FLOOD EARLY WARNING SYSTEM IN PRACTICE

EXPERIENCES OF NEPAL

PRACTICAL ACTION
Technology challenging poverty

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Forewords

Flood Early Warning System (EWS) is one of the key programmes implemented by Practical Action in Nepal since 2002. With around one and half decades of experience, the system has developed from piloting and grown to the current status effectively saving lives and properties across many communities. Practical Action is engaged with the Department of Hydrology and Meteorology (DHM) , Government of Nepal for the establishment of community based flood EWS in eight major river systems (Kankai, Koshi, East Rapti, Narayani, Seti (Pokhara), West Rapti, Babai and Karnali) in Nepal. Moreover, technical support have been provided to scale out the system to other rivers in the country and in establishment of cross border flood EWS between Nepal and India.

We have realised, there is a need of EWS in South Asia regional scale as the disasters are not limited within the political boundary. To make this happen, there is a need for strategic coordination and collaboration between and among the nations, and advancement of technologies to meet the needs. Besides flood, the EWS is equally essential for other hazards like landslides and earthquake both at national and regional levels. However, flood EWS will remain a focus programme of Practical Action in South Asia and in Nepal. In addition, watch and warn to ICT based system, upstream – downstream linkages for EWS, collaboration with DHM, relevant government line agencies and partner organisations in the region for technical advancement, expanded geographic coverage, capacity development and support in policy formulation need further strengthening in the system in coming days.

I acknowledge my colleague Gehendra Bahadur Gurung, Head of Disaster Risk Reduction and Climate Change for preparing manuscript of this publication based on his decade of experience on flood EWS in Nepal. I highly appreciate technical review, inputs and feedbacks to this document by Dr. Dilip Kumar Gautam. I thank my colleague Sumit Dugar for preparing updated river basin maps, and Upendra Shrestha and Archana Gurung for editing and arranging this publication.

This publication captures long standing experiences of Practical Action and hope that it will be useful for other practitioners who are interested and engaged in EWS for Disaster Risk Reduction (DRR).

Achyut Luitel
South Asia Regional Director
Practical Action

Contents

Abbreviations

a.m.	ante meridiem
APF	Armed Police Force
BCM	Billion Cubic Metre
CBEWS	Community Based Early Warning System
CBS	Central Bureau of Statistics
CDO	Chief District Officer
CDMC	Community Disaster Management Committee
DAO	District Administrative Office
DDC	District Development Committee
DDRC	District Disaster Relief Committee
DEOC	District Emergency Operation Centre
DHM	Department of Hydrology and Meteorology
DIPECHO	Disaster Preparedness of European Commission Humanitarian Organisation
DMC	Disaster Management Committee
DPNet	Disaster Preparedness Network
DPRP	Disaster Preparedness and Response Plan
DRR	Disaster Risk Reduction
DWIDP	Department of Water Induced Disaster Preparedness
EWS	Early Warning System
FM	Frequency Modulation
GIS	Geographic Information System
GLOF	Glacial Lake Outburst Flood
HEC-RAS	Hydrological Engineering Centre's River Analysis System
IPCC	Inter-governmental Panel on Climate Change
LDMC	Local Disaster Management Committee
LDO	Local Development Officer
LDRMP	Local Disaster Risk Management Plan
MoFALD	Ministry of Federal Affairs and Local Development
MoHA	Ministry of Home Affairs
MoPE	Ministry of Population and Environment
NDRF	National Disaster Response Framework
NEOC	National Emergency Operation Centre
NGO	Non-Government Organisation
NPC	National Planning Commission
NPR	Nepalese Rupees
NRCS	Nepal Red Cross Society
NSDRM	National Strategy for Disaster Risk Management
p.m.	post meridiem
PVA	Participatory Vulnerability Assessment
SMS	Short Message Services
SoHAM	Society of Hydrology and Meteorology
SOP	Standard Operation Procedure
SP	Superintendent of Police
SWC	Social Welfare Council
UNISDR	United Nations International Strategy for Disaster Reduction
VDC	Village Development Committee
VDMC	Village Disaster Management Committee
VDMP	Village Disaster Management Plan
VHF	Very High Frequency
WECS	Water and Energy Commission Secretariat

CHAPTER 1

Understanding the Early Warning System

Early Warning has been defined as "the set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organisations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss" (UNISDR, 2009). This definition is also upheld by IPCC (2012).

The definition captures a broad range of hazards. Therefore, it looks a bit abstract and speaks at macro level. Some words like timely and meaningful are relative. The definition might be further elaborated to accommodate additional scope, for example, early warning does not only reduce the possibility of harm or loss but in practice it reduces both the absolute harm and loss of lives and properties if the hazard occurs as predicted. The ultimate aim of early warning is not only reducing the "possibility" but it is also reducing the "real" loss and harm. UNISDR elaborates that "a people-centred early warning system necessarily comprises four key elements: 1) Risk assessment and knowledge; 2) Risk Monitoring and Warning; 3) Risk Information Communication and Dissemination; and 4) Capacity building for response. The expression, "end-to-end warning system" is also used to emphasise that warning systems need to span all steps from hazard detection to community response.

A community based Early Warning System (EWS) keeps the community at the centre; reaching its benefits, reducing loss and damages to individuals and the organisations.

Figure 1 shows the basic elements of EWS. However, the elements need further elaborations. The **Risk Assessment and Knowledge** needs communities and stakeholders' participation. The communities and the stakeholders should be aware

Figure 1: Four elements of effective early warning system

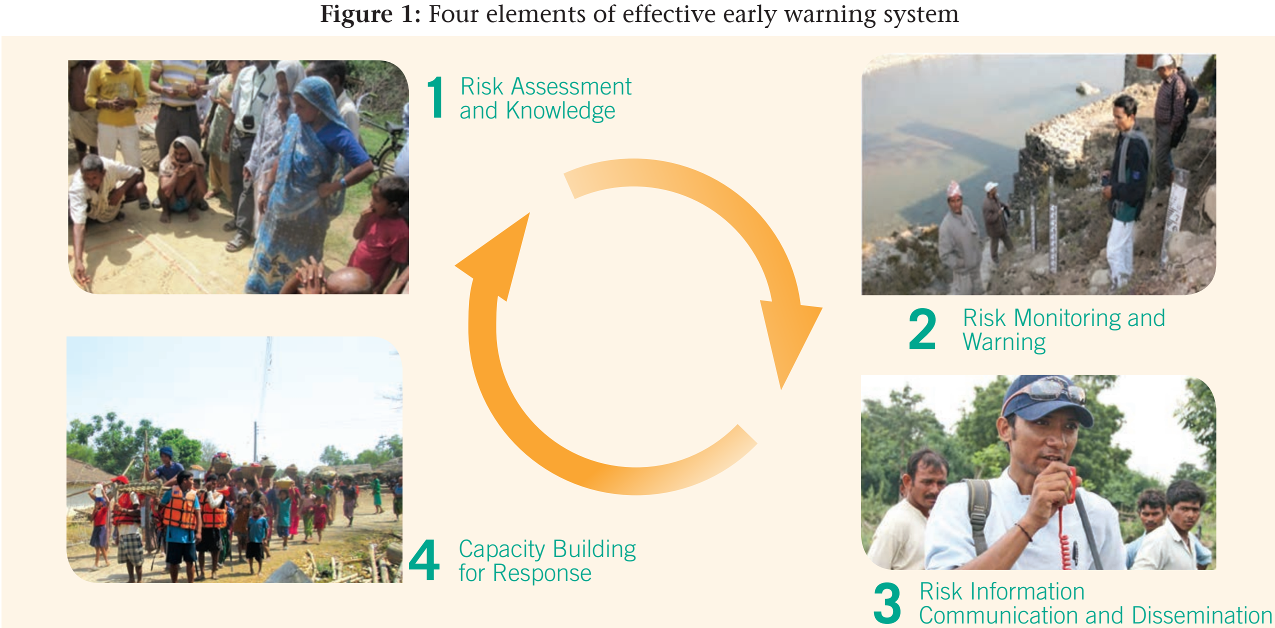


Table 1: Checklist of four elements of effective early warning systems

Risk Assessment and Knowledge	Risk Monitoring and Warning	Risk Information Communication and Dissemination	Capacity Building for Response
Systematically collect data and undertake risk assessments	*Develop hazard monitoring and early warning services*	*Communicate risk information and early warnings*	*Build national and community response capabilities*
• Are the hazards and the vulnerabilities well known? • What are the patterns and trends in these factors? • Are risk maps and data widely available?	• Are the right parameters being monitored? • Is there a sound scientific basis for making forecasts? • Can accurate and timely warnings be generated?	• Do warnings reach all of those at risk? • Are the risks and the warnings understood? • Is the warning information clear and useable?	• Are response plans up to date and tested? • Are local capacities and knowledge made use of? • Are people prepared and ready to react to warnings?

Source: UNISDR (2006)

of the risk. This element is the foundation of the EWS that shapes the activities to be undertaken under the other three elements. In the case of the second element, **Risk Monitoring and Warning**, it is beyond hazard monitoring focused more around risk monitoring. Because monitoring does not limit to hazard, it includes monitoring of risks due to hazard. If hazard is not going to result in any disaster or does not create any risk, there is little use of information coming from monitoring of hazard. Nonetheless, monitoring of the hazard will be the actual practice on the ground, but without knowing the risk, simply monitoring of hazard and issuing warning will not be a complete task. So, along with monitoring of hazard, the associated risk should be monitored. Warning is issued only when critical level of hazard that causes significant risk is detected. In case of the third element, **Risk Information Communication and Dissemination**, communication and dissemination go hand in hand once warning is issued. Communication of warning takes place from institution to institution and person to person, whereas dissemination takes place in the form of mass communication through radio, television, megaphones, sirens, among others to make the reach of information at individual level.

Communication and dissemination process does not only cover alert and warning of hazard but also provide risk warning or information including possible response measures as advisories. On the fourth element, **Capacity Building for Response**, the capacity should be viewed beyond local level which is also needed at subnational and national level authorities and stakeholders to understand, respond and manage the implications.

The response is a coordinated effort between local, sub-national and national authorities or even in case of trans-boundary events between the countries. So, response capacity is also needed at trans-boundary or international level. Once the warning information is received, the district and central level authorities and the stakeholders send search and rescue teams with skill and equipment to support the communities to safely evacuate and bring them out of the risk zone. They also need to provide immediate humanitarian supports, both non-food and food items. Therefore, the capacity building for response (knowledge, skills and resource) should be targeted to all stakeholders including the government authorities at local, district, national and trans-boundary levels. Table 1 shows the four key elements of EWS with questions that need to be answered while undertaking the activities under each element of EWS.

This framework gives a systematic guidance for development and application of EWS. In the following paragraphs, each EWS element and the check questions under the elements is discussed for more clarity.

Risk Assessment and Knowledge

The risk mentioned here is disaster risk. Early warning provides warning on disaster risk to those who are exposed to a hazard and need to respond to warning information. Therefore, risk knowledge and risk information are the first and the most important elements in EWS. According to the UNISDR (2009), disaster risk is "the potential disaster losses, in lives, health status, livelihoods, the assets and services, which could occur to a particular community or a society over some specified future time period." The definition of disaster risk reflects the concept of disasters as the outcome of continuity of risk conditions. Disaster risk comprises different types of potential losses which are often difficult to quantify. Nevertheless, with knowledge of the prevailing hazards and the patterns of population and socio-economic development, disaster risks can be assessed and mapped in broad terms.

For simplicity, this document will use the following equation for disaster risk:

Disaster Risk = Hazard × Vulnerability (quality and quantity of life and properties exposed to the hazard)

In the above equation, the arithmetic symbol "×" (multiplication) is used as the disaster effect that occurs in multiplied scale between hazard and vulnerability. Capacity plays important roles in DRR. However in this equation, highly vulnerable means less capable.

The disaster risk has two factors, first is hazard and the second is quality and quantity of lives and properties prone to hazard. In order to get proper risk knowledge and risk information, systematic assessment of hazard and its impact on quality and quantity of lives and properties need to be studied. Risk is dynamic because the elements of risk are dynamic, so is the trend and pattern of hazard and the population; their properties and assets should also be reviewed periodically. Such patterns and trends of hazard and the elements in risk should also be projected for the future. The flood volume could be static, increasing or decreasing; the increasing trend shows high risk. Similarly, the pattern of flood in the floodplain can be changing because of change in bed level, sedimentation, erosion and other development activities. Change in flood pattern might bring risk to new locations, new communities, or new assets and properties other than previously exposed population and assets. Change in population and their assets is observed over the time in the flood zone.

From the above information we can say that disaster risk assessment assess lives, properties and their values at different levels of flood and identify the critical level of flood that can significantly bring adverse effects to the community. Based on the past trends, probability of reaching the critical level can be assessed. Once detail risks are assessed and risk information is known, the risk information and knowledge should be shared and disseminated among the stakeholders and communities at risk. The information should also be made available to communities and stakeholders whenever they want it. Understanding of risk information by communities and stakeholders will enhance other elements of the EWS. The risk assessment allows the communities and stakeholders identify the assets and population likely to be affected by flood or hazard at different levels or scales. The hazard needs to be monitored so that when it reaches critical levels, warning can be issued to the communities and stakeholders.

Risk Monitoring and Warning

The risk monitoring and warning service is based on monitoring of hazard (flood), the population and their properties. These elements (flood, population and properties) are dynamic which result into change in risks over the time requiring continuous monitoring and information update. But the question is "are the right parameters being monitored?". In the case of flood, monitoring of flood level is very important during flood season. The real-time flood EWS is based on flood information that comes from monitoring of river at gauge station on real-time basis. At the gauge station, flood level, discharge and velocity are monitored. Flood level has been considered as the key monitoring indicator for flood EWS. Different instruments and methods are used for flood monitoring including manual staff gauges or/ and automated instrument including float, radar or bubbler system. In fact, there should be more than a single monitoring system to ensure if one fails, the other still works.

Beside floods, monitoring of population and their properties in the flood plain is important. These factors change seasonally and over years. The population may move-in and move-out, physical development may occur in flood prone areas over the time. The dynamics is seasonal as the crops change and movement of people change between the seasons which need continuous monitoring.

The warning based on real-time flood information provides very short lead time especially for the communities located close to the flood monitoring station. The communities residing in distance from the downstream of the gauge will get longer lead-time to prepare, protect and move towards safer place before the flood actually arrives to them. But it cannot be assumed that every person will be at home when warning is issued. Similarly, the stakeholders also require adequate time to reach to the communities to support for rescue and evacuation. As the warning information from real time flood monitoring has a short lead time, there is a need for a forecast based early warning system as well. Although there are uncertainties in forecasting, EWS based on forecasted information increase the lead-time significantly, allowing people with more time to prepare to respond. If they know the likelihood of flood in advance before days, they will be able to manage their day-to-day activities to minimise the loss and damage. The accuracy of flood information decreases with increase in lead time as the flood information depends upon rainfall monitoring and weather forecasting. So wherever possible and where resources and capacities are within the reach, it is desirable to adopt a number of monitoring and forecasting mechanisms. Monitoring and forecasting system should be based on sound scientific tools and methodologies to answer the question "is there a sound scientific basis for making forecasting?". The accuracy of monitoring and forecasting depends on use of scientific tools, methodologies and systematic risk assessment.

Risk Information Communication and Dissemination

The the warning and information coming from monitoring of flood level, population and properties exposed to different levels of flood need to be timely and quickly communicated and disseminated to the stakeholders and communities at risk. There are two activities – communication and dissemination. In this document, communication is considered as the flow of warning information from institution to institution whereas dissemination is the flow of the warning information from the source and institutions to wider users reaching at individual level. The warning information should reach to each household and each individual in the communities within the flood (hazard) zone in advance so that the communities have sufficient time to be prepared before the flood reaches them. The timely communication and dissemination of warning enable people to save their lives and moveable assets and properties. To ensure reach of the information, institution to institution and individual to individual communications system needs to be established using various effective communication means such as telephones, Very High Frequency (VHF) radio, Short Messaging Service (SMS), Internet, home-to-home visits.

For wider dissemination of information, various mass communication channels suitable to the local context such as television, radio, sirens and megaphones can be used to ensure information reach to every individual of the likely affected area. Local televisions and radios which focus and prioritise the local issues can be pivotal. Hence, use of a diverse means of communication and dissemination ensures that the warning information reach not only to those who are at risk but also to those who are responsible to support the communities at risk. Dissemination also enhances the reach of warning to neighbouring communities who may not be at risk of the flood (hazard) but can play crucial roles in supporting communities who are in the flood zone.

Understanding of warning information by the receiver is very important. It primarily depends on accuracy in assessing risks and its uncertainties and dissemination of risk information along with its uncertainty to the people at risk and stakeholders responsible for responding the risk information. It also depends on active participation of the communities and stakeholders in risks assessment, use of language that communities understand, the ways it is disseminated, and the ownership of information by the stakeholders and communities. Very importantly, warning information should be owned and understood by the Chief District Officer (CDO) who is the responsible authority to mobilise the rescue and relief team in the district for response, rescue, relief and humanitarian assistance to the communities at the time of disaster.

Communication and dissemination of warning takes place through a number of means and channels, so all actors in the communication channel including the radio broadcasters, VHF radio operators, telephone service providers, etc., needs to be aware of the existing EWS system and interpretation of the information being communicated. The warning information should also include what needs to be done by the communities and stakeholders in the form of advisory in order to make the information usable. Such information or advisories include but not limited to: location of safer places to go to; focal points for additional communication and further assistance; availability and location of goods and services for evacuation; rescuing and caring of other persons, assets and properties; likely time of flood reaching the communities; among others.

Capacity Building for Response

Once warning information is reached or received by the communities at risk and stakeholders, they need to respond to the information. This needs capacity in their part to understand the information (discussed in the previous sections), including means and skills to respond to the information. Individual households, community as well as stakeholders at national level, all need to be capacitated. At the household level, each individual should be able to protect their lives and assets or properties by packing and carrying with them at the time of evacuation. Such valuables include ornaments, certificates, licenses, cash, land ownership papers, citizenship, passport and others. The individuals should also be able to carry such materials as food and clothes for the emergency period. They should be able to identify safe routes and means of transport like community boat and safe shelters or any location for safe evacuation.

At the community level, there should be committees and task forces. These committees and task forces should have adequate and needful skills, materials and equipment to communicate and evacuate people to a safer place once they get warning information. Such needful equipment and materials may include megaphones, hand sirens, life jackets, boats or tubes which support the committees and task forces in their operations. On top of these, they should also have adequate materials such as tents, tarpaulins and groundsheets needed for emergency shelters.

At the stakeholder level, including government institutions at district and national levels, diverse capacity is needed. Such capacities are in addition to what the people have at local level. They should also have capacity to manage temporarily displaced people after the disaster. Such management requirements could be food, clothes, medical supplies, clean drinking water, toilets, utensils, tents, tarpaulins, groundsheets for temporary shelters, among others. Management needs in temporary shelters could be different for different categories of people like male, female, children, elder, persons with disability, pregnant women, among others.

The other important stakeholders are media like radio and television which disseminate the right information at right time to the right mass. These stakeholders should have access to the information and have capacity, skills and equipment to rightly interpret the information for timely dissemination to the targeted audiences.

Response capacities and skills at all layers – from community to district and national stakeholders – for a number of activities are essential. The capacity demands adequate and right equipment, mechanisms and skills for communication at each layer, and governance skills of the authorities at the time of emergency. It needs a systematic and institutional mechanism for coordinated response. Moreover, the other important component of the capacity is to have a well explained and well understood plan of actions for response to early warning. Such plan could be at district and community levels which should be tested beforehand and actors of the plan should be well acquainted with it. The plan should be reviewed and drilled periodically to enhance the capacity of the communities and stakeholders. Drilling practices is necessary to help making the plan more realistic. A complete set of procedure and activities in the form of Standard Operating Procedure (SOP) should be prepared and shared with all stakeholders.

CHAPTER 2

Rivers and Floods in Nepal

The rivers in Nepal are categorised in three systems based on their origin. The first category of river is snow or glacier-fed rivers that originate from the Himalaya. The second category of rivers originate from the Mahabharat or middle mountains and the third category originates from the Churiya Hills or lower hills. Mahakali, Karnali, Narayani and Koshi are the rivers of first category. These rivers are perennial and they contribute around 78 per cent of the average annual discharge of rivers in Nepal (Water and Energy Commission, 2011). The second category rivers are Babai, West Rapti, Bagmati, Kamala, and Kankai. These rivers contribute about 9 per cent of the average annual discharge from Nepal (ibid). The third category of river constitutes a number of small rivers originating from the Churiya and lower regions and contributes 13 per cent of average annual discharge of rivers. The first and the second categories of rivers are perennial.

The third category rivers are mostly dry or have negligible discharge in low flow season or months of the year. Nepal receives 17.2 BCM of water from Tibet (China) and drains 227.5 BCM annually to India (Sharma, 2014).

Nepal's rivers flow through narrow channels of high gradients. In mountains, the average gradient of rivers is 40 m per kilometre (WECS, 2011). The average slope for all categories of rivers based on measurement of 51 rivers ranges between 10 to 32 per cent (Sharma and Adhikari, 2004). The rivers flow with high velocity in hills and the mountains carrying heavy loads of sediments due to erosion and as they enter lower elevation, the gradient becomes flatter enhancing sedimentations causing rise in bed level and increasing potential for flood. Table 2 provides information regarding gradients of the rivers in Nepal.

Map 1: Major river basins of Nepal

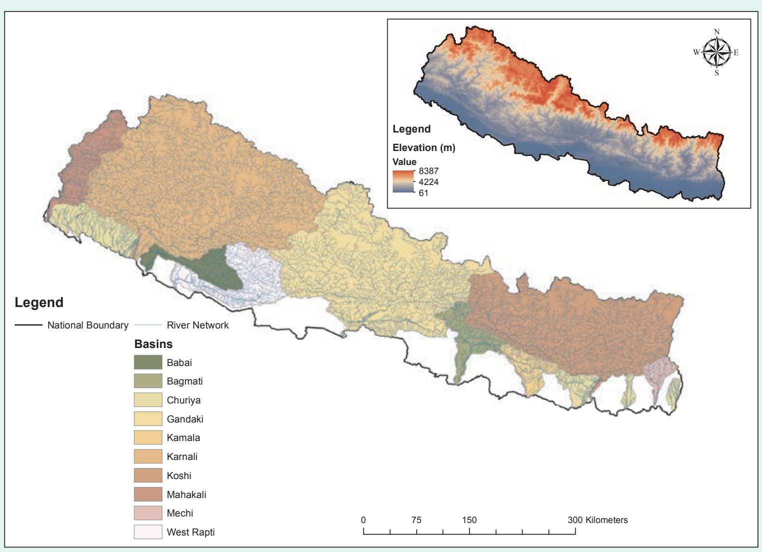


Table 2: River gradients in Nepal

River	Upper point (ft)	Lower point (ft)	Length (miles)	Drop in Feet/ Mile
Mountain Rivers				
Arun	Tibet (10,000)	Mughaghat (1,500)	93	91
Tamor	Sakathum (2,500)	Mahasar (1,500)	42	24
Sunkoshi	Kodari (5,000)	SurungKudule (1,500)	98	36
Khimti	Lomsa (10,000)	Benighat (1,852)	36	226
Likhu	Ranganag (7,500)	Kolanger (1,700)	34	170
Dudhkoshi	Jubing (5,000)	Kudule (1,550)	46	75
Trishuli A	Rasuwa (6,000)	Jharakatteri (2,500)	20	175
Trishuli B	Mailing pati (10,000)	Karmang (3,000)	6	1,250
Budhigandaki	Bihi (5,000)	Arughat (2,000)	31	97
Daroudi	Dhansira (4,000)	Sangu (1,500)	17	147
Marsyangdi	Bhraka (11,000)	Chepeghat (1,500)	64	148
Madi	Taprang (6,000)	Prajuli (1,500)	18	250
Maidam Khola	Head (5,000)	Singhi (2,500)	10	250
Seti Khola	Peak (6,500)	Bathala (1,500)	23	217
Kaligandaki	Riri bazar (2,000)	Hungighat (1,500)	17	29
Rapti	(LibangGaun (3,000)	Ramdighat (2,137)	22	39
Karnali –Kunar Khola	Shankhalagna (14,862)	Confluence of Karnali (4,450)	32	327
Humla Karnali	Simikot, Dandagaun (7,000)	Manma (3,226)	61	62
Main Karnali	Sirpato (4,500)	Bhankot (2,500)	42	47
Mugu Karnali	Mengiri (7,055)	Karnali confluence (5,000)	24	86
Sinja Khola	Riyan (10,000)	Peripalni (4,000)	44	136
Bheri	Barikot (6,000)	Dali (4,000)	14	142
Bheri	Simi (5,000)	Confluence of Sani Bheri (2,830)	30	72
Seti (Salmor Khola)	Head (13,500)	Chaprokhola (1,250)	91	135
Seti (Kaligad)	Korali (6,000)	Muttibar (2,800)	18	178
Seti (Thalara Khola)	Head (8,000)	Mouth (4,800)	4	925
Thuligad	Khargau (4,000)	Atari (2,400)	14	114
Rau Khola	Kotlinara (4,000)	Tillar (2,000)	11	181
Budhiganga	Chaurantha (5,500)	Mautiyana (1,500)	29	138
Mahakali	SamserDamba (4,000)	Barmdeomandi (1,000)	96	31
Chamila	Guljar (6,000)	Lumsal (1,750)	35	121
Surnagad	Kathmandu (6,000)	Jakha (1,400)	28	164
Lower hills and Terai Rivers				
Mechi	Helang (1,000)	Kalughat, India (250)	32	23
Bearing Barkha	Jalkalyani (750)	Gamhari (169)	42	14
Kankai	Rangapani (1,500)	Butabara (246)	41	31
Puakhola	Godak (2,500)	Rangapani (1,500)	4	250
Deo Mai - Jogmai	Upper Bhitte (5,000)	Sirkot (1,000)	18	222
Singhahinadi	Dangi (1,000)	Bhawanipur, India (203)	31	27
Kamala	Tintale (1,500)	Manurwa, India (212)	32	40

River	Upper point (ft)	Lower point (ft)	Length (miles)	Drop in Feet/ Mile
Tinau	Pokharathok (2,500)	Betenia (300)	33	67
Banganga	Junhawa (1,000)	Taulihawa (454)	18	30

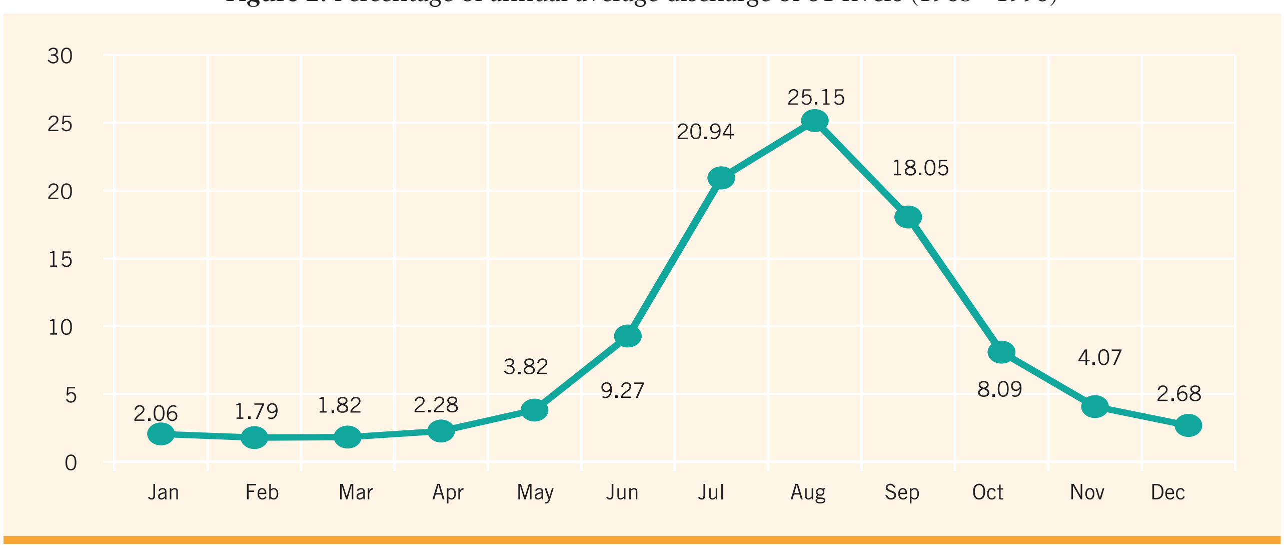
Data Source: Sharma (1972)

In the lower sections, Mechi has 5 ft, Kankai has 12 ft, Singhahi Nadi has 4 ft, Kamala has 3.8 ft, Tinau has 25 ft, and Banganga has 6 ft drop in each mile of length indicating the flat topography that favours siltation and flooding (Sharma, 1972). Similar is the case with other rivers in the western Nepal like that of Rapti, Babai, Karnali and Mahakali in the lower sections. July, August and September are the high river flow in Nepal. The highest river discharge is in August. February has been observed as the driest months (Figure 2). About 80 per cent of total river discharge occurs during five months (June - October) of the year (Water and Energy Commission, 2011).

The river discharge follows annual rainfall pattern. Rainfall is the triggering factor to flood. Rainfall intensities with 60 mm in 1 hour, 80 mm in 3 hours, 100 mm in 6 hours, 120 mm in 12 hours and 140 mm in 24 hours have been normally considered as critical and have potentiality to trigger both flood and landslides in Nepal depending upon the topography (*http://www.hydrology.gov.np/new/bull3/index.php/hydrology/rainfall_ watch*). The number of days with intensive rainfall has also been found to be increasing in Nepal (Baidya et.al., 2008) which signifies potential increase in flood and landslide events in the years to come. Intensive and localised rainfalls that generate heavy runoff with heavy soil erosion on the hill slopes in upstream are responsible for floods in the rivers downstream. The flood is further aggravated by landslides which increase sedimentation load in the rivers and occasionally block the rivers in hills thereby creating landslide dammed lake outburst flood.

The mean annual rainfall in Nepal from 1976 - 2005 was 1,857.6 mm, out of which 79.58 per cent

Figure 2: Percentage of annual average discharge of 51 rivers (1963 - 1995)



Sharma and Adhikari (2004)

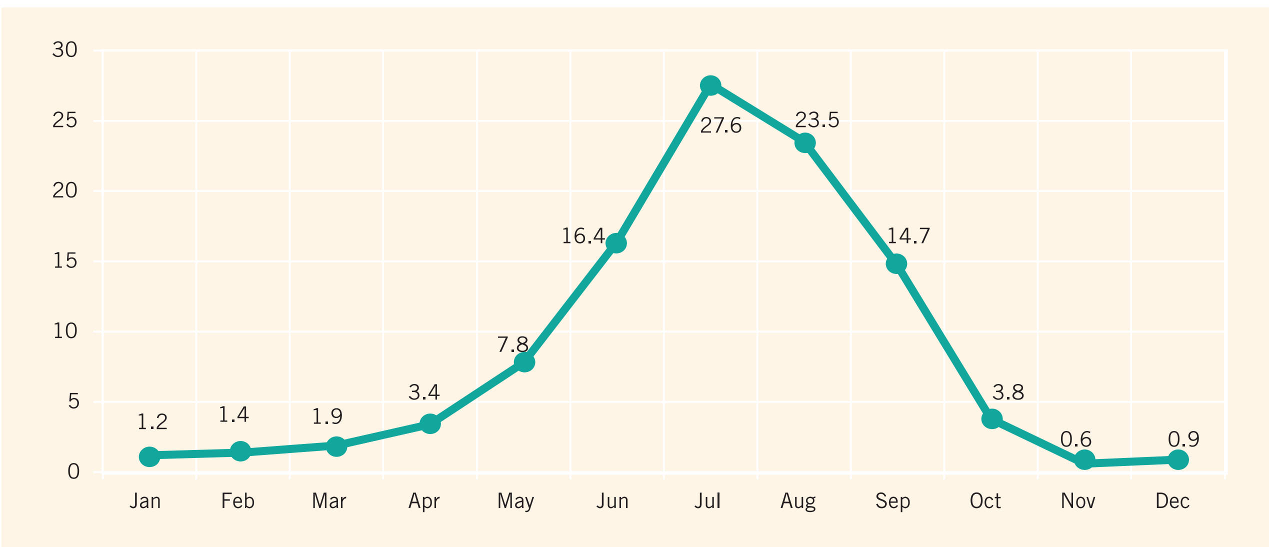
was during the monsoon season (June - September) (Practical Action, 2009). July has been observed as the highest rainfall month and April as the driest (Figure 3). The normal date of monsoon onset and withdrawal from Nepal has been identified as June 10 and September 23 respectively. However onset and withdrawal dates of summer monsoon have been delayed in recent years (Gautam and Regmi, 2014).

Figure 4 shows slight delay in onset of monsoon which is not significant though. Figure 5 shows delay in withdrawal date of summer monsoon which is significant; especially since 2002, there has been an upsurge in the dates being delayed. In both onset and withdrawal cases, the dates show high variability, indicating uncertainty of onset and withdrawal dates. Such uncertainty of summer monsoon increases uncertainty of flood and drought. There are evidences of early (before June) and late (after September) flood events because of change in rainfall patterns proving the need of early warning system in the normal, pre and post-monsoon seasons as well.

Flood has been defined almost in similar logic in different literatures. IPCC (2012) defines flood as "the over flowing of the normal confines of a stream or other body of water, or the accumulation of water over areas that are not normally submerged". It is a "temporary rise of water level in a river or lake or along a seacoast, resulting in its spilling over and out of its natural or artificial confines onto land that is normally dry" *(http://science.yourdictionary.com/flood)*. The artificial confines also cover drainages, irrigation canals, among others. Flooding is a longer term event which may last days or weeks. A flood that lasts for less than 6 hours is usually termed as flash flood. (*http://www.srh.noaa.gov/mrx/hydro/flooddef.php)*. Floods occur after heavy rainfalls due to high runoff, or sudden release of water after a temporary or an existing lake burst due to dam failure. Floods include river (fluvial) floods, flash floods, urban floods, pluvial floods, sewer floods, coastal floods, and glacial lake outburst floods.

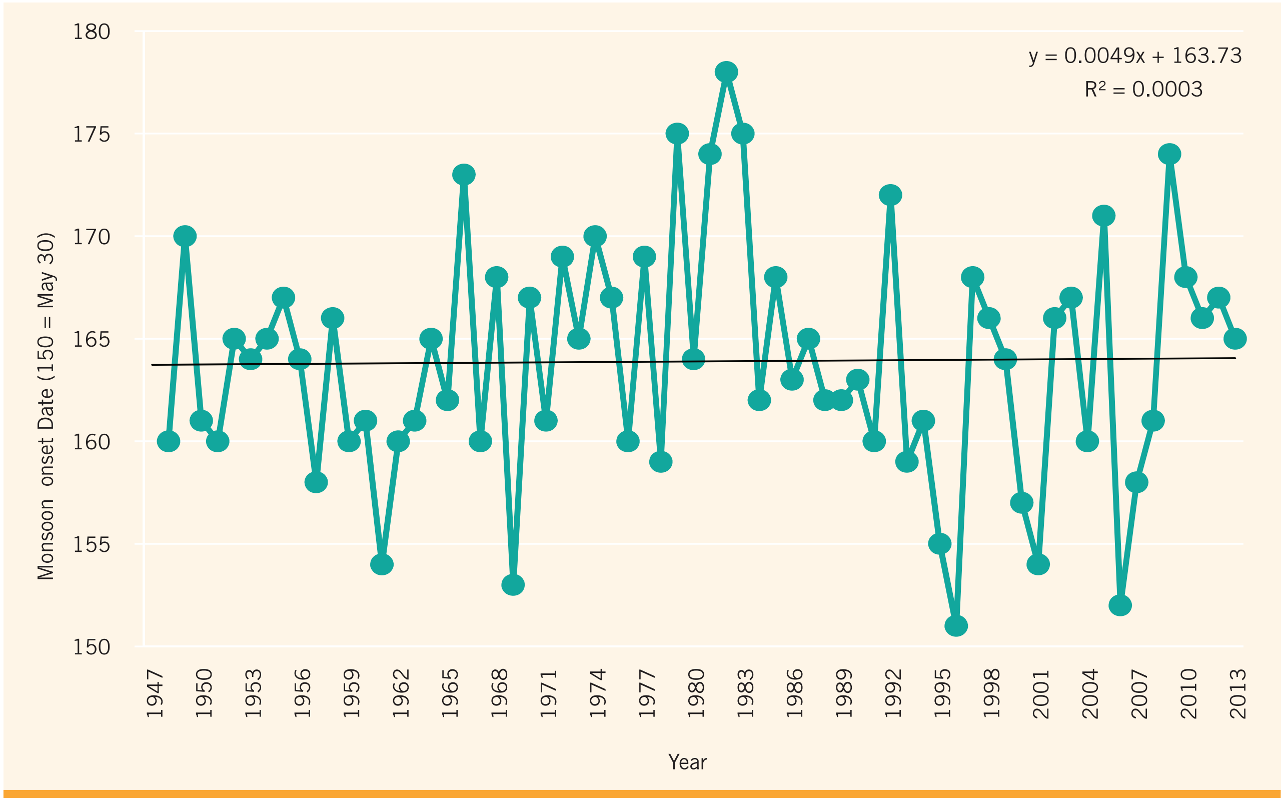
Floods and landslides are the highly rated hazards in Nepal in terms of destruction of human lives and properties. From 2001 to 2007, properties worth over NPR 9.9 billion has been destroyed by natural disasters such as: i) floods and landslides, ii) fires, iii) wind, hail and thunderstorm, and iv) earthquakes; of which over 78 per cent was due to floods and landslides (MoHA, 2008). Flood and

Figure 3: Nepal monthly rainfall distribution in percentage (1975 - 2005)



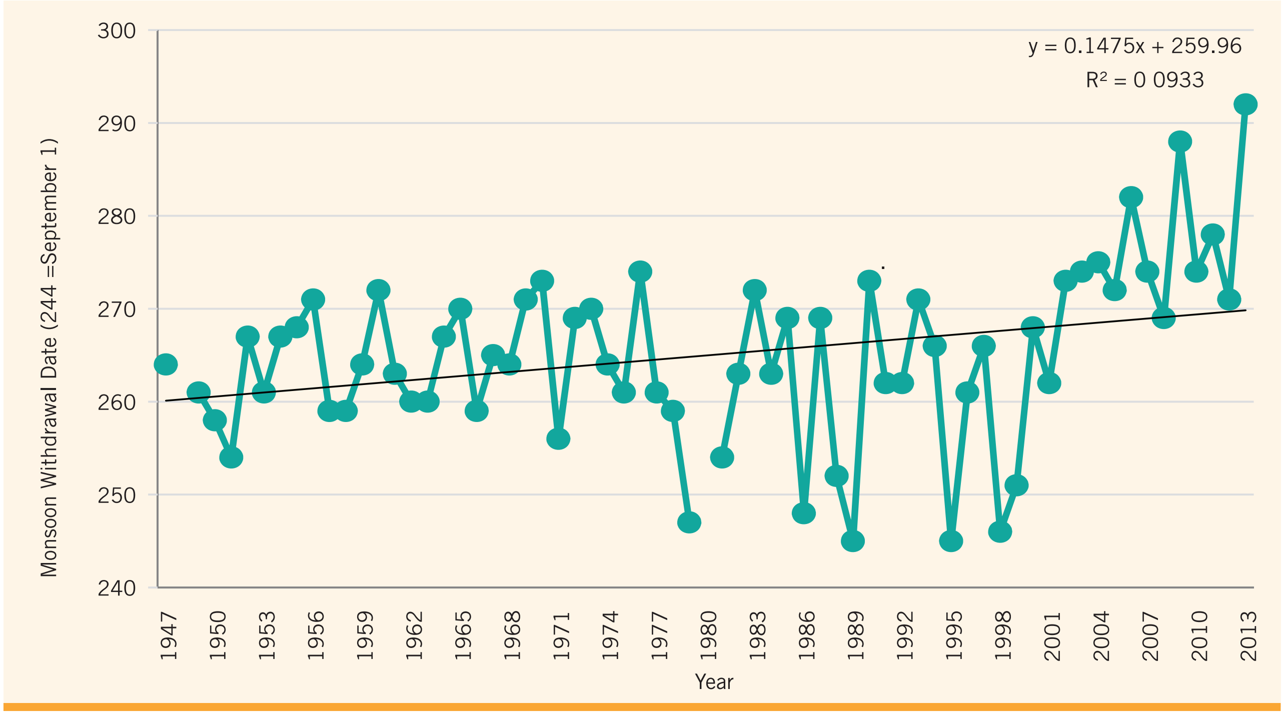
Source: Practical Action (2009)

Figure 4: Onset of monsoon in Nepal



Source: Sharma (2014)

Figure 5: Withdrawal of monsoon in Nepal



Source: Sharma (2014)

landslides together took lives of 8,061 from 1983 to 2011 having an annual average death of 278 people (DWIDP, 2011 and 2012). Desinventar (2011) has reported that flood alone took lives of 3,329 people from 1971 to 2011 in Nepal. During the same period property loss due to flood was NPR 5,846,249,069 making 27.6 per cent of the total loss due to natural disasters (Table 3). Details of economic loss due to various disasters have been reviewed in Nepal Disaster Review, 2011 which is also available on *http://moha.gov.np* (MoHA, 2011). Out of four monsoon months, July and August are the two months when most of the flood events occur in Nepal (Figure 6). While looking into Figure 6, the events are fluctuating between July and August. During the later years (2010 and 2011), more events have been observed in later months of the monsoon season.

The flood early warning system should be able to monitor the rainfall and flood round the clock as extreme rainfall can take place round the clock during monsoon. Round the clock manual monitoring of rainfall and flood is very costly and also could pose risk to the life of monitors themselves. Therefore, the current flood early warning system promoted by DHM and Practical Action in Nepal uses equipment like tipping bucket and radar gauges that automatically monitor rainfall and flood level and uploads the information to web server through telemetry system to provide information to key individuals and public. The information is accessible from the website of the Government of Nepal (*www.hydrology.gov.np*).

Table 4 provides information on spatial distribution of flood events and their effects in Nepal. The Central Development Region has faced more

Figure 6: Monthly disaster events, Nepal

Source: DWIDP, 2009, 2010, 2011 & 2012

Table 3: Human casualties and property losses due to different disasters in Nepal (1971 Feb - 2011 Feb)

Event	Deaths	Injured	Missing	Houses Destroyed	Houses Damaged	Affected	Relocat-ed	Evacu-ated	Loss in Local currency
Epidemic	16,566	43,076	0	0	0	514,535	0	2,243	2,631,040
Landslide	4,476	1,589	626	18,491	33,960	574,020	24,252	2,975	1,017,801,224
Flood	3,329	523	663	95,944	89,934	3,935,933	155,192	19,866	5,846,249,069
Fire	1,328	1,200	186	72,367	1,932	264,114	16,753	392	9,288,104,131
Accident	1,280	491	202	5	473	2,509	31	7	89,600,000
Thunder storm	1,091	2,111	1	328	465	8,447	123	0	31,575,967
Earthquake	882	7,024	0	34,810	57,004	39,596	8,522	0	580,753,700
Cold wave	595	83	0	0	0	2,393	0	0	134,650,000
Structural collapse	414	643	8	1,282	623	2,671	756	2	40,060,285
Boat capsize	284	154	541	0	0	410	0	294	320,000
Avalanche	234	99	45	32	33	1,298	29	3	19,053,100
Strong wind	171	480	0	2,013	7,443	38,815	5,503	0	415,844,026
Panic	89	121	0	0	0	0	0	0	0
Rains	88	44	3	740	1,858	66,921	4,122	173	379,373,069
Snow storm	88	44	828	102	59	12,950	4,700	132	2,000,000
Other	77	64	11	68	0	11,982	0	2	1,000,000
Forest fire	65	45	410	1,835	2	16,392	0	0	1,260,189,301
Hail storm	65	100	2	208	1,635	210,963	0	220	2,049,452,606
Storm	52	283	2	1,022	566	2,397	0	0	24,634,280
Heat wave	42	20	0	0	0	381	0	0	0
Explosion	34	91	0	4	1	19	0	0	215,200
Plague	11	0	0	0	0	50	0	0	7,122,000
Famine	10	0	0	0	0	589,957	615	413	0
Biological	0	0	0	0	0	0	0	0	15,600,000
Drought	0	0	0	0	0	1,625	0	0	11,700,000
Frost	0	0	0	2	0	5	0	0	520,000
Leak	0	0	0	1	0	0	0	0	2,000,000
Liquefaction	0	0	0	1	2	16	0	0	0
Pollution	0	0	0	0	0	1,000	0	0	0
Sedimentation	0	0	0	0	0	0	109	0	0
Total	**31,271**	**58,285**	**3,528**	**229,255**	**195,990**	**6,299,399**	**220,707**	**26,722**	**21,220,448,998**

Source: Desinventar (http://www.desinventar.net/DesInventar/results.jsp)

Table 4: Spatial distribution of disaster caused by flood (1971 – 2011)

Geography	Deaths	Injured	Missing	Houses Destroyed	Houses Damaged	Hhs Affected	Hhs Relocated	Hhs Evacuated	Losses in NPR X 10^6	Education centres	Hospitals	Crop Damages Ha.	Cattle Lost	Damages in roads Mts
Eastern Region	436	86	71	34,125	20,976	845,456	37,845	4,994	2,581	10	-	63,044	7,750	17,840
Central Region	2,017	226	279	37,834	48,220	2,571,856	36,378	7,097	2,064	5	3	146,979	28,216	4,660
Western Region	454	95	218	8,873	4,302	246,476	6,364	5,318	135	32	-	10,101	1,490	17,200
Mid-Western Region	194	57	41	9,009	12,342	103,568	55,787	162	324	6	-	13,500	499,202	1,124
Far Western Region	228	59	54	6,103	4,094	168,577	18,818	2,295	743	13	-	6,174	626	34

Source: Desinventar (http://www.desinventar.net/DesInventar/profiletab.jsp?countrycode=npl)

human casualties compared to others, whereas Eastern Region has faced high economic losses. This indicates that disaster risk is not necessarily high in geographical areas where frequent hazard (flood) events occur, but it depends on where more and valuable assets or properties and vulnerable people are exposed to the effects of hazard.
The eastern Nepal has relatively more economic activities with fairly better infrastructure and has higher population density compared to the western Nepal. Therefore, even the flood events are lesser in eastern than in western Nepal, the total value of property loss is higher there.

Damage of properties by flood are mainly due to: i) destruction of economic infrastructure such as road, bridges, irrigation canals, and human settlements; ii) destruction of natural assets such as agricultural fields and grazing lands; iii) inundation and sedimentation on standing crops; and iv) killing of livestock and damaging of assets inside the house including food materials and other valuable goods, assets and properties. In Nepal, most of the settlements in the hills are on the slopes that can avoid likely disasters from the floods. However in the foothills, there are settlements close to the river banks as it is considered as strategic locations for trade and business, and for other socioeconomic activities. Although, many settlements are safe from regular flood that occur in the nearby rivers, those very close to river banks are prone to even regular floods in the river.

CHAPTER 3

History of Community Based Flood Early Warning System in Nepal

This section looks back in the history of flood EWS in Nepal and cites Practical Action's experience in establishing Community Based Early Warning System (CBEWS) in Nepal. Practical Action initiated and developed community based flood early warning system with co-funding from various cycles of DIPECHO.

The early warning system in Nepal was initiated in east Rapti river in Chitwan District of Nepal in 2002. East Rapti belongs to second category of rivers as it originates from the Mahabharat hills in Makawanpur District and meets Narayani River at Golaghat, Chitwan before it exits from Nepal to India. East Rapti is joined by its tributaries – Manahari, Lothar and Madi Rivers before confluence to Narayani. Bhandara in Chitwan was the first community where the CBEWS was piloted in 2002.

Why East Rapti River?

The east Rapti River set the boundary of the Chitwan National Park in the south and human settlement in the north of the river. Owing to the protection by the park, there is good vegetation coverage on the southern bank of the river. But on the northern bank, there is almost no forest and is covered with cultivated lands. As a result, the northern bank of the river is annually affected by the river flood entering in the settlements causing losses and damages of lives and properties. In 1993, the central region of Nepal was hit by one of the historic disasters, landslides and flood due to cloud burst in the region. Chitwan was severely affected by the flood. Because of recurrent flood in east Rapti and since the river was very much sensitive to the rainfall where sudden flood occurs immediately after the rainfall, the pilot flood EWS was initiated from east Rapti.

The early warning system was built based on indigenous practices of the community and their expectations. Traditionally, local people monitor the river when there is high rainfall or rise in the river level due to upstream rainfall. Usually, household members living close to the river watch and monitor the river. When the individual monitoring the river feels that the river level is dangerously increasing, overflowing the bank or entering into the settlement, then the person communicates warning information to rest of the households in the community and the settlement. The information is manually communicated making loud sounds and relaying the messages door to door. When households get the information they leave the house and go to safer places, usually raised part of a land. However, there were some limitations in the traditional practices mentioned above. The limitations were:

- The lead time was very short as the households or communities receive the message, the flood already spilled over the bank and entered into the settlement.
- There lacked systematic preparedness in communities that enhances capacity to respond to the flood information.
- The set procedures were not practiced mostly during the night time.

In view of above constraints and limitations of the traditional flood early warning practice, the communities in Bhandara shared following views:

1. Community wanted a raised tower nearby the river from where they could observe the river upstream. The community members shared, when there is a flood in the river, fog or mist appeared above the river due to force of flood water. Such rising mist could be seen from distance. So if they had a tower nearby river they could observe such mist over the river upstream from the height. Seeing the sign of flood in to the distant, they could have more lead time.

Photo 1: The first EWS tower in Bhandara, Chitwan

2. Community wanted to have a siren in the tower so that the warning information could be disseminated efficiently than by communicating from house to house or from person to person, which needs rapid movement of individuals.
In order to enhance the dissemination of the information, the communities also requested megaphone and some rescue gears.

3. Community requested for small mitigation activities along the river bank in strategic sections from where the flood entered or was likely to enter the settlement.

4. Following the discussion with communities, the tower also had lighting system with yellow and red lights for different information. Yellow light for warning level, meaning the river level is raising, may spill over the bank and red light for danger level, meaning river is spilling over the bank, you need to leave the house.

The community expectations based on the learning from their traditional practices and experiences were addressed in the early phase of early warning system which led to development of watch-and-warn system.

Watch-and-Warn System

The watch-and-warn system started from Bhandara village of Chitwan in 2002 with construction of a 40m tall iron angle tower, fixed with a ladder and a roofed platform from where a watch person could monitor the river upstream. The tower had light on top of the pole extended above the roof and was equipped with an electric siren to provide warning sound when the watch person found the flood level increasing and possibility to enter in the settlements. The watch person would decide to blow the siren based on their knowledge and experience. The communities were expected to take valuable materials and assets with them and leave their house to move to a safer place after hearing sound of the siren.

Two level of siren signals were set and agreed with the communities – the first siren was of short duration or lap which meant symptoms of flood is observed in upstream and is increasing with possibility of entrance in the settlement. The community were oriented to take the following actions once they hear the first siren:

- Pack valuables like money, jewelleries and important papers such as academic certificates, land ownership certificates, house ownership certificates, citizenship and other ID cards.
- Safely keep moveable assets such as grain sacks, utensils, equipment to a safer location inside the house usually to the first storey of the house. Move small livestocks to safer location.

The second siren was blown if the flood level increased and was spilling over the bank with likelihood of entering into settlements. The second siren was played for a longer duration or lap compared to the first one which indicated that the flood was arriving close to the communities and was most likely to cross the river bank entering in the settlement. Moreover, the tower was also equipped with yellow and red light. The flood watchperson set the yellow light signal together with the first siren and red light signal with the second siren. The purpose of putting light was to make it visible from distance during the night in case people were unable to hear the sound of the siren. The communities were oriented on following actions after the second siren:

- Release cattle, buffalo and other large animals from the shed so that they can also go towards safer places.
- Carry all the valuables and important materials which have been packed and leave the house to go to a safer place, usually a raised location which is identified during the time of risk assessment.
- Return back to the houses only after the flood level recedes to normal level.

Photo 2: Grain sacks moved to safer location

Photo 3: Grain sacks moved to safer place

The communities initially proposed to assign a flood watchperson on rotational basis from each household, but as everybody were not familiar with flood watching, they later decided to appoint one individual for monsoon, especially in the month of July and August and provide remuneration collected (cash or kind) from the communities. The person living close to river who traditionally involved in watching flood and providing warning to the communities was selected as flood watchperson.

Following the piloting of watch-and-warn system in Bhandara, Chitwan, the system was extended to other villages along the Rapti River in Chitwan (Meghauli, Jagatpur and Piple VDCs) and Narayani River in Nawalparasi District (Pithouli, Kohluwa, Narayani and Parsouni VDCs). Based on the learning from Bhandara experience, improvements were made in the system established in the above mentioned new locations.

The improvements included:

- Raised height of the watch tower (60m) to increase the length of vision.
- Attached safe ladders in the tower to ease getting up and down from the tower.
- Better weather protection to the watchperson through roof and protection walls.
- Increased siren capacity from 12 volt to 220/240 volt to be heard in distance.
- Equipped with flush light system which helped to monitor the flood during night.
- Prepared EWS operation manual and provided training to the watchpersons.
- Established more formal system together with EWS components (risk knowledge, communication, dissemination, capacity building).
- Enhanced communications between upstream and downstream watchpersons through the use of telephone to inform flood.

The scaling out of watch-and-warn EWS undertook activities all elements of EWS. Capacity development included both hardware and software activities. Hardware activities included repair of walkways, construction of bridges, culverts and flood way which helped in releasing the flood water and smooth transportation of people and goods at the time of flood events. Moreover, construction of emergency shelters, small scale mitigation activities, and providing the communities with rescue boats, hand siren, megaphones, ropes, safety equipment, flash lights, among others enhanced their response capacity. The watchpersons was provided with water boots and torchlights so that they can conveniently perform their duty during the monsoon and at nights as well.

Photo 4: Modified EWS tower in Meghauli, Chitwan

The software activities included awareness campaign such as mock drills, folk song competitions during different festivals and occasions, wall painting, poster display, sign posting, and school level DRR art and essay competitions. The activity also included cross learning visits of the communities and visit of target communities to the upstream river gauge stations.

At the later stage of the scaling out phase, linkage between the upstream river gauge station of the Department of Hydrology and Meteorology (DHM) and the community was established. The river gauge readers and the communities were supported with telephone lines and sets to enhance exchange of information between them. Telephones were provided to the key people in the communities especially to the chairperson of Disaster Management Committee (DMC). This enabled DMC chairperson to receive flood information from gauge reader which enhanced faster dissemination of information and increased lead time to the communities.

The communities were also supported in formation of community level DMC and task forces for communication and dissemination, first-aid, and search and rescue. The DMC members and task forces were oriented on their roles and responsibilities and provided training to enhance capacity in delivering their responsibilities effectively and efficiently.

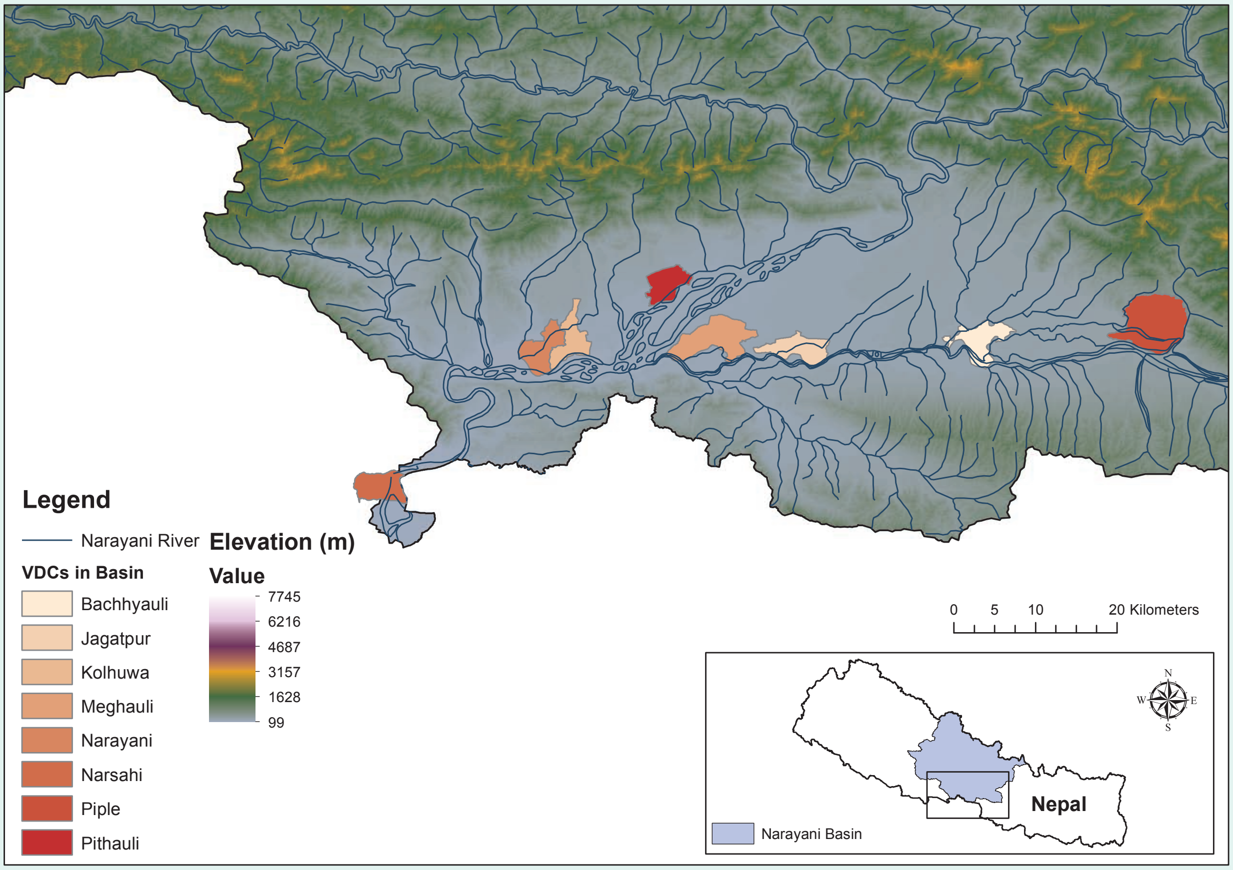
To establish the system and enhance ownership of the community, their active participation ensured in site identification for watch tower installation, community mobilisation, establishing user committee and labour contribution in small scale mitigation. Practical Action facilitated the communities to perform their responsibilities by purchasing external materials and necessary equipment for tower construction and small mitigation activities in addition to conducting training.

Pros and cons of watch-and-warn system

The watch-and-warn flood EWS was built on existing practices and experiences of the communities. It had following positive aspects:

Photo 5: Community awareness through mock-drill

Map 2: East Rapti and Narayani watershed



- Flood EWS was of first such system established in the community. The siren installed in the tower helped to quickly disseminate information reaching to more households in short time compared to the traditional person to person system. Flood monitoring by the watchperson, communications between the communities and the river gauge reader increased the lead time compared to the traditional practice.
- The linkage between the communities and gauge reader was also established during implementation of watch-and-warn EWS. In this stage, the linkage from one tower person to another was also developed which increased lead time of flood information. The inter community linkages established by the system increased support among the community members. The upstream community provided flood information to the downstream communities. Moreover, people living in high land rushed down to rescue low land communities when they heard the siren.
- As a practice of EWS, communities were supported with: i) small mitigation activities such as putting spurs along the river banks and protecting bank cutting ii) enhancing response capacity of the communities through awareness and training. As part of capacity building activities, the communities involved in vulnerability map preparation of the settlement where they identified and mapped out most vulnerable sites and households and identified the evacuation routes and safe (raised) locations to be used at the time of flood. Such activities

increased capacity of the communities to respond to the flood warning and reduce their vulnerability or risk to the flood.

- A very important part was, the communities felt empowered and secured psychologically as they did have the warning system in the communities since no such warning system existed earlier.

Followings are the limitations of watch-and-warn system:

- The system did not work effectively during the night time and day time with poor visibility. The flush lighting system installed in the tower was not enough to enhance the visibility in the river upstream.
- The siren was not effective means for warning particularly to those households located in distance or at depressed locations; during heavy rainfall and in the night when people were asleep.
- During the monsoon 24 hour flood monitoring by experienced watchperson is required. It is impossible to expect this from a single individual and in the lack of other people with flood monitoring skills in the community.
- The watchperson also needed to take care of their own family and properties, during the time of flood. So when there was a flood, their priority was usually to protect their own family and properties which sometimes resulted into inadequate warning to the communities.
- The focus of the system confined within local territory – physically, institutionally and socially, whereas the flood comes from distance in upstream and linkage with upstream was not systematically established. The response capacity need be extended to district and national authorities as well which was not the case back then.
- In the absence of reliable electricity supply, the electric siren could not be operated when there were disturbances on electricity line particularly during heavy rainfalls or thunderstorms.

Learning from the watch-and-warn EWS system

The watch-and-warn EWS system was developed from a very primitive idea of early warning system

Photo 6: Bio-dyke along the river to reduce the bank cutting

focusing mainly on providing flood warning to the communities. The concept of EWS was not even clear that time which consists of four elements as discussed in the first chapter. However, it was learnt that there was a need to have longer lead time for warning to enable people protect their lives and properties as they would get flood information when flood almost crossed the river bank and entered into the settlement. Because of short lead time, other learning was that the linkages between upstream and downstream gauge was an essential component of the system to increase the lead time. Also, until then flood information from hydrological stations of DHM was not officially shared with the downstream communities which were vital component in EWS. So it was learnt that the communication between gauge reader and the communities needed formalisation and institutionalisation for uninterrupted flow of warning information.

A Complete and Institutionalised Early Warning System

The EWS replicated from east Rapti and Narayani Rivers in Chitwan and Nawalparasi Districts to west Rapti and Babai in Banke and Bardiya Districts from September 2007. The west Rapti and Babai Rivers are two important rivers in mid-western Nepal, where recurrent floods occur. The rivers are of second category.

The flood in Babai River affects Gulariya Municipality, and six VDCs namely Bagnaha, Dhodhari, Baniyabhar, Padnaha, Magaragadi and Mohamadpur of Bardiya District. Of the six VDCs, Patabhar, Mahamadpur and Bagnaha are highly vulnerable, Magaragadi and Baniyabhar are moderately vulnerable and Dhodhari is less vulnerable to flood in Babai (Bardiya DPRP, 2071). There are 28,814 households and 1,47,739 people residing in these VDCs (CBS, 2012). Each year on an average 964 people from these VDCs and municipality are affected by flood (Bardiya DPRP, 2071). Similarly, west Rapti affects eight downstream VDCs in Banke District which are Binauna, Phattepur, Kamdi, Bankatti, Betahani, Holiya, Gangapur and Mataheiya. The total population in these VDCs is 68,695 with a total of 12,007 households (CBS, 2012). Each year the flood in west Rapti affects around 838 households (Banke DPRP, 2071).

Based on learning from watch-and-warn system, a complete and institutionalised EWS was designed in west Rapti and Babai. This upgraded system is relatively advance in flood monitoring than watch-and-warn with enhanced communication between the communities and gauge reader. Practical Action worked closely with DHM for communicating flood information from river gauges to the downstream communities and the stakeholders in the district headquarters. The Flood Forecasting Project of DHM upgraded the hydrological and meteorological stations by installing telemetry system. The system enabled to transmit real time rainfall and flood information at the gauge stations to a web server continuously in an interval of one hour. This real time flood information played an important role in advancement of flood EWS as it can provide more lead time. Moreover, the Flood Forecasting Project of DHM conducted cross section surveys, flood hazard mapping and assessment of warning and danger level using a HEC-RAS model and GIS tools. The study recommended the warning level and danger level at Kusum gauge station for west Rapti as 5 m (1500 m^3/s) and 5.40 m (2000 m3/s) respectively (Gautam and Dulal, 2013).

Telemetry Based Flood EWS

In this upgraded flood EWS, the real time flood information data is accessed from the server, interpreted based on the flood threshold level and provided warning to the vulnerable people by institutionalising the communications and response system at local and district level. At the local level, a community based communication and

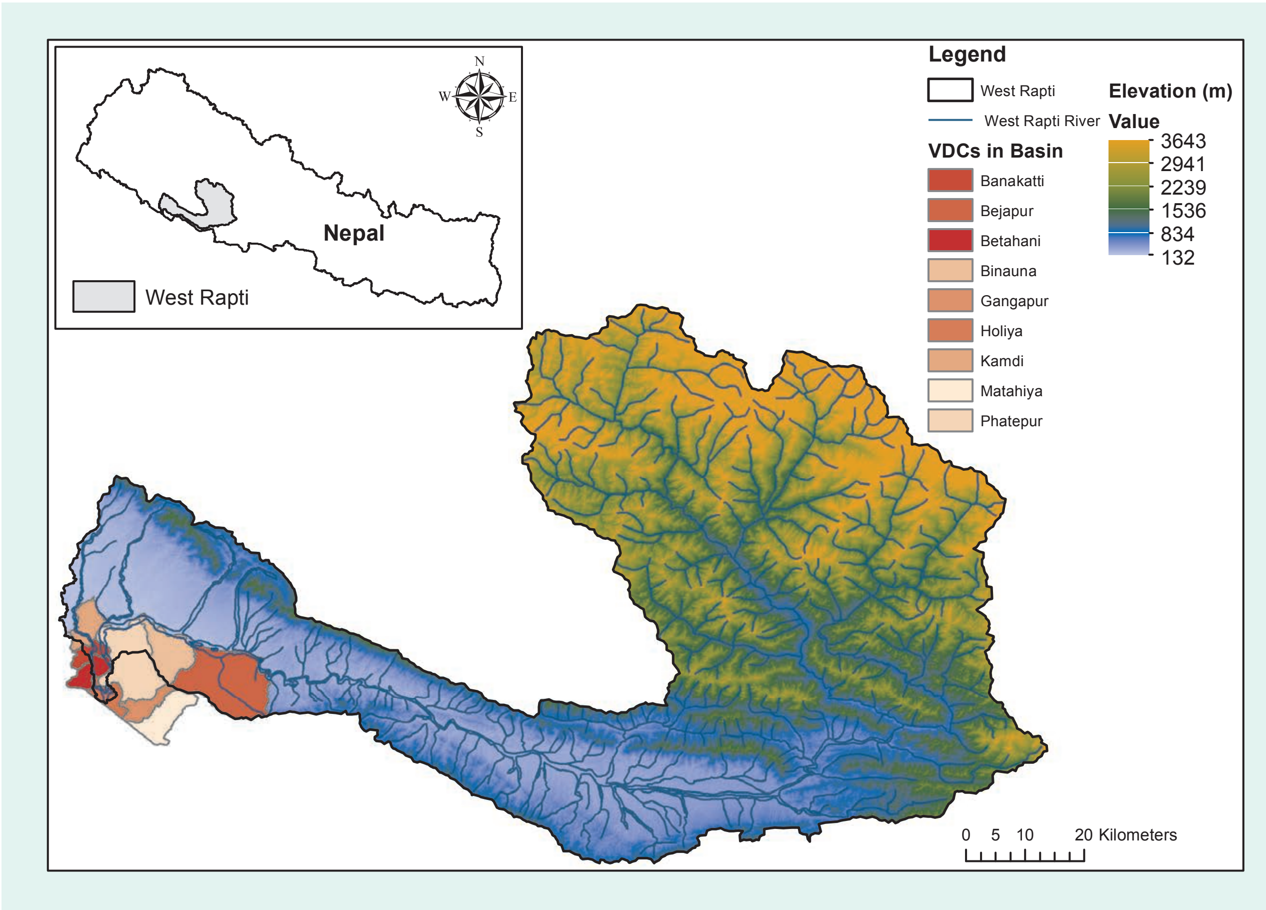
Photo 7: River gauge station at Chisapani, Karnali River

dissemination mechanism was formed comprising the District Disaster Relief Committee (DDRC), Local Disaster Management Committee (LDMC), local non-governmental organisations, local media and the flood gauges of DHM (Gautam and Phaiju, 2013). The flood information was disseminated using various communication channels. The gauge station remains as the key source of information which is communicated to the key individuals including chairperson of DDRC, Local Development Officer (LDO), Chairperson of District Chapter of Nepal Red Cross Society (NRCS), District Police Office, closest police station and army barrack, local FM radios, key persons of NGOs who are involved in early warning system, VDC chairperson and CDMC.

With enhanced awareness at the community level, people also directly asked gauge readers about likelihood of floods using telephone. The gauge reader responded each of the calls received. The regular telephone communication is not necessarily a warning. It basically updates status of flood. But when flood level reaches to warning or danger level, information are communicated to district authorities - DDRC, who issues the warning message to the communities. Simultaneously, communities may get warning information from the chairperson of DDRC who is the authorised body for information dissemination when flood level reaches to warning and danger levels at gauge station. The gauge reader also communicates the information on warning and danger levels to the village authorities – chairperson of VDRC.

The flood information are also disseminated through Internet. The flood warning bulletin is posted on the website of the DHM (www.hydrology.gov.np) which is accessed by any individuals with the Internet connectivity. It is communicated by SMS as well. When the flood level reaches to warning or danger level, it triggers SMS which is sent to key government officers. Monsoon 2016 onwards, SMS is disseminated to all mobile numbers of Nepal Telecom and NCell to the ones in periphery of flood risk zone while issuing flood warning. The real time flood information is also displayed on electronic boards in the District Emergency Operation Centres (DEOC), where there is a 24/7 duty bearer. When

Map 3: West Rapti River basin



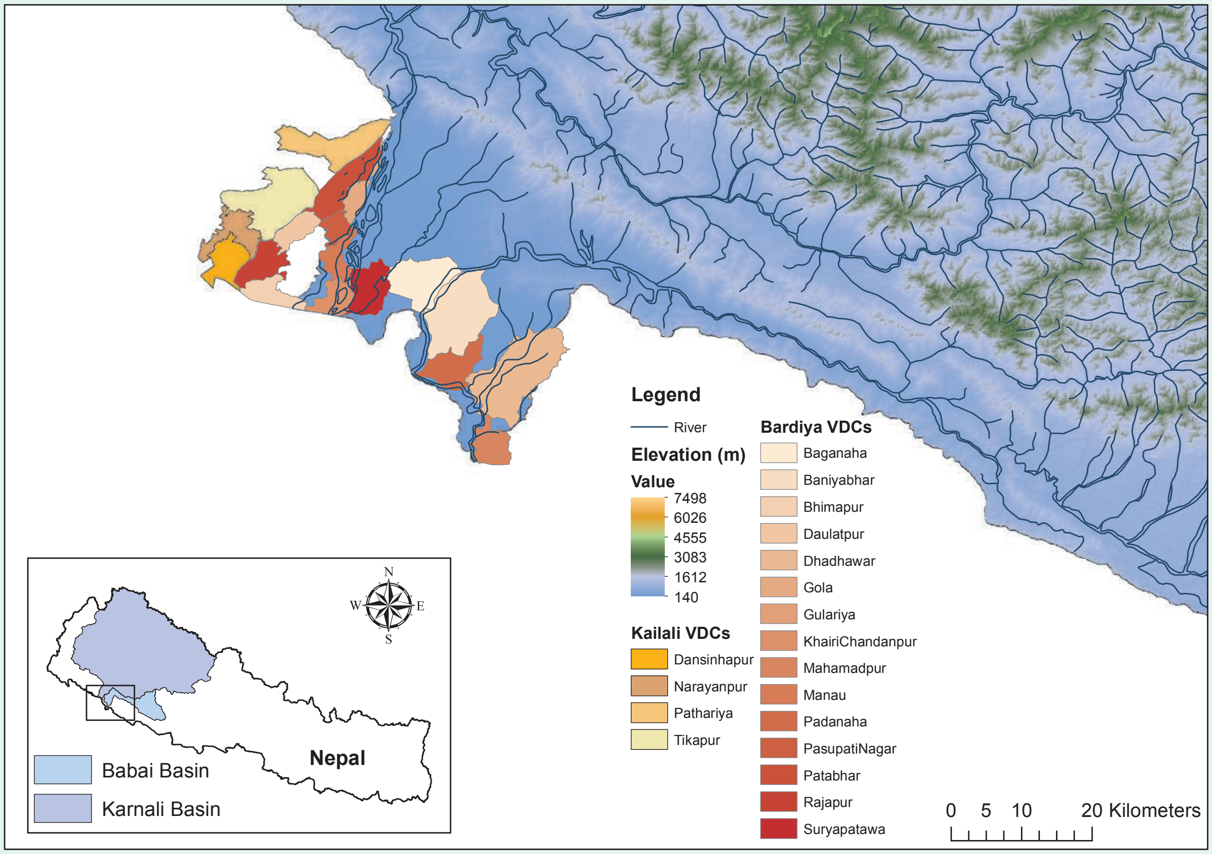
the flood level reaches to warning or danger level, it triggers an electric siren. The siren also rings on the website when the flood level reaches to warning or danger level.

The flood information is also communicated to local FM radios. Once the FM radios access or get the information, they disseminate the information to the public but when flood level reaches to warning or danger level, they provide breaking updates so that people in the flood zones can prepare and leave for safe locations.

Advantages of Telemetry Based Flood EWS

The telemetry system increases warning lead time that ranges from 30 minutes to 5 to 6 hours depending on distance of the communities from gauge station. For the communities who are at distant downstream, 5 to 6 hours is a reasonable lead time. But the household members may not necessarily always be at home when the warning is issued. They might be at the farm, in the forest or in the market. Following the warning they might need to go home to protect their assets, livestock and take out valuable properties. During such situation, even 5 to 6 hours might also be insufficient. The communities who are close to the gauge station get less lead time of around 30 minutes which is very short. Under such condition, flood might reach to the communities even before flood information as communication channel might take some time while communicating from person

Map 4: Karnali and Babai River basin

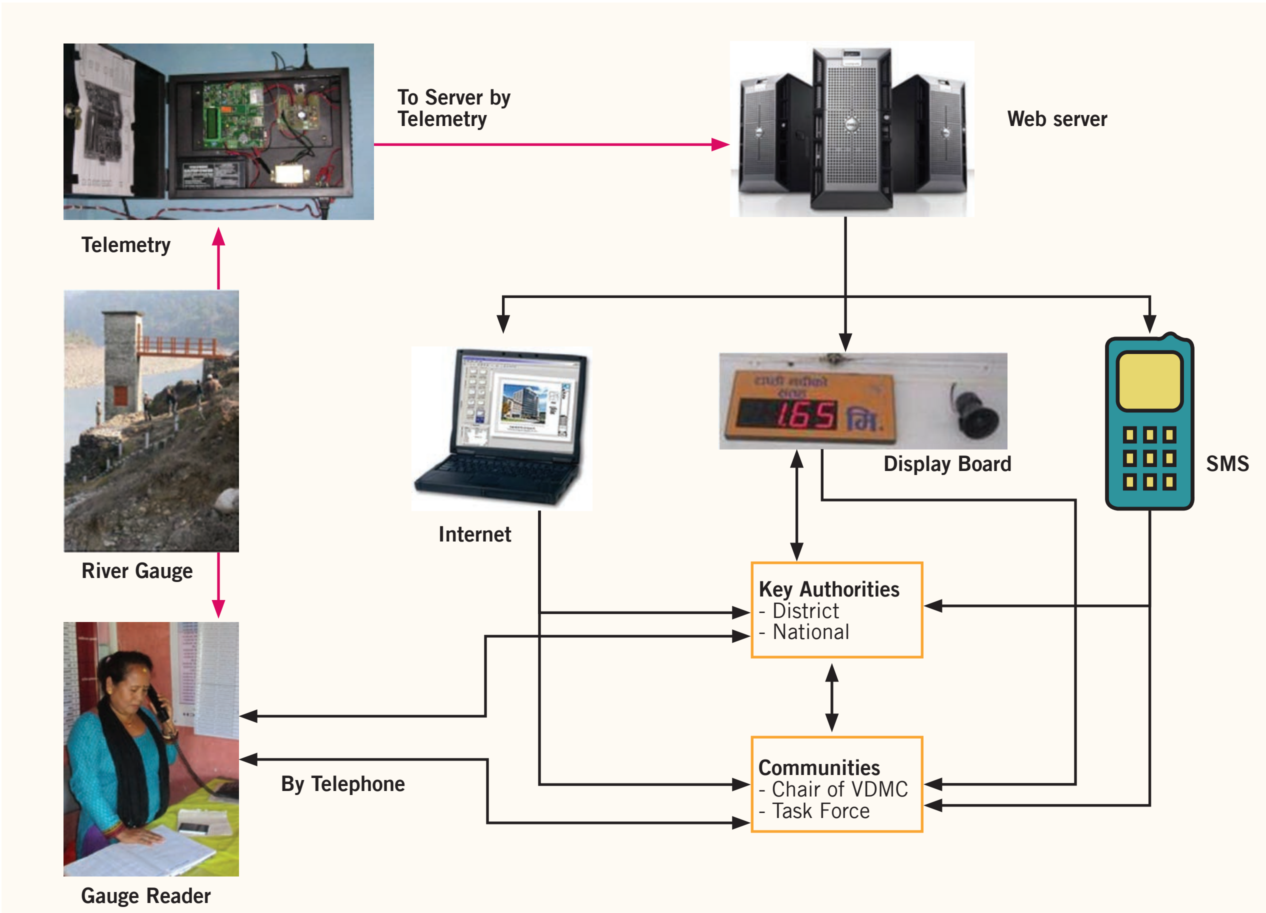


to person and from institutions to institutions. Especially when it is warning or danger level information, it requires to go through some official procedures which is time consuming. To avoid delays in communication, continuous update of flood information to the communities is essential particularly for those who have very short lead time.

The telemetry system is institutionalised by linking government institutions for authenticity of information provided and sustainability of the system. As the flood gauges are managed by the government, flood information generated by the gauges are authentic. The information passes through the government channels like DDRC and government officials so it is institutionalised and is sustainable.

The telemetry system provided more lead time compared to the watch-and-warn EWS although it is still insufficient. Increasing lead time provide longer time for the communities to save their lives and properties particularly while they are out in the field and during the night.

Figure 7: Risk information communication including telemetry system



CHAPTER 4

Flood Early Warning System in Practice

This chapter highlights the current flood EWS practice in major river systems in Nepal - east Rapti, Narayani, west Rapti, Babai, Karnali, Koshi and Kankai. The system follows the four elements of EWS in line with the UNISDR framework as briefly described in chapter one.

Risk Assessment and Knowledge

Risk knowledge is about flood information and information of communities living in the flood zone and their assets. The DHM has identified two levels of flood which has special significance. The first one is identified as warning level and the other as danger level. Flood warning level is identified as the level of water at gauge station which has potentiality of full-bank water flow at the most vulnerable section of the river downstream. It is the flood flow that just passes over the river bank, but does not affect nearby settlements. The danger level is identified as the level of water at gauge station corresponding to water level at the most vulnerable section of the river downstream which spills out of the river bank and starts entering into the settlement zone or no-river zone affecting people and their properties with inundation up to one metre (Gautam and Dulal, 2013). These levels are assessed by using computer flood models. The warning and danger levels for major rivers are given below in Table 5.

The warning levels are meant to make communities aware of the flood level that will reach to full bank capacity. This information helps communities to get ready and prepared to be evacuated from their home and save lives and properties. But the flood level may or may not increase beyond warning level. If it increases and reaches to danger level, then the flood will cross the riverbanks, get spilled over and enter into the settlement zone or areas of no-river zone at several sections. Once the flood is at danger level, communities must leave their homes to save their lives and valuables. For people living at most vulnerable section of the river, warning level is the most critical level to take decision.

Table 5: Warning and danger levels for some of the main rivers in Nepal

S.No.	Name of River	Monitoring (gauge) Station	Warning Level (m)	Danger Level (m)
1	Karnali	Chisapani	10.00	10.80
2	Babai	Chepang	6.00	6.80
3	West Rapti	Kusum	5.00	5.4
4	Narayani	Narayanghat (Devghat)	6.80	8.00
5	East Rapti	Rajaiya	3.00	3.70
6	Koshi	Chatara	5.60	6.80
7	Kankai	Mainachuli	3.7	4.2
8	Mahakali	Parigaon	5.80	7.00

Source: www.hydrology.gov.np

Implications of warning and danger levels on the ground

The effects of warning and danger levels will be specific in each community downstream. It depends on characteristics of land surface and settlement pattern in downstream of gauge station. This requires flood risk mapping to know where, what assets and properties, and who will be affected at different levels above warning and danger levels. Although the warning and danger levels of the flood is assessed through systematic and scientific flood modelling, using HEC-RAS programme, it has some limitations to measure every metre contour to reflect the reality on the ground as there are raised and depressed ground surfaces in short distances. Therefore, in this chapter we will discuss on participatory approach to flood risk assessment for risk knowledge to further elaborate the implications of the calibrated levels of flood map on the ground level.

Participatory flood risk assessment

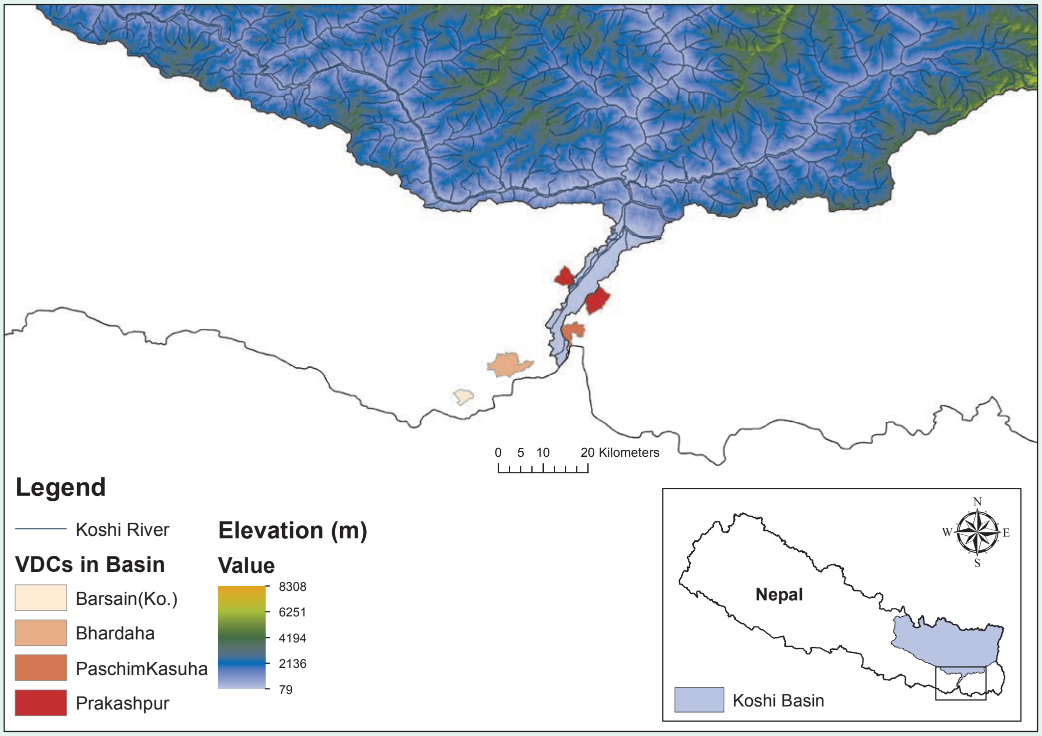
The first step of participatory flood risk assessment is to review the history of flood events with communities. The communities share past flood events with information like the year, date of flood, inundated affected areas and households (destroyed and damaged), number of lives lost, details of individual and community properties and assets lost, among others. Only those events are noted or recorded which are recognised as disaster by the communities including the quantitative effects on lives and properties. The assessment is done at each community level as different communities are affected differently during different flood levels.

Once the date, time and effect of the flood events from the communities are noted, the information from the flood gauge station is reviewed to correlate with the community information. Flood levels at the gauge station are identified when there were significant flood events at the communities. The correlated information for the two critical flood level, warning and danger, are very important. This exercise lets the community know about where the location, who the households and which the assets or properties of communities and individual would be or were affected when the flood will be/was at warning and danger levels. This exercise helps communities to know their risks when the flood is at warning level and danger level.

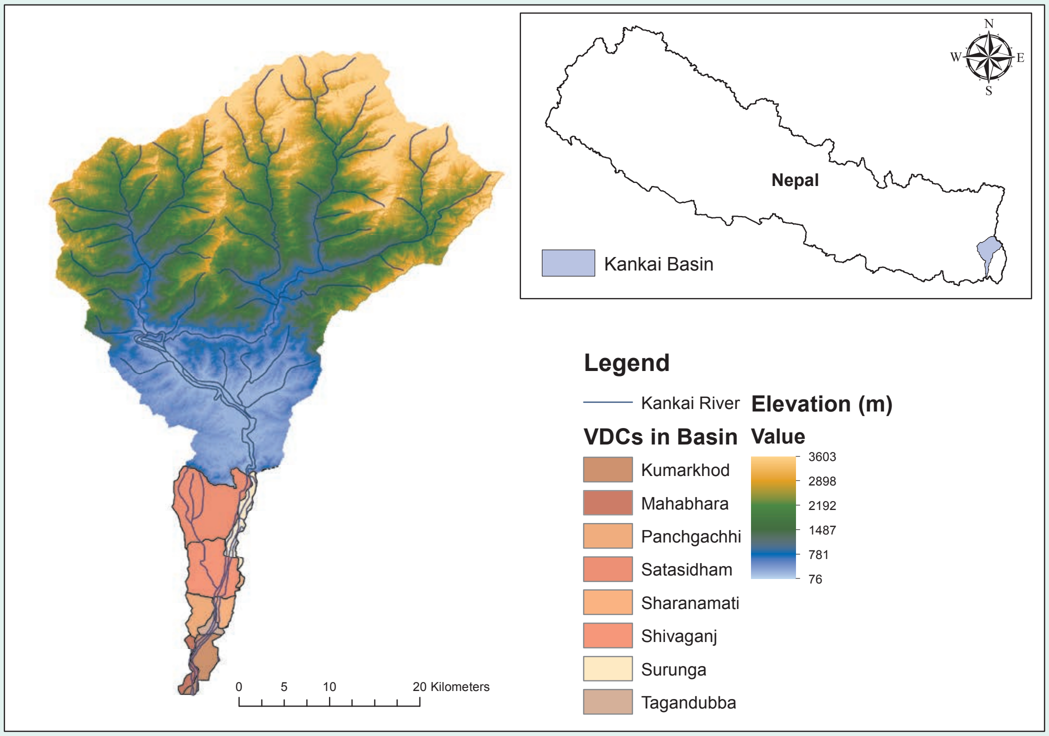
Table 6: Understanding risk information

Knowing the flood		Knowing the exposure and vulnerability		Risk Information
• When does and did the flood occur? Are these dates changing? • What are the highest flood records in the gauge station? • What is the time of travel of flood from gauge station to different communities downstream? • What are the critical levels (warning and danger levels) of flood?	X	• How many households and people are there in different communities in the flood effect zone in downstream? • What are the physical infrastructures that are at risk to flood? • What are/how many natural assets like (agricultural land, forest, water, etc.). are in threat to flood? • What are the status and condition of the livelihood assets – their susceptibility, vulnerability, among others to flood ?	=	• What are the likelihoods of damage of lives and properties at warning and danger levels of the flood? • What are the economic values of the possible loss of the assets due to flood at various levels?

Map 5: Koshi River basin of Nepal



Map 6: Kankai River basin of Nepal



In addition to these two levels, also the risk at different levels of the flood beside warning and danger levels is known. Such information are shared with the district stakeholders and respective government line agencies such as DDRC so that the stakeholders are aware of the risk at different levels of flood measured at gauge station.

The risk level is identified by the communities based on their overall perception. The factors that determine the perception of risk level include close proximity of the settlement and houses to the river, low or depressed location, weak housing structure and more frequent effect of flood. It also includes social and economic factors like number of children, elderly and pregnant women in the family, and income level of the households.

Lead time calculation

There are scientific tools and methodologies available for lead time calculation. In these rivers the lead time calculated through scientific methodologies was verified through community participation by using floating materials like footballs or volleyballs. The balls were released at gauge stations and their travel times to different communities along the river side were calculated. The community members participated very enthusiastically in this process as the method was simple and they could physically see and understand the process. Table 7 illustrates an example from Karnali River. The table shows that within the same ward or community, the flood travel time from gauge station or the lead time differs.

This table is presented here as an example. In the communities where there are flood warning system (Babai, west Rapti, Narayani, east Rapti, and Koshi), such lead time has been calculated for different communities downstream of gauge station.

Risk Monitoring and Warning

The risk monitoring mainly observes two elements of risk, i) the flood (hazard) and ii) the elements in flood risk. Among the two elements, flood is more dynamic so risk monitoring is basically monitoring of flood. The interpretation is "when flood level is high at gauge station, there is a high risk in the communities". Risk monitoring also includes monitoring of elements in risk, such as infrastructure, community economic activities, and community movements. However, beside human movement, most of the assets or properties like infrastructure and settlements are static; they change in slow pace compared to flood which changes within hours during rainy season. The elements at risk are reviewed annually during pre-monsoon (pre-flood) time to know whether there are any changes in quantity and quality of the assets, households and population those are exposed to flood which has brought about changes in the risk.

Monitoring of flood is done at the gauge station whether it is rising or falling or reaching to warning level or danger level. Monitoring goes on 24 hours during the monsoon as flood can occur at any time when there is a continuous and heavy rainfall in the river catchment. The gauge readers increase frequency of visit to the station for physical verification when there is rainfall. When the gauge reader observes increase in flood level, reaching to warning and danger levels, they communicate the information to the stakeholders and communities especially the DDRC chairperson and chief or duty attendant at DEOC. The information can also be monitored by stakeholders from distance with the help of display board installed at DEOC or on the web page at *www.hydrology.gov.np.*

Since the information is linked with lives and

Table 7: Lead time (flood travel time from gauge station) and the community risk level in Karnali River, Nepal

Gauge Station: Chisapani	River: Karnali
Latitude: 28 38 40	Longitude: 81 17 30
Elevation: 191 m	Station No: 280

S.N.	Name of community	VDC/Municipality	ward	Lead time*	Level of risk**	District
1	Rajipur	Patabhar VDC	4	1hr 30m	M (Medium)	Bardiya
2	Banghusra	Patabhar VDC	4	1hr 35m	H (High)	Bardiya
3	SonahaGaun	Patabhar VDC	9	1hr 45m	H	Bardiya
4	Sankatti	Patabhar VDC	9	1hr 45m	H	Bardiya
5	Dakshinpur	Gola	8	2hr	L (Low)	Bardiya
6	Murghahawa	Rajapur Municipality	1	2hr 30m	H	Bardiya
7	Chanaura	Rajapur Municipality	2	2hr 35m	H	Bardiya
8	Premnagar	Rajapur Municipality	2	2hr 45m	H	Bardiya
9	Nangapur	Rajapur Municipality	5	2hr 55m	M	Bardiya
10	Tighra	Rajapur Municipality	6	3hr	H	Bardiya
11	Chakkapur	Rajapur Municipality	10	3hr	H	Bardiya
12	Tediya	Rajapur Municipality	10	3hr 10m	M	Bardiya
13	Anantapur	Rajapur Municipality	11	3hr 10m	M	Bardiya
14	Shangharshanagar	Rajapur Municipality	12	3.hr 30m	M	Bardiya
15	MuktakamaiyaTol	Rajapur Municipality	13	4hr	H	Bardiya
16	LahurTol	Rajapur Municipality	13	4hr	H	Bardiya
17	Shankarpur	Rajapur Municipality	13	4hr	H	Bardiya
18	Majhara	Khairichandanpur VDC	13	3 hr 15m	H	Bardiya
19	Lalpur	Khairichandanpur VDC	1	3hr 15m	H	Bardiya
20	Jhapti	Khairichandanpur VDC	7	3hr 30m	H	Bardiya
21	Pattabhaujhi	Suryapatuwa VDC	5	3hr	H	Bardiya
22	Bankatti	Tikapur Municipality	3	3hr	M	Kailali
23	Nuklipur	Tikapur Municipality	3	3hr	H	Kailali
24	KarmiDanda	Tikapur Municipality	3	3hr	H	Kailali
25	Dakshinshahipur	Tikapur Municipality	2	3hr 30m	H	Kailali
26	Simreni	Tikapur Municipality	2	3hr 40m	H	Kailali
27	Simreni	Narayanpur VDC	7	3hr 50m	H	Kailali
28	MahadevTol	Narayanpur VDC	8	4hr	H	Kailali
29	RamjanakiTol	Narayanpur VDC	8	4hr 10m	H	Kailali
30	Dhamitol	Narayanpur VDC	8	4hr 20	H	Kailali
31	Suryapur	Dhansinghpur	2	4hr 30m	M	Kailali
32	Banjariya	Dhansinghpur	2	4hr 35m	M	Kailali
33	Bangaun	Dhansinghpur	2	4hr 40m	H	Kailali
34	Phanta	Dhansinghpur	1	4hr 45m	H	Kailali
35	Ramdanda	Dhansinghpur	1	4hr 50m	H	Kailali

Source: ** Flood travel time from gauge station to the communities*
*** Level of risk as perceived by the communities*

Table 8: Monitoring of flood

Manual and physical monitoring of flood (staff gauge)	Flood monitoring from distance (Bubbler, Float)	Flood monitoring from distance (Radar)
• Is the flood level increasing, decreasing or stable? • Is the flood reaching and/or exceeding warning and danger levels? • Verification of the flood level manually and physically by the gauge reader.		

properties of the people downstream, it needs to be verified by manual reading of staff gauge. Occasionally, the debris that comes with flood obstructs the instrument to transmit actual flood information. Therefore, manual verification is very important during the time of the flood to avoid false warning to the communities. Once the community and stakeholders get the warning information, they will understand who, where and what assets or properties will be affected. Upon receiving the warning information, the communities in the location which is likely to be affected, will disseminate the information to all the households and the individuals to get ready to leave their house.

Risk Information Communication and Dissemination

Flood information is communicated through a number of means and channels to the stakeholders and communities. The main means of communication is telephone, both mobile and landline and other means is website or Internet. During stakeholder meetings and workshops, the key individuals and their telephone numbers are identified. These telephone numbers are shared widely among district stakeholders, community leaders and the gauge reader. Communication trees or channels are prepared, one for each river system and it is used for better flood information flow among stakeholders during the time of flood.

The communication takes place formally and informally. Formally, DHM issues bulletin and posts to the website. Usually formal communication starts when flood level reaches to warning and danger levels. The gauge reader communicates with the district authorities mainly the Chief District Officer (CDO) who is the Chairperson of DDRC, the Chief of DEOC, in-charge of the nearest police station and army barrack, Chairperson of Red Cross district chapter, focal person of non-government organisation who is working closely with the gauge reader on EWS. Upon communication by gauge reader to the CDO, he/she verifies the information from relevant officials

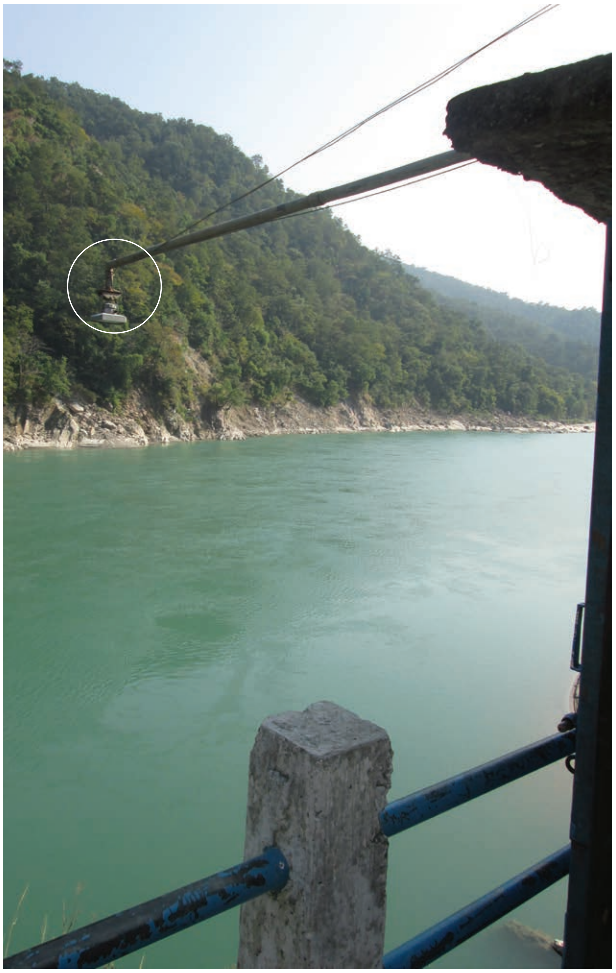


Photo 8: Flood monitoring by radar at Chisapani, Karnali River

Figure 8: Screen shot of real time flood information of Nepal

www.hydrology.gov.np/new/bull3/index.php/hydrology/screen_display

RIVER WATCH

S.N	Station Index	Station Name	Water Level (m)	Flow (m^3/sec)	Warning Level (m)	Danger Level (m)	Trend	Status
1	240	Karnali at Asaraghat 2016-07-20 13:35:00	2.96	987.40	5.7	6.4	Falling	-
2	241	Lahare Khola at Tallo Dungeshwor 2016-07-21 09:45:00	3.04	100.46	5	5.5	Rising	Below Warning Level
3	259.5	West Seti at Dipayal 2016-07-21 09:45:00	6.97	920.30	8.6	9	Steady	Below Warning Level
4	269.5	Bheri at Samaijighat 2016-07-21 09:20:00	5.20	1038.00	7.1	8	Steady	Below Warning Level
5	289.95	Babai at Chepang 2016-07-21 09:50:00	3.74	-	5.50	6.10	Falling	Below Warning Level
6	291	Babai at Bhada Bridge 2016-07-21 09:45:00	5.72	354.59	9.5	10.5	Falling	Below Warning Level
7	330	Mari at Nayagaon 2016-07-21 08:50:00	2.86	-	-	-	Steady	-
8	375	West Rapti at Kusum 2016-07-21 09:50:00	2.79	170.40	5.00	5.40	Steady	Below Warning Level
9	415.1	Aadhi Khola at Borlangpul 2016-07-21 09:30:00	1.66	-	-	-	Falling	-
10	417	Badigad at Rudrabeni 2016-07-21 09:10:00	3.47	532.00	-	-	Rising	-
11	425	Seti at Jyamirebari 2016-07-21 09:15:00	1.68	-	4.8	-	Falling	-
12	430.5	Seti at Damauli 2016-07-21 09:45:00	2.45	196.50	-	-	Rising	-
13	439.7	Marsyangdi at Bimalnagar 2016-07-21 09:35:00	19.45	-	-	-	Rising	-
14	445	Budhigandaki at Arughat 2016-07-21 09:45:00	2.66	-	-	-	Steady	-
15	447	Trishuli at Betrawati 2016-07-21 09:45:00	3.54	519.40	-	-	Falling	-
16	449.91	Trishuli at Kali Khola 2016-07-21 08:19:00	7.62	-	9.7	11	Rising	-
17	450	Narayani at Narayanghat 2016-07-21 09:35:00	5.46	5033.80	7.3	8.4	Rising	Below Warning Level

Date: www.hydrology.gov.np

especially those from DHM. Once the information is confirmed and verified, the CDO communicates to other members of DDRC to get ready for possible community evacuation. The CDO also communicates or asks the Chief of DEOC to communicate to the Chairpersons of the Village Disaster Management Committee (VDMC) to get ready to evacuate the community members to safer locations. Generally telephone is used to communicate but the CDO also uses wireless VHF radio set to communicate with the rescue forces (police) if the telephone system does not function properly, which usually happens at times of heavy rainfall.

Informally the gauge reader also communicates with other stakeholders and the community members. The informal communication takes place to update the flood information, not necessarily when the flood is at warning and danger levels. Such communication takes place through telephone which keeps the communities updated on the status of the river. The gauge reader also communicates to local FM radios which are responsible to disseminate information to the communities. Upon receiving such information, the FM radio broadcasters disseminate the information through their regular flood bulletins or updates. When the

Table 9: FM radios involved in dissemination of flood information in different flood areas

	Name of FM Radios		
S.No.	East Rapti and Narayani (Chitwan and Nawalparasi)	West Rapti, (Banke)	Babai and Karnali (Bardiya)
1	Kalika FM	Himal FM (92.8)	Fulbari FM(100.6)
2	Hamro FM	Bageshwari FM (94.6)	Babai FM (106)
3	Synergy FM	Bheri FM (105.6)	Ramjani FM (89)
4	Bijaya FM		
5	Radio Chitwan		

Table 10: District authorities who receive SMS for flood EWS

S. No.	Name	Office
Chitwan District		
1	Chief District Officer (CDO)	District Administration Office
2	Information Officer, DDC	District Development Office
3	Gauge Reader	Gauge Station/Devghat and Rajaiya
Bardiya District		
1	CDO	District Administration Office
2	Local Development Officer (LDO)	District Development Office
3	President, District Chapter	Nepal Red Cross Society (NRCS), District Chapter Office
4	Superintendent of Police (SP)	Armed Police Force (APF)
5	SP	Nepal Police
6	Major (Chief of the Barrack)	Nepal Army
Banke District		
1	CDO	District Administration Office
2	Assistant CDO	District Administration Office
3	LDO	District Development Office
4	President, District Chapter	NRCS, District Chapter Office
5	SP	APF
6	SP	Nepal Police
7	Colonel	Nepal Army

flood reaches to warning and danger levels the FM radio broadcasters also provide breaking news or information in the middle of their other programme.

The communication of information takes place at the national level, the DHM provides updated flood information to the National Emergency Operation Centre (NEOC) and Disaster Management Unit of the Ministry of Home Affairs (MoHA). The MoHA then communicates the information mainly through web posting and SMS to its regional and district offices. A display board installed at NEOC displays flood information of major rivers of Nepal where telemetry system are established. The communication also takes place from district and regional administration offices to national level regarding the status of floods on the ground.

The flood information is communicated to key individuals in the districts and at the national offices through SMS. The automatic system generates SMS and transmits to the designated mobile telephone numbers when the flood levels reach to warning and danger levels at gauge stations. Audio sirens are also triggered at display boards and on the website when the flood levels reach to warning and danger levels.

In addition to district stakeholders, the flood warning and danger level SMS are also sent to following officials in the central offices:

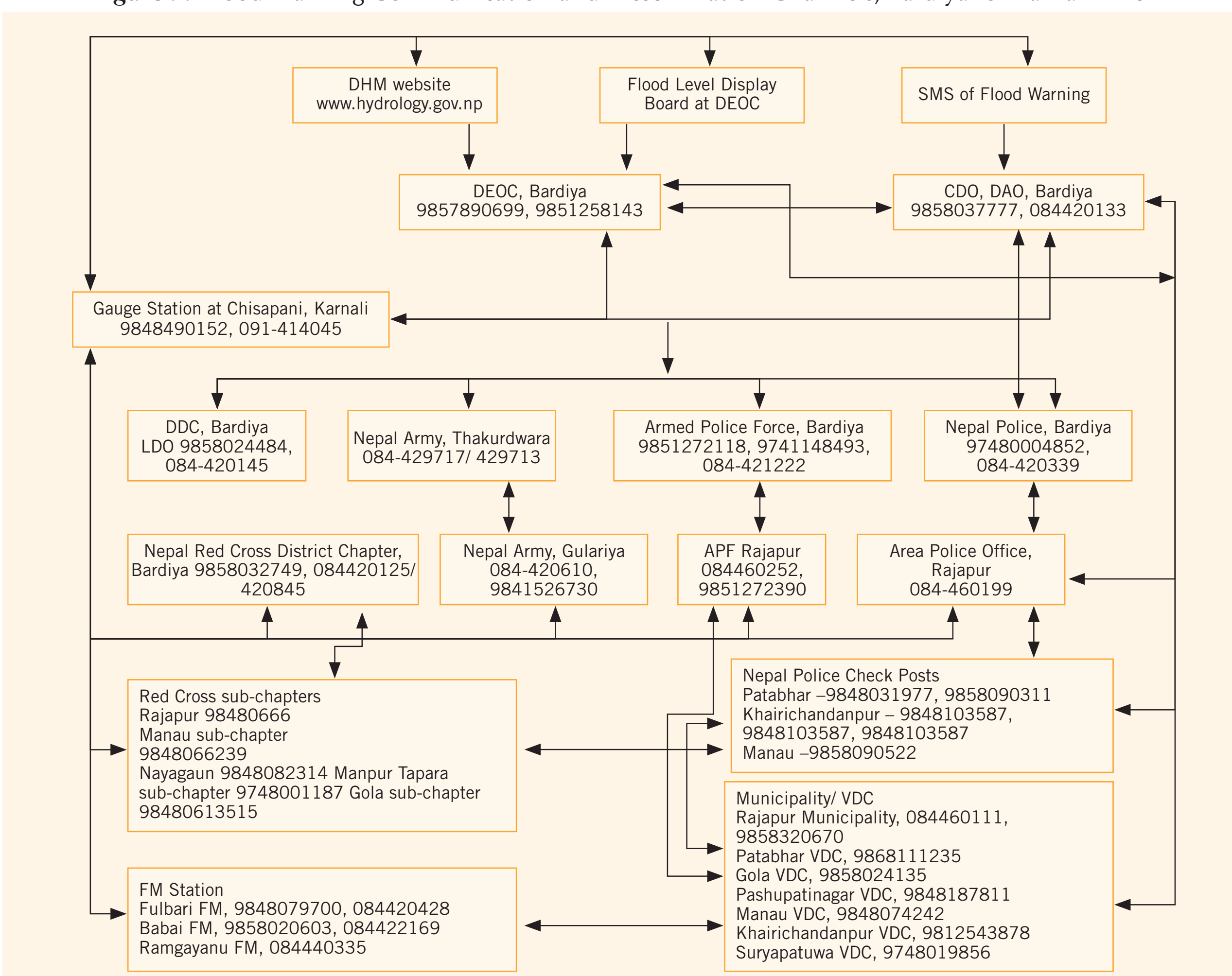
S.No.	Name	Office
1	Director General	DHM
2	Chief, Flood Forecasting Section	DHM
3	Chief, Disaster Management Division	MoHA
4	Chief, NEOC	MoHA

There is a need to make uniform list of SMS receivers in the district. This needs discussions and agreement with CDMC, VDMC, DDRC, DHM, Ministry of Federal Affairs and Local Development (MoFALD) and MoHA. From monsoon of 2016, mass SMS has been brought into effect in which all mobile number bearers of NTC and NCell who are present in the flood risk zone at the time of warning receive SMS when the flood level reaches warning and danger levels.

Dissemination of risk information is basically to provide flood information to the communities, households and individuals. Once the risk information is communicated to different stakeholders and head of the LDMC and CDMC in the communities, the

Photo 9: Electronic display of flood level at CDO Office, Narayani

Figure 9: Flood Warning Communication and Dissemination Channels, Bardiya for Karnali River



information should reach to each household and individual member of the households.

The information dissemination takes place through diverse activities and means at the community level. There are three task forces in the communities: Early warning task force, search and rescue task force and first aid task force. Each task force comprises of five members who are trained on their roles and responsibilities they have to play during the time of disaster. Early warning task forces play vital roles in information dissemination in the communities. Once the members of early warning task force receive the information from the Chairperson of the CDMC, the members of the task force blow hand siren and visit home to home with megaphone to inform the members of each house. The early warning task force members also pay special attention to those households with most vulnerable members in their family including persons with disabilities, elderly, pregnant women and children. They ensure that each household and their members receive the flood information.

For effective use of hand siren it has two distinct messages. For warning, the siren is played for short duration for about 10 seconds and may be repeated for 3 or 4 times. For the danger information the siren is played for a longer span for about 30 seconds and is repeated for 3 or 4 times to ensure that all households have heard the siren. To ensure reach of information to each household, the siren is complemented with home visits by the members of early warning task force and megaphone.

The local FM radios also disseminate flood information, once they receive information from DDRC and from the websites. Broadcasting of flood information by FM radios enhances information reach to wider communities including those who

Figure 10: Risk information dissemination

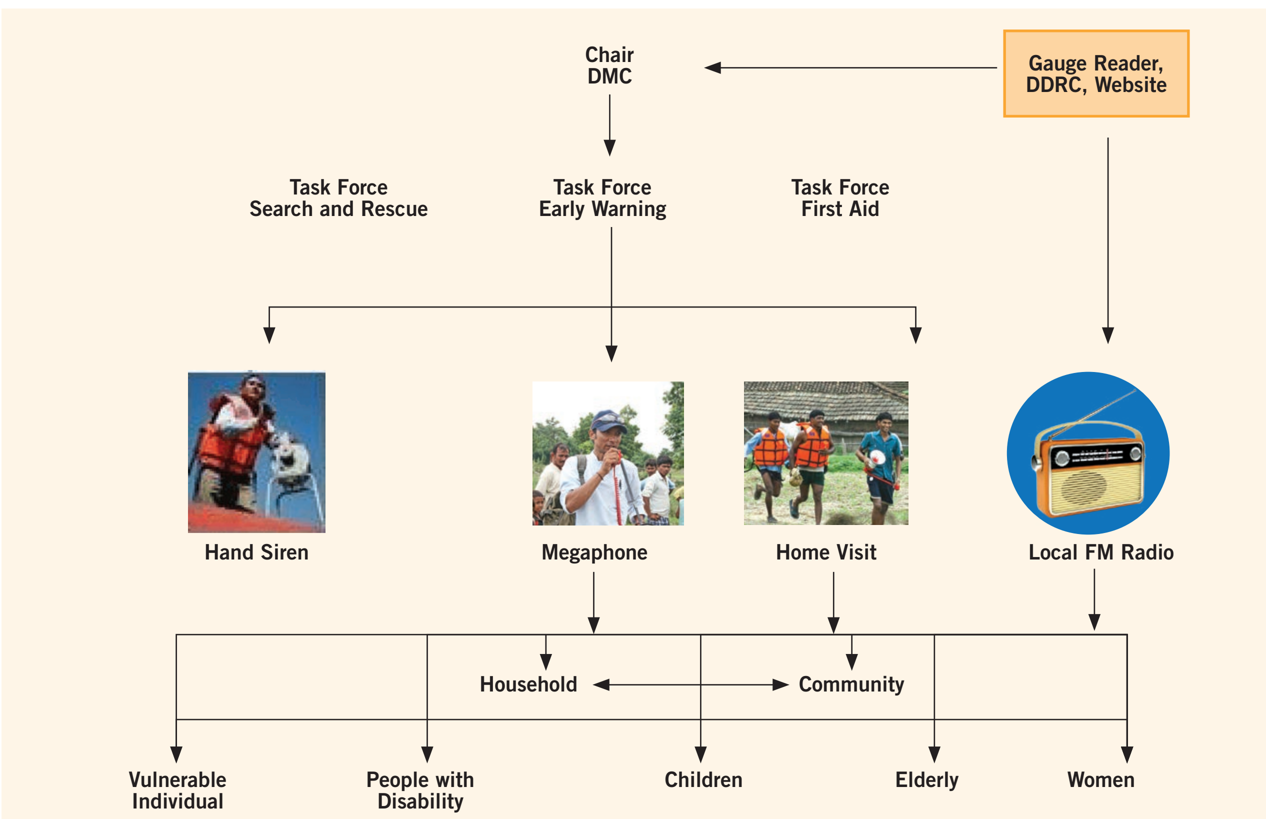


Photo 10: Flood emergency shelter

are outside the flood zone. After receiving message, community members outside the flood zone go to help communities who are likely to be affected by the flood.

Capacity Building for Response

Capacity of the communities and stakeholders are strengthened to enhance their understanding on elements of EWS and their actions to respond to the flood or risk information they receive. A number of community level and district level activities are implemented. Such activities include i) understanding of risk ii) awareness on need of preparedness iii) actions required at local level for preparedness and iv) need based infrastructure development to enhance response capacity of communities and reduce impacts of flood. The capacity building also addresses needs of the authorities and stakeholders so that they can effectively play their roles and support communities in delivering each element of EWS.

The participatory risk assessment enhances capacity of communities to understand their risk to flood and sharing of such information with the stakeholders enhances their risk knowledge. Awareness activities during local events, festivals and **Disaster Day** enhance awareness of the flood risk and response activities among communities and individuals. EWS mock drills are also organised as preparedness activities during the pre-monsoon season. Involvement of security forces in mock drills proved to be an important strategy to capacitate the security forces to involve in community actions and increase understanding and strengthen linkage between communities and security forces for mutual support. The DDRC and the VDMC lead in implementation of mock drills at district and VDC levels.

Software activities together with hardware activities are vital to enhance capacities of the communities and stakeholders. Communities and security forces are supported with search and rescue gears and materials including life jackets, rescue ropes, boats, torches and other necessary materials that are required for rescue action. Communities are also supported with improvements on trails, bridges and flood ways which enhance smooth flow of flood water and movement of communities during the time of evacuation. Supports are also provided to communities for construction of community flood or emergency shelters where they take temporary shelter for one to two days or more when needed. From the temporary flood shelter, the community members might go back to their respective houses once the flood recedes back to normal, or they might be transferred to other temporary shelters where they need to stay for longer durations until their houses are repaired or rebuilt.

Training to members of VDMC, CDMC, task forces and different other community members strengthened their capacity to understand how EWS functions and what should be their roles and responsibilities during the time of response and throughout the EWS.

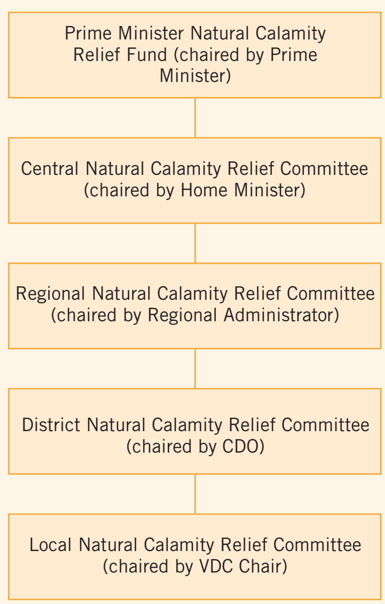
Upgradation of hydrological and meteorological observation stations is equally vital with advance technologies in order to enhance monitoring capacity of the gauge reader and staff of hydrological stations. Regular training to staff members who monitor the hydrological stations make them further aware of their roles in saving lives and properties of the communities and at the same time it also helps build their capacity to observe and maintain the equipment for a sustained and regular service.

Institutional Arrangement for Disaster Risk Management

Figure 11 illustrates the institutional arrangements for disaster management in Nepal at national, regional, district and village levels as per the Natural Calamity Relief Act, 1982. The roles and responsibilities of each of the committees at different levels have been explained in the act. Since this act is prepared for rescue, relief and rehabilitation, it does not address the EWS for any hazard.

The other legal documents of the Government of Nepal are National Strategy for Disaster Risk Management (NSDRM) (2009) and National Disaster Response Framework (NDRF) (2013) which are directly relevant to disaster management. Currently EWS has no separate strategy and legal document despite the fact that it is recognised in the previous two strategic documents. A national strategy for EWS is a need felt to strengthen EWS and replicate it widely across the country to link the national action with Sendai Framework for DRR in which replication of EWS is one of the seven targets.

Figure 11: Existing institutional structure for disaster relief mechanism in Nepal



CHAPTER 5

Future of EWS and Sustainability

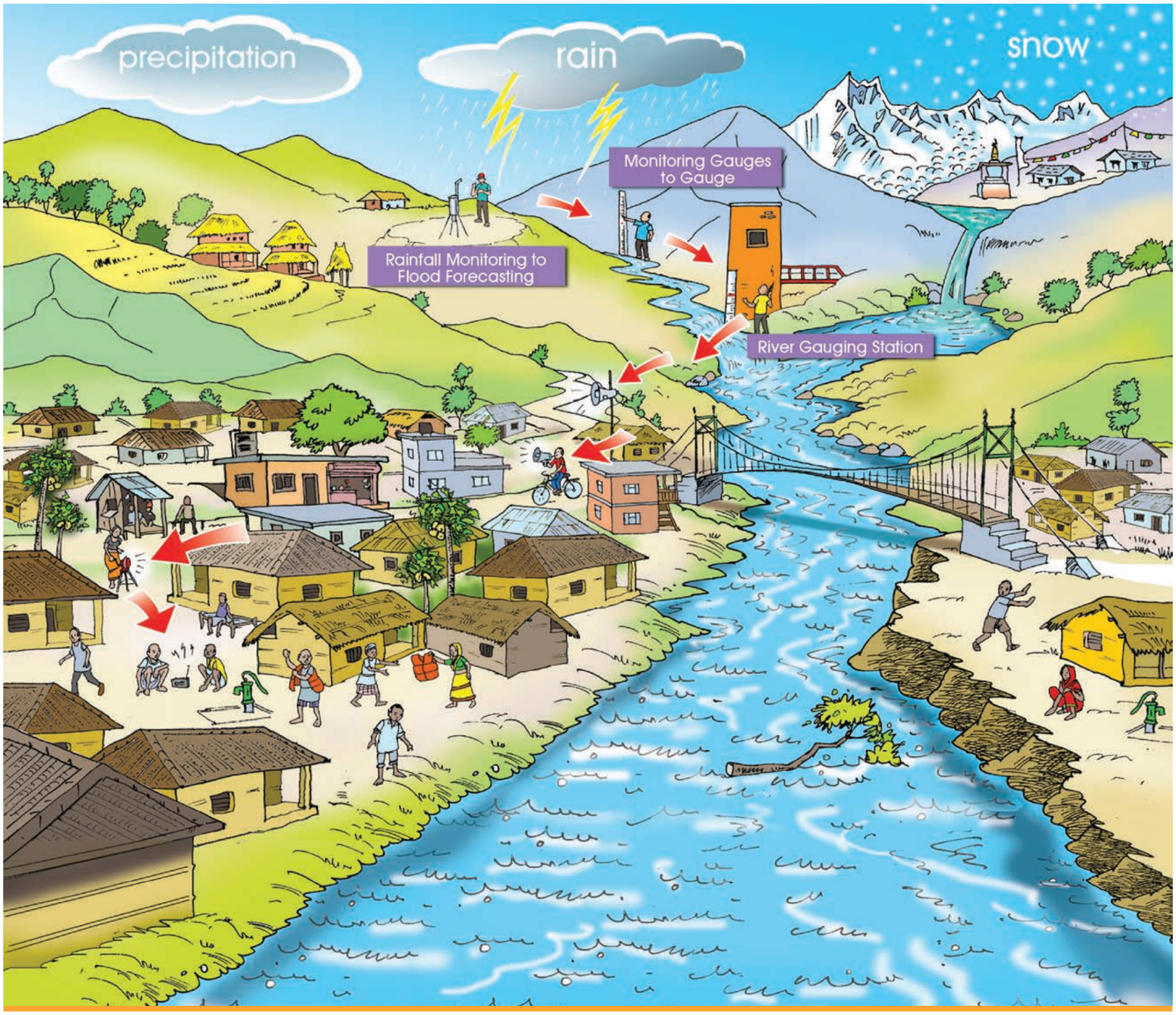
It is proven that flood EWS saves lives and properties; however, there is a dire need to scale out the EWS across the country. The importance of EWS should also be recognised by the policy and decision makers to enhance its scaling up and scaling out. At the strategy level, the need of EWS has been recognised by different documents. However, a clear strategy for scaling out and scaling up of EWS across the geographic regions of the country is not yet clear. National strategy for EWS has been drafted by the DHM and MoHA which is yet to be approved by the Government of Nepal. Approval of the strategy will definitely enhance replication and expansion of EWS across the country. Beside policy level constraints, there are certain technical limitations in the current flood EWS. One of the limitations is short lead time. It is possible to increase the lead time by monitoring the flood level and rainfall throughout the upper catchment of rivers and using flood forecasting models. The lead time can further be increased by modelling flood forecast based on weather forecast information in the upstream of the river basins. Currently, such technologies and practices are at initial stage in Nepal and needs their advancement for their effective use.

The current flood EWS in Nepal is focused to the floods in lower section of the rivers where flood gauges and the flood maps already exists. However, flash flood in the mountains is evident to the fact that it has different characteristics to the floods in the plain. The monitoring of flood in the mountains might require different technologies. Similarly, the communication and dissemination approaches in the mountain terrain might demand different approach. It is not possible to visit home to home in the hills because of difficult terrain but the sound of a hand siren might reach distances compared to that in the plains. Therefore, flood EWS is equally important to be tested and adopted in the hills and the mountains for localised EWS for flash floods citing the risks of glacial lake outburst and landslide dammed lake outburst. Monitoring of rivers or floods in the hills and mountains is also equally challenging in addition to risk information communication and dissemination. Currently, radar systems are in piloting phases.

The other important aspect of sustainability and expansion of EWS is its institutionalisation as an integral part of disaster management programme in the country. The Government of Nepal has identified nine minimum characteristics as basic essentials for CBDRR among which EWS is one. In order to institutionalise the nine minimum characteristics, practitioners need policy and legal documents for effective and uniform implementation across the country. This also needs technical guiding documents so that there is uniform understanding and practice among all the practitioners. The existing Disaster Management Act has a very less reflection of lessons learnt after the formulation of the act back in 1981. This act needs to be updated with latest national and international learning and decisions made at different times.

For institutionalisation of the EWS, one of the major issues observed is incentive package provided to the gauge readers. The incentives provided to them is important especially for the monsoon period when their 24 hours attention is needed to monitor the

Figure 12: River basin approach for flood forecasting



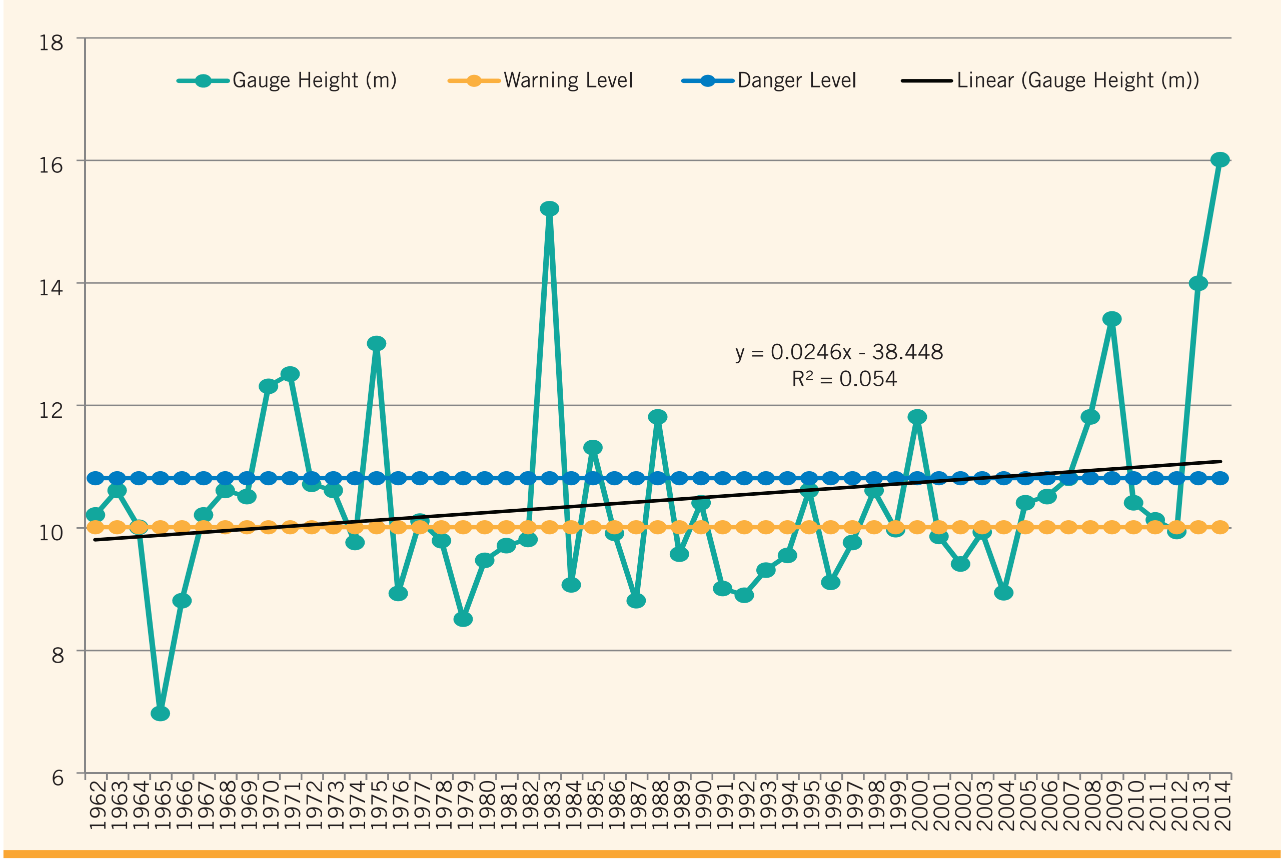
flood. There are some incentives being provided by the DDCs in the form of additional allowance for the monsoon period but as it is not institutionalised, it very much depends on individual decision of the CDO and LDO, and the frequency of follow up made by the gauge reader and other stakeholders in the district.

A smooth EWS is dependent on a number of other infrastructures available in the district and the communities. These include quality and coverage of telephone service, electricity facility, trained human resource especially within the security forces, and orientation of the government officials on the system. Telephone and electricity facilities are crucial during monsoon. There can be physical damage caused by flood and landslides and their services may be interrupted from some hours to even several days. If there is such scenario, the EWS cannot work effectively. Under such circumstance, other means of communication play vital roles such as VHF radio sets which is usually available with the security forces. Electricity is important especially to recharge batteries and to keep the radar and telemetry system functioning. When there is complete degeneration of batteries due to disruption in the electricity line, there are evidences that the EWS cannot work efficiently. So, alternatives to recharge batteries should be provisioned in an advance such as solar battery chargers. It also demands new equipment or technologies for flood monitoring that can run with batteries for several days or months once charged fully.

The other important aspect for sustainability and reliability of EWS is the condition of monitoring stations or river gauge stations. The structure of the stations and equipment inside them should be protected from possible damages by the flood because they are the key structures in EWS without which EWS is fairly impossible. Evidences show that the flood monitoring stations are not safe during large flood events. Potential large floods scenarios have to be factorised in the design of the flood gauges which is essential especially when the flood characteristics is becoming erratic and there is high probability that such events will increase in the coming years due to change in climate. Alternative flood or risk monitoring mechanisms should be established.

The rivers in Nepal bring high sedimentation load and debris forcing the river change its course in relatively short period of time. The warning and danger levels identified based on previous studies change over time and the levels may not be applicable after some years. So there is a need of timely review of flood map and readjustment of the warning and danger levels. The assessment is also

Figure 13: Gauge level of Karnali at Chisapani (m)



essential for community's vulnerability and exposure in the flood prone zones. Since the human activities and development interventions in the flood prone zone keep changing, the risk scenario also changes. There is also a need to capacitate civil servants and security forces on EWS at the time of service entry training and refreshers or in-service training.

Floods have transboundary effects. They are not limited by political boundaries. Therefore there is a need to scale out the EWS practices at trans-border scale which needs coordination and collaboration between the concerned countries with bilateral agreements or multilateral agreements if it involves more than two countries. The cross border initiatives in flood EWS by Practical Action in Karnali River in collaboration with other partners between Nepal and India has large benefit potential to downstream communities in India. The communities in India get a long lead time which enables them saving their lives and properties significantly.

Due to climate change, the uncertainties will further increase and the EWS has crucial roles to play. As suggested in previous sections, there is a need of forecast based EWS. Because of uncertainties in climatic extremes, such forecast based EWS would be of probabilistic in nature based on weather forecast information and real time observation of rainfall in upstream. The monitoring and forecasting technologies could be different from one hazard to another, but the communication and dissemination systems could be common. Different hazards might also need different types of capacity for the communities and stakeholders to respond. There is also need of EWS for other hazards including landslides, Glacier Lake Outburst Flood (GLOF), epidemics, earthquake and fire.

The historical extreme data of the flood are not going to be same in the future. A development planning that considers past extreme data will not be sufficient in the future because of climate change impacts. So, there is a need to project and develop scenario of future extreme flood for EWS and different other development activities in the flood zones along the river valleys. A future scenario of the risk is essential for both risk reduction and risk proofed development interventions in the future.

Figure 13 shows that the flood level is in increasing trend in Karnali River. Therefore, any development plan or DRR plan that assumes highest flood in the past will not be able to address the need of the highest flood that is likely to occur in future. Since there is an increasing trend in flood level, the plans need to address projected flood in the future.

A Case Study of Flood EWS in Action in west Rapti, Banke on August 2012

Water level progression

On 3 August 2012, river level of west Rapti at Kusum hydrological station was 3.12 m at 9:00 a.m. (figure14). The level started rising and reached 3.77 m at 10:00 a.m. The level crossed warning level of (5 m) at 1:00 p.m. This was due to heavy rainfall in the catchment of west Rapti the previous day. The water level crossed the danger level (5.4 m) at 2:00 p.m. then it continued rising and reached 7.24 m at 12:00 midnight. Water started receding at 1:00 a.m. On 4 August 2012 at 10:00 a.m., the water was below danger level and at 11:00 a.m. it dropped below the warning level. The real time screen shot of the website (www.

Map 7: Banke District and flood affected VDCs in red

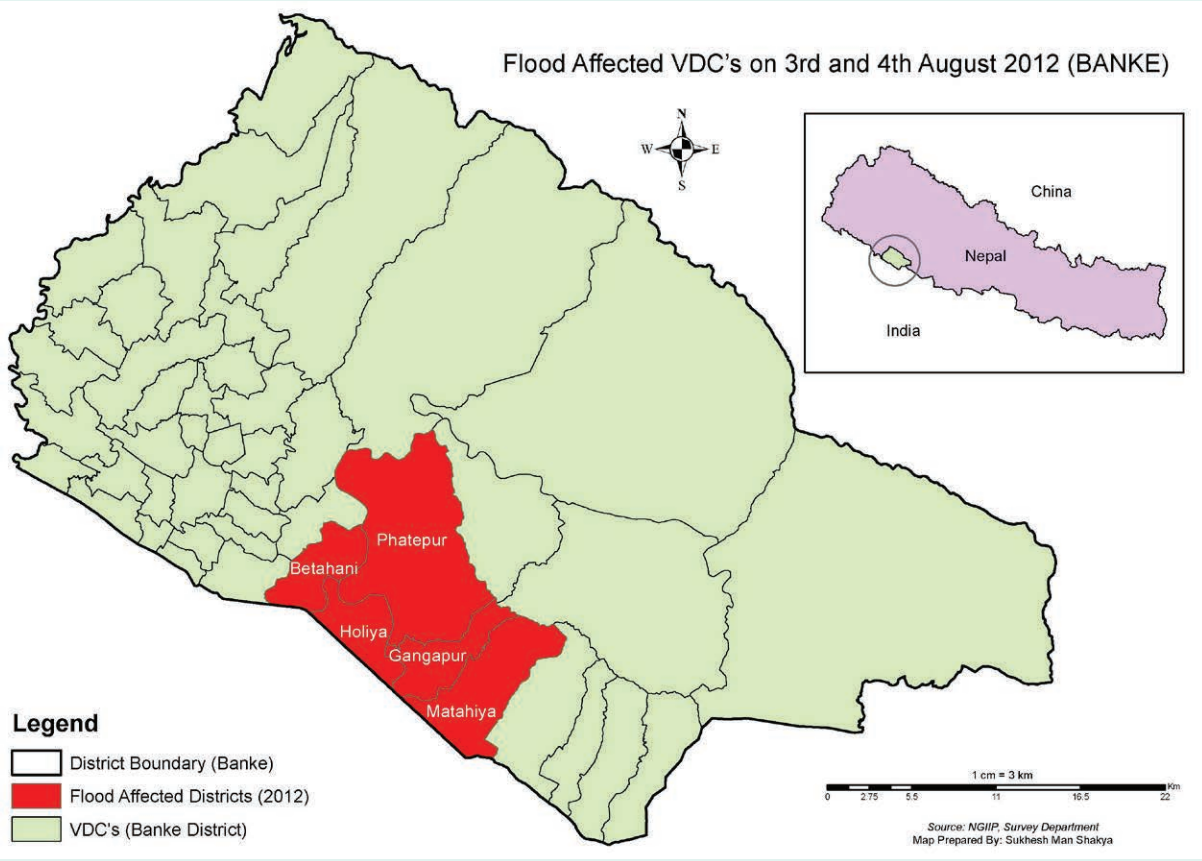
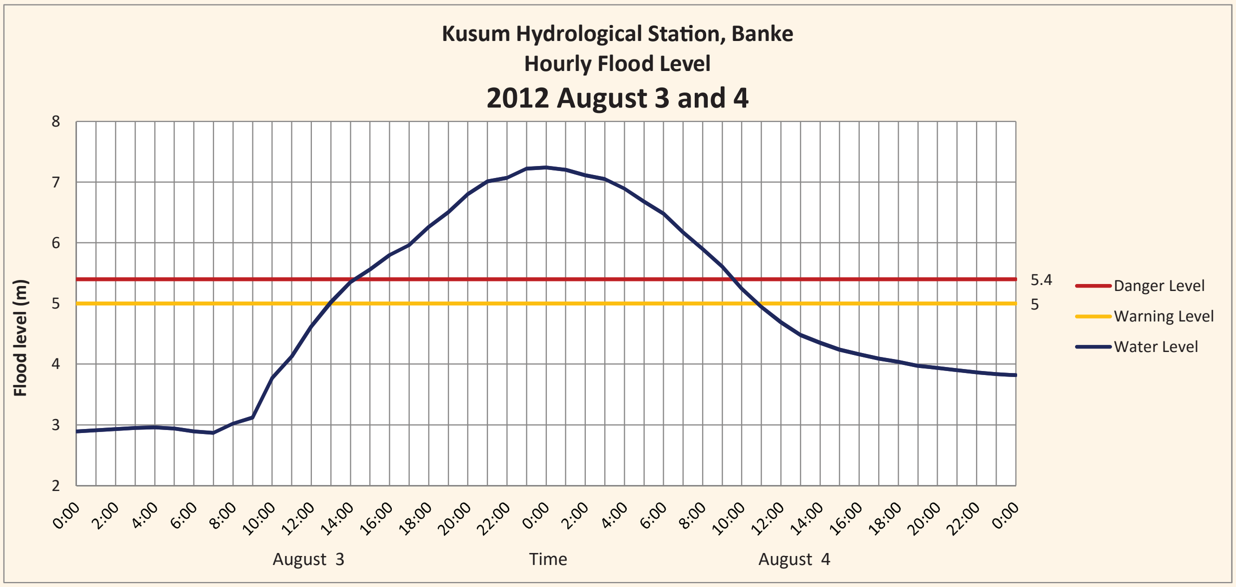


Figure 14 : Water level progression graph of west Rapti at Kusum hydrological station



hydrology.gov.np) when water level crossed danger level is shown in the Figure 15 below. When water level reached or crossed warning or danger levels, automated siren rang from the website as well.

Stakeholders in Action

Electronic display board (Photo 11) at District Administration Office (DAO) of Banke District rang first siren when water reached warning

> *"This is a great achievement. I am happy, despite the huge flood, there is no human casualties. I heard this was the worst flood in Banke. Thanks to the timely information circulation, I was able to communicate with Indian counterpart to open all the 14 gates of Laxmanpur Barrage."*
>
> ***- Mr. Dhundi Raj Pokharal***
> *CDO, Banke District*

Photo 11: Electronic display installed in DAO, Banke

Figure 15 : Real time screen shot taken of river watch from www.hydrology.gov.np when water level at Kusum overtopped danger level. Red row is showing water level at west Rapti

Government of Nepal
Ministry of Environment, Science and Technology
Department of Hydrology and Meteorology
Flood Forecasting Project

RIVER WATCH

S.N	Station Index	Station Name	Water Level (m)	Flow (m^3/sec)	Warning Level (m)	Danger Level (m)	Trend	Status
1	240	Karnali at Asaraghat 2012-08-03 16:15:00	4.89	-	-	-	Falling	-
2	259.5	Seti at Dipayal 2012-08-01 15:00:00	7.35	-	-	-	Rising	-
3	269.5	Bheri at Samaijighat 2012-03-20 16:10:00	1.68	-	-	-	Steady	-
4	280	Karnali at Chisapani 2012-08-03 16:10:00	8.76	5869.40	10.00	10.80	Rising	Below Warning Level
5	289.95	Babai at Chepang 2012-08-03 15:45:00	3.40	463.00	6.50	7.00	Rising	Below Warning Level
6	291	Babai at Bhada Bridge 2012-08-03 04:39:50	4.31	-	-	-	Rising	-
7	330	Mari at Nayagaon 2012-08-03 15:11:52	1.91	-	-	-	Rising	-
8	339.3	Jhimruk at Cherneta 2012-08-03 16:18:36	2.98	-	-	-	Falling	-
9	375	West Rapti at Kusum 2012-08-03 16:21:10	5.81	2494.90	5.00	5.40	Rising	Above Danger Level
10	419.1	Kaligandaki at Kumalgaon 2012-08-02 18:07:04	3.75	1037.00	-	-	Steady	-

We succeeded to be alive and save our valuables only because communities got flood information on times.

- Mr. Pralad Dhobi
Inhabitant of Holiya VDC

level. Immediately after the first siren, CDO Mr. Dhundi Raj Pokharel informed security forces to disseminate the information to police posts of vulnerable communities as soon as he received SMS from the automated system installed at Kusum hydrological station.
CDO also checked the information from Ranjha station of DHM. Deputy Superintendent of Police, Mr. Uday Tamang was constantly following the flood update. He was preparing to visit Holiya, one of the highly flood prone VDCs, to get the real time situation update. Nepal Army also disseminated alert messages to respective army posts in the flood prone areas.

As soon as the warning information was received, the police squad reached Holiya, at 2:30 p.m. on 3 August. The squad brought along ropes and life jackets. They were all set for rescue effort if needed. Sub Inspector of police from Betani post, Krishna Bahadur Thapa arrived flood vulnerable communities and made people aware on water level at Kusum. Different local FM radios including Krishnasar FM, Himal FM, Bheri FM, Radio Xpress, and Jana Awaz FM, broadcasted flood information. Local media including TV journalists followed the flood forecasting website.

Photo 12: Police squad at Holiya with rescue gears

Community in Action

West Rapti affects five VDCs namely Holiya, Betahani, Fattepur, Gangapur, Kamdi, Binauna, and Mattaiya of Banke District. Mr. Pralad Dhobi, member of EWS task force of Holiya, received flood information from Kusum gauge reader, Mr. Bhadra Bahadur Thapa at 1:30 p.m. on 3 August. Mr. Dhobi immediately disseminated the message blowing the hand operated siren. Bishnu Adhikari, member of EWS task force of Fattepur, was out of the village when he received the call from Mr. Dhobi. He urgently informed community people over phone and asked to operate hand siren. People received flood information in every VDC in advance.

People in Kamdi VDC stayed overnight in Machan (an elevated makeshift tower used for various purposes like watching animals entering crop fields, watch water level in river, among others) with all their valuable items and documents. Hasma Ansari, who also represents VDC level DMC mentioned,

> “Everyone was aware of approaching flood. It is all because of our early warning system.”
>
> ***- Agya Ram Barma***
> *Inhabitant of Betahani*

“People were constantly in touch with gauge reader and getting updates. People were scared when water level crossed 7 m. However, receding water level in the river brought back some relief in them.”

In Binauna VDC, there was no one around when water entered Prashadi Tharu’s house. Chhatak Bahadur Tharu and Sailendra Tharu, members of local committee, rowed boat and secured the valuables like documents and stored grains. However, they failed to save 50 kg of millet since water rose instantly. Similarly, in Bankatti VDC, people were well aware in their part that their place will be inundated.

Photo 13: A man escorting his buffalo to safe place

The mechanism developed for flood information, communication and dissemination worked well during the flood time. Badhelal Yadav, a local resident later happily shared, "nobody lost their lives or got injured, thanks to the early warning of flood to the community."

Mr. Agaya Ram Barma, member of DMC, Betahani, informed community people to evacuate when he received message about water level crossing the threshold at Kusum. The flood took 6 hours to reach this community from Kusum. People were evacuated to safe place along with their valuable belongings. People also successfully rescued their livestock. Female, children, and elderly people left their houses when they were informed that water level crossed danger level. Most of the men stayed on the river bank for water level monitoring.

Community people were constantly in touch with gauge reader, Mr. Thapa. People were also aware that water started receding after 1:00 a.m. on 4 August. They stayed in safe place over night and came back home when water was completely gone from their houses and fields.

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The renowned economist Dr. EF Schumacher established Practical Action in 1966 to prove that his philosophy of 'Small is Beautiful' could bring real and sustainable improvements to poor people's lives. With its Head Office in the UK, Practical Action works in more than 20 countries including India through its country and regional offices in Bangladesh, Kenya, Nepal, Peru, Sri Lanka, Sudan and Zimbabwe. Practical Action's approach is guided by its vision of a sustainable world free of poverty and injustice, in which technology is used for the benefit of all.

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Disaster risk reduction – Reduced risk of disasters for marginalised groups and communities

Practical Action has been working in community based EWS in Nepal since 2002 – specifically on systems which give early warning of flood.

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Practical Action
House No. 1114, Indira House
Pani Pokhari, Lazimpat
PO Box 15135, Kathmandu, Nepal
T. + 977-1-4423 639, 4423 640, 4413 452
E. info@practicalaction.org.np
W. www.practicalaction.org/nepal

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