Flash Floods Study

(Final report)

FLOOD FORECASTING AND EARLY WARNING ENHANCEMENT PROJECT

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ENTRO is an organ established to implement the Eastern Nile Subsidiary Action Program within the framework of Nile Basin Initiative

Egypt, Ethiopia, South Sudan, Sudan

EXECUTIVE SUMMARY

This is the final report of the Flash Floods Consultancy for the EN basin. The report discusses the flash floods situation in the EN countries, flood types, flash floods prone sites, existing flood EWS, mitigation measures and ends up with guide lines for developing effective flash floods EWS to reduce the loss in human lives and properties in the region.

Two types of flash floods were observed in the EN basin; riverine flash floods and storm flash floods. Most of the flash floods in EN are as a result of torrential rainfall for short period of time. Flash floods prone sites were delineated; most of the flash floods prone areas are urban areas across wadi systems and along the River Nile floodplains.

The dominant trend of floods management practices in EN is only concentrated on the course of major rivers, high rainfall in tributary river and seasonal wadi has been an area that not always received adequate focus. This effect needs to be kept in view while preparing flood management plans at state/ provincial/regional level. Structural and non-structural flood mitigation measures are practiced in the region. The main structural measures are flood protection works such as embankment, levees, earth dams and river training works. The non-structural measures like floodplain mapping, preparedness, and flood EWS.

In the backdrop of increasingly alarming flash floods risk in the EN member states, it is necessary to design new development and coping strategies; modify the existing ones and make flash floods risk management an integral part of development plans. The existing structural flood management system in the EN region should be reviewed in the present flood risk perspective. The watershed and flood management practices in the countries need to be reviewed and evolved keeping in view the high rates of urban growth and stress on land use patterns. The land use plans should be based on intensive assessment of flood risk in the region and it would be a better idea to make the land use plans based on multi hazard risk assessment for sustainable use of economic resources for development. The infrastructure and plans in major cities should be reviewed at regular intervals and should be designed to make room for improvements in future. The existing plans should be upgraded to withstand flash floods risk.

This report has raised many critical gaps, community awareness regarding flash floods gaps, hydro-meteorological data gaps, capacity building gaps, institutional arrangement and communication between different stakeholder's gaps. The major gap raised by this report is absent of flash flood forecast and early warning system.

Regarding the hydro-meteorological capacity, ground-based meteorological networks often have incomplete observations that commonly are available at point scale and fixed intervals, the network coverage is sparse, especially in flash flood prone areas. There were gaps in hydrological data, most of the flash floods were from isolated rainstorm, many wadis and khores which carry the generated runoff are ungauged.

Flood Early Warning Systems are well installed and established for most of the river systems in the EN, but is in the sub-basin that there are no unified operational flood forecasting & and early warning system in the whole EN. Currently, ENTRO implementing a project for enhancing the existing FEWS to cover the entire basin. The FEWS systems are mainly depending on the monitoring and forecasting of the rainfall on the upper catchment. WRF model is commonly used for rainfall forecast in EN, new WRF model was developed for the entire EN. The newly developed model will contribute a lot to the flash floods forecasting and EWS.

Hydrological models based on HEC-HMS are used for rainfall-runoff transformation, while hydraulic models (HEC-RAS and USGS- Global Flood Tool) for flood routing and inundation extend. The main source of input rainfall forecast is provided by Local Meteorological Authorities, ENTRO and IGAD Climate Prediction and Applications Centre (ICPAC) in Nairobi. Most of this information is related to riverine forecast not flash flood forecast.

Making the vulnerable communities aware of flash floods risk is a major area of focus. A multi prong approach for spreading awareness: through print and electronic media, distribution of information material, community workshops, street shows should be made an intrinsic part of DRR activities in the EN countries in the context of flash floods risk management. The preparedness, rescue and relief contingency plans should have special emphasis on the vulnerable segment of the communities likely to be affected by floods: the poor, old, women, pregnant, children and the disabled.

Flash floods EWS worldwide and regionally were reviewed. There is a rich experience in the field of flash floods EWS, the Flash Floods Guidance System (FFGS) was found to be the best state-of-the-art technique for global application for flash floods forecast and EWS. Few limited instance of flash floods EWS were observed in the EN, these instance are site-specific and as a result of research projects; One case in Egypt for wad Watier and another case in Sudan for Gash river.

Guide lines for developing effective flash floods EWS for the EN were proposed. Two types of flash floods EWS is suggested; Local and Regional flash floods EWSs. The local flash floods EWS is a site-specific, it is based on the hydrodynamic modeling. Fortunately, all the software and models used by ENTRO to address riverine flood are applicable for the flash floods modeling. For regional flash floods EWS, the global Flash Floods Guidance System (FFGS) is proposed to be implemented in the EN basin. The global FFGS is based on the monitoring and watching of weather condition over the region using remote sense data, it gives necessary warnings for imminent flood risk.

One of the major areas of future focus should be the exchange and transfer of collaborative exercises to improve the existing flash floods risk management and preparedness mechanism in the region. The indigenous knowledge available with the communities in EN has been very effective in historical and ancient times in protecting the villages and towns from flood risk. It is imperative to document the wealth of indigenous knowledge available in the region and integrate them into the developmental and management plans of the flood prone areas.

Mainstreaming Disaster Risk Reduction (DRR) into the developmental plans is recommended for long term flood risk resilience in the risk prone areas at national, regional and local level. Application of DRR in flood management will have great impact on rapid recovery, rehabilitation, reconstruction and economic growth.

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ABBREVIATIONS AND ACRONYMS

BAS	Baro-Akobo-Sobat
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
EN	Eastern Nile
ENTRO	Eastern Nile Technical Regional Office
EWS	Early Warning System
FEWS	Flood Early Warning System
FFEW	Flood Forecast and Early Warning

FFGS	Flash Flood Guidance System
HAD	High Aswan Dam
HEC-HMS	Hydraulic Engineering Center's-Hydrologic Modeling System
HEC-RAS	River Analysis System
HRC	Hydraulic Research Center
GIS	Geographic Information System
GSMaP	Global Satellite Mapping of Precipitation
ICPAC	IGAD Climate Prediction and Applications Centre
IPCC	Intergovernmental Panel on Climate Change
ISFF	International Symposium on Flash Floods
JICA	Japan International Cooperation Agency
MoIWR	Ministry of Irrigation and Water Resources (Sudan)
MWRI	Ministry of Water Resources and Irrigation and (Egypt)
NDMA	National Disaster Management Authority
NFC	Nile Forecast Center
NFS	Nile Forecast System
NGOs	Non-Governmental Organizations
NMA	National Meteorological Authority
NMHSs	National Meteorological and Hydrological Systems
NOAA	National Oceanic and Aeronautics Agency
SREs	Satellite Rainfall Estimates
TRMM	Tropical Rainfall Measuring Mission
UN	United Nation
UNESCO	United Nation Education, Sciences and Culture Organization
UNICEF	United Nation International Children Emergency Funds
USGS	United States Geological Survey
WHS	World Heritage Sites
WMO	World Meteorological Organization
WRF	Weather Research and Forecasting model

Chapter 1: INTRODUCTION

1.1. Background

On the global scale the number of recorded extreme events of flash flood and droughts have increased significantly over the last 50 years representing the greatest rise of all natural disasters. Recent studies using climate models, predict that through climate change and variability as a result of global warming, the hydrological cycle will become more intensified resulting in more weather extremes hence more flood and drought events (IPCC, 2012). To date, despite the great advancement in flood and drought management, we still experience catastrophic losses of human life, livelihoods and property as a result of these extremes every year. It is understood that flood risks will not subside in the future, the situation is worsening each year. History shows that communities that fail to recognize and adequately plan for these hazards can suffer horrendous losses in life and property, as well as response and post-disaster clean-up costs that decimate federal, state and local protection budgets.

In response to the frequent flash floods phenomena that striking The Eastern Nile (EN) basin countries, Eastern Nile Technical Regional Office, located in Addis Ababa, Ethiopia, has taken the initiative to address the flash floods in the region. The EN basin consisting of Egypt, Ethiopia, South Sudan and Sudan, and with a population of over a quarter of a billion inhabitants (expected to double in less than two decades) is perhaps the most important part of the Nile Basin. Its significance is not only because of its geo-hydro-political relevance or the fact that it is home to over half the population of the entire Nile Basin (important as these are), but also because of the hydrological significance of the river Nile that courses through it.

The ENB has been the site of the some of the most advanced civilizations of the ancient world. The annual Nile flood that carried fertile sediment from the Ethiopian Highlands transformed the deserts of Sudan and Egypt into rich agricultural lands along its course. Apart from the Nile River itself, the ENB encompasses an extraordinary range of ecosystems from high mountain moorlands, montane forests, savanna woodlands, extensive wetlands and arid deserts. Within the ENB, most of the people in Ethiopia, Sudan and the newly-independent South Sudan are rural, depending largely on the natural resource base for their livelihoods, while in Egypt nearly half the population is urbanized, although the Nile provides the basis for agriculture, power generation and water transport. The richness of the natural and human resource base notwithstanding, the basin's peoples face huge challenges:

The ENB with these huge wealth of natural resource, frequently suffer frequent flash floods disasters, which endangering its future development and resources potential. The existing Flood Forecasting and Early Warning (FFEW) address and covers only riverine flooding for selected flood prone areas. While evidence shows significant portion of the Eastern Nile basin is frequently affected by flash floods. Flooding events in 1998, 2006, 2010, 2013 and 2014 in different parts of the basin has shown as urbanizing grows many more areas in the basin are expected to be affected by more frequent flash floods. Therefore, is necessary to start assessing the vulnerable areas for flash flood and develop strategies to implement a system that mitigate flash flood threat.

1.2. Objectives of the Consultancy Service

The overall objectives of this consultancy work are to assess the extend and identify types of flash flood in Eastern Nile basin and to develop guide lines for effective flash floods early warning system to minimize loss of life and infrastructure damage.

The specific objectives are:

- ✓ Mapping of frequent flash flood prone areas in EN basin.
- ✓ Identify types of flash floods in EN basin
- ✓ Guide line on availability of flash flood early warning system in EN basin.
- ✓ Development of guide line to be implemented for development of flash flood early warning system in EN.

1.3. Scope of the Consultancy Service

The study can be achieved through three tasks as given in TOR (Annex B), and as detailed below:

Task I: Flash flood assessment; review flash flood event in the ENB. Carry out a study on classifying types of floods, map out sub catchments with frequents flash floods occurrence. Assess the current hydro-meteorological infrastructure in these sub catchments and any existing early warning systems. Assess current practice to mitigate flash floods. Identifying flash flood measures before, during and after floods.

Task II: Guideline to address flash flood; review both regional and international methods in addressing flash flood with proper forecast and early warning system. Develop a guideline to ensure up to date methodology that can be adopted with for ENB to address flash flood of different types. Identify the best practices for short, medium and long term relief activities. Provide policy advice in relation to flash flood management in ENB for the different relevant stakeholders and institution involved in flash flood.

Task III: Capacity building activities.

1.4. Methodology of the Study

A qualitative methodological approach was adopted based on the scope of work, objectives, criteria and deliverables of the Study. The study mainly focused on mapping of frequent flash floods sites, the current practice in flood & flash floods early warning system, assessment of hydro-meteorological capacity and mitigation measures in EN and development of guide lines to address flash floods.

Primary and secondary data were collected. The primary data was gathered through face-to-face and telephone interviews with key informant including officials, experts, and researchers involved in flood forecasting and early warning. Secondary data was obtained through reviewing of documents including ENTRO reports, government reports, NGO's reports, books, internet, and other published and unpublished documents.

A questionnaire was designed to collect Key information such like;

- ✓ Questionnaire regarding the flash floods; Availability of flash floods EWS, institutions responsible for EWS, data providers, communication methods.
- ✓ Questionnaire regarding the floods mitigation measures; Structural/non-structural, effectiveness of the measure used.

- ✓ Questionnaire regarding flood affected areas and communities; which area are frequently flooded, how frequent and long it was flooded.
- ✓ Questionnaire regarding hydro-met data, density of network, frequency of records etc.

1.5. Structure of the Report

This report gives a detailed description of flash floods situation in the EN with special focus on the flash floods prone sites, management and mitigation measures used, existing EWS and proposed guide line to develop effective flash floods EWS in the region. The report consists of eight Chapters as follows:

The current chapter (Chapter 1) is a general introduction about the consultancy, its rationale, objectives and methodology.

Chapter 2; Discusses the flash floods science, definition, types, causes and consequences etc.

Chapter 3; Presents different flash floods prone sites in the EN.

Chapter 4; Discusses the different management and mitigations practices in the region and worldwide.

Chapter 5; An overview of the existing hydro-metrological stations and the gaps in EN.

Chapter 6; Discusses flood early warning systems, definition of EWS, elements of EWS and the existing FEWS in the EN.

Chapter 7; is a review of the existing flash floods EWS in the region and worldwide, and guide lines for developing effective flash floods EWS for the EN.

Chapter 8t; is the conclusion and recommendations of the report.

Chapter 2: FLASH FLOODS SCIENCE

2.1. Definition of Flash Floods

A flood, in general, occurs when water overflows or inundates land that's normally dry. The flash flood can be defined as "a flood of short duration with a relatively high peak discharge" (WMO-UNESCO, 1974). More extensive definition was given by the National Weather Service of the USA, "a flash flood is a flood that follows the causative event (excessive rain, dam or levee failure, etc...) within a few hours". Two essential differences between a flash flood and a normal flood can be distinguished: the speed with which it occurs and the time interval between the observable causative event and the flood, which is less than four to six hours. The six-hours duration is generally proposed as the best 'break point duration' between a normal flood and a flash flood. This means, in particular, that the standard and conventional flood warning techniques, models and organizations are not suitable for use with flash floods. The two best words describe a flash flood and its hydrographs are "Sharp and unexpected". In this respect, it is usually difficult to forecast because the time to peak is very short and the rate of flood rise is very great.

2.2. Flash Floods Causes and Consequences

Flash flood can happen in a multitude of ways, most common from excessive rainfall, failure of hydraulic infrastructure, rapid ice melting in mountainous region and even an unfortunately placed beaver dam can overwhelm a river and send it spreading over adjacent flood plain. Coastal flooding occurs when a large storm or tsunami causes the see to surge.

Flash floods occur throughout the world, and the time thresholds vary across regions from minutes to several hours. The time duration of flash flood depends on many factors; land surface, geomorphological, and hydro climatological characteristics of the region. However, for the majority of these areas there exists no formal process for flash flood warnings, there is a lack of general capacity to develop effective warnings for these quick response events.

In the ENB e.g., Floods is caused by two sources; River flooding, i.e., high waters spell over the banks, and flash floods caused by torrential storm rainfall over rural or urban areas. Although it is difficult to assess accurately the flood damage, in particular in far past, huge flood damages were reported during high rain storms. Damage consists of; loss of human lives, loss of agricultural lands (crops and fruit trees along the rivers banks), loss of live stocks, damages to building, infrastructures and public services. High floods, usually accompanied by spread of diseases and outbreak of epidemics such like (Malaria, diarrhea, bilharzias, and other water borne diseases).

Sometimes flash floods cause more damage than river floods. In 2007 in Sudan, while river flooding is below critical level, the torrential rainfall over Sudan brought what the Sudanese Government called the worst flash floods in living memory. The United Nations reported large damages in different States: half million people affected, 64 people died, and about 30,000 houses destroyed (source: Sudan Floods-Bulletin# 2, United Nations, 2007).

2.3. Differences Between Flash Floods and Normal Floods

The distinctive feature of the flash flood is the rapid rising of its hydrograph (figure 1). The hydrograph of a flash flood is very sharp, with peak discharge higher than for normal floods and with the total flood volume quite small. The rising and falling limbs of the hydrographs of flash floods are very steep, with time-to-peak generally not more than 1 to 6 hours. Natural flash floods generally occur on catchments of small to moderate size whereas normal floods may occur at any type of catchment.

Flash floods frequently occur in basins with large impermeable areas, sparse vegetation, and steep slopes. Flash floods happen very suddenly and are usually difficult to forecast. The damages incurred are often very serious, including loss of human life. Normal floods can be forecast to give some warning and thus a certain amount of protection. Flash floods generally arise from extreme rainfall events and intensities. In arid and semi-arid areas, the meteorological and hydrological regime is conducive to flash flood generation.

Governments in all countries of the world are paying increasing attention to research into flash floods. There is a shortage of hydrological and meteorological data, hydrological research is very deficient. Flash flood research is becoming increasingly important, particularly with regard to improved data collection techniques, defining flash flood types and the reasons for their formation, properties, and spatial and temporal distribution, forecasting techniques and warning system.

2.4. Characteristics of Flash Floods

2.4.1. Suddenness of occurrence

Flash floods generally result from high-intensity storms of limited area1 extent or perhaps through a glacier-dammed lake outburst. The time to peak may be only a few hours or even tens of minutes. Conventional forecasting methods cannot provide adequate warning and people have insufficient time to move away from the floods. Floods arising from glacier-dammed lake outbursts are similar to dam-break floods but the suddenness is more significant.

2.4.2. Randomness of area1 distribution

The number of flash floods in large arid and semi-arid zones is not insignificant the frequency of occurrence is indeed very small, perhaps only once in many years. Although flash floods at specific sites and during a certain period occur for specific reasons, the area1 distribution is statistically random .

2.5. Types of Flash Floods

Flash floods can be considered under five categories based on the type of causative event:

- ***River flash floods*** (when rivers overflow and inundates the surrounding areas). It usually originates from heavy rainfall in the upper catchment, which causes unpredictable surges in the rivers.
- ***Heavy rain flash floods*** (storm flash flood), which is generally short in duration and can cause major damage in villages and urban areas.
- ***Dam Break***, this rarely happen because of comprehensive risk analysis and dam safety.
- ***Snow melting***, particularly in polar regions
- ***Tsunamis and surges*** due to oceanic cyclones and earth quake

The first and second types of flash floods are predominant in the Eastern Nile Basin. River floods were much discussed and well covered in the Eastern Nile Basin. FFEW was developed and well established for most of the riverine system of River Nile (Verkade & Werner, 2010). This report will intensively discuss *Storm Flash floods* and EWS in the ENB.

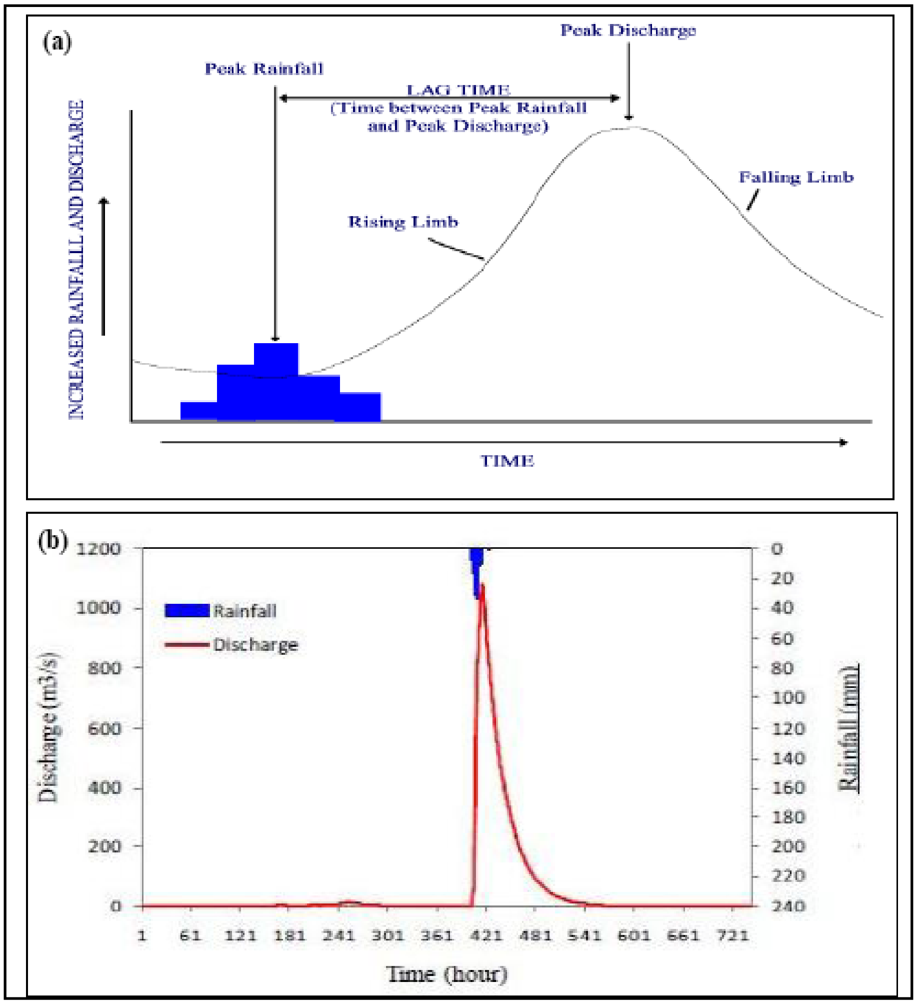

Figure 1: Typical normal food hydrograph (a) and flash flood hydrograph (b)

2.6. Strom Flash Floods

Floods are natural phenomena that have always been an integral part of the geological history of the earth. Flash Floods occur along the rivers, streams, and lakes and coastal areas, in alluvial fan, in ground-failure areas such as subsidence, in areas influenced by structural measures, and in areas having inadequate urban drainage systems (Satish et al., 2009).

In the ENB e.g., Floods is caused by two sources; River flooding, i.e., high waters spell over the banks, and flash floods caused by torrential storm rainfall over rural or urban areas. Sometimes storm rainfall flash floods cause more damage than river floods. In 2007 in Sudan, while river flooding is below critical level, the torrential rainfall over Sudan brought what the Sudanese Government called the worst flash floods in living memory. The United Nations reported large damages in different States: half million people affected, 64 people died, and about 30,000 houses destroyed (source: Sudan Floods-Bulletin# 2, United Nations, 2007).

Although it is difficult to assess accurately the storm flood damage, in particular in far past, huge flood damages were reported during high rain storms. Damage consists of; loss of agricultural lands (crops and fruit trees along the rivers banks), loss of live stocks, damages to building, infrastructures and public services. High storm floods, usually accompanied by spread of diseases and outbreak of epidemics such like (Malaria, diarrhea, bilharzias, and other water borne diseases).

2.6.1. Causes of storm flash floods

The causes of storm flash floods may be broadly categorized as natural and anthropogenic.

Natural causes are:

i) High intensity rainfall
ii) Erratic spatial distribution of rainfall
iii) Inflows from rivers in the urban drainage system during high stages.
iv) General topography (slopes) of the land surfaces.
v) Orientation and movement of the rain storm.

Anthropogenic causes are:

i) Increase in imperviousness due to urban growth results in large quantities of storm water.
ii) Unplanned settlement which leads to obstruction of natural waterways.
iii) Inadequately and improperly designed drainage system.
iv) Human behavior which leads to blockage of drainage system

2.6.2. Impact of storm flash floods

The impacts of storm flash flooding can be summarized as follows:

i) Direct damages, i.e., the damage caused to human lives and the property due to increase in velocity of flow and depth of inundation.
ii) Indirect damages, i.e., damages due to disruption of services and its consequences such as the loss incurred due to traffic disruptions, administrative costs involved in bringing back the normalcy of the life, poor turnout in industries leading to productivity loss, spread of epidemic etc.
iii) Long term damages due to social consequences, like delays in economic development and low property value in frequently flooded regions.
iv) Flash floods represent a constraint on regional development.
v) Major source of erosion and pollution.
vi) Environment, health and socioeconomic impacts include; loss of life and properties, displacement, lack of clean potable water due the collapse of pit latrines that pollute the water and so enhancing the spread of diseases such as diarrhea and cholera.

Chapter 3: FLASH FLOODS PRONE AREAS IN EASTERN NILE BASIN

3.1. Introduction

Heavy rainfall and runoff of the large volume, improper land use and the absence of scientific soil conservation practices are identified as the major factors for flash floods in EN basin. Urbanization with the insufficient infrastructure facilities such as drainage system triggers the urban flash floods together with global phenomena like climate change, which has increased rainfall intensities. The increase in population and subsequent need for land have forced more and more people to live and work in these vulnerable areas, thereby intensifying the risk to life and property in the event of major floods

The Eastern Nile constitute all rivers that originate in the Ethiopian highlands and flow towards the main Nile in the west. Four sub-basin systems that make up the Eastern Nile namely; the Main Nile, the Blue Nile, the Tekezze-Atbara, and the Baro-Akobo-Sobat. Figure 2 shows these sub-basins and their major tributaries and flood prone sites, details of sub-catchment with frequent flooding country-wise also were given.

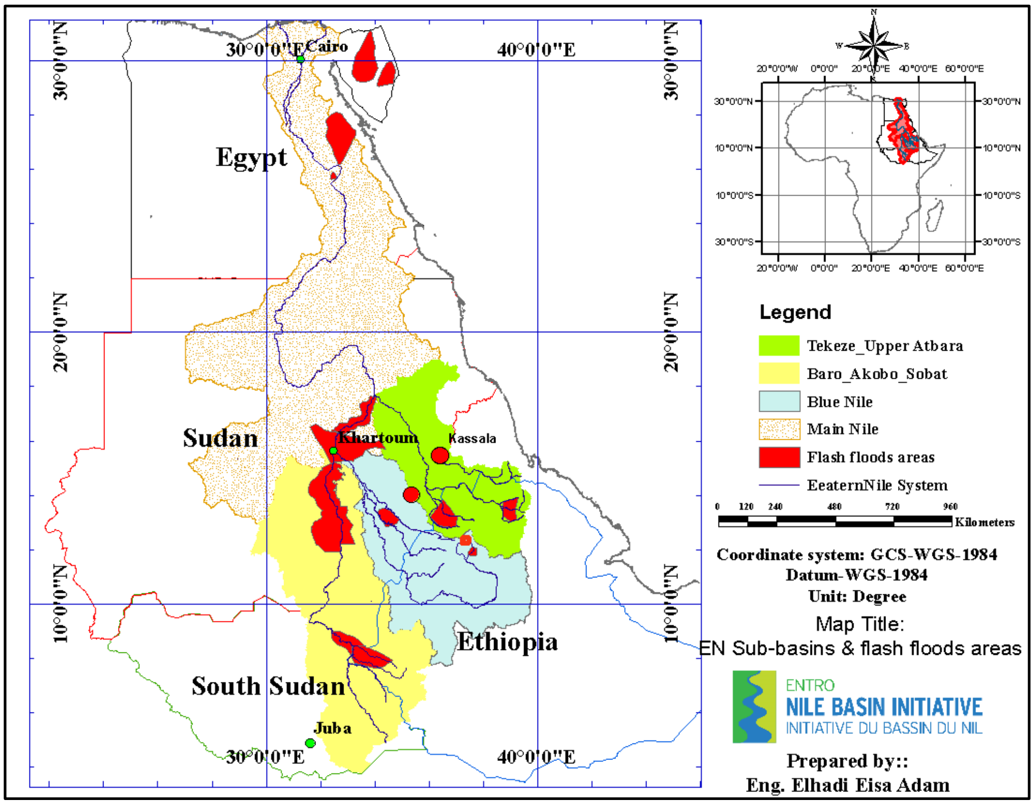

Figure 2: Eastern Nile Sub-basins with flash floods sites

3.2. Egypt

Flash Floods in Egypt are common natural disaster occurring in most parts of the arid and hyper-arid regions of East Desert, West desert, Sinai Peninsula and Red Sea (Samir et al., 2013). The flashfloods severely threaten the infrastructures, human lives and destroying their livelihood, moreover affecting the country's business, economy and threaten the archaeological sites (Vanderkimpen et al., 2010). Egypt economy depends on archaeological tourism because it represents one of the very important resources of national income (Kantouch et. al., 2020; Sumi et al., 2013; Youssef et al., 2005). Figure 2 shows mapping of flash floods prone sites in Egypt.

3.2.1. Wadi Watier (Sinai Peninsula)

Wadi Watier is situated in the South Sinai governorate of Egypt (Figure 3). It is one of the most active wadis in Sinai with respect to flash floods. The catchment has an area of 3580 km2 and classifies as a hyper-arid catchment. During flash floods, a high-velocity flood wave with a high sediment load is channeled along the canyon. The flood wave can reach a height of 1–2 m. This usually results in severe damage to the international road, which in some parts is totally washed away (Cools et al., 2012).

3.2.2. Wadi El-Arish (Sinai Peninsula)

Wadi El-Arish is located on the Sinai Peninsula, Egypt, it flows toward the Mediterranean Sea and its downstream part is El-Arish City. This wadi infrequently receives flash flood water from much of northern and central Sinai which make a great threat to the life and property of El-Arish City residents. It is the largest ephemeral stream system on the Sinai Peninsula, its catchment area is calculated to be 20,700 km^2.

3.2.3. Wadi Qena (Main Nile)

Wadi Qena, is located at the eastern side of Qena meander of the River Nile, between Red Sea in the east and River Nile in the west. Although, the Eastern Desert of Egypt is located in the arid and the hyper arid region, the region occasionally subjected to intense rainfall events over fairly short duration. These rainfall events, as in many other arid regions, resulted in severe local thunderstorms due to unstable weather conditions (Samir et al., 1991).

Another flash flood prone area is, ***Wadi Abu- Hasah*** on Tell El-Amarna archaeological sites especially, tombs of the kings, as well as the highways connecting and crossing the towns of El-Menya. Tell El-Amarna archaeological area, which frequently damaged by flashfloods of Wadi Abu Hasah, is located in the west central part of the Eastern Desert, in El-Menya Governorate, Egypt.

3.2.4. The Valley of the Kings (Main Nile)

The Valley of the Kings is a UNESCO World Heritage Site with more than 60 open tombs in Luxor, Egypt. In 1994, most of these tombs have been damage by flash floods (Kantoush et al., 2020).

Recently this year, 2020, storms have caused damage and havoc in several parts of the country namely; in the governorates of Qena, New Valley, Sohag and Monifia, where authorities report 5 people have died. Dozens of trees were uprooted and at least 5 buildings destroyed. Flooding was reported in parts of the governorates of Suez and Cairo, where the drainage system was overwhelmed and water supply cut. Schools, public offices and some air- and seaports were closed and train services suspended. http://floodlist.com/africa/Egypt-floods

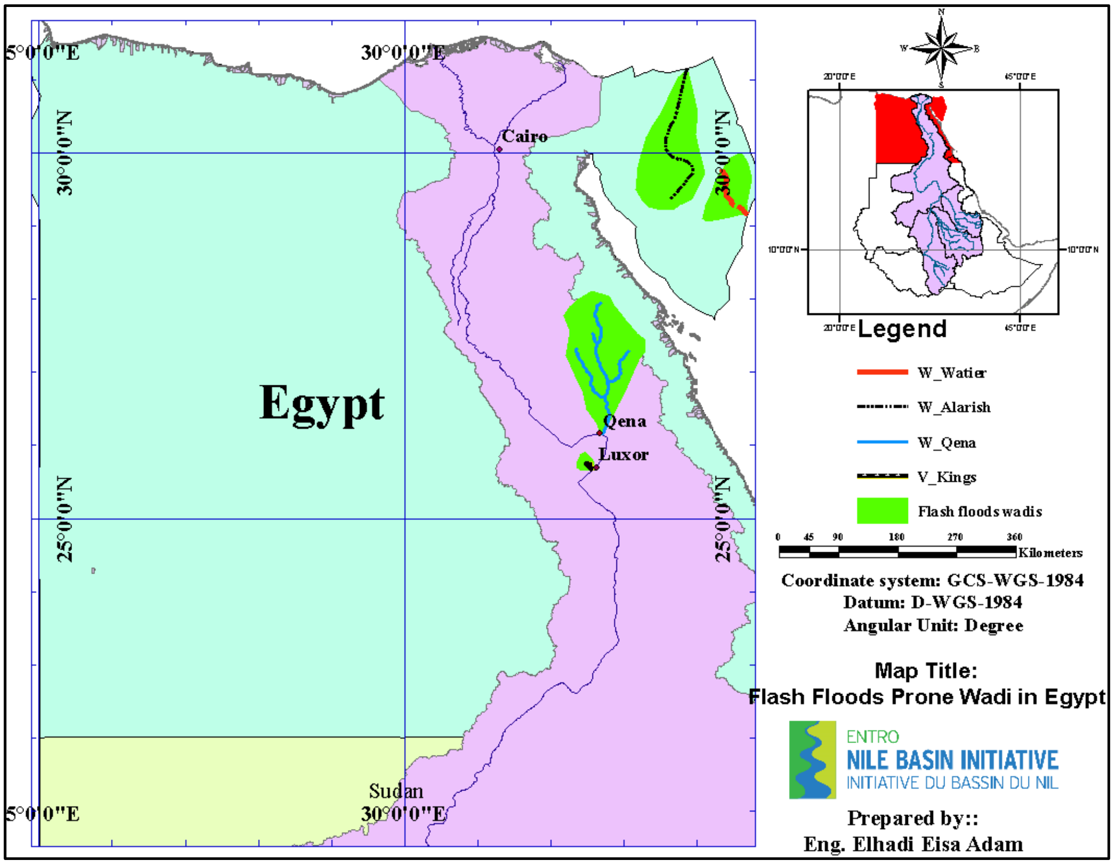

Figure 3: Flash floods prone areas in Egypt

3.3. Ethiopia

The rainy season in Ethiopian context is concentrated in 'kiremt' period, when about 80% of the rain were received. Rainy season flooding is one of the major environmental problems of the people living in the most part of Ethiopia. Many factors responsible for the high flash flood in the country, which can be enumerated as; the intensive rainfall in the up lands of the watershed, sparse vegetation cover, steep slopes and low infiltration capacity of the ground surface. This floods at times of unusually high rainy days overtop the normal flood ways and create a lot of damage and loss of lives.

Flash floods are more commonly associated with isolated and localized intense convective rainfalls in Ethiopia. They occur both in highland and lowland areas and their occurrence is very random. They cause life loss as well as property damage. They can better be mitigated through watershed management instead of flood protection works (Teshome, 2020). Figure 4 shows flash floods prone areas in Ethiopia.

3.3.1. Gambella Region (Baro-Akobo)

Gambella plain lies in the western part of Ethiopia and is part of the Baro-Akobo river basin. Gambella city, which is the regional capital, lies about 800 km from Addis Ababa, capital of Ethiopia. Major rivers in the areas are Baro, Akobo, and Gilo. Most of the plain is subject to seasonal flooding, which is also attributed to poor drainage condition. The city of Gambella is subject to occasional flooding caused by the Baro river and some of its tributaries. Most important causes of flooding in the Gambella area are flooding resulting from rivers overflowing their banks and flooding due to inadequate drainage. The riverine flooding is further aggravated due to the backwater effect from Pibor and Sobat rivers. Severe flooding, estimated to be a 50-year event, occurred in 1988 with the following consequences (Abdulkarim, 2004).

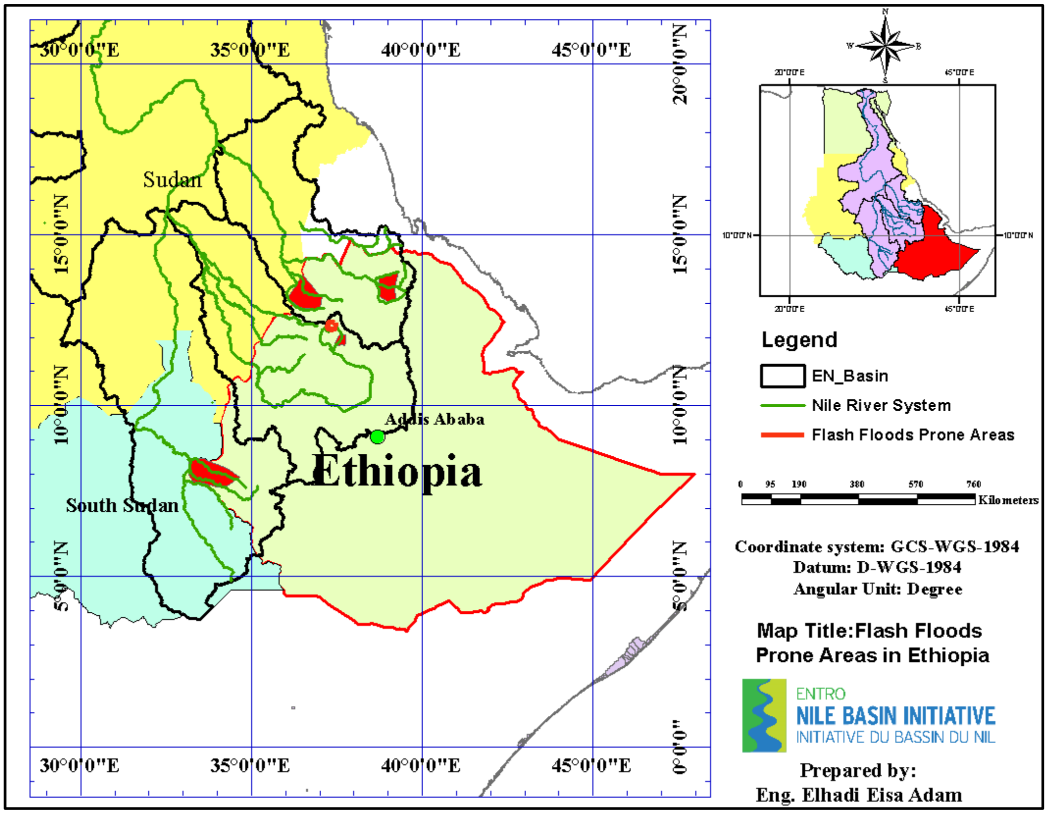

Figure 4: Flash floods prone areas in Ethiopia

3.3.2. Lake Tana (Blue Nile)

Lake Tana, is located in the northern half of Ethiopia. There are many rivers draining into the lake, some of which are causing huge damage to property and life to the surrounding farming community. There are several flood risk areas around Lake Tana, two areas were frequently flooded resulting in great damage; the floodplains of the Fogera woredas and the floodplains of the Dembia woredas (RIVERSIDE, 2010). Severe flooding has occurred in the Fogera floodplain and the Dembia floodplain. The causes of flooding are believed to be ponding of excess rainfall in floodplain depressions, rise of lake level and overflow of the rivers draining into the lake.

In the Fogera plain, overflow from the Gumera and the Ribb Rivers resulted in flooding on Fogera Woredas. The flooding in the northern part of the floodplain is primarily caused by bank overflow of the Ribb river and tributaries to the Ribb in the lower stretch of the river near Lake Tana.

In the Dembia plain, flooding occurs mostly on the lower part of the Megech and the Dirma Rivers. During high flows and high lake levels especially flooding occurs in areas near the lake due to overbank flow of the rivers in combination with the backwater effect of the lake.

3.3.3. Humera (Tekeze-Setit-Atbara)

Humera, in Tekeze-Atbara sub-basin, is frequently flooded site in the north-east part of Ethiopia. The flat area at Humera (near Ethio-Sudan boarder) is flooded from overflow of Tekeze River over its banks. This will occur during extreme rainfall conditions in the upper catchment of Tekeze basin.

3.4. South Sudan

3.4.1. Baro-Kobo-Sobat plain (BAS)

South Sudan is one of the countries with a unique setting for flooding. Most part of the country is low lying and 80% of the landmass is flood plain thereby leaving the country highly vulnerable to the threat of repeated floods. The pattern of flooding in the country also points towards an increase frequency of floods. Being located in the lower stretch where the river floor gradient is very gentle, this in turn results in less flow of water into the White Nile and the rivers attempt to adjust the water volume by overflowing their banks and nearby plains. Figure 5 shows mapping of flash floods prone areas in South Sudan plains of BAS.

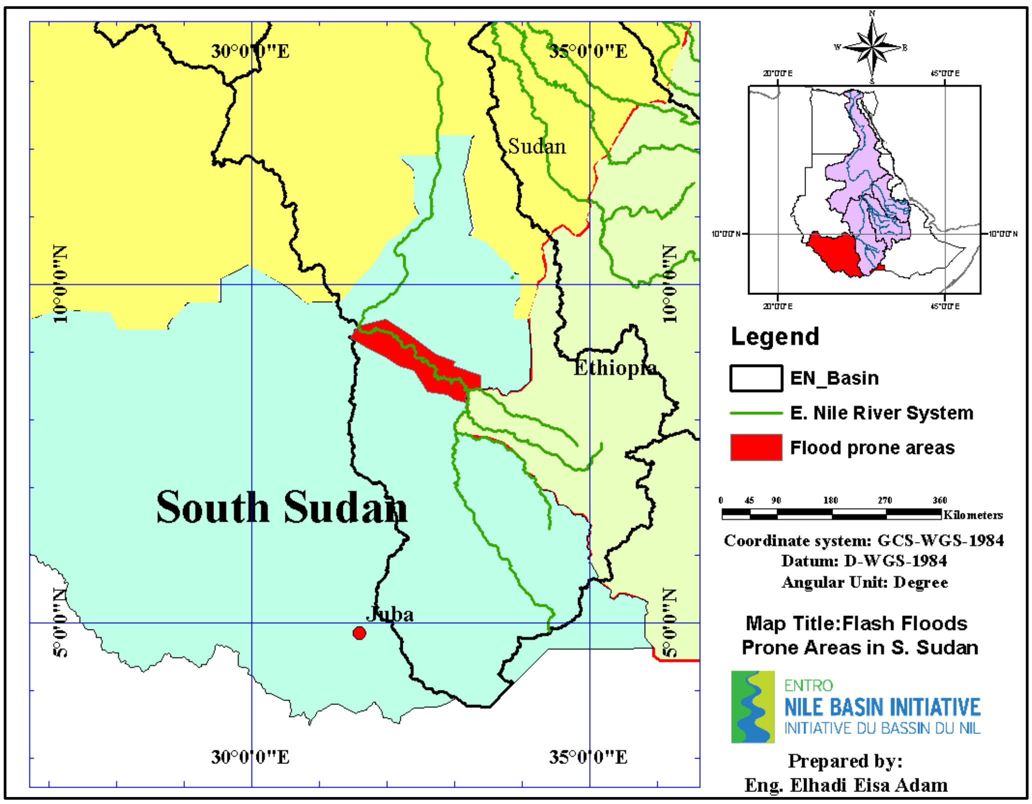

Figure 5: Flash floods prone areas in South Sudan

As of late October 2019, unusually heavy seasonal flooding is affecting large areas of South Sudan, flooding has since been reported in a total of 27 counties, in eastern and northern parts of the country. Estimates that between 600,000 and 800,000 people have been affected, according to authorities. Ayod, Maban, Mayom, Nyirol, Pibor and Uror in Greater Upper Nile were among the counties most heavily affected by the floods.

According to report by MSF, floods are a regular occurrence across the country, last year's rainy season has been unusually heavy, bringing flash floods that have inundated whole towns (https://www.msf.org.uk/article/south-sudan-msf-assessing-emergency-needs-after-severe-flooding). Hundreds of thousands have lost their homes,

crops and cattle. Many have been left stranded by the floods, marooned on small islands of land and cut off from basic services and healthcare. Flooding is limiting access to basic services and restricting the ability of humanitarian agencies to assess and respond to needs.
It is also worth mentioning that the most types of floods that are very common in the Republic of South Sudan are the rain floods which happen almost in most parts of South Sudan. The second part of the floods occurring in South Sudan is the river floods. This type of floods mostly happens around Bor, Malakal etc.This is because of the overflow of the rivers. The third type of flood is the flash floods, this mainly happens in the arid and some semi-arid floods. This type of floods is common in places such as Kapoeta in the former Eastern Equatoria States The main causes of these frequent occurrences of these floods were due to poor drainage system and topography of land which enable the river banks to overflow.

3.5. Sudan

Like other EN member states, Sudan also has long history of floods. In the years the country has faced major flash flood events resulting into loss precious livestock's and infrastructures. Flash floods in Sudan are generally caused by heavy concentrated rainfall during the rainy season and flooding from seasonal wadis. Floods are regularly occurring during the period from July to September every year. Both riverine and flash floods cause great damage to life and properties especially in lower area along the Nile river and its tributaries. Flash Floods in Sudan affect considerable number of people, damaging of thousands of homes and causing the deaths of herds of cattle. Ecosystem and environment may also be affected negatively by some metrological parameters that increase the risk and pressure on the hydrological system.

The sequences of severe floods in Sudan were recorded in 1946, 1962, 1965, 1975, 1978, 1979, 1988, 1994, 1998, 1999, 2006 and 2013. However, in 2019, the climatic variability through intensified rainfall regimes together with urban development has made many states in Sudan increasingly exposed and vulnerable to extreme flash floods.

Rapid urbanization and reclaiming of areas close to riverbanks has added a new dimension in the country as seen recently in Khartoum flooding in 2015 and the threats of urban floods in Kassala in the year 2018. Floods have caused loss of infrastructure and livelihood, led to large scale migration and, in some cases, relocation of affected communities (El hadi et al., 2018; Elhag and Eljack, 2016). The states in Sudan most vulnerable to flash floods are; Khartoum, Kassala, White Nile, Nile River, Gadarif and Sennar; many other parts of the country have also experienced floods in recent or historic. Figure 6 shows mapping of flash floods prone sites in Sudan.

3.5.1. Sharq Al-Neel Locality, Khartoum State

Sharg Al-Neel area, in Khartoum State, is one of the most flood prone areas. The locality is frequently affected by heavy flash floods during the rainy season. East Soba, Elfaki Hashim, Marabee Elshareef, Wad-Ramli and Wawisi, represent the main areas that frequently affected by flash flooding due to wadis flooding. Several wadis dominate the area towards River Nile, the most famous are; Soba, Green Valley, and Hasseb (figure 6). The area experienced major floods during the years 1988, 2007, 2013 and 2014. Last year, 2019, both floods and heavy rainfall swept through areas which located in the North of the locality (Wad Ramli). This flash flood led to collapse of a large number of houses and residents, people were displaced, and some families were forced to take shelter and protect themselves in schools and other save buildings (Redwan, 2020).

3.5.2. Gash River, Kassala State

The Gash, in Kassala State, Eastern Sudan - is a seasonal flashy river, originates from the Eritrean and Ethiopian highland, and flows during the period from July to September. The Gash river crosses Kassala city, the capital of Kassala State, and divided it into to part; east and west. Despite the intensive flood protection work, the city is still under a high risk of catastrophic flooding causing great damages to properties, infrastructures and endangering human lives (Elhadi et al., 2018; Isam et al., 2012).

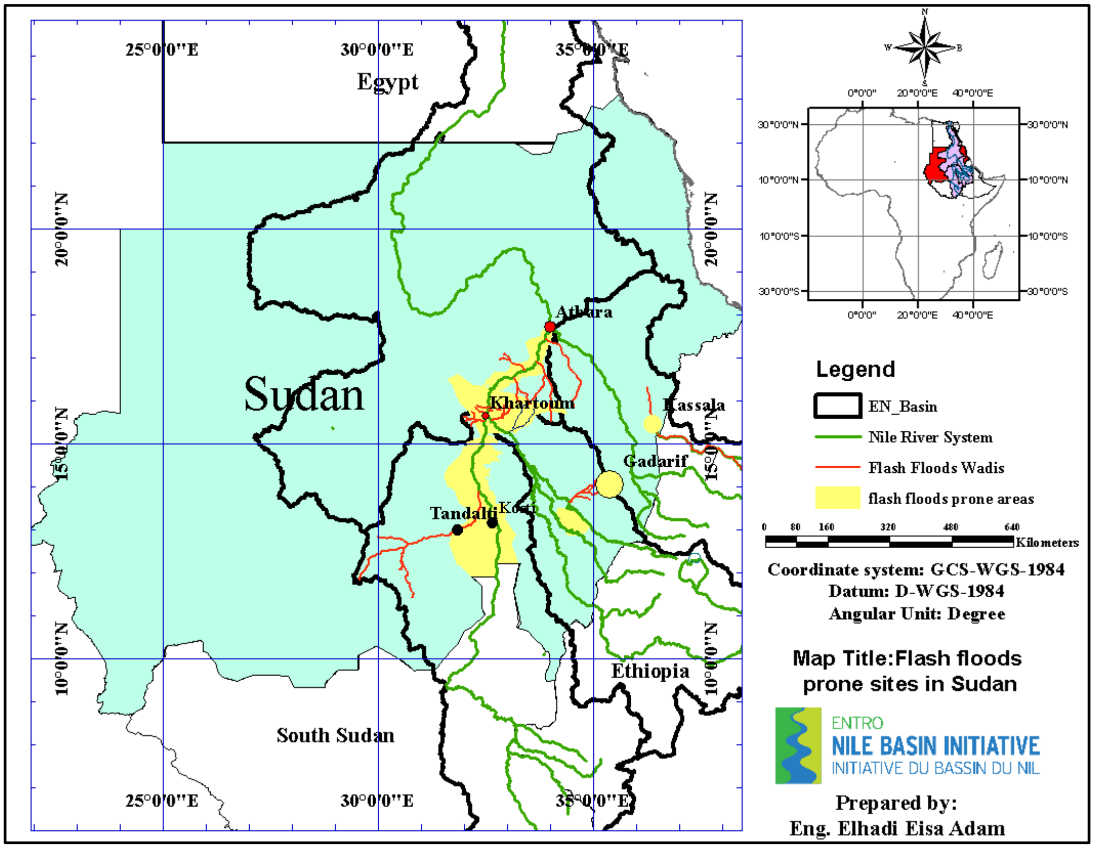

Figure 6: Flash floods prone areas in Sudan

3.5.3. White Nile State

Many seasonal flashy wadis cross White Nile State from south and south-west directions. Last year, 2019, heavy rainfall generated tremendous flash floods which cut the export highway road linking Khartoum to North Kordufan State for many weeks. More than 25 villages were washed out, the Governor of the White Nile state declared state of emergency, the relief activities distributed by Helicopters because all the roads were unpassable.

Khore Abu Habil one of the seasonal flashy wadis, it is originating from the South Kordufan State mountain in the south west part of the Sudan, and takes it is way through North Kordufan State till discharge into the While Nile River in White Nile State North of Kosti city. During rainy season when flooding, it causes great damage to cities and rural areas located along its course like Tendalti city.

Chapter 4: FLASH FLOODS MANAGEMENT AND MITIGATION MEASURES

This section summarizes the situation on exiting management and mitigation measures in the EN countries. It largely documents the knowledge gained by the author through review of available documents, discussions with concerned people, and visits to some of the flood prone sites. An attempt is made to give an overview of the different aspects of flood preparedness, mitigation planning and management practices. A general observation by the author is that most of the activities related to disaster management in the region are response-oriented, reactive measures.

4.1. Introduction

Flood mitigation is the process under which different bodies try to reduce the current and the future vulnerability of the communities to natural hazards. The promotion of the mitigation planning helps to ensure a safe and a responsible development. The advantages of the different mitigation systems are to decrease flood water velocity, to increase the time before the flood peak reaches lower parts of the drainage system.

The key characteristics of flash floods that should be taken into consideration when developing a management strategy are: the unforeseeability of the place, local scale of the event, and particularly the violence of the phenomenon, as well as the very short response time and the great threat to human lives. The solutions developed for the management of river floods do not prove effective in dealing with flash floods, which require separate means.

The flood mitigation measures can be broadly classified as structural and non-structural measures; the latter would seem to be the key deserving particular attention in effectively limiting the damage caused by flash floods. This does not mean that structural measures are of no assistance, but the typical procedures, like the building of reservoirs and embankments, cannot always be adopted in areas susceptible to flash floods. Small scale structural measures can, on the other hand, play an essential role in delaying the flow of water, allowing it to be locally retained, or diverting it from places where it could pose a threat to people or properties. Operations to limit the shifting of debris, or to stabilize hillsides in areas at risk of landslides are important. The flood resistance of buildings potentially at risk (flood proofing) should also be secured. It should, however, be noted that flood proofing may not be considered an option where high flow velocities and associated debris loads of flood water can be expected. The dynamic forces of such conditions on structures in general and on residential buildings in particular are very uncertain and difficult to assess. The structural method of flood management is very expensive and laborious that is why most of the time non-structural methods are adopted. Building of flood early warning system (FEWS) is the most effective and easiest way for managing flooding.
What is considered key in managing flash floods is the activity of local authorities in warning and responding to floods, with their main goal being to limit the danger to human lives. The activity of local authorities in warning and responding to floods is essential to limit the danger to human lives and property. Flash flood warnings are generated on both a national (and international) level, generally assigned to meteorological and hydrological services, and on a local level. Local warning systems allow us to, on the one hand, to adapt solutions to the locally existing risk, and, to the capabilities of the local communities.

4.2. Flash Flood Mitigation and Management Cycle

Flood has been identified as one of the major disasters in EN basin exposing the communities to very high degree of risk. However, it has often been seen that the measures undertaken are not enough and they fail at times to give way to flood hazards. Floods have occurred in the protected areas due to overtopping, breaching or in some cases, failure of the protection structures. Land use practices need to be projected with foresight keeping in mind the future areas of concentrated growth and their proximity to flood risk zones. It is also found that the flood related data collection and transmission networks need to be strengthened and augmented for generation of more effective flood warnings.

4.2.1. Proactive paradigm

The pro-active paradigm includes; preparedness, prediction & warning, and prevention & mitigation. Figure 7 shows the flood management cycle which can be followed to reduce the damage incurred by flash floods (Satish et al., 2009).

Preparedness, preparedness measures attempt to prevent potential risks turning into disasters, both at societal level as well as at individual level. It involves resource inventory, logistical planning, evacuation planning etc. well ahead of any potential flood event. Making the vulnerable communities aware of flash floods risk is a major area of focus. A multi prong approach for spreading awareness: through print and electronic media, distribution of information material, community workshops, street shows should be made an intrinsic part of DRR activities. The preparedness and contingency plans should have special emphasis on the vulnerable segment of the communities likely to be affected by floods: the poor, old, women, pregnant, children and the disabled.

Prediction and Warning, prediction and warning were done just hours before and immediately at the start of an event. This includes flood forecasting by accounting the upstream stages of the streams and rainfall forecasts. Early warning systems include the dissemination of correct information to the target user on the duration of occurrence of the event through media, World Wide Web, Messaging Services etc.

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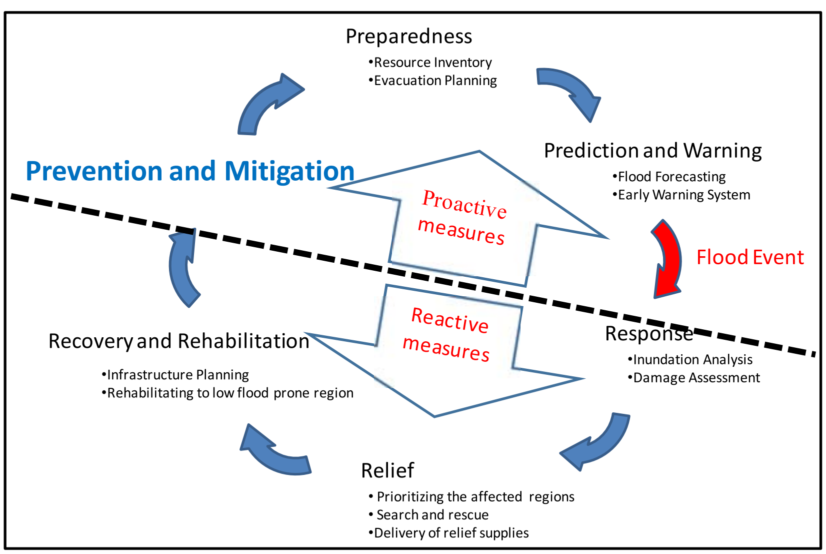


Figure 7: Flash flood mitigation and management cycle (Source: Satish et al., 2009)

4.2.2. Reactive paradigm

Emergency Response, response measures are implemented during or directly after a flooding incidence. They need advance planning and preparedness to respond to the emergency. Inundation analysis and preliminary damage assessment were carried out to provide relief measures.

Relief, flood effected regions were prioritized for evacuation, search and rescue operations were carried out. Delivery of relief supplies were done based on the needs. This process requires advance planning for identifying safe zones and stock piling to meet the demand during emergency.

Recovery and Rehabilitation**,** recovery measures include provisional reconditioning of the basic services and infrastructure and proper infrastructure planning to reduce the risk. Rehabilitation is carried at a better location where the risk of flooding is minimal. Livelihood options in frequently flooded areas are a major concern and affect the communities. The paradigm for flash floods risk management need to be broadened from simply post-disaster response to a more comprehensive approach that also includes prevention and preparedness measures. More effective prevention strategies would save not only tens of billions of dollars, but save tens of thousands of lives. Funds currently spent on intervention and relief could be devoted to enhancing equitable and sustainable development instead, which would further reduce the risk and disaster.

4.3. Worldwide Experience on Flash Floods Management and Mitigation

4.3.1. Experience from Japan, *Disaster Risk Reduction (DRR) and Disaster Risk Management (DRM)*

As natural disasters have become more frequent and intense, causing substantial impact and losses, the world has commonly recognized that prevention and mitigation is crucial in disaster management, realizing the need to strengthen not only the post-disaster measures, but also proactive measures for reducing risk. Most approaches followed worldwide for flood management can be categorized as response-oriented (after occurrence of disasters, reactive measures; DRM). In case of DRM approach, disasters can repeat itself. Mainstreaming DRR into the developmental plans are a must for long term flood risk resilience in the risk prone areas at national, regional and local level.

Japanese International Cooperation Agency (JICA) has fast experience in DRR worldwide. Figure 8 below presented by JICA, the figure represents the JICA experience in DRR investment. The figure shows the benefits when investment in DRR is applied against DRM. From the figure, it is clear how the economic growth significantly affected.

The important of mainstreaming of DRR has begun to be recognized internationally as many nations have realized that disaster damage hinders their economic growth significantly. One dollar of investment in DRR can saves around 7 dollars of damage due to disaster (Suzuki, 2020). The mainstreaming of DRR suggests the following three goals, though there is no clear definition yet:

- ✓ Each government should address DRR as a highest political agenda.
- ✓ All development policies and plans should include DRR as integral element
- ✓ More investment should be made for DRR (river improvement, diversions, bank maintenance etc.)

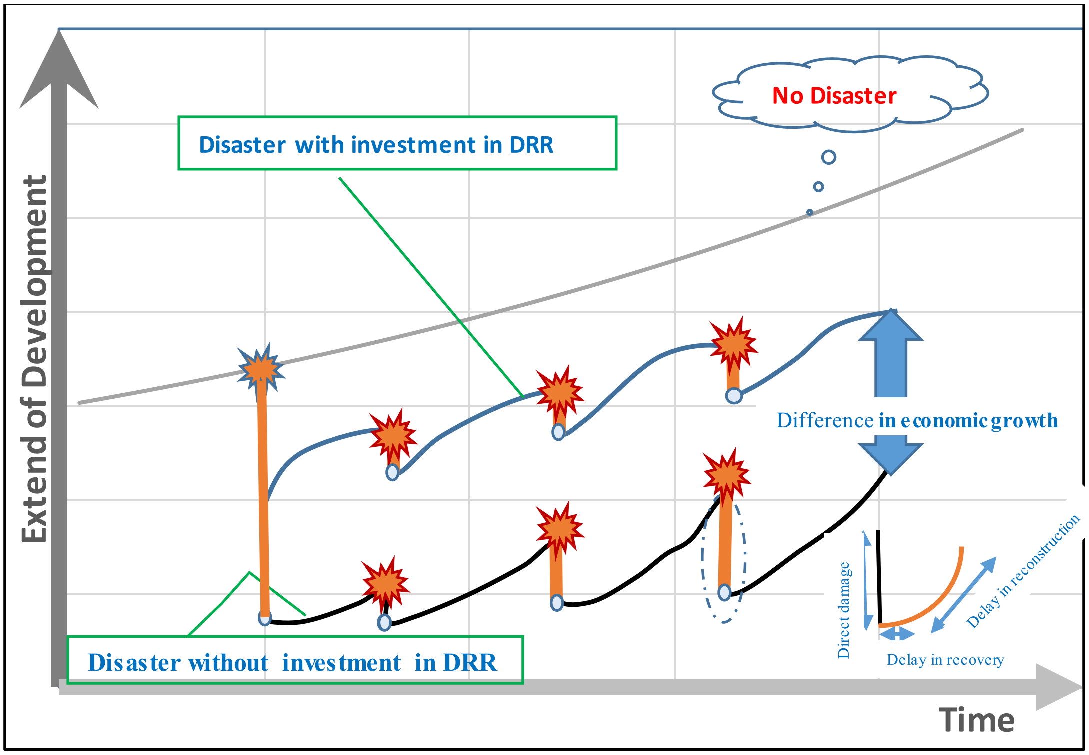


Figure 8: Typical figure for importance of investment in DRR (Source: Suzuki, 2020).

4.3.2. Experience from USA

Most of the flash floods in USA is on Alluvial Fans (AF) and Flood Plains (FP) (Thomas, 2002). AF and FP management includes actions to reduce losses to human resources and/or protect benefits to natural resources associated within the floodplain. The objectives of the AP and FP management are to; minimizing impacts of flows; maintaining or restoring natural floodplain processes; removing obstacles within the floodplain voluntarily or with just compensation; keeping obstacles out of the floodplain; Educating and planning for emergency preparedness; and ensuring that operations of floodwater management systems are not compromised by activities that interfere with, or are damaged by, design floods of these systems (Jeremy et al., 2015; Thomas, 2002)

Management and mitigation measures in USA are based on three pillars:

- Better understanding of and reducing risks from reasonably foreseeable flooding; this can be achieved through increase of awareness, mapping of flood prone areas, monitoring, executive orders, flood warning, community response program etc.
- Multi-objective-management approach for flood prone areas; This should be promoted by flood management approaches to ecosystem restoration and agricultural conservation, Best Management Practices (BMP), proactive and adaptive management of flood prone areas, vector control (water borne diseases), watershed monitoring, coordination among agencies and groups, state general plan guidelines and training, education, and professional certification for Multi-Objective floodplain management.
- Local assistance, funding, and legislation; This includes, new and existing funding sources, Task Force (TF) recommendation priorities, outreach programs, National Flood Insurance Program Compliance Encouragement (NFIPC), establishment of advisory committee and interagency barriers.

4.3.3. Experience from Europe

In Central and Eastern Europe, flash floods are a phenomenon that takes place in small regions, characterized by limited spatial extent, and this is why the damage they cause can best be limited on the local level (Skøien et al., 2018). The main tool in this effort are flood preparedness and response plans on the local level. These plans should come about in co-operation with various actors: local self-governments, river administrators, crisis services, residents of the areas at risk, owners of companies located on these terrains, local NGOs, private companies involved in emergency response and recovery as well as meteorological and hydrological services, and geological ones. It is essential that the state creates a coherent legal framework and support for local activities, particularly in terms of division of competencies between particular administrative levels and sectors. The relevant legal solutions concerning spatial planning will also provide support, including the mapping of high-risk areas and restrictions in their use. An additional factor supporting local communities if damage is caused should be a financial system, including an insurance system to provide the possibility of speedy recovery after a flood and sharing of risk.

Flash floods management as part of overall flood management policy and strategy

The minimization of human loss of life represents one of the core aims of an integrated approach to flood management. Loss statistics indicate that flash floods are in fact the most lethal flood type. Therefore, for regions prone to flash floods, governmental flood management policy should explicitly specify the Government's approach and applicable measures to work towards this aim as part of its overall flood management policy and strategy. Government should on the appropriate institutional levels comprehensively address all flood issues. In this it needs to be recognized that the traditional flood management approach employed for low-land riverine floods proves ineffective for flash floods, mainly due to difficulties with accurate forecasting for flash floods, the short warning lead-times, and consequently the requirement to involve much more closely local knowledge, and foster the local preparedness and response capacities.

Another aim of flood management policy that emerged later and is still evolving in various countries points at maximizing the net-benefits from flood plains, rather than aiming solely at minimizing flood damage. This results from the recognition that land resources in many countries are scarce and the development pressure on those land resources keeps on growing. In the mountainous regions where flash floods are most common, floodplains usually represent valuable development assets for settlements, infrastructure, industry and agriculture. In other terms, the comparably low costs of developing and exploiting the floodplains, has attracted humankind for centuries, and will do so in the future.

Example of structural measures in Europe; river channel improvement, dams and retention reservoirs, training works, flood protection and drainage projects, flood proofing and abatement. Non-structural measures can be summarized as: flood forecasting and early warning, disaster planning and preparedness, public awareness raising, land use and planning control, acquisition of flood land and property relocation, flood insurance and social security measures (e.g. compensation).

4.3.4. Experience from South Asia

The recurring floods in South Asian countries inflict heavy degree of economic losses, loss of lives; disruption of community development processes; evacuation and in some cases rehabilitation of communities; renewed investment in developmental processes to name a few. The strategies for flood risk management in South Asia has been in the form of; Flood prevention which reduces the risk of overbank capacity from being breached; Flood abatement by reducing storm flow and peak discharge rates and Societal responses whereby the communities develop strategies to cope and live with this hazard in areas of low recurrence interval and history of repeated flooding (Mriganka et al., 2012).

Various flood protection measures have been adopted in the region, which are mainly structural in nature. Construction of flood levees to reduce bank overflow, construction of dams to facilitate controlled flow of water downstream, check dams to reduce sediment discharge in the main course of the river, construction of spurs to train river flows, gabion walls and dykes to ensure aligned and directed flood water flows, bypass channels to relief main control structures from flood water pressure, effective flood discharge routing from dams etc. are some of the popular measures that have been around in the region for past century.

Some non-structural measures have also been adopted in the region for flood management. Afforestation or reforestation of the upper catchment areas is adopted by many countries to reduce surface run off. Terracing of the slopes and contour plantation are also attempted to meet this objective. One of the important non-structural measures adapted to a large extent is advance Flood Forecasting and Warning System (FFWS). The FFWS is a combination of rainfall runoff computer models, numerical models, weather surveillance radars, quantitative precipitation measurement radars, High Resolution Picture transmission system, High Frequency Radio transmission.

4.4. Flash Floods Mitigation Measures in EN

4.4.1. Introduction

The recurring floods and flash floods in EN basin countries inflict heavy degree of economic losses, loss of lives; disruption of community development processes; evacuation and in some cases rehabilitation of communities; renewed investment in developmental processes to name a few. The strategies for flood risk management in EN basin has been in the form of flood prevention which reduces the risk of overbank capacity from being breached; Flood abatement by reducing storm flow and peak discharge rates and societal responses whereby the communities develop strategies to cope and live with this hazard in areas of low recurrence interval and history of repeated flooding.

The existing flood control facilities in EN should be reviewed in the present flash floods risk perspective. The dominant trend of river management practices is only concentrated on the course of major rivers, high rainfall in tributary river and flash floods sites has been an area that not always received adequate focus. This effect needs to be kept in view while preparing flood management plans at state/ provincial/regional level. The land use plans should be based on intensive assessment of flood risk in the region and it would be a better idea to make the land use plans based on multi hazard risk assessment for sustainable use of economic resources for development. The infrastructure and plans in major cities should be reviewed at regular intervals and should be designed to make room for improvements in future.

Some non-structural measures have also been adopted in the EN region for flood management in riverine system and flash floods prone areas. One of the important non-structural measures adapted to a large extent is advance flood forecasting and warning system. Two recent projects supported by ENTRO has developed a hydrologic model (using HEC-HMS) for the entire Blue Nile catchment, including the portions of the basin in Ethiopia, and a hydraulic model (using HEC-RAS) for the Blue Nile from El Diem to Khartoum. The system is a combination of rainfall runoff computer models, numerical models, satellite rainfall products, quantitative precipitation measurement by virtue of which rain and flood forecasting & warning is issued by mandated national agencies to facilitate evacuation of people from low lying areas likely to be flooded.

Recently, ENTRO developed flood risk maps, for different return periods, for some flood sites as one of non-structural measures to mitigate flood consequences. Flood risk maps is highly recommended to be developed in whole EN region, it will to some degree be used as a planning tool for future flood protection from flash flood hazards.

4.4.2. Egypt

Various flood protection measures have been adopted in Egypt, which are mainly structural in nature. Construction of flood levees to reduce bank overflow, construction of dams to facilitate controlled flow of water downstream, construction of spurs to train river flows, gabion walls and dykes to ensure aligned and directed flood water flows (Kantouch et. al., 2020) etc. are some of the measures that have been used in Egypt.

The Nile Forecast Center (NFC) is responsible for issuing warning message for imminent riverine flood wave in the Nile. There is a large coverage of weather forecast all over the country but limited flash flood forecast system, which cover some tourist and UNESCO World Heritage Site (WHS) (El Quosy, 2020). One of the successful instance of non-structural measures of flash floods mitigation, Egypt developed an early warning system called Flash Flood Manager, acronym “FlaFloM. The “FlaFloM” was proposed by a project co-funded by the EU and Egypt in 2012. The FlaFloM was developed for forecasting flash floods in wadi Watier catchment, located in the Sinai Peninsula. It is the first of its kind in the Arab world and the entire Nile Basin (Cools et al., 2012). The system consists of a number of components, which are automatically activated and linked: a rainfall forecasting model (Weather Research and Forecast model), a hydrological model (custom-built to reflect arid region conditions), a hydraulic model (Info Works-RS) and a warning module (Flood Works). Though the wadi is not contributing to the Nile system, but still it is the only systematic flash flood early warning system in the region.

The Valley of the Kings (VOK), UWH site, is one of the most vulnerable areas to flash floods in Egypt. Protection walls have built there to protect the tombs from frequent flooding of the VOK. Kantoush et al. (2020) have carried hydrological study for the assessment of protecting work of the tombs. They used TELEMAC-2D model and 50 and 100 years return period floods. They are more than 60 tombs scattered around the valley, it is difficult to protect all this number of tombs through structural measures. They used two criteria for ranking the tombs; cultural (number of publications about the tomb) and economical (number of visitors), accordingly, they selected two tombs for protection. Based on the results of hydrological modeling, they suggested heightening of the existing walls to protect the tombs from flash floods.

4.4.3. Ethiopia

Various flood protection measures have been adopted in Ethiopia, both structural as well non-structural measures have been practiced in Ethiopia. In most of the cases, structural flood mitigation measures are used as part of other multi-purpose water resources projects under the domain of the Ministry of Water Resources. In the Gambella plain, structural measures in the form of dikes have been recommended to protect the city of Gambella from flooding. The system composed of dikes, drains, pumps, and floodwalls. Construction of flood levees to reduce bank overflow, construction of dams to facilitate controlled flow of water downstream etc. are some of the measures that have been used.

National Disaster Management Authority (NDMA) ensures timely preparedness and dissemination of related forecasts and warnings to district administration through provincial disaster management authorities' issues flood forecasts and warnings through a country-wide network of stations.

Flood Early Warning System models was developed for Lake Tana area as one of non-structural measures. These models were developed using HEC HMS, HEC RAS and WRF rainfall data as input. Combination of these tools produce flood forecast with 3 days' lead time. Recently, ENTRO developed flood risk maps around Lake Tana and some other floods sites as one of non-structural measures used for flash floods risk management.

4.4.4. South Sudan

Floods are a regular occurrence across the country, but last year's rainy season has been unusually heavy, bringing flash floods that have inundated whole towns (https://www.msf.org.uk/article/south-sudan-msf-assessing-emergency-needs-after-severe-flooding) . Most of the flash floods occurred in the low land and flood plain of the Baro-Akobo-Sobat (BAS), where structural mitigation measures are very expensive and not viable. Models for flood forecast and early warning were developed for BAS, the features of the models were based on the hydrological model developed in HEC-HMS software for rainfall runoff transformation and the hydraulic based USGS GIS flood tool for flood wave routing and inundation extend. The hydrology of the BAS model was based on HEC-HMS software and hydraulic was based USGS GIS flood Tool. The water elevation from the model is transpose to digital elevation model to find inundations extent for this basin area.

4.4.5. Sudan

Like any other ENB countries, Sudan frequently suffer from torrential flash floods from seasonal rivers and wadis (Bashar, et al., 2011; Abdo, 2015). Both structural and non-structural measures have been practiced in Sudan. Construction of flood levees to reduce bank overflow, construction of spurs to train river flows, gabion walls and dykes to ensure aligned and directed flood water flows (e.g. Gash river), construction of dams to facilitate controlled flow of water downstream (Khartoum wadis), diversion structures (e.g. Khor Abu Habil) etc. are some of the popular measures that have been around in the Sudan for past century. Figure 9 shows some of the existing and proposed earth dams across different wadis that flows towards Khartoum. The storage of the reservoirs is used for different purposes, like agriculture, fishery, recreation and reducing flood peaks

As a result of the frequent flooding in the Gash river, many researchers address the importance of developing FEWS for the Gash using different modeling environments (Abdo et al. 2008; Bashar et al., 2011; Giriraj, 2013; Rokaya, 2014). But the absence of reliable hydro-meteorological data is a common limitation among these studies. Recently, a flash flood early warning system was developed for Gash river (Elhadi et al., 2018). Reliable discharge data were obtained for the calibration of the hydrologic model, which developed using HEC-HMS software. TRMM-3B42RT V7 data set after bias correction were use as input for the hydrologic model (Elhadi et al., 2019). The model simulates the rainfall-runoff process well, the simulated hydrograph very close to the observed one.

The system operated in the last flood season 2019, using TRMM as well as GSMaP data sets, most of the time the peak rainfall reasonably coincides with the observed peak runoff, and reasonable lead time was obtained.

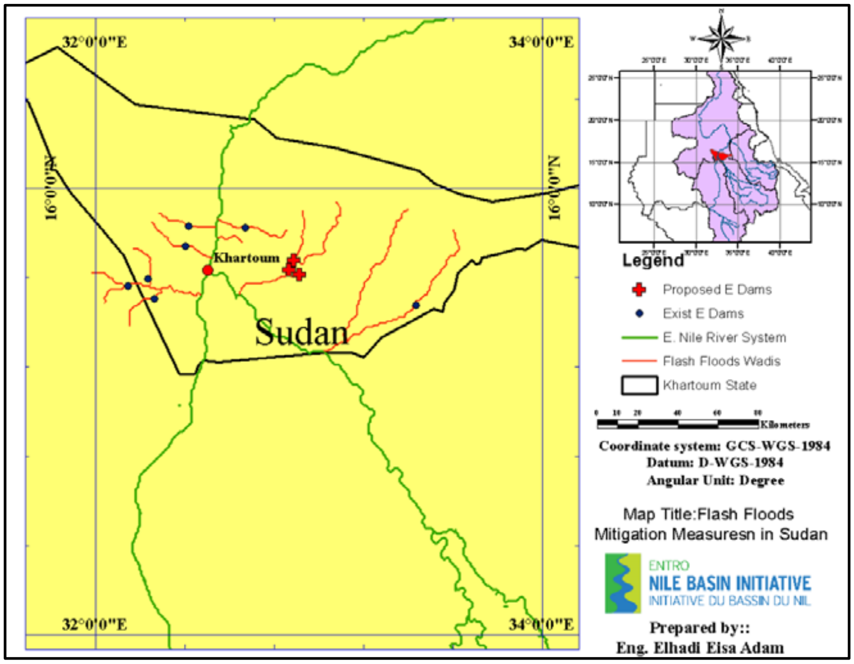


Figure 9: Example of different flood protection earth dams across wadis (Khartoum State).

4.5. Proposed Flash Floods Best-Management-Practices (BMPs) for EN

In the backdrop of increasingly alarming flash floods risk in the EN member states it is necessary to design new coping paradigm or modify the existing management and mitigation practices. The end point of this guide lines is to reduce the vulnerability of EN communities to flash floods disasters. From the lessons learnt regionally as well as worldwide practice, following are import hints to be implemented for best management practice in the region:

- Flash floods risk management should be an integral part of developmental plans in the region.
- Establishment of unit be responsible for flash floods management regionally or at national levels with clear mandate.
- Mapping and delineation of flash floods prone areas for different return period. (e.g. 50, 100 years etc.)
- Implementation of proactive measures (preparedness) will effectively reduce the response efforts.
- Integration of the indigenous practice in flood management and EWS in any future strategies.
- Encourage the investment in Disaster Risk Reduction (DRR), enhancing disaster preparedness for effective response, and to "building back better" in recovery, rehabilitation and reconstructions.
- Science and knowledge; which can be summarized as: increase awareness in disaster risk, data platforms, climate change and adaptation measures, etc.
- Involvement of stakeholders in all stages of management activities, and encourage community based disaster risk management.
- Strengthening disaster risk governance to manage disaster risk (e.g. councils).

- Local assistance, funding, and legislation; this includes, new and existing funding sources, Task Force (TF) recommendation priorities, outreach programs, National Flood Insurance Program Compliance Encouragement, establishment of advisory committee and interagency barriers.

Chapter 5: HYDRO-METEOROLOGICAL DATA

5.1. Introduction

Data and statistics are important in understanding the impacts and costs of disasters. Systematic disaster data collection and analysis can be used to inform policy decisions to help reduce disaster risks and build resilience. Novel statement given by Margareta Wahlström, United Nations Special Representative of the Secretary-General for Disaster Risk Reduction, 2019 "Access to information is critical to successful disaster risk management. You cannot manage what you cannot measure".

Flash flood forecasting is data-intensive and highly dependent upon the timely processing of a variety of information before and during flash flood events. Some types of data are available in real time through the internet and satellite downlinks. Most types of data, however, are collected using local sensors and communicated using regional wired and wireless infrastructure. Multiple-sensor networks are critical to the success of an end-to-end system. The Most important data for flash floods management are rainfall and runoff.

It has been observed that Hydro-meteorological are well documented in the EN. Figure 10 shows rain gauge network in EN, at national level, National Meteorological Authorities are taking the responsibility of installing, maintaining and monitoring the network, while Ministries of Water Resources responsible for hydrological data.

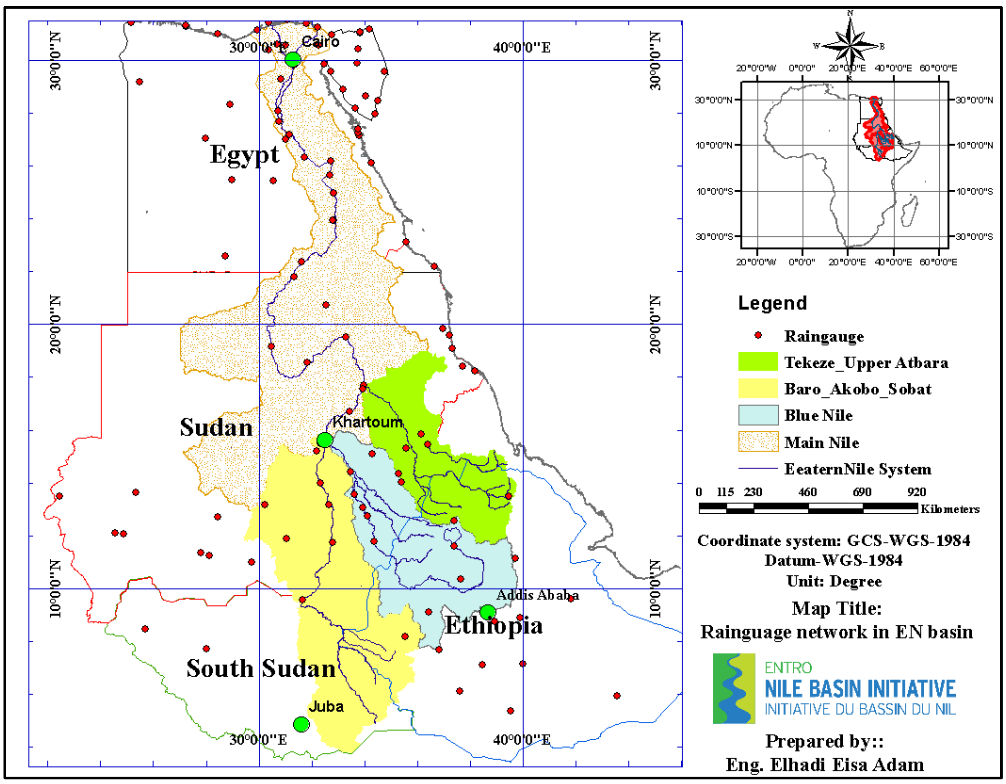


Figure 10: Rain gauge network in the EN basin (Source: WMO web site, https://oscar.wmo.int/surface/#/)

5.2. Egypt

5.2.1. Weather data

The Egyptian Meteorological Authority (EMA) operates the climatic stations which are distribution in the country. Many institutions benefit from the observations and forecasts made by the EMA such as the aviation industry, tourism industry, for the agriculture sector, for environmental protection, for estimation of lake Nasser evaporation losses and thereby aiding in the operation of the reservoir. EMA operates weather forecasting centers also.

5.2.2. Flow data

The river Nile is regulated by the HAD in Egypt and any downstream gauging on the main river measures the releases and spills. There are seasonal wadis that cause occasional flash floods damage. There are two classes of river gauging stations, those that measure river stage only and those that measure stage and discharge. There are river gauging stations at most of the control barrages downstream of the HAD.

5.3. Ethiopia.

5.3.1. Rainfall data

There are two rainy periods in Ethiopia, the 'Belg', which is for most part of the country the smaller rain period, and the 'kiremt', which is the main wet season (Abdulkarim, 2004). The National Meteorological Agency of Ethiopia (NMA) has setup wider coverage of meteorological stations nationwide. Various weather elements that routinely recorded at these stations enable the Agency to monitor day to day variation of weather as well as climatic fluctuations in long-term. Major portions of Ethiopia that prone to droughts as well as floods are not yet well covered with standard stations.

Rainfall in Ethiopia is highly influenced by altitude. The highlands generally receive more rainfall than the low lands. There are two rainy periods, the 'Belg', which is for most part of the country the smaller rain period, and the 'kiremt', which is the main wet season.

5.3.2. Flow data

The Hydrology Department, Ministry of Water Resources, operates the gauging stations in all the basins in the country. Most of these stations are equipped with staff gauges for daily measurement of river/lake levels. Overhead and bank-operated cableways are used for discharge measurement, which are then used for the development of rating curves. For most of the stations, flow data is compiled as average daily flow. A few stations, may have continuous hydrographs resulting from Automatic Level Recorders (Abdulkarim, 2004).

5.4. Sudan

5.4.1 Rainfall data

In Sudan the existing precipitation network is part of the climatic network of the Sudanese Meteorological Authority (SMA). The SMA is responsible for installing and maintaining weather stations, for collecting, archiving, and disseminating meteorological data. "Other related institutions are installing rain gauge for certain job of function within framework of projects, sometimes these data sets are not part of the SMA network", said officer in SMA. These stations are operated by fulltime staff of the SMA who report the measurements every three hours using radio communication and/or telephone lines. These modes of communication seem to work well for the daily use to which the data are made. Basic data collected include: daily rainfall, humidity, soil temperature, air temperature, etc. The observations are automated as telemetry systems but not cover the catchments of flash floods sites.

With support from IGAD Remote Sensing project, SMA forecasting unit build a forecast center. The center receives satellite imagery and rainfall estimation/forecasting from ICPAC and produces daily forecast. The system accessible to other institutions and stakeholder involved in FEWS, such as the MoIWR and can get data in the form of rainfall estimates, in real-time. This system could make a very good starting point for the forecasting component of the FFEW.

The gaps regarding Rainfall data

- There is a distinct gab in network coverage in the flash flood prone areas
- Necessary coordination with other related institutions that installed rain gauge for certain job or function and make data available for different users.

5.4.2 Flow data

Within the Nile system, hydrological data is collected and maintained by the Nile Waters Directorate of the Ministry of Irrigation and Water Resources. The hydrometric network consists of gauging stations (which can be stage-only measuring type or stage-and-discharge measuring ones). Stations are typically equipped with a stone or concrete staff gauge that is read manually by an observer. Some stations are equipped with radios so that the observer can report daily measurements to MoIWR in Khartoum. Discharge measurement equipment is maintained locally at some sites and varies from current meters on bank operated cableways to current meters operated from boats or ADCP.

The gaps regarding hydrological gauges' data

The major gab is in the monitoring of flash floods stream. There is a directorate in the MoIWR responsible for wadi "Grownd water and wadi directorate", they have many gauging stations in the major wadis, but unfortunately currently most of them are not working.

5.5. Satellite Rainfall Estimates (SREs).

The global systematic decline of in situ networks for hydrologic measurements made the hydrologists today to realize that rainfall data from the vantage of space has the potential to become a cost-effective source of input for hydrological modeling and flood prediction in data scarce region.

In the last decades, there are trends towards trust in using real time SREs in hydrological modeling and operational flood forecasting & FEWS after the good performance which they have shown (Grime, 2003; Guleid, et al., 2002; Ledesma and Futter, 2017; Hossain et al., 2007; Li et al., 2009). Satellite rainfall products are available from near-real time (hourly) to monthly average for different spatial resolution (grid cells).

The advances in remote sense added more advantages to rainfall observation, meteorological satellites expand the coverage and time span of conventional ground based rainfall data for a number of applications. In the regions of poor coverage of rain gauge network or areas with scarcity of ground rainfall data, the SREs is the best alternative and supplement to the ground-based observations in order to implement a cost-effective flood prediction (Li et al., 2009; Ledesma and Futter, 2017). There are three main data sources for SREs; geostationary thermal infrared (TIR), Passive Microwave (PMW), and rain gauges (Thiemig et al., 2013). The primary scope of satellite rainfall monitoring is to provide information on rainfall occurrence, amount and distribution over the globe for meteorological applications at all scales.

SREs and RADAR rainfall are becoming an alternative to ground rainfall observations in poor coverage regions. The main advantage of these SREs is that they overcome data shortages due to low density of installed rain gauges, and discontinuities and lack of immediate access to data due to political boundaries that divide trans-boundary catchments. Although satellite rainfall data offers an effective and economical method for observing rainfall rates and amounts over large areas, the use of satellite rainfall data in hydrologic studies and FEWS remains limited because of the uncertainty associated with SREs (Theming, 2013). Systematic bias might introduce unwanted uncertainties in the results of hydrological applications which may lead to wrong results, which could subsequently result in devastating consequences in the case of flood forecasting. That is why validation of the SRE is required before use. The use of rainfall RADAR is highly recommended in the region, it will enhance the monitoring system and can provide accurate and continuous coverage.

5.6. Study and Validation of SREs in the Region

Many researchers studied different SREs data set over the EN; In study carried by Dinku et al., (2007) to validate different SREs data sets (CMORPH, CPC, GSMaP, PERCIANN & TRMM-3B42) using ground monthly data over East Africa (Ethiopia). However, the SREs were over estimating the rainfall but it looks relatively good for application.

Other researchers studied SREs data sets (CMORPH & TMPA) over the Nile Basin (Haile et al., 2013; Habib et al, 2013; Habib et al, 2014; Theming, 2013), the products after bias correction found to be good assets for hydrological modeling. One of the important point that they have mentioned, SREs were sensitive to topography. Elhadi et al., (2019) validated TRMM-3B42RT V7 over Gash basin, the bias computed for monthly data then the obtained values were used to correct daily data because daily observed data are not available.

However, these products cannot be used confidently without calibration; ground rainfall or observed hydrograph can be used for calibration of SRE (Artan et al., 2007; Habib et al., 2014).

SREs were contaminated, the products should be evaluated against ground observation prior uses for any hydrological studies (Hughes, 2006; li et al., 2009; Vernimmen et al, 2012; Theming, 2013). Generally, there are two approaches for validation of satellite rainfall namely; ground truthing and Hydrological modelling. The former is to compare the SREs data set directly to ground observation, and the later based on the ability of SREs to reproduce the outflow hydrograph at the basin outlet (Nguyen, 2015).

The statistical tests of error functions can be used to evaluate the performance of the satellite rainfall data. Many statistics are available like; Nash-Sutcliffe Efficiency (NSE), Root Mean Square Error (RMSE) and coefficient of determination (R^2). There are three methods to compare SREs to ground rainfall observations namely; point-grid, grid-grid and areal-average.

5.7. Weather Forecast Models Used by ENTRO

Forecasted rainfall in the Upper Blue Nile and BAS in Ethiopia, as well as over other catchments in EN basin were done using Operational Numerical Weather Prediction Models. Currently a regional numerical weather prediction model from Weather Research and Forecasting model (WRF) is used by ENTRO, which gives 3-day ahead forecasted rainfall. However, the use of forecasted rainfall can increase the lead time noticeably for flash floods forecast and early warning system.

Recently in 2020, ENTRO has developed a regional rainfall forecast model with in the "***Flood Forecasting and Early Warning Enhancement Project***" using Weather Research and Forecasting model (WRF). This developed model is very important for the flash flood early warning system for the EN, it will provide the necessary input near real time QPEs. As we have seen from the literature review WRF model is very important for both; local and regional flash floods forecasting system.

Fortunately, tools to acquire and process the GFS 25km rainfall forecast data were developed within the above mentioned project. Tools for acquisition and analysis of TAMSAT, CHIPRS, CMORPH, ARC2, RFE2 and

GsMAP rainfall estimates were developed for the EN to provide near real time QPEs. The data is downloaded in its native, then processed for the Eastern Nile region at hourly intervals, this will add more to the forecasting capability of the flash floods forecasting system

Chapter 6: FLOOD EARLY WARNING SYSTEMS IN EN

6.1. Early Warning System

Early Warning System (EWS) can be defined as a system of data collection to monitor hazards in order to provide timely notice when a crisis threaten to elicit an appropriate response (NOAA, 2010). It can also be defined as the set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threated by a hazard to prepare and to act appropriately and in a sufficient time to reduce the possibility of harm or loss. Determining the need to warn, even need issuing an accurate and timely warning, is not the end goal of an early warning system. The ultimate goal is to save life and property.

6.2. Elements of Early Warning Systems

There is general agreement on the structure of people centered early warning systems; namely, risk knowledge, monitoring and warning service, dissemination and communication, and response capability. Since the concept was introduced the capacity to provide tailored information to individuals has increased along with an ever expanding access to mobile technology. Thus it is now possible to be increasingly specific about warnings to individuals at risk, increasing the importance of the concept of people centric warning systems. It also means that individuals need to be more aware of their risks and the warning systems must increasingly support forecasts of impacts so that those at risk can fully understand the consequences and actions that need to be taken.

6.2.1. Risk knowledge

Risks arise from the combination of hazards and vulnerabilities at a particular location. Identification and assessments of risk require systematic collection and analysis of data and should consider the dynamic nature of hazards and vulnerabilities that arise from processes such as urbanization, rural land-use change, environmental degradation and climate change. Risk assessments and maps help to motivate people, prioritize early warning system needs and guide preparations for disaster prevention and responses.

6.2.2. Monitoring and warning services

Warning services lie at the core of the system. There must be a sound scientific basis for predicting and forecasting hazards and reliable forecasting and warning systems that operate 24 hours a day. Continuous monitoring of hazard parameters and precursors is essential to generate accurate warnings in a timely fashion. Warning services for different hazards should be coordinated where possible to gain the benefit of shared institutional, procedural and communication networks. This can be achieved through a multi-hazard early warning system that coordinates and integrates the needs of different stakeholders.

The impact of heavy precipitation, for example, will vary over a catchment area depending on many factors that contribute to the vulnerability of people. Some will have little risk others may be in life-threatening situations. It is very important to make sure that those at risk are properly informed and actions are taken to protect them. Targeting those at risk also creates a more effective response and reduces the risk of warning fatigue and false alarms.

6.2.3. Dissemination and communication

Warnings must reach those at risk. Clear messages containing simple, useful information are critical to enable proper responses that will help safeguard lives and livelihoods. Regional, national and community level communication systems must be pre-identified and appropriate authoritative voices established. The use of multiple communication channels is necessary to ensure as many people as possible are warned, to avoid failure of any one channel, and to reinforce the warning message.

6.2.4. Response capability

It is essential that communities understand their risks; respect the warning service and know how to react. Education and preparedness programs play a key role. It is also essential that disaster management plans are in place, well-practiced and tested. The community should be well informed on options for safe behavior, available escape routes, and how best to avoid damage and loss to property.

6.3. Current Practiced Flood EWS in EN

There is no unified operational flood forecasting system for the whole Eastern Nile basin. Current Flood Forecast and Early Warning activities does not cover the entire Eastern Nile. Models have been developed for upstream of

Lake Tana basin, Upper Blue Nile (U/S El diem) and Baro Akobo Sobat (BAS). One of the gabs of this available forecasting tools is lacking of flash flood forecast as presented by many studies conducted by ENTRO.

Reliable, real-time flash floods forecasting on a time scale of hours or even part of hours can provide enormous humanitarian and economic benefits. The catastrophic loss of life and property brought about by flooding can be greatly reduced by timely warnings. Effective FEWS should include detecting and forecasting flood hazards and developing warning messages. The warning messages should be disseminated at sufficient lead time and in understandable language to authorities and at-risk public. This will help to prepare a community-based emergency planning so as to reduce potential impact on lives, livelihood, and socioeconomic aspects. Such type of flash flood early warning system is absent in the entire EN basin. There were few instance of flood forecast.

6.3.1. Egypt experience in flood EWS

Real-time forecasting of inflows into the High Aswan Dam (HAD) is made by Nile Forecast Center (NFC), where statistical techniques are used which relate flow at a number upstream gauging stations in the Sudan to those at the entrance to the lake.

6.3.1.1. The Nile Forecast Center (NFC)

It is a more sophisticated and well-equipped forecasting center within the planning sector of Ministry of Water Resources and Irrigation (MWRI) of Egypt, which is responsible for monitoring, forecasting and simulation of the Nile flow with special mandate of forecasting the flows into HAD. NFC started operation in 1990 with the following main objectives (El Quosy, 2020).

- ✓ To provide a routine forecast of inflow into lake Nasser, which will be used for planning reservoir operation activities.
- ✓ To bring the various forecasting activities in earlier times under one roof, where both meteorological as well as hydrological forecasts are made.
- ✓ To enhance the capacity of the ministry in flow simulation and forecasting activities

Other Institutions are collaborating in flood mitigation and planning activities through a permanent committee that is composed of Nile water sector, planning sector, irrigation sector, research institutions, HAD authority, and others. The mandate of this committee is to set policy and take decisions about flood management, lake level and water allocation. The NFC is a multidisciplinary center, with good representation of meteorology, hydrology, hydraulic engineering, and information technology.

6.3.1.2. The Nile Forecast System (NFS)

The NFS is a system of hardware and software (including system of models) that are used to forecast rainfall as well as inflow into the HAD in real-time, in short- to medium- term and seasonally. Major limitations in the estimation of rainfall from satellite imagery arise due to the small number of rain gauge stations in Ethiopian highlands that report to the GTS and, thus, become available to the NFC. The primary purpose of the forecasts made by the NFC is for planning the management of the High Aswan Dam.

The commissioning of the high Aswan dam (HAD) has changed the flow regimes of the Nile river in Egypt significantly. Obviously the regulation of the flow and thereby the damping out of the fluctuations in the flow rates between the seasons is the main positive impact of the dam. Real-time forecasting of inflows into the HAD is made by the Nile Water Sector, where statistical techniques are used which relate flow at a number upstream gauging stations in the Sudan to those at the entrance to the lake. There is a more sophisticated and well-equipped forecasting center within the planning sector of MWRI, which is responsible for monitoring, forecasting and simulation of the Nile flow with special mandate of forecasting the flows into High Aswan Dam (HAD). Other Institutions are collaborating in flood mitigation and planning activities through a permanent committee that is composed of Nile water sector, planning sector, irrigation sector, research institutions, HAD authority, and others. The mandate of this committee is to set policy and take decisions about flood management, lake level and water allocation.

6.3.1.3. Stream flow forecasts:

Forecasts/predictions are made with various lead times:

- Real time forecasting of runoff: this is made using the real time estimation of rainfall. The real time satellite images, which are input to the rainfall estimation over the Ethiopian highlands are the ones taken from previous day. Data from about 6 climatic stations in Ethiopia, which are part of the GTS, are also used to calibrate the estimate. Flows estimated using the water-balance models at the NFC could be compared with the actual observations. The most upstream hydrometric station for which the NFC can get flow data is the Eddeim station on Blue Nile close to the Ethio-Sudanese border. By forecasting the flow at Eddeim, the gain in lead-time is estimated to be about two days.
- Short-term forecast of rainfall: forecast of rainfall for a period of up to three days ahead. The forecasts are used, mainly, as qualitative indications of rainfall patterns in forecast periods and no quantitative conclusions are drawn from them
- Seasonal forecasts: these are forecasts for up to 9 months ahead, of inflow into lake Nasser. Forecasts are updated (improved) every 10 days as actual observed flow data become for stations upstream of the lake.

6.3.2. Ethiopian experience in flood EWS

From the available literature operational flash forecast system is not exist in Ethiopia. The National Disaster Risk Reduction and Management Council (NDRMC) of Ethiopia led multi-sector National Flood Task Force issued flood alert based on the National Meteorology Agency (NMA). The system issues first alert at the beginning of rainy season (April) for specific regions (Teshome, 2020). Subsequently, by the end of May, the National Flood Task Force updated and issued a second Flood Alert based on the monthly NMA weather update for the month of May when there is indication of a geographic shift in rainfall from the southeastern parts of Ethiopia (Somali region) towards the western, central and some parts of northern Ethiopia. The Flood Alert has therefore been revised to provide updated information on the probable weather condition and identify areas likely to be affected in the country to prompt timely mitigation, preparedness and response measures. The Alert updated regularly based on revisions in the NMA forecast and changes in the situation on the ground.

6.3.2.1. Flood forecast warning and communication

There is no systematic real-time flood forecasting system in Ethiopia, which can be used in the overall management of flood disasters. Seasonal and short-term forecasts of rainfall by the NM A are frequently used to issue warning regarding likelihood of flooding. These warning messages are issued through the national radio and are often not in the form that could be used for planning emergency response activities. Below are outlined the forecasting activities of the NMA:

- Now casting weather forecast: up to twelve hours (upon request)
- Short-range weather forecast: 1-3 days
- Medium-range weather forecast: up to ten days
- Long-range climate prediction: from one month-four months (one season lead time)

6.3.2.2. Major gaps in Flood EWS in Ethiopia

- The existing early warning system does not facilitate effective co-ordination between stakeholders. Data sharing and collaboration between institutions, ministries and ENTRO is not institutionalized.
- Major limitation of the flood alert system issued by NDRMC it is too general, which does not indicate a particular area that could be affected by the flood.
- Flood early warning is not issued on flash floods.
- The warning practice does not encourage the participation of the public and non-governmental organizations.
- The emphasis of the EWSs is response rather that preventive actions.

6.3.3. South Sudan experience in flood EWS

A flood forecast models were built for the Baro-Akobo-Sobat (BAS). The features of the models were based on the well-known quasi-distributed hydrological model developed in HMS software and the hydraulic based USGS GIS flood Tool. In the development of BAS flood forecast model for Gambella and Sobat Floodplains, the anticipated relative peak runoff during the forecast period were used as input to the hydrodynamic model component that was developed for Gambella Floodplain and the Sobat areas. Hence, verification was done with mean daily gauge readings from Gambella and Itang Stations. Alternatively, Global Flood Tool from USGS was used to model the inundation patterns for different depths of the rivers (Abdulkarim, 2004).

6.3.4. Sudan experience in flood EWS

In Sudan there is a systematic arrangement for flood forecasting, warning communication, and emergency response. As a result of the severe flooding during August 1988 along the River Nile plain in Sudan, the Ministry of Irrigation and Water Resources (MoIWR), of the Sudan, installed a Flood Early Warning System (FEWS) at the Nile River system in 1991. The "FEWS-Sudan" model is used to enable more advanced warning for future floods from the Nile (Saghayroon & Adam, 1996; Abdo and Ahmed, 2008) The objective of the project is to discuss the main concept of the modeling systems required for the "FEWS-Sudan". The system, "FEWS-Sudan", in operation since 1992 and stopped some years later then reinstalled in year 2010 by Deltares of Netherlands and the Hydraulic Research Center (HRC) of the MoIWR of the Sudan (Verkade & Werner, 2010). The system, FEWS_Sudan, is still working but it was influenced by the construction of GERD and Heightening of the Roseirse dam besides absent of observed rainfall from Ethiopia Plateau.

6.3.4.1. Flood forecast warning and communication

- Real-time flood forecasting is made at the forecasting unit at the Nile Water Directorate, Ministry of Irrigation and Water Resources. The forecasts are disseminated to beneficiaries through diverse media, telephone, through radio and the TV. Flood levels at different damage sites have been divided into zones: ALERT, CRITICAL, and FLOODING. The threshold stage for each level is determined based on the elevation of the riverbank at the point of interest, which are usually the flood damage centers.
- Short-term forecast of rainfall: forecast of rainfall for a period of up to three days ahead. The forecasts are used, mainly, as qualitative indications of rainfall patterns in forecast periods and no quantitative conclusions are drawn from them
- Seasonal forecasts: these are forecasts for up to 6 months ahead, of inflow at the Blue Nile and tributaries. Forecasts are updated every 10 days as actual observed flow data become for stations upstream of the lake. This forecast is normally used for planning.

6.3.4.2. Major gaps in Flood EWS in Sudan

- The flood EWS covers only River Nile and major tributaries, flash floods areas are not covered
- All the catchments outside Sudanese borders, there is a problem in data sharing.
- Inadequate observation, monitoring and forecasting systems in highly vulnerable/risky areas,
- Upgrading of forecasting procedures to ensure effective use of local and regional products, and systematic forecast verification.
- Data collection and communications are manual, real-time data are not available for both river and rain gauges.
- Inadequate forecasting frequency (one per day) and coverage and sustainability of monitoring system.

Chapter 7: GUIDE LINES FOR EEFECTIVE FLASH FLOODS EWS FOR EN

7.1. Introduction

There is a growing interest in the establishment of effective flash FEWS in EN. Up to now, no comprehensive guideline on how to establish and run such a system in the EN context. Flash floods have a different character than river floods, notably short time scales and occurring in small spatial scales. Forecasting of flash flood is quite a different and complicated challenge than traditional flood forecasting approaches. In forecasting of flash f loods, we are concerned foremost with the forecast of occurrence of heavy rainfall in short duration. Warning systems related to river flooding have a longer lead time than those for flash floods events, which may have very short warning periods.

There is no single solution to the problems of warning systems for flash floods. Flash floods are site specific and each problem area must be evaluated by competent personnel who can decide which of the available methods is most appropriate. Generally speaking, the greatest benefit will come from adequate technical advice and community preparedness in advance of floods and the establishment of the appropriate flash flood warning system. In every case, the local community must be closely involved in the effective use of community action plans that guide the emergency measures required by the local situation. The importance of the advanced preparation cannot be over-emphasized, because the time scale of the flash flood is too short to permit the development of an action plan, deployment of equipment, and establishment of communication channels after the flood threat becomes evident.

Generally, no matter which measures are used in the system, advanced or retrograde, complicated or simple, automatic or manual, it must transmit the flash flood messages immediately and accurately to the flood prevention administrations, community and people under risk in advance, so that there is enough time to make efficient preparations and plans to evacuate from the flood plain to nearby highlands or some other safe place. In this way, flash flood consequences can be minimized and flash flood prevention benefit maximized.

7.2. Flash Floods EWS Practice

7.2.1. Worldwide experience in flash floods EWS

Flash floods causes annually an average of 5,000 deaths and inflict heavy economical losses worldwide, exceeding any other flood-related event. They have enough power to change the course of rivers, bury houses in mud, and sweep away or destroy whatever is on their path. They are among the world's deadliest disasters and result in significant social, economic and environmental impacts. Accounting for approximately 85% of the flooding cases, flash floods also have the highest mortality rate (Joost et al., 2014, WMO, 2019).

As the global population increases, especially in urban areas, and societies continue to encroach upon floodplains, the need for flash flood early warning systems becomes more paramount. In response to this need, the World Meteorological Organization, the U.S. National Weather Service, the Office of U.S. Foreign Disaster Assistance, and the Hydrologic Research Center formed a partnership in 2007 to develop and implement an early warning flash flood forecasting system (Flash Flood Guidance System – FFGS) for global application (WMO, 2019).

7.2.1.1. Flash Flood Guidance System (FFGS)

The Flash Flood Guidance System (or shortly – FFGS) is a forecaster's tool designed to provide hydrological and meteorological forecasters with readily and accessible quality controlled precipitation estimates from weather radars and satellites, precipitation measurements (rain gauges), forecast data from Numerical Weather Prediction models, and other information to produce timely and accurate flash flood warnings worldwide (WMO, 2019).

Flash Flood Guidance System with global coverage enhances early warning capabilities of the National Meteorological and Hydrological Services (NMHSs). Currently over 3 billion people in 67 countries are being provided early warnings of potential flash flooding through their NMHSs working in concert with their National Disaster Management Agencies. FFGS systems have been implemented for multi-country regions around the world as shown in the following map (Figure 11). The general implementation approach is designed to support capacity building in the regions and aims at the reduction of flash flood hazard impacts to life.

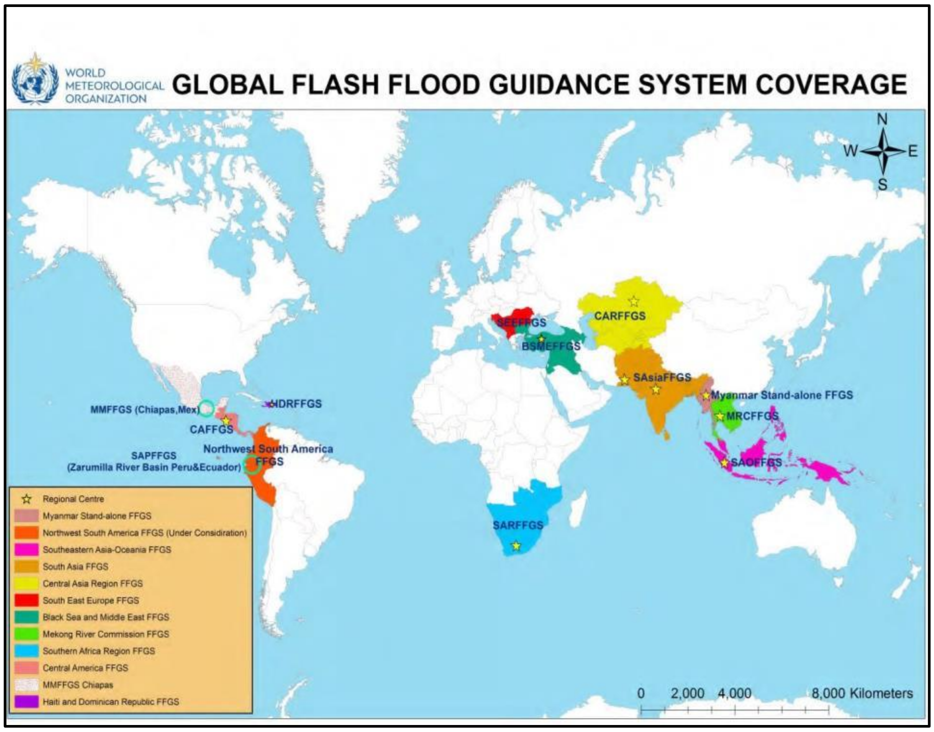


Figure 11: Flash Flood Guidance System (FFGS) with Global Coverage (WMO web site)

The main objectives of the FFGS are:

- Enhance NMHSs capacity to issue flash flood warnings and alerts;
- Mitigate adverse impacts of hydro-meteorological hazards;
- Enhance collaborations between NMHSs and Emergency Management Agencies;
- Generate flash flood early warning products by using state-of-the-art hydro-meteorological forecasting models;
- Provide extensive training including on-line training to the hydro-meteorological forecasters;
- Foster regional developments and collaborations; and
- Support WMO Flood Forecasting Initiative.
- Encourage transboundary collaboration.
- Improve community awareness of flash flood disasters to permit action

The primary purpose of the FFGS is to provide operational forecasters and disaster management agencies with real-time informational guidance products pertaining to the threat of small-scale flash flooding throughout a specified region (e.g., country or portion of a country, several countries combined). The FFGS provides the necessary products to support the development of warnings for flash floods from rainfall events through the use of remote-sensed precipitation (e.g., radar and satellite-based rainfall estimates) and hydrologic models. The system supports evaluations of the threat of flash flooding over hourly to six-hourly time scales for stream basins that range in size from 25 to 200 km^2 in size.

The FFGS outputs are made available to users to support their analysis of weather-related events that can initiate flash floods (e.g., heavy rainfall, rainfall on saturated soils) and then to make a rapid evaluation of the potential for a flash flood at a location. To assess the threat of a local flash flood, the FFGS is designed to allow product adjustments based on the forecaster's experience with local conditions, incorporation of other information (e.g., numerical weather prediction output) and any last minute local observations (e.g., non-traditional rain gauge data) or local observer reports. Important technical elements of the flash flood guidance system are the development and use of a bias-corrected radar and/or satellite precipitation estimate field and the use of land-surface hydrologic modeling.

The system provides information on rainfall and hydrologic response, the two important factors in determining the potential for a flash flood. The system is based on the concept of *flash flood guidance* and *flash flood threat*. Both indices provide the user with the information needed to evaluate the potential for a flash flood, including assessing the uncertainty associated with the data.

- ***Flash Flood Guidance*** is the amount of rainfall of a given duration over a small stream basin needed to create minor flooding (bank full) conditions at the outlet of the stream basin. For flash flood occurrence, durations up to six hours are evaluated and the stream basin areas are of such a size to allow reasonably accurate precipitation estimates from remotely sensed data and in-situ data. Flash flood guidance then is an index that indicates how much rainfall is needed to overcome soil and channel storage capacities and to cause minimal flooding in a basin.
- ***Flash Flood Threat*** is the amount of rainfall of a given duration in excess of the corresponding Flash Flood Guidance value. The flash flood threat when used with existing or forecast rainfall then is an index that provides an indication of areas where flooding is imminent or occurring and where immediate action is or will be shortly needed.

FFGS Major Components

- Meteorological components which comprises of two major components of Weather Research Forecast (WRF) model for grid based prediction through numerical schemes and multi-parametric synoptic weather monitoring for overall probability of rainfall in particular region.
- The hydrological component comprises of a hybrid approach of lumped grey box model known a rational model in combination with a quasi-distributed hydrological model known as the HEC-HMS in Arc GIS platform. While the first approach provides the forecast for the peak value for the river basin, the distributed model provides the forecast for the daily hydrograph for that basin. Comparing both the forecast with the established flooding thresholds for that river, issue of flood waring is decided.
- The third component is the post flooding identification of embankment breaches and general monitoring of embankment. Figure 12 below shows the flow chart and component of the FFGS.

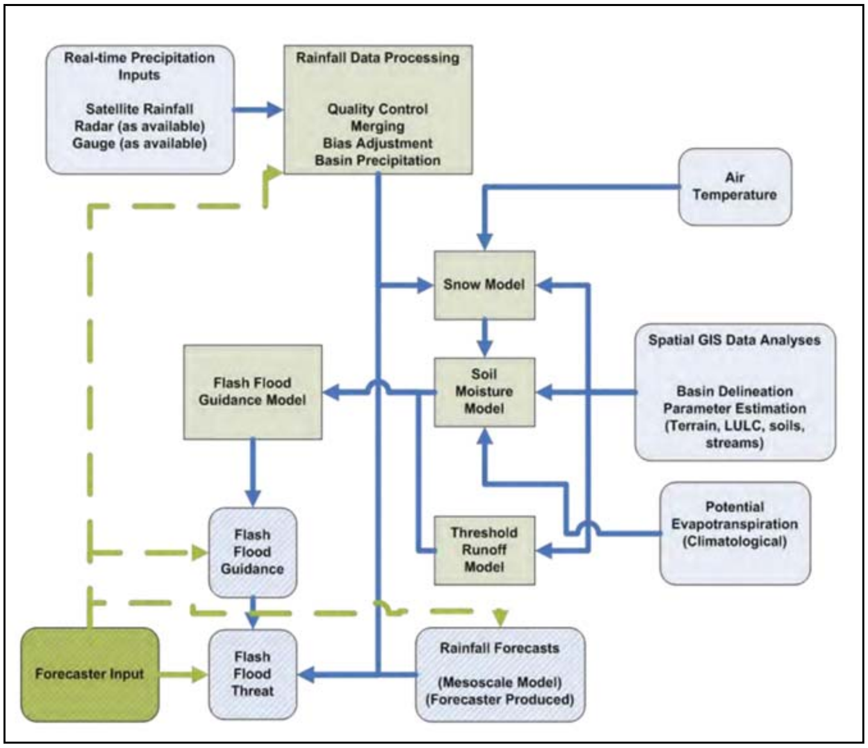


Figure 12: Schematic Flow Chart of the Flash Flood Guidance System (Source: WMO, 2018).

WMO's FFGS seeks to strengthen the capabilities of National Meteorological and Hydrological Services (NMHSs) to issue timely and accurate flash flood warnings and to integrate these in their operational activities. It also seeks to foster coordination between NMHSs and disaster management authorities (DMAs). Figure 13 show the implementation of the FFGS at regional/global scale.

The Flash Flood Guidance System is an efficacious means of reducing the loss of lives and property, over the past decade has led to a significant reduction in the loss of life and property in those countries where it is being used. By the end of 2019, WMO has produced an animation explaining the challenges of flash floods and the benefits of the Flash Flood Guidance System as an important disaster management tool to save lives and decreasing economic losses. This is now available in Arabic, French, Spanish and Russian (WMO, 2019).

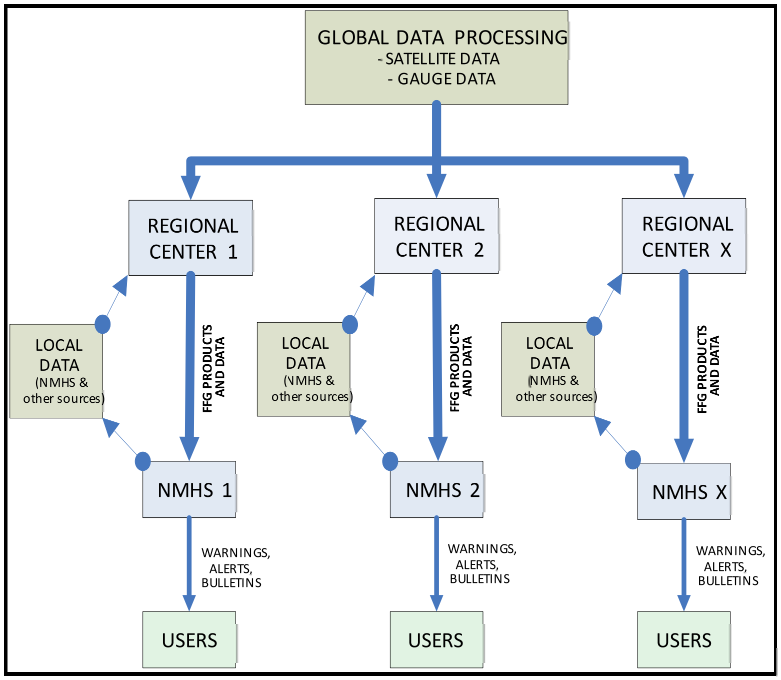


Figure 13: FFG System Schematic – Global Implementation (Source: WMO, 2018).

FFGS Forecaster Products

The types of products available to forecaster vary by FFGS based on needs and requirements. The types of products available to a forecaster through the interface of the FFGS include the following:

- ✓ RADAR Precipitation – Radar-based precipitation estimates
- ✓ MWGHE Precipitation – Satellite-based precipitation estimates
- ✓ GHE Precipitation – U.S. NOAA-NESDIS Global Hydro Estimator SATELLITE Precipitation estimates
- ✓ Gauge MAP – Gauge-based mean areal precipitation (MAP) for stream basin areas
- ✓ Merged MAP – Merged mean areal precipitation for stream basin areas.
- ✓ ASM – Average soil moisture (model-based)
- ✓ FFG – Flash flood guidance
- ✓ IFFT – Imminent flash flood threat (a current "observation" of flash flood threat)
- ✓ PFFT – Persistence flash flood threat.
- ✓ ALADIN forecast – Quantitative precipitation forecast
- ✓ FMAP – Forecast mean areal precipitation for stream basin areas (using mesoscale model rainfall forecasts)
- ✓ FFFT – Forecast flash flood threat (using mesoscale model rainfall forecasts)
- ✓ Gauge MAT – Gauge-based mean areal temperature for stream basin areas
- ✓ Latest IMS SCA – Fraction of stream basin area snow cover (from U.S. NOAA-NESDIS)
- ✓ SWE – Model-based snow water equivalent for stream basin areas (reflects the state of the snowpack)
- ✓ Melt – Snow melt (cumulative melt over the period of 24–96 hours for each stream basin area)
- ✓ Surf Met gauge stations – surface meteorological stations available.

7.2.1.2. Korean Experience in Flash Floods Early Warning System

Korea Flash Flood Guidance (KoFFG) has developed over Han River basin. KoFFG consider all components of FFGS mentioned in previous paragraph and schematized in figures 12&13 (Threshold runoff, soil moisture accounting and radar rainfall estimates) and composed of Regional Data Assimilation and Prediction System (RDAPS) to forecast a flash flood warning and watching.

Azama et al., (2017) developed flash flood early warning system for Mushim river in Korea. The system is developed to inform people about ongoing and upcoming flash flood events to avoid the loss of life and property. Hardware and software based smart technology is used to develop an early flood warning system for Mushim stream watershed to send to end users early flood warning messages about potentially impacted areas. Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) is the core of flood alert application provides the forecast with sufficient lead time and decides the threshold conditions of runoff/stage. Short range weather forecasts from Korea Meteorological Administration (KMA) at every three hours' interval, are stored in hydro-meteorological database and fed in HEC-HMS for identification of flood risks. Server-Client based program used to visualize the real time flood condition and to deliver the early warning message. Flood hazard maps thus developed which can be used by policy-makers and responsible authorities, as well as to local residents in finding suitable measures for reducing flood risk in the study area.

7.2.1.3. Thailand Experience in Floods Early Warning System

Sunkpho (2011), developed a real-time flood monitoring and warning system for a selected area of the southern part of Thailand. The system developed to monitoring water conditions: water level; flow; and precipitation level, in Nakhon Si Thammarat, a southern province in Thailand. The developed system is composed of three major components: sensor network, processing/transmission unit, and database/ application server. These real-time data of water condition can be monitored remotely by utilizing wireless sensors network that utilizes the mobile General Packet Radio Service (GPRS) communication in order to transmit measured data to the application server. The application server is a web-based system implemented using PHP and JAVA as the web application and MySQL as its relational database. Users can view real-time water condition as well as the forecasting of the water condition directly from the web via web browser or via WAP. The developed system has demonstrated the applicability of today's sensors in wirelessly monitor real-time water conditions.

7.2.2. Flash Floods EWS in the EN

7.2.2.1. Egypt Experience in Flash Floods Early Warning System

Wadi Watier Flash Floods Manager (FlaFloM)

An early warning system for flash floods has been developed for Wadi Watier in Sinai Peninsula, Egypt (figure 14). The Flash Flood Manager (FlaFloM) developed within a framework of joint project co-funded by the EU under the LIFE Third Countries Fund (Cools et al., 2012). The system is aimed at developing an early warning system for forecasting flash floods in the Wadi Watier catchment. The system consists of a number of components, which are automatically activated and linked: a rainfall forecasting model (Weather Research and Forecast model), a hydrological model (custom-built to reflect arid region conditions), a hydraulic model (InfoWorks-RS) and a warning module (FloodWorks).

Wadi Watier is one of the most active wadis in Sinai with respect to flash floods. The Wadi is a hyper-arid catchment with an area of 3580 km^2. The EWS is automated one, which designed to deliver forecasts in less than

15min and forecasts 24h in advance. Considering that the required lead time for an effective response is about 2h, the system meets the lead time requirements. Rainfall forecasts are produced by means of the Weather Research and Forecasting model (WRF). Every day, a rainfall forecast for the next 48 hours is prepared.

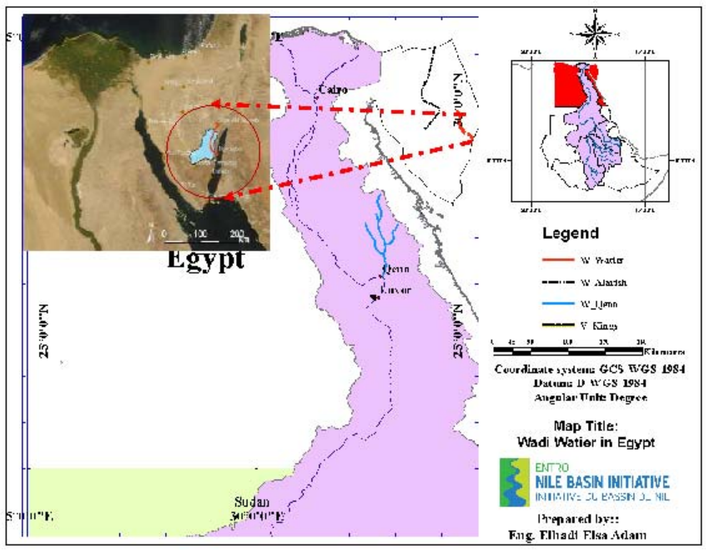


Figure 14: Location Map of Wadi Watier, Egypt

The EWS automatically activates and links all the components in real time, whenever a new rainfall forecast is submitted. The results from the models and the warnings issued by the warning module can be viewed by means of a flexible and user-friendly graphical user interface (GUI). This GUI was constructed by means of the software package "FloodWorks", figure 15 below shows the early warning system components (Cools et al., 2012). The system is capable of gathering data, generating forecasts, displaying visual warnings or alerts on the GUI, sending e-mails to a pre-defined address list and generating reports.

The EWS issues warnings whenever pre-defined thresholds are exceeded. Thresholds can be defined for rainfall, runoff, water level, and discharge and can be issued from each component of the chain that composes the EWS. For each of these, three different thresholds can be defined. The first threshold (*start*) indicates the onset of rainfall, runoff, and discharge or the presence of some water in the reservoirs; the second threshold (*warning*) indicates the possibility of dangerous floods; the third threshold (*alert*) indicates a high likelihood of dangerous floods.

In the current operational system of the FlaFloM, only a rainfall threshold has been applied. Based on local experience with flash floods in the Sinai Peninsula, a warning is issued when the cumulative rainfall over a 6h period exceeds 10mm. When the cumulative rainfall exceeds 15mm, an alert is issued (Cools et al., 2012).

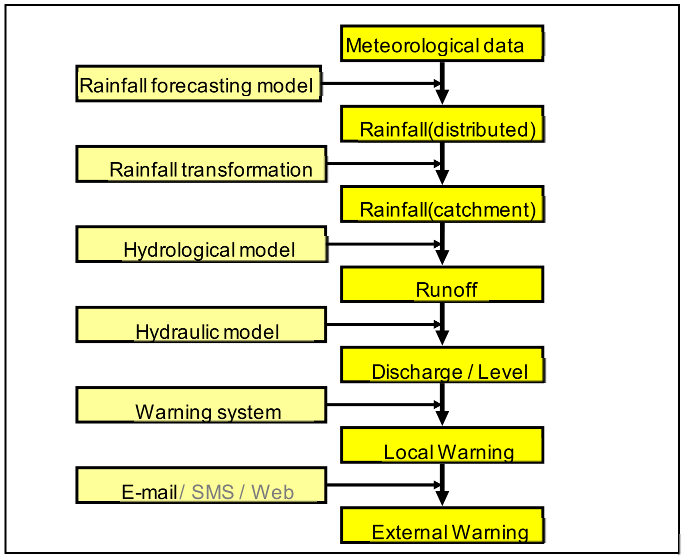


Figure 15: Early warning system components for Wadi Watier, Egypt (cools et al, 2012).

7.2.2.2. Sudan Experience in Flash Floods Early Warning System

Gash River Flash Floods EWS, Kassala State

The Gash, in Kassala State, Eastern Sudan - is a seasonal (flashy) river, originates from the Eritrean and Ethiopian highland, and flows during the period from July to September. The Gash river crosses Kassala city, the capital of Kassala State, and divided it into to part; east and west (figure 16). Despite the intensive flood protection work, the city is still under a high risk of catastrophic flooding causing great damages to properties, infrastructures and endangering human lives (Elhadi et al., 2018; Isam et al., 2012).

In the last five decades, the major floods that had been experienced in Gash with great damages were in:1975,1983,1988,1993,1998,2003,2007,2014. In 2003, the flash floods from the Gash river swept 50 % of the city of Kassala (Abdo, 2015; Isam et al., 2012). In 2016, the flood water cuts the main highway road which links Kassala and Port Sudan, the main Sudan Sea Port (Elhadi et al., 2018).

As a result of the frequent flooding that strikes Kassala city and its surrounding areas, there were many studies that highlight the importance of developing forecast models for the river. Bashar, et al. (2011) tested the utility of space technology in managing the water resources in Gash river. The study used Geo-spatial stream flow model, which developed by United States Geological Survey department (USGS), as simulation tool and Rain Fall Estimate (RFE) data sets as input. One thing that has been noticed in his study, RFEs were not validated against ground rainfall. The model capture the peak well (R^2= 0.56) and reproduced the observed situation with reasonable accuracy. Rokaya (2014), tried to simulate rainfall-runoff process and develop flood simulation model for flood forecast and irrigation water management in Gash basin. He used four different SREs; RFE, TRMM, ARC-2 and ECMWT as input to run HEC-HMS model. SREs is validated using Kassala station data only. TRMM and RFE showed good performance as well as events hydrological modeling with HEC-HMS. Giriraj and Sharma (2013), tried to develop a flood simulation model for best water allocation for spate irrigation in Gash scheme. Absence of reliable observed discharge and rainfall data were the common limitations among these studies.

Recently in 2018, a robust Flash Flood Early Warning System was developed for the Gash river for the first time based on hydrologic modeling (Elhadi et al., 2018). The Gash FEWS was developed by the Water Research Center of the University of Khartoum under a research project funded by the Ministry of Higher Education and Scientific Research of the Sudan. The Hydrologic Modeling System (HEC-HMS) software of the United State Army Corps of Engineer - Hydrologic Engineering Center was used for rainfall-runoff simulation. The Hydraulic Engineering Center's River Analysis System (HEC-RAS) was used for routing the outflow hydrograph in the river reach further downstream. The study used near-real-time Satellite Rainfall Estimates (SREs) data from the source "Tropical Rainfall Measuring Mission (TRMM-3B42RT V7)" to generate point as well as area-average rainfall over the catchment. A multiplicative bias procedure was adopted to validate the TRMM data sets (Elhadi et al., 2019).

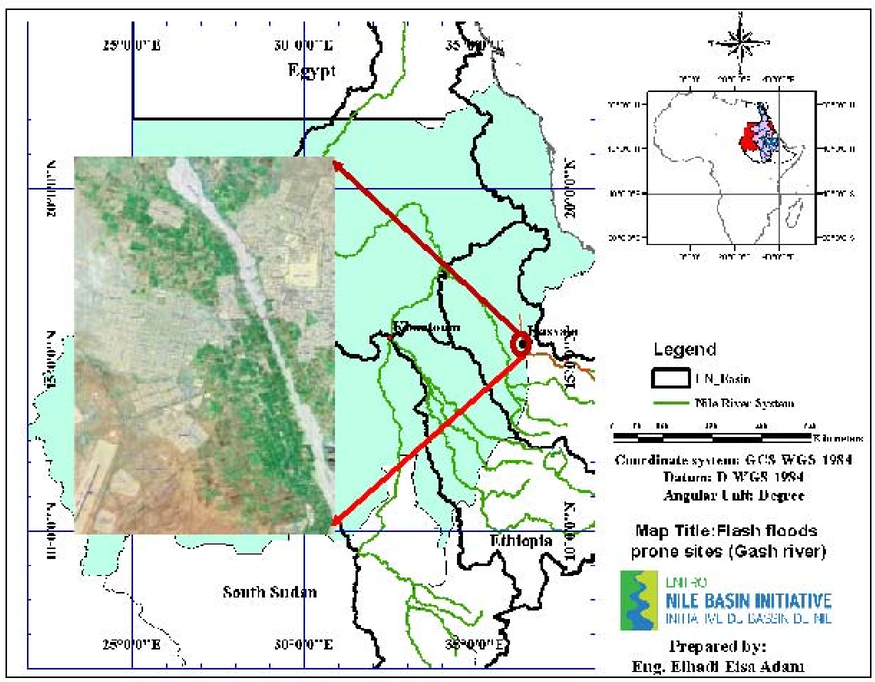


Figure 16: Location of Kassala city in Gash plain

Discharge data are available from Gash River Training Unit (GRTU) of the Ministry of Water Resources and Irrigation (MoWRI), in Sudan for a considerable period of time which used for calibration of the models. A semi-distributed rainfall-runoff model based on HEC-HMS software was developed. The results of hydrological modeling indicate reasonable correspondence between observed discharge and SRE in terms of peak and time to peak.

Rainfall-Runoff analysis showed a lead time in Gash basin – time from rainfall event, in upstream of catchment, to arrival of flood at Gera Station of 20 hours. Based on the lag time obtained, a manual FEWS for the Gash river was developed .The FEWS depends on the forecasted flow from the hydrologic model. The main function of the proposed FEWS is to issue warning message when threshold stage values are recorded at Gera station to prevent disasters flooding further downstream.

The model performed well in simulating the timing and magnitude of the stream during flooding. It provides improved monitoring and forecast information to guide relief activities (Elhadi, et al., 2018). The developed FEWS for Gash river is a manual type, it was designed in a such way to monitor the occurrence of flood waves, and issuing warning message when the hazardous flood event is imminent or already happening.

The alert level at Gera and Kassala Bridge stations

According to the GRTU practice there are some alert levels, above which the flood wave might break the embankment. At Gera station the level of 536.00 meter is the alert level, where at Kassala Bridge the level is 507.00 meter. Figure 17 shows the staff gauge at Kassala Bridge gauging station. These photos were taken on Monday 11, July 2019, when a flood wave reach value of 506.8 m. In the picture, the alert level is painted in red (507.00).

Gash River FEWS and FEWS-Sudan, as a result of the severe flooding during August 1988 along the River Nile plain in Sudan, the Ministry of Water Resources and Irrigation (MOWRI), of the Sudan, installed a Flood Early Warning System (FEWS) at the Nile River system in 1991. The "FEWS Sudan" model is used to enable more advanced warning for future floods from the Nile (Saghayroon & Adam, 1996; Abdo and Ahmed, 2008) The objective of the project is to discuss the main concept of the modeling systems required for the "FEWS-Sudan". The system, "FEWS Sudan", in operation since 1992 and stopped some years later then reinstalled in year 2010 by Deltares of Netherlands and the Hydraulic Research Center (HRC) of the MoWRI of the Sudan (UKCC, 2010; Verkade & Werner, 2010).

Figure 17: The alert level at Kassala Bridge gauging station.

Attempt has been made to add Gash river model in "FEWS-Sudan" model to be run within the system (figure 18). All the necessary changes to accommodate the model had been made according to Deltares guide lines (Verkade

& Werner, 2010). HEC-HMS model was added to the "FEWS Sudan" interface, the SRE data source were connected and added to the model, but unfortunately the model was not run, this issue is recommended for further investigation (Figure 18). This effort opens the window for the researchers to attempt incorporating the flash floods prone catchment to the existing FEWS environment and run the forecast using same procedure for FEWS.

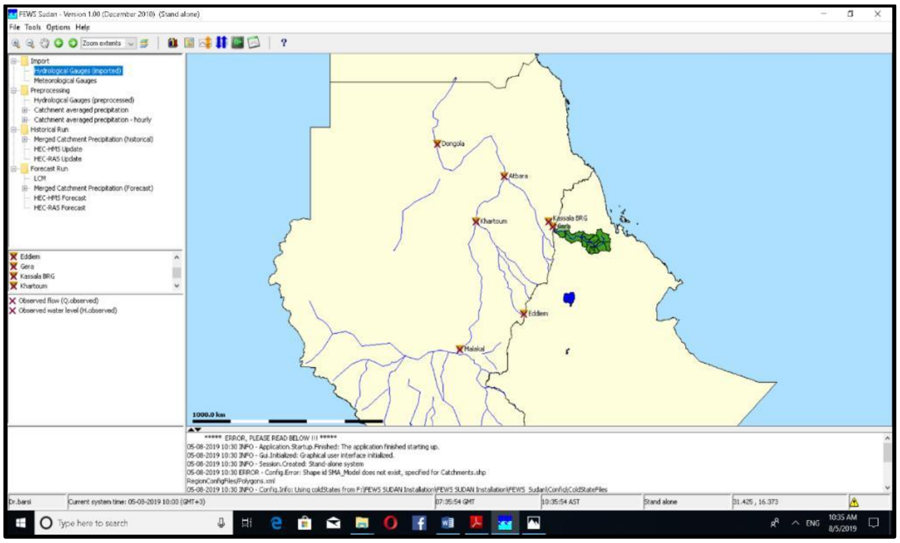


Figure 18: Gash catchment in the FEWS_Sudan interface (source: Elhadi et al 2018)

7.2.3. Stakeholders Need and Requirements in EN.

Flash floods EWS is very important for community, it can help in the following aspects:

- ✓ Planning flood response activities
- ✓ Taking necessary precautions to protect infrastructures
- ✓ Taking preventive measures against water borne diseases
- ✓ Encourage the appropriate response by the recipients

7.3. Possible Types of Flash Floods Forecasting Techniques for EN

Two types of flash floods forecast are applicable for the EN; Real-time and short-term. The two types are important for flood hazard management. Flood hazard management is primarily aimed at making plans to reduce flood hazard and control exposure. Flood forecasting is an essential tool for providing people still exposed to risk with advance notice of flooding, in an effort to save life and property.

7.3.1. Real-time flash floods forecasting

Real-time flood forecasting can be classified into three main categories (Andre et al, 2020):

Empirical scenarios; The empirical scenario approach relies on experience and observations of the past. This approach uses knowledge of previous flood events (e.g. accumulated rainfall in one hour, water levels) and establishes threshold levels based on historical accounts. Once these thresholds are exceeded a warning is issued. ***Pre-simulated scenarios***; In the pre-simulated scenario approach a scenario catalogue is created covering a range of flood events. As the name suggests, this approach requires some form of hydrological and hydrodynamic simulation. The modelling approach is based on data availability and a library of scenarios is created and stored.

In general, this approach uses information about the given rainfall forecast along with a set of rules for selecting the probable scenario. This can be done manually or by an automated system, and based on the results of the selected scenario, a warning is issued.

Real-time simulations using NWP models (WRF) or SREs (Now- cast); In the real-time simulation approach, hydrodynamic simulations are performed in real-time and their results are disseminated to responsible authorities and/or to the public through web services or as a SMS-message on mobile phones. The calibrated hydrological and hydrodynamic simulation model is fed with rainfall information in real-time and the simulations are performed and flood locations are identified. Areas or facilities with greater risk are usually identified in pre-studies and once the water level exceeds a certain threshold at that facility a warning is issued.

7.3.2. Short-term flash floods forecasting

Short term forecast gives advance warning of one up to three days of imminent flood hazard. The accuracy of short-term forecasts is generally lower than the real-time forecasts and mostly provide a tendency of upcoming rainfall. Two approaches can be used to carry out short-range forecasts; Hydrological modelling and, Streamflow correlation / routing (translation of flow). Short-term operational prediction of flash floods is different from that of large river floods in several aspects. Notably, short lead times for forecast, warning and response make operational flash flood prediction challenging, while they also make it a hydro meteorological problem, rather than a purely hydrological prediction problem. Furthermore, their potential occurrence at any time during a day or night also necessitates 24x7 operations for flash flood forecasting and warning.

Typically, the choice of a particular flood forecasting approach is based on the desired accuracy, forecast horizon, degree of complexity required, cost of producing the forecast, technological capacity and finally the available data. Each approach for flood forecasting has its advantages and disadvantages, but data constraints, technological capacity and the desired level of accuracy will ultimately determine the approach that can be implemented.

7.4. Input Data Sources for the EWS

7.4.1. Ground stations

The primary basic inputs to flash flood forecasting systems are rainfall, river stage/discharge, or both. These are the same basic requirements as for conventional flood forecasting systems, and although the same equipment is often used, these data collection systems can be manual or automated. Because of the short time interval (less than six hours) between the observed rainfall or upstream river height and the flood at the point of interest, the delays inherent in manual observation, reporting and recording systems are usually too great for useful forecasts and warnings to be made in time that is why automated system (telemetry) is preferred.

Automatic data-collection systems are usually based on a digital output from the sensor. Rain gauges are primarily of the tipping bucket type which provide a convenient incremental pulse count. River stage sensors, are usually a shaft rotation type which require a digital attachment from a flat well or a pressure transducer from a pressure line, either closed or a gas-purged line. These digital outputs can be telemetered by land-line (dedicated, telephone or telex lines), or by radio using ground or satellite repeaters.

The design of ground station networks for flash flood forecasting follows the same principles and techniques as those applied to conventional flood forecasting systems. The arrangements of rainfall stations network should take into consideration the areal variation of rainfall and the topographical catchment features.

7.4.2. Radar

As many flash flood situations result from thunderstorm rainfall, the accurate assessment of areal rainfall is a major problem in flash flood forecasting. Although the catchments are often small, many of them are in mountainous areas where orographic effects will increase the areal variability of rainfall. The use of RADAR in the EN basin is not much seen, it would be better to enhance the monitoring systems with such technology. Radar can be especially useful in assessing areal rainfall because it gives an aerial perspective and has the facility to estimate areal rainfall quickly

7.4.3. Satellite Rainfall Estimates (SREs)

Satellite data may also be used for estimating rainfall amounts and areal distribution. Recently, SREs has been used as alternative for regions with poor coverage of ground rainfall. As with radar, it is necessary to automate this technique using digital imagery data to provide the real-time speed and accuracy required for flash flood forecasting.

7.4.4. Quantitative Precipitation Forecasting (QPF)

Quantitative precipitation forecast (QPF) products are frequently considered to be part of the data available for flash floods forecasters. However, QPF plays an important role in flash flood forecasting. As a flash flood by definition is a flood which occurs after a short time interval between the causative event (usually heavy rainfall) and the flood at the point of interest, QPF is an extremely useful tool for both the meteorologist and the hydrologist. QPF shows both the areal distribution and the amount of the rainfall expected to occur over a given time period. The most important feature of QPFs is that they alert the forecaster to the potential for excessive rainfall.

7.5. Flash Floods Forecasting Techniques

Flash flood forecasting techniques can generally be considered as one of four groups: (Hall, 1981). First group, those based on meteorological input only, essentially the forecasting of heavy rainfall over an area. Second group, those based on hydrological techniques which use observed rainfall and/or river stage data to predict the flood height or to warn of impending river rises; and. The third group, those which are a combination of meteorological and hydrological techniques. The third group is generally the most useful as it has the advantages of additional warning time based on forecast rainfall and of specific flood forecasts based on predicted and observed rainfall, usually verified against observed river height. A fourth group covers those hydrological and hydraulic models which can be applied to the "dam break" situation.

7.5.1. Meteorological techniques

Meteorological techniques are essentially the forecasting and/or the advice of heavy rainfall. If meteorological conditions conducive to heavy, intense rainfall are observed or forecast for an area, a flash flood watch is issued. The flash floods watch alert residents of the area to the potential occurrence of rainfall which could result in flooding. Flash flood watches are usually valid for periods of 12 hours or less and may cover all or part of the forecast area.

The greater the lead time the more useful the watch, hence flash flood watches are more effective if issued prior to the onset of heavy rainfall. If excessive rainfall or actual flooding is reported a flash flood "warning" is issued. These are normally issued for periods of less than four hours and may be made for a single drainage basin although they usually cover several districts or counties. Flash flood warnings require residents of the area to take necessary precautions against flooding. Rainfall observers and automated rain gauges that can be interrogated by the meteorologist on demand or which warn of heavy rainfall, are the main source of data. Radar is especially useful as it gives an aerial perspective with a wide coverage and can delineate potential trouble areas.

7.5.2. Hydrological techniques

The simplest hydrological technique is to monitor the river upstream of the point of interest and to base flash flood warnings on stream rises. In view of the short times involved and in order to provide continuous monitoring, this system should be automated. A simple flash flood alarm system can include three components: a river station, an intermediate station and an alarm station (Abhas et al., 2012). The river station used for sensing the critical water level, and connected to the intermediate station. The alarm station can be located in an appropriate place in the community with continuous staffing, it receives a continuous signal from the river station. When the critical level is reached at the river station an audible and visible alarm can be activated.

The observation of rainfall rather than upstream river rises requires some form of hydrological model or assessment to determine the resulting flood potential. These may range from a simple "rule of thumb" of rainfall rates exceeding a given value over a given period to a complex hydrological model. To eliminate the delays inherent in centralized data collection, analysis and forecasting and warning, flash flood forecasting systems generally need to be developed on a local basis or, as “a local flash flood warning system”.

In flash flood forecasting the main requirement may be the quick identification of the fact that critical danger thresholds will be surpassed rather than the accurate definition of the magnitude and timing of the flood peak. Thus flash flood forecasting does not necessarily have to be complex, simple models may sufficient.

7.5.3. Meteorological - hydrological techniques

The most effective means of flash flood forecasting is to combine both meteorological and hydrological forecasting techniques. The use of QPF can extend the watch lead time which is the key parameter in forecasting flash floods. A flash flood warning system which has the advantages of a combined approach is consisting of three tasks:

- ✓ Collection of event-reporting data (sensors)
- ✓ Transfer of the data to the computer at the River Forecasting Centre (RFC) (processing)
- ✓ Streamflow forecast/flash flood warning generation.

The latter involves the input of WRF from the Weather Service Forecast Office and observed rainfall and river stage data.

7.5.4. Dam-break techniques

Catastrophic flash flooding results when a dam (either man-made or artificial - ice walls, jammed debris, etc.) fails and the outflow through the breach in the dam inundates the downstream valley. Usually the dam-break outflow is several times greater than any previous flood. Flooding due to dam break is a mega-disaster as it is associated with huge loss of life and property. An unusual high peak in a short duration and presence of a moving hydraulic shock/bore make it a different problem as compared to other natural floods. Little is known of failure modes of artificial or natural dams and failure may not occur until a certain flow over the crest of the dam is attained for an undetermined duration of time. Sometimes, blockage of water due to deposits caused by landslide takes place. When this natural blockage fails due to increased amount of water at the upstream, huge flooding occurs. The behavior of this flood is similar to that of dam break floods. Hence, forecasting of dam break floods is almost always limited to occasions when failure of the dam has actually been observed. Software such MIKE-11 can be used for dam break modeling.

7.6. Models and Software for Flash Floods Forecasting

Different flood forecasting service models exist based on the needs of end users: a system may be developed for the public or strictly dedicated to the authorities. There is no single consistent approach worldwide but the basic principles of a good warning system are shared by all. All the software used in the existing ENTRO FEWS are applicable for flash floods forecasting (hydrological models such as HEC-HMS and Hydraulic models such HEC-RAS and USGS tools). Even the existing FEWS system used for the Blue Nile, can be modified and used for modeling the rainfall-runoff process and routing the output hydrograph in the flash floods sites (Deltares, 2010, Elhadi et al, 2018).

Besides above mentioned software, variety of models are available which can be sued for flash floods modeling. Two-dimensional (2D) models are much suitable for floodplains, because they can determine the inundation extend beside simulating the rainfall runoff process such as; HEC-GeoRAS, TELEMAC 2D, SOBEK 1D2D, Delft 3D and RRI.

7.7. Proposed Flash Floods EWS for EN.

7.7.1. Introduction

The objective of the early warning systems is to empower individuals and communities threatened by hazards to act in sufficient time and in an appropriate manner so as to reduce the possibility of personal injury, loss of life, damage to property and the environment and loss of livelihoods (UN, 2006). A complete and effective early warning system comprises four key essentials and inter-related elements:

- Risk Knowledge; Detection of the conditions likely to lead to potential flooding, such as intense rainfall, prolonged rainfall, storms or snowmelt
- Monitoring and warning; Forecasting how those conditions will translate into flood hazards using modeling systems, pre-prepared scenarios or historical comparisons

- Dissemination and communication; Warning information via messages and broadcasting these warnings as appropriate
- Response to the actions of those who receive the warnings based on specific instructions or pre-prepared emergency plans.

Failure in any one of the four key elements of an EWS will lead to a lack of effectiveness. Inaccurate forecasts may lead to populations ignoring warnings issued subsequently. The lack of clear warning and instruction may have resulted, for example, in the deaths of people.

From the lesson learned from literature review through this study, two possible types of flash floods EWS can be proposed to be applied to address the flash floods in the EN; local flash floods EWS and regional flash floods EWS.

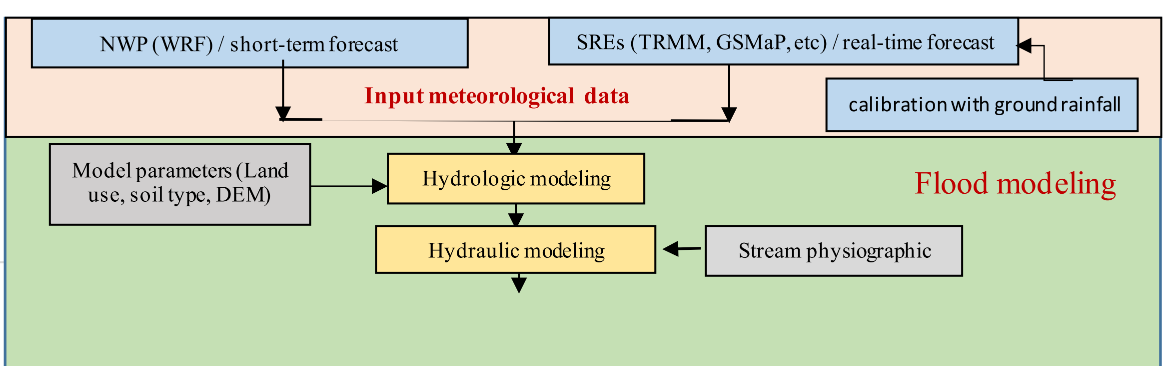
7.7.2. Local flash floods EWS

As it is obvious, the eastern Nile basin comprises many regions. These regions differ significantly regarding their hydrological processes, scale, landscape characteristics, infrastructure and identified user needs. The design of local flash flood warning systems will depend upon site specific problems, such as topography, climate, flood plain population, flood control structures, warning time and the resources available for program implementation. The systems can range from simple networks and procedures to sophisticated computer-based automatic systems.

The local flash floods EWS for the EN can be developed through multiple techniques and methods. As many flash floods EWS, the system can include data collection module which receive the weather data and SREs, necessary bias correction should be made to validate the SREs. The rainfall data is sued as input to hydrological model, which can be developed in specific software such as HEC-HMS. The produced hydrograph can be used directly or introduced to hydraulic model, here one can use specific software such HEC-RAS for routing the hydrograph and determine the water levels and inundation extend from predefined flood risk maps. Consequently, people at risk will be warned to take necessary response and actions.

EN Region Rainfall Forecast program provides a platform to share its information with Eastern Nile communities and to deliver a useful service to them. Continuously monitored for potential severe weather using WRF model and other regional and global NWP models is available which can be used by the system.

The local flash floods EWS can be manual or automated. In manual type, data collection, processing and dissemination of warning is manually. While in automated type, sensors can be used for data collection and system of computer hard ware and software for data processing and warning dissemination. The conceptual design of the proposed local flash floods EWS for EN is illustrated diagrammatically in figure 19 below.



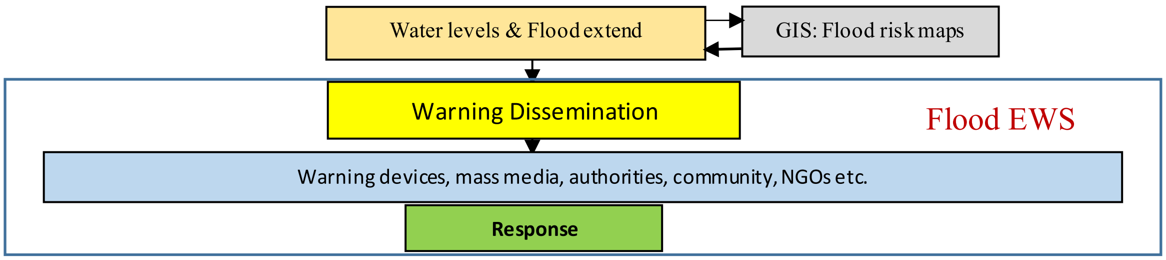


Figure 19: Conceptual design of the proposed local flash floods EWS for EN.

7.7.3. Regional Flash Floods EWS

The regional flash floods EWS can be used to cover the entire EN basin countries as we have seen in the Global FFGS. The Regional Flash Floods EWS can use the available Region Rainfall Forecast program provided by ENTRO and shared with eastern Nile communities to reflect the weather situation over the entire EN. The system can provide advance watch of imminent flood events to floodplain dwellers at the community level to be prepared.

The system can be schematized as given in figure 12 & 13, in this regard, ENTRO can approach the developer of the Global FFGS for possible implementation of the FFGS in the EN.

7.8. Warning Communication and Dissemination

The final forecasts are being communicated to the concerned administrative and engineering authorities of the state and other agencies concerned with the flood control and management work. EN countries already use a wide range of dissemination channels and it should be considered to use these channels as well to make sure no recipients of the forecast information are bypassed. Traditional communication method also can be used such as, telephone or by special messenger/telegram/wireless depending upon local factors like vulnerability of the area and availability of communication facilities etc. On receipt of flood forecasts, the above agencies disseminate flood warnings to the officers concerned and people likely to be affected and take necessary measures like strengthening of the flood protection and control works and evacuation of the people to safer places etc. before they are engulfed by floods.

Chapter 8: CONCLUSION AND RECOMMENDATIONS

8.1. Conclusion

The objective of this report is to assess the flash floods situation and develop guide lines to address flash floods in the Eastern Nile (EN). This report is based on literature review of key documents, field survey and investigations for some flash floods prone areas. The conclusion of the report can be summarized as follows:

8.1.1. Eastern Nile countries frequently experience catastrophic losses of human life, livelihoods and property as a result of flash floods. It is understood that flood risks will not subside in the future, as a result of climate change and variability, the hydrological cycle will become more intensified resulting in more weather extremes hence more flood and drought events. Two types of flash floods were observed in the EN basin; riverine flash floods and storm flash floods. Most of the flash floods in EN are as a result of torrential rainfall for short period of time.

8.1.2. The most vulnerable areas to flash floods in the EN basin were delineated, most flash floods prone areas are urban areas subjected to intense rainfall with poor drainage system and areas along the Nile system plains. Documentation of floods in terms of flood depth, area affected, damage to crops, damage to infrastructures, number of people affected, and overall monetary damage started recently by ENTRO for riverine floods. When flash floods are concerned, few data are available, historic records regarding frequency, magnitude, and duration of flash floods are very scarce. However, the available data showing the total affected area has increased significantly, there is a general trend of increased flash floods propensity in the EN.

8.1.3. Many critical gaps were raised, community awareness regarding flash floods gaps, hydro-meteorological data gaps, capacity building gaps, institutional arrangement and communication between different stakeholder's gaps. The major gap raised by this report is absent of flash flood forecast and early warning system.

8.1.4. Rainfall data is the most crucial atmospheric driver for hydrological modelling. Ground-based meteorological networks often have incomplete observations that commonly are available at point scale and fixed intervals, the network coverage is sparse, especially in flash flood prone areas. There were gaps in hydrological data, most of the flash floods were from isolated rainstorm, many wadis and khores which carry the generated runoff are ungauged.

8.1.5. Flood Early Warning Systems are well installed and established for most of the river systems in the EN, but it is sub-basin-wise there is no unified operational flood forecasting & and early warning system in the whole EN. Currently, ENTRO implementing a project for enhancing the existing FEWS to cover the entire basin. The FEWS systems are mainly depending on the monitoring and forecasting of the rainfall on the upper catchment in Ethiopia. WRF model is commonly used for rainfall forecast, SREs from different sources also were used. Hydrological models based on HEC-HMS are used for rainfall-runoff transformation, while hydraulic models (HEC-RAS and USGS- Global Flood Tool) for flood routing and inundation extend. The main source of input rainfall forecast is provided by Local Meteorological Authorities, ENTRO and IGAD Climate Prediction and Applications Centre (ICPAC) in Nairobi. Most of this information is related to riverine forecast not flash flood forecast.

8.1.6. Currently, there is no body taking care of flash floods forecast at national level or event at states level, and this is a major gap in flash floods management in the region. The humanitarian activities during flood occurrences are highly affected by the lack of information from formal or authorized organization that give warning in advance. From literature review, few instance of local attempts to develop flash floods EWS were observed, these instances are within a framework of research projects. Worldwide review of flash floods EWS showed a vast experience, the most state-of-the-art technology is the Flash Flood Guidance System (FFGS), which developed collaboratively between WMO and HRC of the SU.

8.1.7. Flash floods mitigation measures in EN before, during, and after flood events were reviewed. The emphasis was on structural measures through the implementation of some flood control structures (dams, embankment and hydraulic structures). FEWS and flood preparedness strategies were used also as one of the non-structural methods of floods management but to limited extend. The dominant trend of river management practices is only concentrated on the course of major rivers, wadis basins not always received adequate focus. New BMPs were proposed by this study for flash floods management in the EN. The paradigm for flash floods risk management in EN need to be broadened from simply post-disaster response to more comprehensive approach that also includes prevention and preparedness.

8.1.8. Guide lines for development effective flash floods EWS for the EN were proposed. Two types of flash floods EWS is suggested; Local and Regional flash floods EWS. The local flash floods EWS is a site-specific, it is based on the hydrodynamic modeling. Fortunately, all the software and models used by ENTRO to address riverine flood are applicable for the flash floods modeling. For regional flash floods EWS, the global Flash Floods Guidance System (FFGS) is proposed to be implemented in the EN basin. The global FFGS is based on the monitoring and watching of weather condition over the region using remote sense data and gives necessary warnings for imminent flood risk.

8.1.9. The recent enhancement of the FFWS for EN developed regional rainfall forecast model using WRF model, this advances in rainfall forecasting will contribute much to the flash flood forecasting and EWS in EN.

8.1.10. Development and sustainability of Flash Floods EWS requires political commitment and dedicated investments. The organization building a flash flood warning capability has a mandate by law to warn citizens of impending flash floods.

8.2. Recommendations for Future Works

The study recommended the followings:

8.2.1. Documentation of floods (riverine and flash floods) in terms of flood depth, area affected, damage to crops, damage to infrastructures, number of people affected, and overall monetary damage.

8.2.2. The use of RADAR rainfall is highly recommended, which enhances the monitoring system and provide accurate and continuous coverage for better flood EWS.

8.2.3. The use of rainfall forecast for flash floods EWS (e.g. from developed regional WRF model) will increase the lead time in flash floods sites.

8.2.4. Enhancing the hydro-met monitoring system in flash floods catchment and streams.

8.2.5. The dominant trend of floods management practices is only concentrated on the course of major rivers; adequate focus should be given to seasonal wadi and flash floods streams.

8.2.6. The existing structural flood management system and flood control facilities in the EN region should be reviewed in the present flood risk perspective keeping in view the high rates of urban growth and stress on land use patterns.

8.2.7. The land use plans should be based on intensive assessment of flood risk, and it would be a better idea to make the land use plans based on multi hazard risk assessment for sustainable use of economic resources for development.

8.2.8. The infrastructure and plans in major cities should be reviewed and upgraded to withstand flash floods risk. Making the vulnerable communities aware of flash floods risk is a major area of focus, a multi prong approach for spreading awareness.

8.2.9. The preparedness, rescue and relief contingency plans should have special emphasis on the vulnerable segment of the communities: the poor, old, women, pregnant, children and the disabled.

8.2.10. One of the most intrinsic gabs in flash floods risk management in the region is creation, maintenance and proper use of database and development of robust flash floods EWS. Data should be accessible to the EN basin countries.

8.2.11. ENTRO can approach WMO and HRC of the US for possible implementation of the FFGS in the EN region.

8.2.12. Early warning system should be incorporated as integral components of any nation's disaster risk management strategy, enabling governments and communities to take appropriate measures towards building community resilience to natural disasters.

8.2.13. Mainstreaming DRR into the developmental plans is highly recommended for easy recover, reconstruction and long term flood risk resilience.

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APPENDICES:

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B: TOR

Cooperation in International Waters in Africa (CIWA) (AF-2)

Terms of Reference

Flash Flood Expert (1 International position)

1. BACKGROUND

The Nile Basin Initiative (NBI) is an intergovernmental partnership led by 10 Member States. The partnership was established on 22nd February 1999 and is guided by a Shared Vision Objective: 'To achieve sustainable socio-economic development through equitable utilization of, and benefit from, the common Nile Basin Water resources'. NBI member countries launched a Strategic Action Program with two sub-programs: the basin-wide Shared Vision Program (SVP) that aimed at building confidence, capacity and knowledge base (now phased out), and two Subsidiary Action Programs (the Eastern Nile and the Nile Equatorial Lakes Subsidiary Action Program – ENSAP and NELSAP) that initiate concrete joint investments and action on the ground at sub-basin levels.

The Eastern Nile Subsidiary Action Program (ENSAP) was launched by Egypt, Ethiopia and the Sudan (South Sudan joined in 2012 following its independence) to initiate concrete joint investments in the Eastern Nile (EN) sub-basin. ENSAP is governed by the Eastern Nile Council of Ministers (ENCOM) and implemented by the Eastern Nile Technical Regional Office (ENTRO) headquartered in Addis Ababa, Ethiopia. ENSAP is funded by the four member countries and bilateral and multilateral Development Partners.

The Integrated Development of the Eastern Nile (IDEN) was the first ENSAP project agreed by the member countries in 2002. IDEN consisted of a first set of seven subprojects aiming at tangible win-win gains in watershed management; flood preparedness and early warning; irrigation and drainage; power supply interconnection and regional power trade; planning model along with the Joint Multi-Purpose development Project (JMP) of the Eastern Nile and Baro-Akobo-Sobat Multipurpose Water Resources Development Study Projects.

Currently, ENTRO is implementing its 2nd, 2014-2019, Strategic Plan. The Strategic Plan which is oriented in four strategic directions (i.e. Facilitating Cooperation, Promoting Water Resources Management and Planning, promoting Water Resources Development and Power Trade, and Institution Building) strives to position ENTRO for effective pursuance of its focus on Investment.

The EN Flood Protection and Early Warning Project (FPEW) has been one of the earliest successful IDEN Projects. The Project aims to reduce human suffering caused by frequent flooding, while preserving the environmental benefits of floods. The project emphasis on enhancing regional collaboration and national capacity in flood risk management, including flood mitigation, forecasting, early warning systems, emergency preparedness, and response. The FPEW project that ran until 2010 operated in Egypt, Ethiopia, and Sudan.

After the completion of FPEW project ENTRO initiated with Eastern Nile countries and created a regional Flood Forecast and Early Warning (FFEW) system under the Eastern Nile Planning Model project (ENPM) and the FFEW activity continued under the current Nile Cooperation for Result project (NCORE). The FFEW, since its establishment, has been an important part of ENTRO's activity that continuously been conducted for the last seven flood seasons (June – September). The FFEW has helped the Eastern Nile countries in reducing the loss of life and money by preparing flood forecast bulletins for the Lake Tana (Blue Nile -Ethiopia), the Blue Nile-Main Nile (Sudan) and Baro-Akobo-Sobat(BAS) sub-basins flood prone areas. The FFEW activity have strengthened national offices in terms of capacity and overall reduced the risk of flood devastation for 2.2 million people in the region.

The current FFEWS has gaps on the coverage of the basin, inefficiency and needs enhancement to use most updated and robust system. It is with this objective ENTRO apply and secured a funding from the World Bank by the Cooperation in International Waters in Africa (CIWA) trust fund, and intends to apply to enhance the current FFEW with different aspects. Part of this to have a FFEW system which can address flash floods since the current system covers only riverine flooding for selected flood prone areas. While evidence shows significant portion of the Eastern Nile basin is frequently affected by flash floods. Flooding events in 1998, 2006, 2010, 2013 and 2014 in different parts of the basin has shown as urbanizing grows many more areas in the basin are expected to be affected by more frequent flash floods. Therefore, is necessary to start assessing the vulnerable areas for flash flood and develop a strategy to implement a system that mitigate flash flood threat. ENTRO intends to employ the services of an individual consultant to conduct an assessment study on flash flooding and to development of the conceptual design of flash forecast system.

2. Objective

The objective of this service is to assess the extent and identify types of flash flood in the Eastern Nile basin and develop a design specification of flash flood forecast system. This contribute to a higher level objective, i.e. to ensure a robust forecasting, issuing and warning system that effectively minimize loss of life and damage.

3. Scope of Service

The scope of service is divided into three main Tasks. These Tasks are listed as follows;

3.1. Task 1: Flash flood assessment:

- Review flash flood event in the Eastern Nile basin
- Carry out a study on "Addressing Flash flood in Eastern Nile Basin" with among other activities to

  o Classify types of floods o Map out sub catchments with frequents flash floods occurrence o Assess the current hydro-meteorological infrastructure in these sub catchments and any existing early warning systems o Assess current practice to mitigate flash floods

- Report writing

3.2. Task 2: Guideline to address flash flood:

- Review both regional and international methods in addressing flash flood with proper forecast and early warning system
- Develop a guideline to ensure up to date methodology that can be adopted with for Eastern Nile basin to address flash flood of different types. The guideline shall include a detail terms of reference for the development of Flash flood forecast and early warning system for Eastern Nile basin

3.3. Task 3: Capacity building

- Throughout the study a continuous capacity building activity are going to be given to ENTRO staff with all facilities and cost related to venue and participant covered by ENTRO.
- Participate in at least two validation and consultation workshops

4. DELIVERABLES

Table 1: Deliverable and targeted schedule

Deliverable	Description	Schedule after commencement	Payment

Task 1	A technical document on flash flood assessment on current extent; type's flash flood and current practice in addressing this challenge.	1 - 2 months	40%
Task 2	A guideline on availability of Flash Flood forecast and early warning system world-wide and proposed guideline to be implemented for establishing a Flash Flood forecast and Early warning system for Eastern Nile basin	2 - 3 months	40%
Task 3	• Conduct training • Participate in consultation and validation workshop	1 - 3 months	20%

5. IMPLEMENTATION ARRANGMENT

The Water Resource Planning unit representing ENTRO, is the designated representative of the Client and will be responsible for work oversight and contract administration. The consultant will work closely with FFEW project team leader to create a synergy with this service its contribution to the overall FFEW activity.

The services to be provided by ENTRO include the following:

- Be responsible for the overall implementation of the project and managing the interfaces between this Consultancy and other relevant activities
- Organize and facilitate the training program with the help of the Consultant
- Provision of Office space suitably furnished with electricity, telephone and internet connections at ENTRO office
- Facilitate access to the different government departments/utilities//institutions with data and information relevant to the consultancy

6. QUALIFICATIONS & EXPERIENCE

- At least Master degree in civil engineering/water, resources engineering, hydrology, hydraulic engineering, hydro-informatics or closely related fields
- At least 10 years' experience in flash flood forecast related assignments Experience in modeling flash flood
- Experience in flood management and disaster early warning activities
- Experience in using GIS and hydrologic forecast systems
- Very good command of written and spoken English

7. Level of Effort, Budget and Schedule

The flash flood study consultants shall provide a total of 30 staff days over a period of three months. The Consultant shall work from his/her home venue with travels to the ENTRO as required.

During this period the consultant may undertake at least one trips to ENTRO's offices located in Addis Ababa, Ethiopia.

Payment shall be effected upon submission of invoices to ENTRO as well as submission and acceptance of deliverables. Reimbursable expenses will include international travel (economy class), accommodation and daily subsistence allowance at the ENTRO rate, in accordance with ENTRO policies.