3. It will also contribute to optimization of power production.	Annex 3 + Ch. 9	4.10
Extra hydropower generation on existing dams	Extra turbines on existing dams will not only contribute to power generation, but will also increase the capacity to generate hydropower if reservoir water levels are to be reduced before forecasted floods, as more water is able to pass	4	4.2

Investment	Comment	Chapter	Intervention Sheet
	through the turbines rather than spillways. Such projects are planned for Kariba North, Itezhi-Tezhi Hydroelectric Project and Cahora Bassa Extension.		
Electricity interconnector Malawi and Mozambique	While evaluating the water management options for the Shire, it became clear that the high dependency of Malawi on power of the Shire decreases possibilities for water management. The Interconnector Malawi-Mozambique would make it possible for Malawi to obtain power from SAPP, creating less stress on the Shire River.	4	4.9
New interconnectors in SAPP	When new interconnectors are established, the SAPP countries will have less blackouts and the countries with a surplus of hydropower (during certain periods of the year) have more possibilities to export their electricity production.	11	4.9
Small and medium dams on tributaries	Different stakeholders indicated that for the Zambezi region creating possibilities for livelihoods on tributaries has less negative environmental impacts and is contributing to the economy. The flood protection impacts are limited, but the contribution to livelihoods may create alternative locations for resettlements of persons currently living in floodprone areas.	5	4.3
Extra spillway for Cahora Bassa	The extra spillway is very beneficial for the ecosystem upstream and downstream of Cahora Bassa Dam. However, the impact on the maximum floods still has to be studied further together with the flood operation rule curves considered. A hydrological study has been planned by HCB.	6	4.4
Elevated schools and public buildings	Combining the advantage for improved public buildings such as schools with the need for refuge areas in terms of floods is a win-win situation that is promising. In the Limpopo river basin good examples have been built.	8	4.7

11 Recommendations for follow up after this study

11.1 Issues of scope, scale and decision making on investments in the Zambezi River Basin

This study evaluates possible investments which could have influence on flood protection, environmental flows or dam management in the Zambezi River Basin. The Consultant was asked to recommend on how to take the decision making on investments forward. It is important to realize the following with respect to differences between these investments:

- main purposes of the investments; from hydropower to flood protection;
- types of investments; from infrastructure to flood risk zoning;
- impacts of investments; from strong environmental and socio-economic impacts to very limited impacts;
- phase in which investment is currently; from reconnaissance level to final design; and
- countries and/or private developers in which the investments are to happen, with each having their own priorities and regulations.

Two examples on the extreme ends of these aspects illustrate that ‘apples’ and ‘pears’ are being compared. Flood risk zoning is for flood protection only, is a minimal investment, has no negative environmental impact although it might influence the socio-economy in terms of spatial development, is at a reconnaissance level in most areas of the catchment and is subject to different priorities and legal requirements in different countries. The Mphanda Nkuwa run-of-river hydropower scheme mainly serves hydropower, is an immense structural capital investment, has strong environmental and socio-economic impacts and is already decided on to be built by Mozambique.

The comparison of ‘apples’ and ‘pears’ complicates prioritization on a river basin scale. The decision making process for most investments are also not done at a river basin scale, although different countries may be involved. The Worldbank investment analysis (2010) for the same reason withdrew from drawing conclusions on individual investments. The main objectives of this study (flood protection and safeguarding environmental flows) are not used for primary decision making on investments.

In this light, the following principal objectives and outcomes of good water management for development are recommended to be respected in decision making on investments (Lenton and Muller, 2009). The Consultant has added remarks for applicability to this Project.

Table 11.1: Key messages on objectives and outcomes for good water management for development adjusted for this project (adapted from Lennon and Muller, 2009)

Objectives and outcomes of good water management for development	Applicability to Zambezi River Basin in the context of this study
Societies will use their own practices of governance to determine the appropriate balance between social, economic and environmental goals, which will change over time.	Although ZAMCOM, as any other river basin organisation, may want to influence decision making on investments or support them, it is not recommended to make ZAMCOM the decision maker as (1) investments are not done by ZAMCOM and will influence the countries directly, (2) on the Zambezi river basin scale the decision processes are so complicated that

	little action will be taken. For feasibility studies and EIAs that have been conducted for certain investments in the nineties/beginning of the eighties, it is recommended to check their current validity before final decision making.
An important outcome of good water management is often that social and economic life is more secure than it would otherwise have been.	It is clear from all stakeholder interactions that the goal of poverty alleviation is recognized as primary overall goal in the basin countries. Cost efficiency will be weighed against this primary goal, with decision makers having to weigh investments in water management against those in the health sector or in education sector.
The most important determinants, as well as outcomes, of better water management will usually be found outside of the water sector.	Apart from directly water sector related outcomes as decreased flood risk and increased intrinsic environmental value, primary determinants in the context of this study are (1) decreased poverty (2) increased access to energy (3) increased economic growth. The contribution of the water sector to these outcomes can be crucial if there are ‘bottlenecks’ related to water. However, the influence of other sectors is also crucial. Therefore it is not as easy to evaluate apriori and posteriori the influence of investments in the water sector.
There is not necessarily a contradiction between the protection of the environment and the promotion of economic and social development.	The consulted stakeholders and the Consultants Ecosystem expert team have been very constructive in realizing that poverty alleviation and economic growth are in many instances top priority and both power production and ecosystems services can contribute to this. Discussions in and outside the team suggest that large infrastructure projects such as for hydropower are more positively approached than say ten years ago. In their role, the environmentalists are also clearly suspicious of any major infrastructural development, maybe more than would be necessary after more detailed study in a good Environmental Impact Assessment and evaluation against alternative ways of power production. In the context of the Zambezi River Basin it may be considered to do mono-purpose investments locally, while other locations need to remain as pristine as possible.

The above implies that the evaluation process on a river basin scale will be valuable for ZAMCOM to be able to recommend different stakeholders and actors, but cannot surpass the sovereignty of those stakeholders and actors. This recommended role of ZAMCOM is in line with the role that SADC currently fulfils; to provide Member States with a regional perspective when making national decisions (GOPA/DECON, September 2010). With an established ZAMCOM, protocols and discussions will be more Zambezi focused. For decision making on the investments mentioned in this study also other SADC protocols and co-operations are relevant. For example for investments which influence power supply, the South African Power Pool promotes integration and coordination of activities between different countries. It is recommended that for these projects, SADC/ZAMCOM from the water side, involves the power side at an early stage.

To decide in what way SADC or ZAMCOM should move forward in choosing between investment projects that need their own input, the following considerations are recommended (inspired by Lindemann, 2005 and Lennon and Muller, 2009):

- The largest rate of success for SADC / ZAMCOM's involvement is in investments for which the different governments, financiers, users (i.e. power companies) have clear incentives and which solve a clear problem. However, the involvement may also be required when success is not the objective, but conflict resolution and impact control;
- An international process of decision making is complex and transaction costs may be high; the time required during the process may require adaptation of the goals along the way. This requires flexibility; and
- Despite the undeniable benefits of the activities of international donor and financing organisations, they may have negative side-effects, e.g. problems related to slow and overly bureaucratic project implementation or a lack of ownership.

11.2 Interventions for follow-up after this study

In the previous chapter a distinction has been made between investments not to be promoted, investments that can be recommended under certain conditions and promising investments. In this chapter the interventions suggested are structured into three core subconcepts groups:

- Improved evaluation of water infrastructure investments initiated by different actors;
- Improved flood protection through flood risk zoning and structural flood protection; and
- Improved interaction of energy and water management and its role in flood protection and environmental releases.

Each of these subconcepts introduces different recommended interventions, as presented in Figure 11.1 and further elaborated in the consecutive following intervention sheets.

It is stressed here once again that interventions following from this study have limited impact in the decision making of multi million US$ projects that are initiated for other reasons than improved dam management for flood protection and environmental releases. To consider the intervention sheets as concept notes for new projects should therefore be cautiously considered. The intervention sheets are based on the findings of the Technical Study "Dam Synchronisation and Flood Releases in the Zambezi River Basin". Before implementation further consultation with stakeholders and confirmation of specific details will be required.

In preparing these sheets, it should be noted that a key assumption has been the future ratification of the ZAMCOM agreement by all basin states. As management of the Zambezi River basin is currently limited to piecemeal management by the 8 basin states, implementation of basin-wide strategies is unlikely to be successful until the full ratification of the ZAMCOM agreement has been achieved. Other specific assumptions have been listed for each intervention.

Figure 11.1 on the following page is a schematic summary of the structure and relationship between the concepts and recommended interventions.

The intervention sheets included in this chapter include a number of standardised fields. A brief description of these fields is provided below:

Intervention sheet # - the number of the recommendation/ intervention linked to specific focus areas. Interventions starting with "3" are linked to Concepts and "Recommendations for Precipitation and Flow Forecasting".

Timeframe – the timeframes presented here are approximate and are limited to short term (0-2 years), medium term (2-5 years) and long term (>5 years).

Budget range – to facilitate implementation of the proposed interventions, a budget range has been included to assist with obtaining funding. Four budget ranges have been considered, as follows: < US$ 0.5 million, US$ 0.5-2 million, US$ 2-5 million and > US$ 5 million. It should be noted that the costs presented in this field are rough order cost estimates prepared in most cases from an educated assessment of the likely cost for implementation of each respective intervention.

Linkages – this field details the locations within the report where further information on each recommendation/ intervention can be obtained.

Concept – this field outlines the overall concept to which the proposed intervention is expected to contribute.

Justification – this field explains the rationale behind the proposed recommendation/ intervention.

Actions/ responsibilities – this field lists the specific actions that are required for achievement of the proposed recommendation/ intervention and the responsibility for implementation. Although the SADC Secretariat and the basin states are generally listed as the responsible parties for implementation, the appointment of either consultants, equipment suppliers or contractors will be required as part of the implementation procedure for each recommendation/ intervention.

Benefits/ beneficiaries – this field was included to demonstrate the expected benefits arising from implementation, as well as the likely beneficiaries. Particular attention was given to specifying whether the beneficiaries would be limited to a single country or multiple countries.

Means of implementation – this field briefly describes the expected process for implementing the proposed recommendation/ intervention, such as the expected implementing parties and the actions to be implemented.

Specific assumptions/ risks – this field includes any specific assumptions or risks associated with this specific recommendation.

Comments – any remaining comments or issues not covered by the other standard fields are captured in this field.

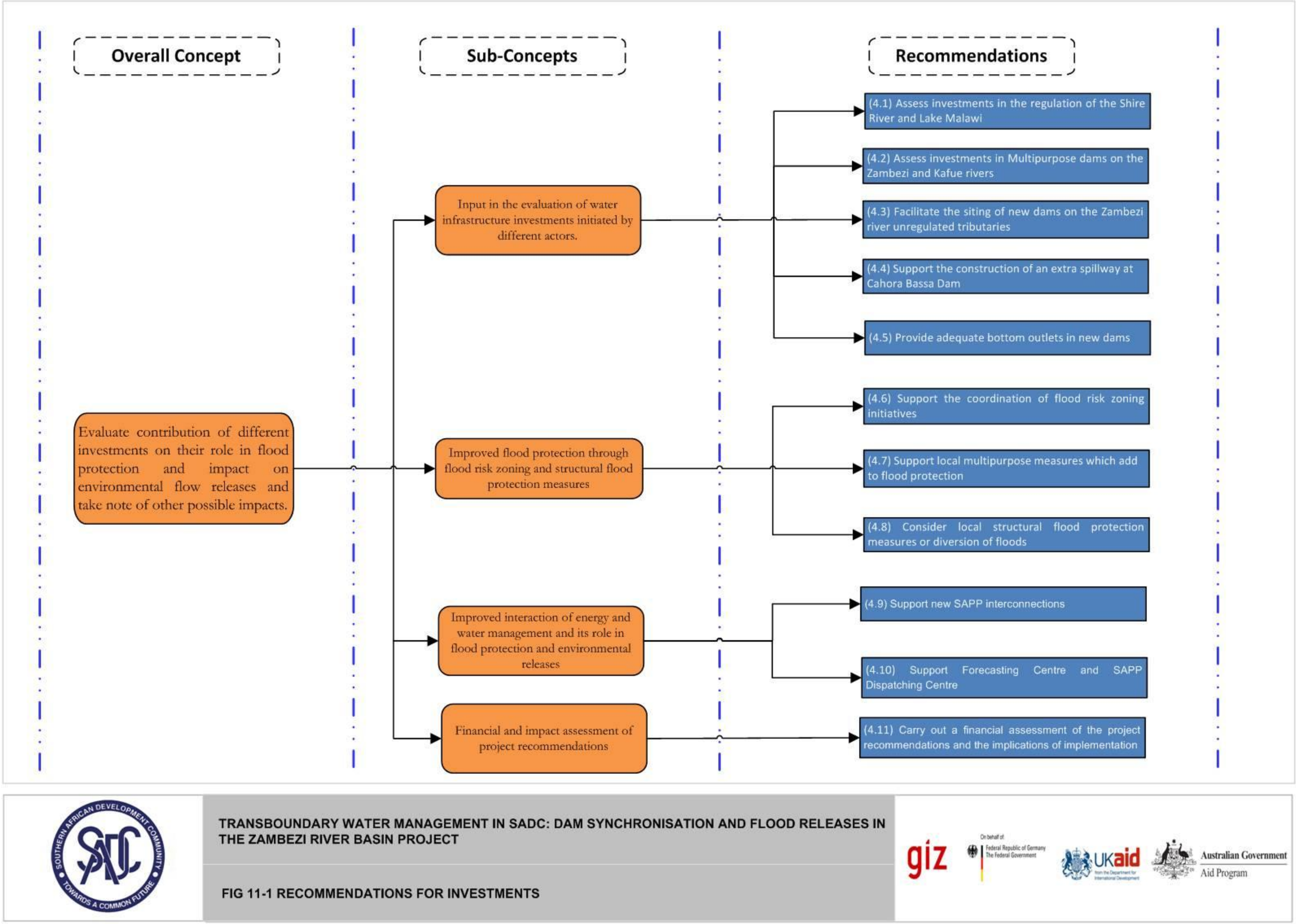


Figure 11.1: Structure of Concepts and Recommendations for recommendations for investments

<table>
<tr><th colspan="6">ASSESS INVESTMENTS IN
THE REGULATION OF THE SHIRE RIVER AND LAKE MALAWI</th></tr>
<tr><td>Intervention Sheet #</td><td>4.1</td><td>Timeframe:</td><td>Short term (0 - 2 years)</td><td>Budget range:</td><td>< 0.5 M USD</td></tr>
<tr><td>Linkages:</td><td colspan="5">Annex 4, Chapter 2, Annex 2, Chapter 6; This intervention sheet is connected to intervention sheet 4.8 (Diversion Ruo river) and sheet 4.9 (Support to Decision making on power interconnector Mozambique-Malawi).</td></tr>
<tr><td>Concept:</td><td colspan="5">ZAMCOM, when formally established, has the mandate to advise riparian states, after which the member states decide and enforce decisions. Lake Malawi is a natural lake with a natural barrier at its outflow into the Shire river. The Kamuzu Barrage is now influencing lake levels and mainly focused on flows for power generation in the Shire river. Three investments are being considered: upgrading of Kamuzu Barrage, pumping scheme at Mponda and Kholombidzo Reservoir.</td></tr>
<tr><td>Purpose:</td><td colspan="5">Mozambique and Tanzania need to be aware of potential impacts of changes in the regulaton of the Shire on the Lake Malawi – Shire system. ZAMCOM pointing out the impacts of the investments on economy and environment and potential flood damage on a river basin scale will assist the government of Malawi to make decisions that are well received by neighbouring countries.</td></tr>
<tr><td>Justification:</td><td colspan="5">The investments have international impact, therefore ZAMCOM has an advisory role and is a platform for dialogue between the affected countries.</td></tr>
<tr><td rowspan="3">Actions/ Responsibilities:</td><td colspan="4">• Support to Upgrading of Kamuzu Barrage which is in an advanced decision making stage, for easier operation of the barrage. The currently done EIA will reveal impacts for environment and human use around the lake. These impacts will depend on the operating rule curve. One gate is currently stuck and urgently in need of repair. If new barrage cannot be built soon, then repair to this gate needs to be done with urgency.</td><td>MIWD
and Tanzania and Mozambique</td></tr>
<tr><td colspan="4">• If the Kholombidzo Reservoir plan resumes, the initiator is advised for a more detailed study on impacts of Kholombidzo Reservoir on flood control and flow releases and on the environmental and socio-economic impacts. This request should not wait until a final design is made.</td><td>ZAMCOM advising MIWD, if Malawi decides to further develop next steps</td></tr>
<tr><td colspan="4">• If discussion about the Mponda Pumping Scheme resumes, the use is advised to be of a limited to a maximum period. The SADC secretariat can assist in promoting the installation of Malawi-Mozambique power inter-connectors instead (Intervention sheet 4.9).</td><td>ZAMCOM advising, only if Malawi again considers the pumping scheme</td></tr>
<tr><td rowspan="3">Benefits/ beneficiaries:</td><td colspan="4">• Upgrading of Kamuzu barrage contributes to extra hydropower generation and easier operation during floods. However, the impact of a 0.2 m higher operating level on upstream human use and ecology, should be considered in the decision making.</td><td>ESCOM; users of electricity in Malawi, MIWD as owner of barrage, upstream residents close to shore</td></tr>
<tr><td colspan="4">• Kholombidzo Reservoir contributes considerably to extra hydropower production. A high Kholombidzo Reservoir has an assessed average generation potential of 157 MW and an additional average continuous production of 22 MW at downstream power stations. A low Kholombidzo Reservoir can provide 170 MW in total. However, by extending power generation on the Shire, there is further dependency of Malawi on outflows from Lake Malawi for power generation.</td><td>ESCOM; users of electricity in Malawi</td></tr>
<tr><td colspan="4">• Not to built Mponda Pumping Scheme will prevent unnatural low levels in Lake Malawi. Not to built Mponda Pumping Scheme will save costs that can better be spent on power interconnector Malawi-Mozambique.</td><td>ESCOM, MIWD, fisheries and transport infrastructure and ecosystem in and around Lake Malawi</td></tr>
</table>

Means of implementation:	The role of the ZAMCOM interim secretariat is limited to diplomacy at this stage; discussing with MIWD the options considered and reacting to next steps undertaken by Malawi. Malawi is in the process of starting a flood and droughts management plan for the Shire subsystem.
Specific assumptions/ risks:	The relation of Malawi with both Mozambique and Tanzania with regard to the Zambezi River Basin is currently sensitive. With Tanzania there is a dispute about the border in the Lake. Mozambique has requested for a thorough EIA on the Shire-Zambezi Waterway. Also, the negotiations with World Bank and between the two countries around the power interconnector have not yet been finalised. The diplomatic intervention of the ZAMCOM (interim secretariat) could be essential.

ASSESS INVESTMENTS IN MULTIPURPOSE DAMS ON THE ZAMBEZI AND KAFUE RIVERS

Intervention Sheet #	**4.2**	**Timeframe:**	Short term (0 - 2 years)	**Budget range:**	Dependent on extent to which intervention is implemented, initially < 0.5 MUSD

Linkages:	Annex 4, Chapter 3; Also see intervention sheet 4.5 on bottom outlets.	
Concept:	ZAMCOM, when formally established, has the mandate to advise riparian states, after which the member states decide and enforce decisions.	
Purpose:	An assessment by ZAMCOM in reacting to the large hydropower investments will have the beneficial approach of forcing the project initiators to adjust designs and operating rules (and therewith the business plan) to better take account of flood control and the ecosystem and human use impacts in the decisions on new hydropower infrastructure. Decisions have been made to proceed with the Mphanda Nkuwa and Kafue Gorge Lower projects by the respective countries. These project developers will however need to consider advice from ZAMCOM with regard to the design, construction and operation of these projects. A decision on the implementation of Batoka Gorge is pending, while Boroma and Lupata are at prefeasibility stage. Itezhitezhi extension has received part of its financing.	
Justification:	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. An advice of ZAMCOM is therefore required.	
Actions/ Responsibilities:	• Support for investments in extra hydropower production at existing reservoirs.	ZAMCOM secretariat to SAPP, ZRA, ZESCO, ZRP, Member States
	• Awareness raising on contributions that new hydropower schemes can have for flood protection and the functioning of the ecosystem.	ZAMCOM / SADC in reaction to newly planned run-of-river schemes, Member States
Benefits/ beneficiaries:	• Extra turbines on existing dams will not only contribute to increased power generation, but will also increase the capacity to generate hydropower if reservoir water levels need to be reduced before forecasted floods, as more water is able to pass through the turbines rather than spillways. Such projects are planned for Kariba North, Itezhi-Tezhi Hydroelectric Project and Cahora Bassa Extension.	users of electricity, power producers, users of downstream floodprone areas
	• 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 region. Their reservoirs are relatively limited for storage of peak flows in comparison to the existing reservoirs of Kariba and Cahora Bassa, but additional power capacity can make it technically possible to release flood storage capacity in Kariba and Cahora Bassa. In comparison to normal reservoir power schemes, the reservoir size is relatively small in comparison to the power generating capacity, which is positive for its impact on human settlements, greenhouse gasses (large reservoirs can increase greenhouse gas emissions) and evaporation losses. The dams of Mphanda Nkuwa, Lupata and Boroma can be operated to contribute to more natural flows in the Zambezi Delta.	users of electricity in the region, users of downstream floodprone areas, ecosystem Zambezi Delta
Means of implementation:	The role of the ZAMCOM secretariat is limited to diplomacy at this stage; a heavy weighing advice in advanced decision making is not yet possible without ratification of ZAMCOM. The SADC secretariat can use the SADC Protocol on Shared River Basins and the Hydropower Sustainability Assessment Protocol (IHA, 2010) to raise awareness on the impacts of the	

	schemes.
Specific assumptions/ risks:	From an environmental viewpoint, large dams generally carry numerous environmental and social hazards, but run-of-river schemes in the already regulated Zambezi would not have the same significant negative impacts as large new reservoirs. Designs and operating rules are recommended to adequately address or minimise the negative environmental impacts.

<table>
<tr><th colspan="6">FACILITATE THE SITING OF NEW DAMS ON THE ZAMBEZI RIVER UNREGULATED TRIBUTARIES</th></tr>
<tr><td>Intervention Sheet #</td><td>4.3</td><td>Timeframe:</td><td>Medium term (0 - 5 years)</td><td>Budget range:</td><td>Budget to be determined national initiatives or RSWIDP (preliminary siting 10 dams ~ 0.15 MUSD)</td></tr>
<tr><td>Linkages:</td><td colspan="5">Annex 4, Chapter 4; Also see intervention sheet 4.5 on bottom outlets.</td></tr>
<tr><td>Concept:</td><td colspan="5">ZAMCOM, when formally established, has the mandate to advise riparian states, after which the member states decide and enforce decisions. Government officials in Zimbabwe, Zambia and Mozambique indicated that new dams in their own country for flood control purposes only have no priority. They need to be justified on some other economic benefit such as irrigation or hydropower.</td></tr>
<tr><td>Purpose:</td><td colspan="5">ZAMCOM assessing and assisting in the siting of new dams will help the different countries to decide on the positive and negative impacts that such dams can have.</td></tr>
<tr><td>Justification:</td><td colspan="5">ZAMCOM has a river basin wide responsibility. The similar challenges water resources development in different areas of the river basin ask for an active role of ZAMCOM where lessons can be learnt. If the dams are considerably large in size or number this will have river basin scale impacts in terms of flood and flow regulation and sediment management.</td></tr>
<tr><td rowspan="2">Actions/ Responsibilities:</td><td colspan="4">• Support for investments in small and medium dams for livelihoods. Assistance with identification of suitable sites in riparian countries or support with implementation of planned dams.</td><td>ZAMCOM /SADC secretariat</td></tr>
<tr><td colspan="4">• Making riparian countries aware of the technical possibilities and impossibilities of use of dams on unregulated tributaries for flood peak storage in conjunction with other uses, together with the impact on downstream and upstream uses. Further investigation would be necessary to determine if other flood protection measures are not more cost effective and can contribute better to ecosystem functioning and economy.</td><td>ZAMCOM / SADC secretariat</td></tr>
<tr><td rowspan="2">Benefits/ beneficiaries:</td><td colspan="4">• In Zambia and Mozambique in particular, the usefulness of dams for irrigation purposes is emphasized. Zimbabwe has existing plans for new dams for water supply and irrigation. The flood protection impacts are limited, but the contribution to livelihoods and to national economic development are appreciable. In planning for flood impact mitigation, finding alternative locations for resettlements of persons currently living in floodprone areas is needed. New dam sites can create those alternative locations.</td><td>livelihoods close to dam sites, people currently in floodprone who would consider resettlement</td></tr>
<tr><td colspan="4">• From a technical perspective, several dam sites were identified in this project that could contribute to flood protection. In Zimbabwe, there is a list of technically suitable dam sites that could be developed. Of these dams, the Gwayi-Shangani dam (635 Mm3) and the Kudu dam (1550 Mm3) on the Sanyati are large enough to have impact on the Zambezi river flows. Mozambique would benefit from new dams on the Luangwa in Zambia, but dams that can prevent flood peaks into Cahora Bassa are difficult to site without major environmental implications. Within Mozambique, technically suitable dam sites have been identified on the Luia and the Revubué. Decisions on the development of any of these dams will be predicated more on socio-economic, institutional, financial, political and environmental considerations than on physical site advantages and issues of basinwide flood control.</td><td>people currently in floodprone areas. In case of dams on Luangwa also the HCB.</td></tr>
</table>

	• Careful siting of dams taking into consideration impacts on basin wide sediment management will be important for ecosystems.	downstream ecosystems
Means of implementation:	This intervention sheet is in support of the project "Small Strategic Water Infrastructure Projects for Livelihoods" and the Regional Strategic Water Infrastructure Development Programme (RSWIDP) , to which is referred for follow up.	
Specific assumptions/ risks:	The identified 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 making floods more predictable. A considerable number of dams need to be developed, to create a significant impact. From an environmental viewpoint the technically identified dam sites on the Luangwa and Lusemfwa (tributary of the Luangwa) are strongly not recommended. For dam sites of tributaries downstream of Cahora Bassa the impact on sediment is of main importance.	

<table>
<tr><th colspan="6">SUPPORT THE CONSTRUCTION OF AN
EXTRA SPILLWAY AT CAHORA BASSA DAM</th></tr>
<tr><td>Intervention Sheet #</td><td>4.4</td><td>Timeframe:</td><td>Short term (0 - 2 years)</td><td>Budget range:</td><td>Only if flood consequences are not taken into account, < 0.5 MUSD</td></tr>
<tr><td>Linkages:</td><td colspan="5">Annex 4, Chapter 5</td></tr>
<tr><td>Concept:</td><td colspan="5">ZAMCOM, when formally established, has the mandate to advise riparian states, after which the member states decide and enforce decisions.</td></tr>
<tr><td>Purpose:</td><td colspan="5">A positive reaction of ZAMCOM can help HCB to find financial support for the extension of Cahora Bassa North. The extra spillway can contribute significantly to the ecosystem functioning upstream and downstream of the dam.</td></tr>
<tr><td>Justification:</td><td colspan="5">HCB is currently conducting a feasibility study on the extension of Cahora Bassa hydropower station that implies an extra spillway for Cahora Bassa reservoir with an additional generating capacity of between 600 and 1200 MW. Changes in the operation of Cahora Bassa reservoir will have impacts on floods in Mozambique and the lower Shire in Malawi. Also, the ecosystems functioning, in particular the functioning of the Zambezi Delta will be positively influenced by changes in the operating of Cahora Bassa. The extra spillway at Cahora Bassa makes it possible to increase change the current rule curve to a flat rule curve at 326 m.a.s.l.. This will increase reliability of supply of water and increase the head for hydropower generation in the end of the dry season. The storage capacity required for dam protection during floods is replaced by the extra spillway capacity to accommodate the 1:10,000 design flood.</td></tr>
<tr><td rowspan="3">Actions/ Responsibilities:</td><td colspan="4">• If advise is needed on the extra spillway, the advantages from an environmental perspective can be pointed out, but careful assessments of the impacts on maximum floods downstream are necessary.</td><td>ZAMCOM /SADC secretariat, if asked for by HCB or other stakeholders</td></tr>
<tr><td colspan="4">• If the design capacity is increased the risk management plan for the downstream area may have to be adjusted if the hydrological study indicates increased peak floods.</td><td>Mozambique</td></tr>
<tr><td colspan="4">• If the operating rule of Cahora Bassa will change and the extra spillway is affected, adjustments in requirements for the joint forecasting centre are necessary.</td><td>ZAMCOM /SADC secretariat and HCB</td></tr>
<tr><td>Benefits/ beneficiaries:</td><td colspan="4">• Apart from making it possible to generate extra power, the added benefit is environmental: the flat rule curve decreases the fluctuations in the levels in Cahora Bassa and deletes the unnatural effect of outflows before the flood season to lower lake levels. With a flat rule curve including an additional spillway, the release of freshets or prescribed floods for the benefit of the environment becomes a more viable option.</td><td>HCB, electricity users in SAPP, ecosystems</td></tr>
<tr><td>Means of implementation:</td><td colspan="5">Support to HCB, with mentioning of specific assumptions and risks, can be expressed in a letter. Coordination of changing needs for operating rule curves for the flow forecasting need will become an integral part of the further development of a basin wide flow forecasting centre.</td></tr>
<tr><td>Specific assumptions/ risks:</td><td colspan="5">The design of the prescribed floods (freshets) needs further study, as different sources give different options (long constant February flood release of 3900 m3/s or 14-day January flood release of 8000 m3/s) and the timing of the flood releases with expected high floods from the tributaries can have a significant impact on the effect of the environmental floods and the peak releases that are necessary. To make such coordinated releases possible also needs a good flow forecasting system.

The extra spillway in combination with the flat rule curve, makes the probabilities of high peak releases from Cahora Bassa higher than in the current situation. Much depends on the coordination with floods at tributaries from downstream, which require a good flow forecasting system. A flood in the lower Zambezi is never caused by Cahora Bassa on its own but is also dependent on flows from unregulated tributaries below the dam.</td></tr>
</table>

Comments:	Strong conclusions and recommendations need to wait for results of on-going feasibility studies on the extension of Cahora Bassa North Bank, expected in 2011. If the flat rule curve is introduced, Cahora Bassa may be in even more need for a good flow forecasting system, see Annex 3. A reaction to the new operating rule curve will also draw from conclusions in Annex 2.

<table>
<tr><th colspan="6">PROVIDE ADEQUATE BOTTOM OUTLETS IN NEW DAMS</th></tr>
<tr><td>Intervention Sheet #</td><td>4.5</td><td>Timeframe:</td><td>Short term, medium term, long term</td><td>Budget range:</td><td>< 0.5 MUSD for development of guidelines</td></tr>
<tr><td>Linkages:</td><td colspan="5">Annex 4, Chapter 8</td></tr>
<tr><td>Concept:</td><td colspan="5">ZAMCOM, when formally established, has the mandate to advise riparian states, after which the member states decide and enforce decisions. Bottom outlets have different functions, among which is sediment management.</td></tr>
<tr><td>Purpose:</td><td colspan="5">Understanding of ministries of water in member states of the function of bottom outlets can contribute to design decisions that will affect the river basin for a long time.</td></tr>
<tr><td>Justification:</td><td colspan="5">Bottom outlets are difficult to change after construction of the dam and therefore need careful consideration at design stage. Sizing of bottom outlets has much downstream impacts, impacts on the lifespan of the dam and cost impacts.</td></tr>
<tr><td rowspan="2">Actions/ Responsibilities:</td><td colspan="4">• Development of guidelines or combining of guidelines to ascertain that environmental, safety, lifespan and cost impacts of sizing of bottom outlets are sufficiently taken into account during dam designs.</td><td>Engineering councils in riparian states, designers of dams and owners of the dams; SADC Secretariat could support development of guidelines.</td></tr>
<tr><td colspan="4">• Assessment of correctness of size of bottom outlets for larger dams</td><td>Ministries of Water Member states</td></tr>
<tr><td>Benefits/ beneficiaries:</td><td colspan="4">Bottom outlets are often required for other reasons than sediment management: preventing siltation of the dam, reducing turbidity of the released water to downstream users of the water, being able to maintain minimum environmental flow releases, being able to lower the water level fast in the event of an emergency for dam safety purposes.</td><td>Ecosystem, downstream water users, residents in floodprone areas downstream</td></tr>
<tr><td>Means of implementation:</td><td colspan="5">Dependent on Actions to be taken: seminars or design manuals, design approvals.</td></tr>
<tr><td>Specific assumptions/ risks:</td><td colspan="5">In considering the use of bottom outlets for sediment management downstream it is important to understand that; flushing can have detrimental environmental impacts both in the reservoir and downstream. Further, flushing whereby the dam is emptied at the beginning of the flood season, is only an option for small and medium sized dams that do not generate hydropower. For large reservoirs flushing of sediment is also not an option as sediment has already settled upstream.

Flushing of sediment will in any case require very experienced dam operators. Also releasing water from bottom outlets requires experienced dam operators, to carefully manage the required mixing of water from different levels of the dam, to prevent direct release of cold, nutrient-rich (hypolimnion) waters from the bottom of the reservoir downstream.

The costs of bottom outlets increases considerably with the maximum flow to be accommodated. Capital costs of bottom outlets also depend on the type of dam and the head of water. Larger gates create other forces on the dam wall and may need extra protection measures against erosion downstream.</td></tr>
<tr><td>Comments:</td><td colspan="5">This intervention sheet also advises on new dam structures that are discussed in intervention sheets 4.2 and 4.3.</td></tr>
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<table>
<tr><th colspan="6">SUPPORT THE COORDINATION
OF FLOOD RISK ZONING INITIATIVES</th></tr>
<tr><td>Intervention Sheet #</td><td>4.6</td><td>Timeframe:</td><td>Short term</td><td>Budget range:</td><td>< 0.5 M USD for coordination of initiatives</td></tr>
<tr><td>Linkages:</td><td colspan="5">Annex 4, Chapter 6</td></tr>
<tr><td>Concept:</td><td colspan="5">Improved flood protection through flood risk zoning can replace flood protection through dam management or extra dams.</td></tr>
<tr><td>Purpose:</td><td colspan="5">Flood risk zoning can serve for regulations for new settlements, current land use practices and rescue and warning.</td></tr>
<tr><td>Justification:</td><td colspan="5">Flood risk zoning coordination at a river basin scale can make efforts of flood risk zoning on a national or local scale more cost efficient and effective. For the areas downstream of the dams, flood risk zoning can improve continuous awareness that dams can spill and therefore cause out of season flooding and/or sudden rise of flood levels. Their are current initiatives in parts of the catchment that each apply different metionds: for example UNOSAT for flood mapping in parts of Mozambique and Caprivi strip for rescue and warning, UN Habitat in Mozambique for new settlements, International Federation of Red Cross for vulnerability assessment for rescue and warning, FEWS Net for early warning, ZRA around Kariba dam to influence current land use practices and new settlements.</td></tr>
<tr><td>Actions/ Responsibilities:</td><td colspan="4">Coordination of different flood risk zoning initiatives currently being developed independently in different riparian countries; further identification of the benefits and limitations of coordination and the possibilities of innovative techniques.</td><td>ZAMCOM / SADC Secretariat to coordinate, Member States to commit.</td></tr>
<tr><td>Benefits/ beneficiaries:</td><td colspan="4">Flood risk zoning efforts can contribute to a combination of:
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
Warning and rescue: risk zoning to use during emerging flood events to set priorities
Coordination between current mapping activities in the Zambezi River Basin is a first and useful step in Risk Zoning that will also benefit flood forecasting and involvement of international relief organisations during floods as well as the understanding between neighbouring countries.</td><td>Residents in floodprone areas. Disaster Management organisations, Surveyor generals, Ministries of Water</td></tr>
<tr><td>Means of implementation:</td><td colspan="5">ZAMCOM / SADC Secretariat to organise workshop between different initiatives, possibly in combination with FEWS Net.</td></tr>
<tr><td>Specific assumptions/ risks:</td><td colspan="5">Flood risk zoning rules for new settlements or for current land use and awareness raising only makes sense as an investment if such a system will be respected by local inhabitants. If flood risk zoning is introduced as a ‘rule’, legal experts and local governments have to be able to ensure compliance, which has proven to be difficult. Flood risk zoning for flood insurance is not a viable option in the Zambezi Region because the economies of the region have not developed well enough to create a market for such insurance and because the data availability prevents good risk calculations.</td></tr>
<tr><td>Comments</td><td colspan="5">Data availability in the region for flood risk zoning is limiting the possibilities for flood risk zoning. A map of maximum flood extents, however, is easy to compile and is useful. Fortunately, only a small level of investment would be needed for the production of such a map. Mapping of flood frequencies, on the other hand, is more difficult. For example, the flood risk zoning around Kariba, where a distinction is made of zones for multi-year crops and seasonal crops, can be copied to other locations. However, it must be noted that in many floodprone areas in the basin local people have already adapted such approaches without any official flood risk zoning, but have decided that there are little viable options for them to move elsewhere.

The current developments in remote sensing will contribute significantly to improved and less costly flood risk zoning in the near future.</td></tr>
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<table>
<tr><th colspan="6">SUPPORT LOCAL MULTIPURPOSE MEASURES WHICH ADD TO FLOOD PROTECTION</th></tr>
<tr><td>Intervention Sheet #</td><td>4.7</td><td>Timeframe:</td><td>Short term</td><td>Budget range:</td><td>< 0.5 MUSD coordination, if not part of ongoing activities. Budget to be determined locally for implementation.</td></tr>
<tr><td>Linkages:</td><td colspan="5">Annex 4, Chapter 7</td></tr>
<tr><td>Concept:</td><td colspan="5">Improved flood protection through structural flood protection measures can replace flood protection through dam management or extra dams. Investments in education and road infrastructure have higher priority in the Zambezi riparian states than investments in physical flood protection measures.</td></tr>
<tr><td>Purpose:</td><td colspan="5">The financial resources of the riparian countries are limited. Combining the efforts of different government departments, local buildings that are located on high ground above flood risk areas can be used as refuge sites during floods and road infrastructure can be made more flood resistant. To achieve this public buildings would be designed and built with their use as flood refuge sites in mind.</td></tr>
<tr><td>Justification:</td><td colspan="5">As a regional knowledge broker, SADC can advocate good experiences gained in other river basins for use in the Zambezi River Basin to support local . Quotation of such success stories will make search for funding easier.</td></tr>
<tr><td rowspan="2">Actions/ Responsibilities:</td><td colspan="4">• Share examples of other river basins or other countries in the Zambezi river basin, for example flood resistant schools and public buildings in the Limpopo River Basin, to the different riparian countries of the Zambezi basin and draw further lessons from country strategies on adaptation measures for floods.</td><td>SADC water and/or infrastructure secretariat in coordination with ZAMCOM secretariat,</td></tr>
<tr><td colspan="4">• Coordinate various government Ministries in the siting and designing of government infrastructe to make buildings multipurpose and suitable for flood refuge and to make roads, bridges and water and sanitation infrastructure flood resistant or suitable for flood protection. .</td><td>Different Ministries in riparian countries</td></tr>
<tr><td>Benefits/ beneficiaries:</td><td colspan="4">• Improved public buildings.
• A clear location of refugee centres which provides temporary shelter and are known by Disaster Management Agencies and local residents.


• Less damage to infrastructure after floods (roads, water and saniatation)</td><td>Children in flood prone areas in their education,
Residents in flood prone areas.

Governments who are to rehabilitate state infrastructure after floods.</td></tr>
<tr><td>Means of implementation:</td><td colspan="5">Contact UN Habitat Mozambique to learn of ways to promote interventions.</td></tr>
<tr><td>Specific assumptions/ risks:</td><td colspan="5">The new schools may attract new residents in floodprone areas as the facilities have a far higher standard than provided currently for education in the region.</td></tr>
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<table>
<tr><th colspan="6">CONSIDER LOCAL STRUCTURAL FLOOD PROTECTION MEASURES OR DIVERSION OF FLOODS</th></tr>
<tr><td>Intervention Sheet #</td><td>4.8</td><td>Timeframe:</td><td>Medium term</td><td>Budget range:</td><td>Budget to be determined per iniative by action holders</td></tr>
<tr><td>Linkages:</td><td colspan="5">Annex 4, Chapter 8 and Chapter 2 section 2.</td></tr>
<tr><td>Concept:</td><td colspan="5">Improved flood protection through flood risk zoning and structural flood protection measures can replace flood protection through dam management or construction of additional dams. Local options for flood protection depend on further investigations locally.</td></tr>
<tr><td>Purpose:</td><td colspan="5">Further investigation of identified flood protection measures can help to assess the feasibility of these measures.For the floodprone areas suitable flood protection measures need to be tailor made for local circumstances and national governments are taking actions.</td></tr>
<tr><td>Justification:</td><td colspan="5">For ZAMCOM it is important to have a good overview of the different flood protection measures being followed by the different member states, because the measures may have transboundary impacts or because riparian countries can learn from each other. In addition, possibilities identified during this study can be brought to the attention of the member states. The support of ZAMCOM can assist in the identification of financiers for further investigations. The measures below for which further investigation is recommended have not been part of the evaluation in this study, but have been identified during the study as possible alternatives.</td></tr>
<tr><td rowspan="4">Actions / responsibilities</td><td colspan="4">Actions below are examples of flood protection measures identified during the study, but other floodprone areas may require additional actions.</td><td>Governments ripariation states, for the examples specified as:</td></tr>
<tr><td colspan="4">• Further investigate the adjustment of Ngoma bridge in the Chobe floodplains between Botswana and Namibia.</td><td>Namibia (Department of Water Affairs is taking initiative</td></tr>
<tr><td colspan="4">• Further investigation in the diversion of flows of the Ruo River into Elephant Marsh where there are very large pools (more than 10 sq km). The pools can then function as retention pools to attenuate flood peaks and reduce flooding around and downstream of Shire Ruo confluence.</td><td>Malawi (Ministry of Disaster Management is coordinating this initiative)</td></tr>
<tr><td colspan="4">• Further investigation into the options of diversion of flows to the Marromeu Buffalo Reserve of the Zambezi Delta or alternatively create locally elevated areas for refuge.</td><td>Mozambique (Ministry of Water Affairs to take the lead)</td></tr>
<tr><td rowspan="4">Benefits/ beneficiaries:</td><td colspan="4">Benefits below refer to the examples mentioned in the actions.</td><td></td></tr>
<tr><td colspan="4">The adjustment of Ngoma bridge could assist in flood protection downstream, creation of fishing opportunities and a positive impact on tourism and wildlife. Both Botswana and Namibia would benefit.</td><td>Namibia and Botswana. Residents in flood prone areas on Chobe river as well as ecosystem there.</td></tr>
<tr><td colspan="4">Diversion of flows of the Ruo through Elephant Marsh Low could reduce the impact of flooding in the downstream Shire and can possible contribute to ecological conditions in the Elephant Marsh.</td><td>Malawi. Flood prone areas Lower Shire and possibly the ecosystem in Elephant Marsh</td></tr>
<tr><td colspan="4">Diversion of flows through Marromeu Reserve would improve the ecological conditions in the marsh and reduce the impact of flooding in surrounding areas of the delta that are populated..</td><td>Mozambique. Ecosystem of the Zambezi Delta and residents in surrounding flood prone areas</td></tr>
<tr><td>Means of implementation:</td><td colspan="5">Further studies will need to be conducted for affected areas, where measures are not yet idenfitied. The measure mentioned for the Chobe already has the intention of Namibia. An Integrated Flood And Drought Risk Management Plan For The Shire Basin in Malawi will be conducted, as advertised January 2011 by the Worldbank. Diversion of flows through the</td></tr>
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	Marromeu Reserve has been suggested in studies for the WWF.
Comments	Also in other regions local interventions in flood protection measures may be useful and cost effective, but these were not identified in this study.

<table>
<tr><th colspan="6">SUPPORT NEW SAPP INTERCONNECTIONS</th></tr>
<tr><td>Intervention Sheet #</td><td>4.9</td><td>Timeframe:</td><td>Short term</td><td>Budget range:</td><td>Not applicable, part of ongoing activities</td></tr>
<tr><td>Linkages:</td><td colspan="5">Annex 4, Chapter 2, Chapter 9</td></tr>
<tr><td>Concept:</td><td colspan="5">Improved interaction of energy and water management and its role in flood protection and environmental releases is assisted through investments in the SAPP network.</td></tr>
<tr><td>Purpose:</td><td colspan="5">Establishment of SAPP interconnections between countries releases the pressure on optimal power production at the hydropower sites in the Zambezi River Basin</td></tr>
<tr><td>Justification:</td><td colspan="5">Malawi is not yet connected to the SAPP network and the limited capacity of the SAPP network is a bottleneck for further export from and import to the Zambezi riparian countries, in particular the interconnections in Zimbabwe which is the backbone of the SAPP network. Also, current thermal power plants in the basin need upgrading. The SADC Water and Energy Secretariat can play a role in advocating for better interconnections.</td></tr>
<tr><td rowspan="2">Actions / responsibilities</td><td colspan="4">• Support to the negotiations between the World Bank, Mozambique and Malawi on the interconnector between Mozambique and Malawi</td><td>SADC Energy Secretariat, SAPP</td></tr>
<tr><td colspan="4">• Support to enhanced and new SAPP interconnections and refurbishment of thermal power stations</td><td>SADC Energy Secretariat, SAPP</td></tr>
<tr><td rowspan="2">Benefits/ beneficiaries:</td><td colspan="4">The pressure on the optimal power generation in the Shire subsystem will be less if it becomes possible for Malawi to obtain energy from other sources. The interconnector will give flexibility in the management of the Shire River and Lake Malawi levels, and there will be little need for the Mponda Pumping scheme, as the energy security is enhanced. There is a possibility to supply the growing energy demand of Malawi (now 300 MW) with power from Mozambique which also translates to extra income for HCB.</td><td>Malawi as energy user and Mozambique as energy supplier. HCB and ESCOM.</td></tr>
<tr><td colspan="4">The SAPP countries will have less blackouts and the countries with a surplus of hydropower (during certain periods of the year) have more possibilities to export their electricity production. The planned interconnector between Zambia and Tanzania can link the SAPP to the East African Power Pool. Other planned new and enhanced SAPP interconnectors are: Botswana-Zimbabwe, Mozambique-South Africa, DRC-Zambia-Zimbabwe-South Africa,Zimbabwe/Zambia-Botswana.</td><td>All hydropower producing countries, in particular Zambia, Mozambique, Malawi. All hydropower importing countries (in particular South Africa)</td></tr>
<tr><td>Means of implementation:</td><td colspan="5">The SADC Water Secretariat informs the SADC Energy Sector to take account of the benefits of an improved SAPP network for water management in the implementation of their investments plans. The SADC Energy Sector can communicate to SAPP and to member states to take account of these benefits.</td></tr>
<tr><td>Specific assumptions/ risks:</td><td colspan="5">Further improvement of the SAPP network may increase the pressure on optimal power production. South Africa may want to import more electricity from the Zambezi hydropower stations.</td></tr>
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<table>
<tr><th colspan="7">SUPPORT FORECASTING CENTRE AND DISPATCHING CENTRE FOR SAPP</th></tr>
<tr><td>Intervention Sheet #</td><td>4.10</td><td>Timeframe:</td><td>When flow forecasting centre is designed.</td><td>Budget range:</td><td colspan="2">< 0.5 MUSD for coordination with SAPP</td></tr>
<tr><td>Linkages:</td><td colspan="6">Annex 4, Chapter 9, (Chapter 6 for impact on flood risks of sudden opening of spillways, Appendix B for impact on sediments of sudden opening of spillways)</td></tr>
<tr><td>Concept:</td><td colspan="6">Improved interaction of energy and water management and its role in flood protection and environmental releases is assisted coupled with the proposed flow forecasting system and the SAPP Dispatch Centre.</td></tr>
<tr><td>Purpose:</td><td colspan="6">Improving the Flow Forecasting Centre to be able to couple with SAPP Dispatch Centre to optimize power production and water management</td></tr>
<tr><td>Justification:</td><td colspan="6">ZAMCOM and SAPP are both regional institutions. If the Zambezi Basin wide flow forecasting centre is established use of this forecasting Centre in conjunction with SAPP operations makes sense.</td></tr>
<tr><td rowspan="2">Actions / responsibilities</td><td colspan="5">• When developing the forecasting Centre Contact, SAPP needs to be involved in an early stage in the design</td><td>ZAMCOM secretariat and SAPP</td></tr>
<tr><td colspan="5">• Examples in the rest of the world where dispatch centres and flow forecasting centres are exchanging information, should be consulted.</td><td>ZAMCOM secretariat and SAPP</td></tr>
<tr><td rowspan="4">Benefits/ beneficiaries:</td><td colspan="5">• Where floods are expected, power production can increase, with the effect of evening out flows to simulate natural conditions, as opposed to sudden opening of spillways. More natural releases from dams can be used as warning signals to downstream communities ahead of flood causing releases from these dams, besides being good for the ecosystem and sediment management</td><td>Residents in floodprone areas downstream of dams, Ecosystems downstream of dams</td></tr>
<tr><td colspan="5">• This creates possibilities for saving water in locations in the region where droughts are expected</td><td>Dam operators, dam management beneficiaries</td></tr>
<tr><td colspan="5">• Overall additional hydropower generation can be optimized</td><td>Electricity Suppliers, users of electricity</td></tr>
<tr><td colspan="5">• Advantages for power production may create revenue for Flow Forecasting Centre</td><td>Beneficiaries of Flow Forecasting Centre</td></tr>
<tr><td>Means of implementation:</td><td colspan="6">When ZAMCOM develops the flow forecasting centre it makes SAPP aware of this development and takes account of the SAPP requirements in further designs to make it possible to connect to a dispatch centre.</td></tr>
<tr><td>Specific assumptions/ risks:</td><td colspan="6"></td></tr>
<tr><td>Comments</td><td colspan="6">Examples of combined flow forecasting and dispatch centres are along the Powell and Campbell Rivers in British Columbia and in North Carolina. Case studies for designs have been published for Three Gorges and Gezhouba in China.</td></tr>
</table>

<table>
<tr><th colspan="6">CARRY OUT A FINANCIAL ASSESSMENT OF THE PROJECT RECOMMENDATIONS AND THE IMPLICATIONS OF IMPLEMENTATION</th></tr>
<tr><td>Intervention Sheet #</td><td>4.11</td><td>Time Frame:</td><td>Short to long term</td><td>Budget range:</td><td>Budget to be determined per recommendation to be investigated.</td></tr>
<tr><td>Linkages</td><td colspan="5">Main report, Annex 1, Annex 2, Annex 3, Annex 4</td></tr>
<tr><td>Concept:</td><td colspan="5">To implement each of the project recommendations will draw upon financial resources of the organisations responsible for implementation and the implementation may have positive or negative economic and social impacts.</td></tr>
<tr><td>Purpose</td><td colspan="5">To prioritize and develop the project intervention sheets into bankable project proposals, assessment of the financial, economic and social impacts of implementing the Project's recommendations is recommended.</td></tr>
<tr><td>Justification:</td><td colspan="5">The Project presents overall concepts and recommendations on ways and means of improving dam management, flow forecasting, hydropower generation, flood protection and environmental flows in the Zambezi River Basin. In general, studies that to improve the dam operating rules and the development of a basin-wide flow forecasting system or investments that improve flood protection or environmental releases, can contribute to the transboundary management of the Zambezi River with due regard for all diverging interests.

Some of the Project's interventions are studies and assessments, including pilot projects. It is premature at this stage to give a comprehensive "if/then" analysis of all the Project's recommendations. Implementing dam management recommendations for the benefit of flood protection or environmental releases will affect power generation. A basin-wide flow forecasting system will provide other benefits besides flood protection and environmental releases, such as improved power production and drought management. Most of the investments investigated in the Project do not consider water management issues for the prevention of floods or the regulation of environmental releases as a first objective. Therefore implementing the recommendations of this the Project may require compromises or may have additional benefits.

The intention of this recommendation is to provide a holistic understanding of the financial, economic and social costs, risks and benefits of the proposed Project Recommendations that are taken further. This financial, economic and social assessment of the Project's Recommendations will facilitate the identification and improved understanding of the anticipated impacts should the Recommendations be implemented and would be the first step in preparing stakeholders, decision makers and funding agencies for implementation, before any commitments are made. It is thus important and critical that this assessment is undertaken before implementation of the preselected recommendations.</td></tr>
<tr><td>Actions/ Responsibility</td><td colspan="3">• Carry out an Assessment Study on the financial, economic and social impacts of implementing the Project's Recommendations.</td><td colspan="2">• ZAMCOM Secretariat, Consultant</td></tr>
<tr><td rowspan="3">Benefits/

Beneficiaries:</td><td colspan="3">• Improved understanding of the overall financial, economic and social impacts of implementing each Project Recommendation, if selected for assessment. This will inform potentialstakeholders /funders before any commitment to implementation is made.</td><td colspan="2">• All stakeholders, but the main beneficiaries would be Dam and Barrage Operators, Disaster Management Agencies and the citizens of Riparian States living in flood prone areas.</td></tr>
<tr><td colspan="3">• Better informed prioritization of the Recommendations.</td><td colspan="2">• Organisations responsible for or funding the recommendations</td></tr>
<tr><td colspan="3">• Possibility to initiate development of risk management plans for recommendations that may have negative impacts.</td><td colspan="2">• Stakeholders negatively affected by implementation of the recommendations. Or those responsible to mitigate negative impacts.</td></tr>
<tr><td>Means of implementation:</td><td colspan="5">• Assessment study / Assessment studies for groups of recommendations.</td></tr>
<tr><td>Specific assumptions/risks</td><td colspan="5">• This should be considered as a short to long term intervention to allow prioritization and sequencing of the Project's recommendations.
• Depending on the particular recommendation being investigated, dam operators, power producers and stakeholders would need to be engaged to obtain their acceptance of the</td></tr>
</table>

	associated assessment. • It is not logical to undertake such assessments for all recommendations as this will increase the cost of each assessment and additionally be too complicated to manage. Each of the recommendations have been prioritized in the Main Report. If this prioritization is accepted by the stakeholders, recommendations of Priority 1 and recommendations that would need long preparation times would be given priority for assessment. Some recommendations clearly do not have large financial costs or high economic and social impacts so do not need an assessment at all. • Before starting an assessment as proposed above, dependent on the project recommendation considered, the availability of data to do such an assessment and the possible insights that can be gained within the project budget and time should critically be looked at. Some insights in impacts can only be computed a priori at a very course level of accuracy, because of all other external influences that will impact on the objectives of the project recommendation. It also needs to be taken into consideration if prioritization will take place at catchment scale or at national scale (see chapter 11).
Comments	This is a cross-cutting Recommendation that does not deal with Investments only but with all Project Outputs. It has been placed under Annex 4 as this is the closing Annex and because social and economic impacts are mainly discussed in this Annex.

11.3 Recommendations for development phases of investments

For different project development phases the activities recommended by SADC for the RSWIDP project development form can be followed. These phases have been developed by the Infrastructure Consortium Africa (ICA) (SADC Regional Strategy for Water Infrastructure Development Programme, SADC, unknown date). Following the ICA phases, below are considerations recommended for each phase.

11.3.1 Project Enabling Environment

The Project Enabling Environment phase includes activities on enabling Legislation, Regulatory Approaches, Institutional Reforms, Capacity Building, Consensus Building. In this respect it is emphasized that:

- The emphasis of SADC/ZAMCOM in contributing to reconnaissance of investments will be on investments that have a strong regional component. Ways to support these in further reconnaissance are prioritization in the SADC Water Infrastructure Programme Implementation Framework or in the SADC Regional Infrastructure Development Master Plan and other regional prioritizing possibilities. The link to outside the water sector goals in the national political priorities / policies also helps (for example, connecting to Millennium Development Goals or to a national priority like the 'agricultural revolution' in Mozambique);
- For a first assessment before the real pre-feasibility stage the criteria used in this report can be a start, if the focus is on flood control and environmental releases (See further Chapter 1):
  - Is the investment physically and legally feasible?
  - Does the investment contribute to flood protection?
  - Does the investment have impact on the river and its associated ecosystem?
  - Is the investment cost effective for flood protection and/or flow regulation?
  - Does the investment have impact on resource economic objectives and other human uses?
  - Does the investment otherwise have impact the biophysical behaviour of the river basin?
  - Is the realization likely to happen?
  - Does the investment benefit two or more countries?
- In the Zambezi River Basin for much of the land, the persons occupying the land are not legal owners as they do not hold formal title to the land but only user rights to the land. It is not expected that legislation can be changed for these investments, it is rather pointed out here that decision making processes for such land are different than for private land. For dams and dykes and other spatially impacting investments this will have effect. It is in most countries the State's responsibility to protect the community owned land. In case of an investment or infrastructure that will benefit the community or where the community can be compensated, due processes need to be followed with these communities;
- It cannot be overemphasized that many investments in the Zambezi River Basin have failed in the operation and maintenance phase. Already in the enabling phase it will be important to think about costs recovery, human capacity, replacement of mechanical and electrical equipment. It is important to assess the carrying capacity of the legal owners of the investment; and
- Consensus building will be a major issue for most investments with an international impact. Consensus building requires first that actors and stakeholders of an investment recognize that this investment may impact on them, that it may come to implementation of this

investment and that there is a role for them to play in the decision making process at this phase of decision making.

11.3.2 Project Definition

This phase includes: Identification of Desired Outputs, Prioritization versus other Projects, Identification of Project Partners and Action Planning, Pre-feasibility Studies.

As learning lessons from this study it is emphasized that:

- The level and scope of the outputs are important to define. Is it protection against damage of floods or is it poverty alleviation? The latter opens far more alternative options for investment. :
- Project partners in terms of hydropower development include the reservoir operators and power companies which each have a particular legal (and historical) status. They have to meet business targets which follow another way of decision making than government investments. It may require some further investigation if they are legally bound to agreements or protocols signed by the governments, for example to the Protocol for Shared Water Courses:
- In 2010, Worldwide Fund for Nature started a four year programme on environmental flow requirements. The insights gained in this project can feed into the to the project definition. World Wide Fund for Nature, JA! and International Rivers are the organizations that seem most vocal in the defense of impacts on the ecosystems. It may be good to inform them and seek their opinion in an early stage: and
- For the prefeasibility studies of hydropower investments it is recommended to consider the use of the assessment framework developed by the Hydropower Sustainability Assessment Forum (IHA, 2010). The World Commission on Dams also proposed procedures for assessment of the building of dams. These were however considered by SADC (2006) as too time consuming to apply in SADC. An assessment as proposed in intervention sheet 4.11 should also be only used when considered useful; the available data can give insight before the decision needs to be made to move ahead or not with a certain project.

11.3.3 Project Feasibility

This phase requires; Organizational and administrative support required to sponsor the project, Financial Modeling, Economic, Environmental and Social Evaluations. Further technical designs.

As learning lessons from this study it is emphasized that:

- It is important to be clear in the TOR for preliminary design on design objectives that take note of the environment, for example flow capacities of bottom outlets of dams, considerations of upstream flooding for spillways; and
- Economic, environmental and social evaluations have to follow nationally specified procedures. It is useful to already align these to similar procedures necessary for possible financiers.

11.3.4 Project Structuring

This phase requires; Public – Private Options Assessment, Project Finance, Legal Restructuring, Technical / Engineering adjustments or further detailing.

As learning lessons from this study it is emphasized that:

- Bilateral financing financiers seem currently most 'active' in the Zambezi River Basin for water management and hydropower infrastructure. China, Brazil, Japan and to a lesser extent Italy show up in the financing lists. International banks each have infrastructure financing possibilities. The African Development Bank, the Development Bank of Southern Africa, the World Bank, the European Investment Bank are each playing a role;
- Financing can be coupled to other 'deals' which require another approach than the normal procedures offered by banks or donors. In particular Chinese finances for water infrastructure are related to decisions on for example mining. Chinese firms offering engineering and construction services can also be a condition of the financing contract: and
- Many projects in Southern Africa are not realized because they are not 'bankable'. It is important to approach timely and in the correct way. See Box 12-1.

11.3.5 Transaction Support

This phase requires; Ongoing Project Finance Structuring, Ongoing Legal Structuring, Ongoing Technical / Engineering Structuring, Procurement Restructuring. No specific learning lessons from this Study are obtained for this phase.

11.3.6 Post – Implementation Support

This phase requires; Monitoring, Evaluation, Re-negotiations / Refinancing.

As learning lesson from this study it is mentioned that:

- Operation and Maintenance has often not sufficiently been thought through before the investment was done; the costs, the human capacity, the material necessary for operation and maintenance. This requires already in the Enabling environment phase sufficient attention, but is here re-emphasized.

Box 11-1 Ways to approach financiers

Learning lessons adapted from the Recommended Strategy for Small and Medium Dam Development in the Pungwe River Basin (De Groen *et al.*, 2009)

- The way in which, and via whom the introduction to financiers is done, is important. It is good to first approach verbally and then explain the request in writing. Donors / Financiers that link to a certain part of government make priorities through this government, be it a ministry or a province. Before the financier is approached it is good to coordinate with their local partner. A donor conference could be a solution, but first make sure that a relationship is built up with the persons responsible for managing the funds.

- It may be necessary to combine different financiers for different parts of the project, as they all have their own objectives and roles. Financiers can play a role in finding other financiers. Some have a coordinating role on behalf of other donors (i.e. GTZ for international river basin management, Netherlands Embassy for water infrastructure in Mozambique)

- The more support is arranged from stakeholders, the more chances of success for financing. This support should therefore also be arranged. In programmes that have a target area that covers for example the whole of a country, projects in the Zambezi River basin will compete with other projects elsewhere and support at national government level is critical in getting finance to be made available.

- To make the project "bankable" it is important to explain the contribution to the objectives of the programme through which the funds will be made available. These are often linked to international goals set like the Millennium Development Goals or Johannesburg 2020, or could emphasize the need to connect to priorities set by the national governments or to the Protocol on Shared Water Resources.

- To make the project a success in terms of outcome, financing has also to be found for additional activities/infrastructure that are related to the infrastructure. For example, dams for livelihood development via agriculture, may need extra financing for agricultural activities

- Clarity on cost recovery of monitoring, operation and maintenance costs is an advantage when trying to obtain funding for capital costs. This is not only necessary for financiers who want return on investment (loans or equity based financing) but for all financiers that are concerned about sustainability. Cross-subsidies are possible from large hydropower dams to small dams for subsistence irrigation.

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Appendix A
Assessment of dam sites planned in the Zambezi River Basin

This Appendix supports Chapter 3 and 4.
As a first selection of potential dam sites for unregulated rivers, a literature study was done. On the basis of this information, some criteria of this study could be evaluated, which are reported on in this Annex. The letters A to G refer to the criteria of this study as explained in Chapter 1.

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; and
H Impact on more than one country.

Table A.1: Dam sites identified by stakeholders or in literature.

River	Scheme	Location			Evaluation criteria of this study	Sources
		Country	Sub-basin	Description		
Upper Zambezi						
Lumbage	Unnamed 1	Angola	12	North East corner of Angola (S 11°27' E 23°30')	B - Small potential for flood protection due to size of project (1)	(1)Worldbank, 2010
Luvua	Unnamed 4	Angola	12	Upstream of Upper Zambezi wetlands (S 11°55' E 22°49')	B - Small potential for flood protection due to size of project (1)	(1)Worldbank, 2010
Luizavo	Unnamed 5	Angola	12	North East corner of Angola (alt. names: Luisaba Luisabo - S 11°40'	B - Small potential for flood protection due to size of project (1)	(1)Worldbank, 2010

River	Scheme	Location Country	Sub-basin	Description	Evaluation criteria of this study	Sources
				E 23°10')		
Lufuige	Unnamed 8	Angola	12	Before Upper Zambezi crossing Angola/Zambia border (S 12°53' E 22°45')	B - Small potential for flood protection due to size of project (1)	(1)Worldbank, 2010
Macondo	Unnamed 9	Angola	12	North East of Angola (S 12° 34' 60” E 23°45')	B - Small potential for flood protection due to size of project (1)	(1)Worldbank, 2010
Middle Zambezi						
Gwayi	Gwayi-Shangani dam (1)	Zimbabwe	6	At the confluence of Gwayi and Shangani	A - Feasibility study done (3) B - Live storage capacity 634 000 Ml (2) D - Cost effective (hydropower, flood control, water supply) E - Water supply to Bulawayo (270 km) (2) Hydropower generation +2 MW (2)	(1)ZINWA, 2010 (2) Ministry of Energy, Water Resources Development, 1992 (3) Ministry of Water Development, 1981
Gwayi	Gwayi Umguza(1)	Zimbabwe	6	On tributary of Gwayi located 115 km North West from Bulawayo	A - Prefeasibility investigation have been carried out	(1)ZINWA, 2010
Gwayi	Bubi Lupane(1)	Zimbabwe	6	On tributary of Gwayi located 115 km South East from Gwayi-Shangani dam site	No info found	(1)ZINWA, 2010
Sanyati	Kudu dam (1)	Zimbabwe	6	Site between Kadoma and Gokwe	No info found	(1)ZINWA, 2010
Sanyati	Mhondoro (1)	Zimbabwe	6	On Mupfure tributary, 60 km SW of Harare (2)	A - Feasibility study (3) E - Water supply (2)	(1)ZINWA, 2010 (2)Makoni *et al.*, 2001 (3)Ministry of Water Development, 1981

River	Scheme	Location Country	Sub-basin	Description	Evaluation criteria of this study	Sources
Sanyati	Muda (1)	Zimbabwe	6	On Mupfure tributary, 50 km South of Harare (2)	E - Water supply (2)	(1)ZINWA, 2010 (2)Makoni *et al.*, 2001
Sanyati	Chivhu (1)	Zimbabwe	6	Tributary of Sanyati, 120 m south of Harare	No info found	(1)ZINWA, 2010
Manyame	Dande (1)	Zimbabwe	2	Tributary of Manyame, site located near Guruve	A - Feasibility study (2)	(1)ZINWA, 2010 (2) Ministry of Water Development, 1981 (3)ARA Zambeze interview 28 April 2010
Kafue	Itezhi-Tehzi	Zambia	7	located at the existing dam site	B - No extra dam capacity but potential extra discharge capacituy (1) C - Impact on wetlands and irrigation development ? (1) E - Extra hydropower generation +80 MW (1) H - Zambia only	(1)Worldbank, 2010
Luangwa	Lusiwasi Ext.	Zam	5	At Lake Lusiwasi ? approx. 330 km North of Cahora Bassa	B – No extra dam capacity but extra discharge capacity(1) E - Extra hydropower generation +40 MW H - Project is in Zambia but benefit could be shared with Zimbabwe (Kanyemba) and Mozambique (Zumbo) in term of flood protection	(1)Worldbank, 2010
Songwe	Songwe	Tan	3	Flows along Malawi/Tanzania border	B - Would contribute to flood protection (1) D - Cost effective by combination of flood protection and power generation E - Extra hydropower generation +150 MW H - Shared by Tanzania and Malawi (1)	(1)Worldbank, 2010
Kafue	Lower Kafue	Zambia	7		A – Feasibility study (2) B - No potential for flood protection (R-o-R) (1)	(1)Worldbank, 2010 (2) Mwelwa *et al.*, 2008

River	Scheme	Location: Country	Location: Sub-basin	Location: Description	Evaluation criteria of this study	Sources
					C - Impact on wetlands and irrigation development ? (1) E - Extra hydropower generation +600 MW (1) G - Considered a serious contender in the medium term (1) H - Zambia only	
N. Ruhuru	Masigira	Mal	3	Flows into lake Malawi	No info found	(1)Worldbank, 2010
S. Rukuru/N. Rumphi	Lower Fufu	Mal	3	Underground run-of the river power station near Chiweta, Flows into Lake Malawi	B - No flood protection (R-o-R) (1) E - Could also provide water to irrigation schemes in Henga valley H - Malawi only	(1)Worldbank, 2010
Lower Zambezi						
Bua River	Mbongozi	Mal	3	Flows into Lake Malawi	A - Several sites identified B - Flooding problems that occur in the lower reaches of the Bua will be minimized C - Elephants, crocodile, antelopes, birds and other small rodents from the nearby Nkhotakota game reserve plus all the in-stream ecology will benefit from increased firm flows from the construction of the dams. E - Rehabilitation of the Bua irrigation scheme, Boosting fisheries. Positive effect on game reserve ecology will boost the flow of tourists to this area. H - Malawi only	LOIC HOW IS REFERENCE?? (1)International Small-Hydro Atlas, 2010
Shire	Kholombidzo	Mal	3	50 km downstream of Liwonde Barrage	See Chapter 2	

River	Scheme	Location			Evaluation criteria of this study	Sources
		Country	Sub-basin	Description		
Shire	Mpatamanga (1)	Mal	3	30 km North East of Blantyre	A - Minimal civil work B - No extra dam capacity but extra discharge capacity D - Not very cost effective H - Malawi only	(1)International Small-Hydro Atlas, 2010
Shire	Kapichira II	Mal	3	30 km South West of Blantyre	A - Minimal civil work (1) B - No extra dam capacity but extra discharge capacity +134 cumecs (1) D - Not very cost effective E - Extra hydropower generation +64 MW F - High, call for EOI published in 2009 H - Malawi only	(1)Worldbank, 2010
Ruo	Zoa Falls (1)	Mal, Moz	3	35 km upstream of confluence of Ruo and Shire	E - Extra hydropower generation +20 to 50 MW (1) H - On the border between Mozambique and Malawi	(1)International Small-Hydro Atlas, 2010
Luenya	Chitse (1)	Zimbabwe	2	Tributary of Luenya, site located 10 km North of Mt Darwin	No info found	(1)ZINWA, 2010
Luenya	Silver Stroom (1)	Zimbabwe	2	Tributary of Luenya, site located 10 km East of Centenary	No info found	(1)ZINWA, 2010
Luenya	Kunzvi	Zimbabwe	2	Tributary of Luenya, at the confluence of Nyagui and Nora Rivers (3), site located about 50 km NW of Harare	No info found	ZINWA, 2010
Luenya	Bindura (1)	Zimbabwe	2	60 km NE of	A - Feasibility study	(1)ZINWA, 2010

River	Scheme	Location: Country	Location: Sub-basin	Location: Description	Evaluation criteria of this study	Sources
				Harare (S 16° 10' 0" E 30° 33' 0")		(2)Ministry of Water Development, 1981
Muira	*contributing to flood flows, no dam site identified yet(1)*	Mozambique	2	Flows into Zambezi at Tambara	No dam site identified	Interview ARA Zambeze, 28 April 2010
Pompoe	*contributing to flood flows, no dam site identified yet(1)*	Mozambique	2	Flows into Zambezi 135 km downstream of Tete	No dam site identified	Interview ARA Zambeze, 28 April 2010
Rios Bons Sinais; Cuacua, goes into Luala then Licuane	*No dams proposed (1)*	Mozambique	1	Zambezi Delta	No dam site identified	Interview ARA Zambeze, 28 April 2010
Revubue	1	Mozambique	2	Flows into Zambezi at Tete	E - Extra hydropower generation +36 MW H - Only Mozambique	Worldbank, 2010
Revubue	2	Mozambique	2	Flows into Zambezi at Tete	E - Extra hydropower generation +110 MW H - Only Mozambique	Worldbank, 2010
Revubue	3	Mozambique	2	Flows into Zambezi at Tete	E - Extra hydropower generation +85 MW H - Only Mozambique	Worldbank, 2010
Luia	4	Mozambique	2	Flows into Zambezi 30 km downstream of Cahora Bassa	E - Extra hydropower generation +267 MW H - Only Mozambique	Worldbank, 2010
Luia	5 Capoche	Mozambique	2	Flows into Luia 25 km upstream of Zambezi	E - Extra hydropower generation +60 MW H - Only Mozambique	Worldbank, 2010

Appendix B
Dams and sediment in the Zambezi River Basin

This is an appendix of Chapter 8 on sediment management and bottom outlets, which was prepared to support conclusions on Sediment Management, also reported on in Annex 2.

The main purpose of Task 10 Sediments is to advise if new dams should be equipped with bottom outlets to facilitate sediment flushing and if the operation of existing dams can influence sediments and sedimentation.

This document describes the impact of dams on sedimentation in the catchment as well as its impact on the livelihood based on the review of the existing literature. In addition this document will address the question of installing bottom outlets for the new dams based on the experience of dam experts in SSI and Rankin as well as best practices in the region.

B.1 Analysis of sedimentation impacts of dams

B.1.1 Introduction

Rivers have a certain sediment ‘hunger’; dependent on the velocity and discharge they can carry a certain amount of sediment. Course sediments are heavier and thus need more velocity. In slowly flowing areas, the sediment is deposited. In a natural river basin, the occurrence of floods in floodplains make the floodplains and river outlet deltas increase in size by deposits from upstream.

Dams influence sedimentation in two ways:
- the dams trap sediment; and
- the dams change the downstream flow regime.

The effect of these changes is summarized in Figure B.1 (quoted from Ronco *et al.*, 2010). This shows that reduction of sediment and reduction of transport capacity both have opposite effects.

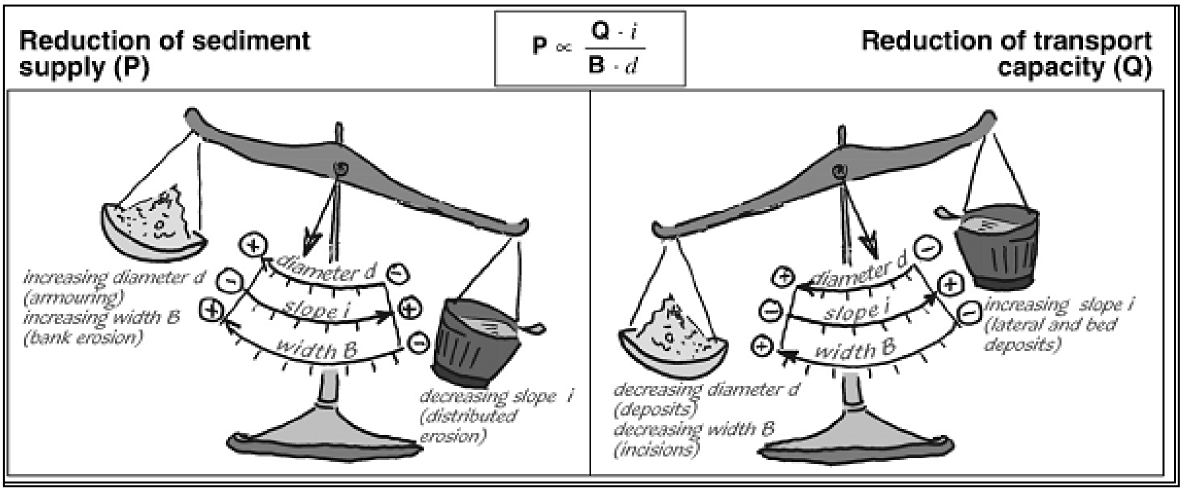


Figure B.1: Response of a river system to a variation of sediment supply (left) or transport capacity (right), as in Ronco et al. (2010) adapted from Lane (1955)

Although both component have an effect on the Zambezi River Basin, this study focuses on the sediment transport in the river rather than sedimentation of dams. The sediment transport capacity of Zambezi River at Tete was halved, especially for the heavier particles, after construction of both Kariba and Cahora Bassa according to Ronco *et al.* (2010).

It is noted that the studies in this literature review only cover part of the Zambezi catchment and do not report on sediment loads in tributaries. Also, no distinction is made between coarser sediments and organic suspended solids.

B.1.2 Middle Zambezi – downstream of Kariba to Kafue confluence

The impact of Kariba dam on the Middle Zambezi is described in the paper 'River bank erosion in the mid-Zambezi valley, downstream of Lake Kariba' by P.R. Guy (1981). In December 1966 permanent sites were established in the Mana Pools Game Reserve to measure rate of erosion over several years. The conclusions of Guy are based on these measurements, on study of aerial photographs and on field experiments before and after opening of floodgates at Lake Kariba. Guy states that the water leaving Lake Kariba either through the turbines or floodgates carries very little silt, as evidenced by the clarity of water even in flood below the dam.

Figure B.2 shows the location of erosion and deposition of different soil types at different times. Below the effect is discussed of:

- changing flows and sediment content;
- distinct water levels during open flood gates;
- vegetation and flow regime; and
- sudden closure of gates.

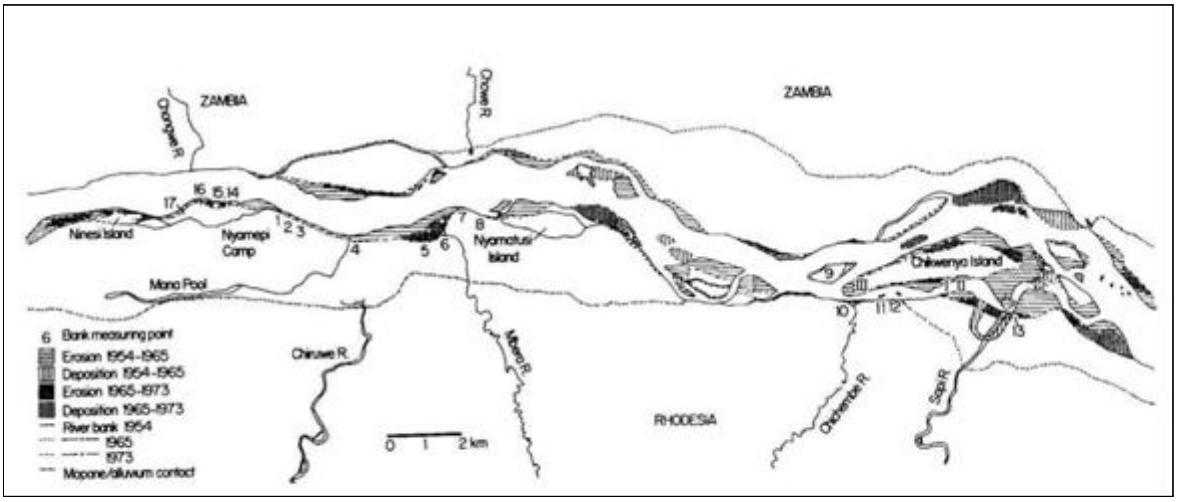


Figure B.2 The study area downstream of Kariba dam, with an indication of the extent of erosion and deposition and the locations of measuring points, as in Guy (1981)

Changing flows and sediment content

Using aerial photographs, it was calculated that a total of about 800 ha was lost through erosion between 1954 and 1965 and about 230 ha between 1965 and 1973, giving a total of 1030 ha lost erosion in 19 years. The 1030 ha were lost from an area that represents only about 10% of the total bank length downstream of Lake Kariba to the Zimbabwe/Mozambique border. The loss was to some extent offset by the formation of about 210 ha of sandbanks.

The recently deposited alluvial soils were found generally very sandy varying in texture. The overlaying cap of sandy clay loams or sandy clays was found seldom more than 1 m thick. The sites with alluvial sandy soils had been more easily eroded than the mopane woodland soils. Such sandy soils would also erode rapidly under a natural flooding regime. At other sites where the erosion was reported less severe, the researchers had little doubt that the unnatural and out-of-season flooding caused by the opening of floodgates at Lake Kariba had contributed to erosion.

In the years 1958 to 1965 when the Kariba Lake was still filling, there may have been a reduction in erosion due to the decrease in water flow. However, Guy (1981) also mentions that during 1954 to 1965, 800 ha were lost to erosion, a mean of 73 ha/year, while from 1965 to 1973 230 ha was lost, a mean of 26 ha/year. The volumes of average annual flow are mentioned probably not to be the most affecting factor, rather the occurrence floods.

Distinct water levels during open flood gates

On the harder, more resistant mopane soils of the Zambezi River Bank, the researchers found two distinct lines etched into the banks by flooding waters. These lines corresponded, possibly coincidentally, to the level of water when one or two flood gates in Kariba are open, but also partly to horizons which are weaker and therefore more easily eroded. Other less distinct lines corresponding to combinations of flood gates could also be seen. Because the water level is at times held very nearly constant, wave action has enabled the water to erode the bank more deeply at the surface level of the water, with less erosion taking place below it. This undermining was said to result in banks collapsing and banks being washed away.

Vegetation and flow regime

Some banks had gentle grass slopes to the water. The grassy vegetation is annual and seemed to have become adapted to periods of flooding and silt deposition. The vegetation itself slows down the water, thereby reducing its erosive force. It is mentioned that out-of-season flooding, i.e. any time between about June and December even for short periods, could well affect the effectiveness of plants on the banks in reducing erosion. Paths of elephant and hippopotamus are also said to affect the erosiveness of the banks, as well as the presence of large trees falling into the river.

Reeds on recently established sandbanks are usually covered by water when the floodgates of Kariba Dam are open. This diminished the stabilising effect of the plants. In some years when the gates of Kariba Dam were closed, the sandbanks have been seen to be covered by silt, in places up to 30 cm deep.

Sudden closure of gates

The sudden closure of gates is said to increase erosion to take place because of sudden changes in ground water pressures. When the six floodgates were closed in 1966, large blocks of bank fell into the river when the groundwater level dropped to that of the river, and at the same time the channels of the floodplain were subjected to downward scouring when the water in them suddenly returned to the river.

Conclusions on sedimentation and erosion

Guy (1981) concluded that erosion may well have been part of the normal river system dynamics, but the damming may have served only to hasten the process. Guy predicted at the time of writing that as erosion would continue, resistant soils would be left, reducing the rate of erosion every year.

B.1.3 Lower Zambezi

The results of damming the Zambezi at Cahora Bassa were well documented by Davies *et al.* (2000). Table B.1 below gives a summarized description of the changes to the sediment transport in the lower Zambezi. The Lower Zambezi is comprised of four macro-scale river–floodplain zones namely; the narrow gorges, mobile sand-braided reaches, an anabranching and a coastal distributary zone, from the Cahora Bassa dam wall to the Indian Ocean coast, respectively. Within the Gorge zone, the Zambezi channel is confined to a narrow valley with relatively high gradients. The Mobile zone has still relatively high and boundary sediments (mostly fine gravel and sand) with a braided sand-bed river dominating. A series of anabranch channels flow through the downstream section to form the Anabranch zone. The distributary zone comes after the anabranch zone as the bed gradient progressively reduces. The coastal distributary zone, has floodplain widths that can reach several hundred kilometers (Davies *et al.* 2000). Table B.1 shows that the morphological responses to flow regulation and the subsequent reductions in sediment loads varied in the different river–floodplain zones.

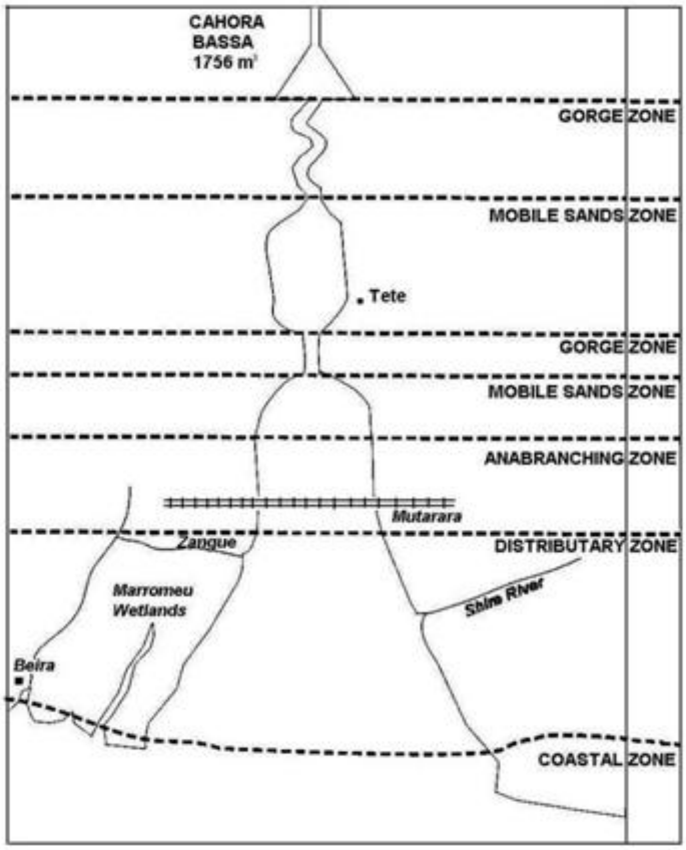


Figure B.3 Different morphological zones in Lower Zambezi (after Davies et al., 2000)

Table B.2: Morphological changes in the lower Zambezi after impoundment of the Cahora Bassa, due to flow reduction and reduced sediment loads (Modified from Davies et al, 2000).

Zone	Before impoundment	Post impoundment
Gorge zone: Downstream of Cahora Bassa dam to the proposed Mphanda Nkuwa dam	• The gorge zone was characterised by high energy and high sediment transport. • The in channel was dominated by deep pools, narrow chutes, bedrock bars, large temporary storage areas that were frequently disturbed.	The zone is characterize by • reduction in flow and sediment load, • removal of large sediment stores • loss of channel in- habitat, • canal-like channel environment, and exposed bedrock in the channel.
Mobile zone: (also called sinuous channel type) Between the proposed Mepanda Uncua Dam site and Boroma	the mobile zone was characterised • by a wide active river-floodplain trough which was frequently inundated, • highly mobile braided sand bed channel that had frequent changes in channel and bar morphology, • high rates of sediment transport, • and narrow fringing permanent floodplain.	the zone is characterised by • reductions in flow but high sediment loads due to supply from eroded gorge material, • stabilisation of braids and bars, • some growth and coalesce, • further stability of bars with growth of vegetation, • incision of main flow channels and the dominance of a small number of channels, • main channel has a meandering function, and increased area of stable floodplain.
Anabranching zone (also called anastomising) Between Boroma and Mopeia	• a very wide valley floor trough that was occupied by an anabranching river system. • many different anabranch channels that convey flows at variable water levels. • complex floodplain habitat. • compound in-channels, hence diverse in channel habitat • lateral exchanges of carbon and nutrients	• a decrease in discharge and sediment loads plus change in sediment texture • decrease in connectivity of floodplain and channels • dominance of a single main channel that incises and conveys the majority of flow • stable fringing floodplain/riparian areas • decreased lateral exchange of carbon and nutrients
Distributary zone: Delta area	• multi channeled distributary system that flows across a low gradient fan complex. • complex floodplain/channel network with diverse habitat • natural deposition zone • high lateral exchanges of carbon and nutrients between floodplain and channels • each channel highly sinuous and U-shaped	• major reductions in discharge and sediment loads • reductions in sediment load, stabilisation of braids and bars, some growth and coalesce • further stability of bars with growth of vegetation • incision of main flow channels and the dominance of a small number of channels • main channel have a

Zone	Before impoundment	Post impoundment
		meandering function • increased area of stabilised floodplain
Coastal zone:	• Large coastal delta with multi-channel system • Natural depositional aggradating system at delta front and near shore area • Individual channels are U shaped and highly sinuous • Lateral exchanges of carbon and nutrients very important for channel and floodplain productivity	• Reduction in discharge and sediment loads • Reduction in sediment load results in erosion of channels and front of coastal zone • Incision and domination of a small number of channels • Major landward progression of coastal delta

Davies *et al.* (2000) emphasized 'the dramatic changes in the morphology of the river floodplain system'. The paper of Ronco *et al.* (2010) states that different authors came to different outcomes of the impact of Kariba and Cahora Bassa Dams on the morphology of the river: Suschka and Napica (1986, as quoted in Ronco *et al.*, 2010) affirmed that 'no evident changes in river bed configuration through aggradation or degradation have been measured and a much larger period will be necessary to find noticeable effects'. Chenje (2000) attributed to the dams: the removal of the sediment stores in the gorge zone (erosion), the incision of main flow channel with the stabilization of braid and bars in the transitional zone, the dominance of a single main channel that incises and conveys the majority of flow in the braided zone, the reduction of the Zambezi delta wetland mangrove swamp area, and the increase of salt-water intrusion.

In addition to previous research, the Ronco *et al.* (2010) developed a numerical model, for which only water width and water slope and flows are used as data input. These have been obtained from satellite images. Some satellite data on the variation of the Zambezi delta have been used for model verification. The simulations are meant to provide the computed space and time evolution over the past 100 years end next 100 years, in the absence and presence of dams. In the presented configuration, the model uses the inputs of water and sediment from the Middle Zambezi and the Luangwa as boundary conditions and does not include other tributaries downstream of Luangwa.

Model results of Ronco *et al.* (2010) are shown in Figure B.4.

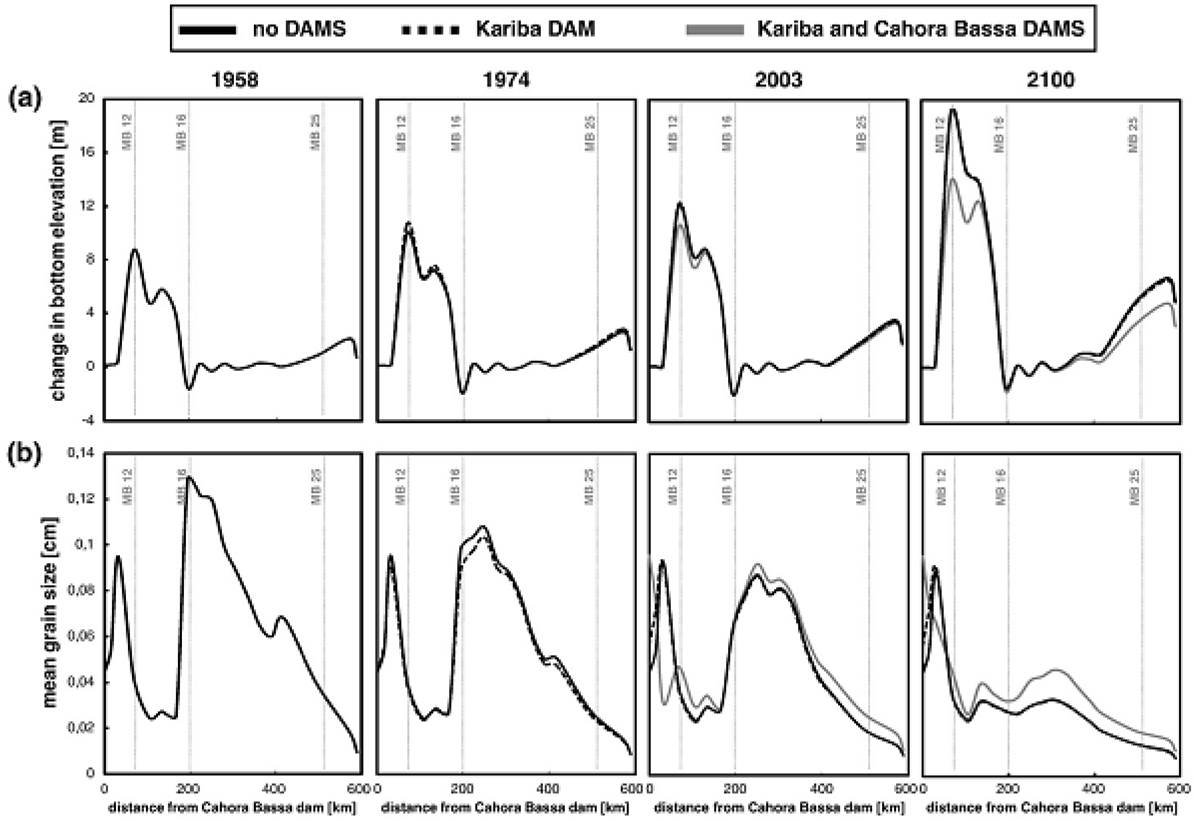


Figure B.4: Simulating the river evolution starting from the 1907 configuration, in terms of (a) change in bottom level, (b) mean grain size variation. (MB 12, MB16 and MB25 are morphological boxes in the model). As in Ronco et al. (2010)

The main results of Ronco *et al.* (2010) are the following:

- During the last and the next centuries, the largest part of the lower Zambezi in undisturbed conditions shows a continuous and almost constant bottom aggradation and sediment fining;
- This 'natural' trend is affected by the construction of the Kariba (1959) and Cahora Bassa (1975) dams, but only in a relatively minor way;
- The perturbations created by the dams, respectively in terms of water flow and sediment interception, appear to propagate along the river with different celerities and with different consequences on the bottom profile and composition;
- The construction of dams has apparently produced an erosion of the delta area, which seems however somewhat recovering.

Ronco *et al.* (2010) state that the simulation results are obviously influenced by the scarce and uncertain information utilized for input data and model calibration but that the forecasts are quite robust.

B.2 Analysis of impacts on livelihoods

The analysis of impacts of changes in sedimentation on livelihoods is based on the paper: 'The impact of hydrological changes on subsistence production systems and socio-cultural values in the Lower Zambezi Valley' (Beilfuss *et al* 2002). This paper is mainly based on oral history and gives a good overview of how local residents perceive the impact of dams on sedimentation and their livelihood regards agriculture and fisheries. Informants described increasing levels of soil erosion and scour along the river channel, and often blamed the management of Cahora Bassa of these changes. The lower amount of sediment carried in the river is blamed for scouring the river bottom and banks.

B.2.1 Impacts on agriculture

In the upper catchment near Cahora Bassa reservoir, agricultural production before the dams was closely tied to flooding of the river, beginning in December and ending in March each year. When the water receded, it left a rich deposit of nutrients along the shoreline. In lowland areas, this spillover extended, depending on the location, over a several kilometer stretch of land. Tawara and Tonga peasants through this region stressed that these rich dark *makande* soils of the floodplains were the most desirable agricultural sites in the region. Other soils in the region do not retain water and are difficult to farm. Given the low and irregular rainfall in Tete region (600 mm/annum) access to the river fed *makande* soils was critical to ensure household food security. Beilfuss *et al.* (2002) point out that the local perception on the negative impact of the Cahora Bassa dam is not only due to the loss of fertile soils, but also due to the forced eviction with the construction of the dam into hamlets with few basic amenities.

Residents near Mopeia noted that the Cua Cua distributary channel is now deeper than in the past, and that sands are now deposited from the Zambezi onto farmlands and reduce soil fertility. The researchers visited some places that were subject to serious farmland erosion, such as the Chipwazo Chieftancy in the district of Caia, where the local population planted “maquengueres”, a special plant with many roots to prevent soil erosion and erosion during flood waters. People living near the river complained angrily that local administrative officers should be warning them before releasing of water from Cahora Bassa dam. Water levels at Tete frequently rise and fall a few meters within hours.

In the extensive floodplain farming region near the confluence of the Shire and Zambezi, the local population classifies various types of soils in the lowlands (*nkulo*) of the river that are considered to be extremely fertile. These types of soils can only be found on the riverine islands (*ntsua*). In the upper terraces of the floodplain subject only to very large infrequent floods, most of the soils are considered to be less productive. In the surrounding savanna, soils are generally devoid of humus. Thus, peasants are willing to undertake persistent farming in areas prone to floods, so that they can utilize the soil and moisture conditions. They grow different crops (corn, vegetables, sweet potatoes, beans and others) and manage to harvest twice per year.

The researchers report that there is a sharp contrast between the unregulated Zambezi tributaries, such as the Revuboe and Luenha, where flood recession cropping is widespread, and the mainstream Zambezi where flood recession is minimal. In several areas in the lower reaches of the Zambezi, floodplain farmers have resettled close to the mainstream Zambezi to cultivate crops in the narrow band of alluvium soil that is inundated each year.

In general, it is mentioned that in the lower Zambezi the utilization of river-fed fields was an integral part of a complex and highly adaptive indigenous agronomic system, which dates back over several centuries. First and foremost, the food production system of the local peasants co-evolved with the seasonal cycle of the river’s flooding patterns.

B.2.2 Impacts on fisheries

In the lower Zambezi residents mention that most of the species of fish they used to see 30 or 40 years ago are also found today but that the size and quantity of fish have dramatically decreased and several species have disappeared – especially in the Zambezi Delta region. Some associated the diminishing fish size to lack of regular annual big floods that replenished the flood supply for the fish; the organic suspended solids. However, there are also other reasons mentioned for the decrease in size and number of fish: (a) blocking of passage of fish, with big fish still occurring in the reservoir, (b) irregular floods that wash away fish eggs anytime, (c) overharvesting of fishes. The impact of suspended solids on their own is therefore unknown.

B.3 Analysis of impacts on the environment

Sediments are derived via inflowing rivers from drainage basins. The soils, the vegetation cover and the drainage ratio (CA:LA ratio) and the catchment slope determine the particle supply rate and the extent to which the sediment is composed of inorganic or organic particles.

Sediments are particles (such as sand and other soils) which settle, or are deposited, on the sides and bottom of water bodies (Shoreline, 2010). Sediments are important in the formation of beaches, spits, sand bars and estuaries and provide substrates for aquatic plants and animals. Sediment also provides nutrients and minerals vital to the health of downstream ecosystems. Various organisms in freshwater environments rely on replenishment of sediment for their reproductive habitat. Changes to sediment (too much or too little) can change substrates or can alter sedimentation patterns and amounts deposited. The amount of sediment reaching wetlands, floodplains, streams, lakes, and the banks of the shorelines is primarily altered by draining or filling wetlands, loss of shoreline roughness (for example, the removal or loss of large woody debris), channelization of streams, shoreline armoring, dams, and the development of structures like boat ramps and groins which are oriented perpendicular to the shorelines. Dredging and bulkheads can also affect how much sediment is present in aquatic shoreline areas.

Sedimentation is the process by which sedimentation drop out of moving waters. Large particles drop out first and fine particles take the longest to leave suspension. Sedimentation is higher near stream mouths as they enter the lake or flood plain.

B.3.1 Effects of changes to sediments retention and transportation on the environment

Dams can produce great benefits by regulating the flow and sediment regimes through flood control, and improved river environment (Yitian *et al.* 2007). The trapping of sediment by dams can reduce sediment deposition in river and lakes below a dam effectively, alleviate shrinkage of the lakes and maintain the living space of aquatic life.

On the other hand, the construction of dams may have a negative effect on ecological environment. Dams alter flow and sediment load of rivers downstream, directly modifying the rivers as the trapping of water and sediments cause adjustment in river morphology and have profound and complicated effect on the relation between the river and lake, flood control, navigation, water environment, the habitat for the aquatic animals, estuary marsh, and seawater intrusion. Furthermore, modified sediment transport processes downstream of the dam, affect floodplain geometry, or down-cut riverbeds, representing in many cases a fundamentally different physical habitat template to support native ecosystems (Richter & Thomas, 2007).

The modifications also include reduction in amounts of sedimentation and erosion, as described in paragraph a.0. These changes may contribute to diminished aquatic habitat quality and quantity. Depending on the size of the reservoir, large amounts of sediment will be trapped, releasing only a proportion of the former load into the downstream reaches e. g. on the Lower Missouri River, where the largest water storage system in North America has decreased the downriver suspended-sediment load to 0.2%–17% of pre-dam loads (Jacobson *et al.*, 2009).

By reducing the magnitude of frequent, moderate floods, dams may lead to channel narrowing as riparian vegetation invades the active channel that was formerly scoured of vegetation by frequent floods. By trapping sand and gravel in reservoirs, dams deprive downstream reaches of their normal sediment load and release sediment-starved, or hungry water, which tends to erode its bed and banks unless the dam has reduced flood magnitude so much that sediment accumulate on the bed instead. In the anabranch zone, marked reductions in the magnitude and frequency of floodplain inundation have caused dominance of one main channel, whereas previously there were several active channels. Many secondary channels have become isolated from the main channel through silting of entrance points (Basson, 2004). Basson (2004) also indicated that in the Marromeu Complex, the upstream sectors experienced widespread encroachment by woody Savanna onto the herbaceous floodplain.

B.3.2 Types of sediments important for nature

Gravel and cobble-sized sediments are very important as habitat for benthic macro invertebrates, and as spawning habitat for salmon and trout. Where these types of sediment are not available, such as may occur downstream of a dam, the impact to these organisms is substantial. On the other hand, too much sediment can cause problems also. For example, sand and finer grained sediment, including silts and clays, can degrade gravel and cobble habitats under some conditions, especially when introduced to the channel at low flows, when it may accumulate on the bed of the watercourse.

Unlike coarser sediments, silt and clay are cohesive, their grains held together by chemical attractions, increasing their resistance to erosion. Often they will form aggregates and act like larger particles as they move through the watershed. But when they are not in aggregate form, they may remain in colloidal suspension for longer periods affecting water quality differently than if they were to settle out onto the bottom of the watercourse or its floodplain through the process of sedimentation. Suspended particles diffuse sunlight and absorb heat. This can increase temperature and reduce light available for algal photosynthesis (Sediment Factsheet - from www.swrcb.ca.gov/water_issues/programs/nps/docs/protocols_sediment_factsheet.doc).

Besides particle size factor sediments also have three components :-

a) organic matter in various stages of decomposition
b) particulate mineral matter , including clays and carbonates and non clay silicates
c) an inorganic component of biogenic origin (e.g. diatom frustules and certain forms of calcium carbonate)

Once the above components are carefully considered, one can draw the following general categories of sediments, which have the most relevance to their environmental impact on the living organisms within the basin:

Category 1 : Nutrient Rich Sediment
Category 2 : Nutrient Poor Sediment

The release of nutrient poor sediments downstream of a dam would have no or little impact on the ecosystem, while distribution of nutrient rich sediments along the basin would have the most impact of the ecosystem.

B.3.3 Importance of sediments in aquatic environments

i) The sediment particle size is of importance to the growth and distribution of benthic invertebrates in the aquatic systems
ii) Lake sediments are the major sites of microbial metabolism in mineralisation of organic matter and biogeochemical recycling of nutrients.
iii) Flood plains are areas of high terrestrial productivity because of the annual deposition of nutrients during flooding. Deposition of nutrient-rich sediments during wet-season floods also increases the fertility of floodplain agricultural fields.

B.3.4 Impacts or reduced sediment transport on the Zambezi environment

- Reduced sediment load in the Zambezi River below Kariba, particularly the coarse sand fraction, and therefore starved the unconsolidated coast of adequate sand supply. Cumulative lack of annual sediment deposition in delta estuaries led to extensive death of mangroves. (Beilfuss and Davies, 1999, Chenje *et al.*, 2000). Beilfuss and Davies claim there is little data to support conclusions, but there hypothesis is that the widespread coastline erosion and mangrove dieback in the delta may be resulting in part from the reduced sediment load'.
- Alluvial terraces in areas such as Mana Pools are eroding as a result of the loss of sediments that once maintained them but that are now trapped within the reservoir.
- Elsewhere it has been suggested that decreased low flows and a reduced frequency of flushing by floods due to impoundments have led to an increased retention of nutrients and fine sediment, resulting in conditions favourable for the growth of filamentous algae and biofilm that is unpalatable for macroinvertebrates, increased armouring of the stream bed and a reduction in habitat availability and quality for macroinvertebrates and small fish.

Appendix C
Table of Bottom Outlet Costing

The table below gives costs of bottom outlets of recent dams in Southern Africa. This table is in support of Chapter 8. Bottom outlets in earthfill dams are generally more expensive.

Table C.3: Costs of bottom outlets of recent dams in Southern Africa

Type of Dam	**Mohale Dam** Concrete Faced Rock Filled	**Berg River Dam** Concrete Faced Rock Filled	**Bedford Dam** Concrete Faced Rock Filled	**Bramhoek Dam** Roller compacted Concrete
Live storage capacity (Mm^3)	857	130	22	22
Dam construction cost (R m) - Excl. VAT	467	572	555	387
Year completed	2002	2007	2011	2010
Rockfill quantity (Mm^3)	7.2	3.2	1	75,000
Dam height (m)	145	65	49	39
Concrete quantity (m^3)	110,000	120,000	63,000	17,000
Estimated bottom outlet cost (MRand)	**84**	**114**	**111**	**46**
Costs of bottom outlet / total costs (%)	18%	20%	20%	12%
Unit cost per cubic meter of rockfill (R/m^3)	65	179	555	
Bottom outlet capacity (m^3/s)	58	200	50	50
MAR (Mm^3/annum)	appr. 1000	139.0	1.8	14.6
MAR (m^3/s)	31.7	4.4	0.1	0.5
Bottom outlet capacity / MAR		4538%	87600%	10800%
1:20 years peak flow (m^3/s)	1300			

Notes:

- Contractor made a 50 MRand loss at Mohale Dam due to poor tendering. Outlet capacity is 58 m3/s and include Intake structure, 700m conduit through mountain and open outlet.

- Berg River's bottom outlet cost include free standing tower, conduit and flip bucket. Capacity is 200 m3/s; this is the first bottom outlet in South Africa that is designed to have a capacity for environmental flows. The capacity is not yet large enough for sediment management purposes.
- Bedford's bottom outlet costs include free standing tower, conduit and large outlet works. Capacity is 50 m3/s.
- Bramhoek Dam's outlet is relatively short, approximately 30m.
- The locality of Mohale Dam in Lesotho should make it more expensive when compared to the other dams.
- All aggregate, filter material and sand are provided free of charge for Bedford Dam (except for transport) making the unit cost even more expensive (210 000 tons).

Unit cost per rockfill is very different between these dams. Reasons for cost increase are:
1. A bull market in construction industry (2002 to 2008) resulting in huge annual increases - refer to annual increases in unit costs since Mohale Dam in 2002 in table above
2. Only 3 contractors tendered for Ingula dams and very large variance in tender amounts
3. It appears that tenderers allow for additional requirements associated with training, OH&S legislation and the environment in the tenders for Bedford and Bramhoek (Ingula scheme).

Appendix D
Making use of the Clean Development Mechanism for new Hydropower in the Zambezi River Basin

The ToRs asked for an expert opinion on the potential of the Clean Development Mechanism for development of hydropower in the Zambezi River Basin. This is reported on in this Appendix and is discussed where new dams are proposed in Chapter 3 and 4 under the criterion "Biophysical impact" for its influence on emission reduction, and "Likelihood of realization" for its influence on financing possibilities.

Use of the Clean Development Mechanism

The Clean Development Mechanism (CDM) is designed to facilitate the registering of carbon equivalent credits, which can be freely traded for money on the open market.. The United Nations Framework Convention on Climate Change (UNFCCC) manages the CDM process, with the brokerage of 'Carbon Credits', facilitated by the private sector. Developing countries can acquire Carbon Credits by developing projects through the CDM process, the carbon credits acquired are then sold on to entities in first world countries. The income gained from these carbon offset projects is then used to offset the costs of a projects development. For owners of the carbon credits the following needs to be understood:

- Their is no fixed income from Carbon Credits per KWh; the initial purchase amount for the credits held needs to be negotiated through a broker with a willing purchaser. Usually the credits sold are held by the purchaser for a set period after which they are again released onto the open market for sale. At this time the price per credit can be renegotiated with the aid of a broker to a new entity. Thus the price of the credits sold can fluctuate as it is also depends on the demand for Credits from industrialized countries, and the availability of credits in the market place.
- In order to register a project within the CDM process, the UNFCC evaluates a project on 'additionality': A project needs to prove that the project would not be financially viable without the acquired Carbon Offsets being considered
- The CDM process which needs to be followed and which is required to register and validate the carbon credits to be earned can take considerable effort and time.

For the three countries that are central in development of new hydropower projects in the Zambezi Basin (Zimbabwe, Zambia and Mozambique) no CDM projects for hydropower have been lodged with the UNFCC to date.

Hydropower and greenhouse gas emissions

Hydropower is a form of energy which has in the past been presented as giving off relatively little greenhouse gasses. Many studies have suggested that greenhouse gas emissions from dams are unequivocally small. However, results of new research indicate that considerable amounts of greenhouse gases are emitted from reservoirs (Gaffin, date unknown):

Firstly, the construction of the dam itself, in some cases an enormous engineering endeavor, consumes fossil fuels and requires the production of large quantities of cement.

Secondly, dam reservoirs flood river basin areas that were formerly vegetated or forested, so they are a form of deforestation. Prior to flooding, land that was formally vegetated represents a terrestrial carbon sink for both CO_2 and CH_4. The sink capacity of the flooded basin obviously ceases when the dam is created. Further, the flooded vegetation itself undergoes decomposition, which leads to the production of both CO_2 and CH_4 (Gaffin, date unknown). When tropical forests are flooded by reservoirs, the trees are left standing in the water with the exception of small areas cleared near the dams. A substantial part of the biomass is left projecting above the water surface and decays aerobically (Fernside, 2000). According to the World Commission on Dams report, where the reservoir is large compared to the generating capacity (less than 100 watts/m^2 of surface area) and no clearing of the forests in the area was undertaken prior to impoundment of the reservoir, greenhouse gas emissions from the reservoir may actually be higher than those of a conventional oil-fired thermal generation plant.

Thirdly, studies also show that large volumes of CH_4 might be released from the water passing through turbines and spillways. In some cases, these emissions can reach up to 70% of the total reservoir emissions (Bambace, 2006). One can assume that most of the CH_4 in the water is released when water passes though the turbines because of the sudden drop in pressure (Fearnside, 2000).

In 2010, the International Hydropower Association (IHA) published the Greenhouse Gas Measurement Guidelines for new freshwater reservoirs.

Alternative sources for electricity production

The above indicates that investments in hydropower may not necessarily be considered for CDM. However, it can be pointed out that once operational, the power generation itself is not emitting greenhouse gasses. Hydropower generates almost zero kg of CO_2 emissions per kWh, other fuel types such as coal generate approximately 1.47 kg of CO_2 emissions per kWh. The United States Energy Information Agency's 1999 report on CO_2 emissions for energy generation (EPA, 1999) quotes a lower emission factor of 0.963 kg of CO_2 per kWh for coal power. The same source gives a factor for oil power of 0.881 kg of CO_2 per kWh while natural gas generates 0.569 kg of CO_2 per kWh. Estimates for specific emission from nuclear power, hydro power and wind energy are variable but are estimated to be about 100 times lower. South Africa's power generation utility, Eskom, emits approximately 0.9 kg of CO_2 per kWh of electricity produced. The proposed power station at Moatize will have a total generating capacity of 1 800 megawatts at full operation, smaller than most of Eskom's coal fired power stations and therefore emitting lower quantities of CO_2.

Firewood and Charcoal as energy sources

In the countries of the Zambezi basin firewood and charcoal are used as an energy source. To lodge a CDM project with the UNFCCC it would need to be proven that the new electricity generated from hydropower can contribute to diminishing greenhouse gas emissions due to the implementation of this technology type as opposed to the current and alternative energy technologies which could be considered for development in the area. Currently the most prevalent method of energy usage within the countries where development is said to take place, stems from the burning of wood and the making and burning of charcoal. The impact from deforestation as a result of the burning of trees for firewood or charcoal needs to thus be quantified for the area, this can however only be done through an extensive study of these activities taking place, possibly through the use of questionnaires and site inspections within representative communities residing close to the proposed hydroelectric power scheme.

However, it needs to be noted that projects to replace coal and wood for cooking have in many cases not succeed in the past because of cultural norms. It is thus not easy to compute a direct swop in energy usage, and consequently carbon saving, as this would not necessarily take place even if electricity became freely available to these communities. For charcoal there is also the added issue of this being a source of income for poor communities. If a carbon equivalency assessment is however undertaken with the proposed primary end users of the electricity to be generated, namely the Republic of South Africa, it is possible to envisage that a carbon saving would be realized, as hydropower would be replacing the use of a traditional coal fired power station.

Appendix E
Flood insurance experiences in other regions

This appendix summarizes the experiences with flood insurances in developing countries, in the United States, Europe and China. Flood insurance is evaluated as part of flood risk zoning in Chapter 6.

E.1 Flood Insurance in the developing countries

Tun Lin *et al.* (2007) provide a summary of potential challenges in adopting flood insurance for developing countries.

Supply Side Factors	Difficulty in assessing risk and vulnerability before the disaster Difficulty in estimating damage after the disaster High administrative costs Limited acces to reinsurance market Global climate change
Demand Side Factors	High premium due to limited risk collective Limited awareness and information Moral hazard problem (relying on government's disaster relief) Low income
Market and Governmetn Factors	Lack of relevant legislation and policies Lack of clear partnerships scheme between the governmetn and the private sector

Figure E.1: Potential challenges in adopting flood insurance in developing countries (Tun Lin et al., 2007)

E.2 Flood Insurance in the United States

Only in the USA an effective nation-wide insurance system exists, administrated by the Federal Emergency Management Agency (FEMA), which was established already in 1969, but also here coverage is limited and private extra coverage needs to be obtained. The program, called National Flood Insurance Program (NFIP), is a Federal program enabling property owners in participating communities to purchase insurance protection against losses from flooding. This insurance is designed to provide an insurance alternative to disaster assistance to meet the escalating costs of repairing damage to buildings and their contents caused by floods. The program is administrated by FEMA (Federal Emergency Management Agency) which identifies flood hazard areas throughout the U.S. and it's territories by producing Flood Hazard Boundary Maps (FHBMs), Flood Insurance Rate Maps (FIRMs), and Flood Boundary & Floodway Maps (FBFMs). The FIRM is the basis for floodplain management, mitigation, and insurance activities for the National Flood Insurance Program (NFIP).

E.3 Flood Insurance in Europe

Various European countries have a type of flood insurance. There are five types of national hazard insurance (Alphen and Passchier, 2007), which are distinct from another in terms of intensity of regulation and state involvement, from M1 (regional public insurance provider) to M5 (national catastrophic fund). Although this distinction in types is useful, none of these forms is found anywhere in Europe in its pure form. For a number of European countries, the type of natural hazard insurance is given below.

The actual coverage of flood insurance in European countries is often in the order of 10% of less, while values of less than 5% are found in many countries. In some cases, a higher coverage is found when the flood insurance is part of an insurance package ("bundled system").

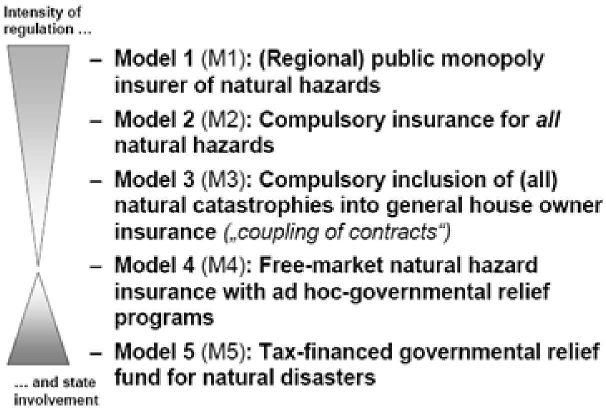


Figure E.12.5: Stylized models for natural hazard insurance (Schwarze & Wagner, 2009)

Table E.4: Natural hazard insurance in Europe

Country	Type of flood insurance	Type
Switzerland	Two types of flood insurance exists, depending on the cantons. Public property insurers exist as monopoly institutions as well as private insurers	M1/M2
Spain	Comprehensive legal compulsory insurance against damage caused by geo-atmospheric hazards and other 'extraordinary events', offered by a state monopoly insurer. The density of insurance is evidently high, due to the obligatory nature of the insurance	M2/M3
France	Natural hazard insurance model very similar to the Spanish model, but includes certain market economy and state-controlled elements. Since 1982, all private insurers are obliged to provide comprehensive insurance protection against natural hazards. However, major natural disasters, which are considered 'uninsurable' (called Catastrophes Naturelles, abbreviated as CatNat), are often taken care of by the government.	M2/M3
Belgium	A national fund exists for major disasters and it is in general completely in the hands of the national government, although a certain combination with the private sector exists.	M3/M5
Netherlands	No national insurance market for flood hazards exists, but a government compensation is possible, although it is up to the government to decide whether or not an event is liable to compensation.	M4/M5
Great Britain	Pure private insurance with a risk-based individual premium is found. There is a high market penetration as the natural hazard insurance is made part of the fire insurance required in case of a mortgage	M3/M4
Austria	Private market exists, but has a very low market penetration (less than 15%). However, a government disaster fund exists which can	M4/M5

	provide up to 50% of damage in case an event is not covered by private parties	
Germany	pure private insurance is found with individual premium calculation in the case of flood damage (Zoning System for Flood, Backwater and Heavy Rain, ZURS), which uses a distinction in four types after 2004. The market penetration for flood damage is low (less than 10%). In case of major flood events, ad-hoc compensation may occur.	M4

E.4 Flood Insurance in China

A first experiment with flood insurance already took place in 1984, but is said to have failed due to inadequate understanding of the nature of flood risk both by the Government and the general public (Tun Lin, *et al.*, 2007). It was initiated by the Huaihe river basin commission for a region with regular flooding. The premium was based on flood frequency and on economic losses of crops. About 30% of the premium was paid by the farmers and the remaining 70% by the Government. However, the project was suspended when no flood had occurred for three years after its start. Since that time, no major developments have taken place in flood insurance in China, although some experiments did take place in the rural area of Jianxi (1992). In 2007 several provinces instituted pilot schemes for agricultural insurance, including flood insurance. This program made use of the experience obtained in the Huaihe basin, and participating insurance companies provided insurance for specific crops. Premiums are shared by the national government, the provincial government, and the farmers. None of these pilot projects resulted in an establishment of a permanent flood insurance program.

A description exists of the possibility of flood insurance in China by Walker *et al.* (2009). They state that flood insurance for property is available in the People's Republic of China (PRC) through normal insurance channels, usually as an addition to fire insurance policies, but the number of policies purchased appears to be relatively small. About 80% of property flood insurance purchased through normal channels is by large and medium-sized enterprises, although some appear to provide employees with household insurance. The general level of property insurance is relatively small at the household and small business levels, and the level of flood insurance is even less, likely due to a combination of cost and relatively high risk tolerance. A limited number of agricultural insurance schemes operate commercially in the PRC and only in specific localities. These policies generally include flood insurance. They cover high-yield crops in areas where risks are well understood by the insurance companies.

Walker *et al.* (2009) conclude that:

1. Flood insurance is only feasible if supported by detailed mapping of flood risk and reliable data on building floor level elevations relative to flood risk levels;
2. Parametric insurance is more suited for flood than most other hazards because of much lower associated basis risk and is always affordable because the property holder can tailor the sum insured to the amount of affordable premium;
3. Parametric flood insurance appears to have a number of advantages for the insurance of properties in the higher risk categories, since it allows the property owner to select an amount of insurance cover independent of the type of property to be covered based on financial costs and benefits;
4. In terms of affordability, a government fund scheme without reinsurance would appear to provide the most feasible approach to flood insurance, but would require a considerable

commitment by the government to assume a liability for large losses from normal revenue in addition to subsidizing premiums; and

5. If a scheme based on indemnity flood insurance is to be implemented, a detailed study of flood damage losses at the building floor level for different types of occupancy and construction type and different depths of floor inundation will be required to estimate premiums reliably.

To optimize the design of any proposed scheme of flood insurance, ensure a low rate of reinsurance, and manage the sustainability of the scheme, it will be necessary to undertake a detailed study of the potential event losses to the scheme and their frequency of exceedence. This requires significant hydrological research.

Appendix F
Case Study Flood Risk Zoning Chobe Floodplains

This Appendix is in support of Chapter 6.

This case study for flood risk zoning considered the Chobe River upstream of its confluence with the Zambezi River. The Chobe River begins as the Cuando River in the highlands of Angola and travels some 700 km in a generally southerly direction before crossing into Namibia near Kongola in the Caprivi, where its name changes to the Kwando River. It then flows south and east through Lake Liambezi and other low lying areas before reaching the Zambezi River at Kazungula, changing its name first to the Linyati River and then finally to the Chobe River (Figure F.6) Although the Chobe River catchment is substantial, flooding of the lower Chobe River is not caused by flows from the upstream basin, but rather as a result of backflow from the Zambezi River due to the presence of the Mambova fault near the Chobe/ Zambezi confluence. Figure F.7 shows the fault near Kasane (Botswana) clearly marked by the division of green (wet) and brown (dry) land.

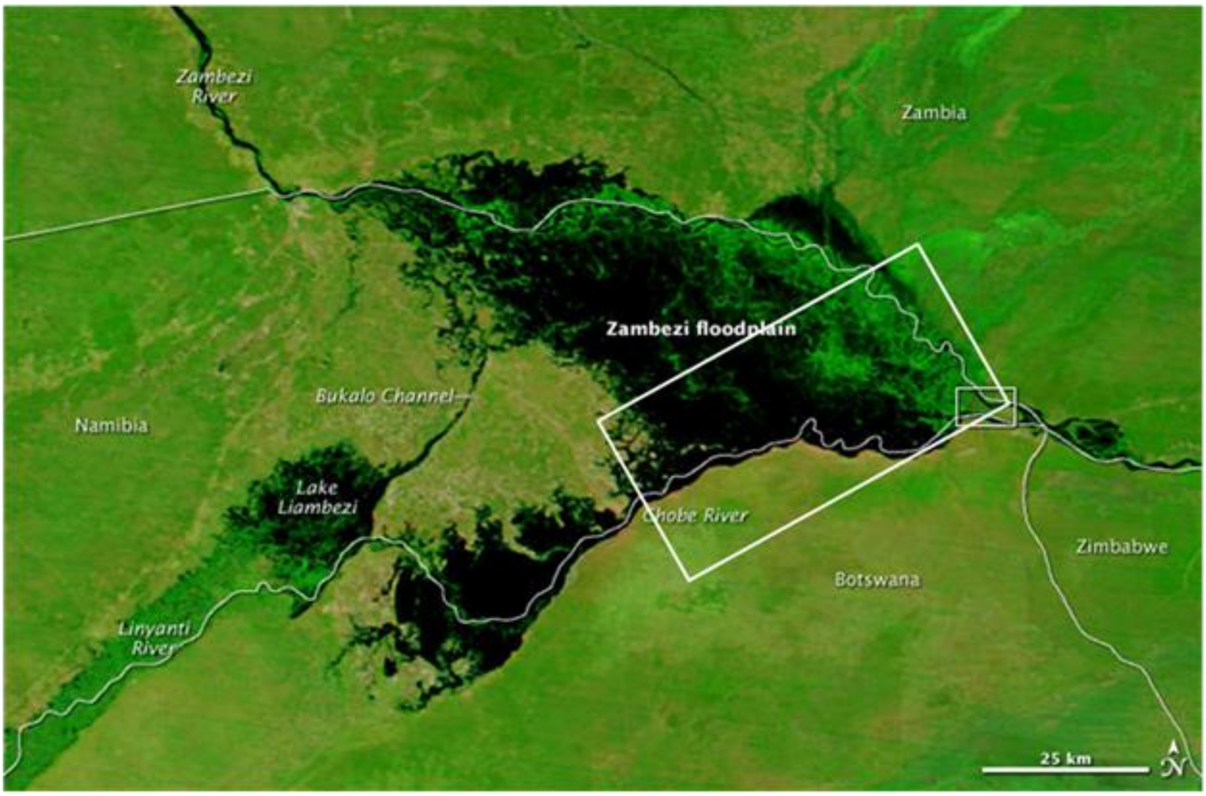


Figure F.6: Satellite (false-colour) image from 8 May 2010 showing floodwaters (in black) upstream of Chobe River/ Zambezi River confluence, with large rectangular outlining case study area and small rectangular outlining zoom in next figure (Source: NASA Earth Observatory).

Figure F.7: Satellite photo from 8 May 2010 showing mechanism of backflow from Zambezi River to Chobe River (Source: NASA Earth Observatory, 2010)

Flood Hazard

Although the period spanning the 1980s and 1990s could be described as a relatively dry period, when the incidence of flooding in the Chobe River was relatively low, the period spanning 2000 to 2010 has been characterized by relatively wet years, with one of the worst flooding years being 2009.

The only flood inundation data currently available for the Zambezi/ Chobe area is historical data – hydrodynamic models of the area upstream of the Zambezi River/ Chobe River confluence have not yet been developed, primarily due to a lack of accurate ground elevation data. However, since 1998, a significant technological advance has been made in that flood water inundation data measured by remote sensing (satellite) has become available. This has allowed an historical database of flood inundation data to be built up, which has already been of significant value for flood risk planning and assessment.

For this case study, flood inundation data for the 2009 flood was obtained from UNOSAT in Geneva, Switzerland, and this data, together with standard GIS feature data, has been used for the purpose of demonstrating how flood risk zoning could be used in the Chobe River area. It should be noted that insufficient data could be obtained in the timeframe available to allow a comprehensive evaluation to be undertaken. Certain simplifications and assumptions have therefore been made to allow a system of flood risk classification to be demonstrated for different applications. The maps included in this study should therefore not be used for any purpose other than assessing the efficacy of the classification system.

Flood Vulnerability

The Office of the Prime Minister of Namibia classifies the area as a Lowland Maize and Livestock zone, see Figure F.8) for which, for the Caprivi strip, the characteristics of socio-economic are as outlined in Table F.5. The villages visited are not in the Case study area, but are supposed to be representative for the whole lowland maize and livestock zone in the Caprivi strip.

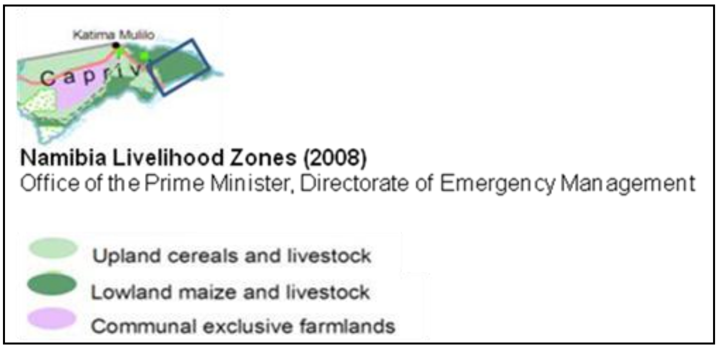


Figure F.8 Namibia Livelihood Zones in Caprivi Strip as used for Emergency Management (as quoted in Namibia Office of the Prime Minister-Directorate Emergency Management, DRAFT 2009) with delineation of case study area

Table F.5: Typical Characteristics of Socio-economic (Wealth) Groups in the Lowland Maize and Livestock Zone Caprivi Strip (Namibia Office of Prime Minister, DRAFT 2009)

	"Very Poor"	"Poor"	"Middle"	"Better-Off"
Percentage of population in the zone	31%	39%	22%	8%
Typical household size	7	7	7	5
Number of wife's per household	1	1	(1-2)	(1-3)
Land Owned	0.5-2 hectares	1-4 hectares	3-40 hectares	4-50 hectares
Land Cultivated	0.5-2 hectares	1-4 hectares	2-8 hectares	4-20 hectares
Cattle Owned	0-4	0-10	27-64	100-200
Goats Owned	0-2	0-5	0-15	0-25
Poultry Owned	0-10	0-10	Oct-20	Oct-15
Productive Assets	2-4 hand hoes Panga, axe 0-1 oxen 0 ox-plough 0 fish nets	2-4 hand hoes Panga, axe 0-3 oxen 1-2 ox ploughs 0-1 fish nets	2-4 hand hoes Panga, axe 4-11 oxen 1-3 ox ploughs 0-2 fishnets 0-3 canoes	2-4 hand hoes Panga, axe 11-24 oxen 4 ox ploughs 0-5 fishnets 0-3 canoes
Economic Activities	• Casual labour • Domestic work • Sale of natural resources	• Casual labour • Sale of natural resources • Construction work	• Formal employment • Trade (Sheebens) • Sale of livestock /crops	• Sale of livestock/crops • Trade • Formal employment

The Baseline study for the Lowland maize and Livestock zone for the Caprivi strip (Namibia Office of the Prime Minister, Draft 2009) summarizes the characteristics of different years as follows.

General Characteristics of a good year:

- Very low flood risk;
- Low human displacement;
- Low crop and livestock destruction;
- High crop production and sale of produce in the market;
- Good livestock conditions; and
- Relatively good household incomes due to good livestock conditions and high market prices.

General Characteristics of an average year:

- Mid season rainfall (December/January);
- Medium level floods;
- Moderate human displacement due to floods;
- Less loss of crops and livestock;
- Normal hunger periods (December-February); and
- Relatively average household incomes due to fairly good livestock conditions and markets prices.

General characteristics of a “bad or crisis” year:

- Timely on set of rainfall (November/December months);
- High level of floods;
- Massive human displacement due to floods;
- Loss of crops and livestock;
- Extended hunger period, i.e. (September to March); and
- Relatively low household incomes due to poor livestock conditions and low market process.

Conclusions to draw from the above information is that in a normal year people already experience three month hunger periods. A flood like in 2009 flooded the area for several months, making cropping not possible. 80% of the population is very poor to poor to the extent that they do hardly have any cash save. These people have maximum 10 cattle, 5 goats and some poultry to protect during flood. They do not or hardly benefit from the benefits of floods in terms of fishing (0-1 fish net).

The baseline report on vulnerability points out that a regional flood early warning system, may be vital to trigger timely relocation of populations at high risk to floods but are not sufficient. Cost effective, community based traditional systems of flood early warning, response and mitigation among others are recommended (Nambia Office of the President, DRAFT 2009) to include:

- Strategies aimed at reducing inequality , for example by creation of small scale industries for processing agricultural produce such as maize and forest related products or review of the licensee fees for the very poor to exploit natural resources;

- Timely provision of information by the local authorities, particularly by the local traditional chief. (addition by this study; how is information provision to the chief?). The information on the 2009 flood is said to be insufficiently accurate;
- Triggering timely relocation of local population into high ground areas with low risk of flooding. In 2009 there is said to have been a general fear of insecurity due to open borders with Zambia and Botswana to leave property behind. There was also no access labour available to start preparing houses on higher grounds. In addition it is mentioned that laws prohibiting cutting of trees were a barrier to start building in time new houses on higher grounds;
- Effective community solidarity such as mutual support among local population through sharing of transport facilities assets such as canoes. It is mentioned that community solidarity is decreasing. In 2009 there were limited transport facilities for timely relocation of household assets;
- Relocation of animals, particularly cattle into higher ground areas within the low land maize and livestock zone of the Caprivi region. In 2009 in particular the relatively rich households were slow in evacuating due to their cattle. It is also mentioned that people did not want to evacuate cattle in fear of livestock diseases; and
- Construction of sand ridges to stop the flow of excess water.

The first four bullets show the importance of improving the processes of rescue and warning, where flood risk zoning can only contribute in providing information. The one but last bullet shows the recognition of flood risk zoning for current land use, in shifting cattle to higher grounds. The last bullet shows the consideration of structural flood protection measures. However the ministry of water affairs of Namibia (2004) does not see this as a feasible option. Roads have however been repaired and elevated after the 2009 flood and also serve as a barrier in low flooded areas, see Figure 7.1

In relation to flood risk zoning the baseline report recommends (Namibia Office of the President, draft 2009):

- More effective collaboration between the traditional authorities, communities and regional/central government;
- Timely movement of populations in high and medium flood risk areas on higher grounds;
- Permanent relocation of people in high risk flood areas to high grounds; and
- Setting of by laws which make it criminal to continue living in high flood risk areas, especially after provision of timely early warning signals.

Acceptance

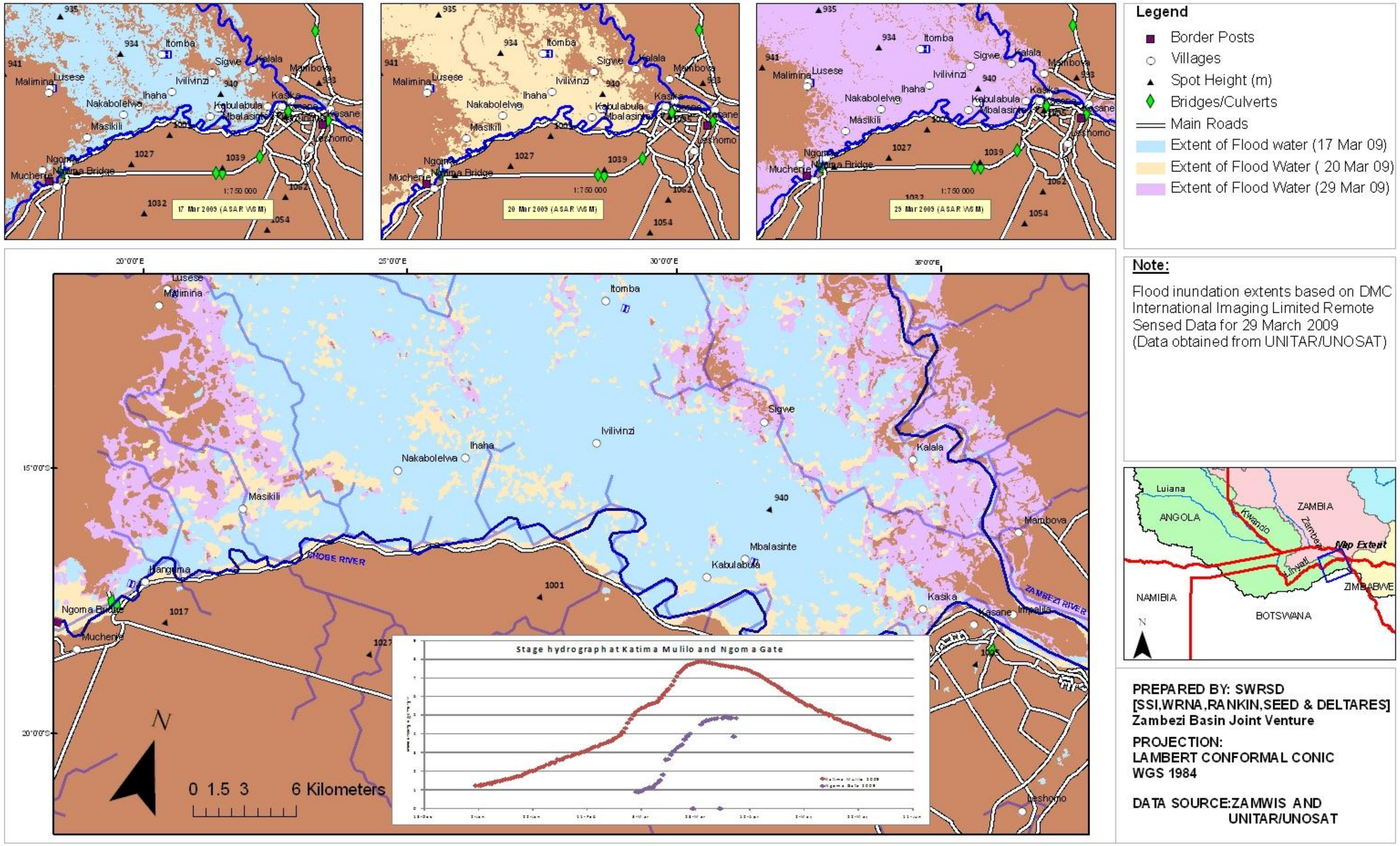
In terms of acceptance of flood risks, information that was specific for the case study area could not be found.

Flood Risk Zoning Mapping

As can be seen, four maps have been prepared as follows:

- *Map 1 Chobe – Flood Inundation Mapping for Chobe River Case Study*: this map is the base map from which the other three maps were developed. It shows the basic features of the case study area, as well as the flood water boundary of the largest event for which flood inundation data is currently available (29 March 2009). Although it would have been useful to also include the flood water extent for an average flood, further work is required to establish this. The map also shows the progression of flood waters in the two weeks prior to 29 March 2009, as well as a comparative plot showing the rise in water levels at Katima Mulilo and Ngoma Bridge.

- *Map 2 Chobe – Conceptual Flood Risk Mapping for Community Education, Chobe River Case Study:* this map shows how the available flood inundation data could be used to identify areas where the awareness of the community should be raised through education and training on how to respond to flood situations. It should be noted that at the scale used for Map 2, the value of this application of flood inundation data cannot be fully appreciated. Ideally, the map should be at a sufficiently small scale that individual dwellings and other important features, such as roads can be identified.
- *Map 3 Chobe – Conceptual Flood Risk Mapping for Regulation of New Development, Chobe River Case Study:* the main purpose of this map is to demonstrate how historical flood inundation data could be used to regulate new development. In river basins where historical or predicated flood inundation data is available for selected recurrence intervals of 50 or 100 years, new development is usually restricted to land that lies outside these areas. In the absence of such data, use has to be made of any available historical data for the maximum recorded flood extent. For this reason, in this case study, the 2009 flood extent has been used to identify areas that are suitable for new development, unsuitable for new development and potentially suitable, but requiring further investigation. The above classification does not take into account the possibility of constructing buildings with elevated floor levels within the floodplain; however, given the typical duration of flooding in the Chobe River floodplain, which can last several weeks, the above option, although feasible, is not likely to be practical.
- *Map 4 Chobe – Conceptual Flood Risk Mapping for Warning and Rescue, Chobe River Case Study:* the last map in the series demonstrates how flood risk mapping could be used to develop mobilization and response plans for evacuation of people in potentially flooded areas to higher ground refuge areas in a flood situation. Using detailed satellite photographs from the 2009 flood (UNOSAT) of the villages included in the Chobe River case study area, villages above flood water levels were identified (refer to map) and designated as "primary flood refuge areas". For flooded villages, potential flood refuge sites located at nearby high ground were identified and are labelled as "secondary flood refuge areas". Additional secondary flood refuge areas were also identified at intermediate locations away from villages for isolated dwellings or unmarked villages. This map therefore allows potential evacuation procedures to be developed. Although not shown on this map the map should ideally also show evacuation routes (key roads); however, road data in GIS format could not be obtained in time for this report.



TRANSBOUNDARY WATER MANAGEMENT IN SADC: DAM SYNCHRONISATION AND FLOOD RELEASES IN THE ZAMBEZI RIVER BASIN PROJECT

1. CHOBE - FLOOD INUNDATION MAPPING FOR CHOBE RIVER CASE STUDY [29 MARCH 2009 - LARGEST FLOOD EVENT FOR WHICH INUNDATION DATA IS AVAILABLE]
(FOR DEMONSTRATION PURPOSES ONLY)

On Behalf of: In Delegated Cooperation with:

Figure F.9: Map 1 Chobe – Flood Inundation Mapping for Chobe River Case Study:

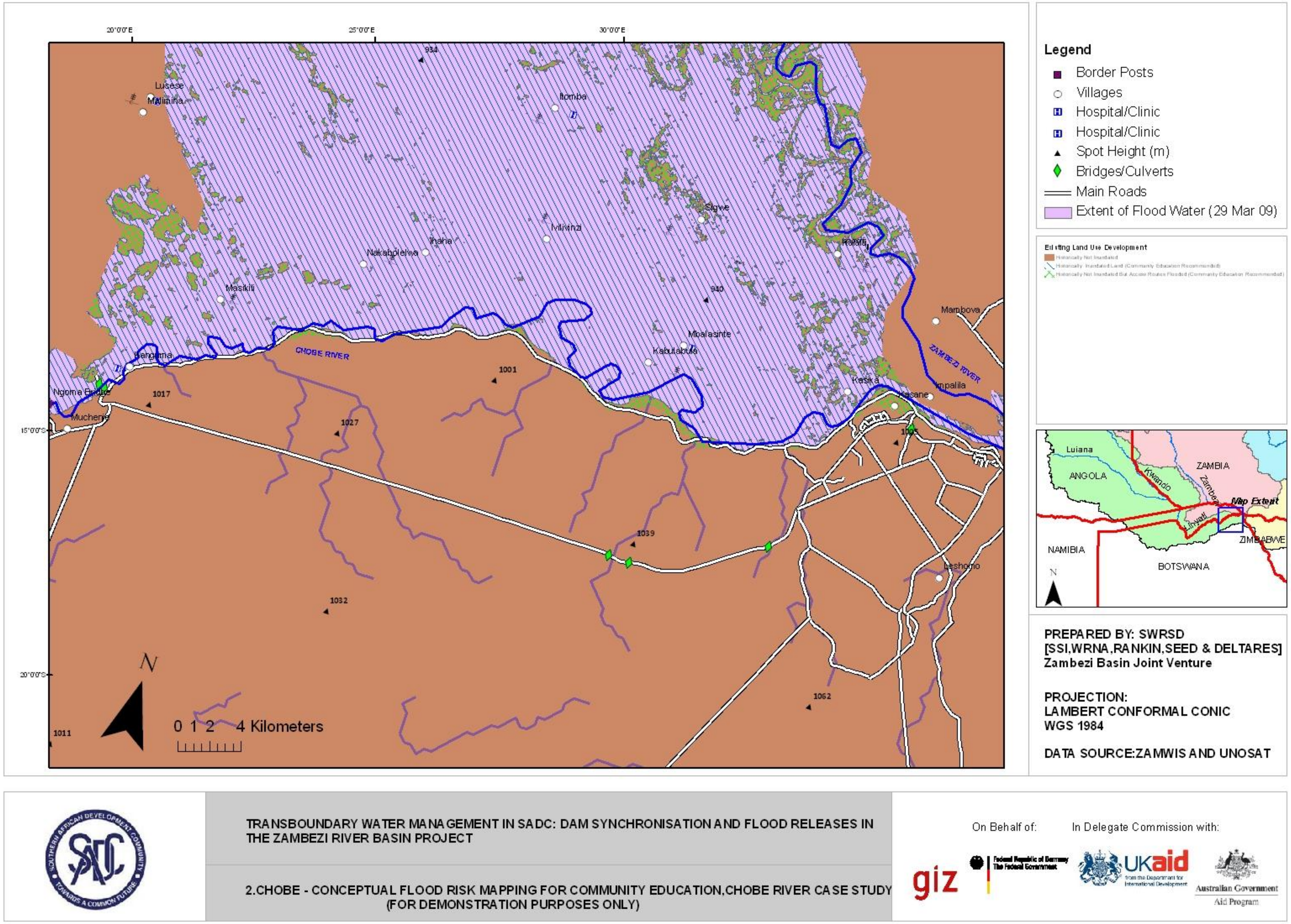
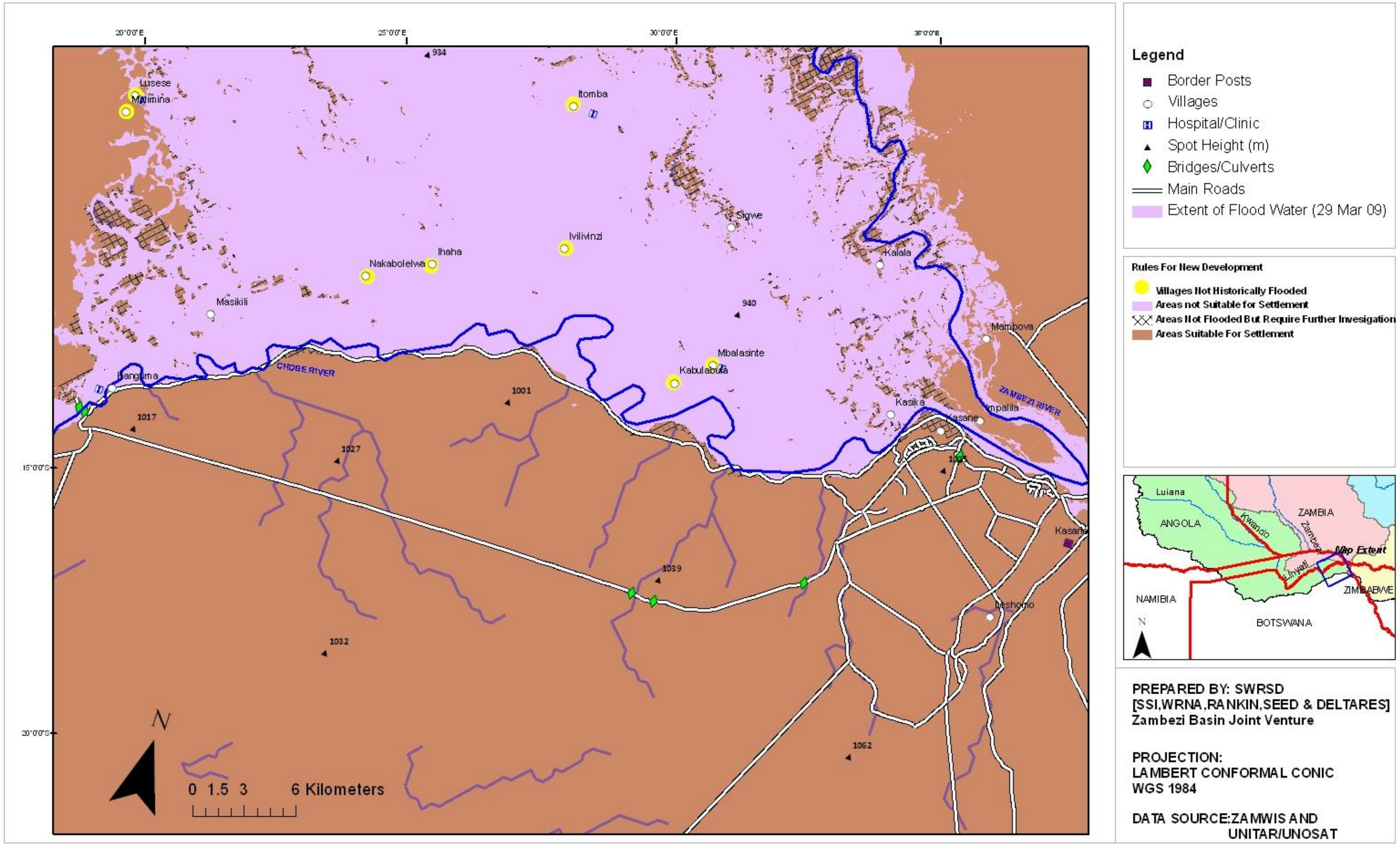


Figure F.10: Map 2 Chobe – Conceptual Flood Risk Mapping for Community Education, Chobe River Case Study:



TRANSBOUNDARY WATER MANAGEMENT IN SADC: DAM SYNCHRONISATION AND FLOOD RELEASES IN THE ZAMBEZI RIVER BASIN PROJECT

3.CHOBE - CONCEPTUAL FLOOD RISK MAPPING FOR REGULATION OF NEW DEVELOPMENT,CHOBE RIVER CASE

(FOR DEMONSTRATION PURPOSES ONLY)

On Behalf of:

In Delegated Cooperation with:

Figure F.11: Map 3 Chobe – Conceptual Flood Risk Mapping for Regulation of New Development, Chobe River Case Study

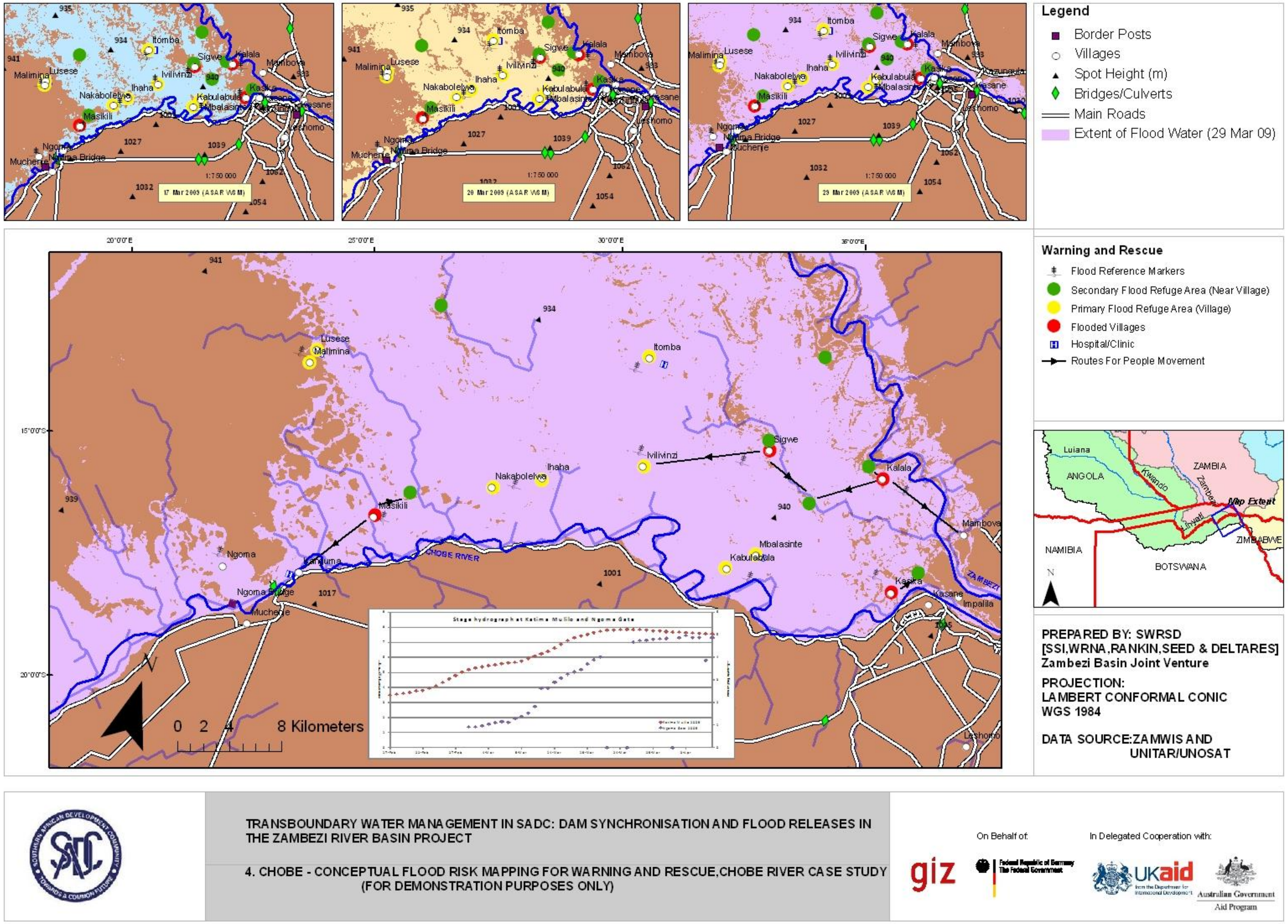


Figure F.12: Map 4 Chobe – Conceptual Flood Risk Mapping for Warning and Rescue, Chobe River Case Study:

Appendix G
Case Study Flood Risk Zoning Lower Zambezi downstream Caia

This Appendix is in support of Chapter 6.

This second case study is along the Zambezi River downstream from Caia in Mozambique. Caia lies close to the confluence of the Shire and Zambezi Rivers (the Shire River flows from the outlet of Lake Malawi/ Nyasa). Figure F.8 shows the case study area.

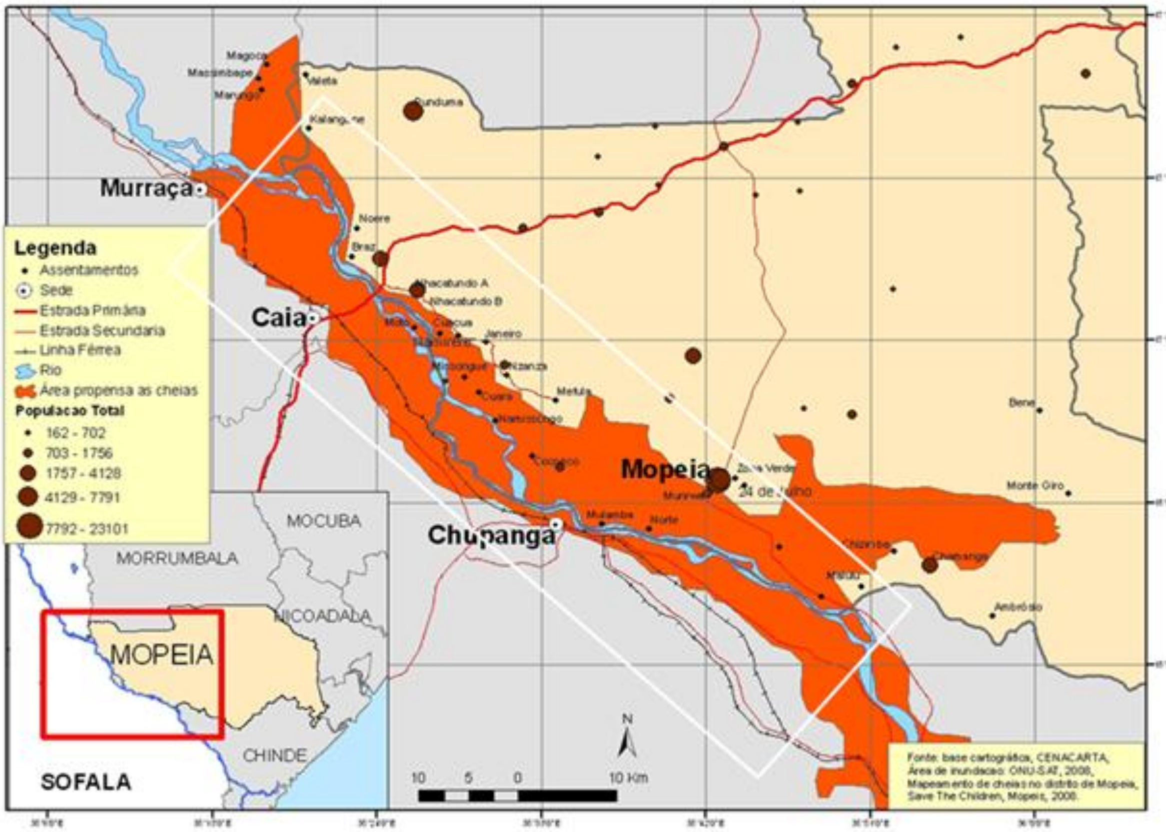


Figure G.1: Case study area delineated on map (orange area subject to flooding in case of severe flood) (Malo et al., 2009)

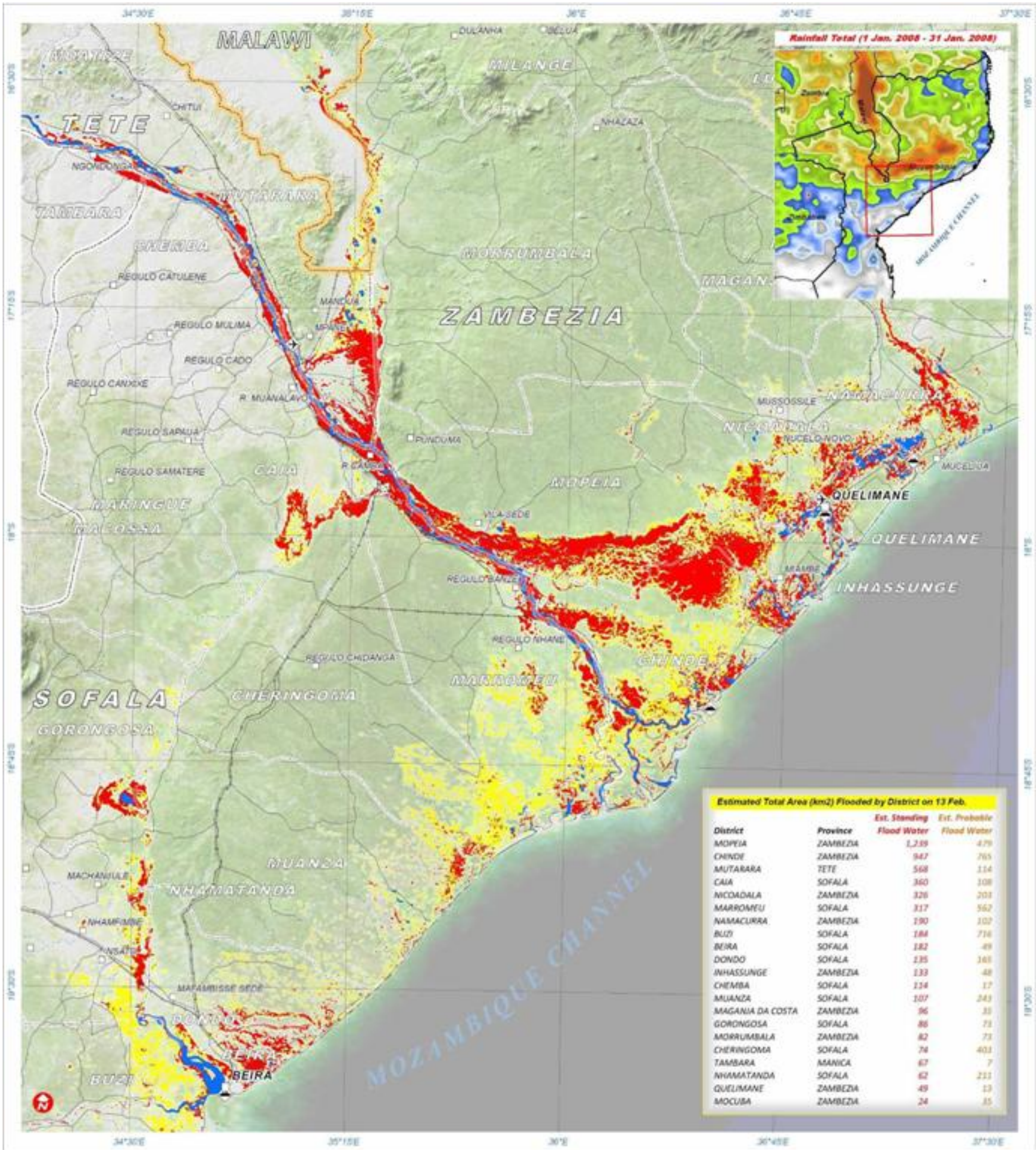


Figure G.2: UNOSAT map of flood of 2008 (blue – pre flood waters Nov 2007, red- standing flood waters 13 Feb 2008 -yellow – probable flood waters Feb 2008, data UNOSAT)

Flood Hazard

The case study area was frequently flooded in the past decade in 2001, 2007 and 2008, showing that floods in the area are a frequent phenomenon. Figure G. shows the extent of the floods in Mozambique in 2008 and therewith the extent of the rescue operation.

Accurate inundation data for different recurrence intervals do not exist for the Lower Zambezi River area, although a Mike-11 hydrodynamic model was developed by DHI Consultants to assist with flood forecasting. The main limitation is that accurate ground elevation data does not exist. Remote sensed inundation data available since approximately 1998 shows that the approximate width of the river and floodplain at maximum inundation exceeds 10 km for most of the 50 km reach under consideration in this case study.

For a large exent of the area, it took several months (2-3) before the land is accessible again for living.

Vulnerability

The main urban settlements along the case study reach are Caia and Mopeia. Caia lies at the upper end of the study reach near the confluence with the Shire, while Mopeia lies approximately 40 km downstream of Caia and some 8 km to the north of the river centreline. Caia and Mopeia have populations of approximately 6000 and 9000 people, respectively. Additional minor settlements lie scattered throughout the floodplain.

Malo *et al*. (2009) show how people were displaced in the area during the floods (See Figure Figure G.).

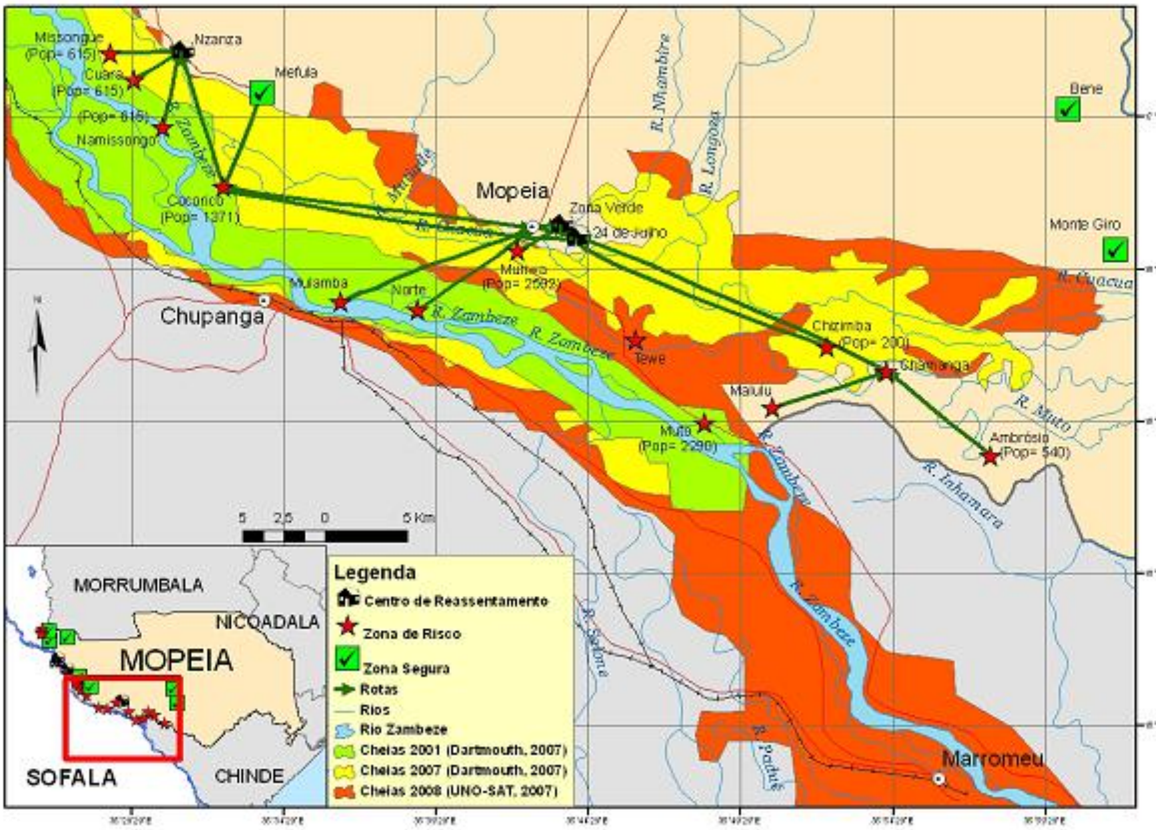


Figure G.3: Arrows show the movement of people during floods (green floods 2001, yellow floods 2007, orange floods 2008) (Malo et al., 2009)

Table G.1: Estimated number of people in refuge camps in 2007in Caia and Mopeia District (Mozambican Government et al. 2007)

Zambezi province Mopeia district	16,870	Sofala province Caia District	51,823
Chimuara Noere	683	Tchetcha	2300
Nhacatundo	4,060	Namacherene	346
24 de Julho	2,065	Mapalane	325
Zona verde	4,294	Mpfumo Domingus	385
Bras	575	Magagade	319
Nzanza Sede	405	Sede DAF	1386
Namirere	1332	Zimbabwe	554
Valeta	809	Chandimba	1585
Mopeia Kalangana	512	Nhambalo	14390
Ambrosio	2135	Nhambalo	21892
		Mfumo Conkho	488
		Chipuazo	300
		Chiramba	2232
		Njezera	1955
		Marra	1205
		Murraca Sapanda Muanaleza	579
		Mfumo Inacio / Bingala Lole	264
		Sapanga Macruzo	345
		Nhacuecha	973

Table G.1: Estimated number of people in refuge camps in 2007in Caia and Mopeia District (Mozambican Government et *al.* 2007)Table G. shows an estimate of the number of people that stayed in refugee camps in Caia and Mopeia district. Specifically for the area around Caia (Mozambican government *et al.*, 2007) recommended the following improvements in terms of emergency relief:

1. Increase aid efforts: latrines, shelter, mosquito nets, soap and food.
2. More community involvement
3. Accommodation centres should have been better equipped with basic infrastructure prior to the crisis, since floods are recurrent in these areas.

In the operational report on the 2007 flood (Government of Mozambique *et al.* 2007) it is further mentioned that *"Many of the accommodation centres were set up during the 2001 floods and were later designated as permanent resettlement centres, where health and education facilities have since been established. Some tension has been reported – particularly around Caia – between people who moved to these resettlement centres after 2001 and people displaced by the current disaster. While their houses have been largely untouched by the floods, residents of the resettlement centres have still been affected and also feel that they should benefit from the emergency assistance being provided to the newly displaced."* This shows that flood risk zoning in terms of settlement has already been taking place to some extent.

No additional data were available on the vulnerability levels of people in the area. But the area is generally poor to very poor.

Flood risk mapping

As for the Chobe River case study, a series of maps have been prepared showing how a system for flood risk classification could be applied to this site. An outline of these maps is provided below (note that details explained in the Chobe River case study that also apply to this study have not been repeated):

- *Map 1 Caia – Flood Inundation Mapping for the Lower Zambezi River near Caia Case Study:* this map shows the 2008 flood inundation extent based on data obtained from UNOSAT. This was the largest flood for which inundation data was available, the 2001 flood being slightly smaller.

- *Map 2 Caia - Conceptual Flood Risk Mapping for Community Education, Zambezi River near Caia Case Study:* as for the Chobe River case study, this map shows how the available flood inundation data could be used to identify areas where the awareness of the community should be raised through education and training on how to respond to flood situations.

- *Map 3 Caia – Conceptual Flood Risk Mapping for Regulation of New Development, Zambezi River near Case Study:* as for the Chobe River case study, the main purpose of this map is to demonstrate how historical flood inundation data could be used to regulate new development.

- *Map 4 Caia – Conceptual Flood Risk Mapping for Warning and Rescue, Caia Case Study:* the last map in the series demonstrates how flood risk mapping could be used to develop mobilization and response plans for evacuation of people in potentially flooded areas to higher ground refuge areas in a flood situation.

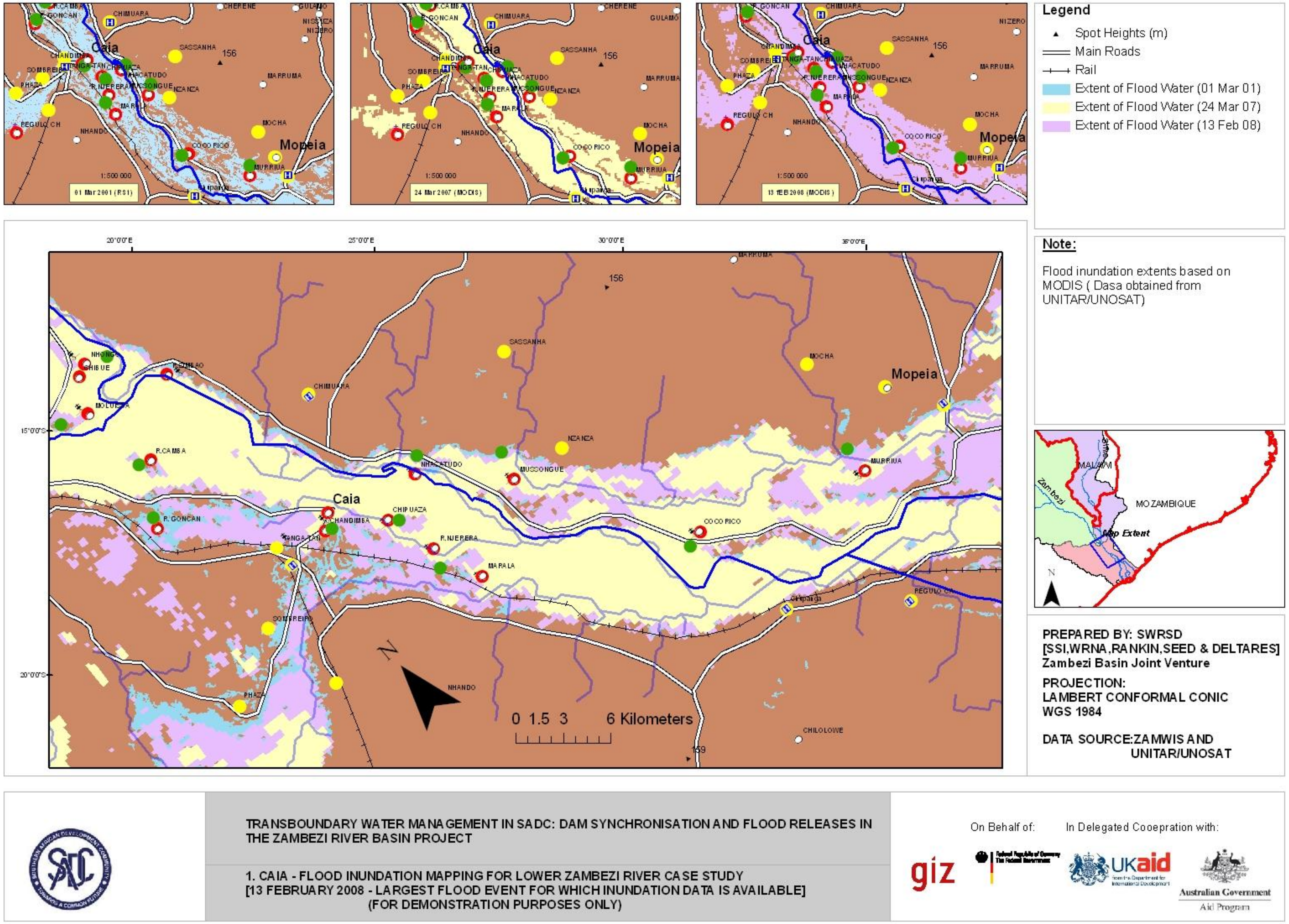


Figure G.13: Map 1 Caia – Flood Inundation Mapping for the Lower Zambezi River near Caia Case Study

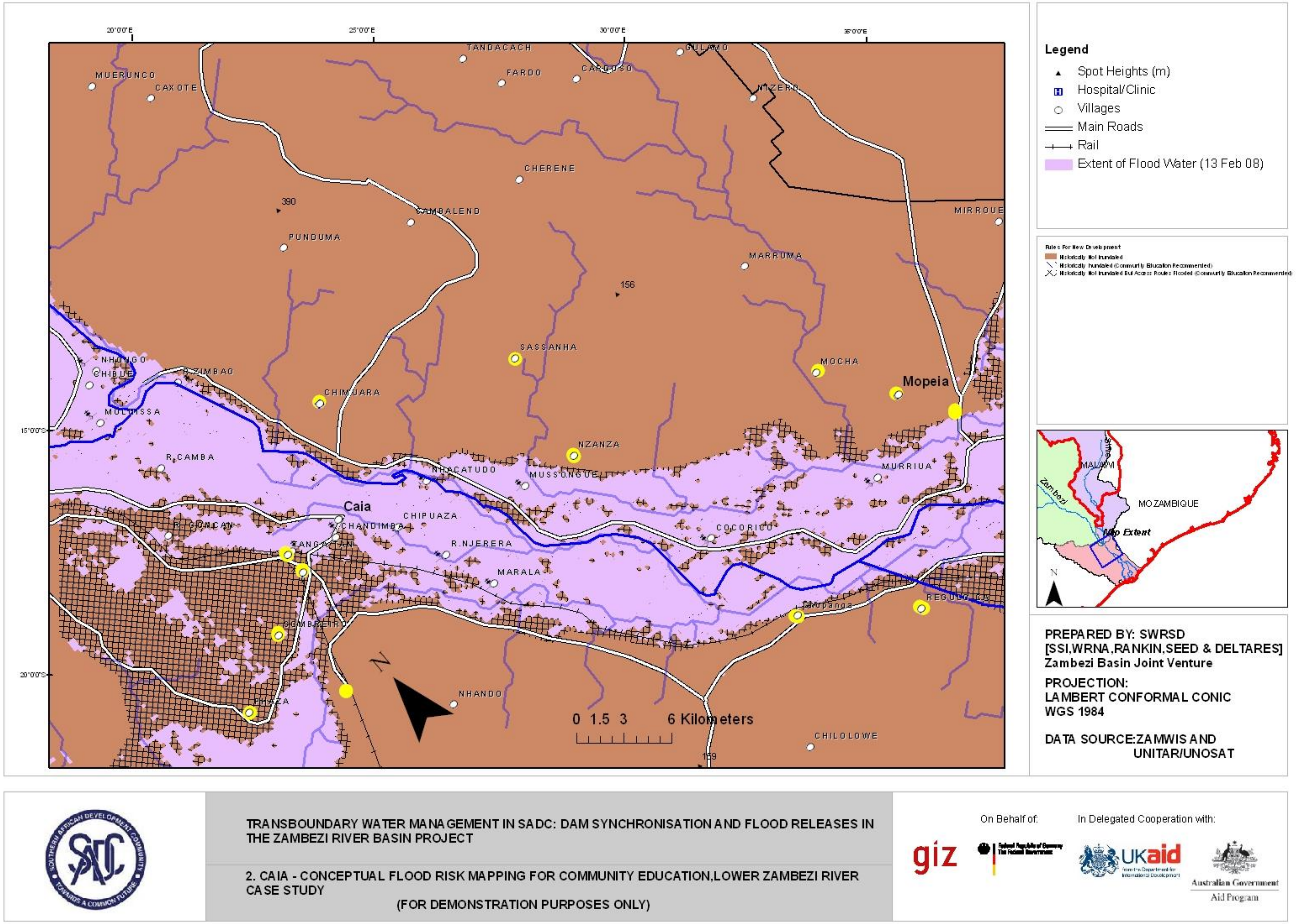
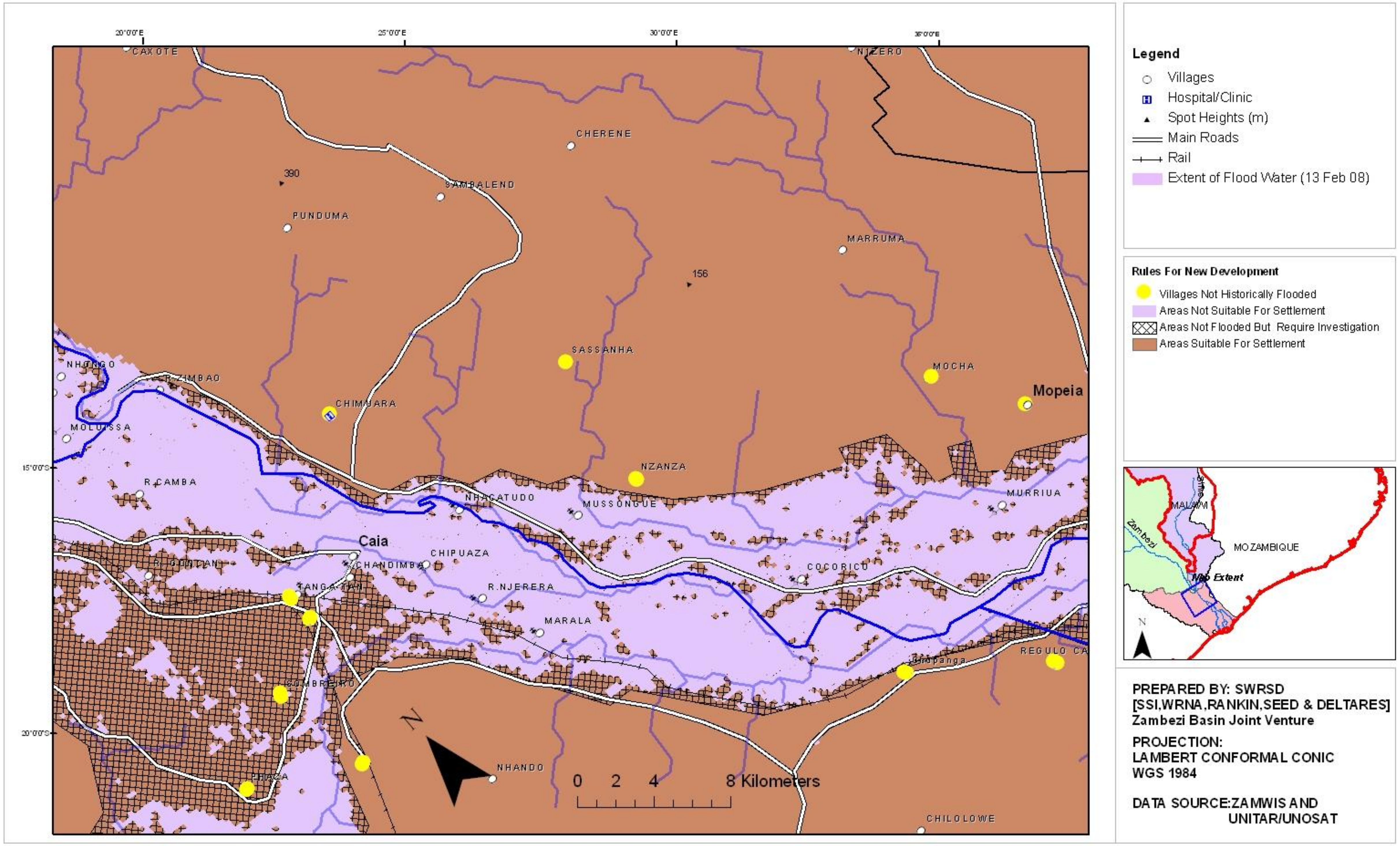


Figure G.14: Map 2 Caia - Conceptual Flood Risk Mapping for Community Education, Zambezi River near Caia Case Study



TRANSBOUNDARY WATER MANAGEMENT IN SADC: DAM SYNCHRONISATION AND FLOOD RELEASES IN THE ZAMBEZI RIVER BASIN PROJECT

3. CAIA - CONCEPTUAL FLOOD RISK MAPPING FOR REGULATION OF NEW DEVELOPMENT,LOWER ZAMBEZI RIVER CASE STUDY
(FOR DEMONSTRATION PURPOSES ONLY)

On Behalf Of: In Delegated Cooperation with:

Figure G.15: Map 3 Caia – Conceptual Flood Risk Mapping for Regulation of New Development, Zambezi River near Case Study

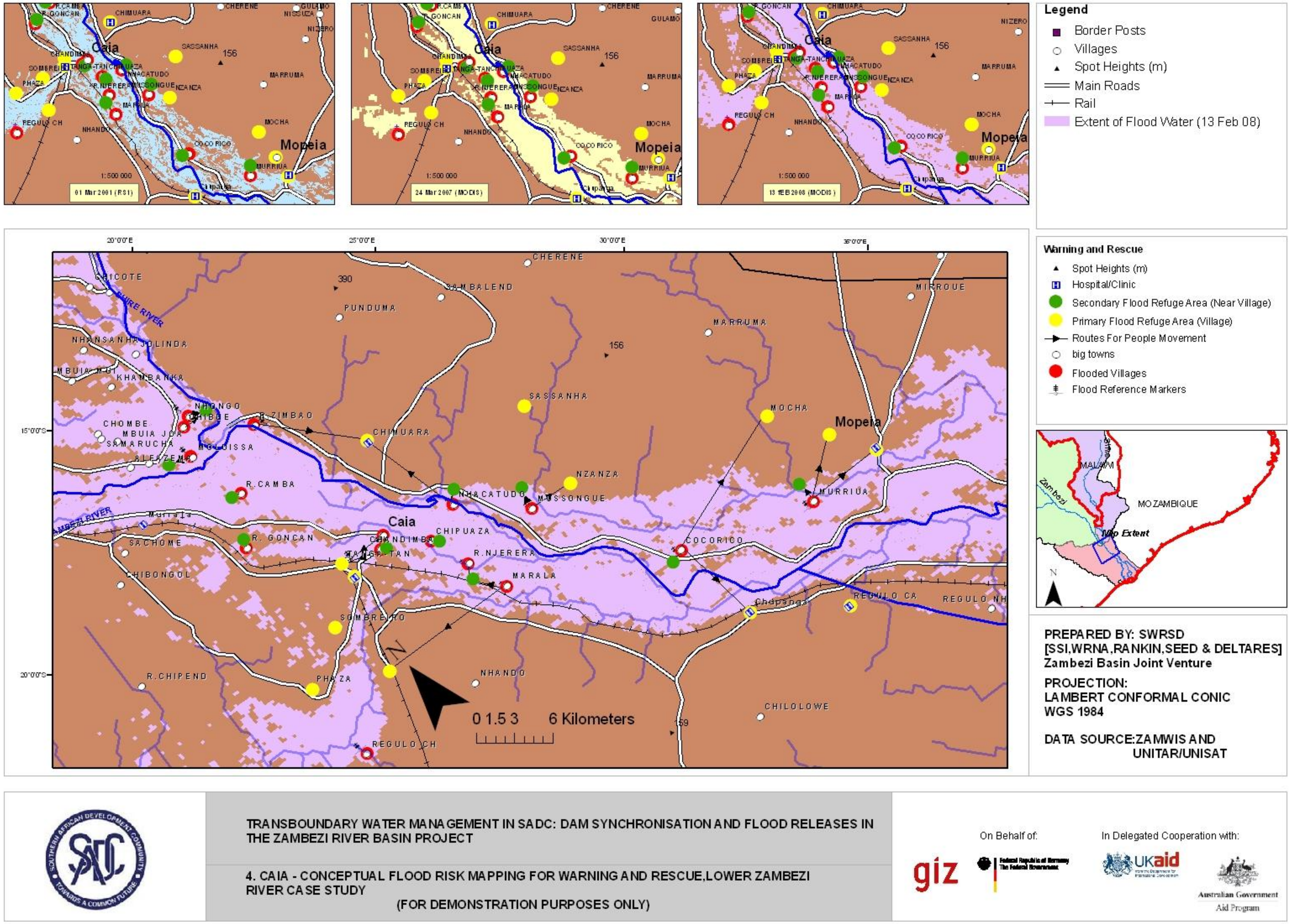


Figure G.16: Map 4 Caia – Conceptual Flood Risk Mapping for Warning and Rescue, Caia Case Study

Appendix H

Information requirements for flood risk zoning

The tables below form part of Chapter 6. They give a first assessment of data requirements and data availability for different applications of flood risk zoning. For example, for Rules for new Settlement the requirement of knowing which area has been historically flooded is high. The requirement to exactly know the frequency of flooding is less necessary. The assessment is a first assessment based on knowhow of the Consultant.

Information requirement

0 = not necessary
+ = useful information
++ = important information
+++ = essential information

Information availability

0 = not available,
+ = to some extent/ for some areas available,
++ = generally available)

Table H.1: For Flood Hazard Potential Assessment, relations between information and purposes of flood risk zoning

Information	Information requirement				Informaton availability			
	Rules for new settlements	Rules for Current Land Use and Awareness Raising	Insurance	Warning & Rescue	Availability of data	Accuracy for historical floods	Investment necessary to obtain data	
Flooded area	+++	+++	+++	+++	+++	High	Limited	Can be derived by satellite observation, partly done by UNOSAT
Frequency	+	++	+++	0	+/-	Almost		Data record too short to accurately derive frequency. Victoria Falls flow record most reliable for frequency indication.
Depth	++	+	+++	+	0	Not available	High	Only possible with detailed DEM, which needs ground truthing by motor bike or at least air flights. RADAR data up to 5 m accuracy.
Lead Time	0	++	0	+++	+	Limited	Considerable	Depends on flood forecasting system
Duration	0	+++	0	+++	+	Limited	High	Only possible to determine for recent floods, otherwise high investment with model.
Velocity	0	+	+	++	0	Not available	High	Only possible with detailed hydraulic modelling requiring detailed DEM, partly unpredictable because dependent on scouring during flood.
Historical Flood Reference	+	0	+	+++	+	Only after 2000 good records	Limited	This gives the possibility to warn; it will be similar to / worse than the flood of year xx; in Zambezi used in local language already
Hazardous Industry	++	++	0	++	+	Not available	N/A	Hardly applicable in Zambezi; but well possible when open cast coal mining is implemented in Mozambique

Table H.2: For Vulnerability Assessment, relations between information requirements and purposes of flood risk zoning and information availability

	Information Requirement				**Information availability**			**Comment**
	Rules for new settlements	**Rules (Current Land Use & Awareness Raising)**	**Insurance**	**Warning & Rescue**	**Availability of data**	**Accuracy for historical floods**	**Investment necessary to obtain data**	
Population and their vulnerability	0	++	0	++	++	Limited	Considerable	No of population only available at district level. In particular in Mozambique, high migration, which makes census data outdated. Satellite image count of houses most reliable. Capacity vulnerability surveys available via Red Cross for a few villages, but general impression of very poor rural communities dependent on floodplain activities (fishing, agriculture)
Land Use	0	+	0	0	++	Limited	Considerable	Satellite images as an indicator
Infrastructure	+	++	+	+	++	Limited	Considerable	In particular difficult for water systems. Some reports on damaged infrastructure of previous flood, but per district not with exact locations.
Refuge Areas	++	++	0	++	0	Limited	Considerable	Needs local input if not available at disaster management agencies
Accessibility / Possibilities for escape	++	++	0	++	0	Limited	Considerable	Needs local input if not available at disaster management agencies
Communica-tion Options	++	++	0	++	+	Limited	Limited	Needs interviews disaster management
Impact on wildlife	0	++	0	+	+	Not available	Large	The impacts on wildlife of floods are only known in qualitative terms, apart from some local studies (see main text)