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**Implementation of the Flood Forecasting Framework for Buzi,  
Pungwe and Save (BUPUSA) Basins  
Inception Report  
(Including Key Design Considerations)**

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FINAL

January 2023





# Executive Summary

## E.1 Objectives of the Project and Scope

The main objective of this Consultancy is to support the development and implementation of the flood forecasting and early warning system for the BUPUSA basins and build the capacity to sustain it.

The scope of work includes (i) designing the BUPUSA FFEWS, (ii) collating and validating relevant data sets, conducting field surveys, (iii) setting up models and conducting hydrological and hydraulic modelling for the BUPUSA basins’ main stems and main tributaries and producing real-time and forecasts of flood conditions at selected points/locations and (iv) assessing the existing institutional capacity, designing and implementing a programme to address the critical gaps and (v) putting in place the institutional documentation to guide the flood forecasting and early warning centre and (vi) conducting independent reviews and updating the FFEWS. These reviews feed into the plan-do-review cycle which will contribute progressive development of the BUPUSA FFEWS and its sustainability.

The consultancy proposed an Inception Phase to clarify stakeholder expectations that might not be self-evident from the bid documents, to start collecting relevant background information, and to establish communication lines with focal points indicated by the Client and other stakeholders. The Inception Phase would then be followed by a design phase where the FFEWS user needs, data requirements, system architecture and warning dissemination mechanisms will be designed. The late start of the project (18 August 2022, less than two months before the expected onset of the flooding season) requires an accelerated approach so that the first version of the BUPUSA FFEWS can be used in a post-season review. *We have therefore expanded the inception phase scope to address key design considerations for early agreement with the stakeholders.*

The specific objectives of the consultancy are given in Table E-1 below. The table specifies where these objectives are addressed in the inception methodology, and derived deliverables or outputs.

**Table E-1: Objectives, links to methodology and outputs**

Specific Objective	Section	Outputs / deliverables
1) To design the BUPUSA FFEWS	Ch 3, Task 1	D1 BUPUSA FFEWS design report
2) Obtain and configure relevant spatial and geophysical data sets and set up the spatial system for rainfall runoff modelling, hydraulic modelling and flood impact assessment incorporating all catchments/impacted areas/points of concern to member states regarding flooding.	Section 4.4, Task 2.4	D2.4 Rating curves for selected river sections and topographic data for flood prone areas
3) Obtain and configure a number of time-series data sets including rainfall and runoff for application with selected models.	Section 4.4, Task 2.4	D2.3 Freeware time series data sets

Specific Objective	Section	Outputs / deliverables
4) To set up and run the HEC HMS model for the whole of the BUPUSA basins to the extents defined in Objective (2).	Ch 4, Task 2	D2.6 HEC-HMS model set up for the BUPUSA FFEWS; D2.7 HEC RAS model set up for the BUPUSA FFEWS
5) To undertake topographic surveys and flow measurements for selected points on rivers and develop rating curves	Section 4.4.7 (1), Task 2	D2.4 Rating curves for selected river sections and topographic data for flood prone areas
6) To process available drone survey data and obtain topographic data for flood modelling	Section 4.4.7 (1), Tasks 2, 2.2	D2.4 Rating curves for selected river sections and topographic data for flood prone areas
7) To set up and run the HEC RAS hydraulic model for selected study areas.	Section 4.2, Task 2.2	D2.7 HEC RAS model set up for the BUPUSA FFEWS
8) To undertake Flood Risk Assessment utilising output from the HEC HMS, rating curves developed, output from the HEC RAS, historical and anecdotal information for selected flood prone areas.	Section 4.3, Task 2.3	D2.5 Flood Risk Assessment Report including GIS Mapping of flood prone areas for live system
9) Set up a system (Delft FFEWS) to generate verifiable, meaningful and user-friendly flood forecasts and warnings. Part of this process should include development of a user friendly and technological appropriate notification system for the distribution of flood warning messages. The method that is adopted and developed needs to be workshopped with the member states and coordinated with the appropriate stakeholders in each country.	Section 3.3.2, Task 1	D4 FFEWS set up and running. System tests and validation reports: Water level flow hydrographs for historical near real time and forecast conditions etc. GIS inundation maps forecasts and early warnings
10) Engage with hydrologists and scientists in developing the BUPUSA transboundary FFEWS.	Section 5.5, Task 3.4	D5.2 Capacity building report
11) To develop and implement a capacity building plan for member states to sustain the BUPUSA FFEWS.	Section 5.4, Task 3.3	D5.1 Institutional capacity assessment report and capacity building plan
12) To develop protocols and guidelines for the FFEWS centre to standardise its approaches and consistently address expectations from users and	Section 5.6, Task 3.5	D5.3 BUPUSA FFEWS protocols procedures and guidelines
13) To conduct reviews of forecasts and warnings generated and their application and use the result to strengthen the plan-do-review cycle.	Section 4.7, Task 2.8	D6 Review reports
14) To contribute to the development of the Transboundary Diagnostic Analysis (TDA) and Strategic Action Plan (SAP) for the BUPUSA Basin	Ch 7, task 5	D8 Report on key issues related to TDA NAPS and SAP
15) To incorporate and mainstream Gender Equality and Social Inclusion (GESI) in the development of the BUPUSA Early Warning Systems.	Ch 8, Task 6	D9 GESI action Plan and reports

## E.2 Flood Hazards in the Three Basins

The risk of flooding in the three basins is highest during and following the November to March rainy season, with peak flows in March and April (World Bank Group, 2019). When river flooding coincides with incoming tropical cyclones, the flooding situation is worsened, as happened during the 2000 floods when Cyclone Eline hit Mozambique.

The GEF BUPUSA feasibility study for the BUPUSA project (WR Nyabeze and Associates, 2022) categorised flood hazards in the three basins:

- **Flash flooding** occur in steep, small catchments as a result of intense rainfall over short periods. High velocity runoff causes erosion and damage to infrastructure.
- **River flooding** results from prolonged rainfall over catchment areas and accumulation of flow from tributaries. Water levels rise and overflow into flood plains and low-lying areas. This type of flooding can inundate large areas, causing extensive damage to settlements and infrastructure, including dam breaks.
- **Landslides** occur when heavy rainfall on deforested or bare areas causes the rock and soil mass to become unstable and shear off hillsides.
- **Sedimentation** occurs when high velocity flows erode exposed soil and deposit the sediment in downstream areas where flow velocities reduce.
- **Coastal flooding** is caused by ocean storm surges that spill into unprotected coastal plains.
- **Urban flooding** occurs when the capacity of inadequate or poorly maintained drainage systems are overwhelmed during heavy rainfall events.

The focus of this project is on river flooding.

## E.3 Key Recommendations from the Inception Phase Assessments

The worst flooding events occur when heavy cyclonic rainfall and storm surges are compounded by high river floods from upstream areas. A flood early warning system that is based on river flood forecasts cannot predict backwater effects in coastal areas due to ocean storm surges, nor will it account for localised flooding from cyclone landfalls and associated heavy rainfall. To address this gap to some extent, a recommendation is to introduce a long-lead cyclone early warning to the BUPUSA FFEWS. While a comprehensive solution cannot be implemented within the scope of the project, we do recommend implementing a simple first step by providing a link from the BUPUSA website to South-West Indian Ocean cyclone track monitoring advisories. Possible sources of these advisories are the La Réunion Regional Specialized Meteorological Center (RSMC), and the US Navy Joint Typhoon Warning Center.

The feasibility of implementing Delft-FEWS has been assessed through discussions with Deltares, and adjustments to implement Delft-FEWS in the approach have been proposed. The following design approaches will therefore be needed for implementation:

- Dissemination of flood warning alerts:
  - Delft-FEWS does not support SMS and email alerts. For the BUPUSA FFEWS, the Salomon Lda team will develop a web app to access post-processed data from Delft-FEWS and to disseminate alerts. It is recommended that the primary dissemination be accomplished with a combination of automated SMS messages and email messages.
  - The Salomon Lda team will develop a BUPUSA FFEWS website to disseminate information to the general public. The website will provide flood alert detail, but will be a secondary, non-essential component of the dissemination system.
  - Disaster management agencies in Mozambique rely on community radio systems to disseminate disaster warnings. It is recommended that the BUPUSA FFEWS disseminate alerts to them.
- Delft-FEWS will be set up in a client-server environment to make remote access possible and simplify system maintenance.
- Mr Hans Beuster from the Salomon Lda team will receive advanced training from Deltares (Customized training of 5 half days in setting up Delft-FEWS system for BUPUSA, and IT training for installation and support of the client-server system). It is recommended that the programme also facilitates the participation of 2-3 modelling experts from the partner states to ensure that advanced modifications and maintenance of the system can be done without external support.
- Training of system operators in the use of the platform will be given by the Salomon Lda team in conjunction with the 2-3 partner state experts who have undergone advanced training. Deltares will provide example training material that we will to be adapted for the BUPUSA system.

The Blue Deal initiative through the Dutch Water Authorities supported DNGRH with the development of hydrological (HEC-HMS) models for the Limpopo, Save and Pungwe basins in Mozambique. According to the project team<sup>1</sup>, the models are relatively simple, require manual data entry and are not well calibrated as reliable rating curves are not available. The project intends to develop a hydrological model for the Buzi basin in 2022. This is a valuable start to providing flood early warning capacity in the three basins. The Blue Deal and GEF BUPUSA project teams are discussing opportunities for collaboration.

The assessment of FFEWS data needs and data availability led to the following recommendations:

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<sup>1</sup> Personal communication, Mr Jan van der Besten, September 2022.

1) **Rating curves.** Rating curves are required in the river reaches where hydraulic modelling will be undertaken to predict inundation extents. The curves will be used to calibrate hydraulic roughnesses (Manning's n values) in the HEC RAS models. There are 29 flow gauging stations in Zimbabwe with rating curves, and 35 flow gauging stations with rating curves in Mozambique. The accuracy of individual curves is not known, but our understanding is that many curves are outdated due to changes in river cross-sections resulting from flooding, erosion, and sediment deposition. ARA Centro is currently updating rating curves in the Pungwe basin. Development of reliable rating curves is a continuous process that requires taking of discharge measurements across a wide range of flow conditions spanning many dry and flood seasons. A pragmatic approach will be followed for the development of the BUPUSA FFEWS:

- The quality and validity of individual rating curves will be established based on advice from hydrologists in the ARAs and in ZINWA, and by assessing the range of discharge measurements and dates of measurements to select rating curves of acceptable quality
- Where rating curves are poor, and where hydraulic modelling is required:
  - In river reaches where good quality topographic data are available (LiDAR / Drone surveys), modelled rating curves will be developed with the hydraulic models.
  - Where good topographic data is not available, we will consider cross-section surveys to establish modelled rating curves.

2) **Historical and forecast precipitation data.**

- We recommend that the Global Precipitation Measurement **GPM** mission datasets be used for estimates of “now” data to set starting conditions for forecast runs, and for calibration of the hydrological models over the full period of GPM data records (2014-present). GPM data are free, have a low latency and adequate resolution (0.1°).
- We will use **GFS** precipitation forecasts for the FFEWS. The data is free, is widely used by the scientific community and importantly, has a 14-day forecast period, relatively longer than other products. If it is possible to obtain ECMWF data from INAM at no cost, we will consider this, but GFS data has the advantage of direct and fast access from global servers.
- Most freely available point rainfall forecasts are derived from gridded satellite data. **Yr** point data is derived from ECMWF data outside of Norway. It is not a given that merging of Yr point data will improve bias in the GFS gridded data. We will use the 2022/23 rain season to compare Yr and GFS data at functioning autographic rainfall stations.

3) **Topographic data.** We will use drone survey data or LiDAR where available. Where this kind of high-resolution data is not available, we recommend the use of **ALOS 3D World** data.

**Modelling of dam operating rules.** Large dams can provide flood storage if water levels are drawn down in advance of a flood event. For the development of the BUPUSA FFEWS, a conservative approach will be followed by simulating normal operation of dams (i.e. abstractions), and not pre-emptive releases. This is to avoid the risk of forecasting based on an optimally managed system while actual operation may be non-optimal. Flood-prone areas in the BUPUSA basins are well known. In Zimbabwe, flooding hotspot areas are in the Chimanimani, Chipinge and Chimanimani districts.

In Mozambique, the Buzi basin flood-prone areas are the Buzi town and district, the estuary, Estaquina and Goonda near the confluence of the Buzi and Revue Rivers, Dombe and the Sussundenga District below the Chicamba Dam.

In the Pungwe basin, floodplains in the Muda area, the N6 road, Nhamatanda, Dondo, Metuchira, Tica, Mafambisse and Beira (Nhangau) are flood-prone.

In the Save basin the flood-prone area is located around the estuary, particularly the Nova Mambone settlement.

The above preliminary identification was validated during the Inception phase by:

- 1) assessment of available satellite flood inundation mapping from the University of Colorado's Dartmouth Flood Observatory (Brackenridge, 2010), and
- 2) referring to post-Cyclone Idai surveys conducted by the International Organisation for Migration in conjunction with Mozambique and Zimbabwe disaster management agencies, using their "Displacement Tracking Matrix" (IOM-DTM, 2021).

The focus of this study's on river floods. Coastal floods will require more advanced modelling and resources which are beyond the capability of this project.

From the above discussion, it is possible to make recommendations on river reaches that require hydraulic modelling to predict inundation extents. The recommended reaches are shown in yellow in the figure overleaf. Case study locations were selected in consultation with Member States at the Inception workshop held in Beira on 14 December 2022. are in tributaries of the floodprone areas along the main stems. Case study river reaches are shown in green in the figure overleaf.

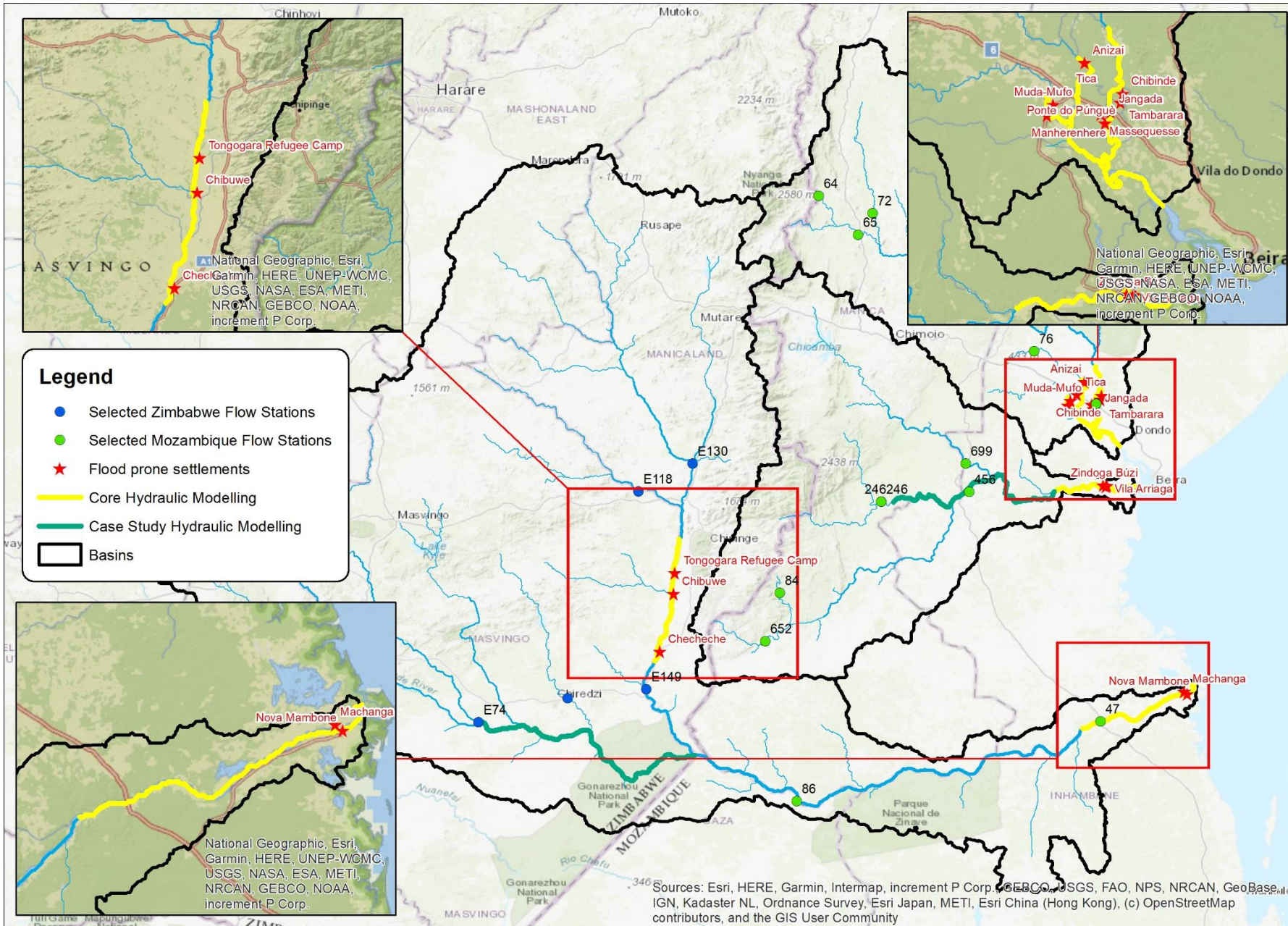


Figure E-1 : Hydraulic Modelling Reaches and Flow Gauges Selected for Forecasting

The study period of 1 June 2022 to 30 September 2024 only covers two flood seasons – 2022/23 and 2023/24. To use the two flood seasons for FFEWS improvement in the best possible way, the following approach is recommended:

**2022/23 flood season:** The *hydrological* models will be set up and calibrated during this period. The post-season review will be used to perform an after-the-fact simulation of discharges in the flood season, and calibration fine-tuning to achieve satisfactory performance.

**2023 dry season:** The *hydraulic* models will be set up and calibrated for flood-prone river reaches to model inundation extents.

**2023/24 flood season:** The post-season review will be used to improve hydrological and hydraulic model calibrations, and if needed, adjustments to input data set selection.

**2024 dry season:** The FFEWS setup will be transferred from development servers to its final institutional home at DNGRH, and to prepare for operational use of the FFEWS in the 2024/25 flood season.

# Implementation of the Flood Forecasting Framework for Buzi, Pungwe and Save (BUPUSA) Basins

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## List of Abbreviations

AMS	Annual Maximum Series
ARA	Administração Regional de Águas / Regional Water Administration
CIESIN	Center for International Earth Science
CHIRPS	Climate Hazards Group InfraRed Precipitation with Station data
CMAP	CPC Merged Analysis of Precipitation
CPC	Climate Prediction Center
DARE	Data Analysis and Reporting Engine
DNGRH	Direcção Nacional de Gestão de Recursos Hídricos / National Directorate Water Resources Management
DWS	Department of Water and Sanitation
EC	Electrical Conductivity
FFEWS	Flood Forecasting Early Warning System
GEV	Gumbel Extreme Value distribution
HEC	Hydrological Engineering Corps
HMS	Hydrological Modelling System
HRSL	High Resolution Settlement Layer
IMS	Information Management System
INAM	Instituto Nacional de Meteorologia / National Meteorological Institute
IUCMA	Inkomati Catchment Management Agency
JWTC	Joint Typhoon Warning Center
KOBWA	Komati Basin Water Authority
LIDAR	Light Detection and Ranging
NCEP	National Centers for Environmental Prediction
PRIMA	Progressive Realisation of the IncoMaputo Agreement
SAP	Strategic Action Plan
TDA	Transboundary Diagnostic Analysis
TPTC	Tri-Partite Permanent Technical Committee
USBR	United States Bureau of Reclamation
ZINWA	Zimbabwe National Water Authority

# 1 Introduction

## 1.1 Project context

Flooding and strong winds caused by cyclones pose the most significant recurring risk to Mozambique. The World Bank (2019) estimates that cyclones affect 2 million people per year in the coastal regions of Mozambique. The worst flooding events occur when heavy cyclonic rainfall and storm surges are compounded by high river floods from upstream areas.

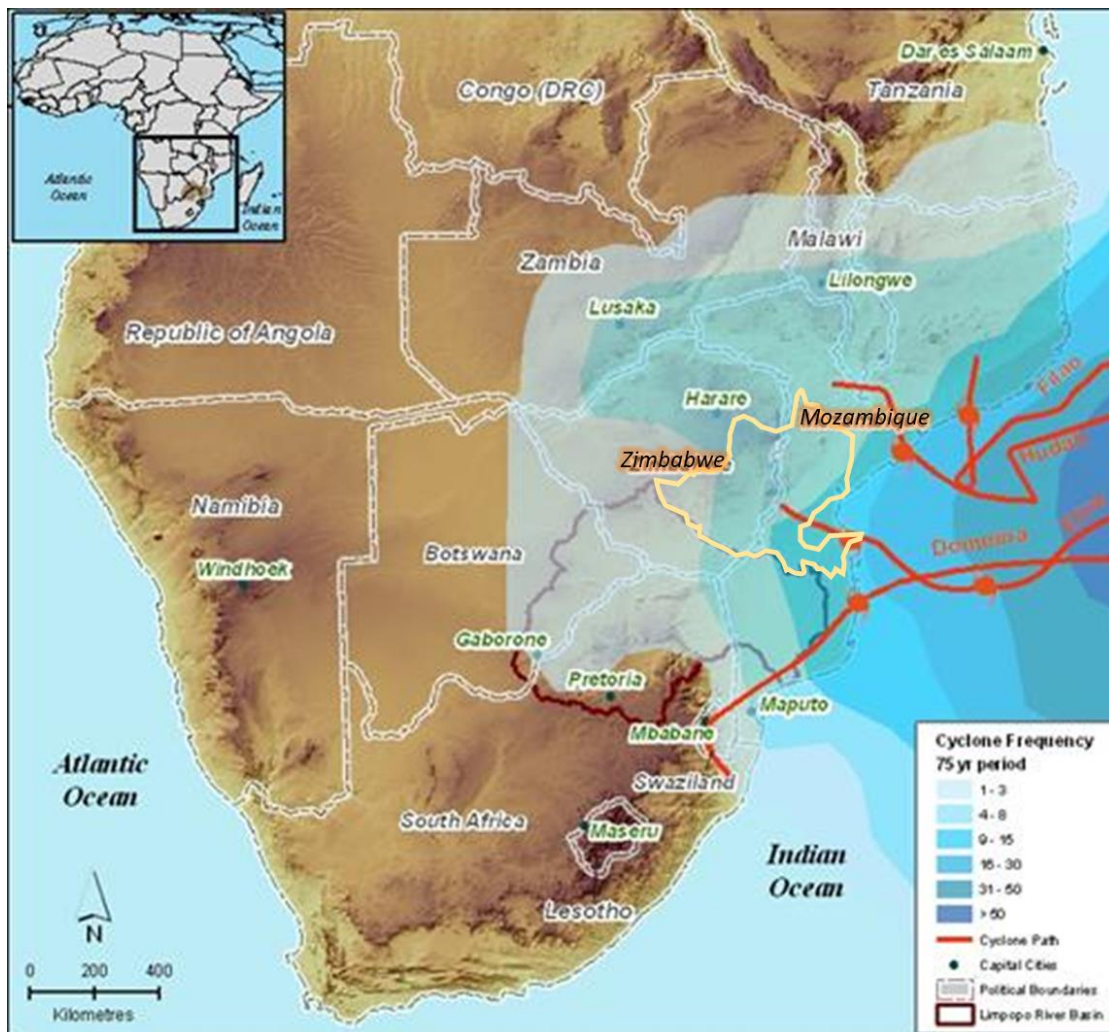


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The GEF BUPUSA feasibility study for the BUPUSA project (WR Nyabeze and Associates, 2022) categorised flood hazards in the three basins, as shown in Table 1-1.

**Table 1-1 : Flood Hazards in the Three Basins (WR Nyabeze and Associates, 2022)**

<b>Primary hazard</b>	<b>Primary cause</b>	<b>Locality of hazard and impact</b>
Flash floods	Heavy and sudden rainfall over a short time causing sudden and very high speeds	Relatively small catchment areas which are relatively steep. The high speed gives the floods strength to carry away heavy objects, causing erosion and damaging infrastructure
River floods	Moderate to very high intensity rainfall experienced over a prolonged period covering large areas.	Accumulation of flow from tributaries results in increased flow rates. Water levels rise and the river overflows into low-lying areas. Large areas can be affected. Infrastructure such as dams and protection works may break, any infrastructure within the flood line such as bridges and water diversion/abstraction works and flow gauging stations etc. may be damaged or washed away. Cropped, grazing and recreational areas, water and wastewater treatment plants, settlements, game reserves etc. may be inundated. The speed of water may reach flash flood levels. People crossing water ways may under-estimate the power of moving water especially at low level crossings.
Landslides	Mass movement of rock and soil on unstable slopes	Deforested areas with steep slopes are vulnerable to landslides during and after heavy rains.
Sedimentation	Heavy rainfall and high flow rates eroding exposed soil	Deforested areas, range lands, cultivated areas mining and built-up areas with steep slopes are vulnerable to erosion during heavy rains. Flood plains are vulnerable to deposition of sediments
Coastal flooding	Sea waves or storms surging and flooding the coast	Unprotected coastal areas or coastal defense works may be overtopped or breached. Intrusion of saline water in estuaries.
Urban floods	Moderate to very heavy rainfall on developed catchments (inadequate or poorly maintained drainage systems, encroachment on natural river courses, flood plains or wetlands)	Developed catchments can increase flood peaks and flood volumes resulting in localised or major flood incidents, for example settlements can be inundated for hours or several days.

Climate change is aggravating flood risk. Climate change models indicate that in warmer climates, overall average rainfall increase by about one to two per cent per degree of warming (IPCC, 2007). This is caused by increased evaporation leading to increases in rainfall. A warmer atmosphere because of global warming holds more moisture before becoming saturated,

causing heavier rainfall (Thow and de Blois, 2008). In the past two decades, Mozambique and Zimbabwe have experienced increased frequency of disastrous flooding as evidenced by cyclones Eline (2000), Dineo (2017), Idai (2019), Kenneth (2019), Chalane (2021) and Ana (2022).

Zimbabwe has similarly suffered from the effects of extreme events with more experiences of dry spells than flooding spells. The frequency of flooding has increased in Zimbabwe since 2000. The traditional flood hotspots in the study area include Chimanimani and Chipinge districts. The flooding events in the eastern highlands of Zimbabwe are strongly related to cyclone activity in the Indian Ocean and often dissipate in the eastern highlands after causing more damage in Mozambique's Pungwe, Save and Buzi Basins.

The extensive damage to infrastructure and loss of life caused by severe flood events can be significantly reduced through implementing an effective and sustainable Flood Forecasting and Early Warning System (FFEWS).

The GEF-funded project "Management of competing water uses and associated ecosystems in Pungwe, Buzi and Save basins" is being implemented by the International Union for Conservation of Nature (IUCN) and executed by GWP-SA together with the Government of Mozambique (GoM) and Government of Zimbabwe (GoZ).

The project's main objective is to strengthen the management of transboundary water resources and connected ecosystems for sustained ecological benefits and improved resilience for the riparian communities. The need for developing transboundary cooperation for water resources management has been materializing for years through several initiatives, including the signing of the Pungwe and Buzi transboundary agreements (the Save agreement is under preparation), and the wish to establish a bilateral tri-basin river basin organisation.

Component 1 of the GEF BUPUSA project contributes to strengthening water-related risk management through the reinforcement of monitoring systems, the development of real-time operational tools, and the empowerment of communities in their flood mitigation autonomy. (Component 2 addresses enhancement of ecosystem services, and Component 3 the development of a Transboundary Diagnostic Assessment and subsequently a Strategic Action Plan).

## **1.2 Objectives and scope of the FFEWS Consultancy**

The main objective of this Consultancy is to support the development and implementation of the flood forecasting and early warning system for the BUPUSA basins and build capacity to sustain it.

The specific objectives are as follows:

- 1) To design the BUPUSA FFEWS
- 2) Obtain and configure relevant spatial and geophysical data sets and set up the spatial system for rainfall runoff modelling, hydraulic modelling and flood impact assessment

incorporating all catchments/impacted areas/points of concern to member states regarding flooding.

- 3) Obtain and configure a number of time-series data sets including rainfall and runoff for application with selected models.
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- 12) To develop protocols and guidelines for the FFEWS centre to standardise its approaches and consistently address expectations from users.
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The scope of work includes (i) designing the BUPUSA FFEWS, (ii) collating and validating relevant data sets, conducting field surveys, (iii) setting up models and conducting hydrological and hydraulic modelling for the BUPUSA basins main stems and main tributaries and producing real time and forecasts of flood conditions at selected points/locations and (iv)

assessing the existing institutional capacity, designing and implementing a programme to address the critical gaps and (v) putting in place the institutional documentation to guide the flood forecasting and early warning centre and (vi) conducting independent reviews and updating the FFEWS. These reviews feed into the plan-do-review cycle which will contribute progressive development of the BUPUSA FFEWS and its sustainability.

## 2 Task 0: Inception Report

**Deliverable (s):** D0, Inception Report (including key design considerations)

**Task Leader:** Hans Beuster

The Inception Report will provide clarity on the deliverables, including the key design considerations for the FFEWS.

### 2.1 Purpose and structure of this Inception Report

The consultancy proposed an Inception Phase to clarify stakeholder expectations that might not be self-evident from the bid documents, to start collecting relevant background information, and to establish communication lines with focal points indicated by the Client and other stakeholders. The Inception Phase would then be followed by a design phase where the FFEWS user needs, data requirements, system architecture and warning dissemination mechanisms will be designed. The late start of the project (18 August 2022, less than two months before the expected onset of the flooding season) requires an accelerated approach so that the first version of the BUPUSA FFEWS can be used in a post-season review. *We have therefore expanded the inception phase scope to address key design considerations for early agreement with the BUPUSA technical team and stakeholders:*

- The selection of a FFEWS Platform and the overall system architecture
- Identification of flood prone areas
- Comprehensive assessment of data availability
- Selection of river reaches for inundation mapping
- Approach to calibration of hydrological and hydraulic models, and forecasting time-steps
- Capacity building approach

The structure of this report follows the sequential tasks described in the Terms of Reference and the Consultancy proposal. The focus of content is on refinement of approaches and clarifying key design aspects of the FFEWS. Proposal approaches that have not changed materially from proposal approaches are not discussed.

### **3 Task 1: Design BUPUSA FFEWS**

**Deliverable (s):** BUPUSA FFEWS design report

**Task Leader:** Hans Beuster, supported by Gerald Howard

#### **3.1 Scope of the design for the BUPUSA FFEWS**

##### **3.1.1 Software scope**

The scope of software that will be implemented to establish the FFEWS is as follows:

- HEC HMS for hydrological modelling,
- HEC RAS for hydraulic modelling
- DELFT-FFEWS as a forecasting platform that integrates hydraulic and hydraulic models, initiates forecasting runs, ingests input data, processes model outputs, and generates warning routines.
- Scripting to automate forecast tasks. This includes downloading precipitation data which will replace forecast rainfall with observed rainfall as the flood event unfolds, thus enhancing the performance of the FFEWS. Automation will also include running the HEC HMS and HEC RAS models to produce forecast inundation as well as automated warnings.

##### **3.1.2 Spatial extent and resolution**

Spatial resolution will be informed by management considerations, points of interest and data availability.

The existing Pitman configuration on the Pungwe River that was developed by Consultec (2004) and modified in 2014 was used as the basis for transboundary negotiations (known as the Joint Strategy) that culminated in a formal agreement (the Bilateral Agreement) on sharing of water resources between Zimbabwe and Mozambique. Building on this previous work, the spatial resolution (sub-catchment division, rainfall averaging and water use) will serve as a starting point. A similar resolution will be used in the Save and Buzi catchments.

The spatial extent of the hydrological models will cover the full extent of the three basins. The coarsest level of subdivision will distinguish between the main stems and main tributaries of the Buzi, Pungwe and Save River Basins with the following distinct modelling units:

- Buzi main stem, Revué River which it flows into hydroelectric Chicamba Dam, Lucite/Rusitu/Lusitu River, Mussapa, Mossurize, Revue and Chinhica rivers.
- Pungwe main stem, Honde, Nyamukwarara, Nhazonia, Txatora, Vunduzi, Mucambezi, Messambizi, Mavuzi, Mezingazi, Urema, Metuchira and the Muda rivers.

- Save main stem and the Runde, Ngezi, Mtshingwe, Tokwe, Chiredzi, Mutirikwi rivers. Macheke, Mwerihari. Nyazvidzi, Odzi, Turgwe and Dewure rivers.

This coarse subdivision then needs to be refined to produce hydrological model outputs at points of interest, namely upstream of flood prone river reaches, at dams with adequate capacity to regulate downstream flows, and at flow gauging stations used for model calibration.

As a minimum, the 12 key automatic river gauging stations identified in the BUPUSA Feasibility Study will be included in the HEC HMS model to assist with calibration and validation (pending availability due to procurement and operational problems outlined at the pre-flood season meeting). This data can be supplemented with 26 other flow gauging stations located in the study area.

### **3.1.3 Data availability and effects on spatial resolution and model performance**

The primary focus on data collection will be to ensure all available daily rainfall is obtained and that storage in large dams is simulated accurately. The availability of daily point rainfall data can be supplemented by satellite based daily rainfall and should thus not limit the spatial subdivision of the hydrological model.

Accurate hydraulic information (relevant cross section data) is a challenge as river channels have been altered by tropical cyclone Idai. This will impose a limitation on the accuracy of the hydraulic modelling tool. Available DEMs will be used but for critical locations field work must be undertaken to provide accurate cross sections.

In summary, the approach is to set up a flood early warning system for the main stem and main tributaries to use freeware data, freeware models, GIS and a freeware database and to obtain reliable forecasts and timely early warnings for the high priority areas.

## **3.2 System architecture - Software components and design approach**

### **3.2.1 Review of modelling framework and tools**

The consultancy proposal recommended the use of an open source, customised forecasting platform that was developed by team members for the Incomati-Usuthu Catchment Management Agency (IUCMA) in South Africa. The customised platform has interfaces with HEC HMS models for data pre- and post-processing and disseminates alerts via SMS and email messages. However, in the BUPUSA FFEWS kick-off meeting and in subsequent discussions, the Client indicated a strong preference for implementing the Delft-FEWS forecasting platform as approved by Member States. We have assessed the feasibility of implementing Delft-FEWS through discussions with Deltares<sup>2</sup>, and have adjusted our approach to implement Delft-FEWS. The following design approaches will be needed for implementation:

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<sup>2</sup> Personal comm. Marc van Dijk, Deltares, September 2022

- Delft-FEWS does not support SMS and email alerts. For the BUPUSA FFEWS, the Salomon Lda team will develop a web app to access post-processed data from Delft-FEWS and to disseminate alerts. Potential usage by target users for the SMS and web app will be assessed. Provisional mechanism linkages with target audiences are given in Table 4-11.
- The Salomon Lda team will develop a BUPUSA FFEWS website to disseminate information to the general public. Potential use by target groups in flood vulnerable areas of BUPUSA tri-basin areas will be assessed.
- Delft-FEWS will be set up in a client-server environment to make remote access possible and to simplify maintenance of the system. During the development phase, the system will be hosted on a cloud server rented by the consultancy team. Due to the high costs associated with cloud servers, the development server will be low-end, with low capacity and availability. The system will be migrated from the development server to its final home at the National Directorate of Water Resource Management (DNGRH) in the 2024 dry season to allow time to verify successful migration and operation.
- Mr Hans Beuster from the Salomon Lda team will receive advanced training from Deltares (Customized training of 5 half days in setting up Delft-FEWS system for BUPUSA, and IT training for installation and support of the client-server system). It is recommended that the programme facilitates participation of 2-3 modelling experts from the partner states to ensure that advanced modifications and maintenance of the system can be done without external support.
- Training of at least three system operators from each partner state in the use of the DELFT-FEWS platform will be given by the Salomon Lda team in conjunction with the 2-3 partner state experts who have undergone advanced training. Deltares will provide example training material that we will adapt for the BUPUSA system.

### 3.2.2 Key design considerations for the BUPUSA FFEWS software

Based on these considerations, we have developed a high-level system architecture for the BUPUSA FFEWS, presented in the Figure 3-1 overleaf.

1. At the centre of the FFEWS is the DELFT-FEWS **forecasting platform**. It is a modular framework within which hydrological, hydraulic, and other types of timeseries based simulation models can be embedded. The framework links the embedded models through model specific **adapters'** and can run the models in a configured sequence. So, for example, the DELFT-FEWS / HEC RAS adapter feeds discharges simulated by HEC HMS to HEC RAS for hydrodynamic modelling. It can work in hindcast (re-forecasting) mode to produce forecasts for times in the past, using only data that was available at the time. This mode is used to assess system performance.

2. The models that will be embedded in the platform for the BUPUSA FFEWS system are HEC HMS (**hydrological** simulation), HEC RAS (**hydraulic** simulation), and HEC RESSIM (**dam** simulation).
3. The forecasting platform has a **scripting environment** within which customised scripts can be developed to:
  - ingest near real time precipitation and river flow data
  - pre-process the ingested data to provide averaged model input data to each hydrological (sub-catchment) modelling unit
  - post-process model outputs to produce a customised set of forecast products
  - push the forecast products to websites in the form of HTML pages
4. The consultancy will develop a **data aggregation tool** (web app) to access post-processed data from Delft-FEWS and to provide additional mechanisms to disseminate alerts. It is recommended that primary dissemination be accomplished with a combination of automated SMS messages and email messages.

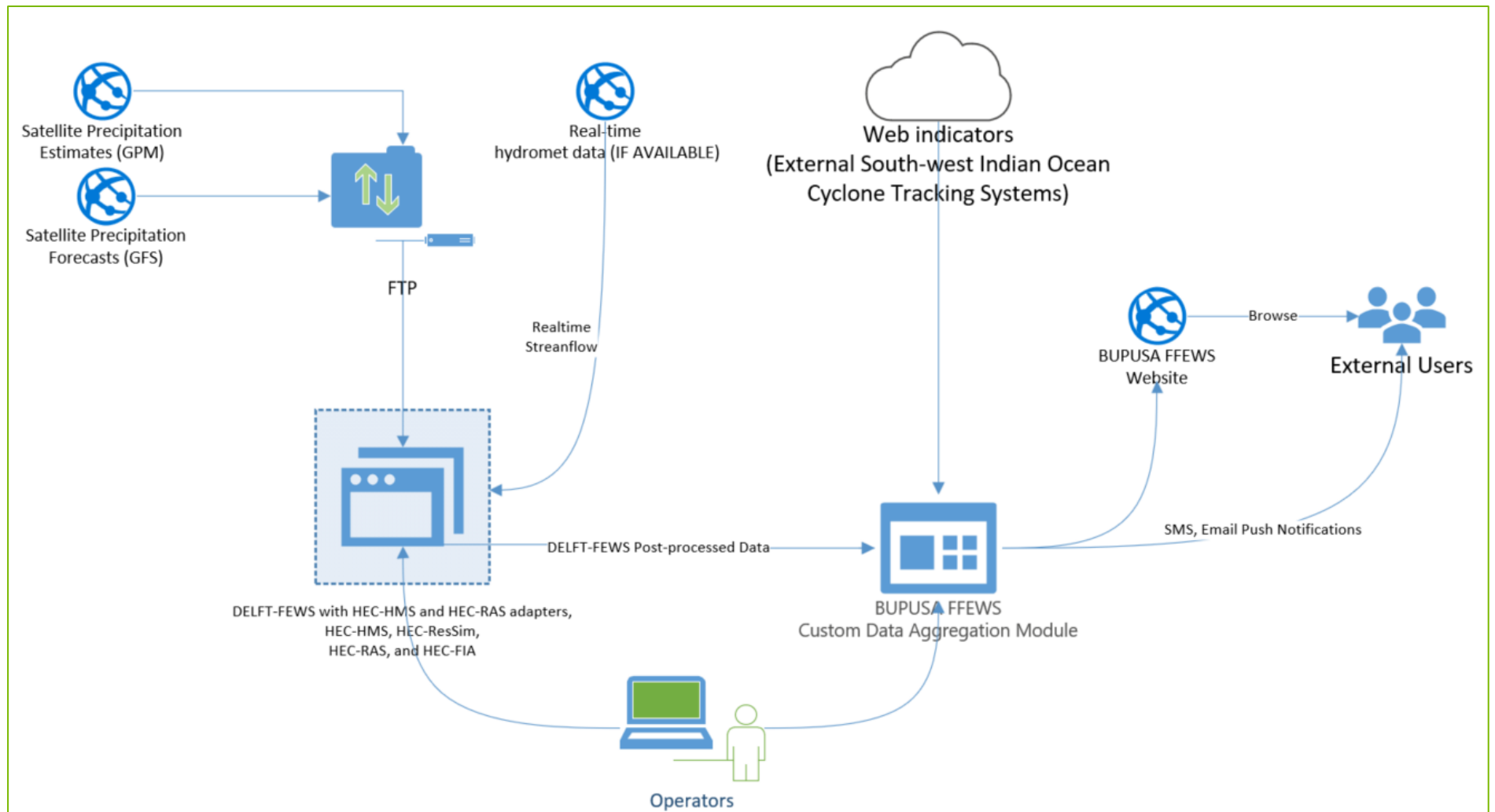


Figure 3-1 : BUPUSA FFEWS High-level Architecture

### 3.2.3 Recommendation on long lead monitoring (cyclone activity)

As discussed in the Project Context, the worst flooding events occur in the coastal areas when heavy cyclonic rainfall and storm surges are compounded by high river floods from upstream areas. A flood early warning system that is based on river flood forecasts cannot predict backwater effects in coastal areas due to ocean storm surges, nor will it account for localised flooding from cyclone landfalls and associated heavy rainfall. To address this gap to some extent, we recommend that a long-lead cyclone early warning be introduced to the BUPUSA FEWS. While we cannot implement a comprehensive solution within the scope of the project, we do recommend implementing a simple first step by providing a link from the BUPUSA website (see architecture discussion in preceding section) to South-West Indian Ocean cyclone track monitoring advisories. Possible sources of these advisories are the La Réunion Regional Specialized Meteorological Centre (RSMC), and the US Navy Joint Typhoon Warning Centre. Provision of cyclone tracking advisories can be used to raise or lower the operational alert status of the Flood and Drought Monitoring Centre in DNGRH. If cyclone activity is reported in the Southern Indian Ocean is reported, the frequency of river flood forecasting can for example be increased from once daily to twice daily.

### 3.3 Hardware components

Deltares recommends<sup>3</sup> the use of Linux virtual servers for installation of the DELFT FEWS software, while Windows or Linux servers can be used for data storage. Specialist advice will be sought from Deltares regarding a hardware (or cloud solution) setup that will match the size and complexity of the BUPUSA FEWS configuration and that will require least maintenance. Based on this advice, we will then make recommendations, and discuss and agree the hosting arrangements with DNGRH.

### 3.4 Database Integration

The use of PostgreSQL (versions 9, 10 or 11) with the PostGIS add-on is recommended. The client-server setup of DELFT FEWS is known to work with PostgreSQL, which is a free and opensource database solution. The database will be used to store model configurations, model states, input data for models (temporary), model results (temporary), spatial data sets and warnings generated.

The hydrological connectivity of watersheds, rivers, and streams in the Buzi, Pungwe and Save basins will be defined. The basic process will entail:

- ❖ Available DEMs will be analysed for areas for sinks and flat areas, and a "depression-less" DEM will be generated.
- ❖ Flow Direction and Flow Accumulation rasters will be generated

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<sup>3</sup> <https://publicwiki.deltares.nl/display/FEWSDOC/Delft-FEWS+Hardware+and+software+requirements+-+2022.02>

- ❖ A Stream Network will be generated from Flow Accumulation rasters, and Strahler Stream Order and Stream Links assigned to stream sections.
- ❖ Watersheds with outlets at points of interest will be generated.

Care will be taken to align points of interest and high flood risk areas.

### 3.5 Development approach

The Terms of Reference anticipated implementation of the plan-do-review cycle with updates to the BUPUSA FFEWS after the first and second seasons. A fully developed FFEWS is expected after the third season. A study period of 1 June 2022 to 30 September 2024 was specified, which only covers two flood seasons – 2022/23 and 2023/24. A late start to the project (18 August 2022) further complicates implementation in that design and development of the first version will only be in place shortly after the 2022/23 flood season. To use the two flood seasons for FFEWS improvement in the best possible way, the following approach is recommended:

**2022/23 flood season:** The HEC HMS *hydrological* model will be setup and calibrated during this period. The post-season review will be used to perform an after-the-fact simulation of discharges in the flood season, comparison with observed discharges, and calibration fine-tuning to achieve satisfactory performance.

**2023 dry season:** The HEC RAS *hydraulic* model will be set up and calibrated for flood prone river reaches to model inundation extents.

**2023/24 flood season:** This season provides the first opportunity to operate a complete system in real time. The post-season review will be used to improve hydrological and hydraulic model calibrations, and if needed, adjustments to input data set selection.

**2024 dry season:** Work in this period will focus on transfer of the FFEWS setup and data from development server to its final institutional home at DNGRH and working with operators to prepare for operational use of the FFEWS in the 2024/25 flood season.

## 4 Task 2: FFEWS Setup

### 4.1 Task 2.1 Hydrological modelling

**Deliverable (s):** D2.6 HEC-HMS model set up for the BUPUSA FFEWS

**Task Leader:** Gerald Howard

The HEC HMS models will be set up for the spatially related points of interest, watersheds and rivers developed in Task 1.

The spatial scale of hydrological modelling will firstly be determined by points of interest. These are the locations of:

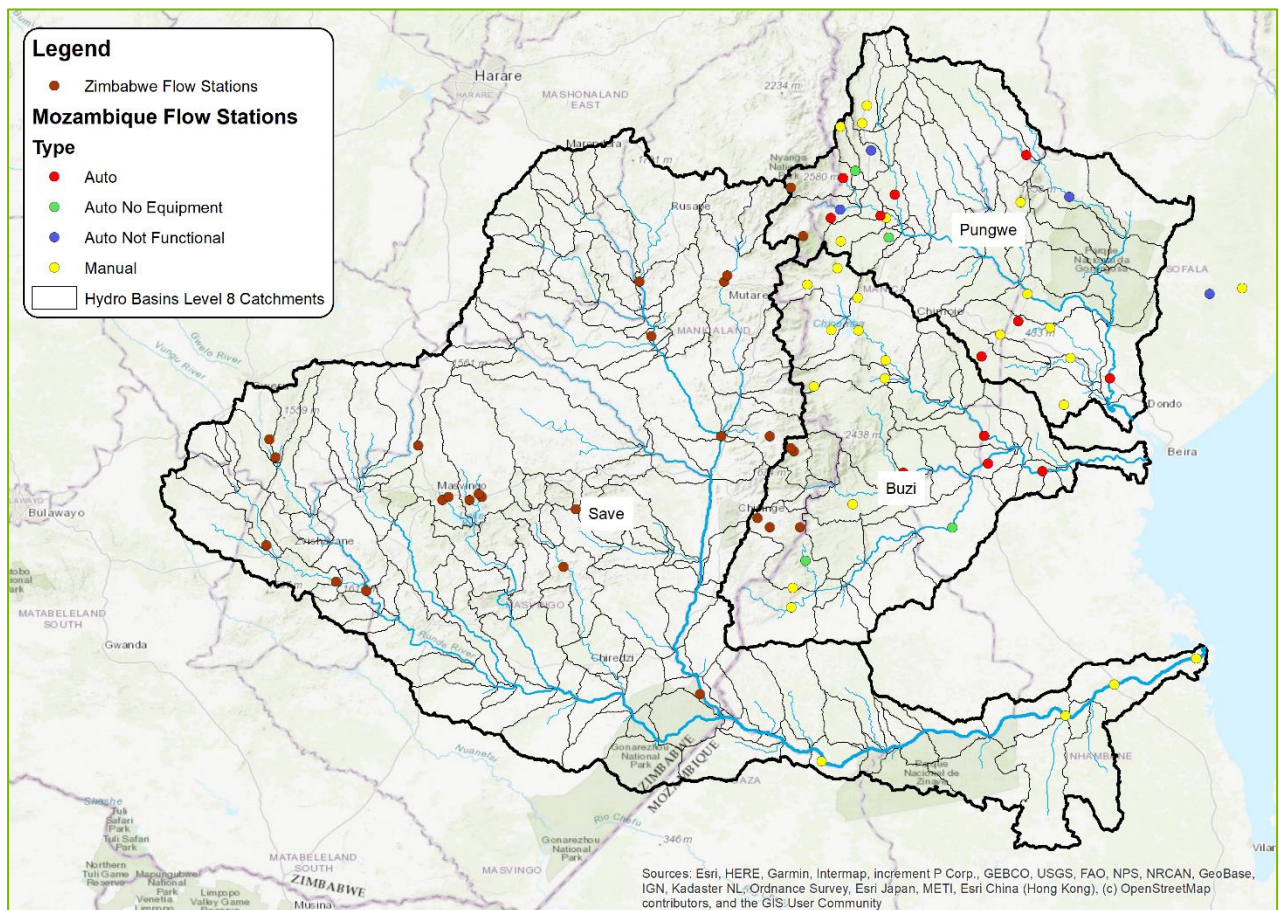
- Existing river flow measuring stations with reliable records

- New automatic stations with telemetry to be installed through the project.
- Flood prone areas,
- Infrastructure exposed to flood risk (roads and bridges, and dams).

The remainder of the basin areas will then be divided into sub-catchments with sizes that approximate Hydro Basins<sup>4</sup> Level 8. This spatial resolution corresponds with sub-catchment divisions used by SWECO (2004) in the Pungwe River hydrological study. The Hydro Basins level 8 sub catchment divisions for the three basins are shown in Figure 4-1.

Rainfall-runoff models will be configured for each of the resulting sub-catchments. Models will be calibrated where reliable flow records exist, and parameters transferred to hydrologically similar ungauged catchments.

The SWECO (2012) Study produced a monograph for the Buzi river that reconcile existing information from various reports. The report provides good background for the current BUPUSA FEWS development. For the Buzi system eleven main tributaries are considered.



**Figure 4-1 : Sub-catchment division for hydrological modelling (prior to division at points of interest)**

For hydrological modelling subdivision based on the location of the major runoff stations as well as geographical features of the river basins was used:

<sup>4</sup> <https://www.hydrosheds.org/products/hydrobasins>

**Table 4-1 : Buzi basin subdivision for modelling**

Basin No.	Sub-basin	Runoff Station	Local Area [km <sup>2</sup> ]	Total Area [km <sup>2</sup> ]
302	Zonwe_ZIM_US_F10	F10	34	31.1
303	Upper_Revue_US_E277	E277	232	
311	Upper_Revue_US_E265	E265	97	
312	Upper_Revue_US_E274	E274	213	
301	Upper_Revue_US_Chicamba	-	2,270	2,846
321	Middle_Revue_US_E263	E263	650	
322	Middle_Revue	-	1,816	5,312
331	Lower_Revue	-	3,130	8,442
201	Rusito_ZIM_US_F7	F7	126	127-
202	Lucito_US_E85	E85	1,854	1,980
211	Upper_Lucito_US_E246	E246	2,821	4,801
221	Lower_Lucito_US_E248	E248	1,691	6,492
101	Buzi_ZIM_US_Bangazaan Dam	-	28	
111	Buzi_ZIM_US_F18	F18	118	146
121	Upper_Buzi_US_E84	E84	627	773
131	Upper_Buzi_US_E427	E427	308	
132	Upper_Buzi_US_E276	E276	2,946	4,027
142	Upper_Buzi_DS_E276	-	2,140	6,167
141	Middle_Buzi_US_E244	E244	2,497	8,664
151	Middle_Buzi_US_E456	E456	1,703	16,859
161	Lower_Buzi_US_E188	E188	1,226	26,527

Considering the large spatial extent of the hydrological models (approximately 163 000 km<sup>2</sup>), and the availability and quality of observed streamflow records, observed and forecast precipitation data and topographic data, calibration of the hydrological models and forecast runs will be done on a daily time step. (In contrast, modelling of a small urban catchment of a few square kilometers with good data at hand can be done on an hourly or sub-hourly time step.) Subject to testing in the setup phase, forecast runs will be done for a lookback period of 2-4 days, and a forecast period of 16 days (the forecast length of GFS precipitation data). Forecast runs will be repeated on a rolling one-day basis.

## 4.2 Task 2.2 Hydraulic modelling

**Deliverable (s):** D2.7 HEC RAS model set up for the BUPUSA FFEWS

**Task Leader:** Gerald Howard

HEC RAS will be used for hydraulic modelling to map inundation extents and depths. To improve robustness and speed of the forecasting system, we propose a judicious combination of 1-D and 2-D models. 2-D models will only be set up in areas with complex flow patterns (sinuous river reaches, reaches where backwater effects can be expected).

In the Inception Phase, the consultant recommended the use of pre-generated “index” inundation maps that are associated with recurrence intervals. The recommendation was based on an understanding that this approach would lead to a simpler, more robust forecasting system with the added advantage that flood warnings can be associated with probable flood return periods. In discussion with Member States at the Beira Inception Workshop of 14 December 2022, stakeholders expressed a clear preference for near real-time flood inundation mapping. The “index map” approach is therefore provisionally discarded.

Figure 4-2 shows an example of inundation mapping.

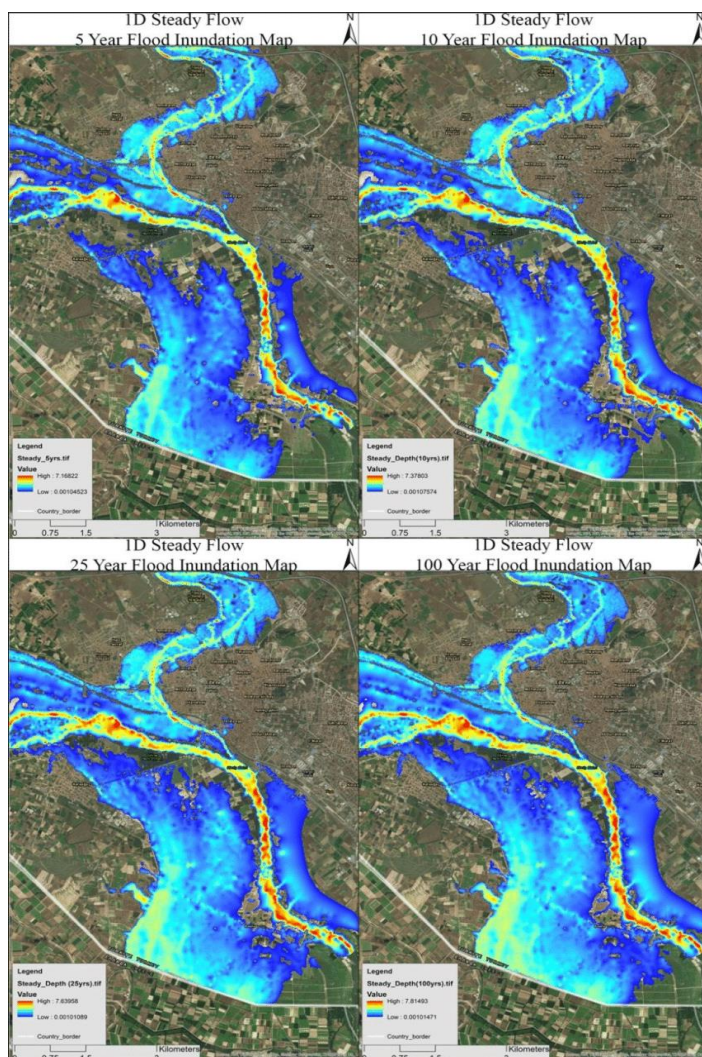


Figure 4-2 : Examples of inundation mapping

### 4.3 Task 2.3 Mapping of flood risk areas

**Deliverable (s):** D2.5 Flood Risk Assessment Report including GIS Mapping of flood prone areas for live system; raster spatial datasets in a structured spatial database (PostGIS).

**Task Leader:** Gerald Howard, supported by Hans Beuster.

#### 4.3.1 Identification of flood prone areas from historical inundation mapping

Flood prone areas in the BUPUSA basins are well known. In Zimbabwe, flooding hotspot areas are in the Chimanimani, Chipinge and Chimanimani districts.

In Mozambique, the Buzi basin flood prone areas are the Buzi town and district, the estuary, Estaquina and Goonda near the confluence of the Buzi and Revue Rivers, Dombe and the Sussundenga District below the Chicamba Dam.

In the Pungwe basin, floodplains in the Muda area, the N6 road, Nhamatanda, Dondo, Metuchira, Tica, Mafambisse and Beira (Nhangau) are flood prone.

In the Save basin the flood prone area is located around the estuary, particularly the Nova Mambone settlement.

The GEF BUPUSA Project conducted preliminary field assessments in the Pungwe, Buzi and Save basins (GWPSA, 2021). Key findings of this assessment include:

- The Mavuzi Hydropower station is located on Revue which is a tributary of Buzi river. During the cyclone Idai 2019, the area was inundated, and the floods caused erosion in both banks of the Mavuzi Barrage dam resulting in destruction of hydrometric equipment, the powerhouse and barrage gates.
- Metuchira local authority is located along Metuchira river which is a tributary of Pungwe river. The area is affected by floods every hydrological year, with most severe impacts registered in the year 2000 and year 2019 due to Cyclone Eline and Idai respectively.
- Buzi Village is one of the most frequently affected by floods in the Buzi Basin. This is evidenced by the most severe floods that occurred in 2000, 2001, 2006, 2007, 2019 and 2020.
- The lower parts of Pungwe River are also frequently flooded. These areas are characterised by vast low-lying areas which form extensive floodplains susceptible to flooding. The road from Beira to the hinterland countries specifically Malawi, Zambia, and Zimbabwe pass through this floodplain such that the city of Beira is completely cut-off during flood events.
- Poorly planned settlements, poor housing infrastructure and poor drainage in most suburban areas of the city of Beira exacerbate the impacts of floods. Some of the infrastructural developments has been done in wetlands and hence the increase in flooding incidences.

- The Chimanimani District in Zimbabwe is located in the upper part of the Buzi Basin. The area is prone to extreme events/cyclones. Particularly, Cyclone Eline and Cyclone Idai have been devastating on lives and livelihoods.
- The Chipinge District in Zimbabwe is in the upper parts of the Buzi Basin. The district was impacted by Cyclone Eline and Cyclone Idai which destroyed lives and livelihoods. Infrastructure such as roads, bridges, communication lines, schools, health facilities and Government services were destroyed during cyclone Idai.
- The Tongogara refugee camp in Chipinge District is located on the banks of the Save river and is often inundated during floods events. The frequency of flooding is increasing because of the siltation of the Save river channel.
- Tugwi Mukosi Dam is located in the Runde catchment and was commissioned in 2017. The main purpose of the dam is to supply water for irrigation in the drought prone areas of the Lowveld. The dam is also of particular importance as it significantly regulates flows, and thus reduces the impacts of floods downstream.
- The Lucite River before the confluence of the Lucite and Buzi Rivers in the Sussundenga, Chibabava and the Buzi Districts has been identified by Mozambique stakeholders as flood prone, and as a location for a case study.
- The Lower Runde River downstream of hydrometric station E74 in the vicinity of Chilonga in the Chiredzi District has been identified by Zimbabwean stakeholders as flood prone, and as a location for a case study.

The map overleaf shows maximum annual inundation extents for the years 2013 to 2020. Inundation extents are shown in shades of purple. Open Streetmap (OSM) settlement locations were overlaid on the map, and settlements that are vulnerable to flooding are indicated with red star icons.

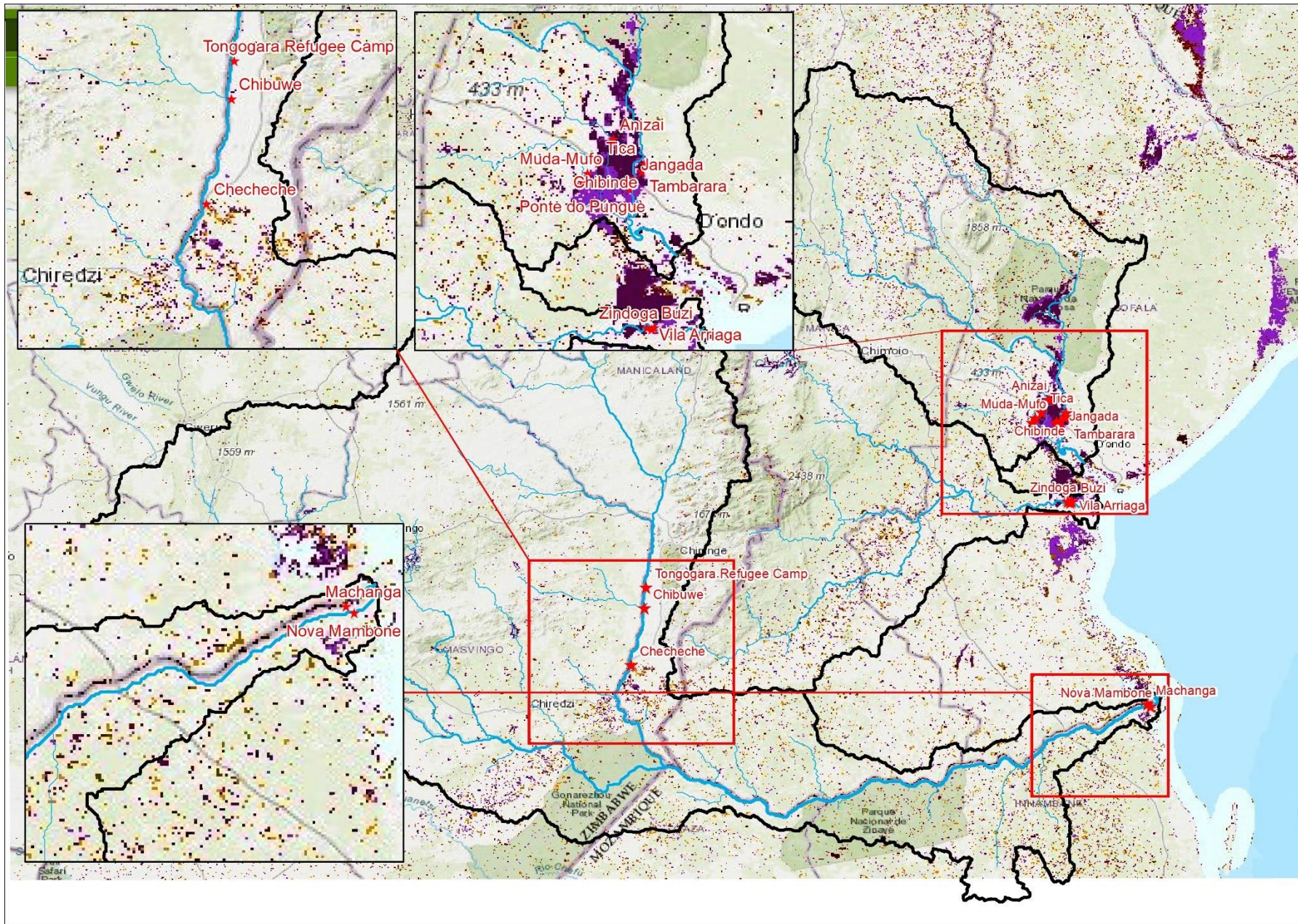


Figure 4-3 - Inundation extents 2013-2020 (shown in purple) and vulnerable settlements (Layer Sources DFO and OSM)

Post Cyclone Idai surveys conducted by the International Organisation for Migration (IOM, 2021) provide estimates of population impacted by severe flooding.

Table 4-2 : Individuals displaced by Cyclone Idai – Mozambique portion of three basins

Admin Level 3	Locality	Males	Females	Total Displaced People	
				Locality	Admin Level 3
<b>Buzi</b>	Bandua	3734	4551	8285	
	Grudja	1030	1229	2259	
	Vila Do Buzi	5128	5133	10261	<b>20805</b>
<b>Cidade Da Beira</b>	Chaimite	1831	1771	3602	<b>3602</b>
<b>Dombe</b>	Bunga	2070	2624	4694	
	Darue	710	600	1310	
	Javera	68	66	134	
	Mabaia	640	708	1348	
	Matacara	5571	5975	11546	
	Muoco	736	879	1615	<b>20647</b>
<b>Dondo</b>	Samora				
	Machel	983	877	1860	<b>1860</b>
<b>Estaquinha</b>	Estaquinha	2981	3287	6268	<b>6268</b>
<b>Goonda</b>	Chinhica	518	397	915	
	Hamamba	2940	2985	5925	
	Mutindiri	1224	1081	2305	<b>9145</b>
<b>Muoha</b>	Muhoa	325	307	632	<b>632</b>
<b>Nhamatanda</b>	Metuchira	1021	1062	2083	<b>2083</b>
<b>Tica</b>	Lamego	1442	1713	3155	<b>3155</b>
<b>Total</b>		<b>32952</b>	<b>35245</b>	<b>68197</b>	<b>68197</b>

Table 4-3 : Individuals displaced by Cyclone Idai – Zimbabwe portion of three basins

Admin Level 3	Locality	Males	Females	Total Displaced People	
				Locality	Admin Level 3
<b>Chimanimani</b>	1	594	713	1307	
	2	185	198	383	
	3	175	207	382	
	5	542	636	1178	
	6	222	277	499	
	7	728	757	1485	
	8	322	335	657	
	9	10	10	20	
	10	230	265	495	
	12	252	276	528	
	13	522	703	1225	
	14	398	487	885	
	15	152	182	334	
	17	291	356	647	
	18	123	140	263	
	19	109	132	241	

Admin Level 3	Locality	Males	Females	Total Displaced People	
				Locality	Admin Level 3
	20	127	196	323	
	21	402	592	994	
	22	347	366	713	
	23	158	115	273	<b>12832</b>
<b>Chipinge</b>	1	744	1486	2230	
	2	190	240	430	
	3	587	807	1394	
	4	226	252	478	
	5	100	140	240	
	6	70	86	156	
	7	520	663	1183	
	8	370	740	1110	
	9	976	1369	2345	
	10	180	245	425	
	11	78	152	230	
	12	293	363	656	
	13	1222	1833	3055	
	14	250	375	625	
	15	193	211	404	
	16	10	25	35	
	17	325	451	776	
	18	333	208	541	
	19	307	288	595	
	20	193	170	363	
	22	97	193	290	
	24	811	1162	1973	
	27	15	25	40	
	28	39	56	95	<b>19669</b>
<b>Total</b>		<b>14018</b>	<b>18483</b>	<b>32501</b>	<b>32501</b>

From the above discussion it is possible to make recommendations on river reaches that require hydraulic modelling to predict inundation extents. The recommended reaches are shown in yellow in the figure overleaf. Case study locations were selected in consultation with Member States at the Inception workshop held in Beira on 14 December 2022. are in tributaries of the flood prone areas along the main stems. Case study river reaches are shown in green in the figure overleaf.

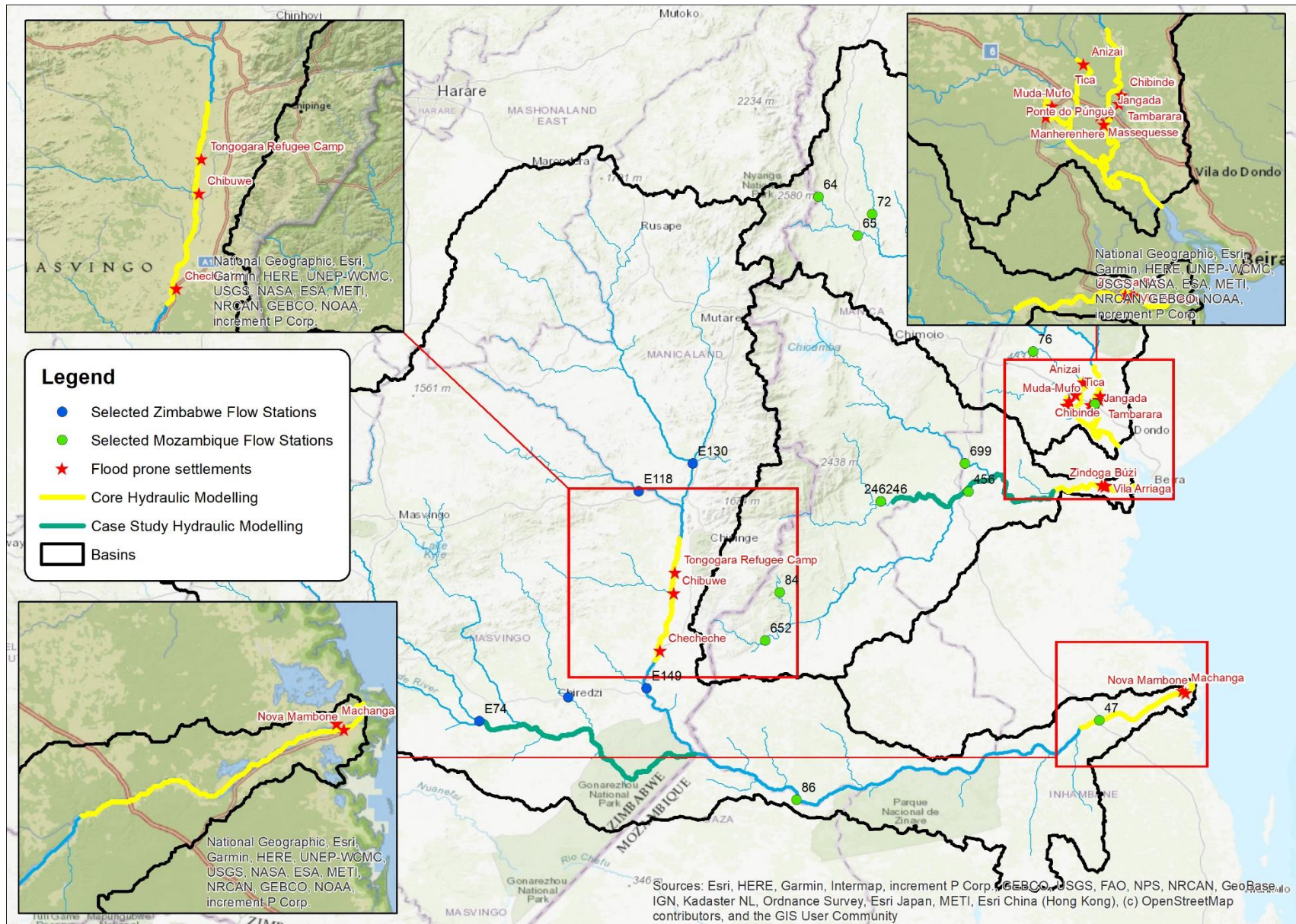


Figure 4-4 : Hydraulic Modelling Reaches

### 4.3.2 Quantifying flood risk

To provide an indication of flood risk, it is necessary to associate probability of occurrence to flood impacted areas. We will introduce probability by associating recurrence intervals (i.e. the average number of years between floods of a certain size) with discharges and inundation extents (where hydraulic modelling will be undertaken).

We propose an approach that will require calibration of the models over the full period of available historical rainfall, in addition to calibration on specific flood events. This requires running HEC-HMS with soil moisture accounting. The advantage of this approach is that the long-term simulated flow sequences can be used to extract recurrence-interval flood discharges from simulated annual maximum series at any point of interest in the three basins. Recurrence interval flood discharges can then be used for steady state hydraulic modelling to associate recurrence intervals with inundation areas.

### 4.4 Task 2.4 Data requirements and identification of data sources

**Deliverable (s):** D2.1 Freeware spatial data sets, D2.2 Procedures and scripts/tools for extracting and configuring time series data sets, D2.3 Freeware time series data sets, D2.4 Rating curves for selected river sections and topographic data for flood prone areas

**Task Leader:** This is a shared task with the following responsibilities:

**Zimbabwe data and information:** Hodson Makurira

**Mozambique data and information:** Francisco Saimone

**Open data sources:** Hans Beuster

A comprehensive data availability assessment was conducted by the study team in the Inception Phase. Data obtained from past studies and relevant reports and documents were collected and analysed by the members of the team.

The following data sets and metadata were collected from stakeholders:

- HEC-HMS model configurations for the Pungwe and Save basins were obtained from DNGRH.
- All available and most recent hydromet data were collected in Excel format at the divisions. This approach was taken to avoid delays which normally occur from the point of collection to processing at ARAs and DNGRH.
- Indications of operational and non-operational statuses of stations were obtained.
- Information on current human resources and materials available were collected during visits to the River Basin Division.
- The most important documents considered were categorised in terms of area relevance to flood disaster management and are listed in **Appendix H**.

#### 4.4.1 Observed and forecast satellite rainfall data sources

Both historical observed and forecast precipitation data are needed to setup the FFEWS. Observed rainfall is used as input to calibrate the hydrological models against observed streamflow, and to ‘warm-up’ forecast simulations. Forecast rainfall is concatenated to a few days of preceding observed rainfall to do forecast runs. For the BUPUSA FFEWS, important considerations are:

- The data must be freely available to contribute to sustainability of the system
- Latency – the difference between when the data becomes available and the time that the data represents
- Spatial resolution – the finer the resolution, the better the representation of spatial variability across the catchment.

#### Estimates of actual rainfall

The table below shows sources of satellite precipitation estimates.

Table 4-4 : Satellite Precipitation Products

No	Product	Coverage	Temporal Resolution	Spatial Resolution	Latency	Data availability
1	<b>GPM:</b> Global Precipitation Measurement (GPM) v5 – IMERG	Global	30 minutes	0.1°	4 hours	03/2014 – present
2	<b>GSMaP Operational:</b> Global Satellite Mapping of Precipitation	Global	1 hour	0.1°	5 hours	03/2014 – present
3	<b>CHIRPS Daily:</b> Climate Hazards Group InfraRed Precipitation with Station Data (version 2.0 final)	Global	1 day	0.05°	3 days	01/1981 – present
5	<b>RFEv2 :</b> The Climate Prediction Center Rainfall Estimation Algorithm Version 2	40°N-40°S,20°W-55°E	1 day	0.1°	1 day	01/2001 - present
7	<b>PERSIANN:</b> Precipitation Estimation from Remotely Sensed Information using	Global	1 day	0.25°	1 day	01/1983/01 – present

No	Product	Coverage	Temporal Resolution	Spatial Resolution	Latency	Data availability
	Artificial Neural Networks - Climate Data Record					

- 1) The **Global Precipitation Measurement (GPM)** mission is an international network of satellites that provide the next-generation global observations of rain and snow. Building upon the success of the Tropical Rainfall Measuring Mission (TRMM), the GPM concept centers on the deployment of a “Core” satellite carrying an advanced radar / radiometer system to measure precipitation from space and serve as a reference standard to unify precipitation measurements from a constellation of research and operational satellites. The IMERG algorithm is intended to intercalibrate, merge, and interpolate “all” satellite microwave precipitation estimates, together with microwave-calibrated infrared (IR) satellite estimates, precipitation gauge analyses, and potentially other precipitation estimators at fine time and space scales for the TRMM and GPM eras over the entire globe. The system is executed several times for each observation time, first giving a quick estimate and successively providing better estimates as more data sets are integrated. The final step uses monthly gauge data to create research-level products. Data: (<https://pmm.nasa.gov/data-access/downloads/gpm>)
- 2) The **Global Satellite Mapping of Precipitation (GSMaP)** algorithms are targeted to produce “best” precipitation estimates. Initially they did not cater for real-time operation and/or data availability. To meet user requirements of such a data in near-real-time, JAXA has now developed and operates a global rainfall map production system in near-real-time since October 2008, and hourly and 0.1-degree resolution binary data and images are available via the internet (<http://sharaku.eorc.jaxa.jp/GSMaP/>) four hours after observation. Core algorithms for the system were developed based on research in Japan in the early 2000s. Data: (<https://sharaku.eorc.jaxa.jp/GSMaP/>)
- 3) The **Climate Hazards group Infrared Precipitation with Stations (CHIRPS)** dataset builds on previous approaches to ‘smart’ interpolation techniques and high resolution, long period of record precipitation estimates based on satellite based infrared Cold Cloud Duration (CCD) observations. The algorithm i) is built around a 0.05° climatology that incorporates satellite information to represent sparsely gauged locations, ii) incorporates daily, pentadal, and monthly 1981-present 0.05° CCD-based precipitation estimates, iii) blends station data to produce a preliminary information product with a latency of about 2 days and a final product with an average latency of about 3 weeks, and iv) uses a novel blending procedure incorporating the spatial

correlation structure of CCD-estimates to assign interpolation weights.  
Data: (<ftp://ftp.chg.ucsb.edu/pub/org/chg/products/CHIRP/daily>)

- 4) Beginning January 1, 2001, the **African Rainfall Estimation Algorithm Version 2 (RFE 2.0)** was moved to operational status, replacing the previous algorithm (RFE 1.0) (Herman et.al. 1997), used from June 1, 1995 to December 31, 2000. The merging technique, the backbone of RFE 2.0, has been shown to significantly reduce bias and random error compared to individual precipitation data sources, thus increasing the accuracy of the rainfall estimates (Xie and Arkin, 1996). Input data used for operational rainfall estimates are from 4 sources; 1) Daily GTS rain gauge data for up to 1000 stations 2) AMSU microwave satellite precipitation estimates up to 4 times per day 3) SSM /I satellite rainfall estimates up to 4 times per day 4) GPI cloud-top IR temperature precipitation estimates on a half-hour basis.  
Data: (<ftp://ftp.cpc.ncep.noaa.gov/fews/fewsdata/africa/rfe2/geotiff/>)

- 5) Among high-resolution, satellite-based, precipitation estimation algorithms, **PERSIANN**, because of its primary reliance on infrared information that dates back to 1979, is very suitable for estimating historical precipitation over the past three decades.

#### Forecast rainfall (Quantitative Precipitation Forecasts)

Several global Quantitative Precipitation Forecasts (QPFs) products are available for near real-time use, as listed in the table below. Data are typically provided as ensembles, reflecting the variation between individual model runs and input conditions.

Table 4-5 : Sources of forecast rainfall

No	Center	Ensemble members	Horizontal resolution	Forecast length	Forecasts (per day)	Free/ Commercial
1	ECMWF ENS	51	0.16° X 0.16°	10 days	2/day	Commercial
2	NCEP (GFS)	20	0.25° X 0.25°	16 days	4/day	Free
3	NCEP CFS v2	24 (28)	~1.0° X 1.0°	0-9 months	4/day	Free
4	ECMWF Extended	51	0.32° X 0.32°	46	Weekly average (monthly)	Commercial
5	NMME	11 models each about 10 realizations	1.0° X 1.0°	0.5-11.5 months	Monthly	Free

- 1) The **ECMWF** forecast ensemble is based upon the idea that incorrect forecasts result from a combination of initial analysis errors and model deficiencies, the former dominating during the first five days or so. To estimate the effect of possible initial analysis errors and the consequent uncertainty of the forecasts, an ensemble is formed of many (currently 50) different, “perturbed” initial states and one unperturbed analysis (the control member (CTRL)). The different perturbations are derived at analysis time during the generation of the ensemble.

Addition or subtraction of small perturbations to the initial distribution of a parameter give several (50 at ECMWF) equiprobable ensemble members each slightly different from the initial, unperturbed analysis of the control member (the 51st member of the ensemble).

Data: <https://www.ecmwf.int/en/forecasts/accessing-forecasts/order-real-time-forecasts>

- 2) The **Global Forecast System (GFS)** is a global spectral data assimilation and forecast model system. GFS forecasts are produced every six hours at 00, 06, 12 and 18 UTC. The GFS graphics are based on 70 km grid (T190) and are available at six hour increments out to 384 hours. The vertical resolution now 64 layers, with a model top at 0.2 hPa. The GFS contains a full suite of parameterized physics as well as accompanying sea-ice and land-surface models. The model structure is computationally efficient and ready for ESMF (Earth System Modelling Framework) and a hybrid (sigma, p) vertical coordinate. GFS started to distribute higher resolution 0.25 degree data to users with its 2015 upgrade.

Data: <http://www.nco.ncep.noaa.gov/pmb/products/gfs/>

- 3) The first **Climate Forecast System (CFS)**, retroactively called CFSv1, was implemented into operations at NCEP in August 2004 and was the first quasi-global, fully coupled atmosphere–ocean–land model used at NCEP for seasonal prediction (Saha et al. 2006). **CFSv2** was designed to improve consistency between the model states and the initial states produced by the data assimilation system. The real-time operational forecasts for CFSv2 obtain their initial conditions from the real-time operational CDAS, version 2 (CDASv2). There are 16 CFSv2 runs per day in operations; four out to 9 months, three out to 1 season, and nine out to 45 days.

Data: [ftp://ftp.cpc.ncep.noaa.gov/NMME/realtime\\_anom/CFSv2/](ftp://ftp.cpc.ncep.noaa.gov/NMME/realtime_anom/CFSv2/)

- 4) The **ECMWF Extended Range** products covering the period up to Day 46 are derived from an extension of the normal 15-day ENS twice per week on Mondays and Thursdays. This is a time scale lying between medium-range weather forecasting (ENS, Day0 to Day15) and seasonal forecasting, which is more reliant on predictability of the oceans and on the impact that tropical sea-surface temperatures have on the atmospheric circulation.

Data: <https://www.ecmwf.int/en/forecasts/accessing-forecasts/order-real-time-forecasts>

#### 4.4.2 Sources of point rainfall forecast data

Measured point rainfall data can be used to correct bias in satellite (gridded) precipitation products. Measured point data is more accurate than the satellite derived estimates, but a pre-condition for forecasting applications is that the data is available in near real time. This means that the stations must be equipped with automatic recorders and telemetry to transmit the data to a data server.

The GEF BUPUSA feasibility study for the BUPUSA project (WR Nyabeze and Associates, 2022) reports that the national meteorological services for the riparian states do not provide forecast rainfall data on their web pages. The study also found that the Trans-African Hydro Meteorological Observatory (TAHMO) have installed 9 stations in Mozambique. In the region, the Southern African Science Service Centre for Climate Change and Adaptive Land Management (SASSCAL) is a joint initiative of Angola, Botswana, Namibia, South Africa, Zambia, and Germany that operates automatic weather stations and provides open data via a data portal. The initiative does not cover Mozambique or Zimbabwe.

Free sources of point rainfall that are available on the web are usually extracted from freely available gridded satellite products. It is important to understand which underlying weather forecasting model is used to know whether the point data will improve the gridded estimates, the forecast time-step, and forecast period.

Yr (<https://yr.no>), is collaboration between the Norwegian Broadcasting Corporation and the Norwegian Meteorological institute. Point forecasts outside of Norway are extracted from ECMWF.

Another reputable product is provided by IBM's The Weather Company (<https://www.wunderground.com/>). Measured point forecasts are provided through its Weather Underground and Wundermap apps. Data is sourced through a global community of personal weather station operators and used for localised forecasts. The company sells compact weather stations that are compatible with its forecasting systems. The API is only accessible to people who own and share data from a personal weather station.

#### **4.4.3 Streamflow measurements, rating curves and measured rainfall**

##### Mozambique

The **Buzi River Basin** has 26 flow gauging stations, of which 20 are operational. 5 flow gauges belong to the flood early warning system (SAC<sup>5</sup>). Available data are not consistent, with many failures occurring during the periods of record.

The basin has 35 rainfall stations, of which 33 are operational. Like the streamflow data, rainfall data have many periods of missing data.

There are also 10 telemetry stations in Buzi (Mozambique). The operational status of these stations are not known at present, and will be established in the implementation phase.

Rating curves (reliability unknown) are available for 12 stations.

**Appendix A** provides detailed lists of flow gauging stations, rating curves, and data availability charts for the Buzi Basin.

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<sup>5</sup> Sistema de Aviso de Cheias

The **Pungwe River Basin** has 28 flow gauging stations, of which 23 are operational. 6 flow gauges belong to the flood early warning system (SAC). Available data are not consistent, with many failures occurring during the periods of record. At this moment, ARA-Centro is updating the rating curves for the SAC stations.

The basin has 35 rainfall stations, of which 33 are operational. Like the streamflow data, rainfall data have many periods of missing data.

There are also 19 telemetry stations in Pungwe basin (Mozambique). The operational status of these stations are not known at present, and will be established in the implementation phase.

Rating curves (reliability unknown) are available for 22 stations.

**Appendix B** provides detailed lists of flow gauging stations, rating curves, and data availability charts for the Pungwe Basin.

The **Save River Basin** has 4 flow gauging stations, all of which are operational. No flow gauges belong to the flood early warning system (SAC). Available data are not consistent, with many failures occurring during the periods of record.

The basin has 4 rainfall stations, of which all are operational. Like the streamflow data, rainfall data have many periods of missing data.

There are also 19 telemetry stations in Save basin (Mozambique). The operational status of these stations are not known at present, and will be established in the implementation phase.

Rating curves (reliability unknown) are only available for 1 station, namely E-86.

**Appendix C** provides detailed lists of flow gauging stations, rating curves, and data availability charts for the Save Basin.

Water level data are collected daily normally at 7:00, 12:00 and 17:00. It can be reduced to one reading at 07:00 or increased in case of potential flood event. Readers located at the stations fill proper data sheet.

Rainfall data are recorded daily at 09:00.

These data are collected quarterly by the Water Resource Management Division, except for the flood early warning stations (SAC) which are collected daily and reported to the division via cellphone and then sent to the ARA's headquarters which also send to DNGRH.

Data in paper form are digitized into a excel spreadsheet and send to ARA. At ARA level, these data are verified and validated.

During quarterly data collection, water quality measurements in selected stations are realized. Also, during these periods, flow measurements are also undertaken.

## Zimbabwe

Zimbabwe is divided into seven catchment management areas. The Save and the Runde catchments are part of the transboundary water system between Zimbabwe and Mozambique. The two rivers systems merge at the exit point into Mozambique and, hence, are treated as separate catchments in Zimbabwe. The Pungwe and Buzi Basins command relatively small catchments on the Zimbabwe side but contribute high rainfall and runoff into the Pungwe and Buzi Basins and, for administrative purposes, are considered to be part of the Save River System.

Historically, Zimbabwe has a dense network of runoff monitoring stations. The Save catchment has 86 streamflow measuring stations while the Runde catchment has 63. However, some of the stations are manual while others have since closed due to inadequate maintenance. There are all several stations which are downstream of dams and, hence, cannot serve purposes of measuring undisturbed flows.

Stations which relatively long years of data and are undisturbed by upstream developments (i.e. potential calibration points for hydrological modelling and parameter transfer to ungauged catchments) are presented in the following tables:

**Table 4-6 : Save runoff stations with up-to-date daily flow records and are relatively undisturbed by upstream developments**

	<b>Station ID</b>	<b>River Name</b>	<b>Location</b>	<b>Year Station Opened</b>
1	E12	Odzi	Maranke Weir	1950
2	E18	Odzani	Municipal intake	1974
3	E21	Save	Condo Dam	1954
4	E30	Runde	Gwenoro Dam U/S	1956
5	E31	Gwenoro	Killarney	1957
6	E56	Karimba	Igudu	1961
7	E59	Singesi	Wedza	1960
8	E61	Odzi	Odzi Bridge	1960
9	E72	Nyakawunga	Odzani Dam U/S	1961
10	E73	Odzi	Selborne	1961
11	E105	Odzani	Odzani Dam U/S	1966
12	E106	Nyambwa	Drenian G/w	1966
13	E115	Turgwe	U/S Rosva Confluence	1967
14	E118	Devuli	Chisurgwe	1967
15	E125	Umvumvumvu	Old Cashel Road Bridge	1970
16	E127	Nyamazi	Selborne	1970
17	E128	Nyakupinga	Minnehaha	1970
18	E129	Odzi	Minnehaha	1970
19	E130	Odzi	Odzi Gorge	1970
20	E132	Umvumira	Lisnakea G/W	1970
21	E136	Rusape	Rusape Dam U/S G/W	1971

	Station ID	River Name	Location	Year Station Opened
22	E144	Impudzi	Chitora	1972
23	E152	Chimbi	Glenfarg	1975
24	F14	Pungwe	Pungwe Causeway	1970
25	F18	Busi	Ypress	1975
26	F10	Zonwi	Hoboken	1966
27	F11	Rusitu	Rusitu Power Station	1968
28	F20	Buzi	Bangazaan Dam	1987
29	F22	Pungwe	Katiyo Natural Control	1987

**Table 4-7 : Runde runoff stations with up to date flow records and are relatively undisturbed by upstream development**

	Station ID	River Name	Location	Year Station Opened
1	E2	Mushagashi	Waterworks Weir	1928
2	E23	Nyamadziwa	Gwenoro Dam U/S	1955
3	E28	Ngezi	Mberengwa Road	1956
4	E30	Runde	Gwenoro Dam U/S	1956
5	E31	Gwenoro	Killarney	1956
6	E35	Umchingwe	Mberengwa Road	1957
7	E40	Little Umtebekwe	Mt Bougai	1958
8	E42	Umtebekwe	Reitfontein	1959
9	E44	Bevumi	Mutirikwi Dam U/S	1959
10	E45	Mutirikwi	Mutirikwi Dam U/S	1959
11	E48	Msali	Mutiriikwi Dam U/S	1959
12	E49	Popotekwe	Mutirikwi Dam U/S	1959
13	E54	Mpopinyani	Mutirikwe Dam U/S	1960
14	E74	Runde	D/S Tokwe Confluence	1961
15	E83	Runde	Tokwe Confluence U/S	1962
16	E84	Tokwe	Runde Confluence	1962
17	E87	Makari	Triangle Regeneration	1962
18	E93	Impali	Impaluli	1965
19	E117	Ngezi	Mushwe	1967
20	E133	Runde	U/S Ingesi Confluence	1970

The stations are fitted with automatic recorders. However, many stations have gaps and have varying lengths of records. Rating curves have been developed for each station and are used to estimate the discharge at each station.

The Enhanced Knowledge and Information System (EKIS) study of 2011 identified priority stations for enhanced transboundary water management. These stations can also be used for flood monitoring and management. The stations are presented in the table below:

Table 4-8 : EKIS Priority Stations

Sub-Basin	Country	Identified Station	River
Buzi	Zimbabwe	F10	Zonwe
		F18	Buzi
Save	Zimbabwe	E130	Odzi
		E43	Save
		E186	Odzi
		E118	Devure
		E21	Save
Runde	Zimbabwe	E133	Runde
		E6	Mutirkwi
		E74	Runde/Tokwe
		E176	Tokwe
		E17	Chiredzi

None of the above stations are telemetric.

#### 4.4.4 Selection of Priority Hydrometric Stations

The BUPUSA GEF project has prioritised 12 out of 38 existing hydrometric stations for implementing the BUPUSA FFEWS (BUPUSA GEF, 2021). According to this report some of these stations have telemetry equipment installed by PP2, GIZ and Hydrometry projects while others have analogue instruments. Figure 4.5 shows the approximate location of the flow gauges.





### Provisional additions to the list of priority stations

Considering the initial identification of flood-prone areas and the updated locations of flow gauging stations shown in Figure 4.6, it is recommended that the initial prioritisation (GEF BUPUSA, 2021) be extended with the following stations:

- E130 Nyanyadzi at Nyanyadzi Dam for measurement of Save and Odzi tributary inflows upstream of the Tongogara / Chibuwe flood prone reach.
- E118 Devuli at Chisurgwe for measurement of Dewure tributary inflows upstream of the Tongogara / Chibuwe flood prone reach.
- Stations that are currently in use by ARA-Centro for flood early warning:
  - E-84 Macuiana
  - E-456 Goonda
  - E-652 Mossurize
  - E-699 Revué EN-1
  - E-64 Pungue Fronteira
  - E-65 Pungue Sul
  - E-72 Nhazónia
  - E-76 Lomaco
  - E-651 Gorongosa

Final selection of stations will be updated during the model calibration process, based on the quality of calibrations, and taking data assimilation requirements for forecasting into account.

#### **4.4.5 Digital elevation data**

Several open digital terrain models have become available in recent years.

- 1) **Space Shuttle Radar Topography Mission (SRTM)**. In late 2014, the United States government released the highest resolution SRTM DEM to the public. This 1-arc second global digital elevation model has a spatial resolution of about 30 meters. Also, it covers most of the world with an absolute vertical height accuracy of less than 16m. While this may be suitable for sharply incised rivers, the vertical (in)accuracy can lead to large errors in inundation extents in floodplains and flat areas
- 2) **ASTER Global Digital Elevation Model**. The data set was jointly developed by NASA and Japan. The ASTER GDEM has a global resolution of 90 meters with a resolution of 30 meters in the United States. Despite its high-resolution and coverage (80% of the Earth), issues with its artifacts have been observed, often in cloudy areas
- 3) **JAXA's Global ALOS 3D World**. ALOS World 3D is a 30-meter resolution digital surface model captured by the Japan Aerospace Exploration Agency (JAXA). Recently, this

DSM has been made available to the public. The data set is the most precise global-scale elevation data now. It uses the Advanced Land Observing Satellite “DAICHI” (ALOS) based on stereo mapping from PRISM.

According to the GEF BUPUSA feasibility study (WR Nyabeze and Associates, 2022), a drone survey of the Buzi River catchment has been done with INGD and a large area of 850 km x 850 km has been mapped. The suitability of this data for use is questionable. Our information is that the surveys were done before Cyclone Idai but this must still be confirmed.

It is recommended that the JAXA Global ALOS data set be used as a primary source of topographic data.

#### 4.4.6 Major water infrastructure

##### Buzi Basin

Major dams in the Buzi River Basin are few and limited to two hydropower dams, the Chicamba Dam (2,020 Mm<sup>3</sup>) and the Mavuzi Dam (1.8 Mm<sup>3</sup>) (SWECO, 2011). Both are found on the Revue River in Mozambique. Chicamba Dam is the larger of the two, but Mavuzi has a higher capacity for generating power. The most relevant characteristics of these dams are summarized in the table below.

Table 4-9 : Dams in the Buzi River Basin

Dam	Dam characteristics		Location	
Chicamba Dam	Dam Capacity at FSL	2,020 Mm <sup>3</sup>	-19.1534	33.1443
	Surface Area	120 km <sup>2</sup>		
	FSL	625 m.a.s.l.		
	Head	52 m		
	Number of turbines	2		
	Total power generating capacity	48 MW		
Mavuzi Dam	Dam Capacity at FSL	1.8 Mm <sup>3</sup>	19°31'32.22"S	33°29'35.11"E
	Surface Area	26 km <sup>2</sup>		
	FSL	345 m.a.s.l.		
	Head	160 m		
	Number of turbines	5		
	Total power generating capacity	50 MW		

Source: SWECO (2011)

##### Pungwe Basin

The current infrastructure includes only the Muda dam, on the Muda River in the lower part of the Pungwe basin (Consultec, 2013). The most relevant characteristics of this dam are summarized in the table below.

**Table 4-10 : Characteristics of the Muda Dam**

<b>Variable</b>	<b>Unit</b>	<b>Value</b>
Latitude	Degrees	19°23'8.81"S
Longitude	Degrees	34° 1'39.54"E
Minimum level of operation	m	90.4
Normal supply level	m	107.5
Live capacity	hm <sup>3</sup>	53.1
Total capacity	hm <sup>3</sup>	55.7
Total height	m	28.0
Dead volume	Hm <sup>3</sup>	2.9
Overflow spillway capacity	m <sup>3</sup> /s	832.0

Source: Consultec (2013)

### **Save Basin**

All the major dams in this river basin are located in Zimbabwe. According to the Zimbabwe Water Act (1998), dams in Zimbabwe are classified as small if they store less than 1 Mm<sup>3</sup> of water or if the height is between 8 and 15m. Large dams store more than 1 Mm<sup>3</sup> or have a height above 15 metres. This suggests that most dams in the country are too small to be classified, hence they are not being accounted for on the national database.

The national database has 149 dams which are classified as large, and these have a combined storage of 12 234 Mm<sup>3</sup>. Large dams in the BUBUSA basin have a combined capacity of 4951 Mm<sup>3</sup>.

#### **4.4.7 Recommendations**

The assessment of FFEWS data needs and data availability led to the following recommendations:

- 1) **Rating curves.** Rating curves are required in river reaches where hydraulic modelling will be undertaken to predict inundation extents, and to establish threshold water levels for warnings. The curves will be used to calibrate hydraulic roughness (Manning's n values) in the HEC RAS models. There are 29 flow gauging stations in Zimbabwe with rating curves, and 35 stations with rating curves in Mozambique. The accuracy of individual curves is not known, but our understanding is that many curves are outdated due to changes in river cross-sections resulting from flooding, erosion, and sediment deposition. Lack of resources to maintain and update rating curves is also an important contributor to the generally poor quality of rating curves. The situation is described in more detail in Appendix I. ARA Centro is currently updating rating curves in the Pungwe basin. Development of reliable rating curves is a continuous process that requires taking of

discharge measurements across a wide range of flow conditions spanning many dry and flood seasons. We will follow a pragmatic approach for development of the BUPUSA FFEWS:

- We will establish the quality and validity of individual rating curves based on advice from hydrologists in the ARAs and in ZINWA, and by assessing the range of discharge measurements and dates of measurements to select rating curves of acceptable quality
- We will make use of discharge measurements currently being undertaken at EFlow sites in the Pungwe basin to supplement rating curves maintained by the two countries.
- Where rating curves are poor, and where hydraulic modelling is required:
  - In river reaches where good quality topographic data are available (LiDAR / Drone surveys), we will develop modelled rating curves with the hydraulic models.
  - Where good topographic data is not available, we will consider cross-section surveys to establish modelled rating curves.

## 2) **Historical and forecast precipitation data.**

- We recommend that **GPM** datasets be used for estimates of “now” data to set starting conditions for forecast runs, and for calibration of the hydrological models over the full period of GPM data records (2014-present). GPM data are free, have a low latency and adequate resolution (0.1°).
- We will use **GFS** precipitation forecasts for the FFEWS. The data is free, is widely used by the scientific community and importantly, has a 14-day forecast period, relatively longer than other products. If it is possible to obtain ECMWF data from INAM at no cost, we will consider this, but GFS data has the advantage of direct and fast access from global servers.
- Most freely available point rainfall forecasts are derived from gridded satellite data. **Yr** point data is derived from ECMWF data outside of Norway. It is not a given that merging of Yr point data will improve bias in the GFS gridded data. We will use the 2022/23 rain season to compare Yr and GFS data at functioning autographic rainfall stations.

3) **Topographic data.** We will use drone survey data or LiDAR where available. Where this kind of high-resolution data is not available, we recommend the use of **ALOS 3D World** data.

4) Modelling of **dam operating rules.** Large dams can provide flood storage if water levels are drawn down in advance of a flood event. Normal abstractions (domestic and irrigation) from dams will be modelled based on recent observed data so that simulated dam volume matches reality. For the development of the BUPUSA FFEWS, a conservative approach will be followed by not simulating operation of dams to regulate flood waters.

Normal dam operation will be modelled but not flood regulation releases. This is so that flood inundation predictions will be conservative. If releases are simulated that in reality do not take place, the model will under predict inundation level.

#### **4.5 Task 2.6 Compilation of a stakeholder database**

A Stakeholder database is needed for the following purposes:

- Consultation around the functionality and development of the FFEWS
- Identification of focal points in agencies responsible for disaster management and early warning – these focal points will be recipients of warnings generated by the FFEWS and will be responsible for further last mile dissemination.
- Identification of focal points responsible for operating the FFEWS and thus key participants in capacity building and training.

In the Inception Phase, the consulting team visited and introduced country teams to key stakeholders, accessed available data, and made preliminary assessments to assess capacity to implement the BUPUSA FFEWS. Available reports and literature were also collected to support project implementation during next project phases.

The stakeholders contacted are those involved directly with flood forecasting and early warning and disaster management in the BUPUSA basins. According to the ToR, these include:

- National hydrological departments
- National meteorological departments
- Regional catchment management institutions/agencies, and
- Disaster management agencies.

Above mentioned institutions are expected to provide data freely, participate in the setting up and run the FFEWS and contribute to improving the FFEWS database.

Other NGOs and cooperating partners such as UNESCO were engaged during the pre-season flood meeting. There are synergies that the Project can benefit from other similar interventions being implemented by other agencies to support FFEWS, namely supporting data collection activities, community engagement and installation of automatic stations.

Stakeholders contacted in the Inception Phase, and the outcomes of the meetings are presented in **Appendix J**.

The preliminary identification will be followed up in the next project phases with structured meetings with focal persons to do capacity and needs assessments.

#### **4.6 Task 2.7 Communication of forecasts and warnings**

For disaster early warning, it is best practice to use two or three different mechanisms to reach as wide an audience as possible, and to match dissemination mechanisms with target groups. A further consideration for the BUPUSA FFEWS is that dissemination needs to

strengthen and complement the dissemination protocols that are followed by disaster management agencies in the partner states, and not to introduce new, possibly conflicting dissemination pathways. With this in mind, it is recommended that the primary focus of the BUPUSA FFEWS warning dissemination be ‘first mile’ dissemination, i.e. warnings to agencies with responsibilities for disaster management. The responsibilities for ‘last mile’ dissemination to communities at risk should remain with the disaster management agencies and using mechanisms that have been tried and tested in disaster situations. In Mozambique the discussions with INGD shows that these initiatives are ongoing and once the system has been setup it will be expected that the FFEWS communicate information directly to the new system. DNGRH should make sure that during the rolling out the national system by INGD communication protocols between the future national system and FFEWS for BUPUSA are developed and implemented.

The following dissemination mechanisms are recommended for implementation:

Table 4-11 : Dissemination mechanisms

Dissemination mechanism	Target audience	Remarks
Short Message Service (SMS)	Focal persons in agencies with disaster management responsibilities	SMS does not require internet connectivity, nor a smartphone.
Email	Focal persons in agencies with disaster management responsibilities	To provide redundancy, SMS as well as email messages should be sent to the focal persons. The email should contain a clickable link (URL) to a website (see below).
Website	Focal persons in agencies with disaster management responsibilities and the general public	The website will provide context and forecast detail that cannot be shown in SMS or email format.

It is recommended that the warning alerts be categorised according to the existing Mozambique disaster management protocol:

1. **Yellow alert** – activated when it is expected to occur an event capable to cause human, environmental or material damage;
2. **Orange alert** – activated when there is an imminent of occurrence of a phenomenon capable of causing human, environmental and material damage, but with the possibility of reversal;

3. **Red alert** – when the event is irreversible, and it is expected human, material and environmental damage of high magnitude.

These alert levels will be linked to discharge and corresponding water levels at individual points of concern.

Delft-FEWS does not support SMS and email alerts. For the BUPUSA FFEWS, the Salomon Lda team will develop a web app to access post-processed data from Delft-FEWS and to disseminate alerts

Last-mile warning dissemination by disaster management agencies to flood-affected communities is described in Section 5.1. This will be very important especially in ensuring that the warnings are disseminated to women, men and other vulnerable populations using commonly and easily accessible platforms/channels.

#### **4.7 Task 2.8 FFEWS Reviews**

**Deliverable (s):** D6 Review reports,

**Task Leader:**

- Dinis Juizo (Progress towards addressing capacity gaps)
- Hans Beuster (State of readiness of the FFEWS)

These reviews feed into the plan-do-review cycle which will contribute progressive development of the BUPUSA FFEWS and its sustainability. The annual pre- and post-season reviews will serve two main purposes:

Firstly, the performance of the FFEWS will be assessed through comparison of forecast and observed discharges (at locations of priority hydromet stations) and inundation (flood prone areas). Locations of poor performance will be identified and causes established. The causes could be poor input data (precipitation, rating curves), or system configuration (river network, sub-catchment division, water infrastructure and operating rules). Measures to address these gaps during the dry season will be identified. Assessed performance and measures will be documented in the review report.

Secondly, the reviews will be used as capacity building and capacity gap identification opportunities. The system performance assessments will be conducted in workshop environments and will include reviews of progress with development of case studies by member state hydrologists. Based on the reviews of case studies, tasks will be assigned to the case study teams and documented in the review report.

#### **4.8 Task 2.9 Updating FFEWS**

**Deliverable (s):** D4 FFEWS set up and running. System tests and validation reports: Water level flow hydrographs for historical near real time and forecast conditions etc. GIS inundation

maps forecasts and early warnings, D6 Review reports, D7 BUPUSA FFEWS development report

**Task Leader:**

- Gerald Howard (Hydrological and Hydraulic models)
- Hans Beuster (FFEWS platform)

The calibration of the hydrological and hydraulic models (Tasks 2.5 and 2.6) must be verified and, if necessary, improved by comparison of forecast discharges and inundation extents with observed data that will become available after the first and second flood seasons.

Observations in these seasons may indicate a need to introduce new points of interest (forecasting points) and to refine the models in areas where forecasting performance was poor. The formal review process and review reports (Task 2.8) will document these improvements and inform implementation of updates.

## **5 Task 3: Institutional capacity building to sustain BUPUSA FFEWS**

**Deliverable (s):** D5.1 Institutional capacity assessment report and capacity building plan

**Task Leader:** Dinis Juizo

This section of the report includes the review and comments provided by the stakeholders during the inception report workshop. In clarifying expectations for the current task, the inception workshop identified the need to consider the following as part of the Capacity Building plan (1) case studies, (2) development and implementation of an Engagement Strategy for Sustainable Financing of the FFEWS and (3) development and application of Database for Vulnerability Assessment and (4) Implementation of local adaptation plans by other stakeholders. The components (2), (3) and (4) will be considered under the TDA developed as part of the overall BUPUSA GEF project, nevertheless it is considered important that while developing the tasks of the current consultancy there is a clear view of the global picture.

### **5.1 Overview of approach**

#### **Determining institutional capacity requirements to sustain the BUPUSA FFEWS**

The project Terms of Reference refers to capacity building in terms of the lack of knowledge about flood modelling. The feasibility study identified the following gaps:

1. Rainfall-runoff modelling (HEC-HMS)
2. Hydraulic modelling (HEC-RAS)
3. Generating flood forecasts and early warning
4. Communicating early warning and last-mile actions; and

## 5. Inclusivity in flood management.

A provision of two training workshop per year have been made for capacity building.

Institutional capacity building requires more than addressing a lack of technical skills to sustain the FFEWS. To achieve this goal, the following factors must be considered:

- Organization – their functions (as defined in their statutes), capacity (compared to their functions), institutional environment (guidelines, coordination), management (clear policy, internal regulation, career development, etc.), support (financial resources, equipment, vehicles)
- Skills – education background and experience, job description, skills and constraints.

A questionnaire will be shared among technicians to score specific questions related to above mentioned topics (**Appendix K**). The questions are structured to inform technical and institutional gaps.

### **Capacity building to address the gaps**

While implementation of capacity building measures in this contract provides for only two trainings per year on technical aspects including modelling and dissemination of early warning messages, the capacity building assessment will inform about long-term actions to be implemented to ensure sustainability of the BUPUSA FFEWS. Delivery of the system itself and technically trainings of technicians to operate the FFEWS is not enough for long-term operation and sustainability if:

1. It is not the mandate of that institution to undertake certain activities;
2. There are no incentives (both financially and work environment) to keep technicians in that particular field. In few years those trained might not be there, and FFEWS will be obsolete.
3. There is no equipment and financial resources to keep collecting (flow) data and update the FFEWS.

With these considerations in mind, the capacity building plan will provide two categories of implementation actions:

1. Implementation of capacity building measures through the consultancy. These measures will address technical capacities of member state counterparts, and as far as is possible, institutional measures such as capacity building around protocols, procedures and guidelines developed through the consultancy.
2. Institutional capacity measures that need to be taken up in the Transboundary Diagnostic Analysis and Strategic Action Plans. These measures will focus on the transboundary and national requirements that are needed for institutional sustainability of operation and maintenance of the system.

The intervention of capacity building will need to tackle both technical and managerial aspects of the institutions involved in order to enable them to fulfil their mandates as expected.

## **5.2 Task 3.1 Current practices and capacity for flood early warning in Mozambique and Zimbabwe**

### **5.2.1 Previous assessments of current practices**

The Feasibility Study for the BUPUSA Project Flood Forecasting and Early Warning System (WR Nyabeze and Associates, 2021) provides a concise and useful summary of current early warning practices in the basin states. The roles of institutions in data provision and use for flood early warning is of relevance to operationalising of the FFEWS, and is repeated here:

The key institutions and other stakeholders have re-instituted pre-season (October) and post season (April) transboundary workshops with support from the GUPUSA GEF project to foster coordinated effort in reducing the impact of floods on transboundary rivers. These workshops are facilitated by the BUPUSA GEF project. The October 2021 workshop deliberated on the rainfall forecasts for the 2021/22 rainfall season, hydrological forecasts and state of preparedness and contingency plans for the hydrological season. It dealt with both floods and droughts. The workshop report also mentions the following as current practice:

- 1) The Meteorological Institute of Mozambique provides rainfall forecasts for OND and JFM for Mozambique, as normal, normal to below normal, normal to above normal, above normal or below normal for districts in each province as maps.
- 2) The Meteorological Services of Zimbabwe provides rainfall forecasts for OND and JFM for Zimbabwe, as normal, normal to below normal, normal to above normal, above normal or below normal for climatological zones overlaid with provincial boundaries.
- 3) The DNGRH is calibrating and testing HEC HMS for flood forecasts in Pungwe and setting up the model for the Buzi basin. Other initiatives include; use of drones for flood monitoring and conducting topographic surveys for river cross sections and flow measurements to revise the alert levels and upgrade the rating curves, maintenance of VHF communication radios to strengthen the communication system. A drone survey of the Buzi River catchment has been done with INGD and arge area n ?850kmx 850km Location data for rainfall gauging stations and communication radios, areas of covered by surveys resolution for surveys are not readily available. (iv) ZINWA monitors water levels and storage in Pungwe, Buzi and Save Rivers and compares them with the previous season. Dams do not have formal operating rules. The rule of thumb is that if forecast rainfall for the season is normal to above normal and starting levels for dams are high large dams release water to safely accommodate incoming inflows. The risk of flooding in downstream areas is evaluated particularly in Malapati, Chiredzi, Lower Runde and low-lying areas of Middle Sabi are evaluated.

- 4) ZINWA provided a typical report produced as an outlook. Pre-season activities include servicing gauging station and establishing new weather stations. Implementation of these activities is constrained by availability of resources including personnel. The outlook has inflow data obtained using Barlow's rainfall-runoff equation runoff ( $Q = K \times R \times A$  where Q is runoff; K-runoff coefficient, R is Rainfall and A is catchment area). A mass balance analysis is conducted to obtain expected water levels in dams. Values of K are obtained by comparing flow estimates with those obtained in the "blue" book on water resources of Zimbabwe.

### 5.2.2 Current practices - outcomes of inception phase consultations

Outcomes of inception phase consultations by the study team on current practices are discussed in the sections that follow.

#### (a) Mozambique

In Mozambique, there are three legal instruments that guide communication of forecast and disaster warnings to local communities, namely:

1. The **Disaster Risk Reduction and Management Law – Law 10/2020 of August 24** establishes the legal framework in the domain of disaster risk reduction and management. A set of principles are established including the principle of single command, in which all institutions involved in the operational plan must act in articulated manner obeying a single orientation.
2. The **Regulation on the operationalization of the integrated platform for the dissemination and communication of information on early warning of floods and cyclones – Decree 27/2022 of June 6** establishes the responsibilities for water resources, meteorology and disaster risk reduction and management to respective ministries to collaborate on development of an electronic platform to share information. During the flood season the Water Resource Department is responsible for daily sharing of flood maps with 3-day advance forecasts with the disaster risk reduction and management agencies. Other information that must be shared includes water levels, dam levels, potential areas at risks, etc.

According to articles 12 and 19, the dissemination of information on flood and cyclone early warning is the responsibility of the disaster risk reduction and management agencies.

In case of potential flooding, with a probability above 50%, the water resource sector must request an emergency meeting with the meteorology and disaster risk reduction and management agency. It is the responsibility of the latter to activate the Technical Council for Disaster Risk Reduction and Management.

3. Beyond the information shared in the electronic platform between the three entities, the Water Resource Department is also responsible for sharing warnings about the hydrological situation and short-term forecasts to the Technical Council, public and private institutions, NGOs, and media using various means of communications including official letters, voice messages, community radios, internet, social media platforms including Facebook, Whatsapp and Telegram.
4. The **National Strategy for the Establishment of an Integrated Flood Early Warning and Integrated Flood and Cyclone Early Warning Information in Mozambique, 2022 – 2030**. This strategy aims to operationalize the above regulations.

In summary, the BUPUSA FFEWS will be used as a decision support tool for the water resources departments of both countries. The forecasts will then be shared to the existing (and established by law) information sharing platforms for disaster risk reduction and management. Existing communication platforms will be used.

On the ground, the communication strategy is set via INGD and its disaster risk reduction and management committees at local level. Water levels are currently being used as a tool for dissemination of early warning, based on historical floods and alert levels established by the ARAs. Training these committees by the ARAs on installation of water level markers with clear warning information is a key requirement.

The Meteorological Institute of Mozambique (INAM) provides 3-monthly qualitative rainfall forecasts for Mozambique.

The Mozambique institutional arrangements for flood early warning consists of the following:

- The ARAs, IP elaborate specific Hydrological Bulletins on the situation in the hydrographic basins and send them to the Provincial, District and Municipal Government bodies, provincial media NGOs, humanitarian organisations and public and private institutions.
- DNGRH issues national hydrological bulletins on hydrological situation and short-term forecast that are sent to the bodies represented in the CTGD (Technical Committee for Disaster Management), media, NGOs, humanitarian public and private institutions at central level.

Various means of communication are used, ranging from letter, email, voice and text messages, the media, NGOs, HF (high frequency) or VHF (very high frequency) radios and social networks such as WhatsApp and Telegram.

Most recently, the Government approved the Disaster Risk Reduction and Management Act (Law nr. 10/2020 of 24 August). This law establishes three sub-systems of disaster risk reduction and management:

- a) Sub-system of early warning and alert;
- b) Sub-system of response;

c) Sub-system of prevention, mitigation, adaptation, and resiliency.

According to this law the early warning can be national or local, depending on the event. Nevertheless, this activity is coordinated by the National Institute for Disaster Risk Reduction and Management (INGD) which integrates other institutions responsible for monitoring and forecasting phenomena likely to cause disasters.

To operationalize the dissemination and communication among the institutions and guide the implementation of the above law, the regulation for the operation of the integrated platform for the dissemination and communication of information on early warning of floods and droughts was approved by Decree 27/2022 of 6 June. This regulation establishes responsibilities for the sectors responsible for water resources management, meteorology and disaster risk reduction and management regarding the needs for sharing information to feed the platform. During rainy season (1<sup>st</sup> October to 31<sup>st</sup> March), the ministry responsible for water resources management must provide information twice a day about the situation and potential flood with a minimum anticipation of 3 days including inundation maps, river water levels, clear explanation, etc.

In March 2022, the National Strategy for the Establishment of An Integrated Flood Early Warning Information Flow System in Mozambique was approved for the period 2022-2030. DNGRH is responsible to announce and publish warnings regarding to floods while INAM is still responsible to cyclones. DNGRH must issue hydrological bulletins based on data received from ARAs and INAM. ARAs can also prepare bulletin to be shared at provincial and district levels.

The system of dissemination is from top to bottom respecting single command principle as shown in figure below.

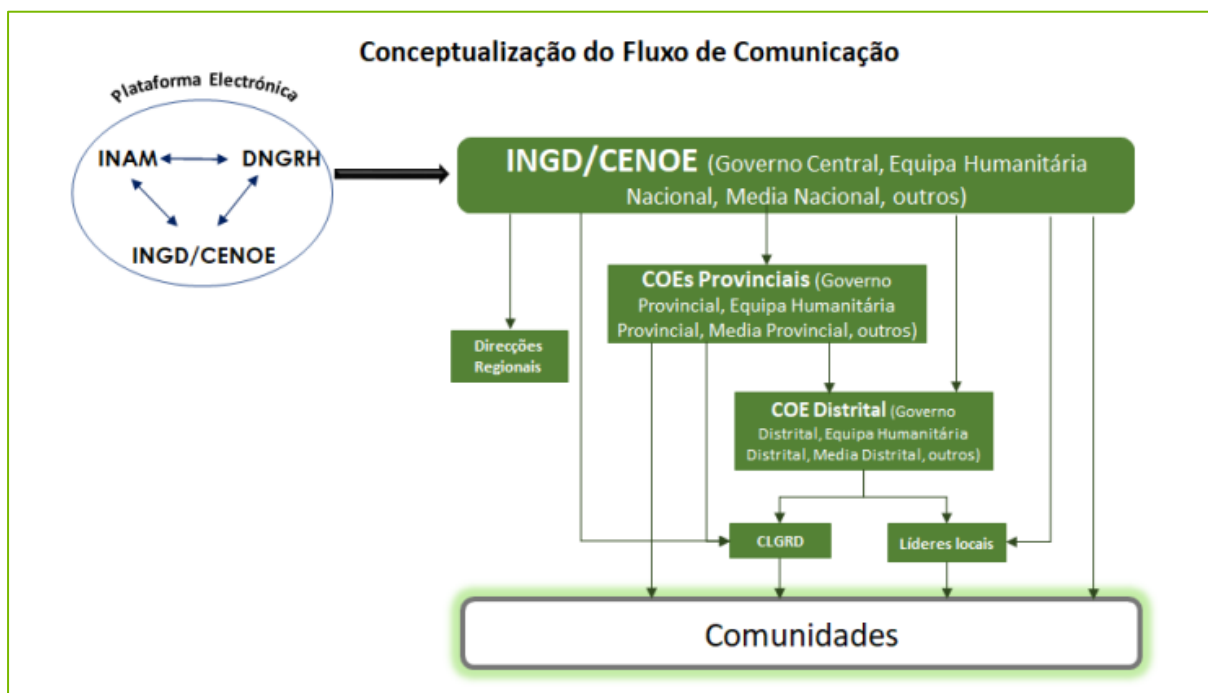


Figure 5-1 : Information dissemination concept from CENOE to communities

One of the objectives of this strategy is to strengthen the national and local capacity in terms of access, interpretation, dissemination, and communication of flood early warning information to local communities. The means of communication for that includes the DataWinners<sup>6</sup> system, provincial radio, community radio, HF and VHF radio.

INGD (2022) identified community radio in the BUPUSA basins which can be used to disseminate flood early warning information:

- Búzi Basin – Chibabava, Voz da Esperança (Búzi District), Chimoio (Sussundenga District), Chipungubira (Mossurize District);
- Púngòè Basin –Gandua (Gondola District);
- Save Basin – Machaze.

Additionally, the strategy intends to install sirens in BUPUSA basins and others.

Three levels of alert were defined according to the Law 10/2020 (see Task 2.7 in Section 4.2).

### **(b) Zimbabwe**

Disasters, in general, are managed by the Civil Protection Unit (CPU). This is a Department within the Ministry of Local Government and Public Works. The CPU has structures that go as far as the District Level and work closely with local government and traditional structures at local levels. Through this system, disasters of any kind are detected at local scales and communicated to District or Provincial levels from where they can be escalated to national level for appropriate interventions. Similarly, information from national level cascades through the same channels to inform community levels. Typical information is drought impacts, diseases and famine at local levels which may need to be communicated to higher levels of decision making up to Government level. In cases of other emergencies such as floods and heavy rains, alert messages are conveyed to community through provincial and district structures. Until recently, telephones and radio communication was standard through appointed officials. In the recent past technological advancement has explored use of media platforms such as community radios, mobile phone applications and print material.

The Zimbabwe Meteorological Services provides qualitative rainfall forecasts over 6 month time horizons and floods over 7 day periods for Zimbabwe ([http://hydrology.soton.ac.uk/apps/zim\\_app/](http://hydrology.soton.ac.uk/apps/zim_app/)) (See Appendix F.) The Zimbabwe National Water Authority (ZINWA) make relatively simple but useful projections of anticipated inflows based on expected rainfall, catchment areas and runoff coefficients. Dam operators release water if pre-season dam water levels are high and rainfall forecasts are above normal. The Zimbabwe National Water Authority (ZINWA) make relatively simple but useful projections of anticipated inflows based on expected rainfall, catchment areas and runoff coefficients. Dam

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<sup>6</sup> DataWinners is an online, do-it-yourself mobile data collection service for organisations in the developing world, designed by Human Network International (HNI). Organisations transform paper forms into digital questionnaires and staff then submit data using any combination of SMS, Smartphone and Web with the equipment they already have.

operators release water if pre-season dam water levels are high and rainfall forecasts are above normal.

Flood forecasts are not common in Zimbabwe. Studies are largely academic in nature and are centred on the Muzarabani District where annual floods occur. Research organisations including Higher Education Institutions and non-governmental organisations are mainly involved in such research work.

Efforts to develop an integrated early warning system are underway through collaboration between the Meteorological Services Department, Zimbabwe National Water Authority and the Ministry of Lands, Agriculture, Water, Fisheries and Rural Resettlement. This National Framework for Climate Services (NFCS), based on the Global Framework for Climate Services (GFCS), will enhance the early warning system for the country. At transboundary scale, there was a component of developing a flood management strategy under the Pungwe Project (Phase 2) but this was not successfully concluded.

### **5.2.3 Related projects and flood risk reduction activities**

#### Global and regional initiatives

The **Climate Risk and Early Warning Systems (CREWS)** initiative is implemented by the World Meteorological Organization (WMO), the World Bank Group/Global Facility for Disaster Reduction and Recovery (GFDRR), and the UN Office for Disaster Risk Reduction (UNDRR). The initiative mobilises funding for climate action that saves lives and livelihoods in Least Developed Countries (LDCs) and Small Island Developing States (SIDS). As one of five regional projects, the initiative supports South-West Indian Ocean countries (Comoros, Madagascar, Mauritius, Mozambique and Seychelles) through the La Réunion and Pretoria Regional Specialized Meteorological Centers (RSMCs). La Réunion RSMC's tropical cyclone forecasts is particularly relevant to know where each cyclone will land, its intensity and scope for damage, and to give enough lead-time to mobilise disaster management.

Of further relevance to the BUPUSA FFEWS, CREWS is participating in the development of a Systematic Observations Financing Facility <sup>7</sup>(SOFF) to provide finance to strengthen ground-based observation networks. This may be a long-term possibility (the facility is still in development) for leveraging finance for improving the BUPUSA real-time hydrometric network.

The **Famine Early Warning Systems Network<sup>8</sup> (FEWS NET)** provides early warning and analysis on food insecurity. Implementing team members include NASA, NOAA, USDA, USGS, and CHC-UCSB, along with Chemonics International Inc. and Kimetrica. Regional early warning products include seasonal rainfall outlooks for Southern Africa.

#### Other initiatives to strengthen flood early warning in the BUPUSA basins

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<sup>7</sup> [https://ane4bf-datap1.s3-eu-west-1.amazonaws.com/wmocrews/s3fs-public/ckeditor/files/SOFF\\_25-26\\_Feb\\_2020\\_workshop\\_outcomes\\_short\\_0.pdf?2wkD6vGdeUuRaGnZIQ\\_zskUT06k6msXO](https://ane4bf-datap1.s3-eu-west-1.amazonaws.com/wmocrews/s3fs-public/ckeditor/files/SOFF_25-26_Feb_2020_workshop_outcomes_short_0.pdf?2wkD6vGdeUuRaGnZIQ_zskUT06k6msXO)

<sup>8</sup> <https://fews.net/southern-africa>

The Blue Deal initiative through the Dutch Water Authorities supported DNGRH with the development of hydrological (HEC-HMS) models for the Limpopo, Save and Pungwe basins. According to the project team<sup>9</sup>, the models are relatively simple, require manual data entry and are not well calibrated as reliable rating curves are not available. The project intends to develop a hydrological model for the Buzi basin in 2022. This is a valuable start to providing flood early warning capacity in the three basins. The Blue Deal and GEF BUPUSA project teams are discussing opportunities for collaboration.

A UNESCO ROSA<sup>10</sup> project to develop a community-focused Flood Early Warning System for the BUPUSA basins is funded by the Austrian Development Cooperation and is currently in implementation. The project is undertaking flood risk mapping and developing a FEWS based on the University of Princeton's Flood and Drought Monitor. The broad scale tool is suitable for preliminary assessments at regional scale.

UNESCO ROSA has also established a localised flood early warning system at the Tongogara Refugee Camp. The project, still at testing stage, will contribute to the reduction of severe impacts of flooding events to vulnerable communities through risk mapping and development of effective and timely communication strategies to facilitate timely interventions and hence minimise exposure of communities to flood related disasters. Experiences from this pilot stage will inform on whether the tool can be upscaled or replicated in other basins.

### **5.3 Task 3.2 Institutional capacity assessment**

Capacity building involves many factors including: human capacity (e.g. Number of technicians, education background and experience, etc.), institutional environment (e.g. procedures, institutional coordination), management (e.g. clear job descriptions, clear staff promotions, salary, incentives, staff retention mechanisms), financial (e.g. necessary resources to undertake field works accordingly), and material (e.g. equipment, vehicles, etc).

Capacity building is a stepwise process and needs time to achieve the transformation required for the institution perform at the desired level. Sustainability of the capacity building also requires that actions are taken at different levels of the institutions as mentioned in the preceding paragraph. Thus, the actions need to be categorized as short, medium and long-term and should continue beyond the project period. Institutions are required to continuously assess their performance and evolve to remain relevant and efficient, defining a starting point and setting a goal for each step is crucial.

The consultant will review the actual situation in all institutional capacity domains and compare with their mandates in FFEW role. The gaps from this analysis will be prioritised in the workshops in order to develop a capacity building plan.

Within the scope of the implementation of the BUPUSA FFEWS the consultant is expected to improve existing human capacity in terms of rainfall-runoff modelling (HEC-HMS), hydraulic

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<sup>9</sup> Personal communication, Mr Jan van der Besten, September 2022.

<sup>10</sup> Contact person: Mr. Koen Verbist, UNESCO Regional Office for Southern Africa (ROSA).  
[k.verbist@unesco.org](mailto:k.verbist@unesco.org)

modelling (HEC-RAS), providing data, generating flood maps, communicating early warning to end users. The requirements for the institutions involved in FFEWS to discharge on their mandate requires interventions of different nature overall a reasonable period of time. Within the duration of the current assignment the consultant will make identification of the interventions related to capacity building i.e. financial commitments received by the institutions to implement early warning related activities; organizational constraints that hinder smooth collaboration between institutions; existing barrier affecting timely sharing/availability of data that mostly affect the cooperation between the met services and water resources management institutions to name a few. While these all aspects should be carefully analysed and addressed the focus of the current institution capacity development is in the technical component related to modelling, forecast a dissemination of information pertaining to disaster reductions. Thus, the focus of the capacity building to be carried out by the consultants is in providing technical training to staff, equip them with the knowledge required to operate the systems and map the require investment in infrastructure and other material needs that will enable the operationalization of the system.

Training of staff will be offered through workshops to be conducted in pre and post flood season. Countries technicians will develop their own case studies for selected catchments and be supported online by the Consultant to calibrate and refine the models and build their confidence with the model. Due to the complexity of these models, the Consultant believes that this long-term coaching will contribute to improve existing knowledge to maintain by themselves the FFEWS after the end of consultancy, ensuring sustainability to the process.

The requirements for the implementation of the technical approach to be rolled out in this study can be summarize as including:

- Availability of space to host the system;
- ITC infrastructure in place to support its operation;
- Human resources to be trained and retained at the institution level;
- Data collections infrastructure in operational state and relaying information to the system;
- Clear mandates (water management vis a vis disaster management) for the institution to operate the system and disseminate the results.

As explained earlier, in order to succeed in implementing the FFEWS, there is need to do more than the technical capacity building envisaged in this assignment as part of the process of developing and installing the system. There are other, contextual or enabling environmental aspects that will have to be addressed. The consultant will thus carry out this part of assessment in two parts:

- 1) To assess the capacity needs in FFEWS. This typically involves:

- a) Analysis of policies and strategies to determine the required mandates and core functions of institutions involved;
  - b) Mapping of the institutions and assess their present functions;
  - c) Identification of the capacity gaps (infrastructure – hardware and software, enabling environment – policies and regulations, human capacity);
  - d) Assessing the capacity gaps of the institutions based on required and actual capacities.
- 2) To prepare a capacity building plan:
- a) Based on desired level of capacity of institutions (institutional as well as human resource capacities) and the identified capacity gaps,
  - b) With clear objectives and targets at medium and long-term,
  - c) Which includes prioritized and sequenced capacity enhancing measures,
  - d) Which contains a result-based monitoring and evaluation framework based on a clear set of indicators,
  - e) With a tentative costing.

For the purpose of this assignment, the following gaps have already been identified and should be included in the capacity building programme schedule:

- 1) rainfall-modelling (HEC HMS),
- 2) hydraulic modelling (HEC RAS),
- 3) generating flood forecasts and early warnings,
- 4) communicating early warnings and last-mile actions, and
- 5) inclusivity in flood management.

### **5.3.1 Analysis of Mandates and Functions**

The mandates and functions of the institutions and organisations involved in the flood forecast and early warning as well as their position in the overall institutional framework, will follow from the national policies, strategies, laws and regulations. The Consultant will study the relevant documents and have interviews with key informants from (i) national hydrological departments; (ii) national meteorological departments; (iii) regional catchment management institutions/agencies and (iv) disaster management agencies.

The analysis will result in the definition of mandates and functions by type (depending on the country's institutional arrangement) and level of organisation:

- 1) public sector: organisations at national, provincial/regional, basin/district level;
- 2) Research institutions (regional or national) ;

### 3) Non-governmental Organizations (NGOs).

#### 5.3.2 Mapping of the institutions and assess their present functions

The second step is the identification of institutions and organisations directly or indirectly involved in the flood forecasting and early warning. Taking the example of Mozambique, the current setup includes mainly three organizations: National Directorate of Water Resource Management (DNGRH) (which receives information from Regional Water Administrations and at local level by River Basin Management Divisions), National Institute of Meteorology (INAM) (which receives information from the provincial delegations) and the National Disaster Risk Reduction and Management (INGD) which has its operational unit, CENOE (National Operational Emergency Centre).

Functions of above-mentioned institutions will be retrieved from their statutes indicated in the table below.

**Table 5-1 : Institutions and Mandates**

<b>Institution</b>	<b>Decree</b>
DNGRH	Organic Statute of Ministry of Public Works, Housing and Water Resources – Resolution 19/2015
ARA-Centro, IP	Organic Statute of ARA-Centro, IP – Resolution 22/2021 Internal Regulation of ARA-Centro, IP – Ministerial Diploma 161/2021
ARA-Sul, IP	Organic Statute of ARA-Sul, IP – Resolution 18/2021 Internal Regulation of ARA-Sul, IP – Ministerial Diploma 141/2021
INAM, IP	Organic Statute of INAM, IP – Resolution 41/2021
INGD	Organic Statute of INGD - Resolution 12/2022
General	Disaster Risk Reduction and Management Act – Law 10/2020 Regulation for the operation of the integrated platform for the dissemination and communication of information on early warning of floods and cyclones – Decree 26/2022 National Strategy for The Establishment of an Integrated Flood and Cyclone Early Warning Information Flow System in Mozambique, 2022-2030

Based on the analysis of the mandates and functions in the sector, the required core functions and capacities will be assigned to each (type of) organisation.

### **5.3.3 Identification of the capacity gaps**

Once the institutions, their core functions and capacities have been defined, the survey methodology will be further elaborated. Research questions in the institutional assessment will cover the following domains or institutional components:

- 1) Mandates
- 2) Functions
- 3) Capacity
- 4) Institutional Environment
- 5) Organisation's Management
- 6) Support

While for the assessment of the individual skills the research questions will be divided into:

- 1) Tasks of the staff member
- 2) Educational Requirements
- 3) Skills
- 4) Constraints in exercising the required tasks

A preliminary list of research questions including indicators is presented in **Appendix K**. The research methodology will be a mix of individual interviews or focus group discussions both with a checklist of research questions and questionnaires. For each of the organizations, an Assessment Report will be produced which will form the basis for the data processing and analysis.

### **5.3.4 Assessing the capacity gaps of the institutions based on required and actual capacities**

The analytical framework as shown in Table 5-2 will be used to analyze the collected data. The analytical framework will be used for:

- Identification of similarities in the institutional assessment by type and level of institution
- Drawing conclusions on institutional gaps by type and level of institution
- Making recommendations for institutional development for each type and level of institution
- Systematic reporting of the assessment, the conclusions and the recommendations.

Table 5-2: Analytical Framework

Capacity/Functions	Present Situation/Baseline	Gaps
A. Institutions		
<i>National/Provincial/District Level</i>		
General Function Capacity Inst Environment Management Support		
B. Skills		
Education Job Description Skills Constraints		

#### 5.4 Task 3.3 Capacity Building Plan

Based on the agreed conclusions and recommendations of the capacity building assessment as well as the desired capacities, the Consultants will elaborate the recommendations into an outline for a Capacity Building Plan. The Capacity Development will consider the measures to be taken at short, medium, and long term. The analytical framework (Table 5-2) will form the basis for the Plan. As mentioned in the approach overview, sustainability measures that will be implemented through the consultancy, and long-term measures that need to be taken into the TDA will be identified.

The consultant will prepare a short note on priorities as well as timing of proposed capacity development actions, which will be discussed with the Client. After agreement with the Client, Consultant will draft the outline for a Capacity Building Plan, including a tentative budget.

#### 5.5 Task 3.4 Implementation of capacity building plan

**Deliverable (s):** D5.2 Capacity building report

**Task Leader:** Dinis Juizo

This task involves implementation of the capacity building plan. Although many prioritised gaps can be identified from institutional capacity assessment, including infrastructures (flow

measurement equipment, hardware and software), and policies and regulations, the competence required in relation to this project is related to the operation of associated technological solution (as indicated in the TOR). We have identified the following key competences that would be required at relevant water management institutions in the two countries:

- Rainfall-runoff modelling (HEC-HMS);
- Hydraulic modelling (HEC-RAS);
- Modelling framework/platform: DELFT FFEWS system (Section 3.2.1).
- Generating flood forecasts and early warning;
- Communicating early warnings and last-mile actions, and
- Inclusivity and gender sensitivity in flood management.

It is our understanding that both countries will need to have internal capacity on advanced hydrological modelling to ensure sustainability of the FFEWS operation after the project. It is thus important that within the larger scope of the support programme training is provided in the following key topics:

- Hydrological modelling (Basic training);
- Hydrodynamic modelling (Basic training);
- Design, development and application of the Flood EWS (Advanced training).

It is our understanding that the client has made provision for training of staff of both countries and these training topics can be accommodate for example under the Transboundary Diagnostic Assessment (TDA).

Regarding the integration of the system into the regular operation of the institutions, a provision has been made, within the current consultancy, for two training workshops per year close to or soon after the pre and post seasons meetings.

During the implementation of the assignment the consult engage stakeholders at pre and post season meetings to build stakeholder knowledge and confidence in the FFEWS. These workshops will focus on how to interpret the warnings, to share deliberate on post season reviews and agree on what needs to change to improve effectiveness of the FFEWS.

To make this activity more practical, each country must set up a case study (see more details under Task 4) and will serve as basis to evaluate their understanding of the system. To guarantee sustainability of the FEWS, technicians will be given the opportunity to collaborate with the Consultant to configure, develop and operate case study systems.

## **5.6 Task 3.5 Development of protocols, procedures and guidelines**

**Deliverable (s):** D5.3 BUPUSA FFEWS protocols procedures and guidelines

**Task Leader:** Dinis Juizo, supported by Hodson Makurira and Francisco Saimone

A set of protocols, procedures and guidelines to “standardize” approaches will be developed. A range of agreements, policies, procedures and arrangements would be required to establish and sustain the FFEWS. These guidelines and protocols will provide a framework within which to develop, operate, evaluate and enhance the FFEWS.

As far as possible and where relevant, protocols and procedures will be used to structure trainings and capacity building to promote institutionalising of the BUPUSA FFEWS.

Recommendations on protocols, procedures and guidelines that may be needed to “standardize” approaches are given in the Terms of Reference, and include (i) rainfall runoff modelling, (ii) selection of data sources, accessing data, sharing data, (iii) selecting models, (iv) reviewing, and (v) communicating early warnings. This list will be refined based on the findings of the institutional capacity needs assessment and gap analysis.

## **6 Task 4 Support on Case Studies (Refinements to Approach and Methodology)**

**Deliverable (s):** D3 Case study models and results including GIS inundation maps forecasts and early warnings

**Task Leader:** Hodson Makurira (Zimbabwe), Francisco Saimone (Mozambique), with technical support from Hans Beuster and Gerald Howard

### **6.1.1 Purpose of the case studies**

The purpose of case studies is to strengthen capacities of the countries’ water sector technicians in rainfall-runoff and hydraulic modelling for operation of the BUPUSA FFEWS. In the case of Mozambique, both ARA-Centro and ARA-Sul technicians have some basic knowledge of HEC-models and some of them even at division level have participated in trainings. However, most of HEC-model setups for some river basins have been implemented via consulting services. No proper confidence are in place in order to maintain or refine them. In Zimbabwe, there are only a few hydrologists and the few that are employed by the National Water Authority or the responsible Government Department are either not working directly in the BUPUSA Basin or have very little exposure to HEC models.

### **6.1.2 Location and selection of case studies areas**

Selection of case study locations can be guided by the areas where the biggest damage was experienced during Cyclone Idai, but in tributaries of the floodprone areas along the main stems. In this way, the FFEWS can be expanded with sub-systems developed by member state specialists, after reviews by the consultancy team and as part of the formal post-season reviews.

The locations of case studies were discussed with the heads of the Departments of Water Resource Management in the two countries.

### Mozambique

- **Buzi Basin** – Flood prone areas in Mozambique are: Buzi town and district, the estuary, Estaquinha and Goonda near the confluence of the Buzi and Revue Rivers, Dombe and Sussundenga District below the Chicamba Dam. Based on that the best location would be Buzi Town.
- **Pungwe Basin** – this basin covers Manica and Sofala Provinces. We did not have clear feedback on the location for establishment of a case study in Pungwe. Historically, in 2001 flooding was registered in Muda area resulting in riverine fields and overflowing of the N6 road (Consultec and Salomon, 2014). Nhamatanda, Beira and Dondo are also important settlements to consider in Pungwe estuary. As preliminary field assessment on flood prone areas in the BUPUSA basins, GWP has prioritized the following flood prone areas in Pungwe basin: Metuchira, Tica, Mafambisse and Beira (Nhangau). These locations can also be decided with ARA-Centro/DGBP in order to select the most suitable case study for the Pungwe Basin.
- **Save** – Nova Mambone could be the location since is the most affected location in terms of flood. Massagena and Jofane stations are the upstream stations that can be used to reduce the risk at Nova Mambone. Locally Vila Franca do Save Station is the last station.

Table 6-1 : Gauging stations related to flood prone areas

Station	River	Name	Latitude	Longitude
E-188	Buzi	Estaquinha	-19.958	34.167
E-67	Pungwe	Mafambisse	-19.4494	34.5375
E-47	Save	Vila Franca de Save	-21.1417	34.5333

### Zimbabwe

The Rusitu and Nyahode river catchments were most affected by Cyclone Idai. The Pungwe, Lower Save and Lower Runde catchments are also prone to flooding. The main flood-prone area is on the main stem of the Save, upstream and downstream of the Tongarara refugee camp. The consultancy will develop the core system for this area. Case studies will then extend the system to the Rusitu and Runde river catchments.

Gauging stations related to these potentially flood zones can be taken as study locations. These are:

Table 6-2 : Gauging stations related to flood prone areas

Station	River	Name	Latitude	Longitude
F14	Pungwe	Pungwe Causeway	18 <sup>o</sup> 24 S	32 <sup>o</sup> 47 E
F18	Busi	Ypress	20 <sup>o</sup> 16' S	32 <sup>o</sup> 40' E

F10	Zonwi	Hoboken	19°05 S	32°47 E
F11	Rusitu	Rusitu Power Station	20°02 S	32°44 E
F20	Buzi	Bangazaan Dam	20°13 S	32°36 E
F22	Pungwe	Katiyo Natural Control	18°22 S	33°08 E
E43	Save	Save Gorge Causeway	21°11 S	32°17 E
E170	Runde	Mteri	21°09 S	21°09 S

## 7 Task 5: Contributing to the Transboundary Diagnostic Analysis and Strategic Action Plan

**Deliverable (s):** D8 Report on key issues related to TDA NAPS and SAP

**Task Leader:** Hans Beuster

During the inception phase, a coordination meeting was held with GWP project managers and technical teams to discuss contributions to the Transboundary Diagnostic Analysis, Strategic Action Plan and National Action Plans. Whilst the BUPUSA FFEWS component is focused on system delivery and implementation, rather than planning, it is anticipated that the following issues related to flood risk management (some of which are already focus area of the BUPUSA Project) be taken up in the transboundary plans:

- Operation of large dams in Zimbabwe to regulate flood waters and reduce flooding risk downstream of the dams, in Zimbabwe and in Mozambique.
- Identification of a core hydrometric network for flood early warning (and other purposes such as monitoring of transboundary flows, environmental flows, and water quality), and investments needed to upgrade and maintain the network.
- Data sharing protocols, and the infrastructure and investments needed to implement the protocols.
- Human and institutional capacity needs for flood early warning and disaster risk mitigation.

The following tasks will inform the Transboundary Diagnostic Analysis and Strategic Action Plans:

**Table 7-1 : Tasks relevant to development of the TDA**

Task	Relevance to TDA
Task 2.1 Hydrological Modelling	Operation of large dams
Task 2.4 Data requirements and identification of data sources	Identification of a core hydrometric network for flood early warning
Tasks 3.4 Implementation of Capacity Building Plan	Transboundary and national requirements that are needed for institutional sustainability of operation and maintenance of the system

Task	Relevance to TDA
Task 3.5 Development of Protocols, Procedures and Guidelines	Transboundary measures that are needed to implement the operating framework described in these documents

As the focus of the FFEWS consultancy is on implementation rather than water resources planning, it will not be possible to comprehensively assess and address these issues, but recommendations that emanate from FFEWS design and implementation will be integrated into the transboundary plans.

## 8 Task 6: Incorporate and Mainstream Gender Equality and Social Inclusion (Refinements to the Approach and Methodology)

**Deliverable (s):** D9 GESI action Plan and reports

**Task Leader:** Dinis Juizo

One of the gaps identified during the development of the strategy for the establishment of the integrated flood and cyclone early warning information flow system was that the messages to become actionable should include different orientations depending on the target audience in terms of location, rural/urban, level of development, gender, people with special needs, vulnerable people, etc.

Radio is the most important dissemination medium in rural areas, yet it is not an asset that everyone has. Therefore, other complementary means are needed.

Families in extreme poverty may need assistance to transport themselves in case of an impending flood.

The spatial and temporal impact and magnitude of the flood should be clear to avoid misinterpretation.

The flood forecasting model should consider these social variables to predict the type of assistance may need to be mobilised by INGD. Sources of information for this can be obtained from the socio-demographic indicators of the latest 2017 General Census of Population and Housing.

Women's participation in local disaster management committees is essential.

Capacity building assessment will produce disaggregated data by gender among involved institutions. Special attention should be given to encourage women participation in case of inequality gap is identified.

Overall, the work will be carried out by the consultant ensuring the GESI is fully considered with the direct help from the client and member states to enhance participation of women and other diversity groups in the development of the system.

## 9 Quality Assurance, Reporting and Communication

The following protocol will guide communication throughout the project:

- 1) On administrative and contractual matters relating to the project, correspondence will be addressed to:

- Salomon Lda. Team: Prof Dinis Juizo (Project Director)
- Client Team: Dr Loreen Katiyo (GWP)

- 2) On technical matters relating to the project, correspondence will be addressed to:

Salomon Lda. Team:

- Mr Hans Beuster (Team Leader) – included in all correspondence.
- Dr Hodson Makurira (consultancy focal person for Zimbabwe)
- Mr Francisco Saimone (consultancy focal person for Mozambique)
- Mr Gerald Howard (Hydrology and Hydraulics)

Client Team:

- Dr Washington Nyabeze (GWP BUPUSA Technical Advisor)

- 3) For meetings coordination and scheduling, correspondence will be addressed to:

Salomon Lda. Team:

- Mr Hans Beuster (Team Leader)
- Prof Dinis Juizo (Project Director)

- 4) It is suggested that the frequency of client / consultancy and programme / stakeholder coordination meetings be as follows:

- Administrative: bi-monthly
- Technical: 5 working days after submission of milestone deliverables
- Presentations to member states (Technical Support Group): 10 working days after addressing comments on milestone deliverables

- 5) For coordination on stakeholder engagement, workshops, and training:

Client Team

- Mr Elisha Madamombe (Regional Coordinator)
- Mr Alfred Misi (IWRM Technical Advisor - Zimbabwe)
- Mr Jose Malanco (IWRM Technical Advisor - Mozambique)

The project team will conduct internal quality control on deliverables. Our Hydrologist-Advisor, Dr Tendai Sawunyama will be responsible for quality control.

## 10 Work Programme and Deliverables

The project work program and delivery milestones have been adjusted to account for the late start of the project. The following is the list of deliverables and milestone dates:

Table 10-1 : Deliverables and milestone dates

Deliverable no	Deliverable	Milestone Date
D0	Inception Report (including key design considerations)	Final version in time for 12 December 2022 workshop with stakeholders
D1	BUPUSA FFEWS design report	30 January 2023
D2.1	Freeware spatial data sets	30 January 2023 (Static data sets)
D2.2	Procedures and scripts/tools for extracting and configuring time series data sets	30 June 2023
D2.3	Freeware time series data sets	Continuously updated
D2.4	Rating curves for selected river sections and topographic data for flood prone areas	30 June 2023, and revisions 31 Aug 2024
D2.5	Flood Risk Assessment Report including GIS Mapping of flood prone areas for live system	30 June 2023
D2.6	HEC-HMS model set up for the BUPUSA FFEWS	Ver 1 30 June 2023 Ver 2 31 May 2024 Final 31 August 2024
D2.7	HEC RAS model set up for the BUPUSA FFEWS	Ver 1 30 Sept 2023 Ver 2 31 May 2024 Final 31 August 2024
D3	Case study models and results including GIS inundation maps forecasts and early warnings	Ver 1 30 June 2023 Final 31 Aug 2024
D4	FFEWS set up and running. System tests and validation reports: Water level flow hydrographs for historical near real time and forecast conditions etc. GIS inundation maps forecasts and early warnings	Ver 1 30 Sept 2023 Ver 2 31 May 2024 Final 31 August 2024
D5.1	Institutional capacity assessment report and capacity building plan	28 February 2023
D5.2	Capacity building report	31 August 2024
D5.3	BUPUSA FFEWS protocols procedures and guidelines	30 Sept 2023
D6	Review reports	Report 1 31 May 2023 Report 2 31 May 2024
D7	BUPUSA FFEWS development report	30 August 2024

Deliverable no	Deliverable	Milestone Date
D8	Report on key issues related to TDA NAPS and SAP	To accommodate early requirements of TDA, initial findings informally communicated from inception until 30 June. Report 30 Sept 2023
D9	GESI action Plan and reports	Plan 28 February 2023 Report 31 August 2024

The key consideration for the work programme is to utilise the flood seasons in the best possible manner for progressive improvement of the FFEWS and CAPACITY building of institutions to operate and use the system (see Section 2.5 and Figure 10-1 below). The revised programme is presented overleaf.

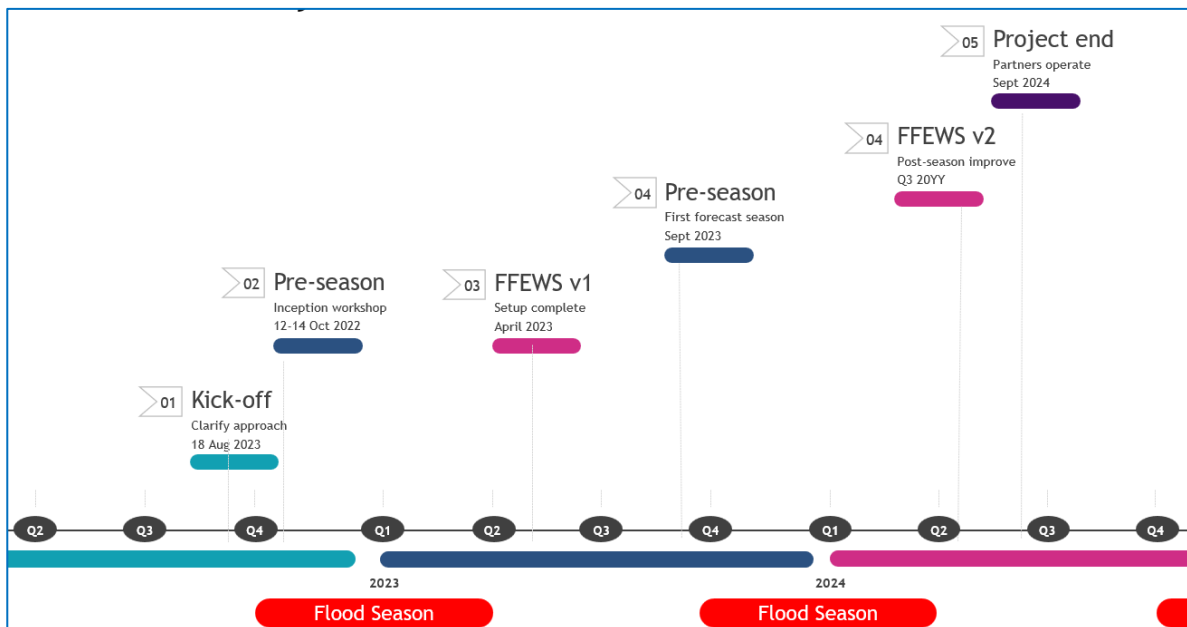


Figure 10-1 : FFEWS Development in relation to Flood Seasons



## 10.1 Project Risks and Response

### 10.1.1 Risk Assessment

Risk assessment is performed for all phases of the programme starting with the consultant phase where the current report belongs to the FFEWS rolling out and utilization by Member States. Risks are evaluated both at managerial level but also in other soft and hard infrastructure aspects that will impact the likelihood of success of the project. While there might be different perceptions and tolerance to risk its identification will reduce the possibility of surprises that might hinder progress or impact negatively on the project. Risk management requires the allocation of measures to the side or people who can best manage them. During the development of the system risk management action will be divided between the consultant and the client. In most case flexibility will enable a quick action and mitigation of risks during the implementation of the consultancy assignment.

When it comes to risks, two key aspects need to be considered:

**Probability** – While risk can be seen as relating to the probability of uncertain future events (as compared to issues which deal with current ones that must be immediately addressed), project issues are risks that have become a reality.

**Impact** – Risk has the potential to impact the project in terms of time/calendar, cost/resources, quality, scope, etc.

In Table 10-2 we have summarised in a matrix the event probability and the likely impact to the project outcomes. The most difficult issues are those that have higher probability of occurrence and can have high impact on the project.

**Table 10-2 : Risk Assessment Matrix**

<b>PROBABILITY Risk will occur</b>	High	<ul style="list-style-type: none"> <li>• Rigid and too formal decision making mechanisms for approvals and deliberations during the implementation of the programme;</li> <li>• Limited coordination between various initiatives in the BuPuSa.</li> </ul>	<ul style="list-style-type: none"> <li>• Limited flexibility from the client</li> <li>• Miss match between resource allocation and workload;</li> <li>• Running out of external funding for joint activities within the BuPuSa initiative.</li> </ul>	<ul style="list-style-type: none"> <li>• FFEWS under predicts impacts of coincident cyclone and river flooding</li> <li>• No qualified staff to be trained or effects of high staff rotation at the client.</li> <li>• No floods during the development of the FFEWS reducing confidence in the system;</li> <li>• Multiple systems being operated at country level;</li> </ul>
	Medium	<ul style="list-style-type: none"> <li>• Lack of resources to collect field data to run the models.</li> <li>• Non synchronized implementation of activities within the BuPuSa programme i.e. TDA, environmental flows determination.</li> </ul>	<ul style="list-style-type: none"> <li>• Delays in implementation due to counterpart unavailability</li> <li>• Lack of project scope clarity or moving project targets</li> <li>• Paucity in data or low-resolution data</li> <li>• No investment in necessary ITC infrastructure for the FEWS hub;</li> <li>• Delays in implementation of the current programme at INGD for the last mile DRR information dissemination infrastructure.</li> </ul>	<ul style="list-style-type: none"> <li>• Stretched resources</li> <li>• Trained staff not confident or able to run the models and tools.</li> </ul>
	Low	<ul style="list-style-type: none"> <li>• Scope creep delaying the implementation and leading to intensive negotiations, clarifications unmet expectations.</li> </ul>	<ul style="list-style-type: none"> <li>• Language barriers for smooth participation and cooperation between countries;</li> </ul>	<ul style="list-style-type: none"> <li>• Institutions responsible for operating the FFEWS do not allocate financial and human resources required for operation</li> <li>• FFEWS is not adequately tested and validated</li> <li>• Time crunch for the implementation of the project.</li> </ul>
	Low		Medium	High
<b>Potential IMPACT on the project</b>				

### 10.1.2 Risk Response

Based on the risk analysis and assessment, the project will employ two main risk response strategies: risk mitigation and risk acceptance. Risk mitigation means to act to reduce the probability and/or impact of a potential risk. While risk acceptance means that if the perceived probability and impact of risk is assessed as reasonable, the project can choose not to take action. In Figure 10-3 we use the example of the highest risk identified to produce a

response table, this can be further expanded to include the other risks of medium and low impact.

**Table 10-3 : Risk Response**

<b>Risks to be mitigated</b>	<b>Mitigation Action</b>	<b>Risks to be accepted</b>
FFEWS is not adequately tested and validated	<ul style="list-style-type: none"> <li>• After-the-fact simulation of 2022/23 flood season</li> <li>• Post-season evaluation of 2023/24 flood season</li> </ul>	Institutions responsible for operating the FFEWS do not allocate financial and human resources required for operation
FFEWS under predicts impacts of coincident cyclone and river flooding	<ul style="list-style-type: none"> <li>• Qualitative long-lead cyclone early warning is introduced to the BUPUSA FFEWS. (RSMC), and the US Navy Joint Typhoon Warning Center</li> </ul>	Delays in implementation due to counterpart unavailability
<ul style="list-style-type: none"> <li>• No qualified staff to be trained or effects of high staff rotation at the client.</li> </ul>	<ul style="list-style-type: none"> <li>• Outsource the operation for sometime.</li> </ul>	Member States need to take action on the medium run
<ul style="list-style-type: none"> <li>• No floods during the development of the FFEWS reducing confidence in the system.</li> </ul>	<ul style="list-style-type: none"> <li>• Make more efforts to have high accurate calibration of the models against past floods,</li> </ul>	
<ul style="list-style-type: none"> <li>• Multiple systems being operated at country level.</li> </ul>	<ul style="list-style-type: none"> <li>• Include a description of the existing models and the main similarities and different to enable staff move from one to the other easily.</li> </ul>	
<ul style="list-style-type: none"> <li>• Stretched resources</li> </ul>	<ul style="list-style-type: none"> <li>• Avoid imposing demands that are beyond the scope and timeline of the project;</li> <li>• Accept that system development is progressive and step by step.</li> </ul>	Appreciate a stepwise approach to system development
<ul style="list-style-type: none"> <li>• Trained staff not confident or able to run the models and tools.</li> </ul>	<ul style="list-style-type: none"> <li>• Intensify communication with trainees, involve staff in technical discussions during development of the system.</li> </ul>	Consultant will drive the confidence building.
<ul style="list-style-type: none"> <li>• Institutions responsible for operating the FFEWS do not allocate financial and human</li> </ul>	<ul style="list-style-type: none"> <li>• Seek for funding, write new proposals for funding</li> </ul>	On the medium run more investment from Member States to the water resources topic are required.

Risks to be mitigated	Mitigation Action	Risks to be accepted
resources required for operation.		
<ul style="list-style-type: none"> <li>• FFEWS is not adequately tested and validated</li> </ul>	<ul style="list-style-type: none"> <li>• Collect past floods information and ensure flow of information from client to the consultant.</li> <li>• Critical review of results by the project consultant Advisor</li> </ul>	The project has two well qualified advisors, one with the consultant and the other with the client that will play a key role in ensuring the quality of outputs are of higher standards.
<ul style="list-style-type: none"> <li>• Time crunch for the implementation of the project</li> </ul>	<ul style="list-style-type: none"> <li>• Avoid pulling the consultant team to the multiple activities of the larger programme while ensuring good communication between the team leaders of the different study workstreams.</li> </ul>	Client to optimise the involvement of various parts in the overall programme.

## 11 References

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## 12 Appendices

### Appendix A – Buzi River Basin Hydromet Stations

#### A1 – List of Flow Gauging Stations

Status: 1 – Operational; 0 – Not Operational;

**Bold** – belongs to flood early warning system

Nr	Station ID	Station Name	Latitude	Longitude	Status
1	<b>E-84</b>	<b>Macuiana</b>	<b>-20.44694</b>	<b>32.85869</b>	<b>1</b>
2	E-188	Estaquinha	-19.95875	34.19314	1
3	E244	Chibabava	-20.26833	33.67139	1
4	<b>E-246</b>	<b>Dombe-Lucite</b>	<b>-19.97836</b>	<b>33.39253</b>	<b>1</b>
5	E248	Matarara	-19.32911	33.83103	1
6	E-251	Mussapa			0
7	E-256	Barragem de Chicamba	-19.18528	33.15389	1
8	E-262	Rotanda/Messambuze	-19.49403	32.91042	1
9	E-263	Cupenha	-19.44911	33.29889	0
10	E-277	Vila de Manica	-18.93425	32.873	1
11	E281	Chitunga/Garvin	-18.84417	33.03778	1
12	E-415	Dopozi	-19.00647	33.15094	1
13	E-427	Chinhica	-20.59925	32.79311	1
14	<b>E-456</b>	<b>Goonda</b>	<b>-19.9167</b>	<b>33.8667</b>	<b>1</b>
15	<b>E-652</b>	<b>Mossurize</b>	<b>-20.70639</b>	<b>32.785</b>	<b>1</b>
16	E-681	Dombe-Mussapa	-19.98675	33.34817	1
17	<b>E-699</b>	<b>Reuvé EN-1</b>	<b>-19.76478</b>	<b>33.84613</b>	<b>1</b>
18	E-sn	Machire	-20.07639	33.25667	1
19	E-sn	Banguira	-21.0233	32.5849	1
20	E-sn	Zonue	-19.03639	32.88472	0
21	E-sn	Revue-Manica	-18.91333	32.93417	0
22	E sn	Messica-Revue	-18.93111	33.09611	0
23		Revue - dir sussundenga	-19.35033	33.30506	0
24	E s/n	Vila do Buzi	19 53 13,3	34 35 40,9	1
25	E s/n	Guara- Guara	19 53 39,1	34 28 38,6	1
26	E s/n	Grudja			1

Managed by  
EDM

## A2 – List of Rating Curves

Nr	Station ID	Station Name	Flow measurements		Rating Curve (RC) = $a*(h-c)^b$				
			Coverage	Nr	a	b	c	Nr of curves	Last update
1	E-84	Macuiana	1960-1975	121	59.604	2.698	1.729	4	09-Oct-73
2	E-188	Estaquinha	1965-1994	139	10.811	2.664	-0.081	5	27-Aug-75
			2013-2015	5					
3	E244	Chibabava	1968-1977	158	17.535	1.64	1.885	6	27-Aug-75
4	E-246	Dombe-Lucite	1970-1977	82	32.044	1.675	0.459	1	15-Oct-70
5	E248	Matarara	1972-1979	57	43.747	2.587	2.948	2	07-Feb-74
6	E-251	Mussapa							
7	E-256	Barragem de Chicamba							
8	E-262	Rotanda/Messambuze	1970-1977	101	3.244	2.649	1.672	3	05-Mar-76
9	E-263	Cupenha	1953-1981	200	13.276	2.138	3.545	4	28-Feb-75
10	E-277	Vila de Manica	1953-1996	111	1.067	1.61	0.293	7	27-Apr-91
11	E281	Chitunga/Garvin	1996	7	1.118	2.8	1.596	1	04-Sep-96
12	E-415	Dopozi	1970-1991	170	0.122	2.8	1.876	10	10-May-88
13	E-427	Chinhica	1970-1976	87	5.027	2.8	1.604	1	29-Dec-70
14	E-456	Goonda	1973-1981	60	95.563	2.005	1.023	4	24-Feb-76
			2014	1					
15	E-652	Mossurize							
16	E-681	Dombe-Mussapa	2015	3					
17	E-699	Revué EN-1							
18	E-sn	Machire							

Nr	Station ID	Station Name	Flow measurements		Rating Curve (RC) = $a \cdot (h-c)^b$				
			Coverage	Nr	a	b	c	Nr of curves	Last update
19	E-sn	Banguira							
20	E-sn	Zonue							
21	E-sn	Revue-Manica	2015	1					
22	E sn	Messica-Revue							
23		Revue - dir sussundenga							
24	E s/n	Vila do Buzi	2015	1					
25	E s/n	Guara- Guara							
26	E s/n	Grudja							

**A3 – List of Rainfall Stations (Status: 1 – Operational; 0 – Not Operational)**

Nr	Station ID	Station Name	Latitude	Longitude	Status
1	P-66	Chitunga/Garvin	-18.8283611	33.0270833	1
2	P73	Comp. Buzi	-19.8365278	34.0835	1
3	P-77	Estaquinha	-19.9588	34.1931	1
4	P-91	Garuso	-18.9762222	33.1723333	1
5	P-93	Vila Manica	-18.9377778	32.8761111	1
6	P-145	Penhalonga	-18.8592778	32.7575556	1
7	P212	Chiraurue	-20.4569444	32.6802778	0
8	P-284	Machaze	-20.8319444	33.3730556	1
9	P-336	Macuiana	-20.4511	32.8636	1
10	P-359	Chibabava	-20.2683333	33.6713889	1
11	P-422	Dombe	-19.9759	33.3955	1
12	P-484	Rotanda	-19.5013611	32.9013056	1
13	P-487	Ampara	-20.3633611	34.5517778	1
14	P-785	Espungabera	-20.4511111	32.8636111	1
15	P-1274	Goonda	-19.9167	33.8667	1
16	P-1070	Revué Ponte EN-1	-19.7653	33.8436	1
17	P-1088	Buzi	-19.8791389	34.0984167	1
18	P-351	Mavita/Moa	-19.5197222	33.1512778	1
19	P-356	Bandua	-19.9658056	34.4161944	1
20	P358	Matarara	-19.9308333	33.6775	1
21	P-1065	Muxungue	-20.3908889	33.9380278	1
22	P-1067	Mangunde	-20.1955556	33.7053333	1
23	P-1087	Nova Sofala	-20.08725	34.7408333	1
24	P-1090	Chaiva	-20.7032222	32.8003056	1
25	P-1096	Chissunguana	-20.2038889	34.1569444	1
26	P-1109	Bagonhe	-20.1272222	33.1213889	1
27	P-1110	Dacata/Goi-Goi	-20.3044444	32.9877778	1
28	P-1163	Matongue	-20.1452222	34.0691667	1
29	P-1163	Vanduzi	-18.9528056	33.2637222	1
30	P-sn	Dopozi	-19.0064722	33.1509444	1

<b>Nr</b>	<b>Station ID</b>	<b>Station Name</b>	<b>Latitude</b>	<b>Longitude</b>	<b>Status</b>
31	P-sn	Macate	-19.4049722	33.51825	0
32	P-sn	Machire	-20.0702778	33.2638889	1
33	P-sn	Buene			1
34	P-sn	Darue			1
35	P-sn	Gruja			1



## Appendix B – Pungwe River Basin Hydromet Stations

### B1 – List of Flow Gauging Stations

Status: 1 – Operational; 0 – Not Operational;

**Bold** – belongs to flood early warning system

Nr	Station ID	Station Name	Latitude	Longitude	Status
1	E-42	Nhandare	-18.7000	33.0500	1
<b>2</b>	<b>E-64</b>	<b>Púngue Fronteira</b>	<b>-18.3484</b>	<b>33.0695</b>	<b>1</b>
<b>3</b>	<b>E-65</b>	<b>Púngue Sul</b>	<b>-18.5547</b>	<b>33.2769</b>	<b>1</b>
4	E-66	Bue Maria	-19.0252	34.1800	0
5	E-67	Mafambisse	-19.4494	34.5375	1
6	E-68	Catandica	-18.0665	33.0559	0
7	E-69	Catandica (Captação)	-18.0473	33.1749	1
8	E-70	Nhacangale	-18.1976	33.2247	1
9	E-71	Messambize	-18.3079	33.1373	1
<b>10</b>	<b>E-72</b>	<b>Nhazónia</b>	<b>-18.4397</b>	<b>33.3547</b>	<b>1</b>
11	E-73	Mavonde	-18.5219	33.0523	1
12	E-74	Metuchira N6	-19.1868	33.8754	1
13	E-75	Metuchira N1	-19.1338	34.0340	0
<b>14</b>	<b>E-76</b>	<b>Lomaco</b>	<b>-19.1703</b>	<b>34.2086</b>	<b>1</b>
15	E78	Muda Serração	-19.3292	33.8313	1
16	E79	Lamego	-19.3361	34.3194	1
17	E-80	Vanduzi	-18.6091	33.9593	1
18	E-82	Mucombezi	-18.6755	33.3201	1
19	E-83	Mavuzi (Pungue Sul)	-18.5681	33.3056	1
20	E-392	Mavuzi (Estrada Mavonde)	-18.6972	33.0568	0
21	E-414	Nhandungue/EN1	-18.2224	34.0775	1
22	E-483	Nhazónia	-17.949	33.2022	1
<b>23</b>	<b>E-651</b>	<b>Gorongosa</b>	<b>-18.9859</b>	<b>34.0851</b>	<b>1</b>
24	E-677	Nhandungue	-18.4514	34.3132	0
25	E-678	Nhancuarara	-18.5668	33.00221	1
26	E-679	Companhia de Vanduzi	-18.8413	33.2805	1
27	E-680	Vunduzi	-18.48207	34.21273	1
28	E-sn	Massimino	-18.1204	33.3006	1

## B2 – List of Rating Curves

Nr	Station ID	Station Name	Flow measurements		Rating Curve (RC) = $a \cdot (h-c)^b$				
			Coverage	Nr	a	b	c	Nr of curves	Last update
1	E-42	Nhandare	1969-1978	63	8.053	2.8	1.512	1	26-Aug-69
2	E-64	Pungue Fronteira	1956-1973	248	35.551	1.667	1.883	2	10/10/1962
			2013-2015	7	34.612	0.792	1.161	1	2022
3	E-65	Pungue Sul	1953-2011	669	26.749	2.131	2.541	4	03-Mar-04
			2013-2015	11	29.961	0.135	0.270	1	2022
4	E-66	Bue Maria	1953-2003	624	9.061	1.3	1.993	14	14-Nov-01
5	E-67	Mafambisse	1955-2011	221	3.221	1.3	1.486	14	05-Jun-92
6	E-68	Catandica							
7	E-69	Catandica (Captação)	1957-1980	425	2.088	1.643	1.111	13	17-Aug-78
8	E-70	Nhacangale	1956-2006	489	6.318	1.3	2.042	15	04-Mar-04
9	E-71	Messambize	1956-2011	364	5.237	1.586	1.293	3	13-Nov-74
10	E-72	Nhazónia	1956-2011	345	9.894	1.482	1.433	9	23-Apr-80
			2004-2014	22	3.573	1.006	2.113	1	2022
11	E-73	Mavonde	1956-1976	318	4.947	2.8	1.505	7	17-Jul-75
12	E-74	Metuchira N6	1956-2011	535	1.039	1.3	1.717	14	19-Oct-89
13	E-75	Metuchira N1	1958-2011	178	1.96	2.017	1.43	5	02-Sep-66
14	E-76	Lomaco	1958-2002	400	5.64	2.189	0.455	19	13-Aug-91
15	E78	Muda Serração	1958-1965	92	2.978	2.182	1.581	3	13-Jan-62
16	E79	Lamego	1963-1973	88	9.346	2.653	1.793	2	25-Apr-67
17	E-80	Vanduzi	1958-1980	143	8.947	2.8	1.472	2	28-Dec-72
18	E-82	Mucombezi	1958-2011	340	4.09	2.8	1.373	5	21-Mar-72
19	E-83	Mavuzi (Pungue Sul)	1956-1982	470	27.858	1.636	1.727	7	16-Jun-81
20	E-392	Mavuzi (Estrada Mavonde)	1963-1976	255	15.475	2.8	2.047	6	22-Dec-69
21	E-414	Nhandungue/EN1							
22	E-483	Nhazónia	1972-1982	107	5.087	1.3	2.551	4	29-Nov-78
23	E-651	Gorongosa	2002-2010	21	96.624	1.3	1.313	2	17-Sep-04
			2004-2010	22	4.064	0.036	2.683	1	2022
24	E-677	Nhandungue							
25	E-678	Nhancuarara							
26	E-679	Companhia de Vanduzi							
27	E-680	Vunduzi							
28	E-sn	Massimino							

**B3 – List of Rainfall Stations (Status: 1 – Operational; 0 – Not Operational)**

Nr	Station ID	Name	Latitude	Longitude	Status
1	P-90	Nhamatanda	-19.2667	34.1975	1
2	P-96	Dondo	-19.617501	34.74158	1
3	P-99	Siluvo	-19.2440	34.0254	1
4	P-103	Cafumpe	-19.1011	33.5716	1
5	P-104	Inchope	-19.2075	33.8317	1
6	P105	Lamego Norte	-19.327	34.32666	1
7	P-106	Gondola	-19.0863	33.653	1
8	P-211	Chimoio	-19.13043	33.5021	1
9	P-368	Murrombozi	-18.5264	34.0178	1
10	P-372	Mavonde (Sede)	-18.6244	33.0379	1
11	P-373	Chitengo	-18.9784	33.353	1
12	P-375	Púngue Sul	-18.5561	33.2806	1
13	P-378	Púngue Fronteira	-18.3474	33.0687	1
14	P-478	Piro	-18.3581	34.3896	1
15	P-484	Savane	-19.38789	34.70765	1
16	P-498	Nhazónia	-17.95700	33.20063	1
17	P-502	Macossa	-17.9008	34.9361	1
18	P-521	Maringue	-17.9670	34.3839	1
19	P-536	Chuala/Honde	-18.32556	33.20204	1
20	P-569	Nhampassa	-17.79645	33.21886	1
21	P-614	Zimpinga	-19.11433	33.8302	1
22	P-685	Serra Choa	-17.9928	33.0151	1
23	P-687	Tica	-19.40265	34.4329	1
24	P-718	Companhia de Vanduzi	-18.8395	33.2828	1
25	P-728	Muda Serração	-19.3318	33.8239	1
26	P-812	Gorongosa	-18.6872	34.0706	1
27	P-862	Catandica	-18.0591	33.1708	1
28	P-963	Muanza	-18.9077	34.7882	1
29	P-1068	Muera	-18.2517	34.052	1
30	P-1269	Macuti	-19.8447	34.895	1
31	P-1272	Metuchira	-19.8447	34.8950	1
32	P-1313	Gorongosa	-18.9859	34.0850	1
33	P-1370	Amatongas	-19.10264	33.81097	1
34	P-1371	Bue Maria	-19.0166	34.1833	0
35	P-1373	Nhamagua	-17.8423	33.4566	1
36	P-1377	Messambize	-18.307	33.1369	1
37	P-1378	Mucombezi	-18.66593	33.31687	1
38	P-1379	Deca	-18.5881	33.1354	0
39	P-1380	Nhacangale	-18.1976	33.2247	1
40	P-1415	Mafambisse	-19.4494	34.5375	1
41	P-1416	Ponta Gea	-19.8411	34.8456	1
42	P-1417	Inhamizua	-19.7271	34.7957	1
43	P-sn	Mavonde (EPC Nhandanga)	-18.51748	33.05043	0
44	P-sn	Cagole	-18.1171	33.3547	1
45	P-sn	Nhangau	-19.7158	35.0106	1
46	P-sn	Barragem de Muda	-19.3881	34.0264	1



## Appendix C – Save River Basin Hydromet Stations

### C1 – List of Flow Gauging Stations

Status: 1 – Operational; 0 – Not Operational;

**Bold** – belongs to flood early warning system

Nr	Station ID	Station Name	Latitude	Longitude	Status
1	E-47	Vila Franca	<b>-21.14167</b>	<b>34.53333</b>	<b>1</b>
2	E-48	Jofane	-21.31361	34.30444	1
3	<b>E-86</b>	<b>Massangena</b>	<b>-21.55</b>	<b>32.95</b>	<b>1</b>
4	E-573	Nova Mambone	-20.98758	35.01119	1

### C2 – List of Rating Curves

Nr	Station ID	Station Name	Flow measurements		Rating Curve (RC) = $a*(h-c)^b$				
			Coverage	Nr	a	b	c	Nr of curves	Last update
1	E-47	Vila Franca	<b>1960/2019</b>	<b>342</b>					
2	E-48	Jofane							
3	E-86	Massangena	<b>1959/1974</b>	<b>15</b>	2.508	1.3	-0.743	<b>1</b>	<b>27-Oct-59</b>
4	E-573	Nova Mambone							

### C3 – List of Rainfall Stations (Status: 1 – Operational; 0 – Not Operational)

Nr	Station ID	Station Name	Latitude	Longitude	Status
1	P-110	Massangena	-21.577167	32.952722	1
2	P-338	Jofane	-21.316667	34.3	1
3	P-1112	Vila Franca do Save	-21.158333	34.566667	1
4	P-1167	Milindile	-21.468056	33.433333	1



## Appendix D – Samples of ARA Bulletins



Boletim Hidrológico, Edição N° 124/ARA-Centro, IP/DG/2021-22, 13 de Maio de 2022

### SITUAÇÃO HIDROLÓGICA DAS BACIAS DO BÚZI, PÚNGUE E ZAMBEZE

#### 1. CONDIÇÕES HIDROLÓGICAS ACTUAIS

##### 1.1. Precipitação Registada (em mm)

Nas últimas 24 horas, ao longo da rede de observação hidroclimatológica das bacias da região centro, não houve registo de chuvas.

##### 1.2. Níveis Hidrométricos Observados

No geral, os níveis de água nas bacias hidrográficas do Púngue e Zambeze registam oscilações com tendência a baixar ligeiramente. Na bacia do Búzi, os níveis mantêm-se estacionários e com tendência a baixar ligeiramente.

##### 1.3. Gestão das Principais Albufeiras

As albufeiras de **Cahora Bassa, Chicamba e Muda** registam níveis de enchimento de 91%, 69% e 100%, respectivamente, com efluências na ordem de 1464 m<sup>3</sup>/s, 21 m<sup>3</sup>/s e 2 m<sup>3</sup>/s, respectivamente.

#### 2. PREVISÃO PARA AS PRÓXIMAS 24 HORAS

Para as próximas 24 horas, nas bacias do Búzi, Púngue e Zambeze não prevê-se alterações significativas do actual cenário hidrológico.

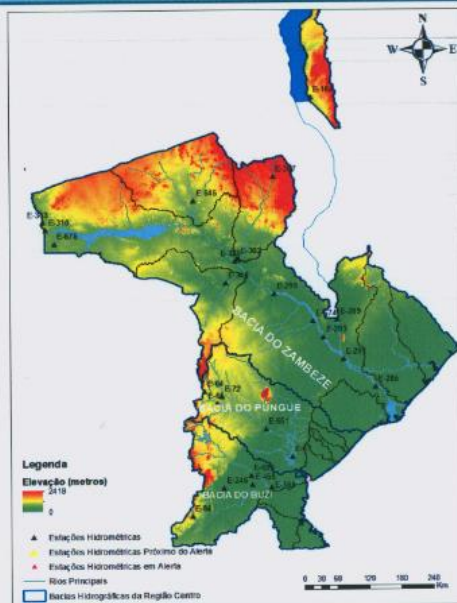
#### 3. ALERTA E PRECAUÇÕES

**A ARA-Centro apela à todos Governos Distritais, Agentes Económicos, Utentes e Beneficiários dos Recursos Hídricos das Bacias Hidrográficas dos Rios Zambeze, Púngue e Búzi e ao Público em Geral para a tomada de medidas de precaução, devendo retirar-se imediatamente das zonas de risco de inundação e não atravessar os leitos dos rios.**



(Técnico Superior de Obras Públicas N1)

## ANEXO I. SISTEMA DE AVISO DE CHEIAS DA ARA-CENTRO, IP



## ANEXO II. BACIA HIDROGRÁFICA DO BÚZI

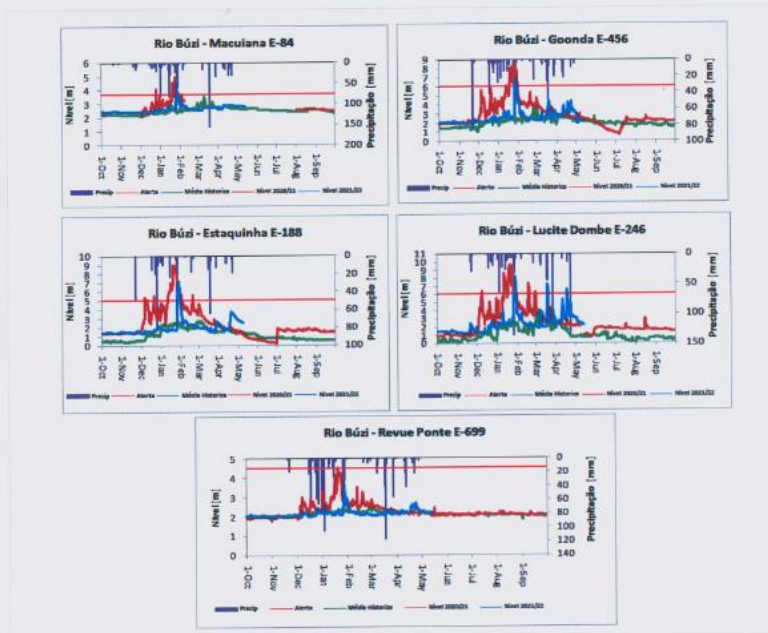
### 1. Dados Hidrológicos Observados nas Principais Estações do Búzi

Rio Búzi: Curso Principal								
Data	Hora	Maculiana E-84: N.Alerta=3,7m		Goonda E-456: N.Alerta=6,0m		Estaquinha E-198: N.Alerta=5,0m		
		Nível (m)	Prec: P-336 (mm)	Nível (m)	Caudal (m <sup>3</sup> /s)	Prec: P-1274 (mm)	Nível (m)	Prec: P-77 (mm)
11-05-2022	06:00	2.81	0.00	2.26	71.78	0.00	S/I	0.00
	12:00	2.81		2.26	71.78		S/I	
	18:00	2.80		2.26	71.78		S/I	
12-05-2022	06:00	2.80	0.00	2.26	71.78	0.00	S/I	0.00
	12:00	2.80		2.26	71.78		S/I	
	18:00	2.80		2.26	71.78		S/I	
13-05-2022	06:00	2.80	0.00	2.26	71.78	0.00	S/I	S/I
<b>Estágio Actual do Alerta</b>		Abaixo do Alerta		Abaixo do Alerta		Abaixo do Alerta		

B

Rio Búzi: Principais Afluentes						
Data	Hora	Dombe E-246: N.Alerta=6.0m		Prec: P-422 (mm)	Revue E-699: N.Alerta=4.5m	
		Nível (m)	Caudal (m3/s)		Nível (m)	Prec: P-1070 (mm)
11-05-2022	06:00	2.36	91.53	0.00	2.16	0.00
	12:00	2.34	90.03		2.14	
	18:00	2.30	87.06		2.18	
12-05-2022	06:00	2.26	84.13	0.00	2.19	0.00
	12:00	2.21	80.54		2.15	
	18:00	2.18	78.43		2.12	
13-05-2022	06:00	2.18	78.43	0.00	2.11	0.00
<b>Estágio Actual do Alerta</b>		Abaixo do Alerta			Abaixo do Alerta	

## 2. Gráficos Ilustrativos da Bacia do Búzi



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## Appendix E. Sample of DNGRH Bulletin



República de Moçambique  
MINISTÉRIO DAS OBRAS PÚBLICAS, HABITAÇÃO E RECURSOS HÍDRICOS  
DIRECÇÃO NACIONAL DE GESTÃO DE RECURSOS HÍDRICOS  
Departamento de Gestão de Bacias Hidrográficas

### BOLETIM HIDROLÓGICO NACIONAL

Edição Nº 060

05/02/2021

#### SITUAÇÃO PREVALECENTE

Nas últimas 24 horas, houve registo de chuva fraca a moderada, na rede nacional de observação hidroclimatológica, destacando-se as bacias dos rios **Zambeze** em *Manje (27.0mm)*, *Daque (22.5mm)* e *Nhavunduca (15.0mm)*; **Sanhote** na *Barragem de Nacala (22.0mm)*; **Lúrio** em *Namapa (25.2mm)*; **Messalo** em *Nungo (34.0mm)* e **Rovuma** em *Mavago (15.2mm)*.

Na **região Norte**, as bacias hidrográficas dos rios **Megaruma** em *Megaruma* e **Rovuma** em *Lussangasse* registam oscilação do nível hidrométrico com tendência a subir, mantendo-se abaixo do nível de alerta.

Na **região Centro**, as bacias do **Púngoè** em *Mafambisse* e **Zambeze** em *Mutarara* registam oscilação do nível com tendência a baixar, entretanto **Zambeze** em *Caia* tende a estabilizar, mantendo-se acima do alerta.

Na **região Sul**, devido à contribuição de montante, as bacias dos rios **Maputo** em *Madubula* e **Limpopo** em *Combomume*, *Chòkvè* e *Sicacate* registam oscilação do nível, com tendência a subir, mantendo-se acima do nível de alerta. A bacia do **Incomátí** em *Ressano Garcia* e *Incoluane* regista oscilação do nível, com tendência a subir, abaixo do nível de alerta e *Magude* tende a baixar, mantendo-se acima do nível de alerta.

As restantes bacias registam níveis oscilatórios com tendência a baixar.

#### ENCHIMENTO DAS PRINCIPAIS ALBUFEIRAS

Na **região Norte**, as albufeiras de Chipembe, Nampula e Nacala registam enchimento de 47.60%, 45.26% e 76.42%, a efectuarem descargas de 0.21 m<sup>3</sup>/s, 0.00 m<sup>3</sup>/s e 0.07 m<sup>3</sup>/s respectivamente.

Na **região Centro**, as albufeiras de Cahora Bassa (HCB), Chicamba e Muda registam enchimento de 78.56%, 89.43% e 100%, sendo que o caudal efluente é de 3472.50 m<sup>3</sup>/s, 155.81 m<sup>3</sup>/s e S/Inf, respectivamente.

Na **região Sul**, as albufeiras dos Pequenos Libombos, Corumana e Massingir registam enchimento de 41.12%, 57.66% e 65.51%, a efectuarem descargas de 2.69 m<sup>3</sup>/s, 0.14 m<sup>3</sup>/s e 0.00 m<sup>3</sup>/s, respectivamente.

#### PREVISÃO

Face às previsões meteorológicas e a situação hidrológica prevalecte, para as próximas 72 horas prevê-se:

Na **região Sul do país**, **oscilação do nível hidrométrico com tendência a subir, na bacia hidrográfica do rio Limpopo em Combomume, Chòkvè, Sicacate e Xai-xai, devido ao escoamento proveniente de montante, mantendo-se em alerta. Prevê-se ainda risco de ocorrência de inundações de MAGNITUDE MODERADA nas zonas baixas e ribeirinhas ao longo da bacia do limpopo.** As bacias dos rios **Maputo** em *Madubula* e **Incomátí** em *Incoluane* poderão registar subida do nível hidrométrico, mantendo-se em alerta.

Na **região Centro**, a bacia hidrográfica do rio **Púngoè** em *Mafambisse* poderá continuar a registar descida gradual do nível e **Zambeze** em *Mutarara* e *Caia* poderá continuar a registar incremento do volume de escoamento, mantendo-se acima do nível de alerta.

Na **região Norte**, as bacias hidrográficas dos rios **Megaruma, Messalo** e **Rovuma** poderão registar níveis hidrométricos oscilatórios com tendência a subir, mantendo-se abaixo do nível de alerta.

Para as restantes bacias hidrográficas não se prevê alterações significativas do actual cenário hidrológico.

A DNGRH apela à população vivendo em zonas baixas e ribeirinhas, particularmente nas bacias do **MAPUTO, INCOMÁTÍ, LIMPOPO, SAVE, BÚZI, PÚNGOÈ** e **ZAMBEZE**, para se manterem em zonas altas e seguras e, evitar a travessia do leito dos rios, devido ao elevado volume de escoamento. Igualmente, recomenda ao acompanhamento permanente da informação hidrológica disseminada pelas entidades competentes.

O CHEFE DO DEPARTAMENTO



Rua da Imprensa Nº 162, 1º Andar, Tel. 21309862, Fax 21305240

Página 1

**EVOLUÇÃO DOS NÍVEIS HIDROMÉTRICOS**

Estação	Dia	Horas	Nível (m)	Prec. (mm)	N.Alerta (m)	Observações
<b>BACIA HIDROGRÁFICA DO MAPUTO</b>						
RIO MAPUTO (Madubula)	03/02/21	07:00	5.09	0	3.5	-
	04/02/21	07:00	5.65	0		
	05/02/21	07:00	5.71	2.3		
<b>BACIA HIDROGRÁFICA DO UMBELUZI</b>						
RIO UMBELUZI (Goba)	03/02/21	07:00	3.85	0	3.5	-
	04/02/21	07:00	3.25	0		
	05/02/21	07:00	2.99	6.5		
<b>BACIA HIDROGRÁFICA DO INCOMATI</b>						
RIO INCOMATI (Ressano Garcia)	03/02/21	07:00	4.9	5.1	5	-
	04/02/21	07:00	4.07	0		
	05/02/21	07:00	4.26	4.2		
RIO INCOMATI (Magude)	03/02/21	07:00	6.1	116.6	5	-
	04/02/21	07:00	6.66	0		
	05/02/21	07:00	6.15	6.3		
<b>BACIA HIDROGRÁFICA DO LIMPOPO</b>						
RIO LIMPOPO (Pafuri)	03/02/21	07:00	5.5	0	5	-
	04/02/21	07:00	6.1	0		
	05/02/21	07:00	5.44	5.8		
RIO LIMPOPO (Combomune)	03/02/21	07:00	6.61	0	4.5	-
	04/02/21	07:00	7.86	0		
	05/02/21	07:00	8.47	0		
RIO LIMPOPO (Chokwe)	03/02/21	07:00	7.11	23	5	-
	04/02/21	07:00	7.37	0		
	05/02/21	07:00	6.9	0		
RIO LIMPOPO (Xai-Xai)	03/02/21	07:00	3.42	51	4.3	-
	04/02/21	07:00	3.9	0		
	05/02/21	07:00	3.38	0		
<b>BACIA HIDROGRÁFICA DO MUTAMBA</b>						
RIO MUTAMBA (Jangamo)	03/02/21	07:00	2.66	9.5	3.8	-
	04/02/21	07:00	2.79	18.5		
	05/02/21	07:00	2.77	0		
<b>BACIA HIDROGRÁFICA DO INHANOMBE</b>						
RIO INHANOMBE (Mubalo)	03/02/21	07:00	3.62	26.2	4.5	-
	04/02/21	07:00	3.62	26.9		
	05/02/21	07:00	S/Inf	S/Inf		
RIO INHANOMBE (Maxixe, P.EN1)	03/02/21	07:00	1.87	0	4	-
	04/02/21	07:00	1.88	6.5		
	05/02/21	07:00	2.03	0		
<b>BACIA HIDROGRÁFICA DO SAVE</b>						
RIO SAVE (Massangena)	03/02/21	07:00	3.64	2	4.5	-
	04/02/21	07:00	3.84	0		
	05/02/21	07:00	3.86	0		
RIO SAVE (Vila F. Save)	03/02/21	07:00	5.37	36.4	6.5	-
	04/02/21	07:00	5.11	0		
	05/02/21	07:00	S/Inf	S/Inf		
<b>BACIA HIDROGRÁFICA DO BÚZI</b>						
RIO BÚZI (Dombe)	03/02/21	07:00	4.73	32.7	5.5	-
	04/02/21	07:00	4.86	S/Inf		
	05/02/21	07:00	4.16	0		
RIO BÚZI (Goonda)	03/02/21	07:00	4.35	60.8	6.5	-
	04/02/21	07:00	4.39	S/Inf		
	05/02/21	07:00	4.11	0		
<b>BACIA HIDROGRÁFICA DO PUNGUE</b>						
RIO PUNGUE (Punguê Sul)	03/02/21	07:00	S/Inf	S/Inf	6.5	-
	04/02/21	07:00	5.1	S/Inf		
	05/02/21	07:00	5.26	0		
RIO INHAZÓNIA (Inhazónia)	03/02/21	07:00	5.41	S/Inf	5.5	-
	04/02/21	07:00	5.16	S/Inf		
	05/02/21	07:00	4.76	0		
RIO PUNGUE (Mafambisse)	03/02/21	07:00	7.98	S/Inf	6	-
	04/02/21	07:00	7.95	S/Inf		
	05/02/21	07:00	7.88	0		

## Appendix F. Sample of Zimbabwe Flood and Drought Monitor (Seasonal Precipitation Forecast)

Zimbabwe Flood and Drought Monitor   Current Conditions   Short-term Forecasts   **Seasonal Forecasts**   About

Forecasts are available out to 6 months.

Forecasts are given as the ensemble mean, with uncertainty represented by the ensemble 5th and 95th percentiles.

03 August 2022 : 30 January 2023

Variable:

Precipitation

Location:

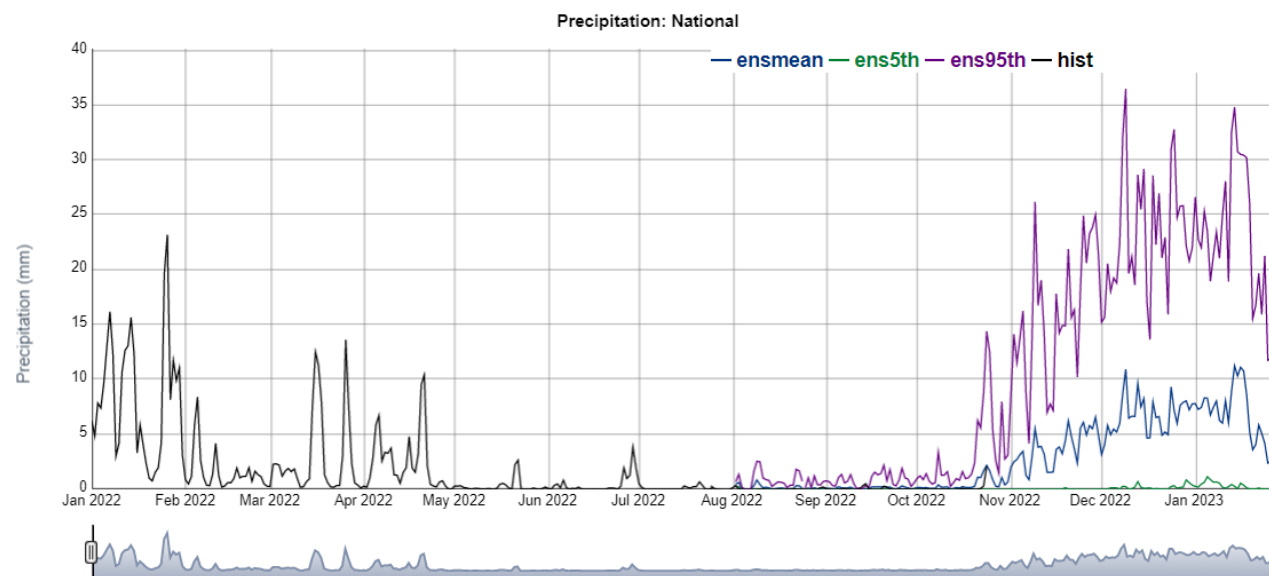
National

Update

Download

Time series

Probability maps



## Appendix G. Consultancy Notes on Pre-season Meeting with Member States, Chimoio, 12 October 2022

### Objective of the Session and Background

- **(W Nyabeze)**

BUPUSA basins are susceptible to floods. Under the BUPUSA GEF Project, the FFEWS is responding the Component 1 which aims to contribute to strengthening water-related risk management through the reinforcement of monitoring systems, the development of real-time operational tools, and the empowerment of communities in their flood mitigation autonomy.

A Feasibility Study for BUPUSA FFEWS was undertaken to identify a sustainable solution for BUPUSA FFEWS. The study concluded to use the DELFT FEWS platform, HEC-HMS and HEC-RAS to be implemented. This technical solution was approved and signed by the riparian states. Both countries also agreed to host the system at DNGRH and contribute to feed the system via regional data centers and provide all required data for free. Following tender process, Salomon Lda was selected and have the responsibility to implement this system together with member states. In order to guarantee sustainability of the implementation of the FFEWS, the consultant must work closely with the technicians in order to ensure implementation of the system after the contract.

### Consultant's Presentation

- **(F Saimone)**. See Annex 1.

### Contributions

1. **(E. Jossefa, DNGRH)**. Is there anything planned in terms of continuing training and assistance after 2024? Because people can leave, and other can retire. It can be important to maintain the system running.  
R: **(W. Nyabeze, Technical Advisor GWPSA)**. From this study is expected to generate key recommendations to feed the Transboundary Diagnostic Analysis (TDA) which will guide the countries to produce the Strategic Action Plan (SAP) and National Action Plan (NAP) to be implemented.
2. **(W Nyabeze, GWPSA)**. In terms of capacity building, two scientists (one for each country) are being trained in HEC-HMS, HEC-RAS in the University of Pretoria.
3. **(Charity Denhere, Zimbabwe Meteorological Department)**. The satellite data that will feed the system will be pre-processed or validated before or not?  
Is the system prepared to receive data from our automatic weather stations?  
R: Yes. As shown in the schematics, the system can use data both from manual stations, satellite and from the AWS, as soon as we establish the link with them.
4. **(Macaringue, ARA-Centro)**. Is there equipment to be acquire to reinforce the water management institutions to do measurements which are important to support this system, as it was mentioned, the rating curves are outdated and needs to be updated. Another suggestion is beside the 2 technicians, is there a possibility to include more technicians from regional water management institution to participate in the training even if online?  
R: **(E Madamombe, Regional Coordinator GWPSA)**. We have limited resources to implement what would be ideal. For now, we have completed the tendering process for acquisition 12

automatic stations to be divided by half for each country. In the next week there will be training to install those stations. However, we are joining efforts with other partners which are implementing projects in the same basins to bring synergies, such as UNESCO. UNESCO: in terms of instruments, our project intends to install 25 automatic water level and weather stations.

5. **(P Sithole, GWPSA)**. Let's make sure we don't leave community behind when we talk about capacity building. It's a reminder that the ultimate beneficiaries are local communities.
  
6. **(Zimbabwe water regulator)**. On the key milestones. It is clear on the deliverables to the consultant. It is not clear about implementation of the case studies.  
R: (F Saimone). From this workshop, at least the flood prone areas must be defined where the case studies are relevant to be implemented. The implementation of case studies will start at the next workshop when the setup is ready and first training workshop will be implemented.
  
7. **(Zimbabwe meteorological services)**. The location of the automatic stations which are going to be installed, was agreed between member states?  
R: **(E Madamombe)**. Yes. Those station will be installed in existing selected station sites agreed with member states.

## GROUP DISCUSSIONS

### Group 1. Flood Vulnerability

People, infrastructure and services affected by floods, collation of site data, setting up and updating database, application of data, risk reduction strategies, case studies areas, etc. location and extent of impacted areas to be considered in setting up FFEWS, stakeholder involvement.

- Presentation (Annex 2)
  - Discussion
1. The location of flood prone areas was too broad. Indication of district is very large area, and most probably not all district area is affected. We need to have clear specific sites/villages.

### Group 2. Flood Early Warning System

FFEWS set up and maintenance, including FEWS framework – requirements on human capacity, data infrastructure, continuity etc. How will scientists from member states interact with this system during its development? Involvement of other stakeholders

- Presentation (Annex 3)
  
  - Discussion
1. **(Director of INAM-Manica)**. We need to think about the flood warning system itself and not the models only because the dissemination is crucial. Community radios are the main source of information in rural communities. Recently, we have conducted a study to understand the effectiveness of the community radios in the dissemination of potential climate extreme events. We found that the flow of information is quite good until the District Government.

However, from there to the community radio there is a gap. We also found that radio professionals are not trained to disseminate this kind of information. Sometimes they disseminate non-official information or from doubted sources like whatsapp. The radio practitioners are sometimes not employed there, they are just volunteers, especially those belonging to the associations.

2. **(INGD-Manica)**. Our experience in the dissemination of disaster related information is through disaster and risk reduction local committees. These committees are installed in flood prone sites. They are composed of 18 members with clear function definition. Three of them are responsible to disseminate early warning information. We have different means of dissemination managed by this committee, including: whistle, flags, megaphone. During dry season, this committee do awareness campaign explaining to interpret the signs. Other type of communication is a river water level sensor linked to the siren. Even during night people listen and can go to a safer place. In order to increase acceptance of messages, the community is gender balanced so woman can disseminate to the group of women.

### **Group 3. Flood Impact Reduction**

Communication and implementation of early warnings including institutional arrangements, requirements on people, equipment etc. community involvement.

- Presentation (Annex 4)
  - Discussion
1. **(D Constantino, DGBS-Mozambique)**. One of non-structural measure for flood impact reduction is also related to the incentives we have to reinforce to the water level readers. In Save Division, we use to invite all key station readers to participate in the basin committee annual meeting so they are presented das important component of the water resource management. Other incentives include provide them bicycles.

# Appendix G-1 Group 1 Plenary Presentation






**FFEWS**



**Group One**

**12 October 2022**








1






### Location and Extend of Impacted Areas to be considered in Setting out FFEWS (BUPUSA)

Place	Basin	Extend
Chimanimani	Buzi	Ngangu Kopa Rusitu
Chipinge	Save	Chipinge District Middle Sabi <b>Musirizwi</b>
Chiredzi	Save	<b>Chilonga</b>
Mwenezi	Save	
Pungwe	Pungwe	Katiyo Area (closer to the border)
Buhera	Save	Buhera District








2






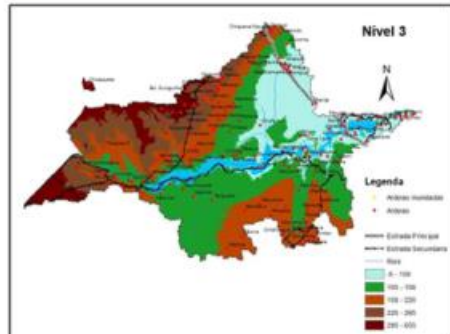
### Location and Extend of Impacted Areas to be considered in Setting out FFEWS (BUPUSA)

Govuro	Save	Nova Mambone
Machanga	Save	Machanga Village
Massangena	Save	Bokota
Mabote	Save	Malindire








3



Area	Áreas Inundadas	TOTAL	MASCULINO	FEMENINO
Machangwa	224	77	347	
Chibhore	233	118	115	
Macangwita	556	243	313	
Mtshati	38	18	20	
Bea Zwa I	1596	677	919	
Chituro	2090	906	1184	
<b>Save</b>				
Musasa	469	166	303	
Metzra	206	98	108	
Gurumane	35	45	50	
Jifene	141	58	78	
Pfumbane	318	137	182	
Chitondane	557	248	305	
Govene	756	324	432	
<b>TOTAL</b>	<b>7280</b>	<b>3200</b>	<b>4140</b>	

4

### Location and Extend of Impacted Areas to be considered in Setting out FFEWS (BUPUSA)

Dondo	Pungwe	Mafambise Nhamakwengeri Chisanje Chipunde Musatwe Nyamataka Mutua
Nhamatanda	Pungwe	Metuchira Lamego Bebedo Makorococho Chiadeia

5

### Location and Extend of Impacted Areas to be considered in Setting out FFEWS (BUPUSA)

Basin	Áreas Inundadas	TOTAL	MASCULINO	FEMININO
Cherimonia	645	313	332	
Mafambise Sede	30684	16073	14611	
Nhamacungwene	407	192	215	
Chisanje	1445	694	751	
Chideia	475	220	255	
Zona Pungwe Rodoviaro	558	275	283	
Zona Musatwe	2410	1196	1214	
Unidade Nhamataka	403	212	191	
Mutua Sede	4600	2323	2277	
Ponte Rodoviaro	492	246	246	
P. Ngwenha	158	80	78	
Phacamisso	60	23	37	
Nhamfembe	18492	9060	8432	
Nsato	18609	9055	9554	
Chideia	3901	1858	1943	
Mucipe	1420	691	729	
Nhampona	1938	954	1084	
Mazanda	1762	853	909	
Mumba	1728	841	887	
<b>TOTAL</b>	<b>90873</b>	<b>45199</b>	<b>48828</b>	

6

### Location and Extend of Impacted Areas to be considered in Setting out FFEWS (BUPUSA)

Place	Basin	Extend
Susundenga	Buzi	Dombe
Buzi		Buzi Village
Musurizi	Buzi	<b>Musurizi</b>

7

### Location and Extend of Impacted Areas to be considered in Setting out FFEWS (BUPUSA)

Basin	Áreas Inundadas	TOTAL	MASCULINO	FEMININO
Chido	905	431	474	
Masqili	452	216	236	
Chinhal	202	93	109	
Musungu	257	110	142	
Masungu-1	86	45	48	
Bandira	162	70	90	
Chicumbua	154	93	63	
Nhambirira	116	58	58	
Chonga	76	36	40	
Nharongwe	936	451	485	
Inhangwana	687	333	364	
Mifundo Baim	655	311	344	
Dondaga	403	198	202	
Musimemwe	760	362	398	
Pandira	129	59	61	
Buzira	658	313	345	
Soala	2529	1181	1389	
Suma	1032	468	564	
Área Com. Acordos De Luzaka	632	303	329	
Chitause	967	473	494	
Nharipoi	648	319	329	
<b>TOTAL</b>	<b>12424</b>	<b>5873</b>	<b>6551</b>	

8



## Infrastructure Affected



- Gauging Stations
- Weather Stations
- Roads and Bridges
- Power lines
- Hospitals
- Schools
- Communication lines
- Houses and shops
- Irrigation Schemes
- Dams (breaching)
- Water Supply stations (including boreholes, treatment plants. Pipes etc.)
- Dip tanks



9



## Case study areas



### Mozambique

- Mafambisse
- Buzi Village
- Machanga and Mambone



10



## Case study areas



### Zimbabwe

- Middle Sabi
- Chimanimani (Ngangu, Rusitu, Kopa)
- Mwenezi
- Nyanyadzi



## Risk Reduction Strategy



- Early warning systems
- Hotspots mapping
- Flood Forecasts
- Information dissemination using community radios (local Languages)
- Training of local Risk Disaster Management Committees (community drills)
- Alternative livelihood projects (small grants projects)



## Appendix G-2 Group 2 Plenary Presentation

### Flood Early Warning Systems

#### FEWS Set up and maintenance

- List of requirements
- ☐ Human Capital
  - Experts in the FEWS and the related models
  - Focal people/volunteers within the communities e.g. committees (SAP-EW-data collection-dissemination of information-group of 18 people -3 disseminate
  - Materials for the trainer of the trainers for sustainability.
- ☐ Financial resources
  - Remuneration and allowances/incentives
  - Training materials
- ☐ Tools
  - Community Radios
  - Automated Recorders (Rainfall and River level)
  - Drones
  - Water level alarms
- ☐ Working Structures
  - From National to community level as well as Basin level

1

### FEWS Set up and maintenance

- ☐ Historic Data for modelling
  - Rainfall data
  - Flow data
  - Dam level data
- ☐ Continuity/Sustainability
  - Data sharing platform
  - Education and awareness of the community
  - Monitoring and maintenance plans beyond project implementation
  - Trainings
  - To be included in the curriculum (from primary to tertiary)
  - Complementing existing structures and institutions
  - Embrace efforts done by other developed countries – Cloud to street platform

2

### Interaction Platform

- Develop a system that accepts all models
- Develop freely accessible data sharing platforms/applications
- Basin agreements on data sharing

3

### Questions/Contributions

- What is currently happening/being done in the basins in terms of FFEWS
- Training/Awareness on traditional instruments in the Chipinge district (important institutions include, Met Office – Announce, National Office directs for action at provincial, then district and local levels)
- All early warning systems need to be considered down to information dissemination (a model can only be effective if the information is disseminated at appropriate levels). How is the information reaching the communities using community radios, since other modes of communication i.e., television are out of reach of the communities. Link between the government institutions and communities are weak (need for clear communication strategy). Most community radios run by voluntary persons (capacitation is important).
- 18 member committees created for flood prone areas (Mozambique). Instruments used include megaphone, sensors..... Local/indigenous knowledge also used.

4

## Appendix G-3 Group 3 Plenary Presentation

### REDUCAO DE IMPACTOS DE CHEIAS

#### GRUP III

#### Identificação das zonas propensas a cheias e inundações:

Ações para mitigação:

##### a) Medidas não estruturais

- Sensibilização das comunidades a abandonar as zonas de risco;
- Potencialização dos comités locais de gestão de riscos de desastres;
- Flexibilização do mecanismo de emissão e disseminação de avisos de cheias;
- Monitoria permanente dos locais propensos a cheias;
- Medição de caudal;
- Alocação de barcos;
- Planos de emergência;

##### b) Medidas estruturais

- Estabelecer rotas de evacuação ou acesso;
- Identificação de abrigos temporários;
- Construção de diques de proteção contra cheias e inundações;
- Construção de barragens;
- Construção de infraestruturas resilientes (casas, serviços, infraestruturas sociais, etc);
- 

#### Questions/Contributions

- Flexibility of the early warnings systems e.g., incentives to local field officers/persons- Cellphones can provide real-time information during floods. Technologies will complement including contemporary technology. ARA-Sul incentivises to the key field officers (those in highly vulnerable areas) through introductions to basin communities (improves their visibility). Information dissemination to the DA now very consistent and strengthened.
- Radios are important especially in situations where network is lost e.g., cyclone idai (need to add more radios)

## Appendix H : Literature, area of interest and relevance category

Document	Area of Interest	Category
Mozambique Water Law, Law nr. 16/91 of 3rd August 1991;	Mozambique	Disaster management mandates
Transboundary Flood Risk Management: Experiences from the UNECE Region, UN, 2009;	General	Disaster management mandates
Disaster Risk Management in Mozambique – Country Note, 2009;	Mozambique	Disaster management mandates, roles and responsibilities
Guidance on National Flood Risk Assessments, WR Wallingford;	General	Flood risk assessments
National Climate Change Strategy, 2013 – 2025, Ministry for the Coordination of Environmental Action	Mozambique	Disaster risk reduction
Assessment of the Hydrological and Hydraulic Situation of Floods in Mozambique 1977-2013, Consultec and Salomon, 2014;	Mozambique	Flood risk assessments
Disaster Risk Reduction Master Plan 2017-2030, 2017;	Mozambique	Disaster risk reduction
National Water Resources Development Plan, 2017;	Mozambique	Water resource development and infrastructure
Mozambique National Water Resources Strategy,	Mozambique	Disaster risk reduction
SADC Revised Protocol on Shared Watercourses	SADC	Data and information sharing
Mozambique-Zimbabwe JWC agreement	Mozambique and Zimbabwe	Disaster management mandates, roles and responsibilities
Mozambique Disaster Risk Reduction and Management Act, Law nr. 10/2020 of 24th August 2020;	Mozambique	Disaster management mandates, roles and responsibilities

<b>Document</b>	<b>Area of Interest</b>	<b>Category</b>
Regulation of the Law on Disaster Risk Reduction and Management, Law nr. 76/2020 of 1st September 2020;	Mozambique	Disaster management mandates, roles and responsibilities
National Strategy for the Establishment of an Integrated Flood and Cyclone Early Warning Information Flow System in Mozambique, 2022 – 2030, National Institute for Disaster Risk Reduction and Management, March 2022;	Mozambique	Disaster risk reduction
Regulation on the Operation of the Integrated Platform for Dissemination and Communication of Information on Early Warning of Floods and Cyclones, Decree nr. 26/2022 of 6th July;	Mozambique	Disaster risk reduction
Organic Statute of the Central Region Water Administration, Public Institute (ARA-Centro, IP), Resolution nr. 22/2021 of 15th June;	ARA-Centro	Disaster risk reduction
Internal Regulation of the Central Region Water Administration, Public Institute (ARA-Centro, IP), Ministerial Diploma nr. 161/2021 of 9th December;	ARA-Centro	Disaster management mandates, roles and responsibilities
Organic Statute of the South Region Water Administration, Public Institute (ARA-Centro, IP), Resolution nr. 18/2021 of 17th May;	ARA-Centro	Disaster management mandates, roles and responsibilities
Internal Regulation of the South Region Water Administration, Public Institute (ARA-Sul, IP), Ministerial Diploma nr. 141/2021 of 25th November	ARA-Sul	Disaster management mandates, roles and responsibilities
Evaluation of the Potential Development and Use of Hydraulic Resources of the Buzi River Basin – Volume 1: Climatological and Hydrological Study, Part 1: Report, DNA, 1980;	Buzi basin	Water resource development and infrastructure
Evaluation of the Potential Development and Use of Hydraulic Resources of the Buzi River Basin – Volume 7: General Outline of River Regularisation and Flood Defence Works, Part 1: Report and Tables, DNA, 1980;	Buzi basin	Water resource development and infrastructure

<b>Document</b>	<b>Area of Interest</b>	<b>Category</b>
Development of the Buzi River Basin Monograph and Joint IWRM Strategy – Monograph Reports and Annexes, SWECO, 2011;	Buzi basin	Water resource development and infrastructure
Development of the Buzi River Basin Monograph and Joint IWRM Strategy – Development Scenario Report, SWECO, 2012;	Buzi basin	Water resource development and infrastructure
Development of the Buzi River Basin Monograph and Joint IWRM Strategy – Preliminary Identification of Buzi and Lucite Multipurpose Projects (Working Paper), Admasu Gebeyehu, 2012	Buzi basin	Water resource development and infrastructure
Development of the Buzi River Basin Monograph and Joint IWRM Strategy – Joint IWRM Strategy Report, SWECO, 2013;	Buzi basin	Water resource development and infrastructure
Updating the Sector Study on Surface Water Resources for Buzi Basin – Volume 1 – Main Report, Consultec, 2015;	Buzi basin	Hydrology
Development of the Pungwe River Basin Joint Integrated Water Resources Management Strategy – Monograph Report and Annexes, SWECO, 2004;	Pungwe basin	Water resource development and infrastructure
Development of the Pungwe River Basin Joint Integrated Water Resources Management Strategy – Development Scenario Report, SWECO, 2005;	Pungwe basin	Water resource development and infrastructure
Pungwe Basin Joint IWRM and Development Strategy Report – Strategy, Justification and Annexes, SWECO, 2006;	Pungwe basin	Water resource development and infrastructure
Updating the Sector Study on Surface Water Resources for Pungwe Basin, Volume 1 – Main Report, Consultec, 2013;	Pungwe basin	Hydrology
Water Allocation Planning in Pungwe Basin Mozambique, P Droogers and W Terink, Partners for Water, 2014;	Pungwe basin	Water resource development and infrastructure

Document	Area of Interest	Category
Hydrological analysis and modelling of the Pungwe River Basin, Mozambique - A study performed under the 'Water Planning Tools to Support Water Governance' (WatPlaG) project, W Terink and P Droogers, ARA-Centro/ Partners for Water, 2014;	Pungwe basin	Water resource development and infrastructure
Integrated Water Resource Management of the Inhambane Province, Consultec and Salomon, 2009;	Save basin	Water resource development and infrastructure
Save River Basin - a shared water resource, Monograph Report, COWI, 2011;	Save basin	Water resource development and infrastructure
Save River Basin - a shared water resource, Development Scenario Report, COWI, 2012	Save basin	Water resource development and infrastructure
Save River Basin - a shared water resource, Joint IWRM Strategy Report, COWI, 2013;	Save basin	Water resource development and infrastructure
Buzi-Save Water Transfer Scheme - Scoping Assessment Report -Project Baseline, CRIDF, 2019;	Save basin	Water resource development and infrastructure
Runde and Save Hydrometric Gauging Stations – Financial Close, CRIDF, 2019;	Save basin	Hydrology
Save River Basin Strategy Implementation – Save Multipurpose Dam Priority – Technical Assistance, CRIDF, 2019;	Save basin	Water resource development and infrastructure
Save River Basin Strategy Implementation - Save Sustainable Water Management – Technical Assistance, CRIDF, 2019;	Save basin	Water resource development and infrastructure
Government of Zimbabwe and UNCT. 2014. Zimbabwe Country Analysis: Working Document. Dated 4 November 2014	Zimbabwe	Disaster risk reduction
UNDP 2016. Mapping of Selected Hazards Affecting Rural Livelihoods in Zimbabwe. A District and Ward Analysis	Zimbabwe	Disaster risk reduction

Document	Area of Interest	Category
UNESCO. Community-focused Flood Early Warning System for the BuPuSa Transboundary River Basins	Buzi-Pungwe-Save	Disaster risk reduction
Zimbabwe National Framework for Climate Services (NFCS) (In development)	Zimbabwe	Disaster risk reduction

## Appendix I : Updates and Maintenance of Rating Curves (Mozambique)

One of the key elements for BUPUSA FFEWS is related to very outdated rating curves which can make difficult appropriate calibrations. ARA-Centro is updating the rating curves for Buzi SAC stations. However, the main problem is related to logistics problems and lack of equipment and vehicles to undertake regular flood measurements (specially for peak flows) to update rating curves. For example, the assessment made in Mozambique was able to conclude that: DGBS (Save River Basin Management Division) have capacity in terms of vehicles and technicians but doesn't have equipment. They have to request the Limpopo division in Chokwe for flow measurement equipment.



**Figure J-1: Available equipment for flow measurements at at DGBS**

DGBP (Pungwe River Basin Management Division) on contrary have benefit from PP2 project and Blue Deal project support in terms of equipment, but they don't have vehicles and boats to do measurements during flood season and update rating curves.



**Figure J-2: existing equipment at DGBP**

DGBB (Buzi River Basin Management Division) is new and they lack both in terms of cars, equipment and human resources. They are about to hire one hydrologist and receive one technician from ARA-Centro headquarters (Tete).

All divisions relies on the ARA's headquarters for funding their activities. Besides, DGBB, other divisions reported that lack of autonomy sometimes makes difficult to perform their activities. Most field campaigns are subject to financial cuts or delays.

As conclusion remark regarding the Designing of the BUPUSA FFEWS, it can be said that it can be made. The main challenge will continue to feed the system continuously with reliable data because of the above challenges. The feasibility study doesn't not include financial implications to the implementation of BUPUSA FFEWS to the institutions. Their current operations are still facing financial constrains even for data collection and management.

## Appendix J : Stakeholder Meetings in the Inception Phase

### Mozambique

Mr. Francisco Saimone visited the following River Basin Management Divisions to collect most updated hydrometeorological data and reports:

- In Beira on the 19 September, working with Mr. Castro Ntemansaka Junior and staff of the Department of Water Resource Operational Management.
- In Chimoio on 20 September, working with Mr. Daniel Batista and staff of the Department of Water Resources Operational Management;
- In Maxixe on 22 September, working with Mr. Gimo Macaraingue and staff of the Department of Water Resource Operational Management.

Dr. Dinis Juízo established contacts with INGD, DNGH in Maputo to collect information.

- INGD is implementing a national programme to invest in infrastructure for last mile information dissemination. The system will be tested in Limpopo, Buzi, Pungwe and Zambezi basins to disseminate disaster related information that will improve the disaster management in the country:
- INGD is initiating a technical platform for continuous communication between the key institutions involved in disaster management. This is necessary because of the permanent and cyclic nature of disaster, in any given year the country is involved in management floods, drought or both. Thus continuity in disaster management is necessary and the country is now asked to move from the ha-doc nature of operation to more permanent. Buzi and Pungwe are important basins that INGD wants to work on specially after the Idai events.

**Table 12-1 : Contacts made with Stakeholders in Mozambique**

Stakeholder	Category (Government / Civil Society / Private Sector / Community)	Role (data provider / disaster management / beneficiary)	Contact Person	Interviewed (yes/no)	Comments / outcomes
Department of Operational Management of Water Resources of Pungwe River Basin Management Division (DGBP)	Government	Water resource management	Castro Ntemansaka Junior (Chief)	Yes	The main objective was to obtain most updated hydroclimatological data, understand the current practice in terms of flood early warning system, verify their (human, material and financial) capacity to undertake their functions.  The Consultant worked in the technical department collecting available data and observed the existing equipment and vehicles.

Stakeholder	Category (Government / Civil Society / Private Sector / Community)	Role (data provider / disaster management / beneficiary)	Contact Person	Interviewed (yes/no)	Comments / outcomes
					The expectation of the technicians in relation to the assignment were discussed. The main constrains was related to lack of vehicles and boats to conduct flow measurements. The division received modern equipment from PP2 project and Blue Deal project, but lack of vehicles. Other constraint is related to financial resources to undertake measurements.
Section of Administration (DGBP)	Government	Water resource management	Marilia Bule (Chief) Dionicia Marques	Yes	A meeting was held with the human resources sector in order to obtain the list of person involved in flood management by age, qualifications, and experience in flood modelling. Although most of the activity is related to data collection, the unit have people that had contact with HEC-HMS. But modelling activity is mostly being implemented at ARA and DNGRH level.
Department of Operational Management of Water Resources (DGBB)	Government	Water resource management	Daniel Batista (Chief)	Yes	<p>This is a new division and it is still in the organization process after the recent institutional arrangement.</p> <p>Two meetings were undertaken with technical department and human resources.</p> <p>On human resources were requested the list of all workers per department, sex, age and position. The administrative department is also responsible for planning. They requested to participate in the field trip to have a better understanding on the work done in the field. Sometimes they respond negatively to the requests from the technical department because they lack of information on the need for those resources.</p> <p>On the technical department existing updated data were collected from different excel spreadsheets. Divisions does not a database. Data are stored in</p>

Stakeholder	Category (Government / Civil Society / Private Sector / Community)	Role (data provider / disaster management / beneficiary)	Contact Person	Interviewed (yes/no)	Comments / outcomes
					<p>different computers in various excel spreadsheets. Their main goal is to manage data collection and transfer to ARA. Actually they lack of technical people, only 2 permanent and 1 intern is working in the division. They also have a technical unit in the dependency located in Dombe. It is in the process of receive one hydrologist from the ARA-Centro headquarter.</p> <p>In terms of equipment, they lack of vehicles and equipment. They depend mostly to Pungwe division and ARA-Centro headquarter to collect flow data. ARA-Centro team is currently updating the rating curves of Buzi key stations, particularly because most of sections are completely modified after cyclone IDAI.</p>
Section of Administration (DGBB)	Government	Water resource management		Yes	
Save River Basin Management Division (DGBS)	Government	Water resource management	Gimo Macaringue (Director)	Yes	<p>The meeting was held with the director of division and all technical team. The Consultant was informed in terms of the existing staff, data, equipment, vehicles and financial resources allocated to the division to perform the tasks.</p> <p>In general, this division is operating for some time but now responding to ARA-Sul, in the recent past Save belonged to ARA-Centro. The technical staff at least know about the existence of the HEC-HMS. It is not being implemented at the division level. The division have adequate vehicles but has lack of flow measurement equipment. Their equipment only</p>

Stakeholder	Category (Government / Civil Society / Private Sector / Community)	Role (data provider / disaster management / beneficiary)	Contact Person	Interviewed (yes/no)	Comments / outcomes
					measures low flows. They have to request equipment to Chokwe (Limpopo Division) to undertake field campaigns. Another constraint is related to financial resources to do the measurements.
ARA-Centro	Government	Water resource management	Francisco Macaringue – Head of Technical Department	Yes	This interview was done telephonically and complemented with personal interview during pre-season flood meeting. The objective was to obtain relevant data for flood modelling and existing modelling at ARA-Centro level. There are more technical capability in terms of flood modelling at ARA-Centro. Their experience with limited information generate forecast and support decision making. It was informed that there is a HEC-HMS model setup running at DNGRH.

## Zimbabwe

Dr Makurira established contacts with the focal points and visited Harare and Mutare, also to complete the collection of information.

Table 12-2 : Contacts made with Stakeholders in Zimbabwe

Stakeholder	Category (Government / Civil Society / Private Sector / Community)	Role (data provider / disaster management / beneficiary)	Contact Person	Interviewed (yes/no)	Comments / outcomes
Ministry of Lands, Agriculture, Water, Fisheries	Government	Hosts Departments of Water, Agriculture	Permanent Secretary	No	

and Rural Resettlement					
Department of Climate Change Management	Government	National and International Climate Change Management programmes	Mr W Zhakata	Yes	They do not have a tool that they are using. They are however, interested in climate change science, impacts and mitigation strategies at local and regional scale
Meteorological Services Department	Government	Weather Forecasting, Custodian of Meteorological data	Mr J Ngoma	Yes	Zimbabwe has recently launched the Zimbabwe Flood and Drought Monitor (FDM) which was developed with collaboration with Princeton University and University of Southampton and funded by UNESCO (IHP). This is open access and predicts floods to seven days and droughts to six months. Other previous efforts have not been very successful because of licencing requirements which discourages access by many stakeholders
Zimbabwe National Water	Quasi- Government	Collection and processing of	Chief Executive Officer, Catchment		There is currently no working tool that is in place to

Authority (ZINWA)		hydromet data, water infrastructure planning and development	Managers for Save and Runde Mr H Chengeta (Hydrologist)	Yes	monitor high flows in rivers. However, near real-time runoff monitoring stations have been set up in the Muzarabani and Mbire Districts. Similarly, stations have been set up in the Chimanimani and Chipinge Districts in the Eastern Highlands which are prone to floods. There is need to translate real time observed flows to flood hazard mapping on real time basis to timely activate disaster management strategies. Near real-time stations in the Pungwe catchment require upgrade and installation of a new logging system.
Environmental Management Agency (EMA)	Quasi- Government	Management and conservation of the land, water and other natural resources	Director General/Provincial Managers for Manicaland and Masvingo	No	
Save Catchment Council	Stakeholder Water Management Institution	Water allocation and management of	Council Chairman	No	

		water resources in the catchment			
Save Catchment Council	Stakeholder Water Management Institution	Water allocation and management of water resources in the catchment	Council Chairman	No	
Provincial Government Officers District Councils	Local Government structures	Planning and development of projects in the Districts including Civil Protection	Provincial Administrators District Administrators	No	
Civil Protection Unit	Government	Monitoring and implementation of relief measures against natural disasters	Director of Civil Protection	No	
Institutions of Higher Learning	Quasi-Government	Research	Research Directors		
Chiefs and Headmen	Traditional Leadership	Indigenous knowledge	Chiefs and Headmen		
Ministry of Lands, Agriculture, Water, Fisheries and Rural Resettlement	Government	Hosts Departments of: Water, Agriculture	Permanent Secretary		

Department of Climate Change Management	Government	National and International Climate Change Management programmes	Mr W Zhakata		
Meteorological Services Department	Government	Weather Forecasting, Custodian of Meteorological data	Director		
Zimbabwe National Water Authority (ZINWA)	Quasi- Government	Collection and processing of hydromet data, water infrastructure planning and development	Chief Executive Officer, Catchment Managers for Save and Runde		
Environmental Management Agency (EMA)	Quasi- Government	Management and conservation of the land, water and other natural resources	Director General/Provincial Managers for Manicaland and Masvingo		
Save Catchment Council	Stakeholder Water Management Institution	Water allocation and management of water resources in the catchment	Council Chairman		
Save Catchment Council	Stakeholder Water Management Institution	Water allocation and management of water resources in the catchment	Council Chairman		

Provincial Government Officers District Councils	Local Government structures	Planning and development of projects in the Districts including Civil Protection	Provincial Administrators District Administrators		
Civil Protection Unit	Government	Monitoring and implementation of relief measures against natural disasters	Director of Civil Protection		
Institutions of Higher Learning	Quasi-Government	Research	Research Directors		
Chiefs and Headmen	Traditional Leadership	Indigenous knowledge	Chiefs and Headmen		

## Appendix K : Preliminary Research Questions and Indicators for Capacity Building Assessment

	Research Question	Indicator	Degree <sup>11</sup>
A. Organizations			
1.	<b>GENERAL INFORMATION</b>		
	Name Address Type of organisation		
2.	<b>FUNCTION</b>		
	Does the required function of the organisation as defined in analysis of mandates & functions coincide with the actual function  a. As described in the organizations' statutes  b. As perceived by senior management	Required function coincides with actual function  a. according to statutes  b. as perceived by senior management	5/4/3/2/1  5/4/3/2/1
	Describe the discrepancies in required and actual functions		
	What actions are required to adapt the organisations' function		
3.	<b>CAPACITY</b>		
	Compare the required capacity as defined in for this type of organisation with the actual capacity  a. as shown in the organization structure  b. actual staffing capacity	Actual capacity coincides largely with the required capacity:  a. as shown in the organisation structure  b. actual staffing capacity	5/4/3/2/1  5/4/3/2/1
	Describe the discrepancies in required and actual capacities		

<sup>11</sup> 5:highest, 1: lowest

	What actions are required to adapt the organisations' capacity		
4.	<b>INSTITUTIONAL ENVIRONMENT</b>		
	Are laws and regulations regards sufficiently known? Flood forecasting Strategy	<ul style="list-style-type: none"> <li>• Main laws and regulations are known by the responsible persons in the organisation</li> </ul>	5/4/3/2/1
	Are proper procedures for FFEWS in place? Guidelines	<ul style="list-style-type: none"> <li>• Guidelines are available and</li> <li>• Known by the responsible persons</li> </ul>	5/4/3/2/1 5/4/3/2/1
	Inter-institutional coordination	<ul style="list-style-type: none"> <li>• Coordination Mechanisms are sufficiently available</li> <li>• Flow of relevant information is satisfactory</li> </ul>	5/4/3/2/1 5/4/3/2/1
	Describe the main constraints in the institutional environment		
	What actions are required in the domain of institutional environment?		
5.	<b>MANAGEMENT</b>		
	<ul style="list-style-type: none"> <li>• Is the management structure (hierarchy) clear to all staff members</li> <li>• Are job descriptions available for all professional staff?</li> <li>• Are management decisions clear to all staff members</li> <li>• Do coordination meetings take place regularly</li> <li>• Is there a clear staffing (promotion) policy available and being implemented?</li> </ul>	<ul style="list-style-type: none"> <li>• Clear management structure (organigram)</li> <li>• Tasks &amp; responsibilities staff clear</li> <li>• Transparent management</li> <li>• Good internal coordination</li> <li>• Good promotion policy implemented</li> </ul>	5/4/3/2/1 5/4/3/2/1 5/4/3/2/1 5/4/3/2/1 5/4/3/2/1 5/4/3/2/1

	<ul style="list-style-type: none"> <li>Is there a clear salary structure available and implemented?</li> <li>Is the financial management structure in place and implemented?</li> </ul>	<ul style="list-style-type: none"> <li>Clear salary structure available</li> <li>Financial management transparent</li> </ul>	5/4/3/2/1
	Describe the main constraints in the management of the organisation		
	What actions are required to improve the management of the organisation.		
6.	<p><b>SUPPORT</b></p> <ul style="list-style-type: none"> <li>Does the organisations have sufficient financial resources to <ul style="list-style-type: none"> <li>a. Make the investments related to the organisation tasks?</li> <li>b. Cover the organisation recurrent costs? <ul style="list-style-type: none"> <li>Does the organisation have sufficient equipment to properly implement the tasks</li> <li>Does the organisation have sufficient transport to implement the tasks</li> </ul> </li> </ul> </li> </ul>	<p>Organisation has sufficient support in terms of:</p> <ul style="list-style-type: none"> <li>Financial resources for investments</li> <li>Financial resources for recurrent costs</li> <li>Equipment</li> <li>transport</li> </ul>	5/4/3/2/1 5/4/3/2/1 5/4/3/2/1 5/4/3/2/1
	Describe the main constraints in support to the organisation		
	What actions are required to improve the support to the organisation.		
	A. Skills		
	<b>Research Question</b>	<b>Indicator</b>	<b>Degree</b>

1.	<b>GENERAL</b> Organisation Position		
2.	<b>EDUCATIONAL BACKGROUND AND EXPERIENCE</b> <ul style="list-style-type: none"> <li>• Have the educational and experience requirements been defined for this position?</li> <li>• Does the educational background and experience match with the requirements of the position?</li> </ul>	<ul style="list-style-type: none"> <li>• Educational background defined</li> <li>• Staff member has educational background and experience as required</li> </ul>	5/4/3/2/1  5/4/3/2/1
3.	<b>JOB DESCRIPTION</b> <ul style="list-style-type: none"> <li>• Has a job-description been defined for this position</li> <li>• Has the staff member knowledge of the job-description</li> <li>• If no job description: has the staff member a good perception of his/her tasks</li> <li>• In the opinion of the staff member: do his educational background and experience fit with the job description and/or tasks assigned</li> </ul>	<ul style="list-style-type: none"> <li>• Well defined job description available</li> <li>• And well known by the staff member</li> <li>• Good perception of task required</li> <li>• Staff member finds him/herself suitable for the tasks assigned.</li> </ul>	5/4/3/2/1  5/4/3/2/1  5/4/3/2/1  5/4/3/2/1
	Make an overall assessment of the suitability of the staff member for this position and describe the main reasons for your judgement	<ul style="list-style-type: none"> <li>• Staff member suitable for this position</li> </ul>	5/4/3/2/1
4.	<b>SKILLS</b>		

	Describe the main skills required for this position and assess whether the staff member possesses these skills adequately	<p>Staff member:</p> <ul style="list-style-type: none"> <li>• Has sufficient skills for this position</li> <li>• Has insufficient skills, but could improve performance through training</li> <li>• Has insufficient skills and is not suitable for this position</li> </ul>	<p>5/4/3/2/1</p> <p>5/4/3/2/1</p> <p>5/4/3/2/1</p>
	Describe what actions (if any) should be taken to improve the skills of staff member		
5.	<p><b>CONSTRAINTS</b></p> <p>Assess the main constraints encountered by the staff member in exercising his/her tasks and categorize these</p>	<p>Constraints in exercising staff members task are related to the organisation's:</p> <ul style="list-style-type: none"> <li>• Function</li> <li>• Capacity</li> <li>• Institutional Environment</li> <li>• Management</li> <li>• Support</li> </ul>	<p>5/4/3/2/1</p> <p>5/4/3/2/1</p> <p>5/4/3/2/1</p> <p>5/4/3/2/1</p> <p>5/4/3/2/1</p>
	Describe what actions could be undertaken to mitigate the encountered constraints.		