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Lake Rukwa Basin IWRMD Plan: Final Report
Volume II (c): Momba Sub-basin Water Resources Management and Development Plan

by

WREM International Inc.
Atlanta, Georgia, USA

April 2016

Lake Rukwa Basin Integrated Water Resources Management and Development Plan

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Disclaimer

The views expressed in this report are those of WREM International Inc. and do not necessarily reflect the views of the Lake Rukwa Basin Water Board, or the views of the Ministry of Water of the United Republic of Tanzania.

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Preamble

This report is one of six Final IWRMD Plan Report volumes developed under the project "Lake Rukwa Basin Integrated Water Resources Management and Development Plan (IWRMDP)." This project was carried out for the Ministry of Water, United Republic of Tanzania, under the Water Sector Development Program (WSDP).

A brief description of these reports is provided below.

Volume I: Lake Rukwa Basin IWRMD Plan Main Report – Volume I contains the synthesis of information generated from all project activities with emphasis on the main study findings, conclusions, and recommendations. It contains results from the basin-wide integrated assessments and recommended actions that cut across sub-basins.

Volume II: Sub-basin Water Resources Management and Development Plans – Volume II (a) to (f) of the report series presents the sub-basin specific water resources management and development plans for Katuma, Songwe, Momba, Luiche, Muze, and Rungwa. The sub-basin plans are the basis for development of the basin-wide IWRMD Plan.

Volume III: IWRMD Plan Implementation Strategy and Action Plan – Volume III presents the IWRMD Plan implementation strategy and action plan which includes two main components: (a) the implementation strategy which highlights the administrative and financial modalities of the IWRMD Plan implementation, and identifies the key players to be involved in implementation of the Plan and their corresponding roles; and (b) the Action Plan which outlines the requisite steps to be taken and preparatory activities necessary to kick-start the Plan implementation process. The report also presents the Monitoring and Evaluation Strategy for the IWRMD Plan implementation process and a Communication Plan for information dissemination to the public to facilitate sustained stakeholder engagement and feedback.

Volume IV: Capacity Building and Stakeholder Participation Plan – Volume IV presents the proposed capacity building and stakeholder participation mechanisms. The report identifies the different basin stakeholder groups, assesses their capacity needs, and proposes capacity building measures to enable them to effectively participate in basin water resources management activities, particularly IWRMD Plan implementation.

Volume V: Rukwa Decision Support System (Rukwa DSS v3.0) – Volume V describes the third version of the Lake Rukwa Basin Decision Support System (Rukwa DSS v3.0) developed to support integrated water resources planning and management. The Rukwa DSS v3.0 is a state of the science information and modeling tool including comprehensive databases; data management and analysis tools; and detailed models for hydrologic forecasting, river simulation, and scenario/policy assessment. The report is a systematic guide to the use of this modern information, modeling, and assessment system for integrated planning and management of the basin water resources.

Volume VI: Lake Rukwa Basin Monitoring Plan – This volume provides recommendations for comprehensive monitoring of the basin climate, surface water hydrology, groundwater hydrology, and water quality. The condition of the existing monitoring networks is critically reviewed and existing gaps identified. Guiding principles for the design of effective monitoring networks are outlined and used as the basis for specific recommendations on network upgrade, expansion, efficient operation, and coordination. Important data management issues are discussed, and an integrated data and information management process is outlined.

Table of Contents

List of Figures

List of Tables

List of Acronyms and Abreviations

BMUs	Beach Management Units
CC	City Council
CITES	Convention on International Trade in Endangered Wild Flora
COSTECH	Commission for Science and Technology
COWSO	Community Owned Water Supply Organization
DC	District Council
DSS	Decision Support System
DWR	Department of Water Resources
EFA	Environmental Flow Assessment
EFRs	Environmental Flow Requirements
FAO	Food and Agriculture Organization of the United Nationa
GBIF	Global Biodiversity Information Facility
GEF	Global Environmental Facility
GoB	Government of Belgium
GoT	Government of Tanzania
GR	Game Reserve
HEC	Human Elephant Conflict
HIMA	Hifadhi ya Mazingira
IMP	Integrated Management Plan
IUCN	The World Conservation Union
IWRDMP	Integrated Water Resources Development and Management Plan
LRBWB	Lake Rukwa Basin Water Board
MC	Municipal Council
MoLDF	Ministry of Livestock Development and Fisheries
MSY	Maximum Sustainable Yield
MW	Mega Watts
NEAP	National Environmental Action Plan
NEMC	National Environment Management Council
NGO	Non Governmental Organization
MNRT	Ministry of Natural Resources and Tourism
PID	Pelvic Inflammatory Disease
SADC	Southern African Development Cooperation
SMUWC	Sustainable Management of the Usangu Wetland and its Catchment
SRF	Systematic Reconnaissance Flight
TAFIRI	Tanzania Fisheries Research Institute
TAFORI	Tanzania Forestry Research Institute
TANAPA	Tanzania National Parks
TanBIF	Tanzania Biodiversity Information Facility
TAWIRI	Tanzania Wildlife Research Institute
TC	Town Council
TTB	Tanzania Tourism Board
TShs	Tanzanian Shillings
WB	The World Bank
WCS	Wildlife Conservation Society
WCST	Wildlife Conservation Society of Tanzania
WMA	Wildlife Management Area
WREM	Water Resources and Energy Management Incorporated

1. Introduction

The Government of the United Republic of Tanzania is implementing the Water Sector Development Programme (WSDP; 2006–2025) to strengthen the existing water resources management framework, improve the delivery of sustainable water supply and sanitation services, and strengthen the capacities of sector institutions. The program includes four main components: (i) Water Resources Management and Development (WRMD); (ii) Community Water Supply and Sanitation (CWSS); (iii) Commercial Water Supply and Sewerage (CWS); and (iv) Sector Institutional Strengthening and Capacity Building.

The current project falls under the Water Resources Management and Development component whose overall objectives are as follows:

(i) Develop a sound water resources management and development framework in all nine water basins for optimizing water resources utilization in a sustainable manner for the various competing uses.
(ii) Promote good governance of water resources through: empowering water users; encouraging participatory and transparent decision-making in the allocation, utilizationprotection and conservation of water resources; devolving ownership to the user level; granting secure water use permits with responsibilities to the water users, community groups, local government and basin boards; and promoting economic instruments to encourage wise use of water.
(iii) Strengthen the capacity of basin boards to address trans-boundary water resources issues.

The overarching objective of the Lake Rukwa Basin IWRMD project is:

"To develop a basin-wide Integrated Water Resources Management and Development (IWRMD) Plan for the Lake Rukwa Basin by (i) assessing water resources and identifying current and future water demands of different sectors, (ii) formulating/evaluating alternatives that will meet those needs, (iii) recommending specific water resources development and management options for the short term (up to 2015), medium term (up to 2025), and long term (up to 2035), and (iv) building capacity of staff of the basin water board and office and other stakeholder agencies to ensure successful development and implementation of the Plan."

This report volume constitutes the Water Resources Management and Development (WRMD) Plan for the Momba Sub-basin, one of the six sub-basins of the Lake Rukwa Basin. The Sub-basin WRMD Plans are the basis and important inputs to the Lake Rukwa Basin Integrated Water Resources Management and Development (IWRMD) Plan. The Sub-basin Plans highlight the major water resources management and development issues and challenges specific to each sub-basin and identify water allocation priorities between competing users within the different sub-basins. In developing the Sub-basin Plans, a number of detailed assessments were carried out. These included (a) water availability assessments under historical and future climate conditions; (b) current sectoral water use assessments and future water demand projections; (c) water balance assessments under historical and future climate conditions; and (d) identification of specific priority intervention measures to address the sub-basin water needs in the short-, medium-, and long-term. To ensure reliability and relevance of the assessment findings, significant time and effort was dedicated towards collection, review, and quality control of the required information and data used in carrying out different technical assessments. All major sub-basin stakeholders were visited and accorded the opportunity to provide input, express their opinions, and raise any concerns regarding the Plan development process. Likewise, all basin regional secretariats and districts were visited, and discussions were held with relevant officials to solicit their input into the Plan development process. Specifically, discussions were held with heads of departments in all basin districts on thematic issues to leverage local experience, seek guidance as key stakeholders, and access relevant district-specific and up-to-date data and information. Detailed data/information gathering questionnaires were circulated to all district heads of departments soliciting sector-specific water use related data and information at ward and village levels. The questionnaire response was 100%, indicating that the districts embraced the Plan development process and importance with great enthusiasm. All relevant documents were reviewed and critically assessed including the latest Regional and District Socioeconomic Profiles; District Development Plans; National Sample Census of Agriculture Reports; Livestock Sample Survey Census reports; and several other important sectoral planning documents. In addition, detailed questionnaires were also administered to several households (about 50 households per ward) in 40 wards spread across all basin districts. The data and information captured in the household questionnaires were vital in establishing baseline socio-economic conditions and the level of dependence on water resources by local communities. Overall, the detailed consultative and data/information gathering process generated significant useful data/information that formed the basis for all the assessments carried out and findings presented in the IWRMD Plan reports.

Based on the data and information gathered, several hydrological and water resources assessments were conducted at sub-basin and basin levels. These studies revealed that the Momba Sub-basin is not experiencing any significant water stress under current water demand levels. However, the situation could change in the short to medium term due to projected increases in irrigation water demand corresponding to the planned irrigation developments. Furthermore, assessments reveal that the sub-basin is already experiencing climate change and is becoming increasingly vulnerable to future climate change. Projected climate change is expected to impact the sub-basin hydrology, agriculture, and water resources. This is because increasing temperatures lead to higher evapotranspiration and reduce surface water flows, soil moisture, groundwater recharge, and lake/reservoir levels. Furthermore, higher crop evapotranspiration will further increase irrigation demand. The combined impacts of rising water use levels and climate change portend reduction of natural water supplies and increased stresses on all water related sectors.

The detailed sub-basin assessment findings, conclusions, and potential intervention measures were extensively reviewed and discussed by sub-basin stakeholders at different fora. Several technical assessment reports containing these findings and conclusions (Interim Reports I and II) were widely circulated to all major stakeholders for review and comments. The reports were also presented at several stakeholder consultation meetings and workshops facilitated by the LRBWB and the project team. Stakeholder comments were extensive and provided guidance to address priority stakeholder interests and concerns. These comments are reflected in the strategic objectives and priority interventions discussed in this report. The interventions were grouped into five strategic program areas to be implemented over the planning period (2016 to 2035):

(1) Water Security Enhancement Program;
(2) Water Resources Monitoring and Assessment Program;
(3) Water Permit Compliance Monitoring Program;
(4) Environment Flow Assessment and Monitoring Program; and
(5) Integrated Watershed Management and Environmental Conservation.

The total estimated budget required for implementation of the Momba Sub-basin WRMD Plan from 2016 to 2035 is about 18.29 Billion TShs. The Plan is expected to be reviewed every five years to benefit from updated water resources assessments and additional water resources data collection. The review will also ensure that the Plan is continuously re-aligned to address other emerging sub-basin challenges and to leverage new development opportunities as they arise.

The report is organized into six chapters. Chapter 1 introduced the IWRMD planning process and its general findings for the Momba sub-basin. Chapter 2 provides a general overview of the Momba sub-basin including its location, topography, climate, water availability, and socioeconomic conditions. Chapter 3 discusses the current sectoral water use levels and water demand projections. Chapter 4 presents the sub-basin water balance assessments and highlights the strategies for addressing current and anticipated water deficits. Chapter 5 discusses the sub-basin Plan strategic goals, objectives and priority intervention measures. Lastly, Chapter 6 presents the Strategic Action Plan and estimated budget.

2. Overview of the Momba Sub-basin

2.1 Location

The Momba sub-basin occupies the southwestern part of the Lake Rukwa Basin and extends over an area about 9,750 km^2 covering parts of Sumbawanga DC, Momba, Kalambo, and Mbozi Districts (**Figure 2.1**). The sub-basin population is about 619,627 (2012 National Census), which is the second highest in the Lake Rukwa Basin after Songwe. The main urban centers are Vwawa, Tunduma, and Laela townships. The sub-basin has an average population growth rate of 3.4% which is above the Tanzania national average of 2.9%. The sub-basin population is projected to increase to about 1,107,054 by 2035, an increase of about 76% (see **Figure 2.2**).

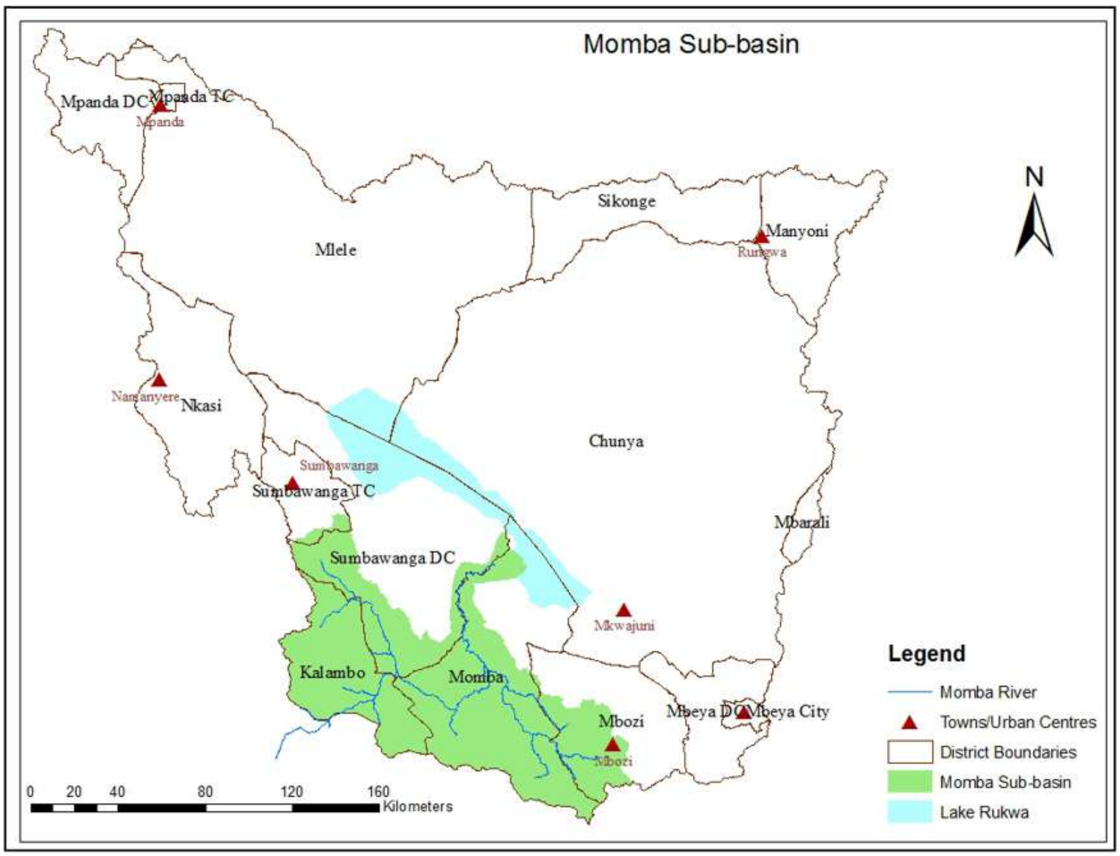


Figure 2.1: Location of the Momba Sub-basin.

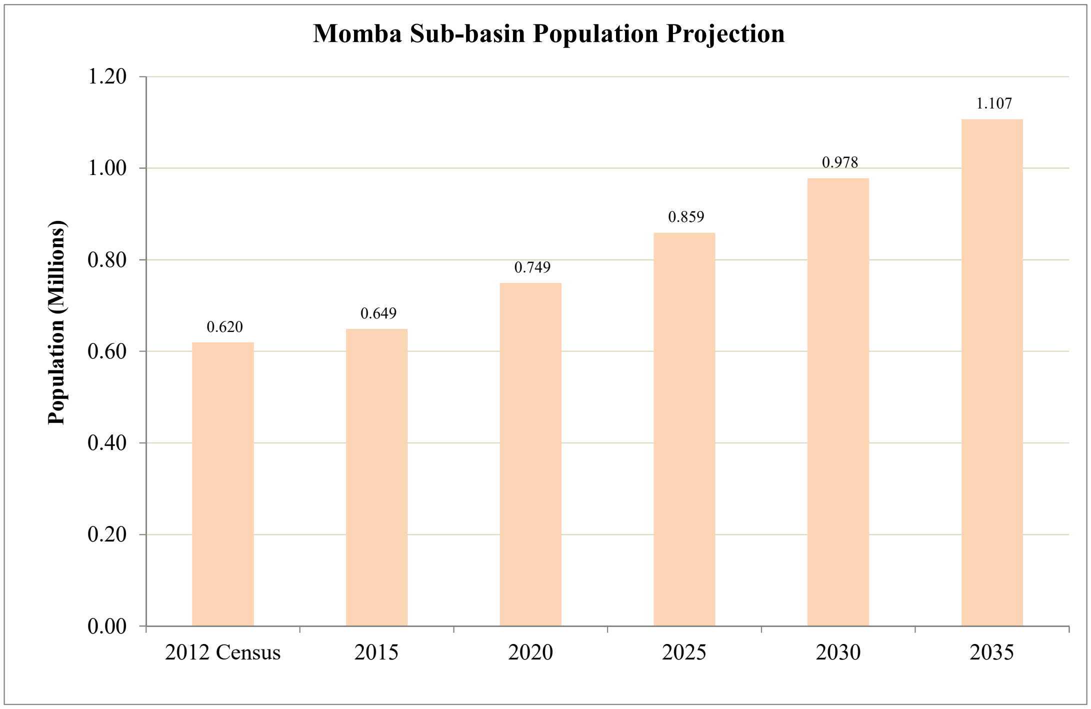


Figure 2.2: Momba Sub-basin Population Projection.

2.2 Physical Characteristics

The western part of the sub-basin lies within the Ufipa Plateau, a highly productive agricultural area with good fertile soils and reliable rainfall. The southeastern part covering Mbozi and parts of Momba district falls within the southern highlands where most irrigation activities take place. A small portion of the sub-basin falls within the Rukwa Valley, an area characterized by extensive flat plains popular for farming, livestock keeping, fishing, and lumbering. The sub-basin topography has gentle plains with moderately slopping hills and plateau lying at an altitude between 1,000 to 2,400m above sea level. The plateau is mostly grassland and is considered to be one of the most productive areas in the region with good fertile ferralitic soils and reliable rainfall.

2.3 Socioeconomic Conditions

Detailed socioeconomic surveys and assessments were conducted to establish baseline conditions and the level of dependence on the basin's water resources by riparian communities. Detailed findings are presented in ***Volume II: Lake Rukwa Basin Socioeconomic Profile***. Findings for the Momba Sub-basin are summarized next.

2.3.1 Socioeconomic Importance

Agriculture is a dominant activity employing more than 90% of the sub-basin population. Major crops grown include coffee, maize, beans, tea, banana, and to a smaller extent Irish and sweet potatoes, paddy, pyrethrum, and cocoa. The sub-basin has high irrigation potential and accounts for about 20% of the current irrigation water use in the Lake Rukwa Basin. There are only three medium scale industries, two coffee processing factories at Lima Central Pulpery Unit (Insani) and Kanji Lalji Limited and GDM Company Limited. Other small scale industries include carpentry workshops, oil seed extracting mills, milk processing, iron smith, maize mills and rice hulls. The sub-basin has good hydropower potential on the Mtembwa River estimated to be about 30MW with a head of about 270 meters. This site is located at Yala Falls downstream of an existing hydrometric station (3B15: Mtembwa at Chipoma) in Mfuto/Yala village in Momba District Council.

2.3.2 Occupation and Source of Household Income

According to a detailed household survey conducted under the study (WREM International, 2013), the majority (73.2%) of household heads are engaged in agriculture (crop farming and livestock keeping) as their primary occupation (**Figure 2.3**). Other significant occupation categories include formal and self-employment (retail shops, street vending, brick and craft making, charcoal burning, transportation). The major source of household income is the sale of agricultural produce (food and cash crops). About 53.4% of the households depend on agricultural produce sales as their main household income (see **Figure 2.4**).

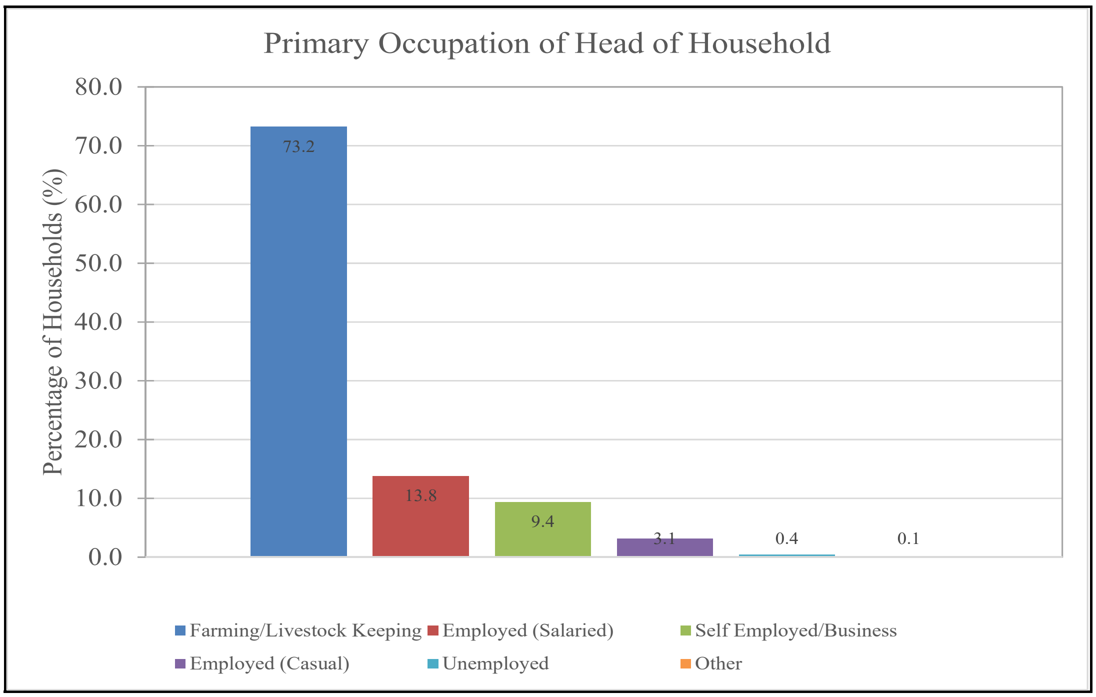


Figure 2.3: Primary Occupation of Head of Household.

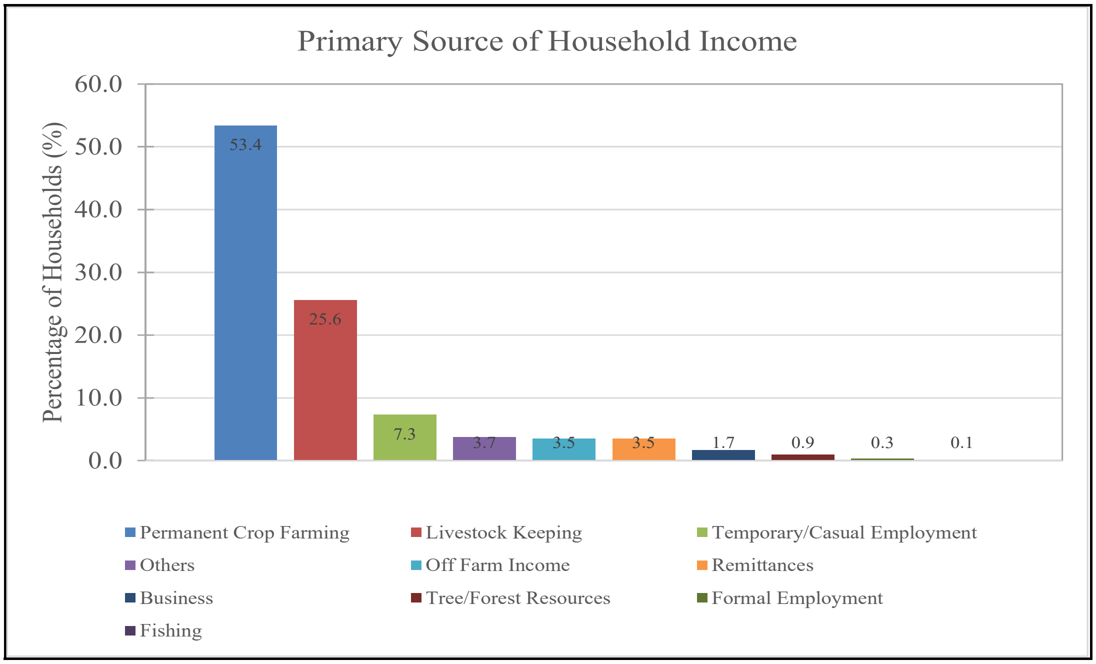


Figure 2.4: Primary Source of Household Income.

2.3.3 Access to Social Services

Domestic Water Supply: District water supply coverage varies from 40% in Momba DC to 48% in Kalambo DC. The coverage in all sub-basin districts is lower than the 2015 national targets.

Sanitation: The majority (more than 90%) of households rely on traditional pit latrines for their household sanitation. This has implications for water pollution due to poor latrine location and construction. Most pit latrines flood during heavy rains and contaminate neighboring water bodies. The problem is most pronounced in crowded, poorly-planned settlements in urban and peri-urban areas.

Energy Source: Fuel wood in the form of firewood and charcoal is the most important source of energy for more than 90% of the sub-basin population. It is mostly used for domestic cooking and lighting and in diverse subsistence economic activities such as brick making, pottery and curing of tobacco. Over-reliance on fuel wood is responsible for the wide spread deforestation observed in many sub-basin areas. This has serious environmental consequences including soil erosion, drying up of water sources, and heavy sediment transport and deposition in surface water bodies.

Health Services: The status of health services in the Momba sub-basin is poor compared to other parts of Tanzania. For example Mbozi DC has a very high number of people per health facility estimated to be about 10,953. There is also a general shortage of medical staff in all sub-basin districts. For example the mean doctor/population ratio for Sumbawanga DC is about 1:258,375 well below the WHO recommended standard of 1:10,000 and national average of 1:25,000.

2.4 Water Availability

Detailed water resources availability assessments were conducted for the whole basin and the findings are contained in *Interim Report I, Volume II: Water Availability Assessments*. Findings for the Momba sub-basin are summarized next. For more details please refer to the above report volume.

2.4.1 Climate

The sub-basin is mostly characterized by tropical climate and experiences one long rainy season (October to May). The dry season starts from around June to September (**Figure 2.5**) with July being the driest month. Annual rainfall ranges from 800 mm in the lowlands to 2600mm in the highlands. Mean temperatures vary with altitude from about 16^{o}C in the highlands to about 30^{o}C in the lowland areas.

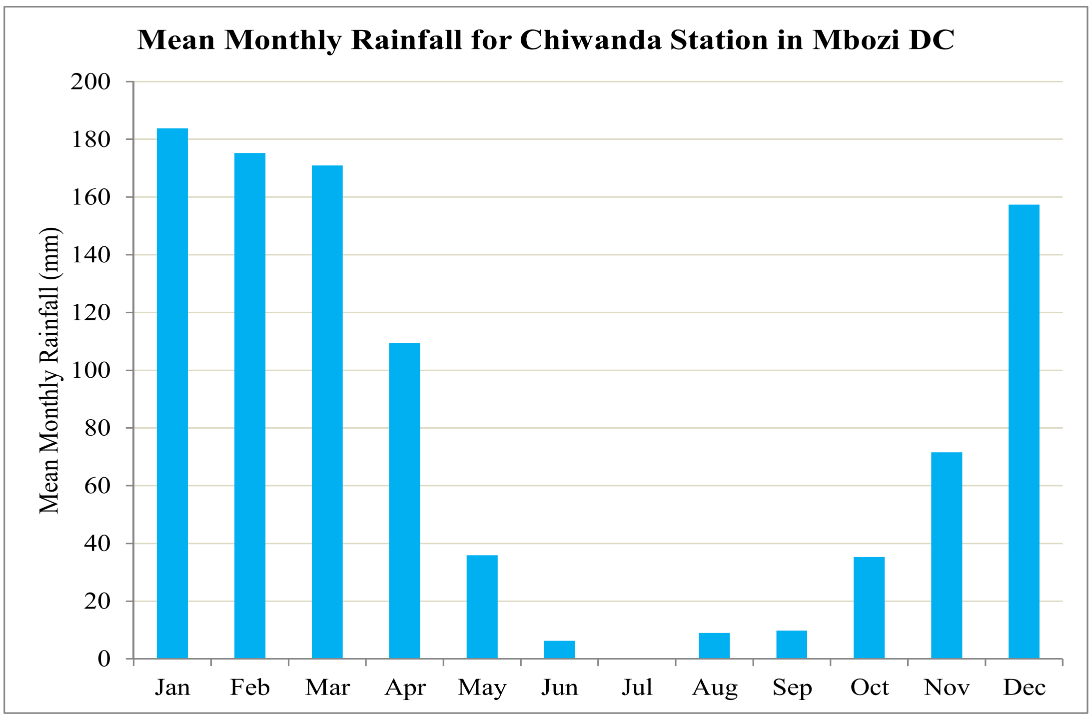


Figure 2.5: Mean Monthly Rainfall for Chiwanda Station in Mbozi DC.

2.4.2 Surface Water Resources

The Momba Sub-basin is drained by four main rivers: Momba, Mtembwa, Saesi, and Nkana. River Mtembwa originates from the Ufipa plateau and drains the northwestern part of the sub-basin. It flows southwards through several vast swamps where it is joined by other smaller rivers before discharging into the Iyunga Samyva swamp. The River then exits the swamp and flows southeastwards before joining River Saesi which originates from the Nthumbe Hills. River Saesi drains the western part of the sub-basin and discharges into the Tesa swamp where it is joined by several smaller rivers that drain the southern part of the sub-basin. From the swamp, the Saesi River flows northeastwards, is joined by the Kipanda and Matonto Rivers, which originate from the Izombo plateau, and crosses the Lyambalyamfipa escarpment into the Rukwa Valley. In the valley, the Saesi River is joined by the Nkana River to form the Momba River. River Nkana originates from the southern highlands in Mbozi District and drains the southeastern part of the sub-basin. It is fed by several rivers including Mpemba and Mko from the Chingambo Ranges. The Momba River flows northeastwards across the Rukwa Valley and finally discharges into the western shores of Lake Rukwa. A small portion of the Momba River watershed (in the southwest) extends into Zambia. Thus, Momba is a transboundary (shared) river, and its integrated planning and management requires the development of mutually agreed upon plans with Zambia.

All the sub-basin rivers exhibit strong seasonality, high flows in the rainy season, and significantly low flows in the rest of the year (see **Figure 2.6**). The rivers register peak flows during March to April and very low flows from July to November.

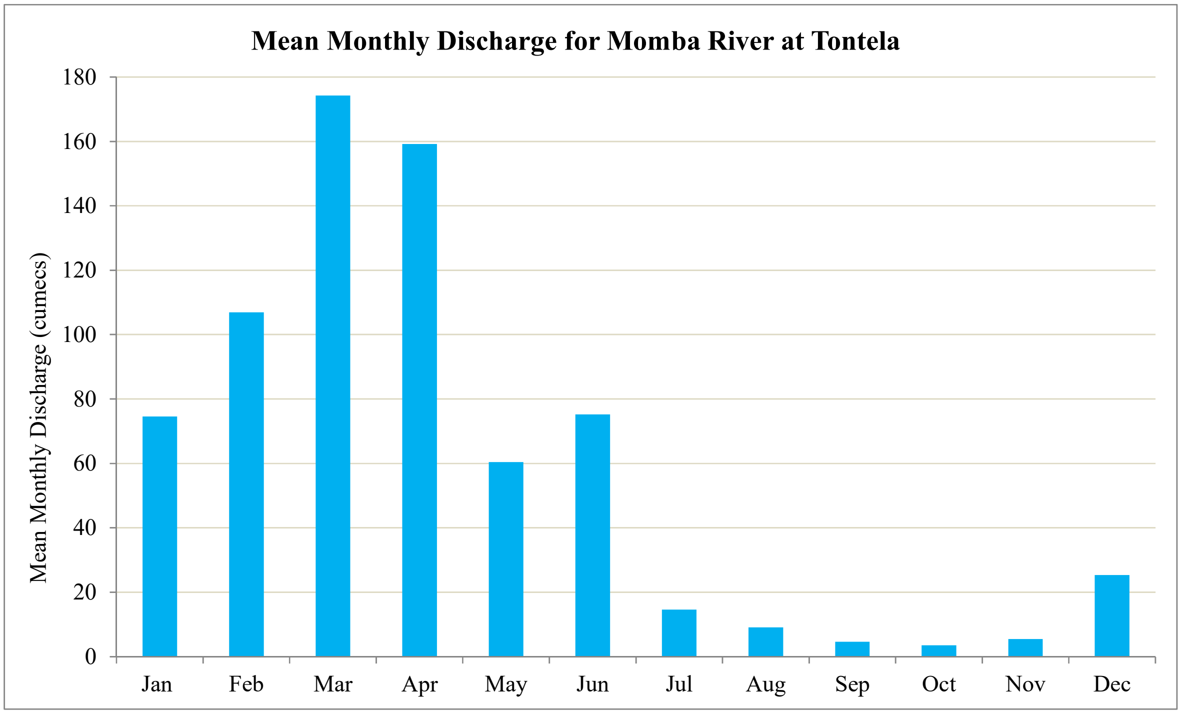


Figure 2.6: Mean Monthly Discharge for the Momba River at Tontela.

The Lake Rukwa Basin Water Board (LRBWB) operates and maintains a water resources data collection network for the sub-basin consisting of the hydrometric, meteorological, and water quality stations shown in **Figure 2.7**. In addition to the above network of stations, a few rainfall stations exist but are operated by other agencies and institutions including the Tanzania Meteorological Agency, Agricultural Research Institutions, Church Missions, and schools.

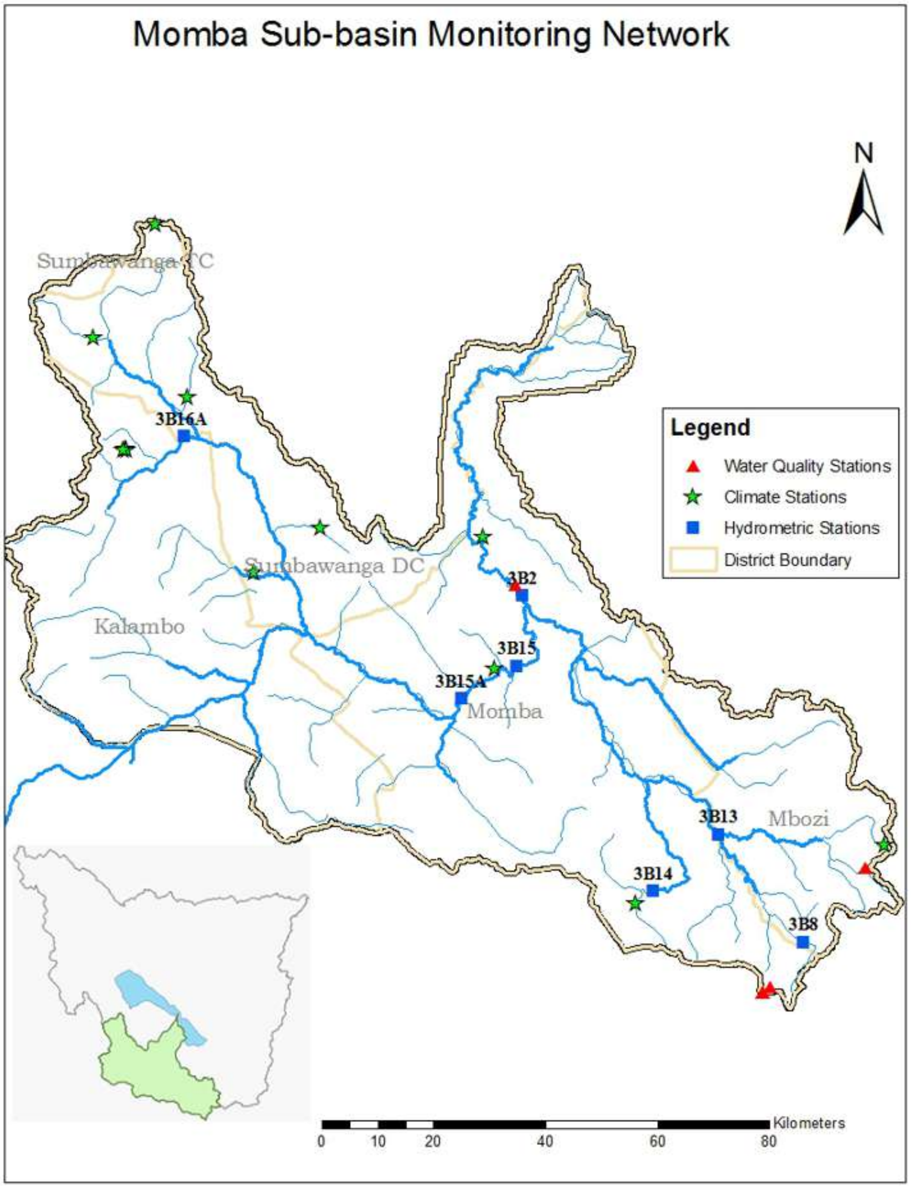


Figure 2.7: Momba Sub-basin Water Resources Monitoring Network.

Table 2.1 shows details of the sub-basin hydrometric stations most of which underwent extensive rehabilitation recently. Two of the stations, Mtembwa River at Luasho (3B15A) and Muko River at Kaziala (3B14), were closed and are nolonger operational. Several of the operational stations have significant data gaps due to inconsistencies in the monitoring program mostly attributed to inadequate funding. The situation is worsened by frequent equipment break downs due to vandalism and poor maintenance. The rating curves of all existing hydrometric stations are outdated and need recalibration.

Table 2.1: Momba Sub-basin Hydrometric Stations.

Station Code	River	Station Location	Data Record	Status
3B16A	Samvya	Yunga	1979 - 2013	Operational [Rehabilitated]
3B8	Mpemba	Great North Road	1957 - 1998	Rehabilitated
3B13	Mpemba	Kombe	1974 - 1997	Rehabilitated
3B15	Mtembwa	Chipoma	1974 - 2012	Operational [Rehabilitated]
3B15A	Mtembwa	Luasho	1978 - 2002	Closed
3B2	Momba	Tontela	1974 - 1999	Rehabilitated
3B14	Muko	Kaziala	1974 - 1982	Closed

2.4.3 Groundwater Resources

There is no existing groundwater monitoring network to provide the necessary data for estimating groundwater potential and aquifer characterization. Nevertheless, groundwater is a major source of domestic water supply in most sub-basin rural areas, especially in Sumbawanga DC where more than 100 production boreholes have been drilled to date. Observations from existing records indicate high yielding boreholes in areas along the Ufipa plateau. A clearer picture of the sub-basin groundwater potential, yield, and spatial distribution will only be possible after establishing a comprehensive groundwater monitoring network and collection of the necessary data.

2.4.4 Water Quality

Generally, the physical and bacteriological water quality is relatively good compared to other Lake Rukwa sub-basins. However, there are some localized cases of high bacteriological contamination mostly in the densely populated urban areas of Tunduma, Vwawa, and Laela. This is mainly attributed to poor household sanitation and poor solid waste management. There are reported incidences of illegal emptying of septic tanks and domestic wastewater into storm water drains, open defecation, and discharge of untreated solid and liquid wastes from cottage industries and car garages into nearby streams. The result is very heavy contamination of water sources located within or around the townships. Physical quality is also poor in a number of sources due to degradation of upstream watersheds. Particularly, the Momba River is known to deliver considerable sediment loads into Lake Rukwa annually. With regard to chemical quality, there are isolated cases of high mineralization around Msangano and Kavifuti villages in Mbozi and Sumbawanga DC respectively.

3. Sectoral Water Use and Demand Projections

3.1 Water Use and Demand Projections

Irrigation is the major consumptive water use sector accounting for 76% of the total sub-basin water consumption. The domestic and livestock sectors account for 20% and 4% respectively. Industrial water use is very small compared to the other uses. The total water demand for the Momba sub-basin is projected to increase from 50 MCM in 2015 to 317 MCM by 2035, an increase of about 534%. The projected increments in the individual sectors are as shown in **Table 3.1** and **Figure 3.1**. Irrigation alone will account for about 94% of the total sub-basin water use by 2035. Smaller increments are projected for the domestic and livestock sectors. A detailed discussion of water demand projections for all Lake Rukwa sub-basins is contained in a separate report volume (*Interim Report 2, Volume I: Water Demand Projections*).

Table 3.1: Momba Sub-basin Water Demand Projections.

Sector	**Demand Projection (MCM)**				
	2015	**2020**	**2025**	**2030**	**2035**
Irrigation	39.70	55.10	103.30	263.20	299.20
Domestic	8.33	9.58	11.45	12.96	14.65
Livestock	1.97	2.23	2.51	2.84	3.21
Sub-basin Total	**50.00**	**66.90**	**117.26**	**279.00**	**317.05**

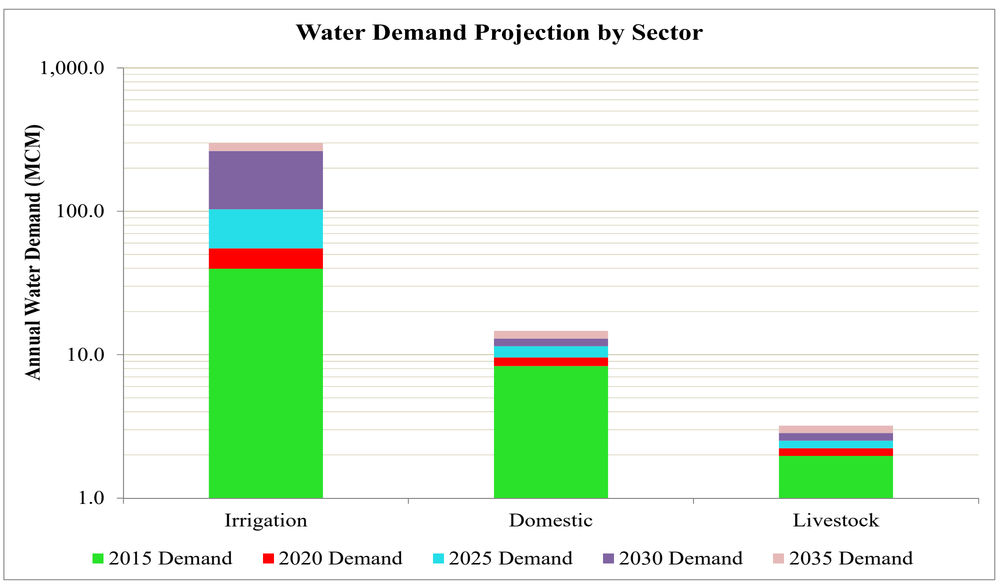


Figure 3.1: Momba Sub-basin Water Demand Projections.

All the sectors mostly rely on surface water sources (rivers, streams, dams). Groundwater is an important source of domestic water supply in a number of rural communities. Although it currently accounts for only 22% of total sub-basin domestic water supply, potential exists for increased groundwater use in the future especially once efforts have been made to assess potential, yield, and spatial distribution. **Figure 3.2** shows the location of major water uses in the Momba sub-basin.

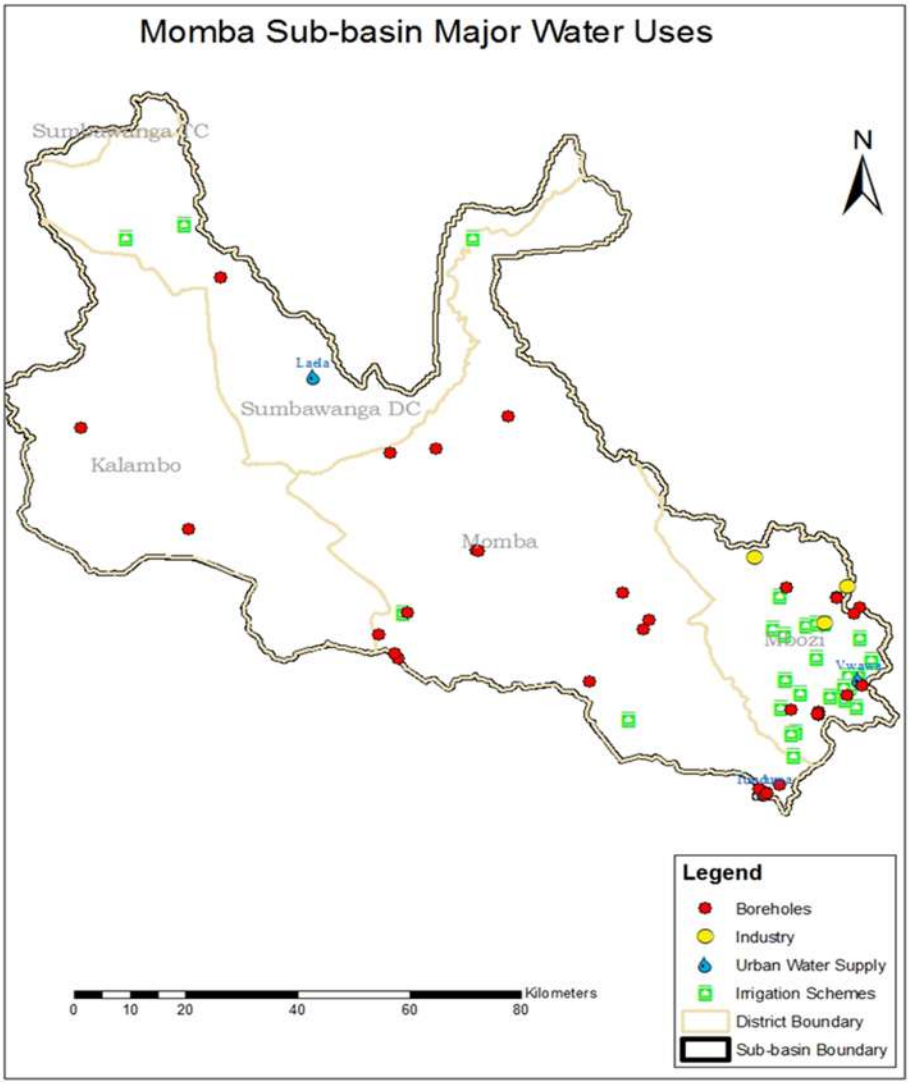


Figure 3.2: Location of Major Water Uses in Momba Sub-basin.

3.1.1 Irrigation Water Use

Table 3.2 shows the major irrigation schemes in the Momba sub-basin most of which are traditional. These traditional schemes are known to be characterized by low water use efficiency and high water losses. The total annual irrigation water use is estimated to be about 39.7 MCM. Maleza is the biggest irrigation scheme accounting for about 20% of the current total irrigated area. A detailed discussion of irrigation water use practices in the sub-basin is presented in **Annex A**.

Table 3.2: Major Irrigation Schemes in the Momba Sub-basin.

Irrigation Scheme	Crops Grown	Scheme Type	Irrigated Area [Ha]	Potential Area [Ha]	Water Source
Ilembo	Maize, Beans, Vegetables, Surgarcane	Traditional	65	300	Nyinaluzi River
Ulumi	Paddy, Maize, Beans, Onions, and Vegetables	Traditional	50	1000	Kapoka River
Mititi	Maize, Vegetables	Traditional	10	100	Saesi River
Maleza	Paddy, Maize, Sugarcane, Cassave, Vegetables	Traditional	400	7500	Momba River
Hasamba	Maize, Beans, Vegetables	Traditional	52	52	Shumba River
Iyende	Rice	Traditional	395	1030	Katukutu River
Naming'ongo	Rice, Maize	Traditional	200	1500	Momba River
Ipunga	Coffee, Maize, Beans, Vegetables	Improved	49	60	Malonji/Mpela River
Mponela	Rice, Maize, Beans, Vegetables, Tomatoes	Improved	206.8	300	Mlambwizi River
Ukwile	Rice, Maize, Beans, Vegetables	Improved	35	70	Ikomela River
Sambembe Irrigators	Coffee, Sugar cane Maize, Bananas and Vegetables	Traditional	250	250	Nkana River
Wasa	Maize, Beans, Vegetables	Improved	30	50	
Itela	Maize, Beans, Sugar cane, Vegetables, Onions	Traditional	50	280	Lwimba River
Chiyanga Irrigators	Maize and Potatoes	Traditional	160	160	Mlambwizi River
Itimba Irrigators	Maize, Vegetables	Traditional	112	112	Itimba River

Figure 3.3 shows the sub-basin mean monthly irrigation water use. Most irrigation activities take place during the wet season (November to March). This irrigation water consumption pattern is attributed to the wide spread supplementary irrigation practiced in paddy growing schemes. Paddy is the most commonly irrigated crop during the wet season. Paddy irrigation starts from November/December to March/April. On average, most paddy varieties require about 150 days to mature. Paddy is usually irrigated for 130 days from the transplanting date to the beginning of the dough/ripening stage. However, watering of paddy farms starts long before transplanting during land and nursery bed preparation. Fields are usually flooded to soften the soils, raise seedlings and in some cases support weed suffocation and decomposition. Initial watering of paddy farms takes about two to three weeks. This watering increases the number of irrigation days from 130 to about 140. Other crops are usually irrigated during the dry season from May to October. Maize, beans and vegetables are usually planted in May, June and July. Harvesting of fresh and dry beans planted in May commences in July and August respectively while harvesting of maize and vegetables commences in August. On average, farms planted with beans, maize and/or vegetables are irrigated twice a week from the planting date to about two to three weeks prior to harvesting.

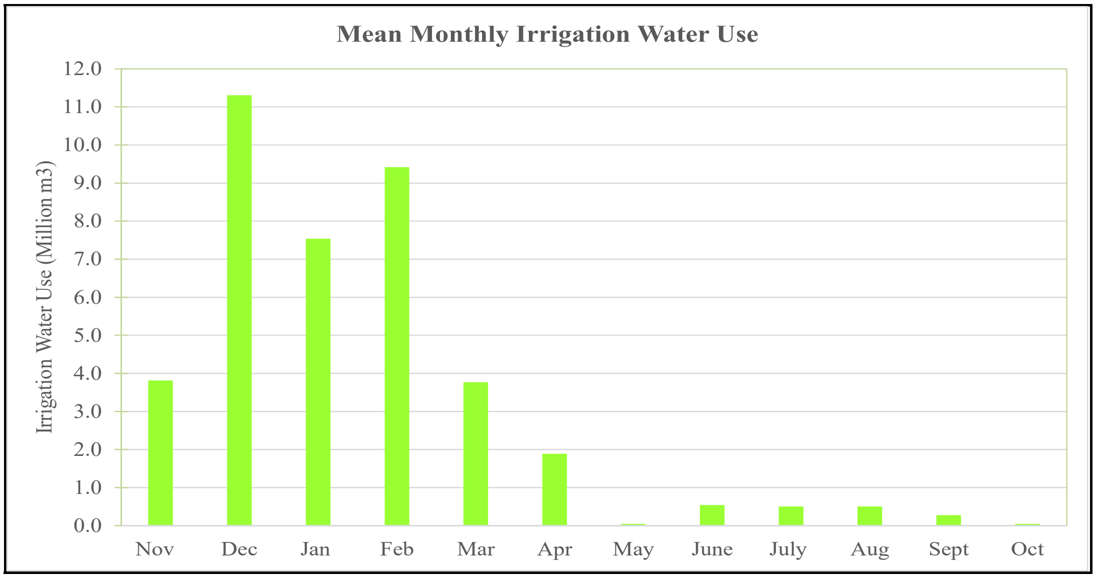


Figure 3.3: Momba Sub-basin Mean Monthly Irrigation Water Use.

Based on the existing national and local irrigation development plans, the annual irrigation water demand for the Momba sub-basin is projected to increase from 39.7 MCM in 2015 to about 299.2 MCM in 2035 (**Figure 3.4**). The high increase in irrigation water demand is mostly attributed to the major irrigation developments planned under different national initiatives, especially SAGCOT, Kilimo Kwanza, and BRN.

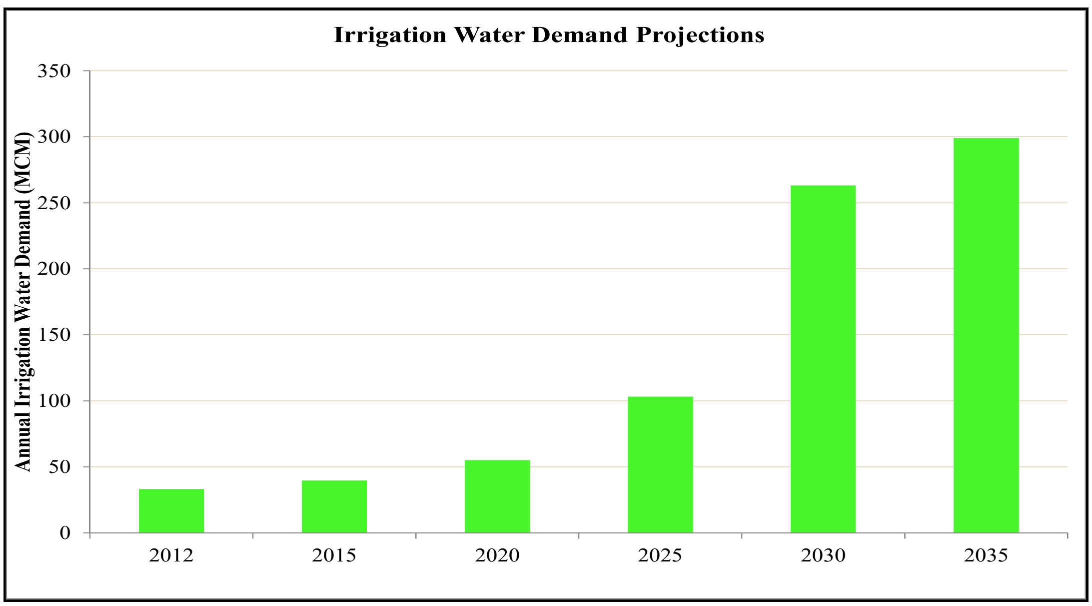


Figure 3.4: Irrigation Water Demand Projections for the Momba Sub-basin.

Issues and Challenges

Although the Momba Sub-basin is currently not water stressed, the projected increase in irrigation water demand under the current inefficient irrigation practices is unsustainable in the long run. Having an irrigation sector dominated by traditional irrigation schemes is very unsustainable. Traditional schemes have inadequate and poorly constructed infrastructure which result in high water losses and, thus, low water use efficiency. Because of the poor infrastructure, actual water abstractions are often more than the required or permitted allocations. There is therefore need to address the inefficient water use in traditional irrigation schemesto contain the irrigation water demand growth within sustainable limits.

Another challenge is inadequate involvement of the LRBWB in planning and implementating major irrigation initiatives. For example, the ambitious agricultural expansion and intensification envisioned under the different national initiatives (Kilimo Kwanza, SAGCOT, and BRN) are being planned with little or no involvement of the LRBWB. The implication is that irrigation expansion plans are being made without careful consideration of current and future water resources constraints and competition with other water uses. The scale of investments under these initiatives only makes economic sense if adequate and reliable water supplies support the planned irrigation activities. It is important that planners of these national initiatives recognize areas where water will be the major limiting factor to achieving agricultural productivity and expansion. Therefore, LRBWB involvement in planning is imperative to ensure that realistic targets are set for maximum irrigable areas under the prevailing temporal and spatial water resources constraints. The LRBWB should be involved in the ongoing rehabilitation and expansion of irrigation infrastructure, with funding from the District Irrigation Development Fund. It is important that the LRBWB provide technical guidance in the ongoing and planned irrigation expansion activities to ensure orderly development and sustainable use of the basin water resources, taking into consideration competing water uses, existing water permit allocations, and environmental flow requirements.

3.1.2 Domestic Water Use

Domestic water supply coverage in the Momba Sub-basin is generally low. Domestic water demand is projected to increase from 8.33 MCM in 2015 to about 14.65 MCM by 2035, an increase of about 76% (see **Figure 3.5**).

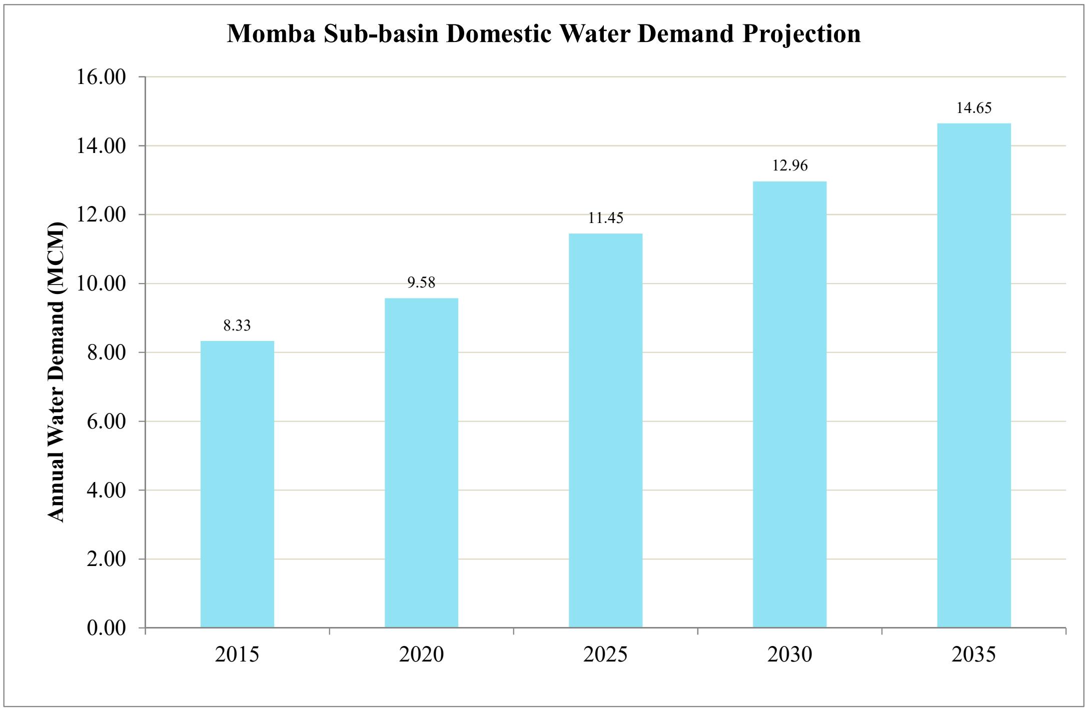


Figure 3.5: Momba Sub-basin Domestic Water Demand Projections.

(1) Urban Water Supply

Momba is a predominatly rural sub-basin with the small townships of Tunduma, Vwawa, and Laela as the only notable urban centers.

Tunduma Water Supply and Sanitation Authority (TUWSA)

TUWSA is a category C public water supply authority established in 2004. The service area has a population of about 97,562 (2012 Census) of whom 14,348 are served with water. The authority serves the Tunduma Township area located in the Mbozi District. Average water demand for the service area is estimated to be 6,900 m^3/day. The utility draws water from four boreholes with an installed total water production capacity of 1,596 m^3/day while the average water production is 526 m^3/day. Water is supplied an average of 5 hours per day. Existing storage facilities consist of three tanks with a combined capacity of 275 m^3. The scheme has no conventional water treatment plant and water is supplied to consumers without treatment. The distribution system has 39.4 km of pipeline, 33 public kiosks, and 426 active water connections. The utility has no sewerage treatment facilities, and households depend on pit latrines and septic tanks for sanitation.

Priority issues for the authority include: construction of additional water sources to supplement existing ones; expansion of water supply infrastructure to meet current and future demand; securing reliable power supplies for the water pumps; and improved scheme management.

Vwawa Urban Water Supply and Sanitation Authority (VUWSA)

VUWSA is a category C public water supply authority established in 2004. The service area has a population of about 56,256 (2012 Census) of whom 29,453 are supplied with water. The authority serves Vwawa Town, which is the headquarters of the Mbozi district. Average water demand for the service area is estimated to be 3,500 m^3/day. The utility draws water from three sources: Haloli Pumping Scheme, Mantengu Pumping Scheme, and Mgombezi/Nalaba Gravity Scheme. The combined installed production capacity is 2,134 m^3/day, while the average water production from the three sources is 1,681 m^3/day. Water is supplied an average of 8 hours per day. Existing storage facilities consist of 9 tanks with combined capacity of 738 m^3. The scheme has no conventional water treatment plant and water is supplied to consumers without treatment. The distribution system has 53 km of pipeline, 98 public kiosks, and 967 active water connections. The water supply system is generally old and inadequate and requires major rehabilitation and expansion to meet the current and future water demand. The utility has no sewerage treatment facilities and households depend on pit latrines and septic tanks for sanitation.

Priority issues for the authority include: reduction in non-revenue water from the current 35%; rehabilitation and expansion of water supply infrastructure to meet current and future demand; addressing diminishing yield during dry periods (find alternative water sources to supplement existing ones); construction of water treatment facilities; and improvement of overall scheme management.

Laela Water Supply Authority (LAWASA)

LAWASA is a category C public water supply authority established in 2004. The service area has a population of about 23,729 (2012 Census). The authority serves Laela Township located in the Sumbawaga Rural District. Average water demand is estimated to be 850 m^3/day while total water production capacity is 1,218 m^3/day. The water produced serves other villages upstream of Laela town. The water reaching Laela town is approximately 194 m^3/day. The utility draws water from two streams, Kuchena and Mpona. The maximum water production attained during the rainy season is about 1,218 m^3/day. During the dry season, the Kachena stream dries up and the yield from the Mpona stream reduces to 50%. Existing storage facilities consist of three tanks whose total capacity is 315 m^3. Water supply is available an average of 3 hours a day. The scheme has no conventional water treatment plant and water is supplied to consumers without treatment. The distribution system has 7.2 km of pipeline, 28 active public kiosks, and 11 active water connections. The area has no sewerage treatment facilities and depends on pit latrines and septic tanks.

Priority issues for the authority include: establishment of a water board and management to run the utility; construction of additional water sources to supplement existing ones; expansion of water supply infrastructure to meet current and future demand; and improvement of overall scheme management.

(2) Rural Water Supply

The main sources for rural water supply include bore holes, springs, gravity flow schemes, rivers, streams, and rainwater harvesting from roof-tops. Groundwater is a major source of water supply in rural areas due to its wide spatial distribution, perennial availability, and reasonably good quality. Of the 1742 existing rural water supply sources in the Momba Sub-basin, 989 (57%) are boreholes, and 488 (28%) are springs. Over the past 20 years, there has been renewed government commitment to invest in rural water supply and sanitation improvement programs to meet development objectives and national targets. Implementation of the rural water and sanitation component of WSDP initially focused on the rehabilitation/construction of small-scale projects that could be financed through the Local Government Capital Development Grant. These "quick-win" projects were either largely already designed or just needed simple rehabilitation to improve existing water supply infrastructure and services. This initiative has helped improve rural water supply and sanitation coverage in most sub-basin districts over two to three years. With the successful completion of out-standing projects and the execution where rehabilitation was possible, the WSDP has begun to focus on new projects in villages that do not have a water supply or that have had but which cannot be viably rehabilitated.This second round of rural water supply infrastructure expansion is expected to significantly improve water supply coverage to within or above the national targets. The biggest challenge, however, is sustainability of the rehabilitated and new water supply infrastructure. Because the rural water supply schemes serve poor communities, they are usually poorly managed and maintained resulting in frequent breakdowns.

Issues and Challenges

One of the major challenges is that the existing water supply infrastructure was largely constructed several decades ago and overall is in poor working condition. Most was constructed to serve a small population and has not been expanded to cope with the rapid population growth. As a result water production for most schemes is low compared with the demand. Several water supply schemes have broken down due to poor maintenance and vandalism.

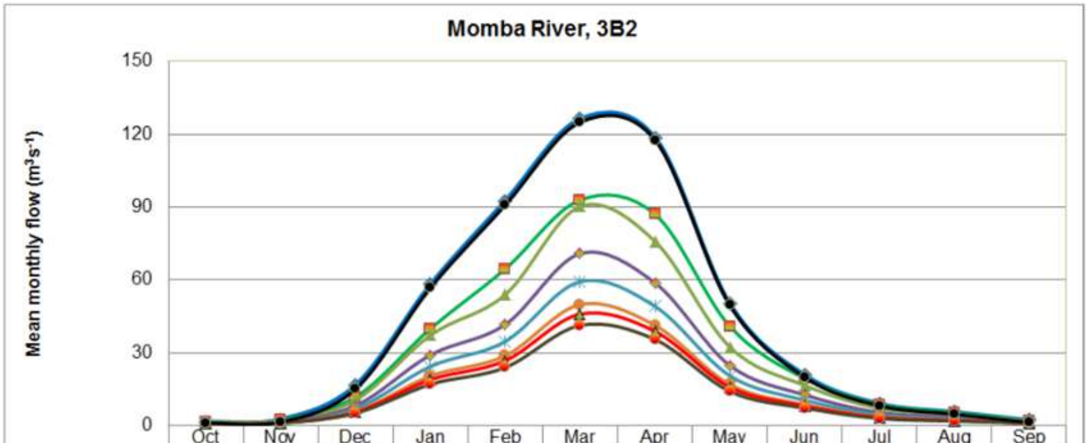
Secondly, UWSAs are faced with increasing water treatment costs due to pollution and high turbidity levels in raw water. Sedimentation is attributed to upstream catchment degradation resulting from widespread deforestation and poor farming practices. There is also increasing disposal of untreated effluent and solid waste into water bodies in urban and peri-urban areas. These, and other uncontrolled human activities in the upstream catchment areas, negatively impact water quality in the rivers and streams which serve as UWSA water sources. The increased water treatment costs are often transferred to water users as tariffs. Higher costs discourage water users from paying for the services. As a result users either resort to use of unsafe water sources or engage in illegal water connections.

Thirdly, the UWSAs do not have the capacity to meet the water demand in their coverage areas due to: inadequate capacity, low production levels, high water losses, inadequate water sources, and general infrastructure deterioration. In some schemes, actual water production is less than the installed capacity implying inadequate water sources, especially during the dry season. Most water supply schemes do not have water treatment facilities resulting in poor water quality. For several schemes, existing infrastructure such as storage tanks and pipe networks has exceeded its design life and has extensive leakage.

3.1.3 Environmental Flow Requirements

The National Water Policy (2002) and Water Management Act (2009) emphasize the importance and need for environmental flow requirements and water allocation as an integral part of integrated water resources planning and management. The Water Resources Management Act (2009) prioritizes environmental flow requirements (only second to domestic water use) in the hierarchy of water allocation, and the Act requires that specific minimum flows be maintained to sustain freshwater ecosystems and ecosystem services.

The Desktop Reserve Model (DRM) was used to generate initial estimates of Environmental Flow Requirements (EFRs) for the Momba River at Tontela. The objective was to recommend preliminary flow estimates to sustain biodiversity and important ecological processes and functions at Momba at Tontela, a critical river section in the sub-basin. **Figure 3.6** shows the recommended environmental flows for the Momba River at Tontela for different EMCs. Detailed description of the EFA findings and recommendations are contained in *Interim Report 2, Volume III*. It is recommended that more detailed Environmental Flow Assessments be carried out for the Momba at Tontela site to establish more accurate EFRs for water allocation decisions. The detailed EFAs should also be carried out for all the critical sub-basin river sections.



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Natural flow	1.36	2.45	16.56	58.00	92.45	126.20	118.51	49.96	20.71	8.88	5.48	2.07
EMC A	1.25	2.17	11.73	39.88	64.49	92.87	86.97	40.82	19.32	8.54	5.20	1.88
EMC A/B	1.20	1.88	10.43	37.18	53.90	90.21	75.80	32.27	16.45	7.00	4.30	1.79
EMC B	0.98	1.49	8.13	29.04	41.57	70.77	58.71	24.67	12.56	5.27	3.25	1.43
EMC B/C	0.86	1.29	6.84	24.31	34.60	59.25	49.05	20.46	10.41	4.32	2.69	1.23
EMC C	0.74	1.10	5.78	20.37	28.70	49.81	41.21	16.85	8.56	3.50	2.19	1.04
EMC C/D	0.72	1.06	5.46	18.84	26.68	45.86	38.72	15.71	7.99	3.26	2.05	1.00
EMC D	0.67	0.99	5.03	16.93	23.86	41.21	35.42	14.01	7.12	2.87	1.82	0.92
P-day flow	0.939	1.380	15.033	56.681	90.765	124.877	117.580	49.542	19.850	8.082	4.659	1.223

Figure 3.6: Comparison between naturalized flow, present-day (P-day) flow and estimated total maintenance flows for different Ecological Management Classes (EMC) for the Momba River at Tontela (3B2) for the period 1982-2011.

3.1.4 Livestock Water Use

Livestock keeping is one of the major socio-economic activities in the Momba sub-basin. Domestic animals constitute one of the most important non-land assets owned by the majority of rural people. Livestock products such as milk, meat, eggs, and ghee are a good source of protein to farmers while the surplus is sold to enhance household incomes. Local and regional demand for livestock products is high and there is, therefore, potential for sustained growth of the livestock industry. The most commonly kept type of livestock include: cattle, goats, and sheep, most of which are indigenous and free ranging with a few hybrids and dairy cattle in isolated ranches. Other livestock kept include pigs, donkeys, chicken, ducks, and pigeons. Total livestock population is approximately 693,669. **Figure 3.7** shows the sub-basin population for the different livestock types. Chicken is the most commonly kept accounting for about 45% of the total livestock population. Cattle and goats are also popular and account for 23% and 13% of the total sub-basin livestock population respectively. The main water sources for livestock include rivers, streams, swamps/marshes, and temporary ponds during the rainy season. In addition to the natural sources, communities have also invested in other livestock water supply infrastructure including charco and other dams. These are usually multipurpose water storage facilities that serve multiple local community water uses such as domestic water supply and irrigation. The annual livestock water consumption for the Momba sub-basin is projected to increase from about 1.97 MCM in 2015 to about 3.21 MCM in 2035 (see **Figure 3.8**). The projected increase in livestock population and water demand will lead to increased pressure on the sub-basin's natural resources and exacerbate the ongoing environmental degradation and water use conflicts.

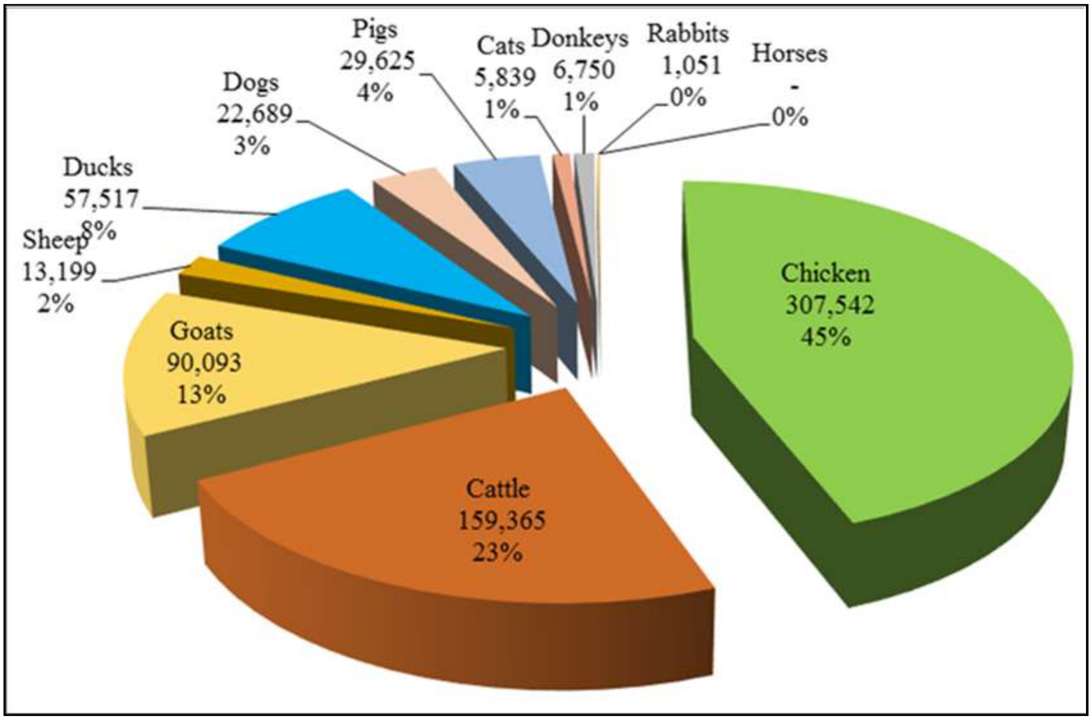


Figure 3.7: Momba Sub-basin Livestock Population.

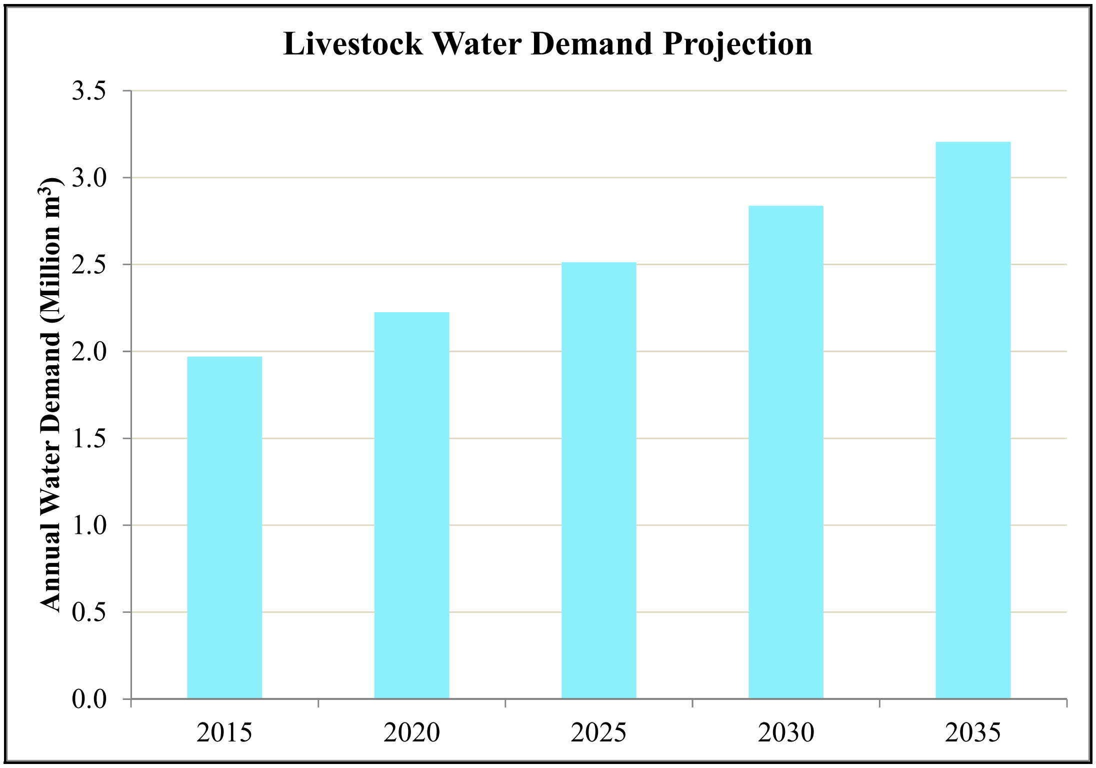


Figure 3.8: Livestock Water Demand Projection for the Momba Sub-basin.

Issues and Challenges

The lack of village land use plans means there are no formally demarcated areas for livestock grazing. As a result livestock grazing takes place on communal lands where other socio-economic activities like farming are also carried out resulting in conflicts between farmers and pastoralists. The lack of designated livestock watering areas also results in pastoralists watering their animals directly in water sources used for other uses. This often results in destruction of water sources and the surrounding catchment areas. The situation is exacerbated by the uncontrolled influx of livestock from neighboring regions which is putting substantial pressure on the sub-basin's natural resources. Several areas have exceeded their livestock carrying capacity thus resulting in overgrazing, soil erosion, land compaction, destruction of wetlands and river banks, and intense land and water use competition and conflicts. There is also reported pollution of surface water sources from cattle dip and slaughter house effluents. Pastoralists are reported to be engaged in bush burning to create a flush of new grass for livestock before the rainy season and to control parasites harmful to livestock. Uncontrolled bush burning has been responsible for destruction of forests and other wildlife habitats. This practice is also reported to contribute to excessive soil erosion and floods as a result of stripping the soil of all vegetation cover.

Figure 3.9: *Left:* Bush burning during the dry season. *Right:* Vegetation destruction and soil compaction by a herd of cattle.

3.1.5 Mining Water Use

Mining is not a major socioeconomic activity in the Momba Sub-basin. Mining water use is therefore currently insignificant and is projected to remain very low in the long run compared to other water use sectors.

3.1.6 Industrial Water Use

There are only three medium scale industries in the sub-basin, two coffee processing factories at Lima Central Pulpery Unit (Insani) and Kanji Lalji Limited and GDM Company Limited (**Table 3.3**). Other small scale industries include carpentry workshops, oil seed extracting mills, milk processing, iron smith, maize mills and rice hulls. Industrial water use is therefore currently insignificant and is projected to remain very low in the long run compared to other water use sectors in the sub-basin.

Table 3.3: Industrial Water Use in the Momba Sub-basin.

Name of Industry	Water Permit Allocation (m3/day)	Source
Lima (Ltd) Central Pulpery Unit	100	Halungu Stream
Kanji Lalji Limited	432	Nsumbi Stream
GDM Company Ltd	50	Borehole

3.1.7 Water Use for Hydropower Generation

The sub-basin has good hydropower potential on the Mtembwa River, estimated to be about 30MW with a head of about 270 meters. The site is located at Yala Falls downstream of an existing hydrometric station (3B15: Mtembwa at Chipoma) in Mfuto/Yala village in Momba District Council (see **Figure 3.10**). The Mtembwa River originates from Nthumbe Hills (in the north-western Momba sub-basin) and is joined by the Saesi River (which originates from Kawimbe hills) to the north-west of Mbala town in Zambia. The Mtembwa River merges with the Nkana River downstream of the Yala Falls to form the Momba River.

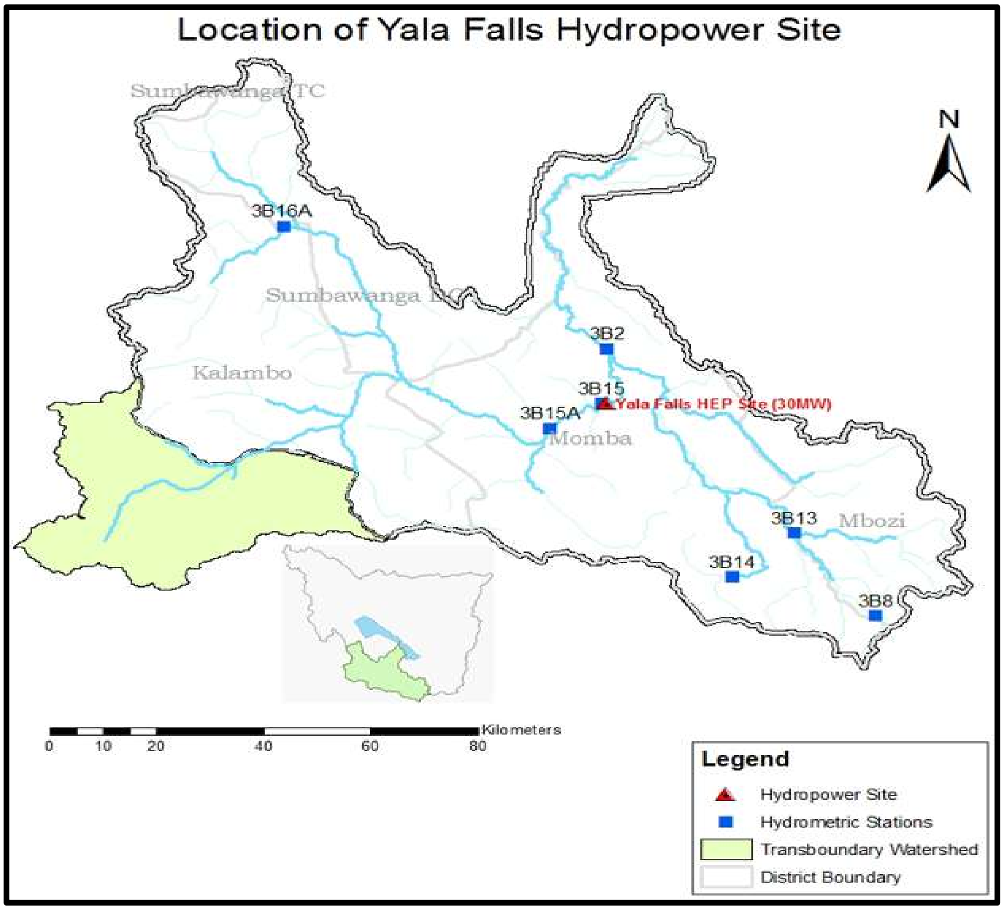


Figure 3.10: Location of the Yala Falls Hydropower Site.

The prospective developers for the Yala hydropower site are M/S CAMAS Sky Africa Ltd. who were granted a water abstraction permit by LRBWB (LRB/WUP/0380 on 27th November 2014) to divert 777,600 m^3/day from the Mtembwa River into a dam after which the water is to be returned into the river downstream of the power plant. Structures proposed for construction include a diversion furrow, filter dam, intake, turbine, pipeline to turbine, and return furrow.

3.1.8 Wildlife Water Use

There are no major wildlife protected areas in the Momba Sub-basin and therefore wildlife water requirements are not a major concern.

4. Sub-basin Water Balance and Deficit Management

4.1 Water Balance Assessment

A sater balance assessment was conducted at sub-basin level as well as for a specific, heavily developed watershed in the southeastern part of the sub-basin. This approach was intended to identify local water scarcity problems in the southeast that would otherwise be masked by a sub-basin level assessment.

4.1.1 Sub-basin Water Balance

The water balance assessment for the Momba sub-basin generally shows adequate water resources to satisfy current and projected water demand with minimal temporal and spatial deficits. **Figure 4.1** shows that the Momba sub-basin is not expected to experience seasonal water deficits under the current and projected water demand levels during the wet season. This is the case even when the seasonal environmental flow requirements are taken into consideration. The situation is slightly different during the dry season (**Figure 4.2**) where a few water deficits are observed during prolonged dry periods, with a maximum frequency of occurrence of about 5.8% under the 2025 and 2035 water demand targets. However, more significant water deficits are observed at a monthly time scale, especially during November (see **Table 4.1**). The frequency of deficits during November increases with increasing water demand targets, from 15.4% in 2015 to 98.1% in 2035. The November deficits occur at the beginning of the rainy season when high water amounts are required for paddy nurseries and fields.

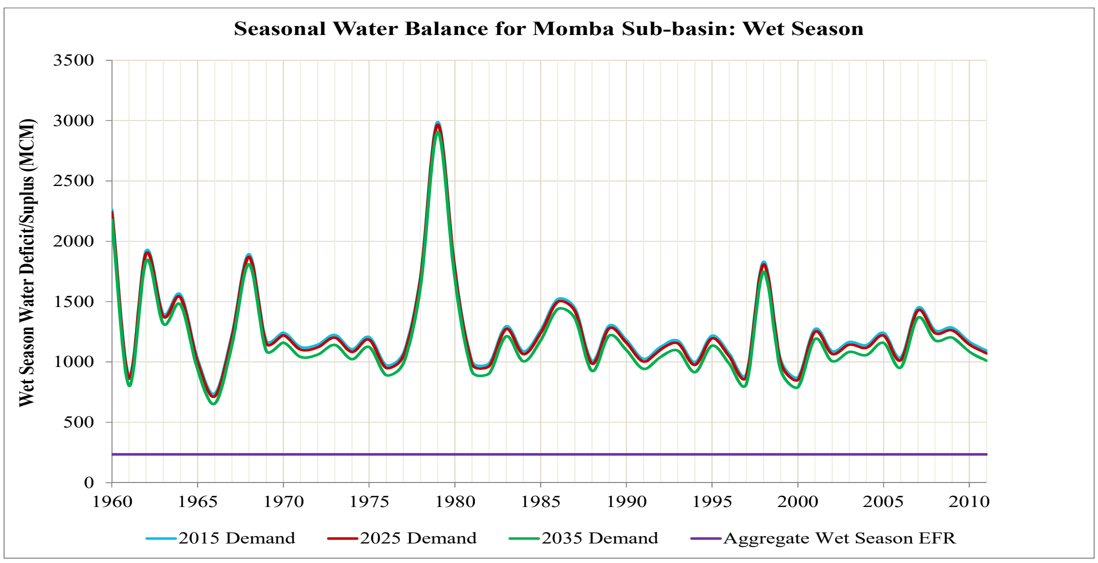


Figure 4.1: Wet Season Water Balance for Momba Sub-basin.

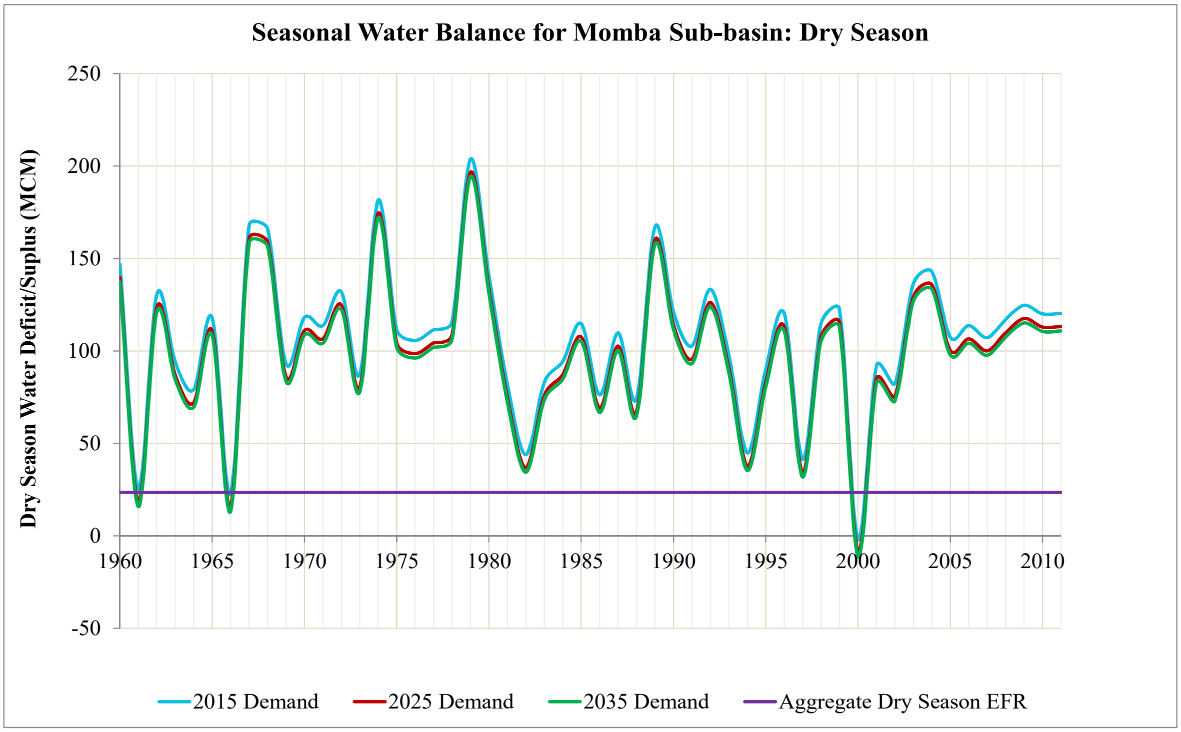
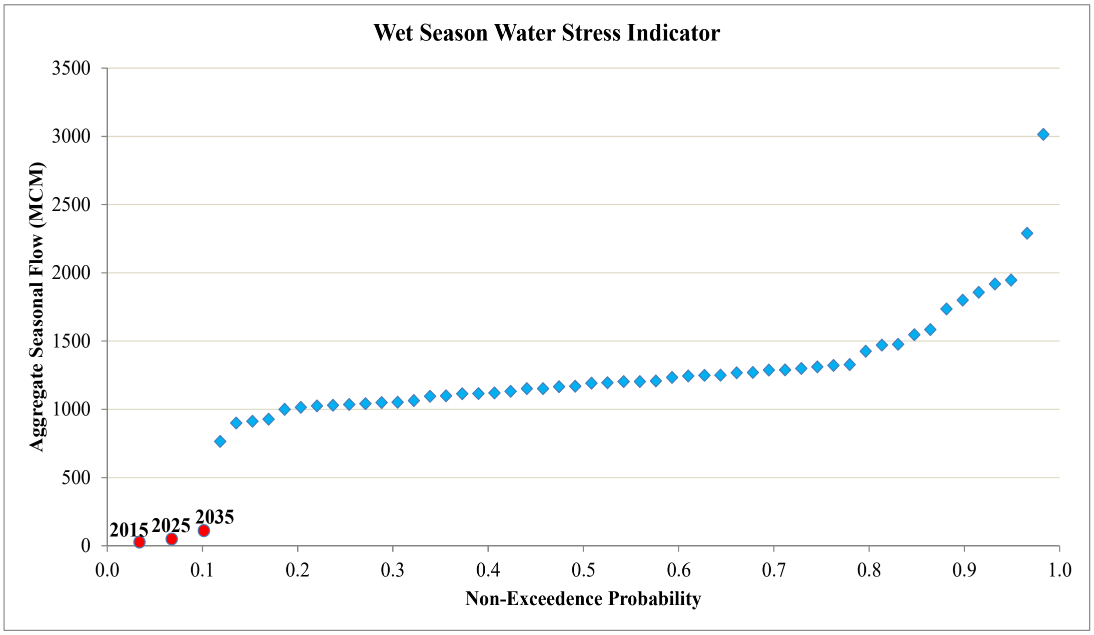


Figure 4.2: Dry Season Water Balance for the Momba Sub-basin.

Table 4.1: Momba River at Tontela Seasonal and Monthly Water Deficits.

Demand	Seasonal Deficits				Monthly Deficits												
		Wet Season	Dry Season			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2015	Without EFR	0.000	0.019		Without EFR	0.000	0.000	0.000	0.000	0.000	0.000	0.019	0.057	0.057	0.057	0.057	0.000
	With EFR	0.000	0.038		With EFR	0.000	0.000	0.000	0.000	0.000	0.019	0.113	0.094	0.094	0.075	0.151	0.000
2025	Without EFR	0.000	0.019		Without EFR	0.000	0.000	0.000	0.000	0.000	0.000	0.057	0.075	0.094	0.057	0.358	0.000
	With EFR	0.000	0.057		With EFR	0.000	0.000	0.000	0.000	0.000	0.019	0.113	0.094	0.094	0.075	0.792	0.000
2035	Without EFR	0.000	0.019		Without EFR	0.000	0.000	0.000	0.000	0.000	0.000	0.057	0.094	0.094	0.057	0.962	0.000
	With EFR	0.000	0.057		With EFR	0.000	0.000	0.000	0.000	0.000	0.019	0.113	0.094	0.094	0.094	0.962	0.302

Figure 4.3 shows an increasing trend in sub-basin water stress in response to increasing water demand. However, the sub-basin is not expected to experience any significant water stress over the planning horizon given that the water demand is projected to remain low compared to water availability. The figure shows that by 2035, water demand will be met in nine out of every ten years in wet and dry seasons. The main challenge, as highlighted above, is the monthly deficits that are likely during November. Construction of strategic water storage infrastructure should help even out the observed month-to-month water deficits and result in overall seasonal surpluses. The dams will be useful in harnessing excess wet season run-off which will help augment dry season low flows. Combined with improvements in irrigation infrastructure and farmer training in good on-farm water management practices, these projects should address water deficits over the planning horizon.



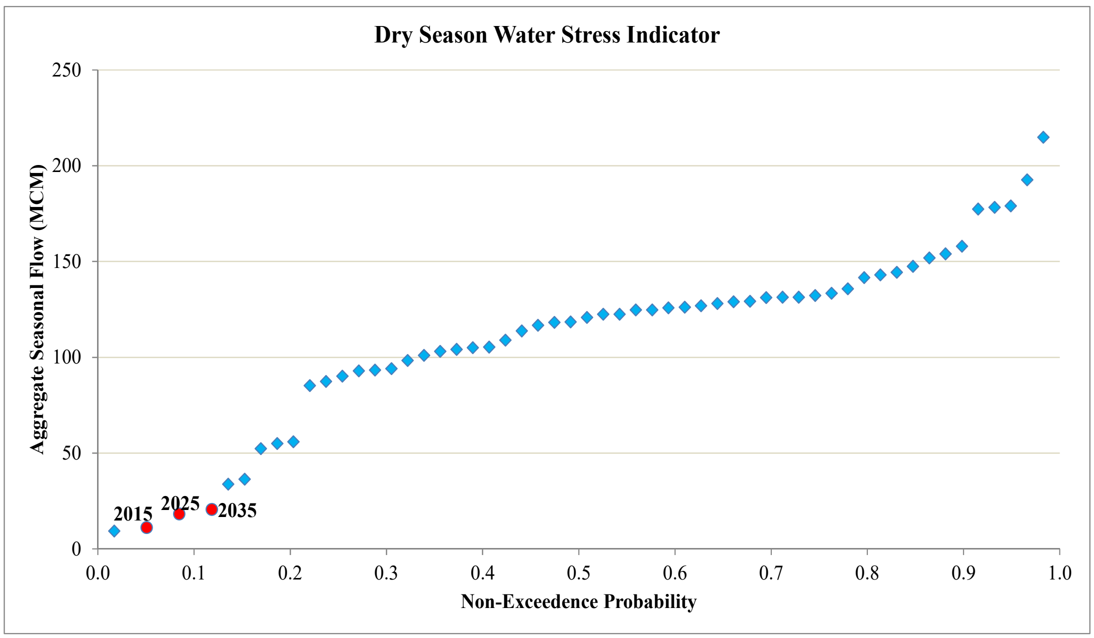


Figure 4.3: Momba Sub-basin Water Stress Indicator.

4.1.2 Water Balance for the Southeastern Watershed

Because of the uneven spatial distribution of water use activities (especially irrigation schemes) in the Momba sub-basin, the previous assessement finding of adequate water supplies could be misleading in smaller sub-watersheds with intense water use. **Figure 4.4** shows that most irrigation activities in the Momba sub-basin are concentrated in the southeastern watershed with only a few schemes scattered in other watersheds. Because of this, the southeastern watershed was the subject of a more detailed water balance assessment to determine whether it is more vulnerable to water stress than other Momba areas.

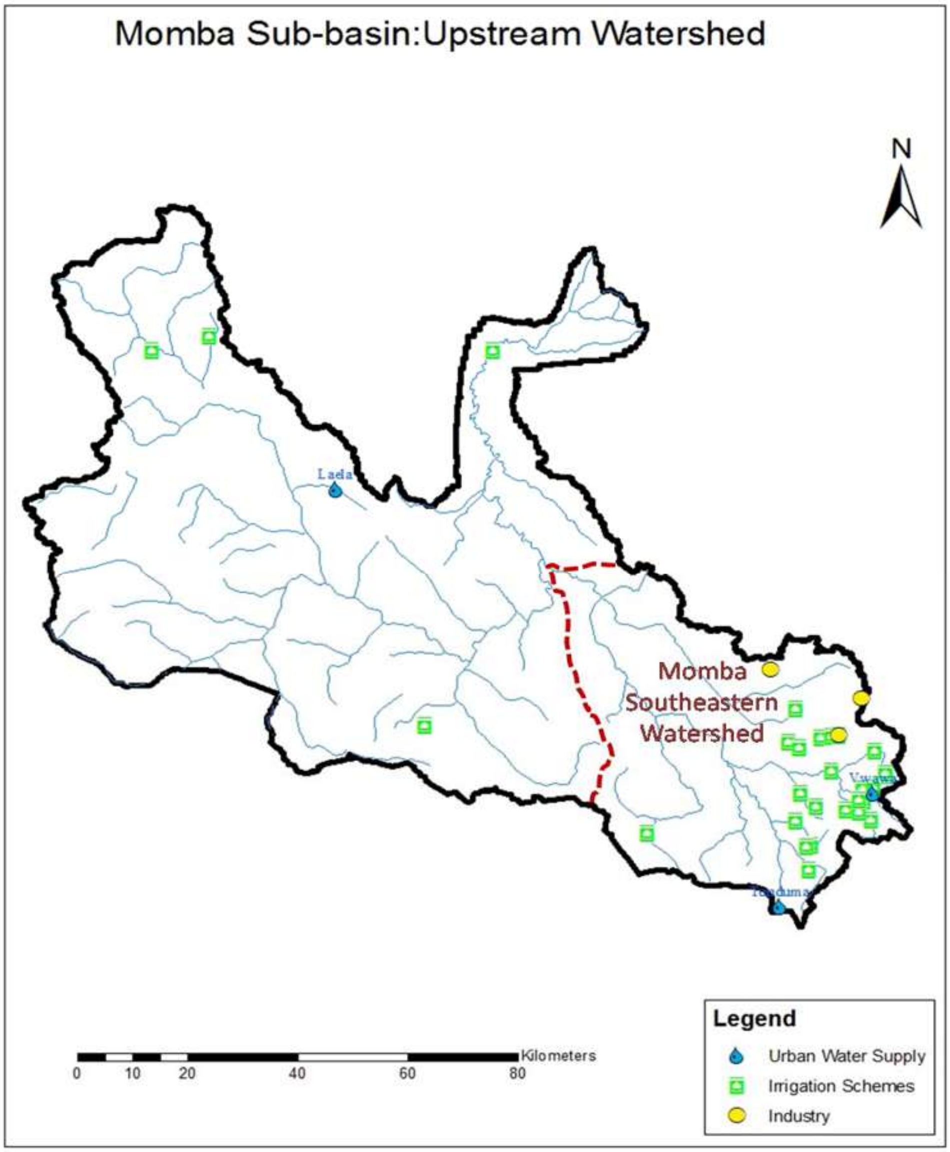


Figure 4.4: Momba Southeastern Watershed.

The water balance assessment for the southeastern Momba watershed indeed shows some differences with the assessment for the entire sub-basin. **Figure 4.5** shows that, like the entire sub-basin, the southeastern watershed does not experience any water deficits during the wet season even considering the full environmental flow requirements. However, significant differences are observed during the dry season (**Figure 4.6**) where the frequency of seasonal water deficits is higher under all demand targets compared to those of the entire sub-basin. For example the frequence of water deficits (under the 2035 demand target) is 17.3% compared to 5.8% for the whole sub-basin. The differences are more pronounced at a monthly time scale (see **Table 4.2**). For example, unlike the entire sub-basin, the southeastern watershed always experiences water deficits during September and November under the 2025 and 2035 water demand targets.

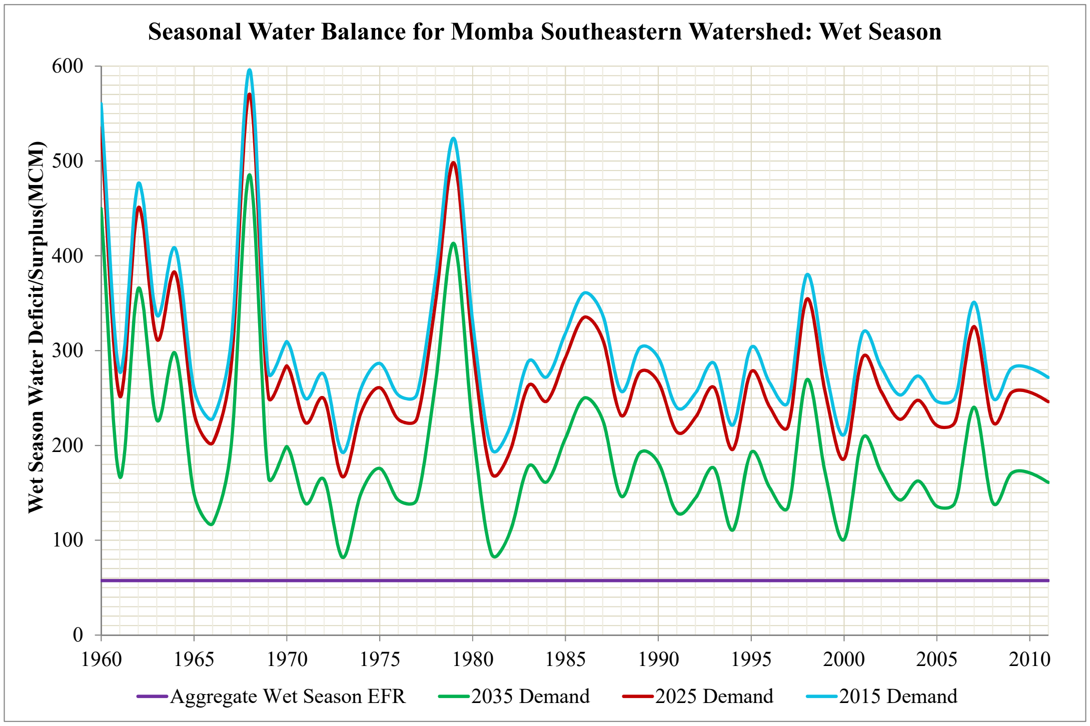


Figure 4.5: Wet Season Water Balance for the Southeastern Momba Watershed.

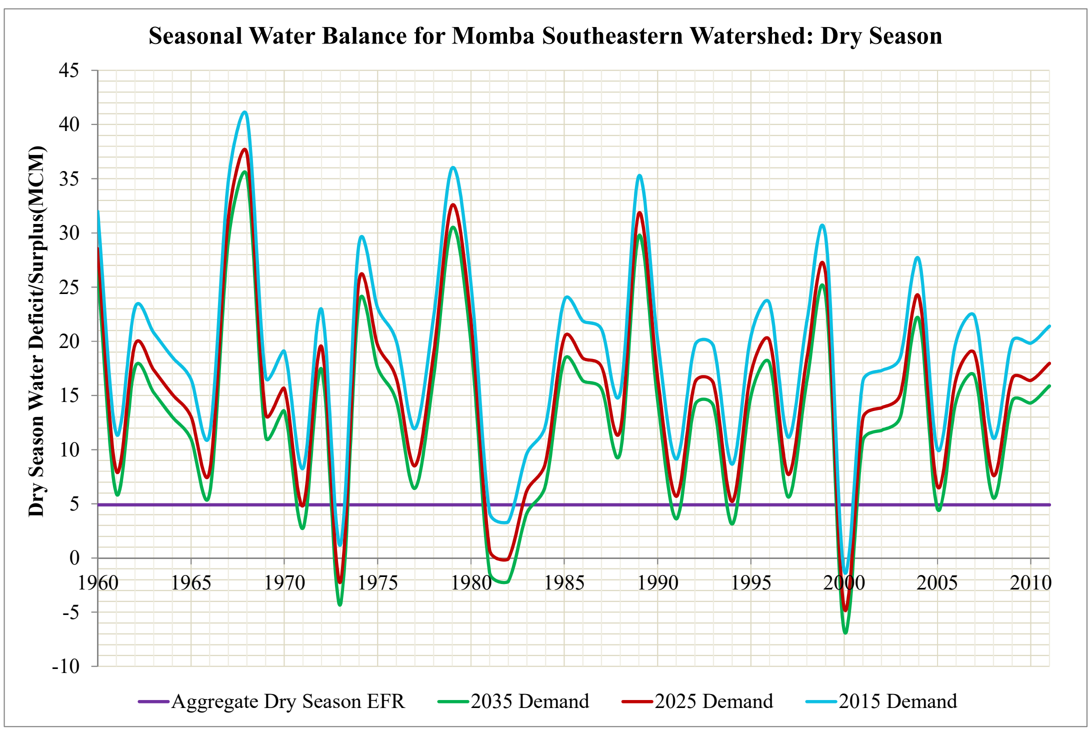


Figure 4.6: Dry Season Water Balance for the Southeastrn Momba Watershed.

Table 4.2: Frequency of Occurrence of Water Deficits.

Demand	Seasonal Deficits				Monthly Deficits												
		Wet Season	Dry Season			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2015	Without EFR	0.000	0.019		Without EFR	0.000	0.000	0.000	0.000	0.000	0.000	0.113	0.132	0.000	0.000	0.943	0.000
	With EFR	0.000	0.075		With EFR	0.000	0.000	0.000	0.000	0.000	0.038	0.189	0.189	0.000	0.000	0.981	0.000
2025	Without EFR	0.000	0.057		Without EFR	0.000	0.000	0.000	0.000	0.000	0.019	0.170	0.208	0.981	0.000	0.981	0.623
	With EFR	0.000	0.094		With EFR	0.000	0.000	0.000	0.000	0.000	0.057	0.264	0.264	0.981	0.000	0.981	0.717
2035	Without EFR	0.000	0.075		Without EFR	0.302	0.000	0.000	0.000	0.000	0.019	0.208	0.264	0.981	0.000	0.981	0.981
	With EFR	0.000	0.170		With EFR	0.509	0.094	0.000	0.000	0.000	0.057	0.283	0.377	0.981	0.000	0.981	0.981

Figure 4.7 shows an increasing trend in dry season water stress in response to increasing water demand for the Momba Southeastern watershed. On average, the southeastern watershed dry season water demand will not be met in two out of every ten years. The southeastern watershed is, therefore, more water stressed than the rest of Momba. The increased stress stems from the more intense irrigation activities going on there compared to other Momba areas, especially during September, November, and December.

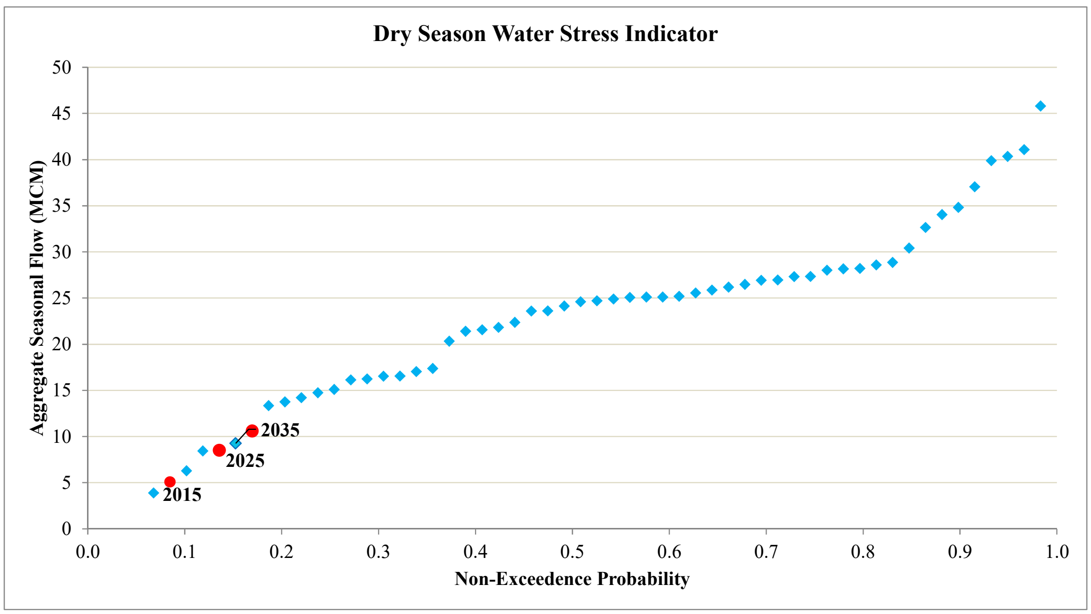


Figure 4.7: Momba Southeastern Watershed Water Stress Indicator.

4.2 Strategy to Address Projected Water Deficits

The Momba Sub-basin is generally well endowed with water resources, and there is no supply-demand gap, except in the southeastern watershed where irrigation activities are most concentrated. Thus, Momba interventions are principly aimed to address projected water stresses and deficits in the southeastern watershed. Construction of strategic water storage infrastructure should help even out the observed month-to-month irrigation deficits and result in overall seasonal surpluses. Storage coupled with improvements in irrigation infrastructure and farmer training in good agronomic management practices should address the projected water deficits over the planning horizon. These two strategic interventions are discussed next.

4.2.1 Increase Water Storage Capacity for the Southeastern Watershed

Surface water will continue to be the major source of water supply for the watershed. The main challenge with reliance on surface water is its seasonality and vulnerability to potential future climate change. However, assessments show that if water storage is adequate, the watershed should meet the projected water demands and also satisfy the full environmental flow targets. The water storage capacity required to meet the projected water demand for the southeastern watershed from 2015 to 2035 is estimated to be about 11.63 MCM.

Preliminary topographical analysis for the southeastern Momba watershed yielded only one small potential storage site (at location 31.8642 E; 8.5994 S). The potential storage determination was based on a digital elevation model (DEM) with 90 m spatial resolution (latitude and longitude). The DEM was analyzed using ArcGIS to evaluate the storage that would be created from the construction of dams of a certain height at promising river sections. The following site-specific information was computed:

(i) The volume and surface area of the inundated land that would result by building a dam at the site.
(ii) The width of the dam.
(iii) The catchment area upstream of the dam site.

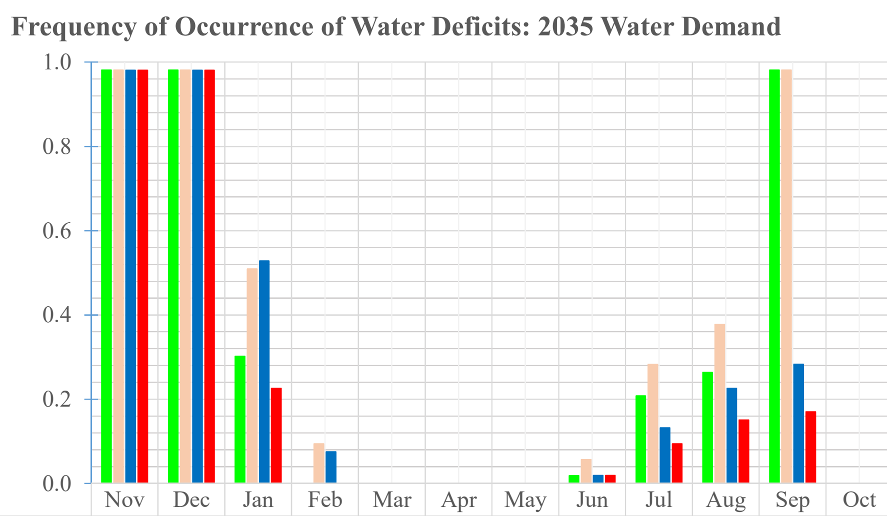
The one potential reservoir development option has a 2.3 MCM storage capacity, a surface area of about 0.34 km^2, dam height and width of 10 m and 450 m respectively, and upstream catchment area of about 152 km^2. Due to potential uncertainties in DEM resolution, the previous reservoir features should be viewed as estimates that need refinement by more detailed field surveys during the follow-up pre-feasibility studies. These caveats notwithstanding, the analysis carried out herein examined practically all potential river locations and provides fairly good guidance on the most promising site for reservoir development.

Detailed simulations of the identified reservoir were next performed using 52 (1960 to 2011) years of monthly natural flows developed by a hydrologic model driven by historical rainfall and potential evapotranspiration series over the upstream watershed (from the CRU data base). These assessments indicate only slight reduction in monthly water deficits with no reduction at all for November and December (see **Figure 4.8**). Namely, this reservoir would not be effective in mitigating the water stress in these months. This is attributed to its small size (2.3 MCM) compared to the storage requirements for this watershed (11.63 MCM). Results from these detailed assessments are presented in **Annex B**.

4.2.2 Improvements in Irrigation Water Use Efficiency

Most irrigation in the southeastern watershed occurs in traditional schemes characterized by inadequate and poorly constructed infrastructure with high water losses and low water use efficiency. The schemes have temporary and poorly constructed water intake works and unlined irrigation canal systems. Thus, any strategy to address the projected water stresses should also include improving irrigation water use efficiency. Studies in other basins in Tanzania (Great Ruaha sub-basin) have demonstrated that modest improvements in traditional irrigation infrastructure can result in appreciable water use efficiency gains and reduction in irrigation abstractions (SMUWC, 2001). Improving irrigation infrastructure would improve irrigation water use efficiency and overall water management. Recommended improvements include construction of concrete water intake structures, lined primary/secondary/tertiary canals, and planned drainage/return canals.

As part of the water balance assessments for the Momba southeastern watershed, a specific scenario was run to demonstrate the benefits of improved irrigation water use efficiency. A gross consumption rate of 1liter/sec/ha was assumed corresponding to improved irrigation operations. Simulations under historical hydrological conditions (1960 to 2011) indicate that, with a 2.3 MCM reservoir in place, improvements in irrigation water use efficiency (from 1.56 l/s/ha to 1.0 l/s/ha) would reduce the projected monthly water deficits (especially in January, July, August, and September) but would not eliminate the water deficits in November and December (see **Figure 4.8**). Additional intervention measures are needed to mitigate the stresses in these two months.



	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Without EFR	0.98	0.98	0.30	0.00	0.00	0.00	0.00	0.02	0.21	0.26	0.98	0.00
With EFR	0.98	0.98	0.51	0.09	0.00	0.00	0.00	0.06	0.28	0.38	0.98	0.00
EFR + Reservoir	0.98	0.98	0.53	0.08	0.00	0.00	0.00	0.02	0.13	0.23	0.28	0.00
EFR + Reservoir + Irr Eff	0.98	0.98	0.23	0.00	0.00	0.00	0.00	0.02	0.09	0.15	0.17	0.00

Figure 4.8: Frequency of Occurrence of Water Deficits in Momba Southeastern Watershed.

4.2.3 Catchment Water Transfer Scheme

Owing to the small potential storage capacity identified in the Momba Southeastern watershed, the option of transferring water from outside the watershed (but within the sub-basin) was considered to close the water deficit gap in November and December. Preliminary topographical analysis conducted for other sub-basin watersheds identified a potential large storage site at location 31.5492 E; 8.9167 S (see **Figure 4.9**). Seven potential development options were identified for this dam site as shown in **Table 4.3** below.

Table 4.3: Storage Development Options at Site (31.5492 E; 8.9167 S).

Option	Potential Resevoir Storage Capacity (MCM)	Surface Area (km^2)	Dam Height (m)	Dam With (m)	Upstream Watershed Area (km^2)
1	1.7	0.44	10	90	100
2	10	1.39	20	90	100
3	31.9	3.21	30	180	100
4	75.4	5.71	40	270	100
5	150.8	9.69	50	360	100
6	273.7	15.02	60	450	100
7	454.3	21.42	70	450	100

This site has a very large storage potential and would satisfy the water requirements for the southeastern watershed if the topography allows for construction of a cost-effective water transfer scheme.

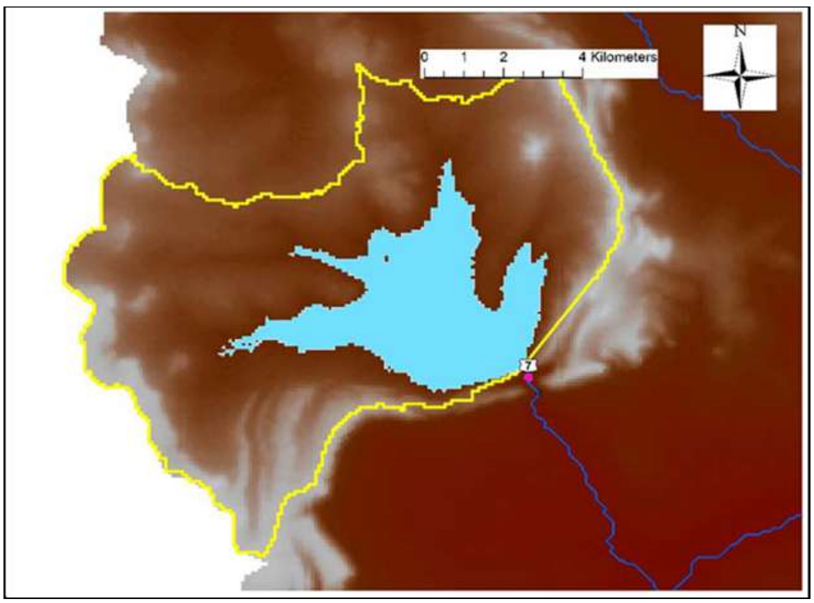


Figure 4.9: Location of Potential Large Water Storage Reservoir in Momba Sub-basin.

4.2.4 Recommended Interventions

The Momba Sub-basin has sufficient water resources to meet its projected water demand growth over the planning horizon. However, the main challenge is the localized water deficits in the southeastern watershed. It is recommended to study the feasibility of constructing a water storage reservoir at location (31.5492 E; 8.9167 S) and a water transfer scheme to the southeastern watershed. This intervention should be complemented by irrigation efficiency improvements other water demand management measures aimed at slowing the rate of demand growth. Irrigation efficiency improvement measures should include improvements in irrigation infrastructure and farmer training in better agronomic practices.

5. Strategic Goals, Objectives, and Priority Interventions

5.1 Vision and Mission

The Lake Rukwa Basin Vision and Mission statements define the overall strategic goal for water resources management and development in all the Lake Rukwa sub-basins. The two statements capture in a concise manner what the basin stakeholders collectively aspire to achieve in the short to long term. The basin vision and mission, therefore, provide the strategic context within which the Momba Sub-basin WRMD Plan is developed.

LAKE RUKWA BASIN VISION:	***"A well-managed basin with improved standard of living for its people through sustainable utilization of water resources"***
LAKE RUKWA BASIN MISSION:	*"To ensure water resources management is strengthened through integrated water resources management for sustainable utilization of water and other renewable natural resources"*

(*Source: LRBWB, 2015*)

5.2 Strategic Goal

The overall goal of the Momba Sub-basin IWRMD Plan is to eradicate poverty and stimulate socioeconomic transformation through sustainable management, equitable access, and efficient use of water resources. This goal is to be realized through progressive improvements to existing water resources management and use practices to achieve a sustainable balance between water availability and demand without compromising environmental integrity.

5.3 Strategic Objectives

The matrix below presents the strategic objectives and intervention areas to be addressed by the Momba Sub-basin WRMD Plan. They describe the broad outcomes expected following implementation of the Plan over the planning horizon (2015 – 2035).

Strategic Objective	Strategic Intervention Areas
Strategic Objective 1: To achieve sustainable balance between water supply and demand in an environmentally friendly manner.	• Ensure availability of water resources of adequate quantity and quality to satisfy current and future sub-basin water demands. • Achieve sustainable water demand growth over the planning horizon.
Strategic Objective 2: To ensure availability of adequate and reliable water	• Upgrade and expand the existing water resources monitoring network to cover all important watersheds and aquifers.

resources data for all watersheds and aquifers.	• Review and upgrade existing data processing, storage, and assessment hardware and tools.
Strategic Objective 3: To identify and register all sub-basin water uses and ensure full compliance with permitting requirements.	• Undertake comprehensive annual water use surveys to identify and register all basin water uses. • Establish water abstraction and use monitoring network to quantify sub-basin water use. • Strengthen permit enforcement and compliance monitoring mechanisms.
Strategic Objective 4: To determine and ensure compliance with environmental flow requirements for all critical river sections in the sub-basin.	• Undertake detailed environmental flow assessments for all critical sub-basin river sections and establish appropriate environmental flow requirements. • Monitor and ensure compliance with the established environmental flow requirements.
Strategic Objective 5: To promote integrated watershed management and environmental conservation.	• Protect vulnerable watersheds and reverse sub-basin environmental degradation. • Control pollution from point and non-point sources.

5.4 Priority Intervention Measures

GOAL 1: Sustainable balance between water supply and demand achieved by 2035.

The main goal of the Momba Sub-basin IWRMD Plan is to balance water supply and demand and ensure that the available water resources satisfy current and future water demands without compromising environmental integrity. A complicating factor is the uncertainty associated with future climatic conditions which may have potentially adverse impacts on water resources availability and demand. Besides the projected demand growth and future climate change impacts, the Water Management Act (2009) specifically recognizes environmental water requirements as a legitimate water use priority that must be considered and fulfilled in all water resources planning and management decisions. Satisfying all sub-basin water requirements involves balancing water supply and demand, with careful consideration of the underlying trade-offs. This is a challenging proposition since it entails implementating a mix of measures to address issues related to sustainable water supply on the one hand and water demand management under environmental flow constraints on the other.

The four objectives to be achieved under this goal are discussed next.

Objective 1: To achieve sustainable water demand growth over the planning horizon.

The Momba sub-basin aggregate consumptive water demand is projected to increase from 50 MCM in 2015 to about 317 MCM in 2035. This rate of demand growth is unsustainable in the long run. The biggest contributor to the demand growth is the projected significant increase in irrigation water demand due to planned irrigation developments. The situation is exacerbated by high water losses in the traditional irrigation schemes due to inadequate water supply infrastructure and poor on-farm water management practices. Therefore managing irrigation water demand growth is a key objective towards achieving sustainable balance between water supply and demand.

Action 1.1.1: **Rehabilitation and upgrading of irrigation water supply infrastructure in traditional irrigation schemes.**

Irrigation water supply infrastructute in traditional schemes should be upgraded to minimize water losses and improve irrigation water use efficiency. Assessment results show that improvements in irrigation water use efficiency from 15% to 30% would translate up to 50% water savings (other factors being constant). This activity requires coordination from the LRBWB to ensure that the intended objectives of irrigation efficiency improvements and reduction in irrigation water use are achieved. As a condition for irrigation water permit renewal, the LRBWB should require that permit holders demonstrate substantive and verifiable progress toward improving irrigation water use efficiency. The LRBWB should set efficiency improvement targets to be met by existing permit holders prior to permit renewal. For new irrigation water permit applications, the LRBWB should require that the applicants commit to a time-bound plan to line all their irrigation canals, install permanent water diversion control and quantity measuring structures and devices, construct lined return canals, and agree to a self-monitoring water abstraction program with mandatory periodic submission of water abstraction data to the LRBWB.

Action 1.1.2: **Comprehensive and routine monitoring of water abstractions/use.**

Routine monitoring of water abstractions and use is very important to ensure that water managers have accurate knowledge of how much water is being taken out of the system, where, and when. This information enables the water managers to determine spatial and temporal water deficits and pinpoint system inefficiencies. There are no systematic measurements of water use/withdrawals in the Momba sub-basin. It is thus difficult to estimate actual water abstractions and accurately reconstruct natural (unimpaired) flow series at key sub-basin nodes. There is need to establish a comprehensive water abstraction/use monitoring network to ensure routine collection of water use data. Establishment of the network should be undertaken in collaboration with water users. As part of the special conditions for all water permits issued under Section 48 of the WRM Act (2009), it is recommended that the LRBWB require all water permit holders to install water abstraction/use measuring devises, keep records of their daily water abstractions/use, and submit this data regularly to the LRBWB. The LRBWB should then, as part of its compliance monitoring program, undertake random spot inspections to cross check the validity and reliability of the water abstraction/use records of individual permit holders. The LRBWB should make it known to permit holders that failure to install water abstraction/use monitoring devises or deliberate recording or submitting false data would result in stiff penalties. To supplement the self-monitoring program, the LRBWB should install water abstraction/use monitoring devises at a few strategic locations for water use verification monitoring.

Objective 2: To ensure availability of water resources of adequate quantity and quality to meet current and future sub-basin water demands.

Sub-basin water balance assessments generally indicate that the Momba sub-basin has adequate water resources and is currently not water stressed, except for localized shortages during prolonged dry periods in the southeastern watershed. However, the projected water demand growth and potential climate change impacts are expected to change the present situation. Assessment findings highlight potential future decreases in the Momba River flows due to the reinforcing impacts of climate change and increasing water demands. There is, therefore, a need to implement appropriate mitigation measures to prevent future unsustainable water use conditions.

Action 1.2.1: **Construct water storage infrastructure to increase sub-basin storage capacity**.

Preliminary topographical analysis was conducted for the Momba sub-basin and a specific potential storage site was identified with capacity up to 454 MCM (at location 31.5492 E; 8.9167 S). It is recommended that the identified site is assessed in more detail to establish its feasibility before a decision can be made regarding dam construction. It is also recommended that a water transfer scheme to the southeastern watershed be studied for technical, economic, and environmental feasibility.

Action 1.2.2: **Conjunctive use of surface and groundwater.**

Currently groundwater is being exploited on a small scale in several sub-basin rural areas mostly for domestic consumption. Considering that groundwater is likely to continue to be the key resource to improve domestic water supply coverage under the changing climate and increasing water demand, there is need for comprehensive monitoring of the sub-basin groundwater resources to ensure their sustainable use. A groundwater monitoring program has been recommended to help develop the required understanding of the sub-basin groundwater potential. Upon collection of adequate data, detailed groundwater assessments should be conducted to identify areas with high groundwater potential for future development and use. The outcome of the basin-wide groundwater assessments will be very valuable in developing a holistic plan for the conjunctive use of surface and groundwater as part of the broader sub-basin water security program.

GOAL 2: Adequate and reliable water resources data available for all sub-basin watersheds.

The Momba Sub-basin has a fairly good spatial distribution of hydrometric stations. However, critical review of the available data shows large gaps and questionable quality from inconsistent and irregular data collection and quality control procedures. Review of the existing rating curves revealed that all were generated 20 to 30 years ago and have not been updated or re-validated since. Another major monitoring challenge is related to groundwater resources for which no monitoring network currently exists. Furthermore, there is no systematic monitoring of sediment transport and deposition, making any estimates of watershed sediment yield hypothetical at best.

Beside the monitoring challenges highlighted above, the current data processing, quality control and storage mechanisms of the LRBWB are inadequate. There is no coherent database and information management system in place to ensure proper data processing, quality control, and storage. Most of the data is stored in different computers accessible to different staff. Some of the historical data is still in hard copy form and needs digitizing to ensure proper storage.
Urgent measures are needed to strengthen the existing water resources monitoring and assessment capacity to ensure sustainable water resources management and development.

Objective 1: Upgrade and expand the existing water resources monitoring network to cover all important watersheds and aquifers.

The existing monitoring network was carefully reviewed during the study and found to be seriously lacking to meet the data and information requirements. Specific recommendations are included in the Plan to improve the existing monitoring network as indicated below.

Action 2.1.1: **Upgrade and expand existing surface water resources monitoring network.**

World Meteorological Organization Guidelines for hydro-meteorological monitoring network design (WMO, 2008) recommend a minimum precipitation network density of 250 km^2 per station in mountainous regions, and 575 km^2 per station in interior plains. For streamflow, the recommended minimum density is 1000 km^2 per station in mountainous regions, and 1875 km^2 per station in interior plains. However, for the Momba sub-basin, such station densities would require very costly investments in monitoring equipment, maintenance, and operational support. Therefore, the most urgent surfacewater monitoring needs pertain to (a) updating and re-validating rating curves for the existing hydrometric stations; (b) consistent and timely collection of data from the existing stations; and (c) routine inspection and maintenance of monitoring equipment to minimize data collection gaps. In the long-term, additional stations could be added when adequate financial resources become available.

Action 2.1.2: **Establish a groundwater resources monitoring network.**

There is an urgent need to establish a comprehensive groundwater monitoring network for routine data collection to characterize groundwater resources. A minimum monitoring network of 21 boreholes has been proposed for the entire Lake Rukwa basin as shown in **Figure 5.1**. Three of the proposed boreholes are to be located in the Momba Sub-basin (see **Table 5.1**). The selection was based on consideration of coverage of main aquifers and recharge areas; close proximity to existing hydrometric/ climatological stations; accessibility; potential use of existing productive boreholes; and minimizing investment and network operation costs. Since the proposed monitoring sites are in close proximity to existing surface water monitoring stations, visits to the stations can be combined with routine visits to the hydrometric/rainfall stations to minimize operational costs. The proposed monitoring network provides reasonable minimum coverage of major aquifer types and areas based on available data but will need to be reviewed and augmented with additional monitoring boreholes as more detailed information becomes available on aquifer characteristics.

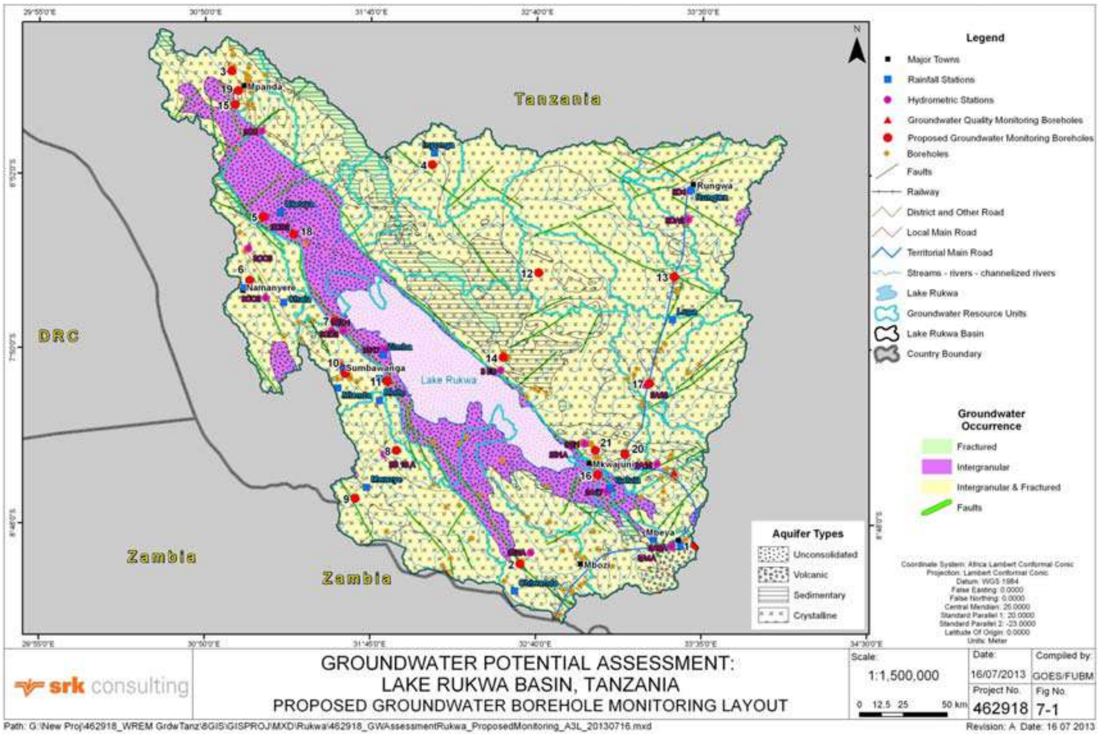


Figure 5.1: Proposed Groundwater Monitoring Locations.

Table 5.1: Proposed Groundwater Monitoring Wells for the Momba Sub-basin.

Borehole Name	Borehole No.	Coordinates		Location	Aquifer Type
Chindi A (Namlinda)	125/2009	9 002 913	453 914	Along the Ufipa fault west of Mbozi	Fault
Ikozi Village		9 071 926	378 324	Near 3B16A Hydrometric station	Intergranular and fractured
Mwimbi Village		9 042 446	353 359	Near Mwazye rainfall station	Intergranular and fractured

Action 2.1.3: **Strengthen and expand the basin water quality monitoring program.**

Based on the existing water quality monitoring challenges identified during the study, the priority intervention measures to strengthen the sub-basin water quality monitoring program pertain to:

(a) Identify and monitor all pollution “hotspots” especially in urban areas (Townships of Tunduma, Vwawa, and Laela).
(b) Improve the capacity of the Mbeya and Sumbawanga laboratories for field sampling and analysis. This should include procurement of field sampling gear, including equipment for measuring sediment transport and deposition (suspended solids and bedload).
(d) Conduct sub-basin wide water quality surveys to bridge data gaps.

Action 2.1.4: **Undertake consistent and timely collection of water resources data and maintenance of the monitoring network.**

The financial resources required to operate and maintain an elaborate monitoring network in an expansive area like the Momba sub-basin are significant. Reliance on central government budget allocations alone forwater resources monitoring operations has proved unsustainable as the funds are inadequate and rarely disbursed on time. Furthermore, the current revenue generated by the

LRBWB from water permit fees is very small to fund network operations. Pending sufficient funding for monitoring operations, the LRBWB should explore other potential options to ensure sustainable and consistent data collection. For example, the LRBWB should explore the possibility of training members of Water User Associations to support the LRBWB in some monitoring activities (e.g., taking daily gage readings and relaying the information by text messages). LGA staff could also be involved in monitoring activities. For example, the LRBWB could have volunteer liaison officers at ward/district headquarters receive completed data forms from gage readers and forward them to the basin offices in Sumbawanga Town or Mbeya City. Local communities neighboring the monitoring stations should be sensitized about the importance of the installed monitoring equipment and help in safeguarding them against vandalism.

GOAL 3: All sub-basin water uses registered and fully compliant with permitting requirements by 2035.

Effective water use monitoring and regulation is important to assess the water distribution system integrity, issue permits, and collect water use fees. The Water Resources Management Act (2009) mandates the LRBWB to allocate and regulate water use through water use and wastewater discharge permits. The LRBWB is required to ensure that permit holder legal rights are protected and access to allocated water is not jeopardized by illegal water users. Although illegal water usage is an offence under the Water Resources Management Act (2009) and carries stiff penalties, the LRBWB still faces the challenge of illegal water abstractions and non-compliance with water permit conditions. This is mostly attributed to lack of awareness and weak enforcement of the law. There are several water users who have either not applied for water use permits or who are using water in total disregard of their permit conditions. There is, therefore, a need to strengthen the water use regulatory and enforcement mechanisms to ensure legal compliance.

Objective 1: Strengthen water resources regulatory and enforcement mechanisms.

One of the main LRBWB challenges is inadequate capacity (technical and financial) to monitor the large number of water users. Monitoring water usage and enforcing compliance with water permit conditions for thousands of water users requires cooperation from the water users and the local communities. However, this cooperation is still not forthcoming. Formation of lower level water resources management structures and sensitization of local communities are important intervention measures to strengthen the LRBWB regulatory capacity. The strategy should also include more active engagement of Local Government Authorities (especially at ward and village levels) and local Water User Groups in water permit enforcement and sensitization campaigns.

Action 3.1.1: **Conduct comprehensive annual surveys of water users to validate legal status, update the water permit database, and apprehend illegal water users.**

Water permit compliance monitoring can be very expensive if LRBWB staff are required to regularly traverse the sub-basin to all water users and validate their legal standing. This kind of activity cannot be planned as a routine undertaking because of budgetary constraints. However, budgetary constraints should not be the limitation either. Other creative ways of compliance monitoring should be explored. For example, the LRBWB could engage key sub-basin stakeholders to hold an annual basin event dubbed "*Operation zero tolerance for illegal water use in Momba sub-basin*". This could be perceived as a 'community policing' (or community ownership) activity to attract corporate sponsorship and leverage support and resources from several sources. Under such an arrangement, the LRBWB would play a coordination role and leverage the strength of the different stakeholders. The process could also be viewed by all stakeholders as transparent and not manipulated by powerful interest groups (big commercial irrigation farmers, politiciansand others). Being an annual event would ensure adequate planning and resources mobilization for effective implementation. In the final analysis, comprehensive permit compliance monitoring should go beyond a few under funded LRBWB staff and instead become a community responsibility jointly planned with the involvement of key stakeholder agencies including police, Local Government Authorities, local leaders, Water User Associations, Water User Groups, NGOs, and CBOs. The LRBWB should ensure that the annual survey is as detailed as possible to capture and verify the required monitoring information during the time of the survey and update the water permit database. The annual event could be supplemented by a few targeted routine enforcement activities by LRBWB staff as and when resources permit.

Action 3.1.2: **Expedite processing and issuance of water permits as an incentive to attract new permit applicants.**

One of the complaints by water users (especially those in areas far from the LRBWB offices in Mbeya) is the logistical burden of the water permit application process (the requirement to travel long distances to Mbeya City to follow up water permit applications). Another complaint is that the permit application process takes too long, years in some cases, and yet water users cannot suspend their water use activities pending issuance of the water permit. These procedural issues serve as a disincentive to water permit applicants and exacerbate illegal water use. It is important that the LRBWB expedites the permit application process and makes it more efficient and less cumbersome to applicants. Addressing these kinds of “small” concerns could make a big and quick difference as the LRBWB addresses other regulatory challenges that require significant time and financial resources.

Action 3.1.3: **Develop appropriate technical tools for objective assessment of water permit applications and compliance monitoring.**

Processing a permit application is complex and requires careful consideration of all potential impacts of the intended water abstraction and use on downstream water users including the environment. This kind of assessment cannot be carried out through a simple visual inspection of the proposed water abstraction site or spot streamflow measurements. There is a need for technical tools that can be used for objective and defensible assessments to ensure consistency in water allocation and permitting decisions. Such tools can be incorporated in the Rukwa DSS and help give credibility to the permitting process and instill stakeholder confidence in the water allocation decisions.

GOAL 4: Environmental Flow Requirements Determined for all Critical River Sections and Compliance Ensured by 2035.

Determination and consideration of environmental flow requirements in sub-basin water allocation decisions is not optional and can no longer be ignored. The environment is a legitimate, albeit a silent, water user whose needs must be considered and fulfilled in water allocation decisions.

Objective 1: To determine and ensure compliance with the environmental flow requirements for all critical sub-basin river sections.

Environmental flow requirements present a significant water use tradeoff with socioeconomic implications for the local population which is mostly dependent on irrigated agriculture for survival and household income. Unfortunately, specific EFRs have not yet been determined for all critical sub-basin river sections. It is important that the desired environmental flow requirements are established through a transparent and technically robust procedure to ensure credibility.

Action 4.1.1: **Conduct detailed EFAs for all critical sub-basin river sections to establish applicable EFRs.**

The Desktop Reserve Model (DRM) was used to generate initial estimates of Environmental Flow Requirements (EFRs) for Momba River at Tontela. It is recommended that more detailed Environmental Flow Assessments be carried out for this site to establish more accurate EFRs to support water allocation decisions. Detailed EFAs should also be carried out for all other critical sub-basin river sections.

Action 4.1.2: **Monitoring compliance with environmental flow requirements.**

Once the EFRs have been determined for all critical river sections, the LRBWB should undertake routine surveillance and monitoring to ensure compliance. The LRBWB should also carry out periodic review of the EFRs for different river sections and modify them in response to increased water demands for other sectors, where necessary.

GOAL 5: Integrated Watershed Management and Environmental Conservation Achieved by 2035.

The Momba sub-basin rivers carry significant sediment load, usually during the rainy season, most of which is deposited in the vast wetlands. This is attributed to the widespread deforestation in the upstream watersheds due to agricultural expansion, illegal logging, charcoal burning, and wild fires. Poor agricultural practices and overgrazing are also contributing to increased river erosion and siltation. These factors combine with the heavy seasonal rains to produce runoff with high sediment loads and organic matter resulting in turbidity, colour, odour, and taste problems in surface water sources. Poor household sanitation and unregulated use of agrochemicals are other causes of surface and groundwater pollution.

Objective 1: To protect vulnerable watersheds and reverse environmental degradation.

This intervention will target critically degraded watersheds where specific integrated management measures will be implemented to reduce erosion and sediment exports from the upstream watersheds.

Action 5.1.1: Demarcation and protection of catchments upstream of important water sources.

Rampant deforestation, over grazing, and wetland degradation are responsible for destruction of important catchments thus undermining their capacity to sustain downstream water sources. The Water Resources Management Act (2009) Section 37 (1) provides for the establishment of protected zones on land draining to or above important water sources. There is need to undertake systematic identification, survey, acquisition, and protection of catchments hosting important water sources serving large populations, especially in urban areas. This initiative should be complemented by intensified enforcement of Section 34 of the Act regarding prohibition of human activities near water sources (restriction of human activities to within sixty meters from river banks, lake shores, dams, and other important water sources).

Action 5.1.2: Identify, demarcate, and protect recharge areas for important groundwater supply aquifers.

The Water Resources Management Act (2009) Section 37 (1) provides for establishing groundwater controlled areas for water supply, commercial/industrial or agricultural development. Groundwater recharge areas shall be identified following detailed assessment and mapping of significant groundwater aquifers.

Action 5.1.3: Preparation and enforcement of implementation of village land use plans.

Preparation of village land use plans in all sub-basin areas will ensure demarcation of specific areas for livestock grazing and watering. Strict enforcement of land use plans will ensure that livestock stay away from communal lands where other socio-economic activities, like farming, are carried out thus minimizing conflicts between farmers and pastoralists. Similarly, designation of livestock watering areas and facilities will ensure that pastoralists do not water their animals directly in water sources used by other users.

Action 5.1.4: Promote sustainable management and utilization of sub-basin forestry resources.

This will focus on reversing the current trend in sub-basin deforestation through implementation of a sub-basin-wide tree planting, agro-forestry, soil and water conservation, and river bank protection initiative using community based forestry management practices. This activity will also support a sub-basin-wide forest survey, classification, and mapping program to establish the extent and severity of forest encroachment and degradation. Local communities will be sensitized and trained on sustainable management and exploitation of forest resources. Local communities will also be encouraged to participate in forest management within their vicinities through the development of comprehensive community-based forest management plans.

Action 5.1.5: Promote sustainable management and utilization of sub-basin wetland resources.

A comprehensive sub-basin-wide wetlands inventory will be undertaken to establish the spatial distribution of wetlands and extent of degradation. Communities will be sensitized and facilitated to develop community-based wetlands management plans.

Objective 2: To control pollution from point and non-point sources.

Action 5.2.1: Regulate and control pollution from Agrochemical Use.

Agrochemicals can be a major source of non-point source pollution if not applied in a controlled manner. Except for a few medium to large scale commercial farms, agrochemicals are not widely used in the sub-basin. However, there is a need for increased vigilance to monitor agrochemical usage to ensure proper use and minimize pollution impacts. Specifically, extension workers need to sensitize farmers on proper handling (storage and application) of agrochemicals to minimize misuse.

Action 5.2.2: Improve sanitation and hygiene in rural households.

The majority of households use traditional pit latrines which can contaminate nearby water sources with fecal bacteria and pathogens, if poorly located or constructed. One of the consequences of this problem is the high incidence of water borne diseases. Diarrhoea—a common water borne disease—ranks among the top five causes of illness and death in the sub-basin. Funds should be availed at the local community level to train local artisans in sanitation technologies and construct demonstration facilities; help in the construction of community (schools, health centers) sanitation facilities; and support communities improve existing latrines.

6. Strategic Action Plan and Budget

6.1 Strategic Action Plan

The Momba Sub-basin Strategic Action Plan (SAP) is based on the specific goals, objectives and actions discussed in the previous chapter. The SAP shows the proposed sequencing and duration of implementation of the planned activities. It provides specific timelines for achieving desired targets during implementation and for monitoring progress against budget expenditures. The Momba Sub-basin SAP is presented in the matrix below.

Momba Sub-basin Strategic Action Plan

FIVE YEAR PHASE	Jul 2016 - Jun 2020					Jul 2020 - Jun 2025					Jul 2025 - Jun 2030					Jul 2030 - Jun 2035					Lead Implementing Agencies
YEAR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
PROGRAM 1: Water Security Enhancement Program																					
COMPONENT 1: Water Resources Infrastructure Development																					LRBWB, LGAs, WUAs
OBJECTIVE: To enhance basin water storage and supply capacity																					
TASK 1.1.1: Preliminary assessment and ranking of potential water storage sites																					
TASK 1.1.2: Prefeasibility studies of priority potential water storage projects																					
TASK 1.1.3: Feasibility studies of priority water storage projects																					
TASK 1.1.4: Construction of priority water storage projects																					
COMPONENT 2: Technical Support for Water Use Efficiency Improvement																					LRBWB, LGAs, WUAs,
OBJECTIVE: To provide technical support for water use efficiency improvements in traditional irrigation schemes																					
TASK 1.2.1: Provide technical assistance to Irrigation associations in planning and implementation of irrigation water supply infrastructure improvements																					
TASK 1.2.2: Monitoring and evaluation of water use efficiency improvements in irrigation schemes.																					
PROGRAM 2: Environmental Flow Assessment and Monitoring Program																					LRBWB, WUAs
OBJECTIVE: To ensure compliance with environmental flow requirements for all critical sub-basin river sections																					
TASK 2.1: Conduct environmental flow assessments and determine the environmental flow requirements for all critical sub-basin river sections.																					
TASK 2.2: Monitor compliance with the established environment flow requirements																					
PROGRAM 3: Water Resources Monitoring and Assessment Program																					
OBJECTIVE: To ensure availability of adequate and reliable water resources data and information.																					
COMPONENT 1: Strengthen water resources monitoring capacity																					LRBWB, WUAs
TASK 3.1.1: Establish a sub-basin groundwater monitoring network																					
TASK 3.1.2: Upgrade and expand water quality monitoring network																					
TASK 3.1.3: Coordinate establishment of water abstraction/use monitoring network																					
TASK 3.1.4: Update and re-validate rating curves for all sub-basin hydrometric stations																					
TASK 3.1.5: Conduct routine and timely collection of water resources data.																					
COMPONENT 2: Strengthen water resources assessment																					LRBWB
TASK 3.2.1: Conduct groundwater resources assessment and mapping																					
TASK 3.2.2: Conduct water quality baseline survey																					

Momba Sub-basin Strategic Action Plan (continued)

FIVE YEAR PHASE	Jul 2016 - Jun 2020					Jul 2020 - Jun 2025					Jul 2025 - Jun 2030					Jul 2030 - Jun 2035					Lead Implementing Agencies
YEAR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
PROGRAM 4: Water Permit Compliance Monitoring Program																					LRBWB, WUAs
OBJECTIVE: To register all sub-basin water use and ensure compliance with permit conditions.																					
TASK 4.1: Conduct comprehensive annual water use surveys and register all water uses																					
TASK 4.2: Develop technical tools for evaluation of water permit applications and compliance monitoring																					
TASK 4.3: Conduct routine processing of permit applications, compliance monitoring, and update of water permit database																					
PROGRAM 5: Integrated Watershed Management and Environmental Conservation																					LRBWB, LGAs, WUAs, UWSAs, Miners, Industries, Farmers
OBJECTIVE: To ensure that all vulnerable watersheds are protected and environmental degradation reversed.																					
TASK 5.1: Promote and support the development and implementation of village land use plans.																					
TASK 5.2: Identify, demarcate, and protect watersheds upstream of major water supply sources.																					
TASK 5.3:Identify, demarcate, and protect recharge areas for important groundwater supply aquifers.																					
TASK 5.4: Provide technical and financial support for catchment afforestation activities in critical watersheds.																					
TASK 5.5: Provide technical and financial support for wetland restoration and conservation activities in critical watersheds.																					
TASK 5.6: Regulate and control pollution from agrochemical use.																					
TASK 5.7: Support and promote improved sanitation and hygiene in rural households.																					

LEGEND	
	Duration of time-bound Program
	Continuous Program
	Duration of time-bound Program Component
	Continuous Program Component
	Duration of time-bound Task
	Continuous Task

6.2 Budget Estimates

The total estimated budgetto implement the Momba Sub-basin WRMD Plan from 2016 to 2035 is about 18.29 Billion TShs. The budget estimates are derived using unit costs from several planning documents (including the Lake Rukwa Basin Business Plan (2010/11 – 2014/15), WSDP—Programme Implementation Manual, District Development Plans, Five Year Development Program-1, and several other sources). **Table 6.1** and **Figures 6.1** and **6.2** show a summary of the budget estimates by program and by implementation phase. Program 1 (Water Security Enhancement) has the highest budget allocation (51%) because of the high capital costs associated with construction of water storage and supply infrastructure. Phase 1 activities account for the highest percentage of the budget (31%) because of the initial investments in the water resources monitoring network and the several initial technical studies to be undertaken under most programs. The detailed budget breakdown is presented in **Table 6.2**.

Table 6.1: Budget Estimates by Program and Implementation Phase.

Momba Sub-basin WRMD Plan Summary Budget Estimate (TShs Billion)					
PROGRAM	**Phase 1 (2016-2020)**	**Phase 2 (2020-2025)**	**Phase 3 (2025-2030)**	**Phase 4 (2030-2035)**	**TOTAL**
PROGRAM 1: Water Security Enhancement Program	2.18	1.48	1.62	2.04	**7.34**
PROGRAM 2: Environmental Flow Assessment and Monitoring Program	0.57	0.20	0.20	0.57	**1.56**
PROGRAM 3: Water Resources Monitoring and Assessment Program	1.98	0.57	0.69	0.71	**3.96**
PROGRAM 4: Water Permit Compliance Monitoring Program	0.58	0.56	0.56	0.56	**2.26**
PROGRAM 5: Integrated Watershed Management and Environmental Conservation Program	0.79	0.79	0.79	0.79	**3.18**
TOTAL	**6.11**	**3.62**	**3.87**	**4.69**	**18.29**

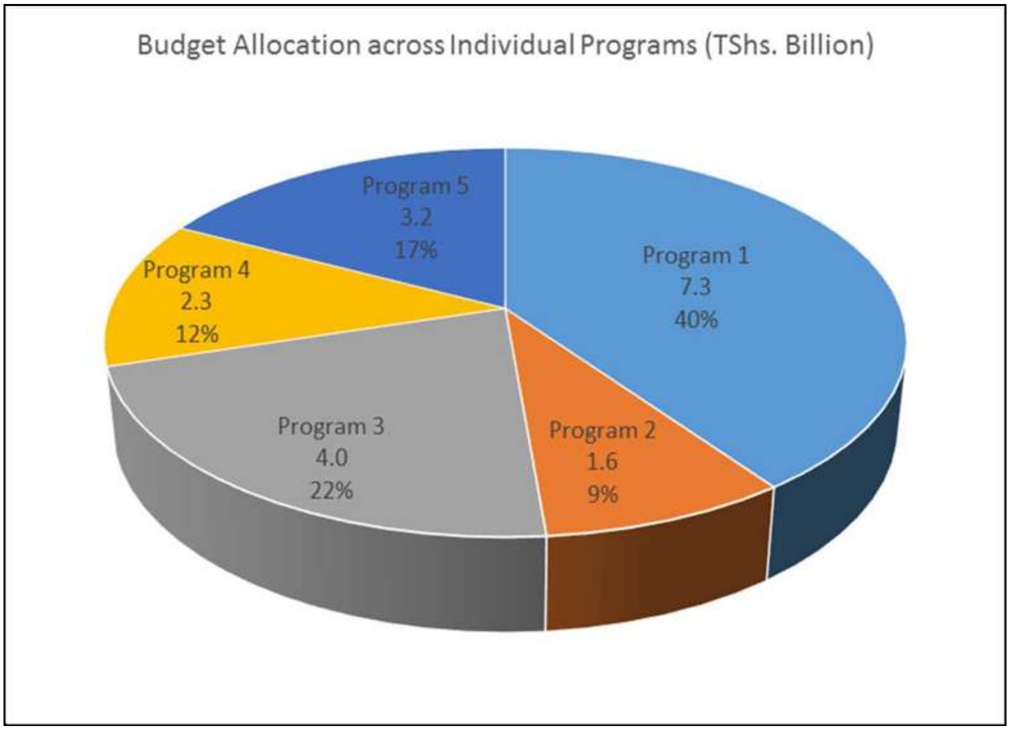


Figure 6.1: Budget Allocation across Individual Programs.

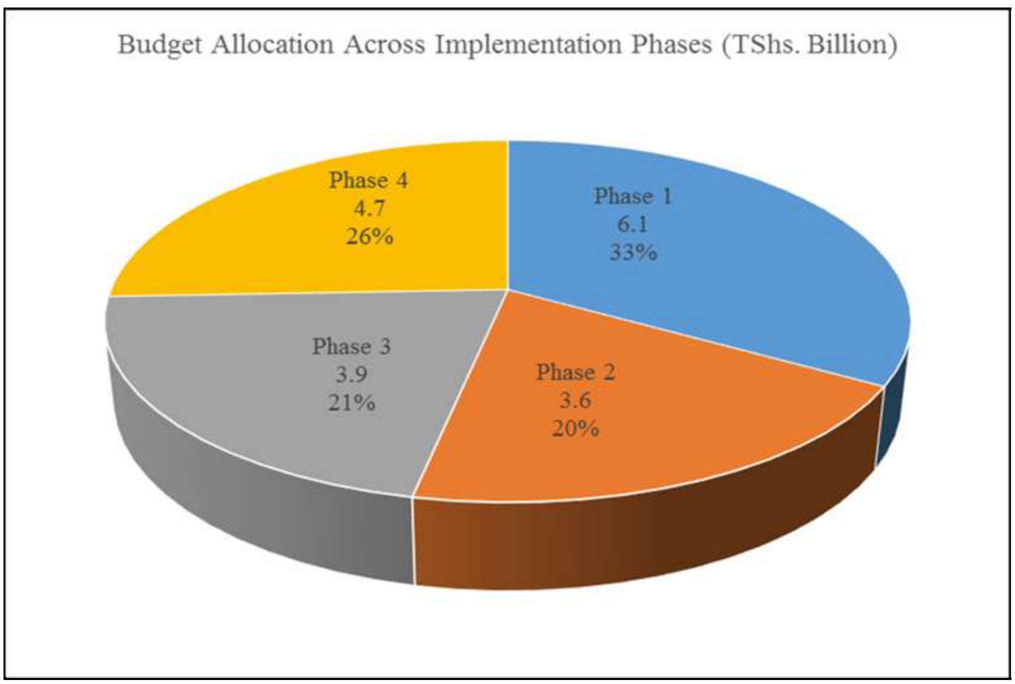


Figure 6.2: Budget Allocation across Implementation Phases.

Table 6.2: Budget Estimates for Momba Sub-basin WRMD Plan Implementation.

	Momba Sub-basin WRMD PLAN BUDGET ESTIMATES (TShs. Millions)			
	Jul 2016 - Jun 2020	**Jul 2020 - Jun 2025**	**Jul 2025 - Jun 2030**	**Jul 2030 - Jun 2035**
PROGRAM 1: Water Security Enhancement Program				
COMPONENT 1: Water Resources Infrastructure Development				
Strategic Action 1.1.1 : Assess potential for and construct surface water storage infrastructure to increase sub-basin water storage capacity.	2,100	1,400	1,400	1,400
Strategic Action 1.1.2 : Assess potential for and construct medium to large scale groundwater supply schemes to increase sub-basin water supply capacity.	-	-	140	560
COMPONENT 2: Technical Support for Water Use Efficiency Improvement	-	-	-	-
Strategic Action 1.2.1 : Provide technical assistance to Irrigation associations in planning and upgrading of irrigation water supply infrastructure and monitor water use efficiency improvements.	84	84	84	84
Program 1 Sub-total	***2,184***	***1,484***	***1,624***	***2,044***
PROGRAM 2: Environmental Flow Assessment and Monitoring Program				
Strategic Action 2.1 : Conduct environmental flow assessments and determine environmental flow requirements for allcritical sub-basin river sections.	369	-	-	369
Strategic Action 2.2 : Conduct routine field visits to monitor compliance with established environmental flow requirements.	160	160	160	160
Strategic Action 2.3 : Conduct regular public awareness raising campaigns on the importance of maintaining environmental flow requirements and consequences of violations.	45	45	45	45
Program 2 Sub-total	***574***	***205***	***205***	***574***
PROGRAM 3: Water Resources Monitoring and Assessment Program				
COMPONENT 1: Strengthen water resources monitoring capacity				
Strategic Action 3.1.1 : Rehabilitate existing surface water resources monitoring networkand update and re-validate rating curves for all functional hydrometric stations.	736	230	230	230
Strategic Action 3.1.2 : Establish network of groundwater level monitoring boreholes to cover all major sub-basin aquifers.	966	-	230	230
Strategic Action 3.1.3 : Establish additional water quality sampling sites to cover all important pollution prone areas.	23	-	-	23
Strategic Action 3.1.4 : Conduct routine and consistent network visits for data collection and equipment maintenance.	184	184	184	184
Strategic Action 3.1.5 : Conduct routine training for technicians and gage readers to ensure collection of reliable data and proper maintenance of monitoring equipment.	46	46	46	46
COMPONENT 2: Strengthen water resources assessment capacity	-	-	-	-
Strategic Action 3.2.1 : Conduct sub-basin groundwater assessments and mapping	-	115	-	-
Strategic Action 3.2.2 : Conduct sub-basin water quality baseline survey.	23	-	-	-
Program 3 Sub-total	***1,978***	***575***	***690***	***713***

Table 6.2: Budget Estimates for Momba Sub-basin WRMD Plan Implementation (continued)

	Momba Sub-basin WRMD PLAN BUDGET ESTIMATES (TShs. Millions)			
	Jul 2016 - Jun 2020	Jul 2020 - Jun 2025	Jul 2025 - Jun 2030	Jul 2030 - Jun 2035
PROGRAM 4: Water Permit Compliance Monitoring Program				
Strategic Action 4.1 : Conduct comprehensive annual water use surveys to locate, verify, map, register and regularize all water withdrawals, waste water discharges and hydraulic infrastructure.	200	200	200	200
Strategic Action 4.2 : Conduct routine processing of new water permit applications and renewals.	40	40	40	40
Strategic Action 4.3 : Develop technical tools for evaluation of water permit applications and compliance monitoring	20	-	-	-
Strategic Action 4.4 : Undertake routine update of the water permit database.	-	-	-	-
Strategic Action 4.5 : Conduct routine field visits to check compliance with permit conditions and apprehend illegal water users.	160	160	160	160
Strategic Action 4.6 : Conduct regular public awareness raising campaigns on the dangers of illegal water abstraction and non-compliance with permit conditions.	160	160	160	160
Program 4 Sub-total	*580*	*560*	*560*	*560*
PROGRAM 5: Integrated Watershed Management and Environmental Conservation Program				
Strategic Action 5.1 : Identify, demarcate, and protect watersheds upstream of major water supply sources	150	150	150	150
Strategic Action 5.2 : Identify, demarcate, and protect important groundwater recharge areas.	150	150	150	150
Strategic Action 5.3 : Provide technical and financial support for catchment afforestation activities in critical watersheds	300	300	300	300
Strategic Action 5.4 :Provide technical and financial support for wetland restoration and conservation activities in critical watersheds	75	75	75	75
Strategic Action 5.5: Provide technical and financial support for preparation and implementation of village land use plans.	90	90	90	90
Strategic Action 5.6: Regulate and control pollution from agrochemical use.	30	30	30	30
Strategic Action 5.7: Support and promote improved sanitation and hygiene in rural households.	-	-	-	-
Program 5 Sub-total	*795*	*795*	*795*	*795*
GRAND TOTAL	6,111	3,619	3,874	4,686

7. References

Mbozi DC 2013: District Plans, Agricultural Sector.

SMUWC 2001: Sustainable Management of the Usangu Wetland and its Catchment. Series of Technical Reports developed as part of the SMUWC project.

Sumbawanga DC 2013: District Plans, Agricultural Sector.

WMO 2008: Guide to Hydrological Practices, WMO-No. 168.

WREM International 2013: Lake Rukwa Basin Integrated Water Resources Management and Development Plan, Interim Report I: Lake Rukwa Basin Socioeconomic Profile and Water Resources Management Framework, developed by WREM International Inc., Atlanta, Georgia, USA, 163 pg.

8. ANNEX A: Irrigation Water Use Practices

(1) Maleza Irrigation Scheme

The Maleza irrigation scheme is a traditional scheme located in Maleza Village in Kipeta Ward, Sumbawanga DC. The scheme was established as a farmers' initiative in response to frequent droughts that often resulted in poor crop yield and food shortages. The scheme serves 574 households with land holdings ranging from 0.5 to 4ha per household. Total potential irrigable area is 7,500ha of which only 400ha is currently irrigated due to inadequate irrigation infrastructure. Rice and maize are the major crops grown. Other crops grown on a smaller scale include sunflower, sorghum, finger millet and vegetables. Most scheme members are also engaged in other economic activities such as livestock keeping, timber production, and fishing to increase household income. Management and operation of the scheme is through Umoja wa Umwagiliaji Maji Maleza, an irrigators' organization established in 2009 to ensure effective operation and maintenance. The association consists of 520 farmers.

Water use and crop production – Water is abstracted from the Momba River and conveyed to the farms by gravity through traditional canals. Existing irrigation water supply infrastructure consists of a constructed intake, a 5.6 km unlined main canal, and a network of earthen secondary and tertiary canals. Farmers mostly practice surface irrigation by flooding their farms from adjacent traditional canals. All the currently irrigated area (400ha) is planted with rice in the wet season. Land preparation for rice cultivation occurs from November to December while harvesting occurs from April to end of May. Farm inputs used include improved seeds, chemical fertilizers, and agro-chemicals. On average, about 3,600kg of rice is harvested per acre during the wet season. Harvested produce is sold to middle men and at local markets.

Constraints/challenges – Major constraints to crop production include: inadequate water for irrigation, poor irrigation infrastructure, and loss of soil fertility which requires increased use of fertilizers. Other challenges include high levels of canal siltation and soil erosion.

On-going works/Expansion plans – Improvement of scheme infrastructure is ongoing. Phase I (2008/2009) involved feasibility studies and construction of head works, main canal construction of 5.6 km, and associated structures. The following activities were implemented during the 2013/2014 financial year under DIDF funding: lining 5.6 km of main canal, construction of a 65m flood dyke, drainage facilities, 1km village access road and a 3km farm access road; and training of farmers on irrigation water management skills and irrigators organization management. The infrastructure improvements enable farmers to irrigate at least 220 ha in the dry season (Sumbawanga DC, 2013).

(2) Naming'ongo Irrigation Scheme

The Naming'ongo Irrigation Scheme is a traditional scheme located in Chitete ward in Momba District. The scheme lies along the left bank of Nkana River in Msangano Plains and has a potential irrigable area of 1500 ha of which only 200ha are irrigated during the wet season. In the dry season only 10 ha, planted with vegetables, are irrigated. The area receives mean annual rainfall of about 650 mm. The scheme was established as a farmer initiative to increase crop productivity and enhance household incomes. The scheme comprises 2,678 small scale farmers from Naming'ongo village with land holdings ranging from 0.5 to 2 ha per household. The farmer association is referred to as "Naming'ongo Irrigators' Association" and was established in 2003. A scheme management committee elected from the association membership is responsible for the overall management including conflict resolution.

Water use and crop production – Water is abstracted from the Nkana River and conveyed to the farms by gravity through traditional canals. Farmers mostly grow rice under supplementary irrigation during the wet season (November to May). Other crops grown on a smaller scale include beans, maize and vegetables. Land preparation for cultivation of rice occurs from November to December while harvesting starts in April and ends in June. Vegetables are normally planted from May to July and are harvested from August to October. **Table A.1** below shows typical crop production practices at the scheme. Harvested produce is either sold to middle men or at the local market.

Table A.1: Crop Production Practices at Naming'ongo

Production	Wet season	
Name of crops	Rice (Irrigated)	Maize (Rain fed)
Cultivated area (ha)	200	340
Maximum yield/acre	15 bags	5 bags
Minimum yield/acre	8 bags	2 bags
Maximum price (Tshs)/bag	40,000	32,000
Minimum price (Tshs)/bag	30,000	15,000
Weight per bag (kg)	80kgs	100kgs

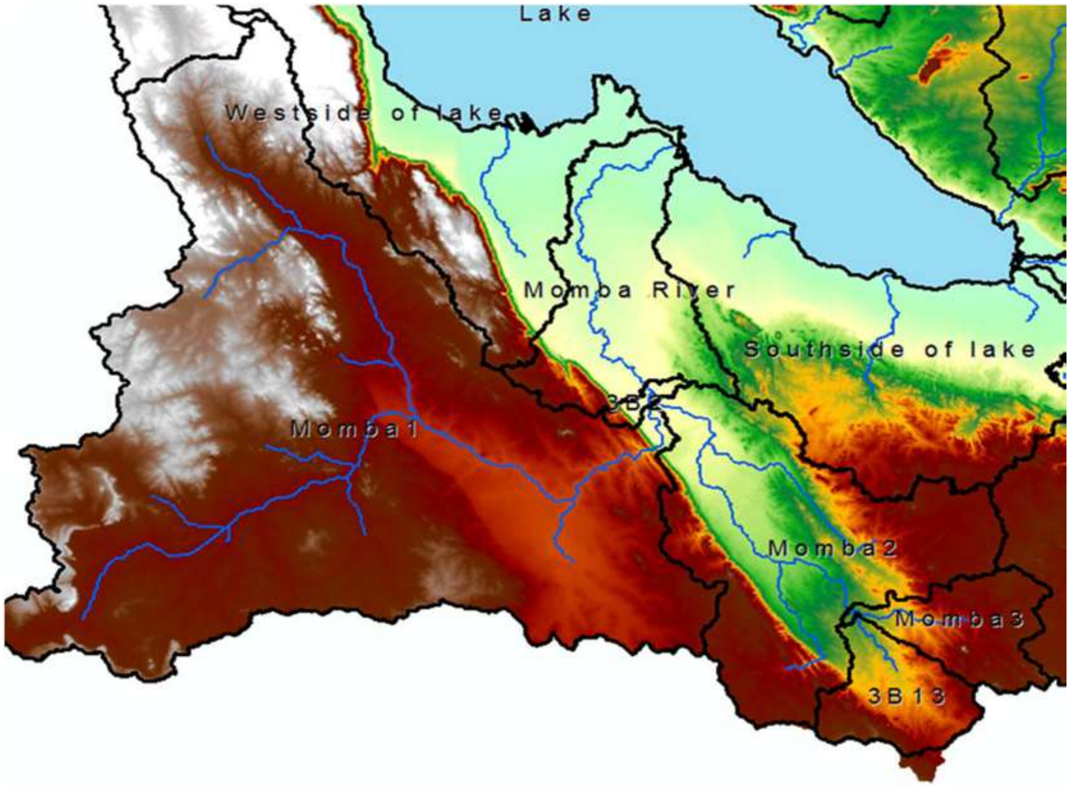
Source: Mbozi DC (2013)

Constraints/challenges – Limitations include poor and incomplete irrigation infrastructure, inadequate water supplies, inadequate knowledge on good irrigation and efficient water use practices, and inadequate skills in effective operation and maintenance of irrigation infrastructure.

On-going works/Expansion plans – Construction of head works and an access bridge is on-going after being washed away by rain. The following activities were implemented during the 2013/2014 financial year under DIDF funding: lining of 1.8km of main canal; construction of flow control and distribution structures; and training of farmers in good irrigation water management practices, organizational and management skills, improved crop husbandry practices, and operation and maintenance of irrigation infrastructure. Successful implementation of the planned activities will increase the command area to 55 ha in the dry season (Mbozi DC 2013).

9. ANNEX B: Assessment of Potential Reservoir Sites

Momba Sub-basin



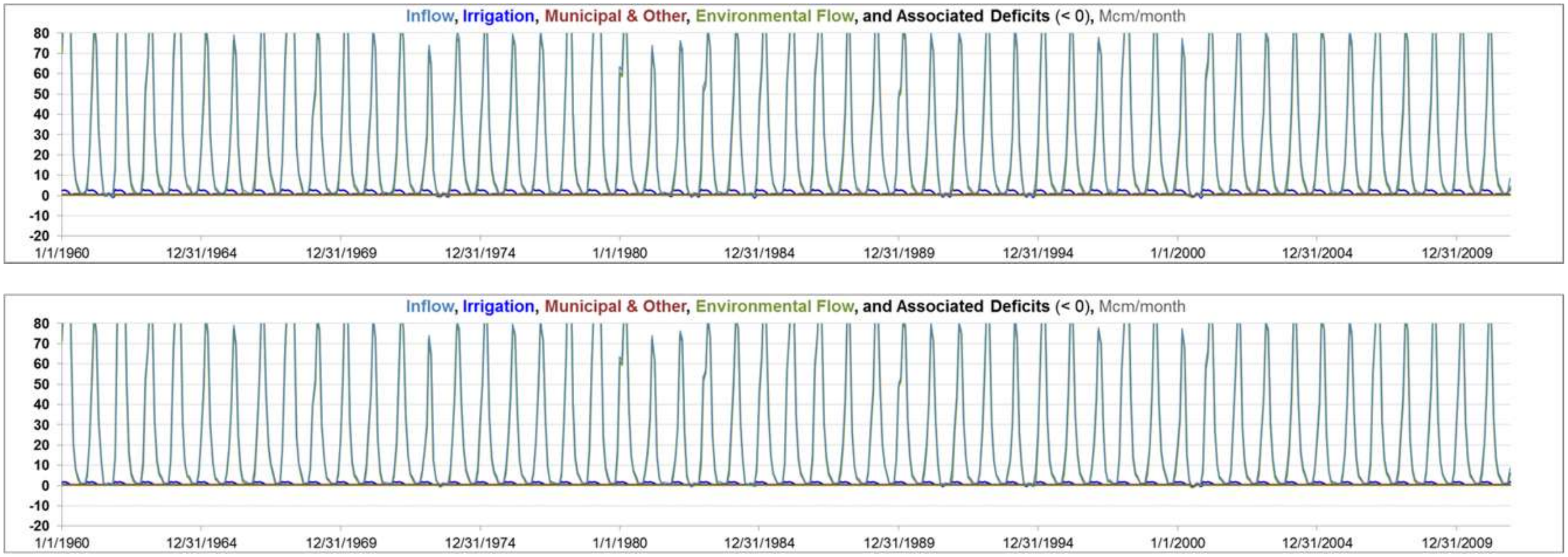
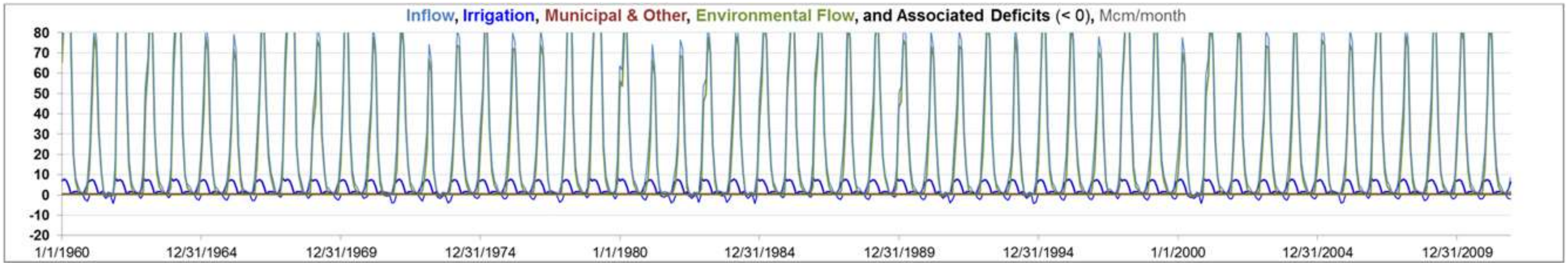


Figure B.1: Southern Momba catchment simulated sequences (Mcm/month) of watershed inflow, irrigation water supply, municipal and other water supply, environmental flow, and associated deficits (negative values) for irrigation efficiencies 1.56 (*top graph*) and 1.00 (*bottom graph*) l/sec/ha. The simulations assume existence of 2.3 Mcm reservoir storage and are based on 1960–2011 hydrologic conditions and 2015 water demand targets. Fairly small storage was assumed because potential sites of high storage could not be identified in southern Momba.

Table B.1: Southern Momba catchment monthly irrigation, municipal and other, and environmental flow water use deficits from 2015 demand targets, and potential annual hydropower production (*tentative estimate*) for irrigation efficiencies 1.56 (*top*) and 1.00 (*bottom)* l/sec/ha. The simulations assume existence of 2.3 Mcm reservoir storage and are based on 1960–2011 hydrologic conditions.

Momba 2 + 3 + 3B13			Water Demands:		2015			Storage Capacity:		2.3	Mcm
Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Irrigation Dfcts, Mcm/m:			Irrigation Efficiency:			1.56	lt/sec/ha					
Dfct Freq	0.000	0.000	0.000	0.000	0.000	0.019	0.038	0.132	0.000	0.000	0.151	0.000
Avg Dfct (> 0)	0.000	0.000	0.000	0.000	0.000	0.286	0.603	0.629	0.000	0.000	1.007	0.000
Max Dfct	0.000	0.000	0.000	0.000	0.000	0.286	0.767	0.811	0.000	0.000	1.436	0.000
Municipal & Other Dfcts, Mcm/m:												
Dfct Freq	0.000	0.000	0.000	0.000	0.000	0.000	0.019	0.038	0.000	0.000	0.000	0.000
Avg Dfct (> 0)	0.000	0.000	0.000	0.000	0.000	0.000	0.384	0.243	0.000	0.000	0.000	0.000
Max Dfct	0.000	0.000	0.000	0.000	0.000	0.000	0.384	0.384	0.000	0.000	0.000	0.000
Env Flow Dfcts, Mcm/m:												
Dfct Freq	0.000	0.000	0.000	0.000	0.000	0.000	0.019	0.094	0.000	0.000	0.000	0.000
Avg Dfct (> 0)	0.000	0.000	0.000	0.000	0.000	0.000	1.094	0.514	0.000	0.000	0.000	0.000
Max Dfct	0.000	0.000	0.000	0.000	0.000	0.000	1.094	0.720	0.000	0.000	0.000	0.000
Hydropower, GWh/yr:		7.474	*Tentative*									
Irrigation Dfcts, Mcm/m:			Irrigation Efficiency:			1	lt/sec/ha					
Dfct Freq	0.000	0.000	0.000	0.000	0.000	0.019	0.019	0.094	0.000	0.000	0.057	0.000
Avg Dfct (> 0)	0.000	0.000	0.000	0.000	0.000	0.019	0.492	0.500	0.000	0.000	0.276	0.000
Max Dfct	0.000	0.000	0.000	0.000	0.000	0.019	0.492	0.520	0.000	0.000	0.479	0.000
Municipal & Other Dfcts, Mcm/m:												
Dfct Freq	0.000	0.000	0.000	0.000	0.000	0.000	0.019	0.038	0.000	0.000	0.000	0.000
Avg Dfct (> 0)	0.000	0.000	0.000	0.000	0.000	0.000	0.384	0.197	0.000	0.000	0.000	0.000
Max Dfct	0.000	0.000	0.000	0.000	0.000	0.000	0.384	0.384	0.000	0.000	0.000	0.000
Env Flow Dfcts, Mcm/m:												
Dfct Freq	0.000	0.000	0.000	0.000	0.000	0.000	0.019	0.075	0.000	0.000	0.000	0.000
Avg Dfct (> 0)	0.000	0.000	0.000	0.000	0.000	0.000	1.094	0.464	0.000	0.000	0.000	0.000
Max Dfct	0.000	0.000	0.000	0.000	0.000	0.000	1.094	0.720	0.000	0.000	0.000	0.000
Hydropower, GWh/yr:		7.497	*Tentative*									



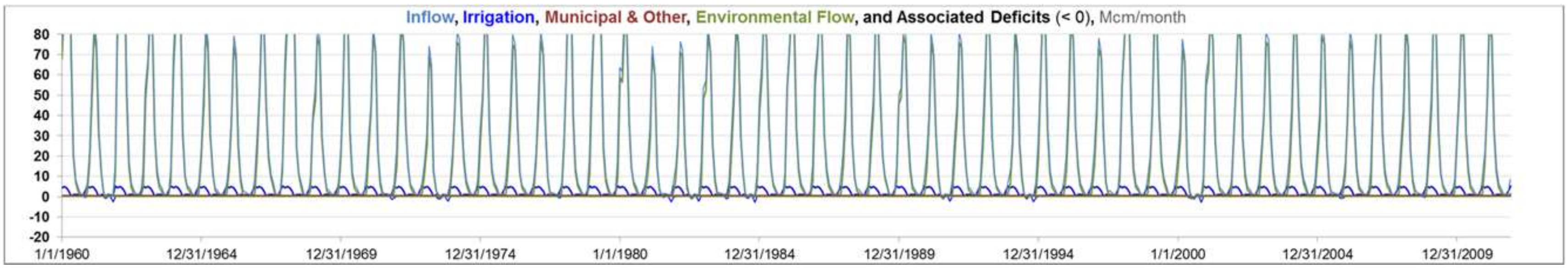
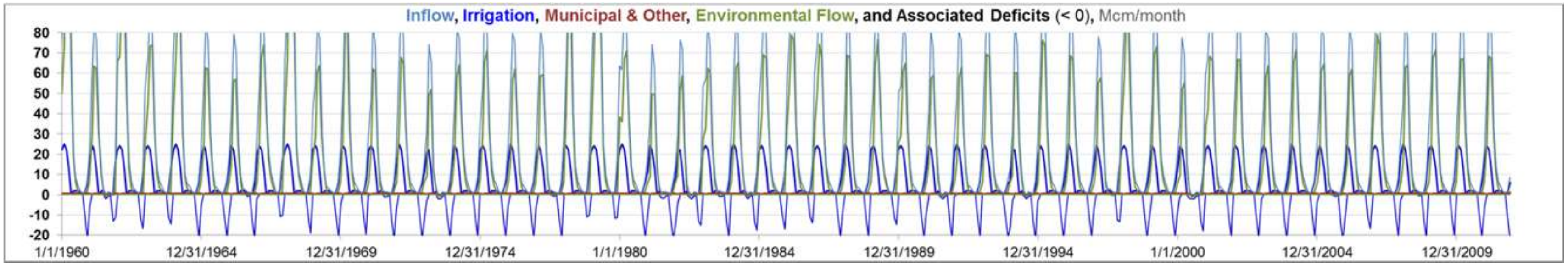


Figure B.2: Southern Momba catchment simulated sequences (Mcm/month) of watershed inflow, irrigation water supply, municipal and other water supply, environmental flow, and associated deficits (negative values) for irrigation efficiencies 1.56 (*top graph*) and 1.00 (*bottom graph*) l/sec/ha. The simulations assume existence of 2.3 Mcm reservoir storage and are based on 1960–2011 hydrologic conditions and 2025 water demand targets. Fairly small storage was assumed because potential sites of high storage could not be identified in southern Momba.

Table B.2: Southern Momba catchment monthly irrigation, municipal and other, and environmental flow water use deficits from 2025 demand targets, and potential annual hydropower production (*tentative estimate*) for irrigation efficiencies 1.56 (*top*) and 1.00 (*bottom)* l/sec/ha. The simulations assume existence of 2.3 Mcm reservoir storage and are based on 1960–2011 hydrologic conditions.

Momba 2 + 3 + 3B13			Water Demands:		2025			Storage Capacity:		2.3	Mcm
Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Irrigation Dfcts, Mcm/m:			Irrigation Efficiency:			1.56	lt/sec/ha					
Dfct Freq	0.019	0.000	0.000	0.000	0.000	0.019	0.113	0.170	0.189	0.000	0.981	0.717
Avg Dfct (> 0)	0.065	0.000	0.000	0.000	0.000	1.126	0.740	1.362	0.520	0.000	2.267	2.392
Max Dfct	0.065	0.000	0.000	0.000	0.000	1.126	1.518	1.561	0.524	0.000	4.221	3.624
Municipal & Other Dfcts, Mcm/m:												
Dfct Freq	0.000	0.000	0.000	0.000	0.000	0.000	0.019	0.094	0.000	0.000	0.000	0.000
Avg Dfct (> 0)	0.000	0.000	0.000	0.000	0.000	0.000	0.503	0.333	0.000	0.000	0.000	0.000
Max Dfct	0.000	0.000	0.000	0.000	0.000	0.000	0.503	0.503	0.000	0.000	0.000	0.000
Env Flow Dfcts, Mcm/m:												
Dfct Freq	0.000	0.000	0.000	0.000	0.000	0.000	0.038	0.132	0.000	0.000	0.038	0.000
Avg Dfct (> 0)	0.000	0.000	0.000	0.000	0.000	0.000	0.856	0.611	0.000	0.000	0.233	0.000
Max Dfct	0.000	0.000	0.000	0.000	0.000	0.000	1.094	0.720	0.000	0.000	0.269	0.000
Hydropower, GWh/yr:		7.021	*Tentative*									
Irrigation Dfcts, Mcm/m:			Irrigation Efficiency:			1	lt/sec/ha					
Dfct Freq	0.000	0.000	0.000	0.000	0.000	0.019	0.038	0.151	0.151	0.000	0.377	0.094
Avg Dfct (> 0)	0.000	0.000	0.000	0.000	0.000	0.599	0.973	0.857	0.040	0.000	1.246	0.400
Max Dfct	0.000	0.000	0.000	0.000	0.000	0.599	0.973	1.001	0.040	0.000	2.706	0.618
Municipal & Other Dfcts, Mcm/m:												
Dfct Freq	0.000	0.000	0.000	0.000	0.000	0.000	0.019	0.075	0.000	0.000	0.000	0.000
Avg Dfct (> 0)	0.000	0.000	0.000	0.000	0.000	0.000	0.503	0.275	0.000	0.000	0.000	0.000
Max Dfct	0.000	0.000	0.000	0.000	0.000	0.000	0.503	0.503	0.000	0.000	0.000	0.000
Env Flow Dfcts, Mcm/m:												
Dfct Freq	0.000	0.000	0.000	0.000	0.000	0.000	0.038	0.094	0.000	0.000	0.038	0.000
Avg Dfct (> 0)	0.000	0.000	0.000	0.000	0.000	0.000	0.596	0.698	0.000	0.000	0.171	0.000
Max Dfct	0.000	0.000	0.000	0.000	0.000	0.000	1.094	0.720	0.000	0.000	0.208	0.000
Hydropower, GWh/yr:		7.262	*Tentative*									



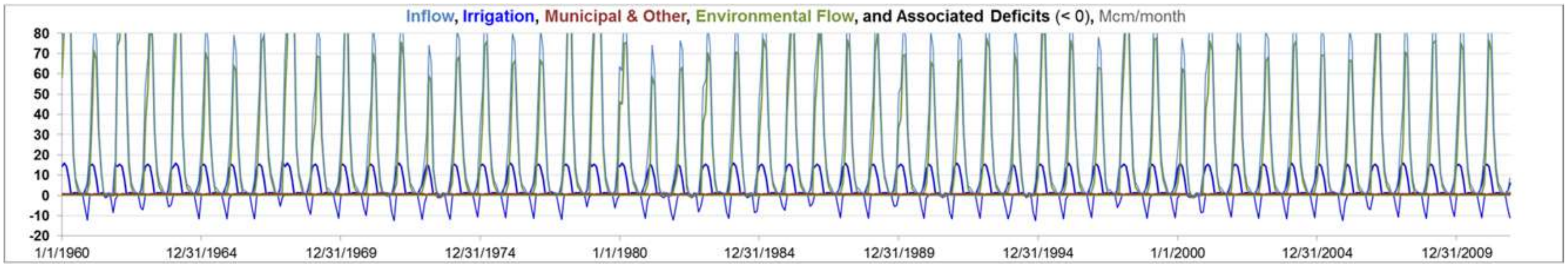


Figure B.3: Southern Momba catchment simulated sequences (Mcm/month) of watershed inflow, irrigation water supply, municipal and other water supply, environmental flow, and associated deficits (negative values) for irrigation efficiencies 1.56 (*top graph*) and 1.00 (*bottom graph*) l/sec/ha. The simulations assume existence of 2.3 Mcm reservoir storage and are based on 1960–2011 hydrologic conditions and 2035 water demand targets. Fairly small storage was assumed because potential sites of high storage could not be identified in southern Momba.

Table B.3: Southern Momba catchment monthly irrigation, municipal and other, and environmental flow water use deficits from 2035 demand targets, and potential annual hydropower production (*tentative estimate*) for irrigation efficiencies 1.56 (*top*) and 1.00 (*bottom)* l/sec/ha. The simulations assume existence of 2.3 Mcm reservoir storage and are based on 1960–2011 hydrologic conditions.

Momba 2 + 3 + 3B13			Water Demands:		2035			Storage Capacity:		2.3	Mcm
Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Irrigation Dfcts, Mcm/m:			Irrigation Efficiency:			1.56	lt/sec/ha					
Dfct Freq	0.528	0.075	0.000	0.000	0.000	0.019	0.132	0.226	0.283	0.000	0.981	0.981
Avg Dfct (> 0)	6.967	2.517	0.000	0.000	0.000	1.616	1.106	1.486	0.870	0.000	11.786	19.111
Max Dfct	15.506	3.661	0.000	0.000	0.000	1.616	1.885	1.928	0.970	0.000	13.106	22.126
Municipal & Other Dfcts, Mcm/m:												
Dfct Freq	0.000	0.000	0.000	0.000	0.000	0.000	0.038	0.132	0.000	0.000	0.038	0.000
Avg Dfct (> 0)	0.000	0.000	0.000	0.000	0.000	0.000	0.391	0.400	0.000	0.000	0.205	0.000
Max Dfct	0.000	0.000	0.000	0.000	0.000	0.000	0.642	0.642	0.000	0.000	0.240	0.000
Env Flow Dfcts, Mcm/m:												
Dfct Freq	0.000	0.000	0.000	0.000	0.000	0.000	0.038	0.132	0.000	0.000	0.113	0.000
Avg Dfct (> 0)	0.000	0.000	0.000	0.000	0.000	0.000	1.094	0.720	0.000	0.000	0.215	0.000
Max Dfct	0.000	0.000	0.000	0.000	0.000	0.000	1.094	0.720	0.000	0.000	0.299	0.000
Hydropower, GWh/yr:		6.178	*Tentative*									
Irrigation Dfcts, Mcm/m:			Irrigation Efficiency:			1	lt/sec/ha					
Dfct Freq	0.226	0.000	0.000	0.000	0.000	0.019	0.094	0.151	0.170	0.000	0.981	0.981
Avg Dfct (> 0)	2.597	0.000	0.000	0.000	0.000	0.962	0.602	1.207	0.352	0.000	6.497	9.512
Max Dfct	7.507	0.000	0.000	0.000	0.000	0.962	1.208	1.236	0.374	0.000	8.401	12.528
Municipal & Other Dfcts, Mcm/m:												
Dfct Freq	0.000	0.000	0.000	0.000	0.000	0.000	0.019	0.094	0.000	0.000	0.038	0.000
Avg Dfct (> 0)	0.000	0.000	0.000	0.000	0.000	0.000	0.642	0.467	0.000	0.000	0.144	0.000
Max Dfct	0.000	0.000	0.000	0.000	0.000	0.000	0.642	0.642	0.000	0.000	0.179	0.000
Env Flow Dfcts, Mcm/m:												
Dfct Freq	0.000	0.000	0.000	0.000	0.000	0.000	0.038	0.132	0.000	0.000	0.075	0.000
Avg Dfct (> 0)	0.000	0.000	0.000	0.000	0.000	0.000	0.845	0.603	0.000	0.000	0.235	0.000
Max Dfct	0.000	0.000	0.000	0.000	0.000	0.000	1.094	0.720	0.000	0.000	0.299	0.000
Hydropower, GWh/yr:		6.606	*Tentative*									