Community Based Flood Early Warning System

Resource Manual

Revised Edition for Telemetry Based Instrumentation

FOR MOUNTAINS AND PEOPLE

About ICIMOD

The International Centre for Integrated Mountain Development (ICIMOD) is a regional knowledge development and learning centre serving the eight regional member countries of the Hindu Kush Himalaya (HKH) – Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan – based in Kathmandu, Nepal. Globalization and climate change have an increasing influence on the stability of fragile mountain ecosystems and the livelihoods of mountain people. ICIMOD aims to assist mountain people to understand these changes, adapt to them, and make the most of new opportunities, while addressing upstream and downstream issues. ICIMOD supports regional transboundary programmes through partnerships with regional partner institutions, facilitates the exchange of experiences, and serves as a regional knowledge hub. We strengthen networking among regional and global centres of excellence. Overall, we are working to develop economically and environmentally-sound mountain ecosystems to improve the living standards of mountain populations and to sustain vital ecosystem services for the billions of people living downstream – now and in the future.

ICIMOD would like to thank the Ministry of Energy and Water (MEW), Government of Afghanistan and the Government of Australia for supporting SWaRMA. We also acknowledge the support provided by CSIRO and other agencies in Afghanistan in implementing this project.

ICIMOD gratefully acknowledges the support of its core donors:
The governments of Afghanistan, Australia, Austria, Bangladesh, Bhutan, China, India, Myanmar, Nepal, Norway, Pakistan, Sweden, and Switzerland.

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Revised Edition for Telemetry Based Instrumentation

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Foreword

The Hindu Kush Himalayan (HKH) region is prone to natural hazards like floods, glacier lake outbursts, droughts, landslides, avalanches, and earthquakes. The unstable geological conditions and steep terrain, combined with climate change and frequent extreme weather conditions, pose myriad challenges for the communities in the region. The frequent occurrence of flash floods, one of the major natural disasters in the HKH region, threatens lives, livelihoods and infrastructure, both in the mountains and downstream. Vulnerable groups like the poor, women, children, the elderly and people with disabilities often suffer the worst impacts.

Since its establishment in 1983, the International Centre for Integrated Mountain Development (ICIMOD) has explored different ways to reduce the risk of natural hazards and the physical and social vulnerability of the people in the HKH region. The establishment of a regional flood information system (HKH-HYCOS) has allowed for a timely exchange of flood data and information for mitigating flood vulnerability. A wide range of information is produced to support multi-scale disaster risk reduction (DRR) systems using satellite rainfall estimation, satellite altimetry-based flood early warning systems, flood inundation modelling, and model-derived hydrological information. The Community Based Flood Early Warning System (CBFEWS), enabled by wireless technology, is one of the promising interventions for minimizing flood risk at the community level. This initiative received the Momentum for Change 2014 Lighthouse Activity Award instituted by the United Nations Framework Convention on Climate Change (UNFCCC).

Considering the need of the stakeholders, the wireless CBFEWS technology has been further enhanced by the use of non-contact water-level sensor (ultrasonic) and telemetry-based systems to detect and measure the water level in the river and upload measurements to the internet cloud. This enhanced the CBFEWS with telemetry has been tested in the field with much success and is being replicated in other river tributaries too.

We hope that this manual will meaningfully contribute towards strengthening the capacity of the vulnerable communities by providing them with early flood warning and thus help reduce flood risk, and save lives and livelihoods.

David Molden, PhD
Director General, ICIMOD

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This Resource Manual has been compiled based on ground-level experiences gathered while supporting the capacity of the practitioners and local resource persons for implementing the enhanced version of the CBFEWS with telemetry in different parts of Afghanistan, India, Pakistan, and Nepal. This CBFEWS with telemetry is supported by the Sustainable Development Investment Portfolio for South Asia in Nepal under the Koshi Basin Initiative (2016) and the Indus Basin Initiative (2017), as well as by the Australian government under the Strengthening Water Resources Management in Afghanistan (SWaRMA) Initiative (2018). This system includes an enhancement of the CBFEWS' wireless flood monitoring instrument, which was piloted in India under the Himalayan Climate Change Adaptation Programme (HICAP) supported by the governments of Norway and Sweden. The instrument was first introduced by ICIMOD's Flash Flood Project supported by the United States Agency for International Development's Office of US Foreign Disaster Assistance (USAID/OFDA), and was tested in Assam, India, in 2010. Acknowledging the impact of the CBFEWS in Assam, the United Nations Framework Convention on Climate Change (UNFCCC) awarded the CBFEWS with the Momentum for Change 2014 Lighthouse Activity Award in the Information and Communications Technology (ICT) category. : ICIMOD would like to thank the Ministry of Energy and Water (MEW), Government of Afghanistan and the Government of Australia for supporting SWaRMA. We also acknowledge the support provided by CSIRO and other agencies in Afghanistan in implementing this project. We would also like to acknowledge the support of ICIMOD's core donors: the governments of Afghanistan, Australia, Austria, Bangladesh, Bhutan, China, India, Myanmar, Nepal, Norway, Pakistan, Switzerland, and the United Kingdom.

We are grateful to colleagues who have contributed to this manual and to all the resource persons who supported us in this effort. Our thanks are also due to the participants of the regional workshop on the CBFEWS, which was instrumental in testing this manual. We sincerely thank all the government organizations and partners for trusting the technology developed by ICIMOD and jointly piloting it in the field: the Afghanistan National Disaster Management Authority (ANDMA), Aga Khan Agency for Habitat (AKAH) in Afghanistan, and the Ministry of Energy and Water (MEW) of Afghanistan; the District Disaster Management Authority (DDMA) of Lakhimpur and Dhemaji districts, Assam, Aaranyak in Assam, Disaster Management Department (DMD) and Yuganter in Patna, India; the Department of Hydrology and Meteorology/Community Flood and Glacial Lake Outburst Risk Reduction Project (DHM/CFGORRP) in Nepal, Bardibas municipality and Mahottari rural municipality, Mahottari, Nepal, and Aurahi rural Municipality, Siraha, Nepal; and World Wildlife Fund (WWF) Pakistan, Aga Khan Agency for Habitat (AKAH), Pakistan, and the Gilgit-Baltistan Disaster Management Authority (GBDMA). We would also like to thank Sustainable Eco Engineering (SEE), Nepal, for their support in designing and manufacturing the CBFEWS instrument. We are thankful to the communities in Afghanistan, India, Nepal and Pakistan, involved in the implementation of the CBFEWS for their active participation and adoption of a system that reduces the risk of flood vulnerability.

We acknowledge the continuous support of Dr Sanjeev Bhuchar, ad interim Theme Leader, Water and Air at ICIMOD, and other colleagues from ICIMOD who supported the implementation of the CBFEWS: Kanchan Shrestha, KBP Initiative Coordinator; Samden Sherpa, Knowledge Park Officer; Mohan Shrestha, Administration and Logistics Officer; and Saisab Pradhan, IT Officer. We also acknowledge the contributions of Dr Pranita Bhusan Udas – Gender, Water and Adaptation Specialist – and Dr Aditya Bastola – Gender Specialist in the integration of gender perspective in the CBFEWS – in giving this manual the final shape. We thank ICIMOD's directorate for providing strategic guidance for scaling up the CBFEWS and showcasing it at the global level. We are also grateful to ICIMOD's country offices in Afghanistan and Pakistan for providing valuable support in the implementation of the CBFEWS.

Last but not least, we would like to thank Dr Arun Bhakta Shrestha, Regional Programme Manager for River Basins and Cryosphere (ICIMOD), and Dr Dhrupad Choudhury, Chief Scaling Operations, Adaptations and Resilience Building (ICIMOD), for envisioning this project, scaling out the project into different parts of the HKH region, scaling up the project by enhancing the instrument technically and reaching out to new stakeholders, and providing continuous technical guidance for the success of this project.

About the Resource Manual

What is the Objective of the Resource Manual?

The main objective of this resource manual is to illustrate the key principles of the Community Based Flood Early Warning System (CBFEWS), explain the usage of the Telemetry Based Water Level Monitoring System (TWLMS) and describe the whole implementation process.

Who is the Target Audience?

This resource manual is primarily aimed at organizations and partners who implement the CBFEWS in the field. It can also be adapted and applied by other relevant stakeholders, depending on their interest and scope.

What is the Scope of the Manual?

Considering the various approaches of early flood warning systems that are in place, this resource manual focuses on the community-based approach developed by ICIMOD together with the Sustainable Eco Engineering (SEE) team; it also focuses on the experiences that ICIMOD and regional partner organizations such as Afghanistan's Aga Khan Agency for Habitat (AKAH), and India's Aaranyak and Yuganter gathered from field deployments in Afghanistan, India, and Nepal. The manual builds on the previous one on "Community Based Flood Early Warning System for the Hindu Kush Himalaya" and then goes on to describe the features of the telemetry-based instrument for CBFEWS.

How is the Manual Organized?

The manual is organized into three major parts. Part I provides a brief background of the CBFEWS and its significance in order to show its impact on the ground. It also discusses the key elements of the CBFEWS: risk knowledge and scoping; the telemetry-based instrument and its functionality; and information dissemination, response capability and resilience building. Part II provides details of the instrument, including introduction to the tools used to fix the instruments; a detailed outlook of the instruments; and guidance and instructions for installation of the equipment, with particular focus on its operation, monitoring, repair and maintenance. Additionally, it includes information regarding the hands-on training on the CBFEWS and its impact stories. Part III provides a list of reference materials.

Abbreviations and Acronyms

2G	2nd Generation
3G	3rd Generation
4G	4th Generation
Ah	Ampere Hour
AT	Application Transparent
AU	Alarm Unit
CBFEWS	Community-Based Flood Early Warning System
COP	Conference of Parties
DA Unit	Data Acquisition Unit
dB	Decibel
dBi	Decibels relative to isotropic radiator
dBm	Decibels relative to 1 milliwatt
DC	Direct Current
DDMA	District Disaster Management Authority
DRR	Disaster Risk Reduction
DU Unit	Data Upload Unit
FRA	Flood Risk Assessment
GHz	Gigahertz
GND	Ground
GPRS	General Packet Radio System
GSM	Global System for Mobile Communications
HICAP	Himalayan Climate Change Adaptation Programme
IC	Integrated Circuit
ICT	Information and Communications Technology
KBP	Koshi Basin Programme
kHz	Kilohertz
L1	Level 1
L2	Level 2
L3	Level 3
LCD	Liquid Crystal Display
LED	Light-Emitting Diode
MHz	Megahertz
mS	Millisecond
NW	Network
PCB	Printed Circuit Board
PV	Photo Voltaic
PWM	Pulse Width Modulation
RCC	Reinforced Cement Concrete
RD	Ready
RF	Radio Frequency
RPSMA	Reverse Polarity Sub Miniature version A (Antenna Connector)
RX	Receiver
SEE	Sustainable Eco Engineering
SIM	Subscriber Identification Module
SREX	Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation
TWLMS	Telemetry Based Water Level Monitoring System
TX	Transmitter
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNISDR	United Nations International Strategy for Disaster Reduction
URL	Uniform Resource Locator
V	Volt
WWLMS	Wireless Water Level Monitoring System

1 Introduction

1 Background

The Hindu Kush Himalayas (HKH) make up one of the most dynamic and complex mountain systems in the world. The region is known to be extremely fragile and prone to natural hazards, which are exacerbated by climate change. It is believed that climate change and other drivers of change have been gradually increasing the frequency and magnitude of extreme weather events and natural hazards in the region. Floods and flash floods are the major climate-induced hazards that threaten the lives and livelihoods of the downstream communities, particularly in the monsoon season. Such floods can be disastrous when it comes to small rivers and tributaries because they get less attention from the government and other agencies concerned. Early warnings are developed at the global, regional or national level to provide flood information. However, according to the Hyogo Protocol and the UNFCCC's Special Report on Extreme Events and Disasters (SREX 2012), the main gap arises from the fact that the information does not reach the most vulnerable communities.

1.1 What is Community Based Flood Early Warning System (CBFEWS)?

The United Nations Environment Programme (UNEP) defines "early warning" as: "The provision of timely and effective information, through identified institutions, that allows individuals exposed to hazard to take action to avoid or reduce their risk and prepare for effective response" (2012). While the United Nations International Strategy for Disaster Reduction (UNISDR) defines "early warning" as: "The set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by hazards to take necessary preparedness measures and act appropriately in sufficient time to reduce possibility of harms or losses" (2009).

The Community Based Flood Early Warning System (CBFEWS) is an integrated system of tools and plans managed by and for communities, and it provides almost real-time early warnings on floods to reduce risks. The CBFEWS is based on people-centred, timely, simple and low-cost technology so as to allow sustainable operation by the vulnerable communities. It disseminates information to the vulnerable communities downstream through a network of key stakeholders that can include communities, government bodies, social mobilizers, volunteers, and NGOs. A properly designed and implemented system can save lives and reduce property loss by increasing the lead time to prepare and respond to floods.

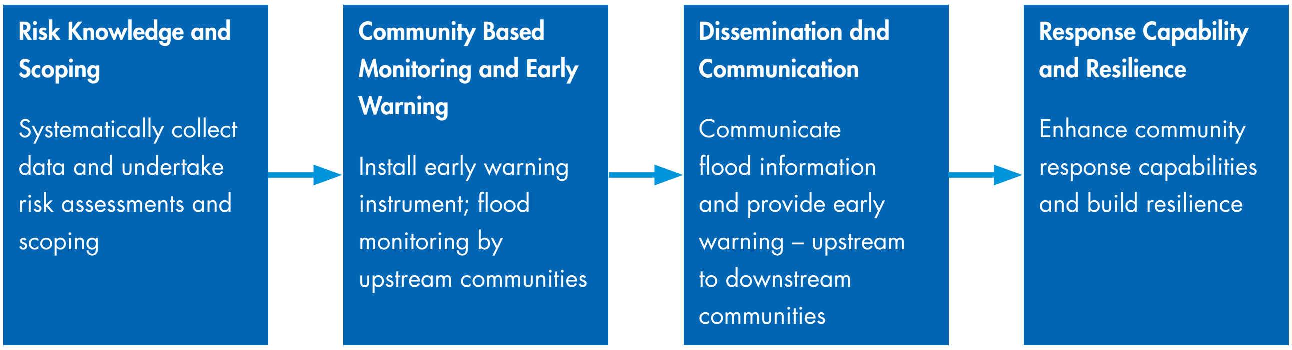
1.2 Key Elements of CBFEWS

The UNISDR Platform for the Promotion of Early Warning has identified four interrelated elements for a complete and effective early warning system. Based on UNISDR's four key elements, the CBFEWS has also defined four key elements for its implementation (Fig. 1). An isolated approach cannot make the CBFEWS successful; it is important to understand that these four elements are interrelated and that failure in one element can result in the failure of the entire system.

Features of CBFEWS

- **People-centred:** All members of the vulnerable groups and district government line agencies are involved in planning, implementing, monitoring and disseminating early warning information on floods, and take the ownership of the system.
  An effective CBFEWS must recognize the differences in vulnerabilities that exist among different sections of societies and also the dynamic nature of such vulnerabilities. The risks due to hazards are not uniformly distributed and thus an effective early warning system needs to be founded on appropriate risk assessment methodologies (UNDP).
- **Low-cost technology:** Any technology employed to support the CBFEWS must be affordable to the communities in order to ensure its sustainability in case replacements or upgrades are needed. Necessary training is also imparted to help build the capacity for caring for the instrument at the local level. The initial cost of the complete

Figure 1: **Four Elements of CBFEWS**



Source: Based on UNISDR, (2006), http://www.unisdr.org/2006/ppew/whats-ew/basics-ew.htm

set of the wireless flood early warning instrument was approximately USD 1,000 (in May 2015). The cost of the telemetry-based instrument is about USD 3,800 (as of April 2018).

- **Near real-time information:** The instrument is installed upstream of the beneficiary community and reads and transmits water-level information in 5-minute intervals. The caretaker is responsible for verifying the transmitted information, interpreting it to ascertain whether it's an early warning information, and communicating with the downstream communities as the water level in the river crosses predefined threshold levels.
- **Multiple modes of disseminating early warning:** The warning may arrive in the vulnerable downstream communities in the form of voice call, text or internet group message from the caretaker upstream or as a loud siren from the triggered alarm unit(s). Key personnel will also receive email messages when preset danger thresholds are crossed by the monitored river.

Points to Remember

The success of the CBFEWS depends on how well the communities understand the risks, receive risk communication and prepare to respond to floods.

- **Lead time:** The time between the warning and the actual arrival of the flood needs to be sufficient for preparedness.
- **Shelter zones and rescue routes:** Safe places and rescue routes must be identified in consultation with the local communities well ahead of any flood event.
- **Condition of equipment:** The equipment needs to be tested, updated and kept in fully operational and reliable condition.
- **Willingness of the communities:** The community members need to be willing to act upon the early warning signals and should be made aware of the procedures involved, for which social mobilization serves a crucial role.

1.3 Regional Hands-on Training on CBFEWS

ICIMOD has developed hands-on training on the CBFEWS with the objective to provide comprehensive technical and theoretical knowledge about the concept of community-based flood risk management (Fig 2). A five-day course has been designed to enhance the capacity of the participants and familiarize them with the CBFEWS process and instrument. The course is designed in the "Learning by Doing" mode so that each of the participants gets an opportunity to practise using and installing the instruments. The training module includes lectures, group work, practical sessions, and fieldwork (site selection, installation of the equipment, etc.). A visual guide is provided to the participants as a reference material to install the system in future. Those who take part in the training include communities and organizations that are implementing the CBFEWS (with technical support from ICIMOD), especially local government officials (technicians), NGO partners, caretakers, and other relevant stakeholders. All the participants should have basic knowledge of handling electrical and electronic goods and of using the internet. The training will be provided mainly in English but modified to other languages as needed.

ICIMOD has successfully completed three such training programmes – in 2015, 2017 and 2018 – for participants from Afghanistan, India, Nepal and Pakistan who were representing communities, local partners and government authorities.

Figure 2: **Regional Hands-on Training**

1.4 Success Stories

1.4.1 Impact on the Ground and beyond the Border

In 2017, the telemetry-based CBFEWS was piloted along the Ratu River. The Ratu River is a transboundary river between Nepal and India. Telemetry Based Water Level Monitoring System (TWLMS) units were strategically installed in Lalgadh and Bardibas in Mahottari district in Nepal and Bhitthamore in Sitamari district in the Indian state of Bihar.

During the monsoon of August 2017, the Ratu River was heavily flooded. The communication channel was engaged by the caretaker in Lalgadh and early warning information was disseminated to the downstream communities in Sarpallo and across the border in Bhitthamore, India; evacuation measures were initiated in the communities. People secured their livestock, valuables and important documents, and were evacuated to the shelter zones. Across the border in Bhitthamore, the early warning message had reached four hours before the actual flood gushed through.

Figure 3: **Caretakers from Nepal and India**

The events of the flood in 2017 was a major milestone for CBFEWS as it brought together people of two neighbouring nations and enabled a transboundary motion of resilience to flood. Caretakers and communities that were once strangers had come together in their shared state of vulnerability to floods.

1.4.2 Rural Women Find Relief with Flood Early Warning System

As a flood-prone area, Sarpallo village has faced summer floods for decades. The villagers' experience in dealing with floods has made them indigenous experts in disaster preparedness. Notably, these efforts are typically spearheaded by young and adult women. This reliance on women in times of disaster has become even more pronounced in the past two decades due to the heavy outmigration of men seeking work abroad. "For a long time, women have stopped depending on men for many things and this is the same with disaster management," says 30-year-old Rinku Singh, a farmer who is also one of the few educated women in Sarpallo village.

Figure 4: **Women of Sarpallo**

A heavy flood hit Sarpallo in July 2016, but the installed early warning system enabled all the villagers to relocate to higher ground with their children, the elderly, livestock, and important documents. The success of the flood information system in Sarpallo has made quite an impact on some local communities in the Koshi basin. For many women like Singh, the system has been a source of relief that helps them to get the right information at the right time.

1.4.3 Early Warning Early Morning

A CBFEWS was established in Sher Qilla village for the Gilgit River in June 2017. On 3 August 2017, at 4:30, the CBFEWS generated a siren that woke up 2,800 people in the 350 households of Sher Qilla. Within an hour, the community had moved about 2,000 livestock and precious belongings to safety before the flood entered the village.

Following the event, Fida Ali, a businessman and Area Volunteer Captain of the Community Emergency Rescue Team said, "The CBFEWS is a miracle for our community. Before it was put in place, we would spend entire nights at the point of origin of the flash floods for situation updates in order to alert others. Now, we can all sleep in peace."

Figure 5: **Community Gathering in Pakistan**

1.4.4 Impact on the Ground

On 5 September 2013, the District Disaster Management Authority (DDMA) in Dhemaji in Assam, India, deployed a national disaster response force in the affected downstream areas of the Jiadhal River upon receiving early warning of a flood. There in Dihiri village, communities were able to save assets worth about USD 3,300 during the flood event. ICIMOD had provided seed money for the locally manufactured CBFEWS instrument. The project's impact on the field was acknowledged by the UNFCCC when it presented ICIMOD and SEE with the Momentum for Change 2014 Lighthouse Activity Award in the Information and Communications Technology (ICT) category.

Figure 6: **A Household in Assam**

2. Risk Knowledge and Scoping

A detailed risk assessment is conducted through systematic data collection and analysis of hazards, vulnerabilities, and existing capacity. This helps us understand the situation, motivate people and prioritize needs for developing early warning systems in order to guide disaster prevention preparations and response measures.

Objectives

1. Identify risk zones
2. Identify vulnerable communities
3. Identify safe shelter zone and rescue routes

$$\text{Risk} = \frac{\text{Hazard x Vulnerability}}{\text{Coping Capacity}}$$

Source: UNISDR 2002:41, as cited in USAID, 2011

2.1 Concept of Risk Knowledge

Flood, which is a natural hazard, need not become a disaster if communities can reduce the loss of life and minimize human suffering by being prepared to respond and by being aware of how to deal with it. For this, we need to understand the nature, frequency, severity and lead time of the flood.

2.1.1 Nature of Flood Hazard

There are two types of flood hazards:

Table 1: **Nature of Flood Hazard**

Flash Flood	Riverine Flood
• Caused by sudden flooding in small river basins for a short duration with a relatively high peak discharge • Occurs within six hours or less after a heavy rainfall event • Occurs in normally dry areas with no visible stream channel • Occurs normally as a result of the run-off from a torrential downpour • Occurs from the failure of landslide dam lakes, GLOF, or sudden collapse of ice jams or due to other river obstructions	• Caused by heavy rain over long periods (days) in the upper catchment areas, leading to rising water levels • Rainfall over large catchment areas • Melting of the winter snow accumulation • Takes place in river systems with tributaries that may drain large geographic areas and encompass many independent river basins • Normally has a slow build-up • Often seasonal • May continue for days or weeks

Source: Katyal, A.K. & Petrisor, I.G. (2011); DWIDP (2009)

2.1.2 Frequency and Severity of Hazard

The severity of flood hazard is determined in terms of casualties and heavy loss of lives and properties. It depends on the following criteria (Table 2).

2.1.3 Lead Time

Lead time in flood forecasting refers to the amount of time a flood takes to reach a particular downstream community from the flood measurement station upstream. The basic principle for assessing lead time is that advance warning should be issued which gives enough time for effective preparatory action. This depends on the need of the target community and area (point of interest), the type of catchment structure, catchment size, catchment response to a given rainfall and the catchment lag time (time taken by the run-off from the furthest corner of the catchment to the point of interest, which translates into longer lag times for larger catchments).

Table 2: **Indicators of Flood Severity**

Location and spatial dimension of flood	An overview of the potential flooded areas can be obtained using maps (topographic maps of the area, maps held by the local authorities or maps produced by or with the assistance of the community at risk). The official maps will complement the maps produced by the community.
Depth of the flood	It can be measured using various sources, such as interviews with local people about their experiences, historical information on the intensity and magnitude of floods, and information on the extent and depth of previous flood events, flood predictions, and flood marks.
Duration of the flood	It is the rate at which the flooding is likely to occur (i.e., rapid onset or slow rise of flood water) and how long the flood event lasts (a few minutes, a few hours, one day, two days, etc.). The number of casualties and extent of the damage depend on the duration of the flood.
Velocity of the flood	It is the speed of the flow of water. Floating debris and materials are indicators of strong currents. Here, information has to be gathered from the local communities about their past experiences with the nature of the flood current. Strong currents might be dangerous and people should not live in houses close to such currents because the houses might collapse due to high-velocity flood.

Adapted from: DWIDP (2009)

2.2 Concept of Risk Assessment

Assessment is a process that involves all the relevant parties in the collection and analysis of information about flood risk and special measures for addressing them. Different participatory mapping tools can be used as per the need of the community and the objectives of the assessment. In all the assessments, communities should be perceived as heterogeneous groups composed of women, men and even third gender belonging to different social classes. Their hazards, vulnerabilities and capacities are shaped not only by their physical location and access to resources, but also by social norms, values, and power relations. These gender and social analysis become an integral part of risk, vulnerability and capacity assessment.

Table 3: **Tools for Mapping of Resources**

Assessment	Tools
Hazard assessment	• Social mapping (house, road, temples, etc.) • Hazard mapping (natural hazard areas, safe areas, etc.) • Resource mapping (schools, health centres, religious facilities, open field, market, forest, safe areas, etc.) • Field survey (interviews, focus group discussions, direct observations) • High-resolution satellite image and field verification (location of bank failure, existing measures, sites of sand mining and its surroundings, former and new channel courses, riverbank encroachment, etc.)
Vulnerability assessment	• Participatory situation analysis is conducted based on hazard assessment, location of the vulnerable community, identification of the most vulnerable groups (people with disability, children, women, the elderly), and mapping of routes and accessibility to evacuation shelter, infrastructure, land use, population at risk, etc. • Ranking is done for each parameter to determine the maximum and minimum vulnerability.
Capacity assessment	• Seasonal calendar (duration and timing of hazards and vulnerability; community members' work schedule, etc.) • Venn diagrams (organizations, their roles and relationship with the community)

2.3 Selection of Community

Selecting a community is the first step in establishing an early warning system. The selection depends on various factors such as the community's vulnerability and interest, cost benefit, the effectiveness and need of the system, etc. In addition, one of the most important criteria for the CBFEWS is the existence of an upstream community to install the instrument, take care of it and disseminate flood information downstream. Refer to '3.4 Criteria for Site Selection to install CBFEWS' for site selection criteria for installation.

After selecting the community and installation site, the next step is to build a rapport with the communities and the stakeholders concerned. It is necessary to build trust and friendship with the local communities so that they can share their issues, problems, and concerns. Rapport building also helps us understand the local context such as the local culture, norms and values, power relations and people's perceptions, which are absolutely essential for the establishment of a successful CBFEWS. Being friendly, transparent, motivated and patient while interacting with the local people is crucial for gaining their trust. The concept, its scope, process, limitations, and roles and responsibilities need to be discussed through community consultations and disseminated through awareness-raising tools such as posters, flyers, and information sheets.

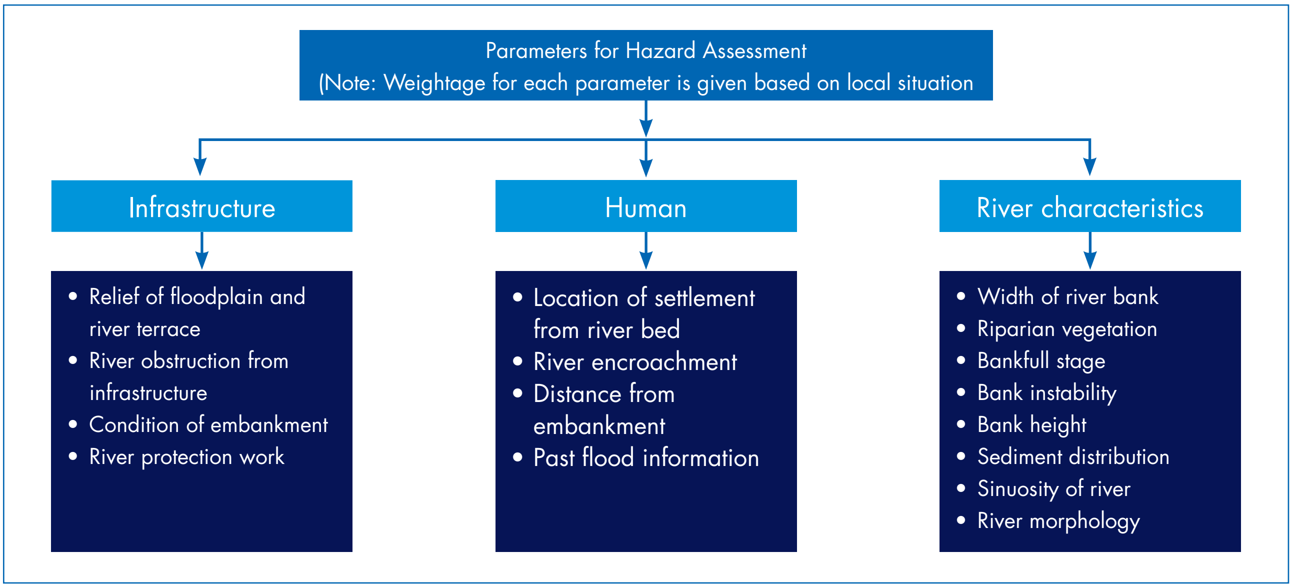
2.4 Field-Based Assessment

The field-based assessment includes the following steps:

2.4.1 Hazard Assessment

Data is collected based on the following major parameters (Fig. 7).

Figure 7: **Parameters for Hazard Assessment**



Ranking: Certain causative factors of flood hazard in each studied river corridor are determined for rating to obtain the hazard level, and their significance will be assessed by weighing their values (DNPWC 2009). Maximum and minimum total weights of the causable factors are calculated based on the priority of the local community. The weight of each hazard level is established considering hazard intensity and probability (Fig. 8).

2.4.2 Vulnerability Assessment

Vulnerability is defined as the degree of damage that may be caused to a given element at risk, or a set of such elements resulting from the occurrence of a natural phenomenon of a given magnitude. It is a function of the magnitude of the event and the type of elements at risk that have or may have certain degree of damage (Fig. 9).

Figure 8: **Hazard Ranking**

Hazard intensity				
Hazard intensity	Danger to population close to the stream	Dange to population in settlement (about 500 m from the stream)	Danger to population 1 km away from the stream	Danger to population more than 1 km away from the stream
High	Yes	Yes	Yes	Yes
Moderate	Yes	Yes	Yes	No
Moderately low	Yes	Yes	No	No
Low	Yes	Yes	No	No

+

Hazard probability	
High	at least once in 10 years
Moderate	once in 10 to 30 years
Moderately low	once in 30 to 100 years
Low	Less frequent than once in 100 years

=

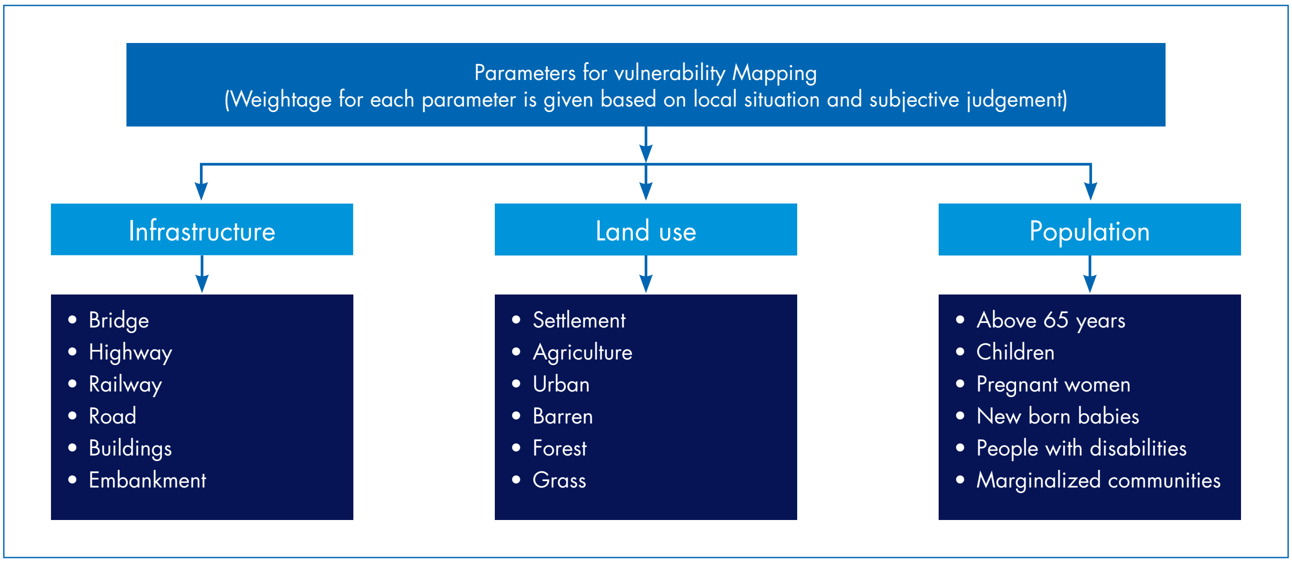
Hazard ranking

	Probability				
Hazard intensity	High	Moderate	Moderately low	Low	
High	High	High	Moderate	Moderately low	
Moderate	High	Moderate	Moderate	Low	
Moderately low	Moderate	Moderate	Moderately low	Low	
Low	Moderately low	Moderately low	Low	Low	

Hazard level
High
Moderate
Moderately low
Low

Source: Shrestha (2008)

Figure 9: **Parameters for Vulnerability Mapping**



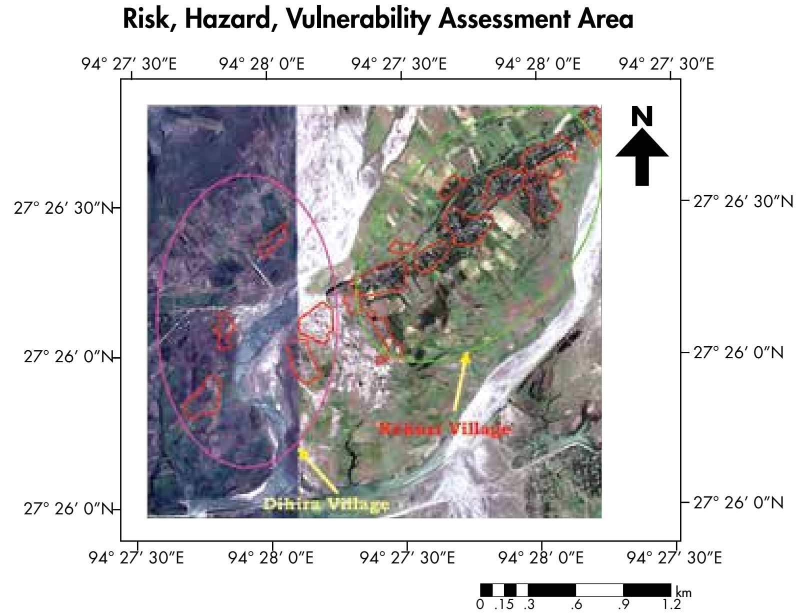
Ranking: Data on various aspects of vulnerability should be acquired during the field survey to rank them according to importance (DWIDP 2009) and subsequently a vulnerability map should be prepared that takes into account the following factors (Fig. 10):

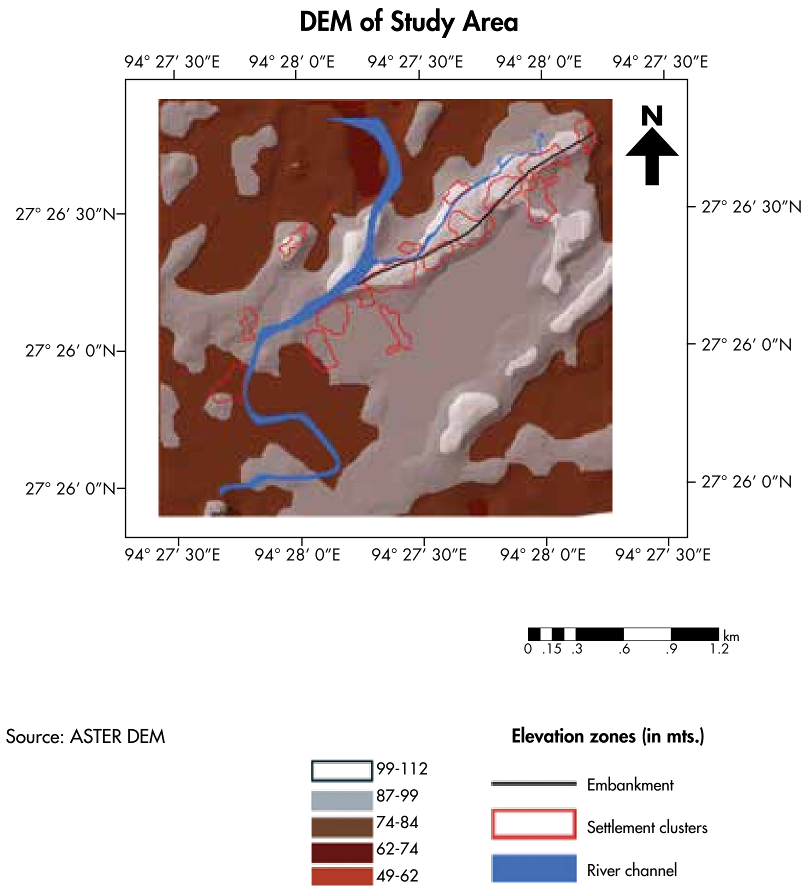
- Degree of probability of flooding in the flood hazard zone
- Infrastructure vulnerable to flood hazard
- Land use vulnerability in the flood hazard zone
- Population vulnerable to flood hazard

Figure 10: **Example of a Field-Based Vulnerability Map – Dihiri and Kekuri Villages, Assam, India**

Vulnerability score	
1. Less distance from embankment	1
2. High distance from embankment	2
3. High altitude	1
4. Low altitude	2
5. High distance from river	1
6. Less distance from river	2

Highly vulnerable	
High distance from embankment	2
Low altitude	2
Less distance from river	2
Moderately vulnerable	
High distance from embankment	2
High altitude	1
Less distance from river	2
Less vulnerable	
Less distance from embankment	1
High altitude	1
Less distance from river	1



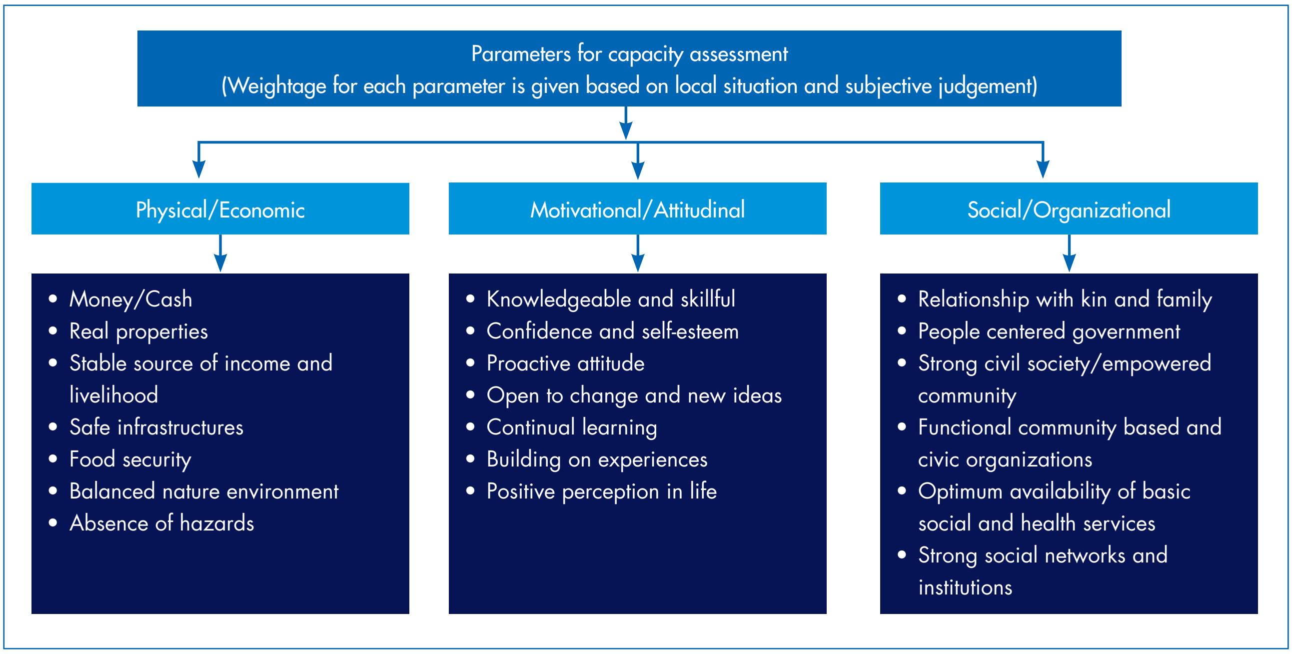


Source: Shrestha, A.B.; Bajracharya, S.R. (eds.) (2013) Case studies on flash flood risk management in the Himalayas: In support of specific flash flood policies. Kathmandu: ICIMOD

2.4.3 Capacity Assessment

Capacity is defined as the combination of all strengths, attributes and resources available within a community, society or organization that can be used to achieve agreed-upon goals. This capacity may include infrastructure and physical means, institutions, society's coping abilities, as well as human knowledge, skills, and collective attributes such as social relationships, leadership, and management (Fig. 11).

Figure 11: **Parameters for Capacity Assessment**



Ranking: Capacity ranking could take the following aspects into consideration (UNDP Capacity Assessment Users' Guide 2008).

- No evidence of relevant capacity
- Anecdotal evidence of capacity
- Partially developed capacity
- Widespread, but not comprehensive, evidence of capacity
- Fully developed capacity

2.4.4 Risk Assessment and Mapping

Risk assessment is a methodology for determining the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability which could potentially harm the exposed people, property, services, livelihoods and the environment on which they depend. Exposure and vulnerability are the key determinants of disaster risk and of impacts when risk is realized (SREX 2012). Communities and individuals are differently exposed and vulnerable based on the unequal levels of wealth, education, ability (disability), health status, gender, age, class, and other social and cultural parameters. For field-based risk assessment, field-based flood vulnerability data, field-based flood hazard data and field-based capacity assessment data are analysed and then risk zones are defined on a risk map.

3. Community Based Monitoring and Early Warning

Note: The CBFEWS instrument discussed in this manual is conceptualized by experts from ICIMOD and manufactured by Sustainable Eco Engineering (SEE) with technical support from ICIMOD. ICIMOD provides technical training to partners and interested stakeholders in this regard. It is requested that any use of this equipment is credited to ICIMOD

Objectives

1. Introduction of instrument
2. Understand its function
3. Community based flood forecasting and early warning

The CBFEWS involves the monitoring of the river water level through different methodologies so as to generate early warning when the water level rises beyond a certain threshold. The flood-monitoring device developed by ICIMOD for the CBFEWS uses a cost-effective and user-friendly technology. The instrument has evolved and adapted over time to generate effective warnings utilizing the latest developments in ICT to deliver early warning to communities.

The latest overhaul in the Telemetry Based Water Level Monitoring System (TWLMS) is one that provides near real-time water-level information through wireless and cellular technology. The system consists of three units: the Data Acquisition Unit (DA Unit), the Data Upload Unit (DU Unit) and the Alarm Unit (AU). The DA Unit is installed at the riverbank. It monitors the water level of the river through its contactless, ultrasonic-based technology and transmits the measurements wirelessly to the DU Unit at predetermined intervals (currently set at 5 minutes). The DU Unit – that can be placed as far as 3 km at a designated caretaker's house with line of sight between antennas – processes the measurements to generate localized messages and warnings and then uploads the measurements to a remote server through a cellular data connection. After processing the measurements, the server displays the data in a time-series chart. It also sends out warning messages when predetermined thresholds are reached or breached, through different media such as emails and SMS for widespread dissemination. Multiple AUs may be placed at vulnerable downstream settlements. An AU is triggered by a precisely worded SMS message. Upon receiving the message, the AU sounds a loud siren, thus facilitating the dissemination of early warning where it is required the most. The SMS message itself may be sent by the designated caretaker after assaying the situation or through servers of the cellular network service providers.

3.1 Why a Telemetry Based CBFEWS?

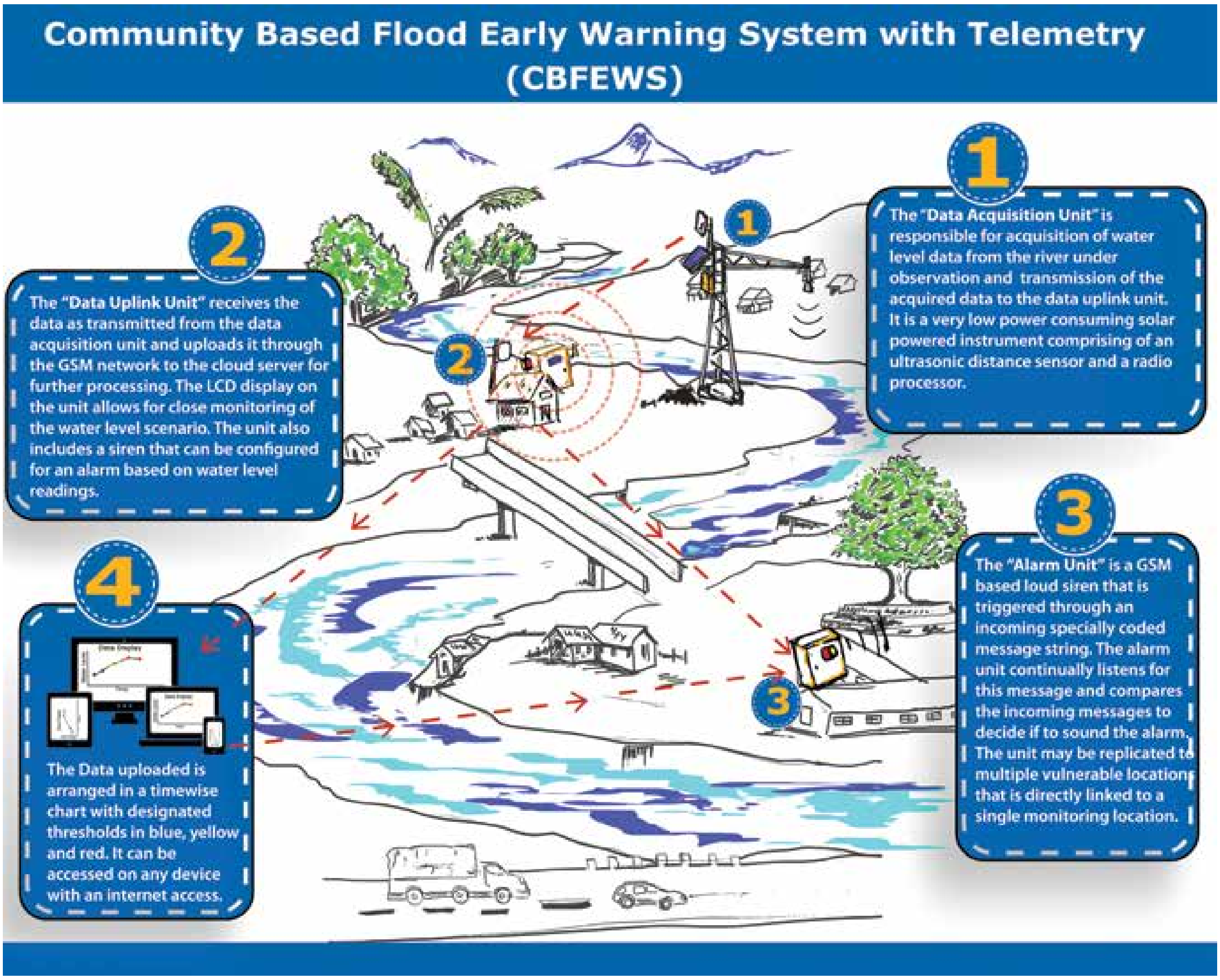
The CBFEWS instrument used and developed by ICIMOD has evolved progressively in the past few years. It started out as a simple open-wire based system that relied on the electrical conductivity of water to connect the open terminals, to the contactless sensor-based instrument that can deliver water measurements accurate to the centimetre to users across the globe.

In comparison to the predecessor of the telemetry-based instrument, which was the Wireless Water Level Monitoring System (WWLMS v3), the current version 4 particularly addresses a few fundamental requisites presented in the 3rd iteration's deployments. The previous version, though effective, was highly localized and had a number of constraints in terms of wider dissemination. The extension of the wireless range between the transmission and reception units to 3 km allows the receiver to be safely located at a caretaker's station within a strong network coverage in order to facilitate the timely uploading of the water level data to the internet through the General Packet Radio System (GPRS)[1] connection in a Global System for Mobile Communications (GSM)[2] network. This system configuration enables a wider outreach through the internet and faster dissemination. The availability of GSM-based

[1] The GPRS is a technology for the support of packet-switching traffic in a GSM network. It enables high-speed wireless internet and other data communications in the GSM. Anker, P. (2005). GPRS. Retrieved from http://www.telecomabc.com/g/gprs.html

[2] The GSM is a wireless telecommunications standard for digital cellular services. Anker, P. (2005). GSM. Retrieved from http://www.telecomabc.com/g/gsm.html

Figure 12: **CBFEWS with the Telemetry Concept**



AUs further facilitates effective dissemination of early-warning information to entire communities far downstream through a single SMS message, thus generating greater lead times for the vulnerable communities. The wide reach of telemetry has also proved effective in facilitating the establishment of a cross-border CBFEWS that brings together communities across international borders.

The telemetry-based system also provides an indication of the water level in addition to an explanation of the river stage (normal, alert and danger levels). The contactless sensor provides timely water-level measurements that can trigger alarms when pre-set danger thresholds are crossed in contrast to the simple, yet effective, contact immersion sensor of the previous version which triggered at a certain water level only. The contactless sensor is an ultrasonic-based weatherproof device with high accuracy. Its contactless nature also helps address the issue of debris flow and sediment accumulation which was present in immersion-type sensors.

The provision of telemetry has thus proved very effective in the implementation of the CBFEWS, and in helping it reach and safeguard a wider audience. The instrument will only evolve and progress in the future, with innovations and efforts focused on better adaptation and resilience to floods and climate change.

3.2 Introduction of Equipment

This section introduces the flood-monitoring instrument for the telemetry based CBFEWS developed by ICIMOD and provides the details of the instrument hardware and the mode of web-based user interface for viewing the data it generates; it also spells out the technical specifications of the instrument. The specific instructions for the installation and maintenance of the instrument are provided in Part II.

3.2.1 Introduction of Telemetric Water Level Monitoring System, Version 4 (TWLMS)

The TWLMS, developed by ICIMOD, is fundamentally an ultrasonic based water level monitoring system, specifically engineered for the wide dissemination of water-level data via telemetry. The system adheres to the CBFEWS implementation procedure of ICIMOD and thus ultimately is owned and cared for by flood-vulnerable communities. The data is primarily used as a forewarning for floods so as to help mitigate flood risks in vulnerable communities, and is also available to a wider audience for study, analysis or viewing. It makes use of an ultrasonic sensor for depth measurement, the Zigbee[3] protocol for data transfer within the local instrument network, and GSM module for uploading data on to the cloud and for triggering alarms via SMS. Further, the data is processed by the server-deployed web application and necessary electronic messages are generated to trigger alarm units, enable display units, and support an existing communication chain.

The CBFEWS implementation process also includes a training component for the operation and maintenance of the instrument so that the community is able to gain full ownership of the instrument and the technology used within it.

Figure 13: **Ultrasonic Sensor**

3.2.2 Different Parts of the Equipment

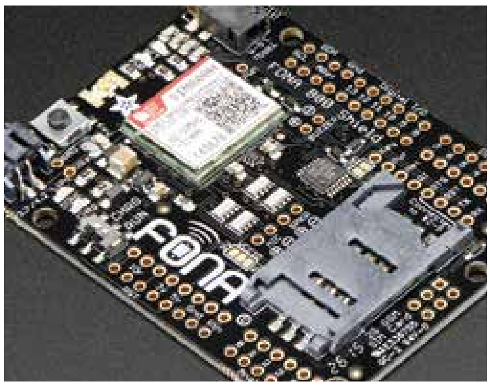
3.2.2.1 Hardware Components

1. Ultrasonic Sensor. The ultrasonic sensor is the key component in measuring the water level. The ultrasonic sensor actually measures the distance between itself and the surface of the water. The distance measured is reduced from the actual height of the sensor from the riverbed to obtain the water level. The sensor uses ultrasonic sound frequency of 42 kHz in order to calculate the distance to an object from its emitter. Its operation is based on the principle of time-of-flight in which it measures the time the emitted sound is reflected back from an object in the path of the flight of the sound. The sensor has auto-calibration features for the temperature and humidity that might affect the velocity of the sound. Further, it features advanced filtering which allows for it to discard smaller objects and measure the distance between itself and the object of the largest size in front of it. This increases its outdoor reliability and efficiency. The sensor is capable of a range of up to 7 m.

2. Radio. Radios are used to transmit data between the DA Unit and DU Unit. The radio in use is the Ember 2.4G. It operates at 2.4G-Hz frequency and uses direct sequence spread spectrum modulation for transmission and high-noise immunity. The radio's features also include packet-buffering, auto-retransmission, and channel verification for preventing data loss.

3. Processor. The entire system features 2 processors – one in the DA Unit and the other in the DU Unit. Each of the processors is responsible for interpreting the data and moving it along to its destination; they are also in charge of the intricate timing and control of events that are required to fulfil the systems' functionality.

Figure 14: **GPRS Module**



4. GPRS interface. The data is uploaded on to the cloud via the GSM module. The module is fitted with a SIM card from a registered network service provider and hence is able to access the internet through the GPRS service provided on the SIM card. The system needs to transmit only a few bytes worth of data each time, and taking into account the additional bytes used in the GPRS data packets, it uses about 1 MB of data per day.

[3] Zigbee is a standard for a radio communication link between equipment over rather short distances to replace a cable, and is especially designed for low power consumption and low cost of infrastructure. Anker, P. (2005). Zigbee. Retrieved from http://www.telecomabc.com/z/zigbee.html

5. LCD display with I2C interface. A 16X2-character LCD screen with 2 rows of 16 characters located at the caretaker's end on the receiver is responsible for displaying the water level to the caretaker and for verifying that the instrument is working as designated. It is tied up to a serial data converter which allows for the parallel input on the LCD to be fed with only 4 input lines. A blue screw adapter at the back of the converter may be used for adjusting brightness.

Figure 15: **Liquid Crystal Display (LCD)**

6. Power Supply. As the system is intended for remote deployment, the power supply becomes a critical part of the design. The system employs DC power supply through lead-acid batteries and recharges the batteries through solar. Power losses have also been considered in the system design so as to maximize the power efficiency of the system. Altogether, the system is able to last up to 5 days without recharging of the batteries. The DA Unit in particular can run up to 11 days on a single charge.

Figure 16: **Lead Acid Battery**

a. Lead Acid Battery: A lead-acid battery is an easily available, solar rechargeable battery constructed with lead cathode and a lead oxide unit within an acid electrolyte. Simple charging procedures, high energy density and easy compatibility with most solar chargers make the chemistry of this battery attractive for solar-powered embedded systems. Despite the low energy to weight and volume ratio, the simple charging procedures, durability and reliability make it a stable option for systems.

b. Solar Panels: Both DA and DU units make use of 18V–20W solar panels. Solar panels convert sunlight into an electric potential difference across their terminals via which current may be drawn. They feed the Pulse Width Modulation (PWM) chargers on the DA Unit and DU Unit.

Figure 17: **Solar Panel**

c. PWM Solar Charge Controller for Lead Acid battery: The PWM charge controller is a widely available solar charger that utilizes pulses of voltage to regulate the charge flowing into the battery and the load. PWM, as stated above, stands for "pulse-width modulation", and accordingly generates pulses of varied time durations to regulate power. It is a simple means of regulating the voltage for a battery to be charged so that only the necessary portion of the energy generated from the solar panels is passed into the battery.

Figure 18: **Solar Charge Controller**

7. *Patch Antenna:* The patch antenna is a passive component responsible for radiating modulated signals into the medium which here is air. The antenna pair is designed to resonate with electrical signals at 2.4 GHz frequency. The antenna used is a 14dBi[4] patch antenna which implies a very high gain in the direction of the antenna. The patch itself is a radiating pattern etched on a copper plate that is designed to increase the directivity and range of the antenna.

Figure 19: **Patch Antenna**

8. *Support Structures for Data acquisition unit:* This comprises the mechanical frame and structure for the installation of the instrument in the field. The structure is a particular example and may vary based on the structural requirements to support the instrument at the site of installation. For the DA Unit, the sensor is housed in a cylindrical iron chamber with outlets for cables and ranging mic. The chamber is mounted at the end of a stainless-steel arm extending from the main frame structure anchored upon a concrete foundation on the riverbank. The main structure, including the extended arm, consists of stainless steel tubing and bars. The structure also houses a waterproof box which houses the DA Unit circuitry. The solar panel for recharging the battery, and the antenna for data transmission are also mounted on to the structure.

*Please refer to structure setup examples for a more detailed illustration.

Figure 20: **Siren**

9. *Siren:* The siren is an audio output device which produces a loud sound when triggered. The siren has a peak loudness of about 120dB[5] which ensures that it can be heard from faraway distances while immediately alerting anyone close by without fail. It is a major component of the alarm system and proves vital to alert the necessary personnel to take immediate action.

3.2.2.2 User Interface

In order to fully accomplish the telemetric portion of the CBFEWS, the system is integrated with a data server hosted at ICIMOD. The data from the server can be conveniently viewed as a chart through a web portal. The chart is a time-wise water-level chart that is updated every 5 minutes. It indicates water level as a series of connected points. The water level points may be BLUE, YELLOW or RED. The BLUE point indicates a normal level and no threat, the YELLOW indicates a risen water level and the necessity to be alert and ready, while the RED point indicates a dangerous water level and the necessity to take action to safeguard from a flood.

It is important to note that the scale for water level adapts itself in accordance with the scale or total variation in the water level which is displayed on the screen at a given time.

The chart also allows for the selection of the appropriate date and the required station in a simple-to-use manner which allows the user to easily access and view the water level data of a specific river-monitoring station on the required date.

On the top-right portion of the web portal, the user can see a bar with the current date. Clicking on the bar opens up a calendar that allows for easy date selection. The user may also type in the date in the format as displayed to manually enter the required date.

[4] The term "dBi", or "decibels relative to isotropic radiator", is used to define the gain of an antenna system relative to an isotropic radiator at radio frequencies. Rouse, M. (March 2011). Decibels Relative to Isotropic Radiator (dBi). Retrieved from https://whatis.techtarget.com/definition/decibels-relative-to-isotropic-radiator-dBi

[5] dB, or decibel, is the unit used to measure the intensity of sound. HowStuffWorks.com (1 April 2000). What is a decibel, and how is it measured? Retrieved from https://science.howstuffworks.com/question124.htm#

Next to the date bar is a drop-down selection menu for the Station ID. The station ID denotes the ID of the stations that are transmitting data to the data server. The user can select the desired station to be viewed.

After this selection, the user must click the "submit" button beside the station ID drop-down menu in order to view the water level chart of the selected station on the selected date.

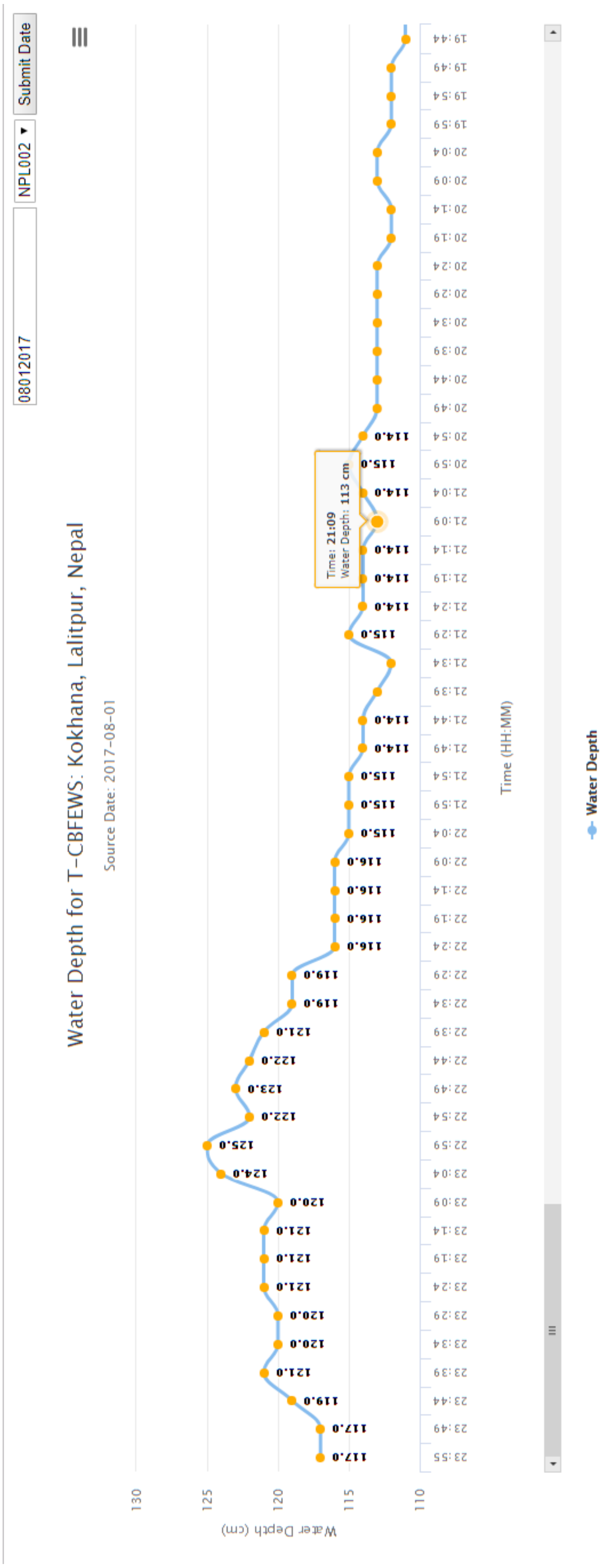


Figure 21: **Web Page Display**

3.2.2.3 Specifications

Table 4: **Specifications of CBFEWS Instruments with Telemetry**

ATTRIBUTE	DATA ACQUISITION UNIT	DATA UPLOAD UNIT	ALARM UNIT
Battery	7Ah lead acid	7Ah lead acid	7Ah lead acid
Charge Controller	PWM based	PWM based	PWM based
Solar Panel	20W 18V	20W 18V	20W 18V
System Voltage	3.3V	5V	5V
Current Draw	27mA steady, 32mA peak	83mA steady, 1A peak	38mA steady, 108mA peak
Current Draw With Siren Active	–	323mA steady average	275mA steady average
Sleep Duration Per Sample	300 sec	–	–
Frequency Used	2.4GHz radio	2.4GHz radio, 900MHz GSM	900MHz GSM
Frequency Sensitivity	-101dBm[6]	-101dBm radio, -120dBm GSM	-120dBm
Antenna Used	2.4G patch	2.4G patch, 900M helical	900M helical
Antenna Connector	RPSMA[7]	RPSMA/SMA	SMA
Other Connectors	Screw jack	Screw jack	Screw jack
Level Sensor Type	Ultrasonic	–	–
RF LOS Range For Radio	3km in clear line of sight	3km in clear line of sight	–
Display	–	LCD display	–

3.3 How Does it Work?

The DA Unit is placed at the riverbank (overlooking a point where water level reaches during flood) and the DU Unit is placed in a house of the nearest village. The house owner (known as caretaker) will take care of the unit and disseminate information received from the instrument to the downstream communities through mobile phone/SMS. The caretaker can optionally generate alarm in the downstream communities by sending a precise SMS message to the Alarm Unit.

Process Summary:

1. Initially, the DU Unit is assembled and kept ready. It diligently waits for the DA Unit to connect to it.
2. The DA Unit is then initiated after the sensor has been properly calibrated to the correct height and position.
3. The water level is measured periodically every 5 minutes and uploaded to the remote server.
4. The uploaded data points may be viewed as a time-based chart through the URL for the TWLMS.
5. If the water-level values are greater than the predetermined thresholds, then the DU Unit generates a localized alarm for the caretaker. After verification, the deployed Alarm Units may be triggered via SMS from caretaker or server.

3.4 Criteria for Site Selection to Install CBFEWS

It is important to install the instrument at a suitable site for its smooth functioning and sustainability. The selection of the site is carried out jointly with the government line agencies and local communities.
The following criteria are important for site selection:

- There must be a clear line of sight between the DA and DU units.

[6] The term "dBm", or "decibels relative to one milliwatt", is used to define the signal strength in the wires and cables at radio and audio frequencies. Rouse, M. (March 2011). Retrieved from https://whatis.techtarget.com/definition/decibels-relative-to-one-milliwatt-dBm

[7] RPSMA is a variation of the "sub-miniature version A (SMA)" connector. SMA connectors are semi-precision coaxial RF connectors that are used as a minimal connector interface for coaxial cable with a screw-type coupling mechanism. International Standard (1979). IEC 60169-15, 1979

- The distance between the transmitter and the receiver should not be more than 3000 metres (the transmission band of wireless is 2.4 GHz).
- The two antennas should be correctly aligned, and have a fairly high ground clearance.
- Both sites should receive unobstructed sunlight so that the batteries can be recharged from the solar panel.
- The DA Unit should be placed at a safe and stable location (it is advisable to find a stable riverbank in order to prevent the equipment from being swept away during floods.)
- The transmitter and the receiver should be installed on the same riverbank so that the caretaker need not cross the river for observation and maintenance of the instrument.
- The caretaker's house, where the instrument is to be placed, should have a mobile network strong and stable enough to enable data connection.
- A local resident should be selected as a caretaker to ensure regular checking and monitoring of the instrument.
- Consensus and coordination between upstream and downstream communities are of utmost importance.

3.5 Flood Monitoring

Once the instrument is installed and tested, the flood event is systematically recorded by the caretaker and the designated focal person (Table 5).

Table 5: **Example of Flood Monitoring and Recording from Ratu River**

No of events (flood)	1	2
Date of flooding	10.08.2017	
Time of flooding (from buzzing of alarm)	1.30 am	
Time of triggering of Alarm unit	8.30 am	
Name of the River	Ratu	
Location of FEWS	Sitamari, India	
Flood Level during triggering of Alarm unit	The water level displayed as 228cm.	
Performance of machine	The care taker got the signal.	
Name of Caretaker who reported	Ranjit Kumar Jha	
Name of Local Mobilizing Organization Team Member who received	Manoj Kumar Jha	
Immediate action taken	Water level verified and Alarm unit triggered for evacuation.	
Follow-up action by the Local Mobilizer Organization	The CBFEWS team was continuously updated via WhatsApp chat group.	
Remarks		

4. Information Dissemination

Disseminating and communicating risk information to the communities and authorities concerned is the integral part of the CBFEWS. When a flood signal is detected upstream, it needs to be disseminated instantly so that people can prepare and respond to it. This warning information must be clear and brief for people to understand it.

Objectives

1. Generating flood information
2. Interpretation of early warning
3. Efficient communication channel
4. Understanding the roles and responsibilities

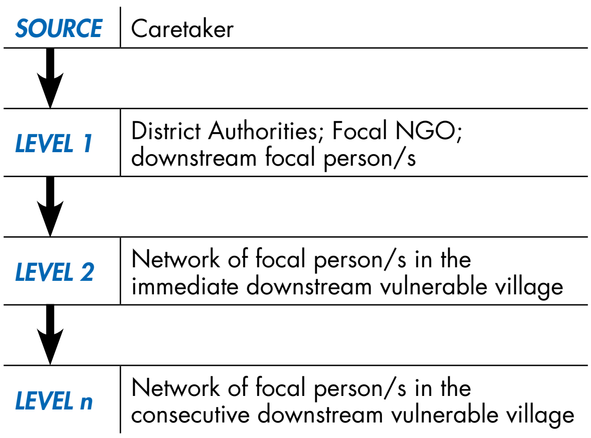
4.1 Source of Early Warning Information

Early-warning information comes from individuals or organizations that generate a risk message and send it to the relevant authorities and vulnerable people. The caretaker is the main source of information within the CBFEWS. The information generated by the instrument must be verified by the caretaker before he/she sends out the flood early-warning information. Every bit of information delivered from the source needs to be reliable, timely, and consistent. The source person needs to correctly type out the trigger message for the AUs. Furthermore, the caretaker should formulate a clear and standardized warning message so that the intended recipients can fully understand the message and act accordingly.

4.2 Recipients of Early Warning

Those who receive the warning message are the nodal persons downstream who are part of the communication network; they receive the message from different channels (for example, directly from the source or other authorities concerned) and instantly communicate it to the households. There will be various levels of recipients (Fig. 22) depending on the distance of the vulnerable settlement along the river and the urgency of delivering the information.

Figure 22: **Level of Recipients of Early Warning**



4.3 Early Warning Message

A warning message is the information sent from the source to the intended recipients in the following ways: in the form of text (e.g., through SMS); verbally or aurally (through siren, telephone, megaphone or by shouting and other means); and visually (through colour, flag or sign). When a flood occurs, the situation does not allow for lengthy conversations. Warning messages should hence be short, concise, understandable, consistent and tailored to the specific need of the intended users. Use of code language, for example, "water reached level 1" or "flood level 1" can shorten the message. But such code language must be explained to the recipients beforehand; in other words, the recipient should know what "flood level 1" means, and then how to respond to it and what precaution needs to be taken. The CBFEWS has three warning levels that can interpreted in the following manner (Table. 6).

4.4 Communication Channel

Communication channel is the network of people created for information dissemination. An efficient and reliable communication network is important for the CBFEWS. An effective communication network, particularly among upstream (caretaker) and downstream (the vulnerable people and the authorities concerned), is of utmost importance, and it should be formed in the initial stage of implementing the system. It can be formed through stakeholder consultations and meetings with local government officials and influential people in the village.

Table 6: **Levels of Warning and Their Interpretation**

UPSTREAM			**DOWNSTREAM**	
Warning Level	**Color of Data indication**	**Siren signal**	**Interpretation**	**Action**
Level 1	Yellow	No siren	High probability of flood	Stay alert and on the standby
Level 2	Orange	Beeping sound	Flood is inevitable in a few hours	Be prepared
Level 3	Red	Continuous ringing	Flood is coming	Evacuate for safety

The major actors in the communication network for the CBFEWS are the caretaker or gauge reader, local governmental authorities (including army, police and disaster response units), village/panchayat heads and other influential people, scientific or relief organizations, the media, and individuals who are concerned about the disaster. Each and every actor should have predefined roles and responsibilities that they would perform before, during and after the flood. Such a communication channel should be made familiar to all the recipients, and as far as possible, it should be consistent across different types of warnings to minimize confusion or misunderstanding among the users. The schematic diagram of a communication channel and information flow is given below (Fig. 23).

Figure 23: **Information Flow, Ratu River**

4.5 Key Actors and Their Roles and Responsibilities

Caretaker

- Take care of and monitor (e.g., check, clean and troubleshoot) flood early-warning instruments
- Monitor flood levels, keep records, and disseminate flood warnings to the authorities and people concerned
- Regularly report on the status of the instruments to the relevant authorities and communities

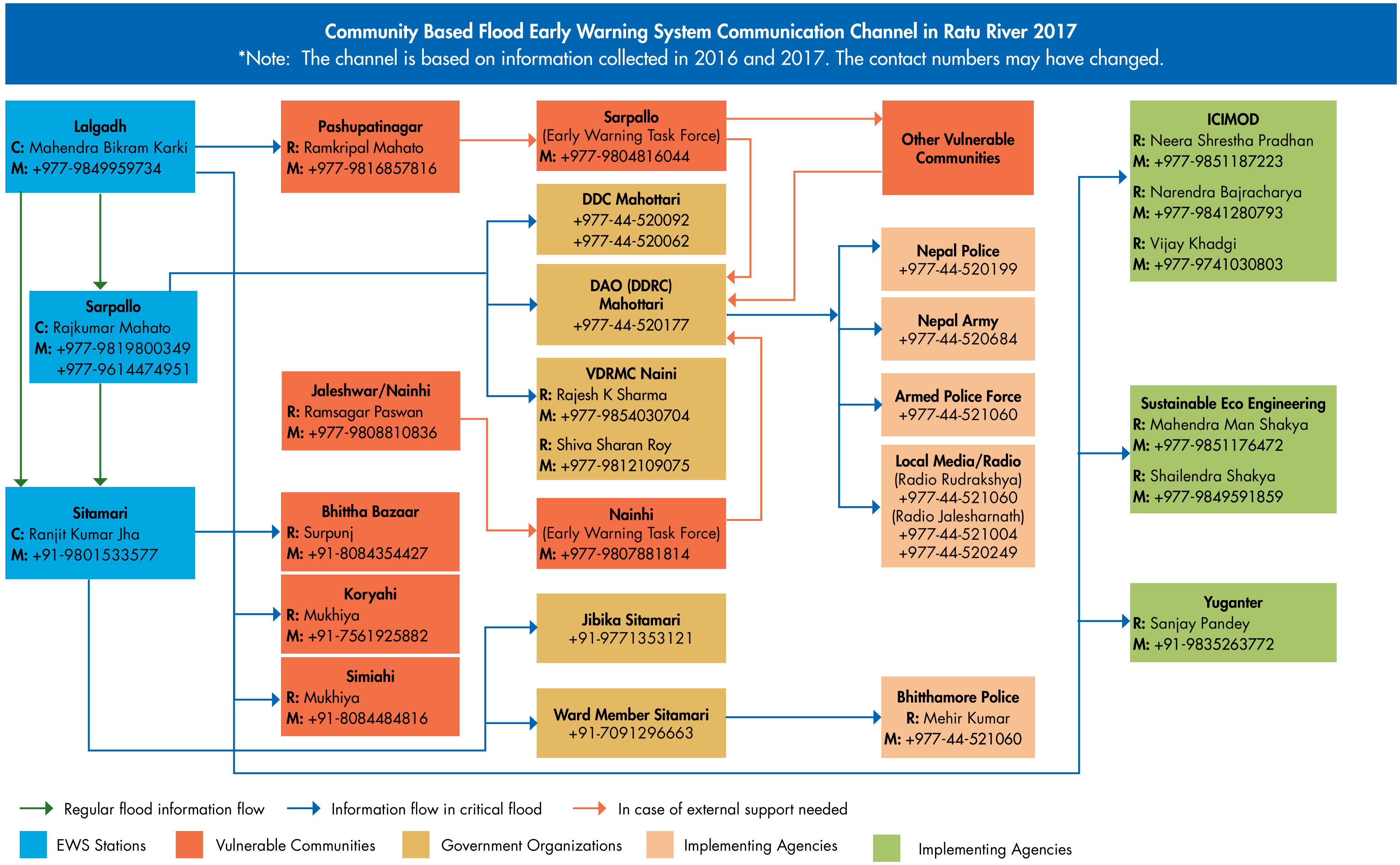
Local Mobilizing Organization

- Identify the major stakeholders, including local government line agencies and focal people in the communities for the CBFEWS implementation
- Mobilize communities for scoping, risk assessment, development of communication channels, awareness- and resilience-building activities
- Support the CBFEWS instrument installation, operation and maintenance for sustainability of the CBFEWS.

Local Disaster Management Authorities

- Monitor and cross-check the situation, circulate information to the organizations concerned and downstream focal persons
- Deploy flood response or rescue teams such as the military, police and civil authorities in the affected areas
- Circulate information to different media organizations

Figure 24: **Communication Channel, Ratu River**



Focal Person in Downstream Vulnerable Villages

- Receive the flood warning and communicate it to the grass-roots level considering that the message reaches women, senior citizens, and those caring for disabled people
- Make sure that each and every member of the community gets the warning information
- Coordinate and disseminate information to different people who are responsible for different tasks, such as those involved in early warning, rescue and first aid

Local Media

- Alert the community by broadcasting or publishing flood warning and information
- Inform the community about the ongoing relief and response activities
- Coordinate with the relief organizations.

Flood Risk Management Committee

In the absence of a community group that can deal with flood risks, a flood-risk management committee can be formed based on common consensus to enhance the capacity of the local people to withstand the effects of flood in an organized way. Forming such a committee can not only unite the whole community and strengthen its capacity, but also provides the authority and leadership for dealing with local flood-related issues. The committee can have several subcommittees or groups to handle: early warning, communication and information; first aid and heath; evacuation and rescue; and shelter management and logistics. The major roles and responsibilities of the flood-risk management committee include:

- Plan, implement and monitor flood-related issues
- Coordinate and establish a network with external agencies and stakeholders
- Coordinate with upstream community
- Coordinate with local people and assign them different responsibilities
- Prepare a flood preparedness plan

Other Actors

The other actors involved in disseminating the early-warning information are: the private sector; the Red Cross; police and army; influential leaders; and local teachers.

Steps to develop a communication and dissemination channel

1. Assess the existing communication and dissemination system
2. Identify a feasible mechanism for communication and dissemination
3. Develop a communication and dissemination plan with technical support from the expert and other relevant organizations
4. Identify roles and responsibilities of each stakeholder
5. Take into account the special needs of all community members, including those impaired aurally, visually or mentally
6. Supply and install the communication and dissemination tools and instruments
7. Prepare an operation and management plan for these tools and instruments
8. Share the agreed-upon communication and dissemination plan with all community members and stakeholders
9. Develop inclusive information, education and communication materials based on local need to raise awareness

4.6 Challenges Related to Communication and Dissemination

- Poor quality of telecommunication system and technology
- Lack of alternative channels for disseminating and delivering information
- Lack of clarity in the warnings issued
- Inadequate understanding of the vulnerable groups and their needs
- Ineffective engagement of the media and the private sector
- Failure of instruments
- Possibility of false alarm, and necessity for verification of the flood scenario from caretaker or upstream focal persons
- Lack of community's trust in the information disseminated
- Obstruction in information dissemination due to the social structure
- Complicated and non-user-friendly tools and instruments
- Lack of awareness of alternative communication channels

5. Response Capability and Resilience Building

SREX 2012 defines "resilience" as "the ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a potentially hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions". In order to build the resilience of a system, response capacities, like early-warning systems, contingency planning and emergency response should be put in place. The effectiveness of response capacity depends on the following four critical components:

1. Establishing Credible Warnings
2. Establishing Disaster Preparedness and Response Plans
3. Assessing and Strengthening Community Response Capacity
4. Enhancing Public Awareness and Education

Objectives

1. Preparedness
2. Building resilience of communities

5.1 Establishing Credible Warnings

Early warnings on floods are generated and distributed to those at risk by credible sources like government bodies, religious leaders, and respected community organizations. The public perception of flood risks and warning services should be analysed to predict community responses. Forecasts and warnings ought to be differentiated and the strategies that are developed should be aimed at earning credibility and trust. False alarms should be minimized as far as possible to build trust in the warning systems.

Before preparing the disaster preparedness plan, it is essential to understand the community at risk. People's participation in an interactive sense is an empowering process which organizations and partners implementing the CBFEWS could ensure through the following steps.

1. To draw efficiency by sharing responsibilities and engaging communities in the form of different social groups in order to decide on the differential risks and capacities of women, men, children, people with disabilities, and the marginalized communities.
2. Increased self-reliance where decisions are taken by the local people themselves to solve local problems. This will help raise awareness, build self-confidence, and reduce dependence on external sources (i.e., relief from government and non-government sources).
3. When development benefits are siphoned off by the non-poor, the elite and the powerful, the disaster preparedness plans can be directed towards building the resilience of the poor, women, children, the elderly, people with disabilities and the marginalized sections. It is essential that the power and control that the elite enjoys over the resources are relinquished as part of the community mobilization process for preparing disaster preparedness plans.
4. Engaging local people and utilizing local resources generate a sense of ownership towards the community-based flood preparedness plan

5.2 Establishing Disaster Preparedness and Response Plans

A disaster response and emergency plan has to address the specific actions that are required to minimize the impact of disaster; for example, drawing a risk map to mark shelter zones and escape routes. The plan has to be prepared in collaboration with the communities and stakeholders who have responsibilities during emergency or are required to take action upon the issuance of warnings. The plan ought to establish the roles and responsibilities of the various groups and stakeholders concerned. It is also important to discuss social and gender norms and values which could prove a barrier to the mobility of the community towards the shelter zones. It thus becomes necessary to provoke the community to think about changing such norms and values.

An effective plan will address communication and information dissemination, evacuation, search and rescue, first aid and health, transportation, shelter management, safe drinking water and sanitation, provision of relief, and collection of data in a systematic manner. Such a plan will be simple, user-friendly and understandable to all users in the community.

5.3 Assessing and Strengthening Community Response Capacity

It is important to assess the current ability of the community to respond to early warnings, and strengthen its capacity. Response to previous flood disasters is to be analysed and the lessons learnt incorporated into future capacity-building strategies. Vulnerability gets reduced when the capacity of the community is enhanced and the impacts minimized, which, in turn, builds resilience.

In order to strengthen the capacity of the community to deal with floods, task forces/groups are to be formed with specific responsibilities, like an early-warning taskforce and search and rescue group. The taskforce needs to have all the required equipment. Regular tests, trainings and drills are to be undertaken to ascertain the readiness of the warning systems and response mechanisms. The evacuation routes and shelter centres are to be jointly identified by the programme team and communities, and subsequently equipped with first-aid facilities, water and sanitation amenities, relief materials, and communication tools.

In the CBFEWS, organizations and partners should focus on the social obstacles –gender inequality, cultural norms and practices, and the domination of the local elites that hinders majority participation. Although the communities have acquired local coping strategies and capacities to reduce some of these vulnerabilities because of the experience of recurring disasters, the vulnerabilities in themselves are a complex web of societal conditions, factors, and processes. At the community level, partnerships should be forged between vulnerable and less-vulnerable groups.

Table 7: **Identification of Stakeholders**

Identification of Stakeholders	
Community Level • Women • Men • Pregnant/Lactating Mothers • Children • People with Disabilities • Marginalized Members • Religious Leaders	**Local Institutions/Committee** • Village Institutions/Community Development Committees • Ward Leaders • Village-level Elected Members • Forest User's Committee • Primary Healthcare Workers • Schoolteachers • Mother's Group • Women Empowerment Groups • Youth Groups • Local NGOs
District Level • Block-level Officer • District Disaster Authority • District Head • District Council Members • Law Enforcement Agencies (Police/Army) • Child Development and Protection Officer (Family and Child Department) • District Education Officer • Central Statistics Organization (applicable to Afghanistan) • District-level NGOs • Elected Representatives	**Provincial/State Level** • Provincial/State Disaster Management Authority/Committee • Ministry of Health • Ministry of Education • Ministry of Women and Child Development • Ministry of Water Resources • State-level NGOs • Elected Representatives (MLAs)
National Level • NGOs/INGOs • Elected Representatives (MPs) • National Planning Commission • National Disaster Management Authority • Ministry of Home Affairs	**Service Providers** • Hospitals (Village/District) • Transportation • School • Local FM Stations • Media Groups

Identifying the stakeholders, Table 7 provides an overall target to work with different actors, but the CBFEWS accords priority to the most vulnerable groups. It also seeks to address the conditions, factors, processes and causes of vulnerabilities brought about by poverty, social inequalities, and environmental resource depletion and degradation.

External agencies with supporting and facilitating roles should be able to identify the right stakeholders to achieve the objectives of the CBFEWS. With the community as the main actor in the CBFEWS, there are different processes for social mobilization and combining local knowledge and science and technology with support from these external agencies.

Table 8: **Mobilization Process for CBFEWS**

Mobilization Process for CBFEWS	
Community/Village Level • Establishing linkages and rapport with community members and local Institution/committee members • Community mapping – survey and identification of inundated houses/villages • Identifying the hazard, safe routes and shelters • Identifying the vulnerable • Identifying the caretaker • Establishing a disaster preparedness committee • Capacity building of the community members and the caretaker of the instrument, and addressing issues of the vulnerable	**Government Institutions and NGOs/INGOs** • Establishing linkages and rapport with different line departments • Engaging the government officials/NGOs/INGOs in community mobilization • Capacity building of the officials on gender sensitivity and DRR • Integration of the CBFEWS with government data – data sharing and monitoring of the CBFEWS • Establishing a dissemination protocol – for caretaker and government line departments/NGOs/INGOs engaged in DRR

Social mobilization is a process wherein the poor women and men and the marginalized participate in local decision-making to enhance their lives and livelihoods by accessing and using the resources available at the local level. In the context of flood warning and preparedness, it is a process to reduce vulnerabilities and strengthen the people's capacity to cope with the hazard.

However, the steps in mobilization may vary depending upon the context of the communities, and institutional mandates. The processes for drafting a local disaster preparedness plan from the above list can be generalized as follows:

- The community and other stakeholders can initiate the process of establishing linkages and building rapport with external facilitators.
- At the community level, an initial understanding of the disaster situation, the early-warning mechanism and the CBFEWS should be established with focus on the vulnerable – women and children, the elderly, people with disabilities, and the marginalized community members.
- Within the community, a participatory assessment of gender, and social analysis of hazards, vulnerabilities, capacities and people's perception of flood risks should be completed.
- The formulation of a disaster response and emergency plan for taking specific actions to minimize the impact of the disaster entails, among other things, the drawing of a risk map in order to mark the shelter zones and escape routes. The plan should also include appropriate preparedness and mitigation measures, including public awareness, capacity building, and education activities.
- A flood risk management committee has to be established. This committee would be responsible for community organization and mobilization, and coordination and capacity building in preparedness and mitigation. (For details, refer to section 4.5.)
- Short- and long-term risk-reduction measures have to be undertaken as preventive measures – in the form of embankments, dams/reservoirs, flood proofing, improved communication channels, etc. (For details, see Table 8.)
- Documentation regarding monitoring and evaluation can bring about continuous improvement in community preparedness and mitigation measures. (For more information, see Table 7).
- The integration of the community/local disaster preparedness plan with the local development planning systems and processes will lead to sustainable and equitable community development.

To pursue the implementation of the disaster response and emergency plan and mobilize the community, the facilitator may have to overcome several challenges. This could include the hierarchical organization of social relationships along the lines of social status, caste, class, gender, religion, and ethnic identity; asymmetrical gender relationships that limit access to resources and recognition; excess bureaucratic control over resources and opportunities; and lack of integration with local development planning systems.

A detailed list of challenges in community mobilization in the CBFEWS is presented in the table below.

Table 9: **Challenges in Community Mobilization in CBFEWS**

Challenges for Community Mobilization in CBFEWS	
Structural • Lack of awareness and information about vulnerability and preparedness to disaster • Lack of coordination and timely communication between different actors • Lack of clarity in responsibilities among actors • Develop community faith in the CBFEWS Model • Ownership on the CBFEWS process from the government authority • Increased reliance on external agencies (NGOs/ INGOs)	**Technical and Financial** • Fast changing technology and update of the equipment • Sustainability – operation and maintenance of the equipment without financial support • Reduced funds for early warning preparedness, disaster management system more tuned to response and relief

To overcome these structural, technical and financial challenges and achieve the CBFEWS goals, it is essential that people organize themselves to identify their needs, influence the direction of designing the disaster response and emergency plan, and strengthen the relevant institutions . For community mobilization and understanding vulnerability, participatory tools and methods such as resource mapping, hazard mapping, transect walk, historical transect and daily-activity schedule can be applied.

In order to build the resilience of communities when it comes to disaster, the above processes should be given important consideration, since their aim is to: build solidarity, self-reliance, and awareness; take collective action; strengthen ownership of the instrument/technology; and monitor, evaluate and integrate the response and emergency plan with the local development plans. Although participatory methods and tools are intended to remove biases (male, elite, professional, seasonal, etc.), often the poor women, children and the lower-caste groups are marginalized. Therefore, it has to be recognized that communities are not homogenous groups – their capacities to access and control resources are different. A disaster response and emergency plan in this context needs to cater to the differential needs of poor women, men, children, the single mother, people with disabilities, lower-caste groups, and other marginalized communities.

5.4 Enhancing Public Awareness and Education

Awareness raising and education are major components of resilience building. Simple information on hazards, vulnerabilities, risks and reduction of flood impacts can help the vulnerable communities and decision-makers to take immediate action. The communities and relevant stakeholders will have to be instructed about how early warnings are to be disseminated and which sources are reliable, and how to respond to different types of signals that are conveyed by the caretakers and responsible authorities. The awareness raising on flood information and preparedness will have to be built into the school curricula from primary to university levels. Public awareness and education campaigns tailored to specific needs of various audiences are important for enhancing the communities' capacity to respond to early warnings on flood and build their resilience. Various tools can be used for such awareness raising –flyers, pamphlets, posters, documentaries, street dramas, mock drills, etc. (Table 10).

Table 10: **Strategies for Building Community Response Capacity**

Aim	Means of achieving	Example of capacity building strategies
To reduce vulnerability	Protect/secure livelihoods, strengthen the community's base of natural resources, challenge gender discriminatory practices that make women more vulnerable	• Skill-development training • Encourage livelihood diversity • Promote access to information • Link to markets • Community participation; offer flood insurances • Enact policies to protect natural resources • Introduce flood-warning capabilities • Create awareness about flooding risks
To improve prevention	Structural measures	• Embankments • Dams/reservoirs • Flood proofing • Land-use regulations
	Non-structural measures	• Improve communication • Improve drainage • Protect wetlands and natural ponds • Monitor river corridors
To learn and evolve	Document the lessons learnt	• Learn from past flooding events • Document the successes and failures of rescue operations to make improvements • Document the extent of the flooded area, depth and damages, and update hazard maps

Source: Ashok K. Katyal & Ioana G. Petrisor (2011)

2 Instrument Details

6. Introduction of Tools and Equipment

6.1 Multimeter

A multimeter (Figure 25) can measure different parameters of electrical circuits. In this technical training, it will be used to measure basic related parameters like DC voltage and resistance, and to check continuity. Before measuring any parameter, the user must assume a possible maximum value of the parameter concerned, so as to position the selection knob on the correct range number label. Each number label indicates the maximum measureable value of the parameter when the knob is in that position. For instance, to measure the DC voltage of a battery, the voltage of a normal chargeable battery should be around 12 V, so the selection knob should be placed in the DC V region of the multimeter and the range should be more than 12 V, preferably 20 V on the multimeter. Because the selected range value is greater than the value of the measurement, the meter can comfortably read the measured value. If the measured value exceeds the range, then the range should be extended by repositioning the knob; otherwise, the multimeter is unable to read the value. Also, the measuring should be done in the right order – the red probe should be in the positive terminal and the black probe in the negative terminal so as to avoid polarity error.

Figure 25: **Multimeter**

Figure 26: **Screwdriver**

6.2 Screwdriver

Used for fastening and unfastening screws used that hold together wires in terminal connectors and components and to make joins. It is available in 2 types: "+" and "-". Each type generally has 3 sizes. The correct screwdriver must be selected based on the size of the screws that are to be worked on.

6.3 Combination Pliers

Combination pliers are used for a combination of gripping and clamping small objects, stripping out wire-sheaths, cutting, and binding wires.

Figure 27: **Combination Pliers**

6.4 Wire Cutter

Wire cutters are used for cutting and stripping wires out of their sheaths. It is used for finer wires where precision is required and thus is smaller than the combination plier.

Figure 28: **Wire Cutters**

6.5 Nose Pliers

Nose pliers are combination pliers with an extended head, and have ends tapered to a small tip. They are especially helpful in gripping small objects and wires, and in cases where precision and strength are required.

Figure 29: **Nose Pliers**

6.6 Slide Wrench

A slide wrench is used to tighten and loosen nuts of different sizes. It has an adjustable jaw that is controlled by a lead screw below it. The size of the jaw can be changed to the size of the nut that has to be worked on.

Figure 30: **Sliding Wrench**

6.7 Ratchet Spanner

A ratchet spanner is used to tighten and loosen nuts. It is of a fixed size and allows for more torque to be applied to the nut.

Figure 31: **Ratchet Spanner**

6.8 Box Cutter

It is a cutting tool. Mostly used when quick cutting is required of tapes, cable ties, paper, etc.

Figure 32: **Box-Cutter**

6.9 File

A file is used for grinding down rough surfaces to smoothen them out. The round file in particular is useful for enlarging holes as necessary.

Figure 33: **File**

6.10 Soldering Iron

A soldering iron is a device used to connect electrical wires with a filler metal. The solder wire is melted on to the ends of the wires that are to be connected. The soldering iron used is a 12 V, 40 W DC iron.

Figure 34: **Soldering Iron**

Note: Do not touch the metal barrel or tip of the soldering iron with bare hands.
Do not rub the tip of the soldering iron on harsh or rough surfaces as it may damage the iron.
The tip may be cleaned with a wet cloth if necessary

Important: Before any operation, choose the appropriate tools of the right size and do not apply excessive force.

7. Layout of Instruments

7.1 Data Acquisition Unit: Closed Box View

Figure 35: **Data Acquisition Unit: Closed Box View**

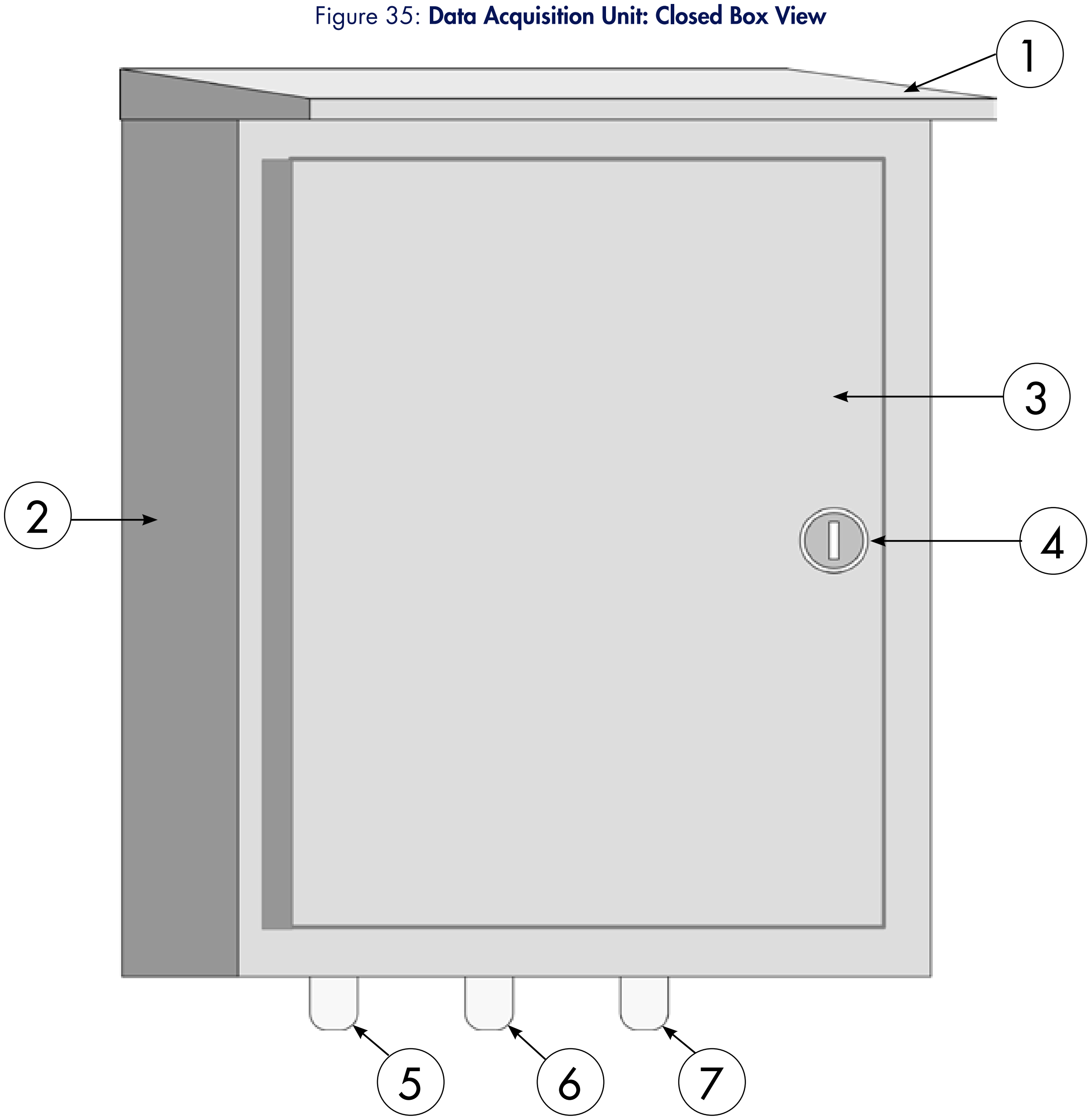


Table 11: **Data Acquisition Unit: Closed Box View**

No.	Description
1	Sloped Rain Roof
2	Metallic Box Enclosure
3	Access Door
4	Key hole for Access Door
5	Waterproof Sensor cable Outlet Gland
6	Waterproof Solar cable Outlet Gland
7	Waterproof Antenna cable Outlet Gland

7.2 Data Acquisition Unit: Open Box View

Figure 36: **Data Acquisition Unit: Open Box View**

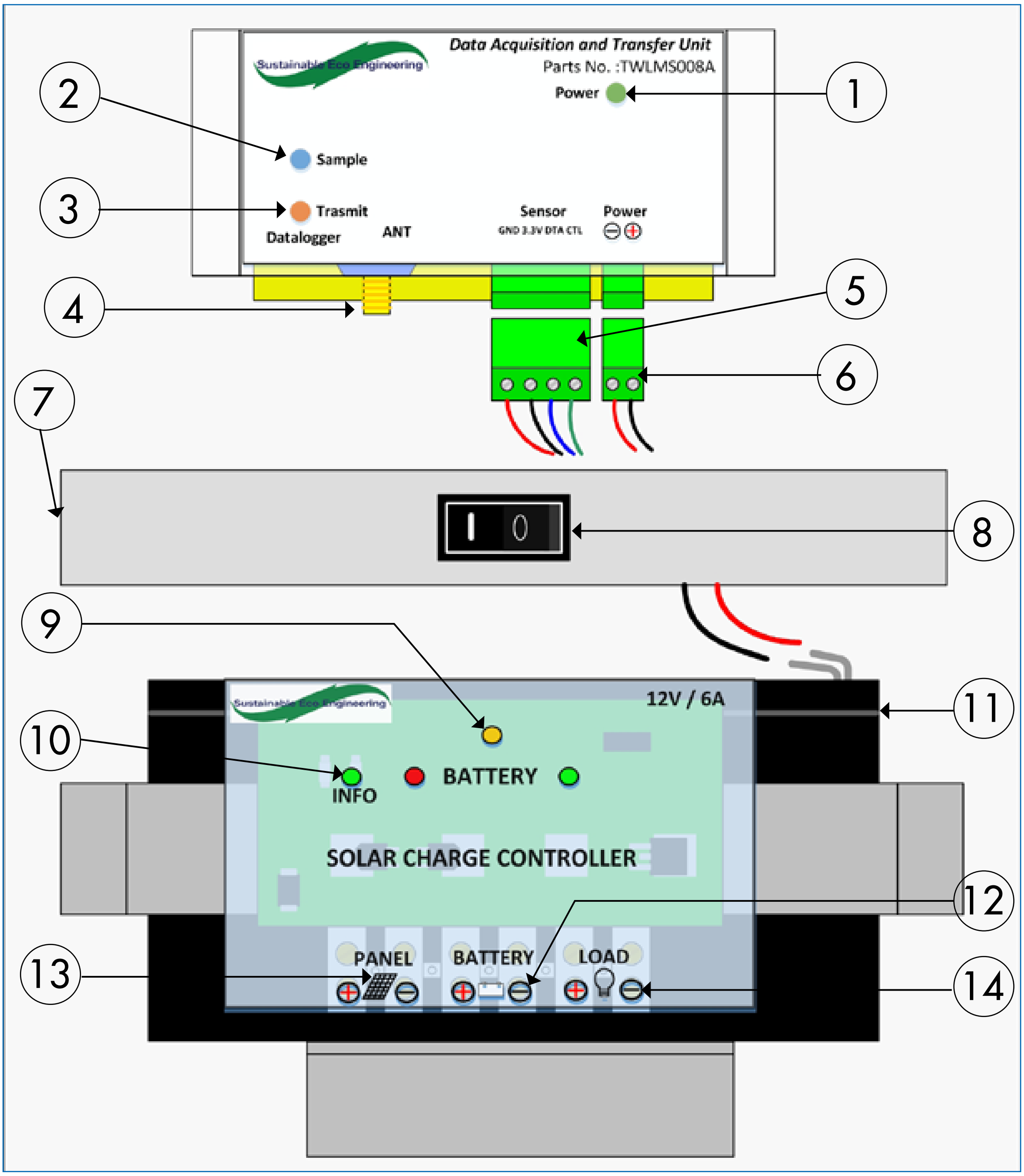


Table 12: **Data Acquisition Unit: Open Box View**

No.	Description	No.	Description
1	Power Indication LED	8	Power Switch
2	Sensor Sampling Indication LED	9	Battery Level Indicators: GREEN, ORANGE, RED
3	Radio Data transmission Indication LED	10	Charge controller Status indication LED
4	Antenna connection: RPSMA type	11	Battery 12V, 7Ah
5	4 Terminal Connection Block for Sensor	12	Battery Connection Screw Terminal
6	2 Terminal Connection Block for Power	13	Solar Panel Connection Screw Terminal
7	Wiring Duct	14	Load Connection Terminal

7.3 Data Upload Unit: Closed Box View

Figure 37: **Data Upload Unit: Closed Box View**

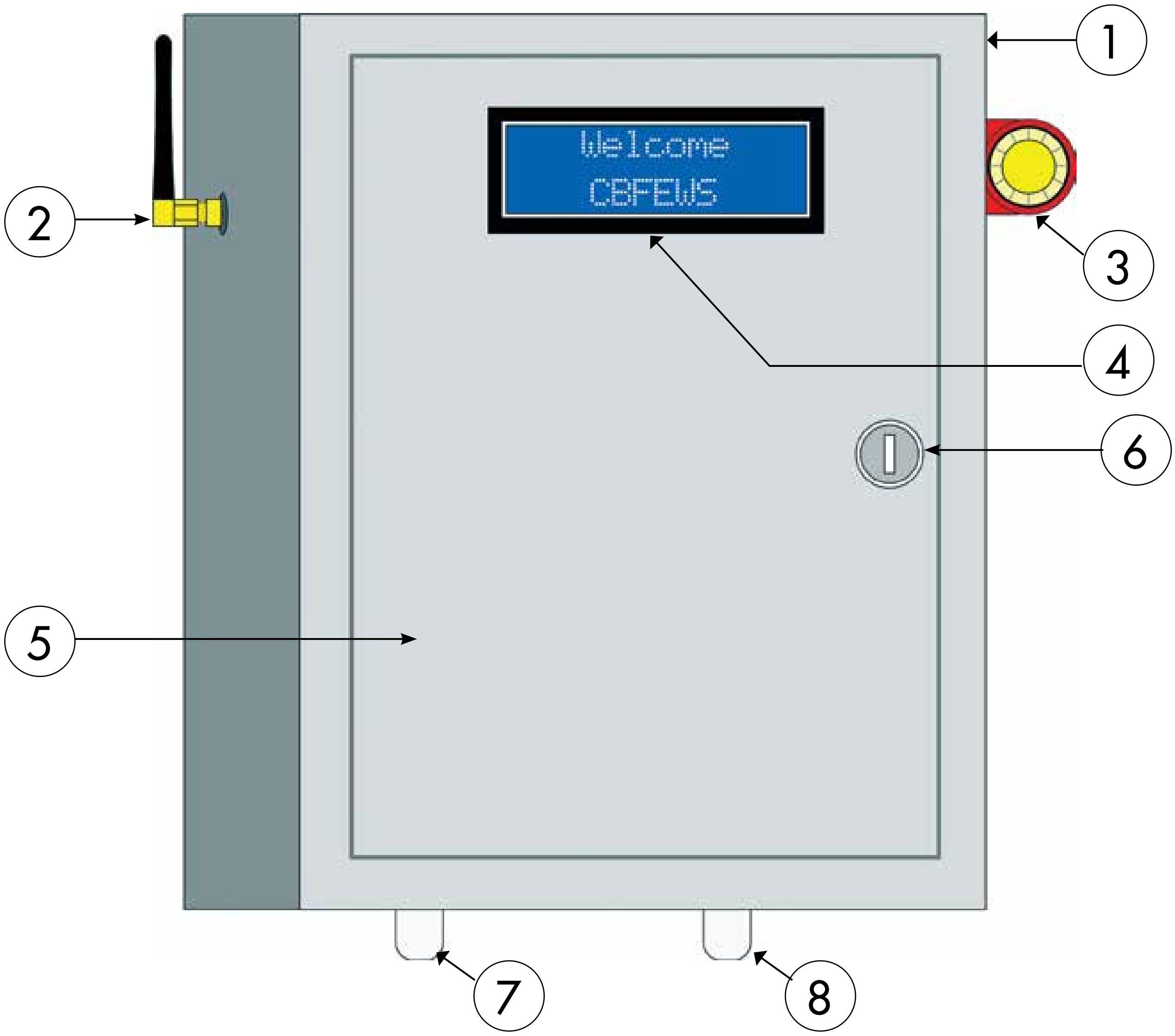


Table 13: **Data Upload Unit: Closed Box View**

No.	Description
1	Metal Enclosure
2	GPRS Antenna
3	Alarm
4	LCD Display with Welcome message
5	Access Door
6	Key Hole for Access Door
7	Waterproof Antenna Cable Gland
8	Waterproof Solar Panel Cable Gland

7.4 Data Upload Unit: Open Box View

Figure 38: **Data Upload Unit: Open Box View**

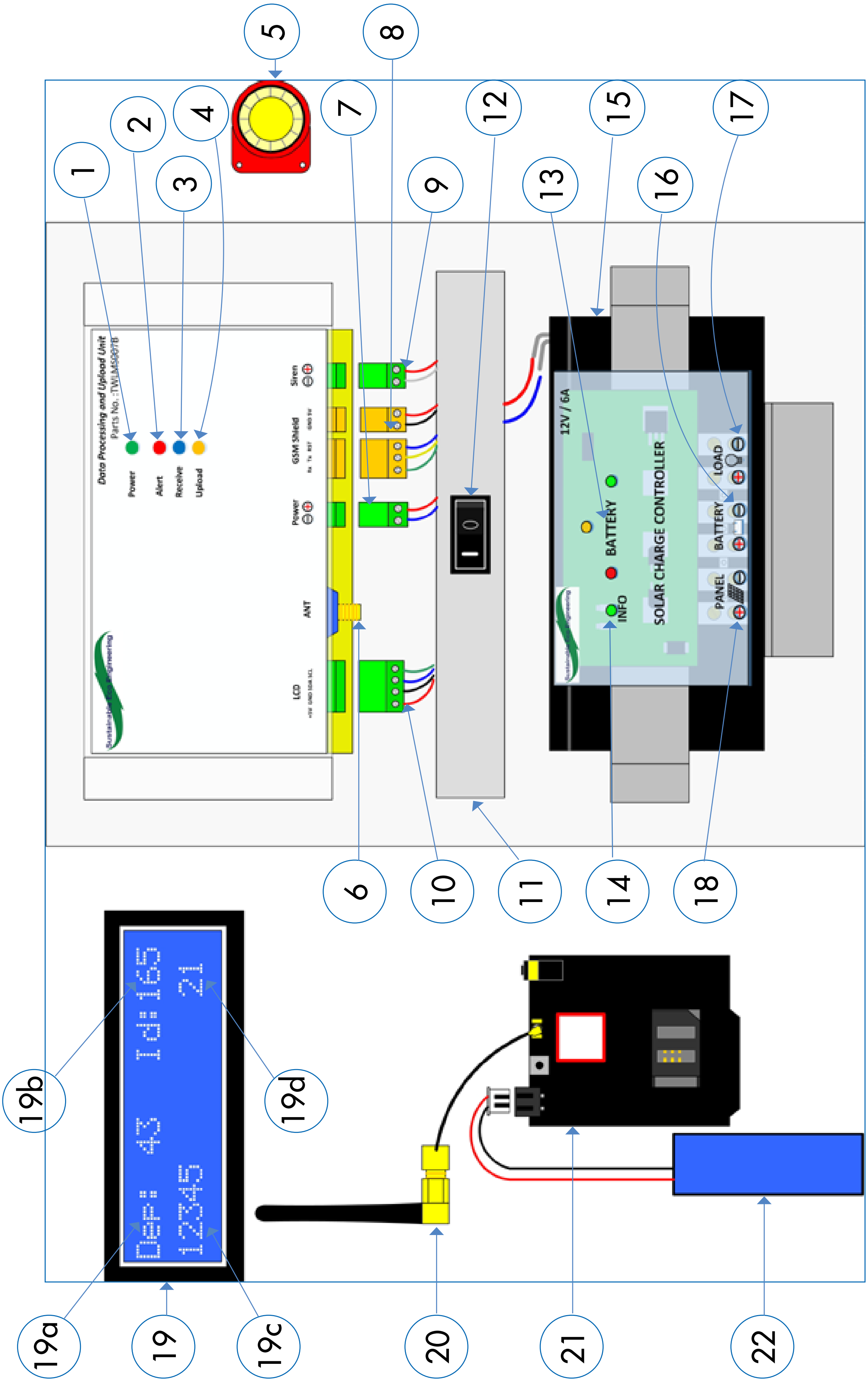


Table 14: **Data Upload Unit: Open Box View**

No.		Description
1		Power Indication LED
2		Localized Alarm Indication LED
3		Data Received from DA Unit Indication LED
4		Web Data Upload Indication LED
5		Local Siren
6		Antenna Connection: RPSMA type
7		2 Terminal Connection Block for Power
8		5 Terminal Connection Block for GPRS module
9		2 Terminal Connection Block for Local Siren
10		4 Terminal Connection Block for LCD display
11		Wiring Duct
12		Power Switch
13		Battery Level Indicators: **GREEN**, **ORANGE**, **RED**
14		Charge controller Status indication LED
15		Battery 12V, 7Ah
16		Battery Connection Screw Terminal
17		Load Connection Screw Terminal
18		Solar Panel Connection Screw Terminal
19		LCD Display
	19a	Water depth measured by sensor represented as Dep.
	19b	The ID of the measured water depth being shown. There are 288 samples/day (0-287). ID resets to 0 after 24hrs.
	19c	Sequence indicating processes completed for successful upload to web. The sequence can go up to 5.
	19d	Network Strength indication. May be between 0 and 31. 11 is the recommended minimum strength.
20		GPRS antenna
21		GPRS module with mobile data processor
22		High Current power cell

7.5 Alarm Unit: Closed Box View

Figure 39: **Alarm Unit: Closed Box View**

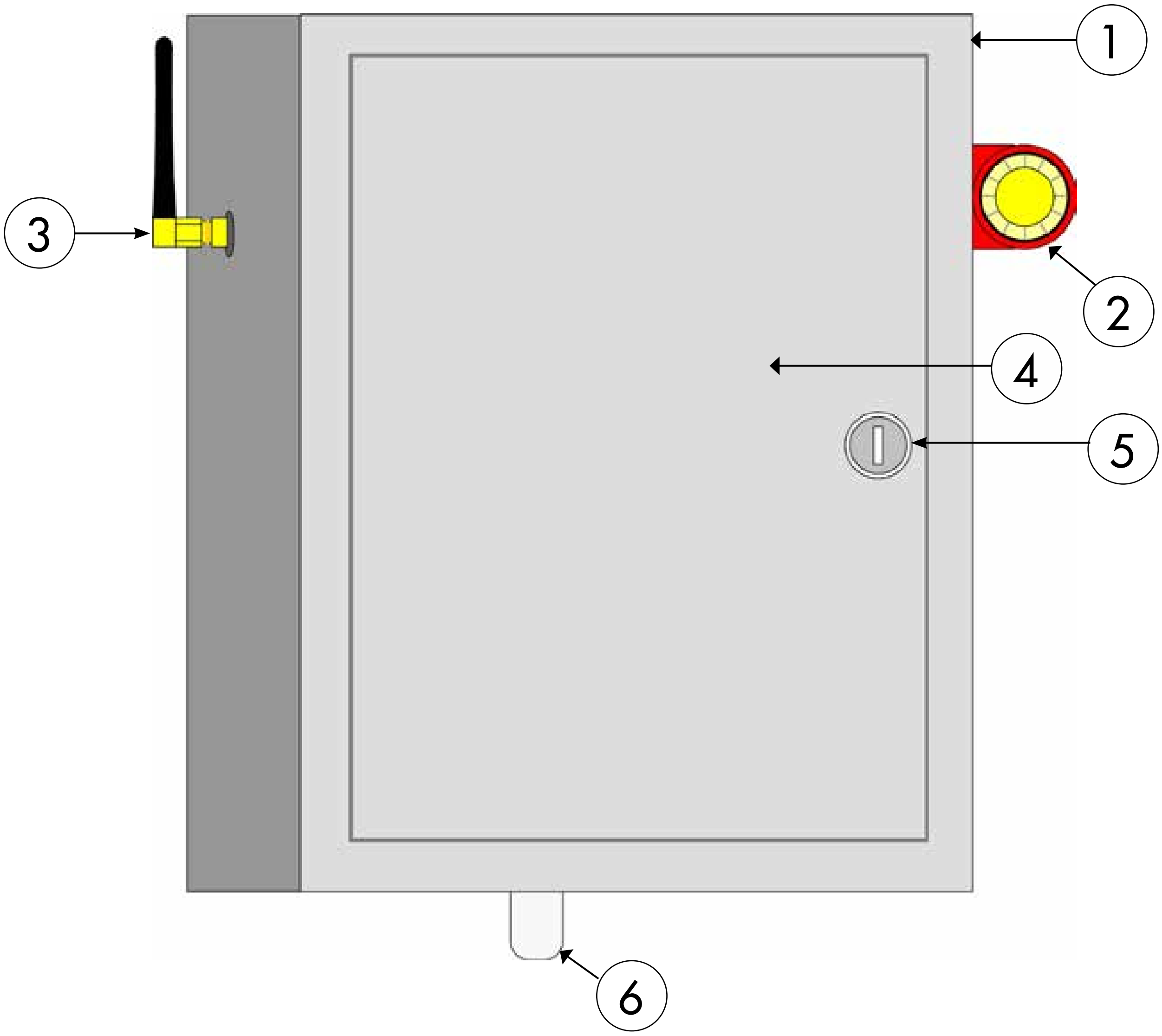


Table 15: **Alarm Unit: Closed Box View**

No.	Description
1	Metallic Box Enclosure
2	Loud Siren
3	GSM Antenna
4	Access Door
5	Key Hole for Access Door
6	Waterproof Solar Power Cable Gland

7.6 Alarm Unit: Open box view

Figure 40: **Alarm Unit: Open Box View**

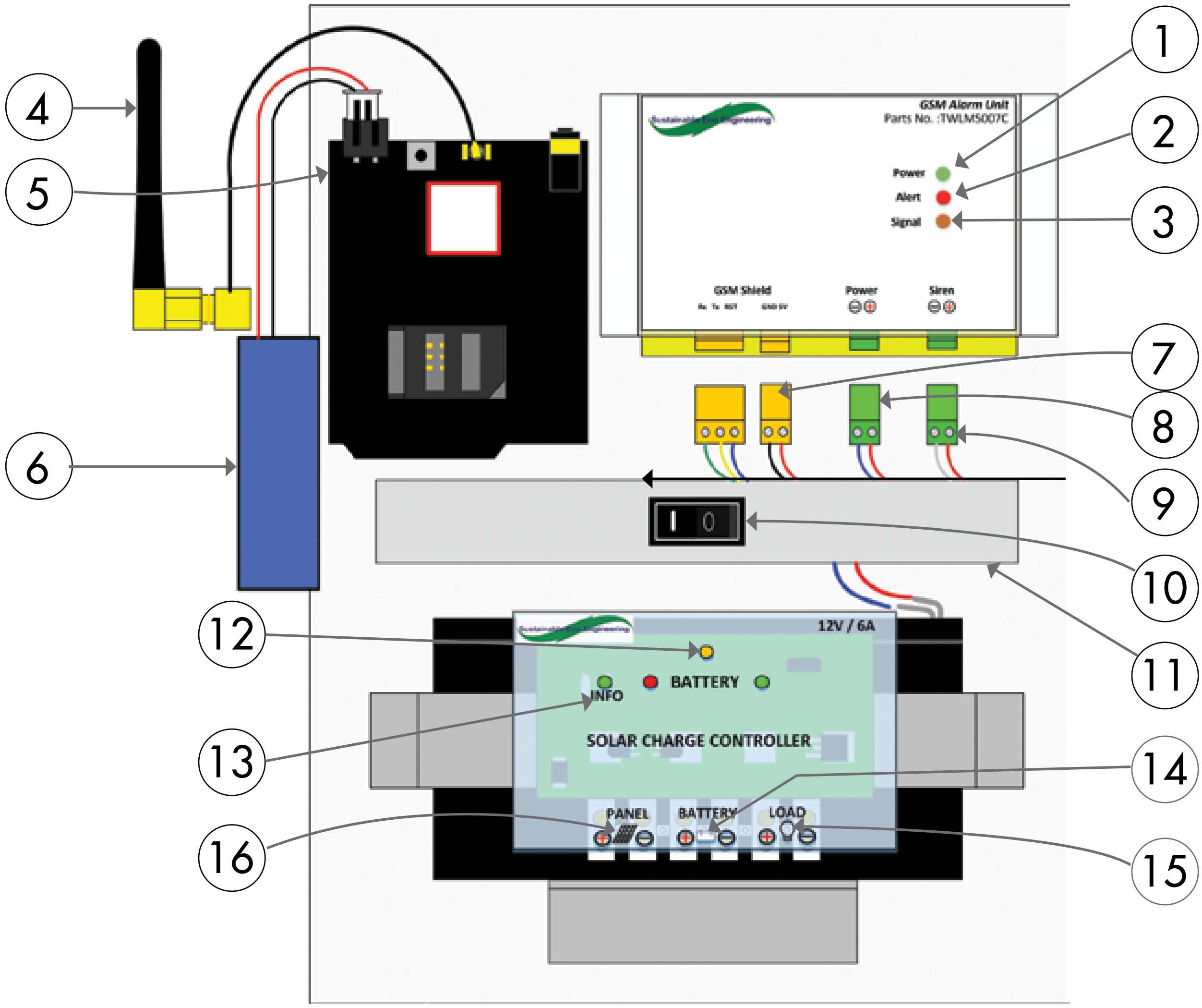


Table 16: **Alarm Unit: Open Box view**

No.	Description	No.	Description
1	Power Indication LED	9	2 Terminal Connection Block for Siren
2	Alarm Indication LED	10	Power Switch
3	GPRS Module Connectivity Indication LED	11	Wiring Duct
4	GPRS Antenna	12	Battery Level Indicators: GREEN, ORANGE, RED
5	GPRS module with mobile data processor	13	Charge controller Status indication LED
6	High Current Power cell	14	Battery Connection Screw Terminal
7	5 Terminal Connection Block for GPRS module	15	Load Connection Screw Terminal
8	2 Terminal Connection Block for Power	16	Solar Panel Connection Screw Terminal

8. Installation of Instrument in the Field

8.1 Pre-Installation

Site Selection Criteria

Data Acquisition Unit

- Clear RF line of sight between the DA Unit antenna and the DU Unit antenna. Large objects such as buildings, metal poles or trees should be avoided between antennas.
- Knowledge of the exact height in centimetres of the sensor from the riverbed.
- Stability of the exact location where the DA Unit will be placed so as to allow for a strong foundation.
- Knowledge of the surroundings of the exact location where the DA Unit will be placed. Surroundings may include key occurrences like physical infrastructure for stable sensor placement or foliage that might need to be cleared.

Data Upload Unit

- Clear RF line of sight between the DA Unit antenna and the DU Unit antenna. Large objects such as buildings, metal poles or trees should be avoided between antennas.
- Network strength at the exact location where the unit will be placed. The lowest minimum acceptable strength for data transfer would correspond to 2 bars on a phone.
- Knowledge of the surroundings of the exact location where the DU unit will be placed. Water leakages during rains and accessibility for cabling need to also be noted.

Alarm Unit

- Network strength at the exact location where the unit will be placed. The lowest minimum acceptable strength for data transfer would correspond to 2 bars on a phone.
- Knowledge of the surroundings of the exact location where the alarm unit will be placed. It has to be ensured that the siren would be as widely audible as possible. Water leakages during rains and accessibility for cabling need to also be noted.

Antenna Setup and Installation

The antenna must be mounted in an open space with a clear view of the other antenna.

Step 1: Place the antenna on its mounting platform.
Step 2: Fix the clamps on to the screwing holes on the back face of the antenna.
Step 3: Turn the antenna such that its wider front face is facing towards the other antenna. The antennas need to be face-to-face.
(The front face is the face with the label, opposite the face with screw holes for clamps).
Step 4: Proceed to change the inclination of the antenna such that the faces of the two antennas are more or less parallel.
Step 5: Connect the RPSMA connector of the antenna to the radio antenna connector head within the instrument casing.

Solar Panel Mounting Method Options

The solar panel needs to be south facing, inclined at 45° to the horizontal.

The solar panel for the DA Unit may be mounted on the tower supporting the unit with a specialized bracket fabricated for the tower itself.

Option 1: Wall Mounting

The solar panel may be wall mounted (Fig. 41) on a stable vertical south-facing plane with the specialized angle brackets provided. The brackets are screwed into the holes drilled on the walls and the solar panel is mounted on to it. Window frames may also be used if mounting it on a wall is inconvenient.

Option 2: Pole Mount

An additional pole may be mounted at a fixed distance beside the antenna pole and the angle bracket may be set up on the parallel pole pair for the solar panel while avoiding the antenna's shadow (Fig. 42).

Option 3: Roof Mount (Figure 43)

a. Inclined roof:

The inclined roof does not require additional angle brackets for the solar panel; only that the roof should be south-facing. The solar panel can be directly fixed to the roof using appropriate supports (Fig. 43a).

b. Plane roof:

The angle brackets may be set up on the ground with additional weights to avoid unwanted movement, and the solar panel may be attached atop the brackets (Fig. 43b).

Figure 43a: **Solar Panel Mounted on Inclined Roof**

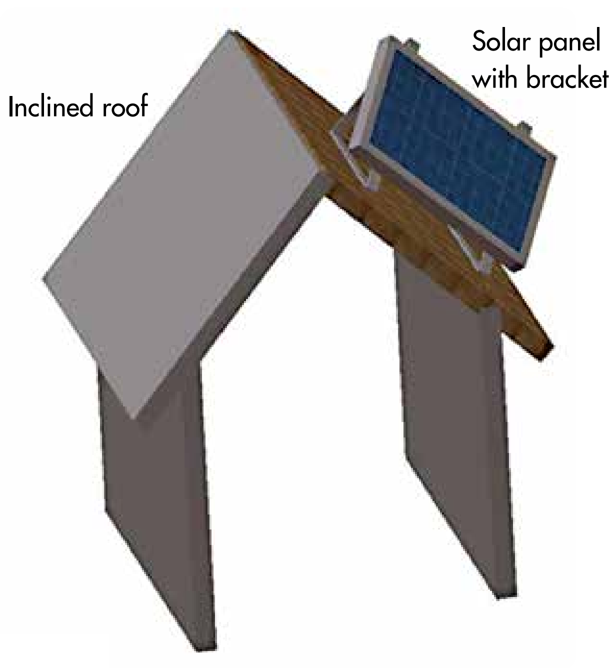


Figure 41: **Wall Mounted Solar Panel**

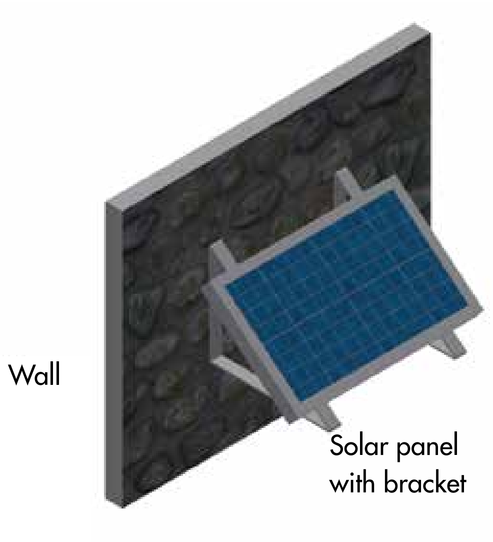


Figure 42: **Pole Mounted Solar Panel**

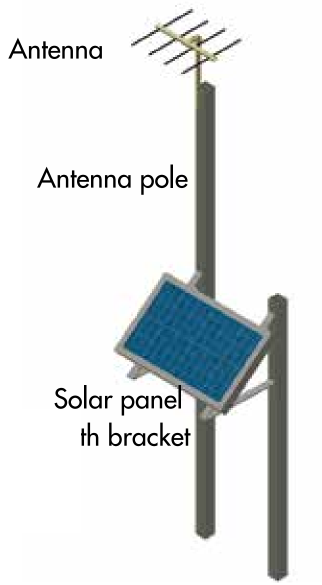
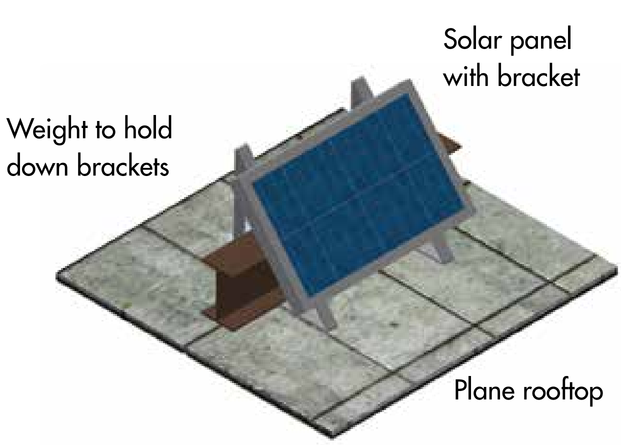


Figure 43b: **Solar Panel Mounted on Plain Roof**



Sensor Setup and Calibration

a. Sensor Connections

Step 1: Prepare No. 1 "+" screwdriver.
Step 2: Note the colour sequence of the wires going into the terminals. (The "Data Upload Unit: Open Box View" can be referred for the colour sequence of the wires.)
Step 3: Unscrew the points on the terminal connector to detach the connector from the wires.
Step 4: Pass the sensor wire through the waterproof gland and into the box.
Step 5: Screw the wires back into the terminal connectors matching the sequence previously noted.
Step 6: Connect the sensor connector into the sensor terminal on the circuit board.

b. Sensor Alignment

The ultrasonic sensor alignment is a critical component of device function and accuracy. The operation of the sensor is based on the principle of time of flight and reflection of sound. The time of flight fundamentally measures the time it takes for the sound emitted by the sensor to be reflected back to the sensor itself. By a few calculations with respect to the speed of sound, the distance to an object can be calculated.

The principle of reflection of sound basically implies that sound waves are reflected back by a surface at an angle equal to the sound waves' angle of approach or incidence. For the sensor to hear back the sound it emitted, the wave must reach back to the sensor. If the sensor is set at large angles to the vertical, the sound waves are reflected far away from the sensor. Hence, great care must be taken to set the sensor vertical to the water surface.

Figure 44: **Reflection of Sound Wave at Large Angle of Approach**

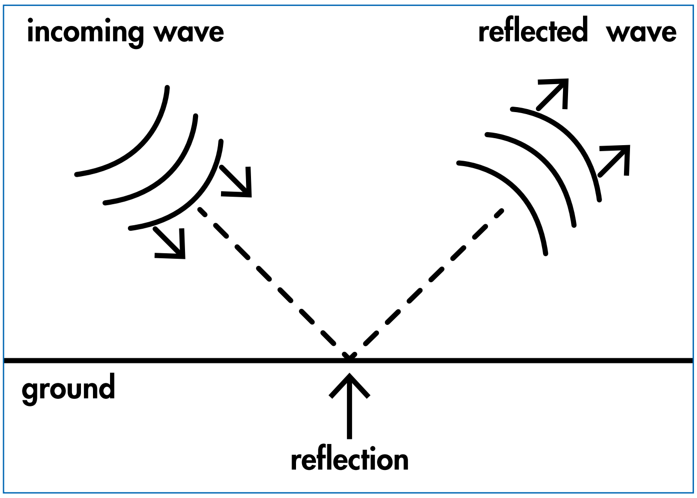
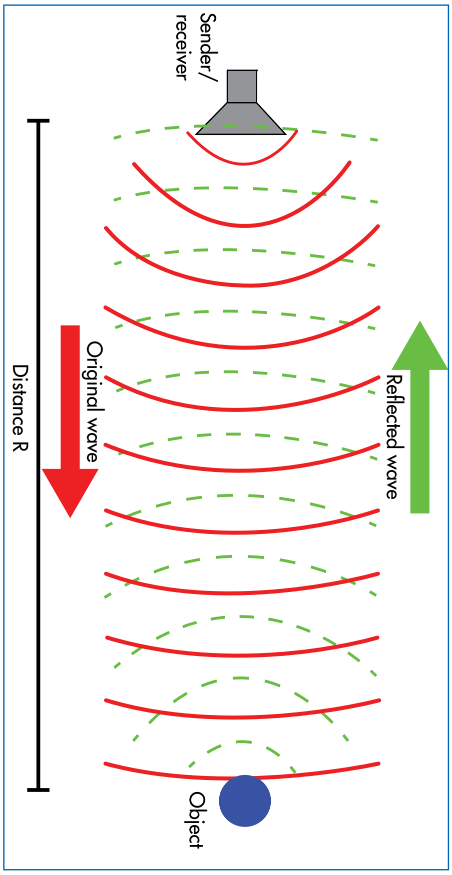


Figure 45: **Reflection of Sound Wave at 0-Degree Approach**



c. Calibration of the Sensor

The warning and danger thresholds for the system are determined by using the community's knowledge of previous flood events as a baseline and documented records of past flooding history. The thresholds are then programmed into the system in order to trigger the alarm when those levels are reached.

The calibration of the sensor, to set it at the correct height on the tower structure should be completed in two phases:

Transference of Height Using Water Level: It is important to know the height of the sensor from the riverbed in order to obtain an accurate measurement of the water level. The existing water level of the river during the time of installation thus must be known to set the height of the sensor. Additionally, the water level for the danger threshold must also be known to set them into the system. They may be found out by referring to a nearby gauge that has been installed. If the gauge is far away, the level needs to be transferred to the site of installation. This may be accomplished through the simple water-level method using a transparent, flexible water tube as follows:

Step 1: Fill a jug or container with water and place it on a high surface.
Step 2: Dip one end of the tube into the jug and place the other end in your mouth.
Step 3: Suck on the tube hard enough to get the water moving but not so hard to get a mouthful of liquid.
Step 4: Once the water starts moving, lower the tube to a height below the container and water should start flowing through the tube.
Step 5: Pull out the tube from the bucket once it is nearly full.
Step 6: Hold both ends of the tube vertically so that no water can escape. Tap your finger along the tubing to loosen and expel any trapped air bubbles.
Step 7: Hold the ends of the tube even with one another, and verify that the water levels line up equally. If they do, you are ready to go. If they do not, you need to continue tapping the tube, as it's likely that air bubbles are still trapped.
Step 8: Have a helper stand at the other end which needs to be levelled and hold up the other end of the tube. Accordingly, one should hold up one's tube at the height that needs to be transferred.
Step 9: The helper should now mark the water level at his/her end. This will be the equal standard height as measured at one's end. This should be the height in reference regardless of the level of the ground.

Figure 46: **Level Transfer Using Water Hose**

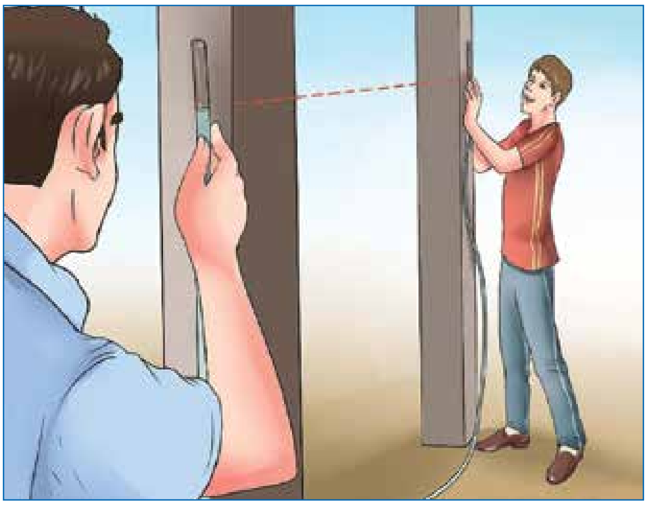
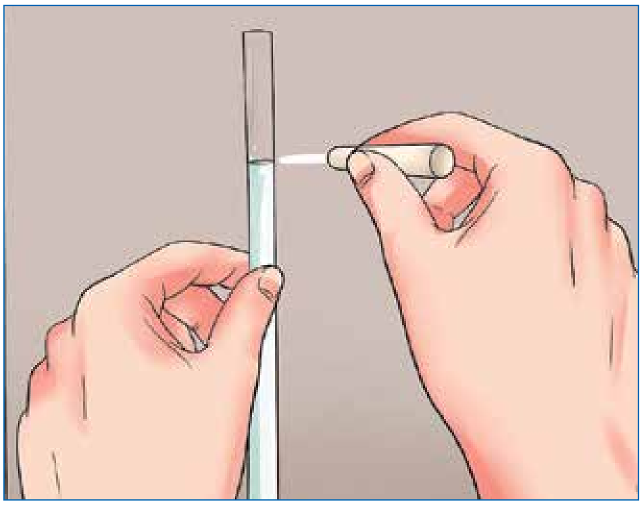


Figure 47: **Marking the Level Transferred**



Note:

- For larger distances, the process may be repeated a number of times until the installation site is reached from the location of the standard gauge.
- This process is of common practice among masons and the help of local masonry personnel can be sought to accurately accomplish the task.

Height Calibration of Sensor Arm: Once the height has been transferred, it is very important to accurately calibrate the height.

For height adjustment greater than 30 cm, the sensor arm can be moved along the vertical section of the tower, up to a total of 2 m. For fine-tuning of a height of less than 30 cm, the neck of the sensor housing can be vertically adjusted.

The calibration process is carried on as such:

1. Once installation is complete, make note of the current depth of the water manually, in reference to the standard height transferred.
2. Take note of the water depth displayed on the LCD screen, which is marked on the DU Unit as "Dep:".
3. Tally the two measurements and calculate the absolute difference if present.
4. Now, if the depth displayed on the LCD screen is greater than the actual depth of the water measured, then the sensor must be LOWERED by the amount corresponding to the difference.
5. Accordingly, if the depth displayed on the LCD screen is lower than the actual depth of the water measured, then the sensor must be RAISED by the amount corresponding to the difference.

d. Structure Setup Example

The generic structure design for the setup of the DA Unit is as presented. However, depending on the surroundings of the selected DA Unit site, the unit maybe set up in a manner completely different to the example presented.

Figure 48: **Support Structure for DA Unit, Isometric View**

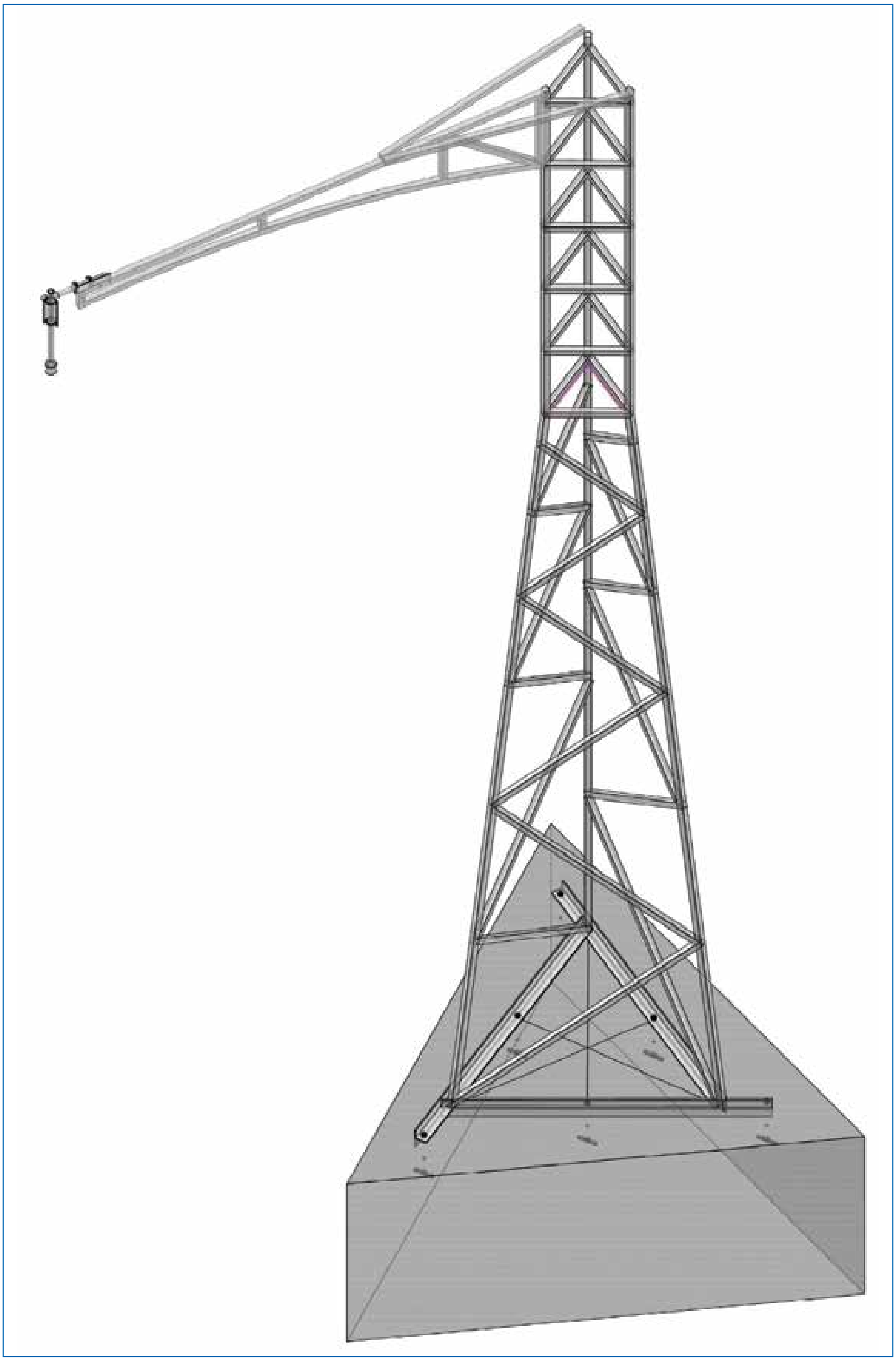
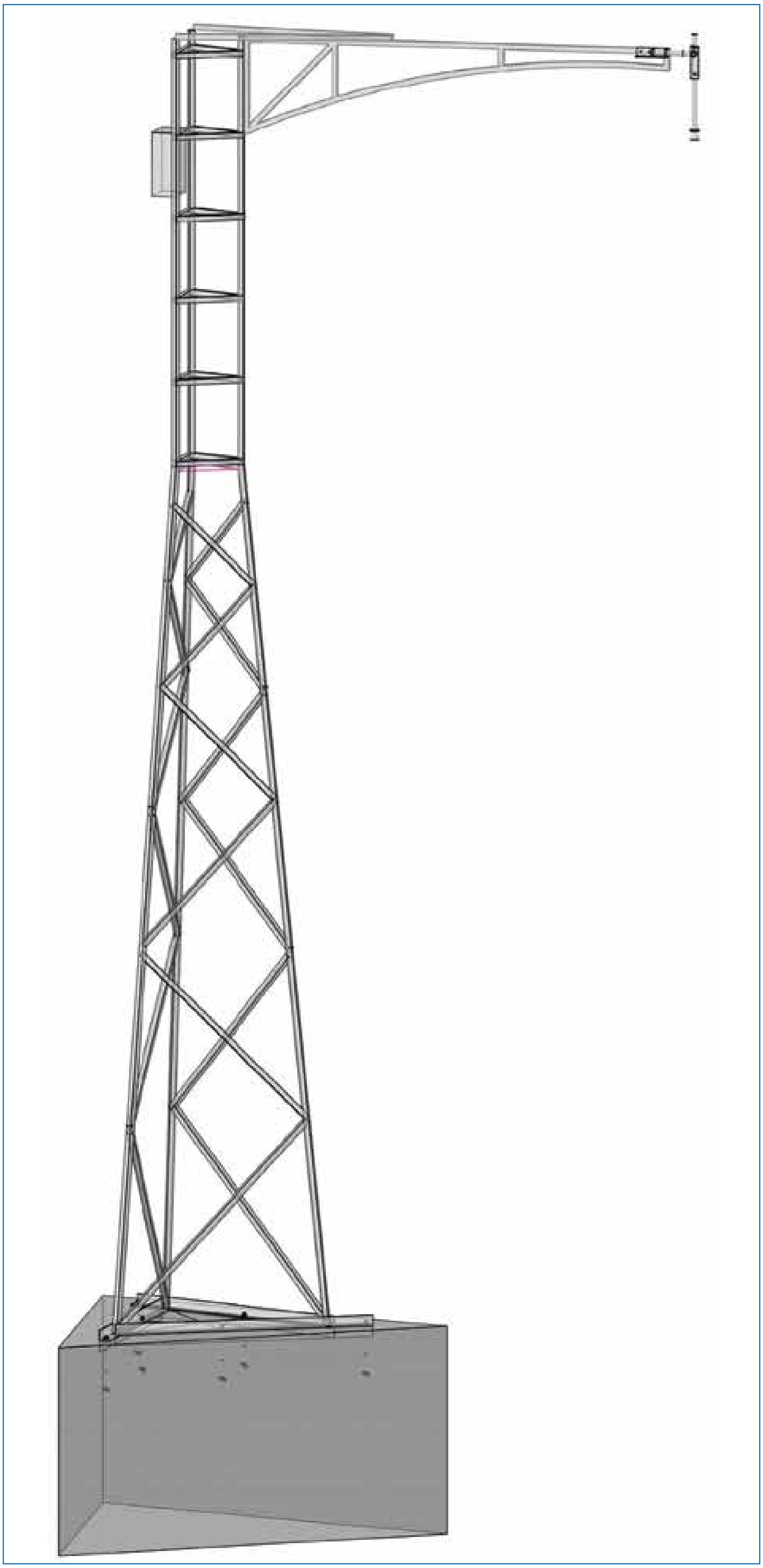


Figure 49: **Support Structure for DA Unit, Side View**



Key points to note with respect to the tower design presented include:

- The foundation is recommended to be of reinforced cement concrete (RCC).
- The foundation is recommended to be an equilateral triangle corresponding to the base of the structure; the triangular shape ensures that the foundation size is minimal.
- The sharp edge of the foundation is recommended to face the opposite direction of the flow of the river to divert water flow and avoid debris collection.
- The height of the sensor-arm structure may require adjustment for the purpose of calibration with respect to the gauge set for the river.
  - For height adjustment greater than 30 cm, the sensor arm can be moved along the vertical section of the tower, up to a total of 2 m.
  - For fine-tuning of height of less than 30 cm, the neck of the sensor housing can be vertically adjusted. (Example of such adjustments can be referred to in the "Calibration of Sensor" section.)
- The sensor housing also allows adjustability in angle – on the plane along the length of the sensor arm and on the plane perpendicular to that of the sensor arm.
- The tower accommodates joints for mounting of antenna and solar panel frames and brackets.

SIM Card for GPRS Activation

For enabling telemetry, a 2G or 3G GSM SIM card with mobile data and internet activated and sufficiently topped up is required. The SIM card is inserted into the device as such:

Step 1: Locate the SIM cardholder on the front face of the GPRS module.

Step 2: Pull backwards on the holder to unlock it. (The direction for opening the holder can be found engraved on the holder itself.)

Figure 50: **GPRS Module SIM Tray Closed and Empty**

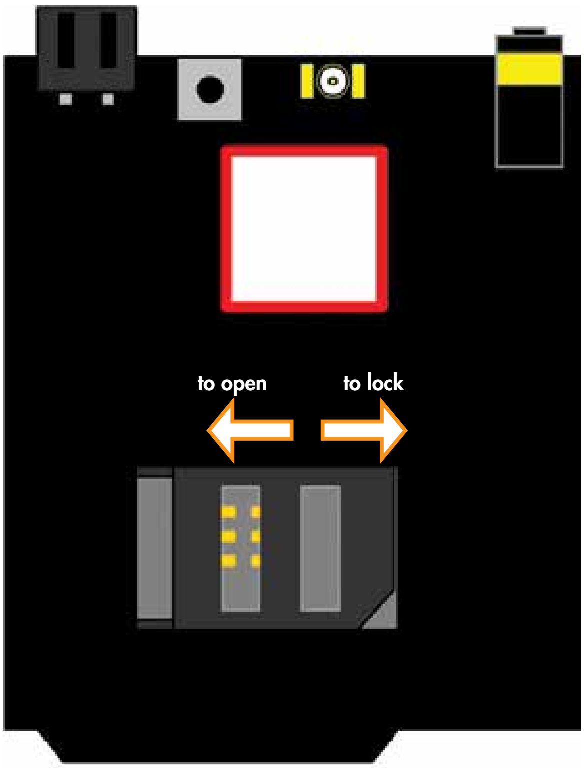
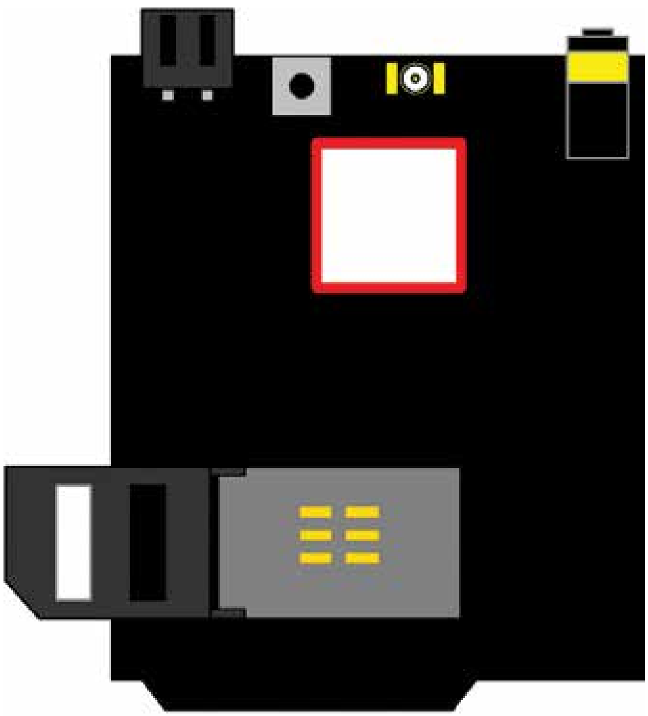
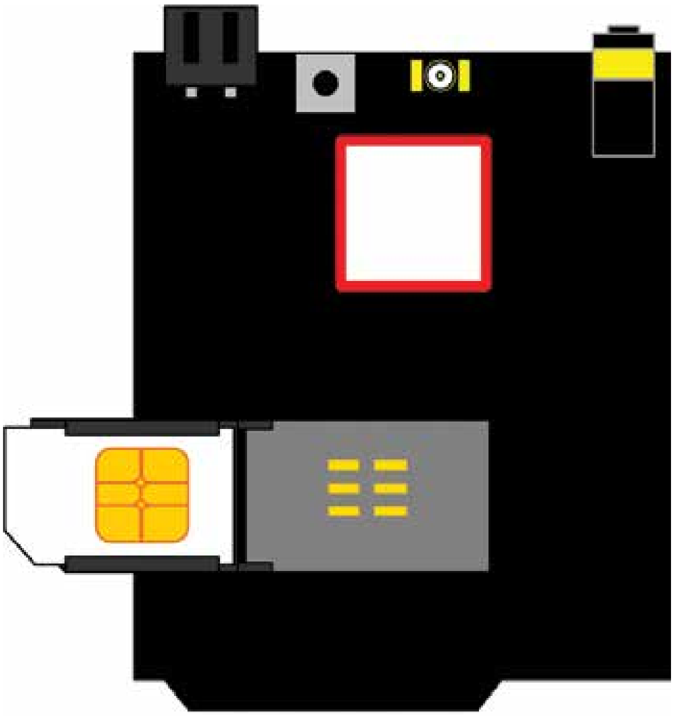


Figure 51: **GPRS Module SIM Tray Open and Empty**



Step 3: Flip over the holder to expose the groove for the SIM card.

Figure 52: **GPRS Module SIM Tray Open and with SIM Card**

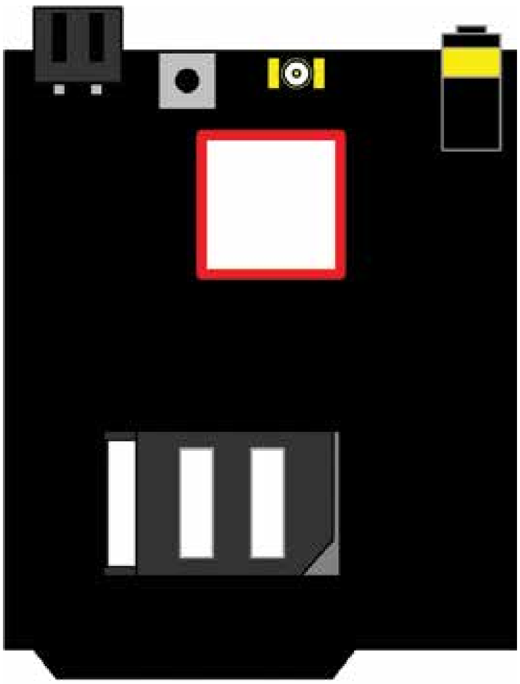


Step 4: Slot the SIM card into the groove path of the holder

Step 5: Flip the holder back into position.

Step 6: Gently press on the holder and push upwards to lock the holder and SIM card into place.

Figure 53: **GPRS Module SIM Tray Closed and with SIM Card**



Step 7: Reposition the GPRS module on to its screw holes if the module was removed for procedure.

Step 8: Insert the screw into a hole and tighten with No. 3 "+" screwdriver. (Slot the screwdriver into the groove and rotate the driver in clockwise direction with its length as axis until the screw is fully tight).

Step 9: Repeat for all other screws.

8.2 Installation Procedures

8.2.1 Setup of Data Upload Unit

The DU Unit should be the first instrument to be set up. It is to be located at the caretaker's house.

Step 1: Equip the GSM module with a sufficiently topped-up 3G-data–enabled SIM card.

Step 2: Connect the two GSM module connectors to the GSM port on the printed circuit board (PCB).

Step 3: Connect the LCD screen connector to the LCD port on the PCB.

Step 4: Connect the siren connector to the siren port on the PCB.

Step 5: Connect the Antenna RPSMA connector to the antenna port on the PCB after completing the "Antenna Setup".

Step 6: Connect the power connector to the power port of the circuit.

Step 7: Connect the battery to the battery port of the charge controller.

Step 8: Connect the solar panel to the panel port of the charge controller.

Step 9: Turn the power switch ON.

Step 10: Once the GSM module LED starts flashing rapidly at about once every second, attach the high-current power cell connector to the GSM module.

Step 11: Observe the BLUE LED on the GSM module for 1 minute – it should flash for 64 mS every 3 seconds. If the LED flashes every second or is lit up continuously after 1 minute, then proceed to "Fault Identification and Rectification: Data Upload Unit".

Step 12: After the GSM module LED is lit up correctly, observe the LCD screen to verify a Welcome statement being displayed on screen. If there is nothing on the screen, then proceed to "Fault Identification and Rectification: Data Upload Unit".

Step 13: Proceed to complete "Setup of Data Acquisition Unit".

Step 14: Wait for the Upload LED indicator on the unit to glow. The water level data should be visible on the Web Page Display, as in Figure 21. The LCD screen should also display the measured water level as "Dep:" and the ID number of that measurement as "Id:", as in Figure 38.

Please refer to "Fault Identification and Rectification: Data Upload Unit" for any anomalies in operations or during setup.

8.2.2 Setup of Data Acquisition Unit

The **DA Unit** should be set up after the data upload unit as it is expected to join the network of the DU Unit radio.

Step 1: Mount the solar panel on to the panel frame.

Step 2: Mount the panel frame on to the main frame facing the direction of maximum solar radiation time. (It is generally south for the northern hemisphere.)

Step 3: Mount the antenna on to the antenna pole following the "Antenna Setup" procedures.

Step 4: Mount the antenna pole on to the main frame such that the antenna is facing the receiver (RX) antenna correctly as stated in the "Antenna Setup".

Step 5: Fix the sensor in the sensor housing and mount the housing on to the sensor arm passing the cable through the appropriate path following the "Sensor Connections" procedures.

Step 6: Connect the sensor connector to the sensor port on the DA Unit PCB.

Step 7: Connect the RPSMA connector of the antenna to the antenna port on the PCB.
(Optionally: connect the data logger plug-in to the plug-in port on the PCB.)

Step 8: Connect the power connector to the power port of the circuit.

Step 9: Connect the battery to the battery port of the charge controller.

Step 10: Connect the solar panel to the panel port of the charge controller.

Step 11: Turn the power switch ON.

Step 12: Wait for the Sensor LED to flash, followed by the flashing of the Transmit LED. The first measured level must have been transmitted to the DU Unit.

Please refer to "Fault Identification and Rectification: Data Acquisition Unit" for any anomalies in operations or during setup.

8.2.3 Setup of GSM Alarm Unit

The GSM alarm unit is to be set up after the DU and DA units.
Note: For the GSM alarm functionality, the option of server alarm trigger or manual trigger must be selected and the development team informed in advance.

Step 1: Equip the GSM module with a sufficiently topped-up 3G-data–enabled SIM card.
Step 2: Connect the two GSM module connectors to the GSM port on the PCB.
Step 3: Connect the loud siren connector into the siren port on the PCB.
Step 4: Connect the power connector to the power port of the circuit.
Step 5: Connect the battery to the battery port of the charge controller.
Step 6: Connect the solar panel to the panel port of the charge controller.
Step 7: Turn the power switch ON.
Step 8: Once the GSM module LED starts flashing rapidly at about once every second, attach the high-current power cell connector to the GSM module.
Step 9: Observe the BLUE LED on the GSM module for 1 minute – it should flash for 64 mS every 3 seconds. If the LED flashes every second or is lit up continuously after 1 minute, then proceed to "Troubleshooting Alarm".

Please refer to "Fault identification and Rectification: Alarm Unit" for any anomalies in operations or during setup

8.3 Checking

Battery Voltage (A)

Step 1: Attach probes on the digital multimeter.
Step 2: Set dial to Voltage DC 20V.
Step 3: Create contact between the corresponding battery terminals and the probes. (Red probe to positive and black to negative.)
Step 4: Take note of the value shown on the multimeter.
Step 5: Compare the voltage with the nominal battery voltage levels: 10 V for 7 Ah lead-acid battery.

Polarity (B)

Important: Polarity inversions are extremely hazardous and will possibly cause immediate PCB damage. Please perform Testing E immediately if polarities are found inverted.
Step 1: Attach the probes to the digital multimeter.
Step 2: Set dial to Voltage DC 20V.
Step 3: Create contact between the probes and the corresponding device terminals.
Step 4: Check for "-" sign appearing on the multimeter display output.
Step 5: Reverse the polarity in case the "-" sign appears.

Continuity (C)

Step 1: Attach the probes to the digital multimeter
Step 2: Rotate the knob of the multimeter to the continuity position. (Generally indicated with a diode "⊣▷⊢" symbol.)
Step 3: Connect the probes to the opposite ends of the wire segment that need to be checked for breakage or discontinuity. For example, the points where a wire is joined..
Step 4: Listen for a continuous beep emitting from the multimeter. If it beeps, then the wire has no breakages and can conduct current through it; it cannot conduct and is broken if no sound is heard.

Siren (D)

Step 1: Power up the unit.
Step 2: Insert the siren audio connector into the siren port of the receiver.
Step 3: Complete the operation of the instrument until the "Alert" LED is continually ON or flashing.
Step 4: Listen for siren ringing corresponding to LED flashing.
Step 5: Replace the siren if the sound is weak or not heard.

Data Acquisition Unit Functionality Check (E)

Step 1: Attach the probes to the digital multimeter.
Step 2: Set dial to Voltage DC 20 V.
Step 3: With the battery connected, check if the GREEN Power LED is ON.
Step 4: Disconnect the battery immediately if the LED is not glowing. It immediately indicates a fault.
Step 5: If the LED is glowing, check to see if either of the Transmit LED or the Sample LED is continuously glowing or flashes in any manner.
Step 6: Continuous glowing of Sample LED would indicate low battery or faulty sensor connection/sensor. Continuous glowing of Transmit LED would indicate improper network or fault in DU Unit. If no LEDs other than the Power LED show any activity upon powering ON, it indicates a fault in TX PCB.

Data Upload Unit Functionality Check (F)

Step 1: Attach the probes to the digital multimeter.
Step 2: Set dial to Voltage DC 20 V.
Step 3: With the battery connected, check if the GREEN Power LED is ON.
Step 4: Disconnect the battery immediately if the LED is not glowing. It immediately indicates a fault.
Step 5: If the LED is glowing, check the LCD screen for the display of "Welcome CBFEWS" message. This indicates that both the processor and LCD are working. An LCD with no glowing screen would indicate it's faulty. Refer to LCD Check (H) if no message is seen. A glowing screen with no message would indicate a faulty processor.
Step 6: Next check if the BLUE LED on the GPRS module is flashing every 3 seconds. The LED being continuously ON or rapidly flashing (64 mS ON and 800 mS OFF; or once every second) indicates a lack of reliable GSM network.
Step 7: With the TX unit fully set up, once a transmission is complete, check if the Receive LED flashes followed by Upload LED after a short while (maybe up to 3 minutes for weaker networks). If the Receive LED doesn't flash, it indicates a radio fault. If the Upload LED doesn't flash, like the Receive LED, it indicates a processor fault.

Alarm Unit Functionality Check (G)

Step 1: Attach the probes to the digital multimeter.
Step 2: Set dial to Voltage DC 20 V.
Step 3: With the battery connected, check if the GREEN Power LED is ON.
Step 4: Disconnect the battery immediately if the LED is not glowing. It immediately indicates a fault.
Step 5: If the LED is glowing, check if the BLUE LED on the GPRS module is flashing every 3 seconds. The LED being continuously ON or rapidly flashing (64 mS ON and 800 mS OFF; or once every second) indicates a lack of reliable GSM network. A lack of network will render the Alarm Unit obsolete. So, it must be moved to a location with good GSM network and RESET.
Step 6: Next the Signal LED should be glowing to indicate that the Alarm Unit is ready to receive and is functional. The failure of the Signal LED to glow would indicate faulty processor.
Step 7: When a message from an appropriate number is sent to the Alarm Unit, check if the Alarm LED is glowing at discrete intervals. If the Alarm LED not responding even with a proper GSM network, it would indicate a system fault.

LCD Check (H)

Step 1: Select a No. 1 "+" screwdriver.
Step 2: Power up the receiver unit.
Step 3: Slot the screw driver into the BLUE adjustment notch on the BLACK I2C adapter.
Step 4: Turn the notch in either direction to see if the "Welcome CBFEWS" message appears.
Step 5: The lack of such a message would mean a faulty processor.

Sensor Functionality (I)

Step 1: Complete Data Acquisition Unit Functionality Check (E).
Step 2: After verifying that the TX PCB is functional, attach the probes to the multimeter and set the dial to Voltage DC 20 V.
Step 3: On the Sensor Terminal Port of the TX PCB, find the small "+" screws visible on the Sensor Connector.
Step 4: With the Negative BLACK probe, touch the leftmost terminal screw below the label GND – short for Ground – of the Sensor Port. (It is usually the Black wire, but always the leftmost wire, going to the sensor.)
Step 5: With the Positive RED probe, touch the terminal screw which is second from the left below the label 3V3 of the Sensor Port. (It is usually the Red wire, but always the wire second from the left, going to the sensor.)
Step 6: Check the multimeter screen for a reading of around "3.3V".
Step 7: Proceed to place the opening of the cup of the sensor over your ear.
Step 8: Listen for a quickly ticking sound. (If no sound is heard, it indicates a faulty sensor.)

9. Operation, Monitoring, Repair and Maintenance

9.1 Operation of the Instruments

Each of the units has a unique operation procedure that goes through numerous processes and provides its own indications to signal that the device is functioning properly.

9.1.1 The Charge Controller

The charge controller is responsible for restoring the charge of the solar rechargeable lead-acid battery via the electrical energy generated from the adjoining solar panel. The charge controller operation is indicated through the INFO LED and BATTERY LED group of 3 LEDs: **RED**, **ORANGE**, and **GREEN**:

1. On connecting the battery, the INFO LED glows RED along with the RED LED of the BATTERY group.
2. After the battery level is detected, the INFO LED glows GREEN and the BATTERY LED glows in accordance with the battery voltage. GREEN indicates an optimally charged battery, ORANGE indicates a moderately charged battery, and RED indicates a minimally charged battery.
3. Once the solar panel is connected, the ORANGE LED starts blinking to indicate that the battery is being charged. The ORANGE LED will however glow continuously if the battery level is moderate and the solar panel is charging the battery from the moderate level.

9.1.2 The Data Acquisition Unit

1. On connecting the battery terminals and the power connector to its port with correct polarity, the GREEN Power LED turns ON.
   Disconnect the power connector immediately if the LED doesn't turn ON, then refer to 8.3 Checking: Polarity (B) and Data Acquisition Unit Functionality Check (E).
2. The Sample LED should light up soon afterwards. It could continue to glow for about a minute due to the training of the ultrasonic sensor for the range employed.
   Continued glowing could indicate improper connections to the sensor or TX PCB damage. Refer to 8.3 Checking: Continuity (C) to check for breakages in sensor wire connections.
3. The lighting up and then going OFF of the Sample LED should be followed by the flashing of the Transmit LED. It could continue to glow for over 5 seconds due to poor RF conditions and difficulty in finding its paired data upload unit radio.
   Note: The setup of the DU Unit must be complete for the data to be sampled and successfully transmitted.
   If the data is not received at the Data Upload Unit after over 5 seconds, then the antenna should be realigned and the sample should be waited for. This could indicate improper antenna connection or alignment, or obstructed line of sight or poor RF conditions. The system could also be reset, but quick resetting should be strictly avoided.
4. The instrument will then proceed to sleep for the next 5 minutes to save power. The procedures will start all over again after 5 minutes.

9.1.3 The Data Upload Unit

1. On connecting the battery terminals and the power connector to its port with correct polarity, the GREEN Power LED turns ON.
   Disconnect the power connector immediately if the LED doesn't turn ON, then refer to 8.3 Checking: Polarity (B) and Data Upload Unit Functionality Check (F).
2. Immediately, the LCD should light up and display the text "Welcome CBFEWS".

3. *If there's no text on the LCD, it could indicate a faulty processor. So, proceed to refer to 8.3 Checking: Data Upload Unit Functionality Check (F)*. Next, the GSM module LED should start flashing. It will start by flashing once about every second which indicates it is searching for network. After connecting the high- current power cell connector, soon the same LED will flash slowly once every 3 seconds which indicates successful network connectivity.
   Continued flashing of the LED once about every second would indicate an inability to find the GPRS network. Proceed to reset the system (turn OFF and then ON again). If the same persists, proceed to relocate to a location with better network coverage and reset the system.
   The system is now ready to receive data and upload the data to the cloud. It is now time to turn ON the DA Unit and wait till it completes its procedures.
   If the DA Unit Transmit LED flashes (i.e., does not glow continuously for over 5 seconds) and nothing is received, it would indicate a faulty radio and the necessity to replace the receiver PCB.
4. Once a valid sample is received, the Data LED will flash and the LCD screen changes to show the sample value as "Dep:___" and its ID as "Id:___".
5. The bottom right of the LCD display will display a number between 0 and 31 which indicates the network strength at the location. It is recommended that the strength be at least 11 for smooth operations.
6. The bottom left will show a sequence going from 1 to 5. The sequence indicates the completion of the necessary procedures for uploading the data to the cloud.
7. In the sequence, after completing 3 and before the appearance of 4, the BLUE LED on the GSM module flashes very rapidly (64 mS ON, 300 mS OFF; i.e., about 3 times in a second).
8. Once the upload is complete, the Upload LED flashes to indicate the same and the GSM module LED returns to flashing once every 3 seconds.
9. When one of the thresholds set for the water level is crossed, the siren starts ringing in the same pattern as that of the Alert LED. The siren rings discretely with short pauses when the warning threshold is crossed, for about a minute, and continuously for about a minute if the danger threshold is crossed.

9.1.4 The Alarm Unit

1. On connecting the battery terminals and the power connector to its port with correct polarity, the GREEN Power LED turns ON.
   Disconnect the power connector immediately if the LED doesn't turn ON, then refer to 8.3 Checking: Polarity (B) and Alarm Unit Functionality Check (G).
2. Soon after the GSM module LED should start flashing. It will start by flashing once about every second which indicates it is searching for network. Soon, the same LED will flash slowly once every 3 seconds which indicates successful network connectivity.
   Continued flashing of the LED once every second would indicate an inability to find the GPRS network. Proceed to reset the system (turn OFF and then ON again). If the same persists, proceed to relocate to a location with better network coverage and reset the system.
3. The system now waits diligently for an incoming message with the correct words which can be received at any undetermined time during its operation. This is indicated by the Signal LED that remains ON.
4. When the correct message is received, the siren rings continuously for a few minutes.
   Once this message is received, the system sets off a long and continuous siren with short breaks in between. This continues for a few minutes and then stops.

9.2 Maintenance of the Instrument

The instrument, as such, requires care and maintenance for longevity of lifetime and effectiveness in operation. For the same, the following points are recommended to be noted and followed:

- External physical impact on any of the instruments is highly discouraged for any reason and care should be taken to not expose the instrument to external impact factors.
- The instruments are recommended not to be subjected to water directly, even though the instruments are built to be waterproof.
- The sensor arm of the DA Unit is recommended not to be subjected to additional weight or external forces to prevent any deformation and misalignment of the sensor.

- Regular cleaning of the instruments to remove dust and foreign particles is recommended for longevity of the instruments' life.
- Timely dusting of the sensor opening is recommended to avoid any external agents occupying the opening.
- Regular cleaning of the photovoltaic panel is highly recommended to maintain efficiency in charging.
- The alignment of the antennas is recommended to be timely checked for external factors forcing their misalignment.

9.3 Fault Identification and Rectification

The equipment has been modified with the most trouble-free mechanism, which entails adapting the integrated PCB system, minimizing wire connections, and implementing a micro controller, which is a reliable modern technology integrated circuit (IC) that uses fewer components. Therefore, the system rarely malfunctions. However, certain circumstances may cause the system to malfunction at times. The trouble-shooting table for each unit explains how to identify and diagnose the problem (Tables 17, 18 and 19).

Reading the Chart

Important: *The chart should be referred to from left to right and top to bottom in order to avoid drastic diagnoses.*

Step 1: Identify the problem. (For example, on the **DA Unit**, the Sample LED might be continuously glowing for more than 1 minute.)

Step 2: Find the description of the problem in the chart. The Problems are listed vertically. (For example, "Sample Light continuously ON for over 1 minute" is the description of the problem mentioned in Step 1.)

Step 3: Go down the column to find the first dotted square. Ignore the dots below the first dotted square for the time being.

Step 4: Check the corresponding possibility of the problem to the right, in the "Possibilities" column. (For example, "Damaged Connections on Sensor" is the most common diagnosis of the problem mentioned in Step 1.)

Step 5: Move further right to the solution for the problem, in the "Solutions" column. (For example, "Checking for Breakages in the wires and reconnecting them" is the solution for "Damaged Connections on Sensor".)

Step 6: If the problem persists, move further down the same column to the next dotted square and repeat Step 4 and Step 5 to address the issue. (For example, if no breakages are found in the wires, then the next possibility is a "Problem with TX PCB" which is indicated by the dotted square further down the same problem description column. The solution recommended for this is checking the functionality of the DA Unit.)

Table 17: **Fault Identification and Rectification Chart for Data Acquisition Unit**

Power LED Off	Charge controller RED lamp glowing	Charge controller no LED glowing	Sample Light continuously ON for over 1 minute	Transmit Light continuously ON for over 5 sec	Sample light not flashing at 5min intervals on TX unit	Possibilities	Solution
●		●			●	Improper Connections	Check all connection joints and screws
							Check all power connections with multimeter
							*Refer 8.3 Checking Continuity (C)
●	●				●	Battery is Low	Check battery voltage
							*Refer 8.3 Checking: Battery Voltage (A)
							Leave battery to charge for a few hours under ample sunlight
●		●				Polarities are inverted	*Refer 8.3 Checking: Polarity (B)
							If the polarities are concluded to be inverted, immediately turn off the power switch
							*Refer 8.3 Checking: Data Acquistion Unit Functionality Check (E)
			●			Damaged Connections on Sensor	Check for breakages in the wire
				●		Antenna misalignment	Correctly align the antenna and then wait for light to go OFF
							*Refer 8.1 Pre-Installation: Antenna Setup & Installation for instructions
				●		Improper Antenna Connection	Make sure the antenna RPSMA jack is fully tightened
							Check for cable breakages or damages to the cable
				●		Incomplete Setup of partner Unit	Complete Setup of Data Upload Unit
							Make sure the Data Upload Unit is ON and functional
							Reset the system
						Problem with Solar Panel	Replace the solar panel and correctly rewire to the charge controller
●		●				Problem with TX charge controller	Check all wiring connections on the charge controller
							Check the polarity of the connections on the charge controller
							Replace the solar charge controller
				●		Problem with radio	Reset the system
							Return the DA Unit PCB.
●			●	●	●	Problem with TX PCB	*Refer 8.3 Checking: Data Acquisition Unit Functionality Check (E)
			●			Problem with the Sensor	*Refer 8.3 Checking: Sensor functionality (I)

Table 18: **Fault Identification and Rectification Chart for Data Upload Unit**

Power LED Off	Charge controller RED lamp glowing	Charge controller no LED glowing	No display on LCD	GSM module LED not flashing very rapidly during number 4 of process sequence (about thrice every second)	GSM module LED rapidly flashing (about once every second)	Receive LED not flashing every 5 minutes	Alarm not ringing	Data not uploaded onto web app	Alarm LED not glowing after thresholds crossed	Data Upload LED not glowing after data is received	Possibilities	Solution
•		•	•								Improper connections	Check all connection joints and screws
												Check all power connections with multimeter
												*Refer 8.3 Checking: Continuity (C)
•	•		•								Battery is Low	Check battery voltage
												*Refer 8.3 Checking: Battery Voltage (A)
												Leave battery to charge for few hours under ample sunlight
			•								Contrast Knob maladjustment	* Refer Tools: Checking: LCD check (H)
•		•	•								Polarities are inverted	*Refer 8.3 Checking: polarity (B)
												If polarities are concluded inverted, immediately turn off the power switch
												* Refer 8.3 Checking: Data Upload Unit Functionality Check (F)
								•		•	Insufficient balance/ expired top-up for phone data	Recharge data balance on SIM card.
				•	•			•		•	Limited Mobile Network in area insufficient to activate data)	Reset the system. (turn it OFF and then ON again)
												turn OFF the system, remove the High-current power cell, wait 1 minute, reattach the cell and turn ON the system again
												Relocate to an area with good cell phone reception and reset the system.
						•					No Line of Sight between antennas	Realign antennas

Power LED Off	Charge controller RED lamp glowing	Charge controller no LED glowing	No display on LCD	GSM module LED not flashing very rapidly during number 4 of process sequence (about thrice every second)	GSM module LED rapidly flashing (about once every second)	Receive LED not flashing every 5 minutes	Alarm not ringing	Data not uploaded onto web app	Alarm LED not glowing after thresholds crossed	Data Upload LED not glowing after data is received	Possibilities	Solution
												*Refer 8.1 Pre-Installation: Antenna Setup for instructions
						•					Improper Antenna Connection	Make sure antenna RPSMA jack is fully tightened
												Check for cable breakages or damages on the cable
											Problem with Solar Panel	Replace the solar panel and correctly rewire to the charge controller
		•									Problem with charge controller	Check all wiring connections on the charge controller
												Check polarity of the connections on the charge controller
												Replace the solar charge controller
							•				Problem with Siren	*Refer 8.3 Checking: Siren (D)
												Replace the Siren.
						•					Problem with Radio	Reset the system (turn it OFF and then ON again)
												Return the Data Upload unit PCB.
•			•			•			•	•	Problem with RX PCB	*Refer 8.3 Checking: Data Upload Unit functionality check (F)

Table 19: **Fault Identification and Rectification Chart for Alarm Unit**

Power LED Off	Charge controller RED lamp glowing	Charge controller no LED glowing	GSM module LED rapidly flashing (about once every second or faster)	Alarm not ringing	Signal LED is not glowing	Alarm LED not Flashing after text message is sent	Possibilities	Solution
•		•		•			Improper Connections	Check all connection joints and screws
								Check all power connections with multimeter
								*Refer 8.3 Checking: continuity (C)
•	•			•			Battery is Low	Check battery voltage
								*Refer 8.3 Checking: battery voltage (A)
								Leave battery to charge for few hours under ample sunlight
•	•			•			Polarities are inverted	*Refer 8.3 Checking: polarity (B)
								If polarities are concluded inverted, immediately turn off the power switch
								* Refer 8.3 Checking: Alarm Unit functionality check (G)
			•		•	•	Limited Mobile Network in area	Relocate to an area with good cell phone reception
							Problem with Solar Panel	Replace the solar panel and correctly rewire to the charge controller
		•					Problem with charge controller	Check all wiring connections on the charge controller
								Check polarity of connections on the charge controller
								Replace the solar charge controller
				•			Problem with Siren	*Refer 8.3 Checking: Siren (D)
								Replace the Siren.
				•	•	•	Problem with Alarm PCB	*Refer 8.3 Checking: Alarm Unit Functionality Check (G)

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