# Annex 21 Operations manual (Operations and maintenance)

Multi-country Project Advancing Early Warnings for All (EW4All)

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# INTRODUCTION

## What is an O&M Plan and why is it required

This Operations and Maintenance (O&M) Plan provides an overarching framework for the O&M of hydrometeorological observation network assets to be installed and operated as part of the Multi-country Project Advancing Early Warnings for All (EW4All). The plan seeks to be compliant with and to complement the international regulatory and guidance material of the World Meteorological Organisation (WMO). It describes the operations and maintenance of all systems necessary for the monitoring, forecasting and early warning of all hydrometeorological variables. The components and configuration of systems set up in the different countries participating in the project will vary. The plan therefore describes a typical hydrometeorological system and its daily and routine operation and maintenance procedures. Additionally, it provides procedures for record keeping and emergency response. This plan is meant to provide an overarching system description which will be further detailed in each country O&M plans. The country specific O&M plans will be living documents which are an essential reference and guidance for the respective NMHS to operate and maintain the hydrometeorological observing network and relevant ICT equipment to ensure its highest operational availability and reliability. All project O&M activities should follow guidance in the Environment and Social Codes of Practice (ESCOP) and should be aligned with the environmental and social safeguards put in place as part of project implementation.

## Objectives

The main objective of an O&M Plan is to achieve an overall operational availability of ≥95% in the observing and dissemination network. O&M Plan seeks to ensure that all O&M activities are implemented following the procedures, processes and instructions defined in the user manuals and guides of the observing systems and related components for the operation and maintenance. The Plan will also guide the O&M activities which fall within the warranty conditions of equipment manufacturers or service providers and ensure that these are carried by the related contractors. The O&M Plan will need to be reflected in any contracts that are used to engage with third parties for O&M services and should clearly define which elements of the O&M plan will be covered by the contractor.

It needs to be noted that hydrological equipment manufacturers and/or suppliers provide detailed O&M manuals and supporting documents as part of the equipment being supplied. These documents are an integral part of the O&M plan as they provide detailed and equipment model/make specific information on procedures and best practices to be followed for operation, calibration, testing and maintenance of the equipment. Most of the user manuals include specific instructions on trouble-shooting malfunctions and errors.

Other objectives of the O&M Plan are to:

1. Ensure sustainable, efficient and reliable operation of the observing, transmission and dissemination systems.
2. Improve the data quality of the observations collected from the observing network.
3. Use available resources efficiently by reducing operational costs.
4. Extend the life cycle of the observing systems.
5. Prepare and update the metadata of the observing systems.
6. Manage the spare part inventory.
7. Enhance capacities of relevant staff in O&M.
8. Determine and implement safety and security precautions.
9. Refine existing method and tools and evolve new ones tailored to local conditions.
10. Provide the evidence to justify allocation of resources for the operation of the observing and dissemination network.
11. Adopt and implement the international regulations and recommendations on observing systems.

## What are the components of an O&M Plan and who implements these

The main elements of an O&M Plan are listed below and described in subsequent sections:

1. A comprehensive list of equipment which need to be operated and maintained by the relevant agencies:
    a. The observation network by the NMHS
    b. The communication and dissemination network by the NDMA for disasters (both slow and fast onset) along with relevant sectoral agencies such as agricultural services and water resources agencies, education, transport etc.
    c. Community based sensors and alarm systems by respective communities
2. Resources needed for the O&M of the above, including:
    a. Human resources and their technical capacities and skills

   b. Financial resources and
   c. Technical resources and equipment such as tools and equipment for field installation, calibration, maintenance, repair and replacement
   d. Logistical resources
3. Standard operating procedures and protocols to be followed for O&M with clear definition of roles. These would include:
   a. Instructions for the operations and maintenance of each component of the equipment and guidance for troubleshooting and minor repairs, including software related errors. Operations and maintenance are presented as separate sub-sections and include calibration equipment and tools required for O&M.
   b. Management of spare parts and the inventory
   c. Safety and precautions.
4. Training and capacity building of relevant staff
5. Reporting on O&M activities
6. Documents, manuals and reference materials applicable to the above.

## LIST OF EQUIPMENT AND COMPONENTS TO BE CONSIDERED UNDER THE O&M PLAN

The components of the different elements of a MHEWS under the EW4All project will vary considerably by country as they include earlier installations and reflect the resources and technical capacities available in the different countries. The list provided here is therefore generic in nature.

### The observation network

7. Different combinations of sensors and equipment are used across meteorological, agro-meteorological, hydrometeorological stations and offshore weather buoys or ocean climate stations. The components and equipment in these stations varies based on degree of automation and systems used for data transmission, storage or recording. Synoptic stations collect data at six hourly periods.

The elements that are observed at a surface observing station are listed below. Each of these is described in detail in the WMO guide[1]:

- Temperature
- Soil temperature
- Atmospheric pressure
- Relative humidity
- Wind direction and speed
- Precipitation
- Snow cover
- Solar radiation and/or sunshine
- Visibility
- Evaporation
- Present weather
- Past weather
- Cloud amount
- Cloud type
- Cloud-base height

Agro-meteorological stations would additionally require sensors to track soil moisture and temperature and air temperature and humidity.

Observation stations can be operated manually or have different degrees of automation and data handling capabilities. The latter includes automatic sensors with analogue or digital loggers and automatic with digital loggers and telemetry units for transmission. The O&M therefore also needs to cover the management of records, manual or digital, and where relevant, digitisation of records, storage and archival of digital files including regular update of

[1] https://library.wmo.int/viewer/68695/download?file=8_I-2023_en.pdf&type=pdf&navigator=1

digital storage devices and the management of telemetry systems which may require regular subscriptions and payments for services by data and telecommunication providers.

Some observation stations require specialized equipment, precautions, highly trained staff and specialized facilities for their O&M. Costs of these operations can be substantive, some examples are below:

Hydrological stations may require construction of weirs or flumes and regular profiling of stream/rivers in order to develop and update the rating curves so that stream/river stage (or height) can be used to derive discharge rates. Reaching such stations can be logistically difficult, particularly during times of flood, when the frequency of required readings is higher.

Logistics of O&M of off-shore observation stations such as buoys are also complex. These O&M operations usually require the use of sea-worthy vessels and operation of diving equipment by trained staff.

In the case of hydrosondes, the use of highly inflammable hydrogen and their launching and landing using balloons and parachutes requires high degrees of safety and the use of specialized equipment including gas detectors, alarms and personnel protection equipment.

Finally, in the case of weather radars, and lightening detection systems, their operation involves round the clock staff. The former additionally require dedicated facilities.

### The communication and dissemination

A MHEWS requires efficient communication of climate information products and services including early warnings, advisories and triggers for early and anticipatory action. In the case of slow onset disasters, this is usually done through channels such as radio, television and social media, however for rapid onset disasters, systems such as cellular broadcasts across emergency channels, SMS systems, sirens and other alarm systems may be utilised. These are typically managed by the National Disaster Management Agencies (NDMA) and operated at Emergency Coordination and Operations Centres (ECOC) which are located at national and sub-national levels. This document only deals with the ECOC, while acknowledging that line ministries may also send out alerts and advisories through a variety of dissemination channels and extension/ground staff. The latter often involve telecommunication providers, including both government owned and privately operated radio, television and cell phone/data service providers. These agencies may additionally operate dashboards and portals for rapid communication to target groups via some of these channels.

Most of the equipment pertaining to these systems resides with public or private service providers in the different telecommunication agencies. However ECOCs are often additionally equipped with VHF and/or UHF radio receivers and associated antennae, satellite radios and transponders (to locate critical assets and personnel). Some ECOCs, particularly in centralised locations are additionally equipped with live data feeds from multiple sources. Furthermore, some areas may have remotely controlled alarm systems and sirens.

All of this equipment requires regular O&M, such as recharging and replacement of batteries and renewal of data subscriptions and services which may be sourced from private providers.

### Community based sensors and alarm systems

Community Based Early Warning Systems (CBEWS) have an important role in MHEWS, particularly in areas vulnerable to rapid onset disasters, regions with gaps in observations, poor communication network or limited capacities of NMHS to provide tailored services. These systems are typically tailored to the local situation and comprise of sensors which are triggered by a threshold to set of a warning or alarm. They are therefore coupled with a communication and/or alarm module and may also transmit data to a central server.

The O&M of CBEWS systems can include frequent calibration, cleaning and regular checks on battery power and transmission, if relevant. It is important that these systems are regularly tested to confirm they are operational as they can be prone to vandalism and damage. The responsibility for the O&M of these systems typically resides with the local Disaster Management Committee (DMC) but may also involve local extension and civil protection agencies, security agencies and NGOs.

## RESOURCES

A number of resources are required for the implementation of an O&M Plan. These need to be planned and allocated annually based on an assessment of O&M operations required by the O&M Plan. These resources are:

### Financial resources

Implementing the O&M Plan requires financial resources to cover travel and DSA of staff for field work, parts, testing and calibration equipment and consumables such as chemicals, balloons (for radiosondes). Financing needs to coincide with the planned O&M activities for which an annual budget needs to be prepared. A sample of the components of a cost analysis has been provided in Annex 1, Table 1 to Table 9 .

### Human resources and their technical capacities and skills

Implementation of an O&M plan requires a sufficient number of qualified and well trained staff, many of who need to operate in remote locations. A table of the human resources available in the different NMHS divisions (national and sub-national) needs to be developed which describes the staff and their responsibilities for O&M. A sample structure has been provided in Annex 2, Table 10. Typical staff roles include:

1. Heads of observatories (national, sub-national) to coordinate the O&M operations
2. Observers for observatories
3. Field hydrologists for stream-flow measurements
4. Maintenance staff

### Technical resources

An O&M Plan requires investment in tools and equipment for field installation, calibration, maintenance, repair and replacement of parts. There are often associated costs of transportation of this equipment and of field staff and, in some cases, mobile calibration vans have been found to be economical. Typical equipment and tools required are:

- Data Collection and Archiving System (usually sited in the ICT centre)
- Network Monitoring and Operating Terminal (ICT centre)
- Calibration Laboratory (mobile or stationary)
- Test and maintenance tool set
- Field calibration set
- Acoustic Doppler Current Profiler
- Universal Current Meter
- Handheld Flow Tracker
- High sensitivity EC meter (for salt dilution gauging)
- Carboy (for salt dilution gauging)

### Logistic resources

O&M operations require substantial logistic support and resources. These include:

- Rooms for the staff for field work
- Room for the operation and maintenance equipment, spare parts and consumable items
- Specially designed and equipped ICT room for servers and terminals
- Buildings for radiosonde operations, including specially designed and equipped rooms for hydrogen generators
- Cars for transportation
- Boats for stream-flow measurements and off-shore observations

## STANDARD OPERATING PROCEDURES AND PROTOCOLS

This section describes the standard operating procedures and protocols that need to be followed for O&M of equipment and for associated activities field work.

### Operations of the Observing System

The objective of the O&M of the observation network is to operate and provide data from all observing systems continuously. A critical component of this system is the Data Collection and Archiving System (DCAS) which collects, processes, archives and disseminates the data from the entire network. The DCAS is usually operated at a central level with support from ICT experts.

The observation network is monitored using the Network Monitoring and Operating Terminal (NMOT) which is also centrally located and is used for planning and implementing maintenance activities. The NMOT provides real-time status information about the observing systems, including whether components are functioning correctly and availability of the data. The NMOT also generates visual and audio alarms to flag problem with the systems in the network, furthermore it includes features for management of the spare part inventory. It needs to be noted that the manufacturer of the equipment usually provides an expected rate of failure for equipment which needs to be considered in the O&M Plan as it has direct bearing on the supply of replacement parts and inventory.

### Manual meteorological observing stations

Operation of the manual meteorological observing stations is usually the responsibility of regional observatories. The technical regulations, manuals and guidance materials of the WMO need to be adopted and implemented in the preparation and implementation of the observation process. The procedures for observations need to be prepared by the headquarters and implemented by the observing stations.

The observers in the manual meteorological observing stations make the observations, prepare the meteorological messages and relay them to the central facility of the NMHS. They are responsible for changing the diagrams of the available drum recorders in the stations such as thermograph, hydrograph and barograph.

Synoptic observations need to be made on 3 hourly basis in the stations, and sent to the NMHS centre by SMS, internet or telephone. If there are less than 3 observers, the observations can be made during daylight hours. The basic steps to be followed during the synoptic observation process are as follows:

1. Read the measured data required for the synoptic observations from the available instruments in the station for measuring wind speed and direction, air temperature and humidity, air pressure, precipitation and daily amount of radiation.
2. Manually observe for cloud coverage, cloud type, cloud height, visibility, present weather.
3. Calculate the parameters of dew point and mean sea level pressure by using measured parameters.
4. Prepare the synop code and check the consistency of the parameters, if there is a mistake make the correction.
5. Record the synop code in the monthly synoptic observation notebook.
6. Send the synop message to the NMHS centre (SMS, internet, telephone).
7. Check if the synop message received by the NMHS centre, if not resend.

Climatological observations need to be made at 3 hourly intervals starting at 15:00 GMT on previous day, and ending at 12:00 GMT of the present day. The data recorded in the climatological observing notebook and needs to be submitted to the NMHS centre at the end of each month. Meteorological posts are required to make the climatological observations twice a day at 15:00 GMT on the previous day and at 03:00 GMT on the present day. The basic steps to be followed for climatological observation process are as follows:

1. Read the measured data for the climatological observations from the available instruments in the station. This includes wind speed and direction, air temperature and humidity, air pressure, precipitation, daily amount of radiation, daily amount of sunshine duration.
2. Make the human observations for cloud cover, cloud type, cloud height, visibility, present weather.
3. Calculate the parameters of dew point and mean sea level pressure by using measured parameters.
4. Record the data in the monthly climatological observation notebook.
5. Send the climatological data records to the NMHS centre on monthly basis.

### Manual hydrological observing stations

Operation of the manual hydrological observing stations is the responsibility of regional observatories. The technical regulations, manuals and guidance materials of the WMO need to be adopted and implemented in the preparation and implementation of the observation process. The processes for the observations need to be prepared by the headquarters and implemented by the observing stations.

The observers in the manual hydrological observing stations make the water level measurements twice a day at 08:00 and 20:00 local time, and send the measured values to the NMHS centre by SMS. The frequency of observations needs to be increased during increased flows which may cause floods downstream. In addition, regular measurements to contribute to the rating curve are to be made at least every 2 months and more frequently based on the local conditions such as changes in stream profile. Instantaneous discharge measurements using salt dilution gauging may also be considered. These observations are to be made by staff trained staff assigned to these tasks by the central and the regional observatories.

### Automatic weather stations

Automatic weather stations (AWS) will be operated round the clock. The observational data will be sent to the NMHS centre on hourly basis via GSM. The data transmission frequency may be increased during periods of inclement weather or extreme weather events. This is to be done by the users in the NMHS centre, e.g. forecasters, maintenance staff, and the frequency could be increased to one or ten minute intervals. The data from the automatic weather stations is to be collected, processed, archived and disseminated by the data collection and archiving system. The expected operational life of an AWS is a minimum of 15 years with necessary maintenance and upgrades during the operation of the systems.

### Automatic hydrological stations

Automatic hydrological stations (AHS) are operated round the clock. The observations are to be sent to the NMHS centre on hourly basis via GSM. The data transmission frequency can be increased during periods of high flow and is to configured by the users in the NMHS centre, e.g. forecasters, maintenance staff. It can be adjusted to one to ten minutes. The data from the automatic hydrological stations is to be collected, processed, archived and disseminated by the data collection and archiving system.

In addition, regular measurements to contribute to the rating curve are to be made at least twice a year and more frequently during the initial set-up to capture the different stages (heights) and subsequently based on the local conditions such as changes in stream profile. Instantaneous discharge measurements using salt dilution gauging may also be considered. These observations are to be made by staff trained staff assigned to these tasks by the central and the regional observatories. The expected operational life of an AHS is a minimum 15 years with necessary maintenance and upgrade during the operation of the systems.

### Upper air observing stations

6. Upper air observing stations need to be operated by the related regional observatories to make the observations at certain times, i.e. 00 and 12 GMT. The expected life cycle of the upper air observing systems is minimum 15 years with necessary maintenance and upgrade during the operation of the systems. An example of the steps followed for the operation of a radiosonde are provided in Annex 9.

Radiosonde stations need special safety and security precautions to avoid the accidents and minimise the risks during the operation. Annex 10 provides a list of the basic precautions.

### Weather Radars

Radars are operated on 24/7 basis by the radar operation centre. Scanning strategies depending on the seasons and weather conditions are to be defined in coordination with forecasting division and implemented by the staff in the radar centre. The products will be generated and distributed to the related divisions in the headquarters and regional observatories. The data from the radars operated by the other agencies will be used to generate composite products.

The data from the rain gauges and disdrometers are to be used for the calibration of the radars. The weather radars are to be operated in accordance with the user manuals/guides provided by the manufacturer or supplier. The expected life cycle of the weather radars will be minimum 25 years with necessary maintenance and upgrade during the operation of the systems.

### Lightning Detection System

Lightning detection system (LDS) are to be operated on 24/7 basis. The data from the lightning detection sensors is to be collected and processed in the NMHS centre for generation of products which are to be distributed to the related divisions in the headquarters and regional observatories. The operation of the lightning detection system is to be made in accordance with the user manuals/guides provided by the manufacturer or supplier. The expected life cycle of the LDS is 20 years with necessary maintenance and upgrade during the operation of the systems.

### ICT Equipment in the ICT centre

ICT equipment, DCAS and NMOT, are to be operated on 24/7 basis by the ICT experts and operation and maintenance staff. DCAS is responsible for the tasks of collecting, processing, archiving and disseminating of the observational data. NMOT systems are to be used as a web based tool for real time status monitoring of the observing network, making remote maintenance, planning, implementing, recording and monitoring maintenance activities, following upcoming maintenance and calibration of the systems, and managing the spare part inventory.

## Maintenance of the Observation Network

Regular maintenance activities within the scope of the maintenance policy will be planned and implementedIn order to keep the systems in the observing network in operation. Maintenance intervals, and activities to be carried out will be defined for each system component in accordance with user manuals/guides provided by the manufacturers or suppliers.

There will be three basic components of the maintenance policy;

1. Preventive maintenance Preventive maintenance will be planned and implemented in scheduled periods regularly in accordance with the user manuals/guides. The preventive maintenance requirements and the activities to be carried out will be defined for each system separately.
2. Corrective maintenance Corrective maintenance activities will be carried out to fix failures in the systems and to repair faulty units. In case of any failure, the faulty unit will be repaired in the site or at the maintenance centre.

3. Calibration Calibration of the measuring instruments in the observing network will be performed by implementing either of:
    a. Laboratory calibration

    Calibration of the sensors will be performed by bringing them to the laboratories operated in accordance with IEC/ISO 17025, General requirements for the competence of testing and calibration laboratories. During the calibration process, transfer functions and offset values will be determined to implement in the AWS for the adjustment of the sensors. Regional Instrument Centres (RIC) of WMO or any laboratory complying with above-mentioned standard and providing the traceability can be used for making the required calibrations.

    a. Field calibration

    Field calibration will be performed for certain instruments, i.e. pressure, air temperature and humidity, solar radiation, precipitation sensors by using the field calibration equipment.

It should be noted that although field calibration can be performed for some of measuring instruments in the network, these instruments will also be calibrated in the laboratory in defined intervals for ensuring the traceability. In order to minimize travel to field sites, spares and equipment required for O&M work should be kept with the field teams, particularly during site visits. It is possible to significantly improve efficiencies by diagnosis of problems with the observation stations ahead of the visits either remotely or through local resources. This will ensure the correct equipment and spare/replacement parts needed for maintenance are taken to the sites during the field visits.

Maintenance activities to be carried for observing systems are described below:

### Manual meteorological observing stations

Maintenance activities in the manual observing stations will be carried out as follows:

<u>Preventive maintenance</u>

1. Daily maintenance
    - Checking and cleaning the instruments, e.g. cleaning of rain gauge, checking if there is a breaking of the liquid column in the mercury-based instruments, will be made by the observers.
    - Checking the drum recorders by the observers
    - If needed, cutting the grass in the observing garden by the observers or a hired worker
    - Reporting to the maintenance staff in the regional observatories if any instrument in fail and not possible to be fixed by the observers
2. Six month-and yearly maintenance
    - Visiting the stations twice a year by the maintenance staff
    - Checking operational status of the instruments in the station by the maintenance team
    - Checking the computer, data transmission equipment and power supplies
    - Making test and control of the instruments by using field test equipment by the maintenance team
    - Cleaning and painting the fences and radiation shields by the observers or a hired worker
    - Checking and recording the siting exposure conditions of the observing station (metadata records) by the observers or maintenance staff
    - Checking data transmission equipment and power supplies in the station
    - Recording all information of the process in the NMOT by the maintenance staff

<u>Corrective maintenance</u>

Any failure in the manual meteorological observing stations can be fixed in two ways:

1. Locally
    - Simple failures will be fixed by the observers, e.g. changing the pens of drum recorders, fixing the breaking liquid column, etc.
    - Failures not to be fixed by the observes will be fixed by the maintenance team in the regional observatories, in case of any need by getting support from the experts in the NMHS centre.
    - Recording all information of the process in the NMOT by the maintenance team.
2. Remotely
    - If there is a possibility of remote access to the stations, failures will be analysed and fixed by experts from the NMHS centre.
    - Recording all information of the process in the NMOT by the maintenance team.

### Calibration

Calibration of the instruments will be made by using a field calibration set in the field or bringing the instruments to a calibration laboratory. The calibration interval for each instrument is defined in accordance with the user manuals/guides of the manufacturers or suppliers.

## Manual hydrological observing stations

### Preventive maintenance

- Daily check of the scale used for the water level measurements in the manual hydrological observing stations will be made by the observers.
- Observers are required check and report if there is any change in the cross-section of the river in the measuring area. If so, the stream profile will need to be measured again and a new rating curve prepared.

### Corrective maintenance

- If the measuring scale is broken or not suitable for measurements, it will be replaced with a new one.
- If the installation position or platform of the measuring scale are destroyed, the problem will be fixed by the observers or maintenance staff.

## Automatic weather stations

### Preventive Maintenance

Regular maintenance activities are to be planned and implemented for AWSs. Site visits by the maintenance staff need to be scheduled as at least twice a year with an interval of 6 months. Additionally, NMOT in the NMHS centre will be used for daily monitoring of the status of the observing systems in the network, checking the system components, and if needed, carrying out remote activities for intervention to the systems. Basic and simple preventive activities for the AWSs installed in the manned stations will be carried out by the observers in the station. Table 11 provides and example for testing AWS sensor while the basic maintenance activities for the AWS are provided in Table 12.

1. Daily maintenance
   - Daily monitoring and checking the status of the AWS via NMOT from the NMHS centre
   - Making remote interventions for basic preventive activities
   - Checking the data transmission, if needed, carrying out any task for ensuring the availability of the data
   - If it is a manned station, daily checking and cleaning of the instruments, data transmission equipment and computers in the station by the observers
2. 6 month-and yearly maintenance (by the maintenance staff)
   - Checking and cleaning of the instruments
   - Checking data transmission equipment, computers (in the manned stations) and power supply units
   - System performance tests including sub-unit and sensors
   - Checking grounding and lightning protection
   - Field calibration, and adjustment if necessary
   - Repairing of any faulty unit, if possible, in the field
   - Cleaning and painting the fences and radiation shields by the maintenance staff or a hired worker
   - Checking and recording the siting exposure change of the observing station (metadata records) by the maintenance staff
   - Checking the ground of the observing garden, if needed, cutting the grass (by a hired worker)

### Corrective maintenance

Any failure in the AWS is to be addressed in two ways:

1. Locally
   - Minor failures are to be repaired by local maintenance staff, if needed, with remote support from maintenance experts in the NMHS centre.
   - More complex failures are to be fixed by the maintenance experts by visiting the sites.
   - The faulty units irreparable in the field are to be repaired in the maintenance centre having suitable conditions and equipment for such activities.
2. Remotely

- Diagnosis activities will be carried out by remote access from the NMHS centre to fix the failures of the observing systems in the field.
- Service application mode or built-in test equipment (BITE) tool of the AWSs will be used for remote corrective maintenance actions.

#### Calibration

Calibration intervals of the sensors are to be defined in accordance with the user manuals/guides of the sensors provided by the manufacturers or suppliers. Field calibration of the sensors will be made by using the field calibration set. If needed, an adjustment process will be implemented after the calibration. Laboratory calibration of the sensors will be made in the laboratories operated in accordance with relevant standards. An example of calibration intervals for different sensors is provided in Table 13. It should be noted that:

1. Calibration intervals are to be determined by considering the manufacturer recommendations.
2. Field calibrations need to be made by trained maintenance staff.
3. Laboratory calibrations should be made in the laboratories operated according to ISO 17025.
4. Adjustments need to be made by the maintenance staff in the field by using relevant transfer functions and offset values.

### Automatic hydrological stations

#### Preventive Maintenance

Regular maintenance activities are to be planned and implemented for automatic hydrological stations. Site visits by the maintenance staff should be scheduled as at least twice a year with an interval of 6 months. NMOT in the NMHS centre should be used for daily monitoring of the status of the observing systems in the network, checking the system components, and if needed, carrying out remote activities for intervention to the systems. An example of basic maintenance activities of hydrological stations is provided in Table 14.

1. Daily maintenance
    - Daily monitoring and checking the status of the automatic hydrological stations via NMOT from the NMHS centre
    - Making remote interventions for basic preventive activities
    - Checking the data transmission, if needed, carrying out any task for ensuring the availability of the data
    - Generating maintenance reports in NMOT
2. Six month-and yearly maintenance (by the maintenance staff)
    - Checking the alignment of the water level sensors
    - Checking the data logger, data transmission equipment and power supply units
    - Field calibration, and adjustment if necessary
    - Repairing of any faulty unit, if possible, in the field
    - Checking and recording the siting exposure change of the observing station (metadata records)

#### Corrective maintenance

Any failure in the AWS can be repaired by two ways:

1. Locally
    - Minor failures will be repaired by local maintenance staff, if needed, with remote support from maintenance experts in the NMHS centre.
    - More complex failure which need more expertise to address will be fixed by the maintenance experts by visiting the sites.
    - The faulty units irreparable in the field will be repaired in the maintenance centre having suitable conditions and equipment for such activities.
2. Remotely
    - Diagnosis activities will be carried out by remote access from the NMHS centre to fix the failures of the observing systems in the field.
    - Service application mode or built-in test equipment (BITE) system of the automatic hydrological stations will be used for remote corrective maintenance actions.

### Calibration

The calibration of the water level sensors will be made in accordance with the user manuals/guides provided by the manufacturers or suppliers at the recommended frequency.

## Upper air observing stations

### Preventive Maintenance

Upper air observing (radiosonde) stations require a high degree of caution as there is a risk of explosion and burning due to hydrogen. It is therefore very important to carry out maintenance of these systems daily and annually in accordance to the O&M Plan. Table 15 provides an example of a form to be filled during maintenance of radiosonde stations.

1. Daily maintenance
   - Checking the fire detection panel by the staff on duty
   - Checking the gas detection panel by the staff on duty
   - Checking the water conductivity value in the generator during balloon inflation by the staff on duty
   - Checking the water level in the hydrogen and oxygen discharge cans by the staff on duty
   - Implementing the instructions for station safety and balloon inflation by the staff on duty
   - Daily monitoring and checking the status of the stations via NMOT from the NMHS centre
   - Making remote interventions for basic preventive activities
   - Checking the data transmission, if needed, carrying out any task for ensuring the availability of the data
   - Generating maintenance reports in NMOT
2. 6 month-and yearly maintenance (by the maintenance staff)
   - Checking the hydrogen generator
   - Checking the ground receiving station, antennas, computer, data transmission equipment and power supply units
   - Checking grounding and lightning protection
   - Repairing of any faulty unit, if possible, in the field
   - Checking and recording the siting exposure change of the observing station (metadata records)

### Corrective maintenance

Any failure in the radiosonde stations will be repaired by two ways:

1. Locally
   - Minor failures will be repaired by local maintenance staff, if needed, with remote support from maintenance experts in the NMHS centre.
   - More complex failure which need more expertise to address will be fixed by the maintenance experts by visiting the sites.
   - The faulty units irreparable in the field will be repaired in the maintenance centre having suitable conditions and equipment for such activities.
2. Remotely
   - Diagnosis activities will be carried out by remote access from the NMHS centre to fix the failures of the observing systems in the field.
   - Service application mode or BITE system of the radiosonde stations will be used for remote corrective maintenance actions.

### Calibration

Calibration of the radiosonde equipment will be made before starting the launching by comparing with the data from the meteorological observing stations.

## Weather Radars

### Preventive Maintenance

Weather radars are complex and high technology systems with the electric, electronic, mechanical and microwave components. Regular preventive maintenance will be defined and implemented for all these components to operate the system properly. Table 16 provides an example of a form for maintenance of weather radars.

1. Daily maintenance

- Daily monitoring and checking the status of the stations via NMOT from the NMHS centre
- Making remote interventions for basic preventive activities by using BITE system
- Checking the data transmission, if needed, carrying out any task for ensuring the availability of the data
- Generating maintenance reports in NMOT

2. 6 month-and yearly maintenance (by the maintenance staff)
   - Checking indicators of each system component
   - Checking grounding and lightning protection
   - Carrying out the activities defined in the radar maintenance form
   - Repairing of any faulty unit, if possible, in the field
   - Checking and recording the siting exposure change of the radar (metadata records)

### Corrective maintenance

Failures in the radar systems are to be addressed locally or remotely based on the severity:

1. Locally
   - Minor failures will be repaired by local maintenance staff, if needed, with remote support from maintenance experts in the NMHS centre.
   - More complex failure which need more expertise to address will be fixed by the maintenance experts by visiting the sites.
   - The faulty units irreparable in the field will be repaired in the maintenance centre having suitable conditions and equipment for such activities.
2. Remotely
   - Diagnosis activities will be carried out by remote access from the NMHS centre to fix the failures of the observing systems in the field.
   - BITE system of the radars will be used for remote corrective maintenance actions.

### Calibration

Calibration of the radars is to be done by following the instructions in the user manuals/guides provided by the manufacturer/supplier of the radar. Calibration process will cover the antenna position, performance characteristic parameters of the transmitter, receiver and signal processor. Furthermore, the constants a and b of Marshall-Palmer equation ($Z = aRb$), which expresses the relationship between the rainfall rate (R) and reflectivity factor (Z), will be determined by using the long-term statistics of the radar data and precipitation measurements from rain gauges.

## Lightning Detection System

### Preventive Maintenance

Lightning detection systems are passive remote sensing systems with fewer maintenance needs.

1. Daily maintenance
   - Daily monitoring and checking the status of the stations via NMOT from the NMHS centre
   - Making remote interventions for basic preventive activities by using BITE system
   - Checking the data transmission, if needed, carrying out any task for ensuring the availability of the data
   - Generating maintenance reports in NMOT
2. 6 month-and yearly maintenance (by the maintenance staff)
   - Checking antennas, processer unit, cabling, communication equipment and power supply units in the field
   - Checking the processing unit of the lightning data in the NMHS centre
   - Repairing any faulty unit, if possible, in the field
   - Checking and recording the siting exposure change of the lightning sensor (metadata records)

### Corrective maintenance

Failures in the radar systems are to be addressed locally or remotely based on the severity:

1. Locally
   - Minor failures will be repaired by local maintenance staff, if needed, with remote support from maintenance experts in the NMHS centre.

- More complex failure which need more expertise to address will be fixed by the maintenance experts by visiting the sites.
- The faulty units irreparable in the field will be repaired in the maintenance centre having suitable conditions and equipment for such activities.

2. Remotely
    - Diagnosis activities will be carried out by remote access from the NMHS centre to fix the failures of the observing systems in the field.
    - BITE system of the radars will be used for remote corrective maintenance actions.

Calibration

Performance test and improvement of the data quality will be made by using the algorithms developed specially for the system by the manufacturer.

**ICT Equipment**

Preventive Maintenance

ICT equipment will be used as the tools for the operation and maintenance network with the maintenance needs for them, too. Table 17 provides an example form for tracking the maintenance of the ICT equipment. The ICT equipment functions need to be checked on a daily basis by its operators. Regular maintenance is to be done twice a year with an interval of 6 months by the ICT experts or EIEC or the third party contractor. These checks should evaluate the system performance and analyse the log files to determine whether the hardware or software are functioning properly and to clean the hardware where needed.

Corrective maintenance

Any faulty unit are to be repaired or replaced by the ICT experts or EIEC or the third party contractor.

### Management of spare parts, calibration equipment and tools required for O&M.

Spare parts and consumable items will be provided for each sub-system for sustainable and efficient operation of the observing network. Management of the spare part inventory will be an important component of the O&M Plan, and will be performed as follows:

- The NMOT will have the feature of registering, following and managing the all spare parts in the observing network.
- All spare parts and consumable items will be registered with their names, brands, models and serial numbers in the NMOT.
- Any activity regarding the spare parts and consumable items will be recorded in the NMOT.
- The sufficient spare parts and consumable items will be available in the spare part warehouse in the NMHS centre and in the regional observatories.
- The MTBF values, calibration intervals, storage life and operational conditions of the systems will be considered for determining the amount of the spare parts to be stocked.
- The annual use and storage life of the consumable items will be considered to get them in the warehouse.
- It is recommended that at least 25% of each system component under operation should be kept as spare in the warehouse of the GHMD. For example, if there are 80 wind speed sensors under operation in the observing network, 20 wind speed sensors should be available in the warehouse.
- The spare parts and consumable items should be delivered to the regional observatories by considering the number and types of the systems they have been operating.

### Safety and precautions

Safety and security precautions need to be taken during the implementation of O&M Plan. Component specific safety and precautions have been provided in the relevant sections. In addition, all national regulation for occupational health and safety need to be followed as they are applicable to all activities undertaken during the implementation of the O&M Plan. In addition, specific safety and security measures and instructions defined in the user manuals/guides of the systems provided by the manufacturers or suppliers need to be adhered to.

## TRAINING AND CAPACITY BUILDING OF RELEVANT STAFF RESPONSIBLE FOR O&M INCLUDING:

Training for staff responsible for the operation and maintenance of the observing network will be provided in an ongoing manner. To this end, training packages with detailed curriculum are to be prepared and implemented. Additionally, manufactures or suppliers of the systems will be required to provide training to the staff on the operation and maintenance of the systems.

A training of the trainers programme for the staff in the NMHS centre of the GHMD is also suggested to ensure continued availability of qualified experts on the observing systems. These experts will give training to the technical staff in the regional observatories. Annual assessment need to be made on the qualification and training needs of the operation and maintenance staff, training programmes will be prepared and implemented based on the results of that assessment.

Training programmes specifically need to cover the following:

- Operation and maintenance of the equipment
- Safety and precautions.
- Field methods where relevant.

## REPORTING ON O&M ACTIVITIES

Table 8 onwards in the Annex provides examples of the types of reports that are to be filed during the implementation of the O&M Plan. In addition to these, the following types of reports need to be designed and provided:

### Schedules

Detailed calendars and schedules of maintenance operations need to be provided and updated on a regular basis. These need to be available to all staff responsible for coordination of O&M activities. A sample is provided in Table 1.

### Field records and notes

Staff engaged in field work as part of the O&M activities need to maintain clear field records and notes which include the following details:

1. Name of component/equipment, for e.g. automatic weather station.
2. Name and identification of the station/component: this should be a unique code which identifies both the type of the equipment and the component.
3. Type of station, for example synoptic, manual, automatic.
4. Location of site, including coordinates if remotely located.
5. Date of visit.
6. Observations: specific observations taken during the field visit. These can include photographs.

The field staff may be encouraged to use electronic notes using tools such as Kobo collect for taking notes. However a field register which summarises the above is also recommended.

### Checklists of actions performed

This refers to the sample tables provided in the annexes.

### Status reports

Status reports may be required for long or complex field missions. These should summarise the issues addressed and provide recommendations based on the observations made during the field visit.

## DOCUMENTS, MANUALS AND REFERENCE MATERIALS

Suggested references for the O&M Plan include public policy documents for the relevant country and existing regulations pertaining to O&M and use of hydrometeorological equipment, occupational health and safety as well as any social and environmental standards which may be applicable. This O&M Plan builds on existing laws, rules and practices and is pursuant to these.

The World Meteorological Organisation (WMO) e-Library is a rich resources for documentation spanning standards, guidelines, manuals and best practices. All documents listed below can be downloaded from this e-library by searching for their names and numbers. Key recommended documents are:

- Technical Regulations (WMO-No. 49), Geneva, Switzerland
- Manual on Codes (WMO-No. 306) Geneva, Switzerland
- Manual on WIGOS (WMO-No.1160), Geneva, Switzerland
- Manual on WMO Information System (WMO-No.1060), Geneva, Switzerland
- Manual on Stream Gauging (WMO-No.1044), Geneva, Switzerland
- Manual on the Global Observing System (WMO-No. 544), Geneva, Switzerland
- Guide to Hydrological Practices (WMO-No.168), Geneva, Switzerland
- Guide to Climatological Practices (WMO-No. 100), Geneva, Switzerland

- Guide to Meteorological Instruments and Methods of Observation (CIMO Guide, WMO-No.8), Geneva, Switzerland
- Guide to WMO Information System (WIS) (WMO-No.1061), Geneva, Switzerland
- WIGOS Metadata Standard (WMO-No.1192), Geneva, Switzerland

In addition, documents provided by the manufacturers and service providers are critical to the implementation of the O&M Plan as they are specific to the model and make of the equipment and often provide information on software (firmware) updates, troubleshooting and replacement of parts prone to wear and tear.

- User manual/guide for Automatic Weather Stations
- User manual/guide for the Automatic Hydrological Stations
- User manual/guide for the Radiosonde Stations
- User manual/guide for the Hydrogen Generator
- User manual/guide for the Weather Radars
- User manual/guide for the Lightning Detection Systems
- User manual/guide for the field calibration equipment
- User manual/guide for the maintenance and test equipment
- User manual/guide for the Network Monitoring and Operation Terminal
- User manual/guide for the Data Collection and Archiving Server
- Operation procedures, process, instructions and forms
- Maintenance procedures, process, instructions and forms

## ANNEXES

### Annex 1: Cost Analysis

Table 1. Sample of schedule for calculation of annual O&M costs. Use the sub-totals from tables 2 to 9 to fill in costs per visit. Note that costs under table 2 for travel may include multiple stations.

| Year | Units to be serviced & Travel | Cost Per Visit | Frequency (number of trips per month) | | | | | | | | | | | | Total Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | J | F | M | A | M | J | J | A | S | O | N | D | |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| | Sub Total | | | | | | | | | | | | | | |

Table 2. Travel and associated costs. Note that some of the costs may not be applicable and also need to be adjusted by the number of visits per year and the number of units that are serviced during each trip. Costs of O&M for different equipment and stations may be grouped based on those serviced by the same team during a single trip

| S/N | Item | Unit Price (USD) | Quantity | Total (USD) |
|---|---|---|---|---|
| 1 | DSA per staff member | | (# staff) | |
| 2 | Vehicle rental costs if applicable | | (# vehicles) | |
| 3 | Fuel costs per vehicle | | (# vehicles) | |
| 4 | Service/repair of vehicle if applicable | | (# vehicles) | |
| 5 | Cost of driver if applicable | | (# vehicles) | |
| 6 | Accommodation costs if applicable (usually not paid | | (# staff) | |

| S/N | Item | Unit Price (USD) | Quantity | Total (USD) |
|---|---|---|---|---|
| | if DSA is covered) | | | |
| | Sub Total | | | |

Table 3. Cost analysis of automatic weather stations

| S/N | Parts | Unit Price (USD) | Quantity | Total (USD) |
|---|---|---|---|---|
| 1 | Data Collection Unit | | | |
| 2 | Air temperature and humidity sensor | | | |
| 3 | Radiation Shield | | | |
| 4 | Precipitation sensor (weighing type) | | | |
| 5 | Wind Speed and Direction Sensor (Ultrasonic) | | | |
| 6 | Pressure sensor | | | |
| 7 | Soil temperature sensor | | | |
| 8 | Soil moisture sensor | | | |
| 9 | Snow depth sensor | | | |
| 10 | Snowwater equivalent sensor | | | |
| 11 | Present weather sensor | | | |
| 12 | Global Solar radiation sensor | | | |
| 13 | Sunshine duration sensor | | | |
| 14 | Wind Mast | | | |
| 15 | Power units | | | |
| 16 | Communication Units | | | |
| | Sub Total | | | |

Table 4. Cost analysis for hydrologic stations

| S/N | Parts | Unit Price | Quantity | Total |
|---|---|---|---|---|
| 1 | Data Collection Unit | | | |
| 2 | Water level sensor | | | |
| 3 | Universal Current Meter | | | |
| 4 | Acoustic Doppler Current Profiler | | | |
| 5 | Hand held flow tracker | | | |
| 6 | Power units | | | |
| 7 | Communication Units | | | |
| | Sub Total | | | |

Table 5. Cost analysis for manual upper air observing system

| S/N | Parts | Unit Price | Quantity | Total |
|---|---|---|---|---|
| 1 | Radiosonde | | | |

| S/N | Parts | Unit Price | Quantity | Total |
|---|---|---|---|---|
| 2 | Balloon | | | |
| 3 | Operational Cost (Hydrogen) | | | |
| 4 | Spare parts for hydrogen generator | | | |
| | Sub Total | | | |

Table 6. Cost analysis for automatic launching system for upper air observing system

| S/N | Parts | | | |
|---|---|---|---|---|
| 1 | Radiosonde | | | |
| 2 | Balloon | | | |
| 3 | Operational Cost (Helium) | | | |
| 4 | Spare parts for system | | 1 | |
| | Sub Total | | | 363,750 |

Table 7. Spare parts for weather radars

| S/N | Item | Units | Unit Price | Total |
|---|---|---|---|---|
| 4.1 | Magnetron tube | | | |
| 4.2 | Solid state pulse transmitter module | | | |
| 4.3 | Protection units | | | |
| 4.4 | Servo Driver AZ | | | |
| 4.5 | Servo Driver EL | | | |
| 4.6 | CanBus modules | | | |
| 4.7 | Low Noise Amplifier | | | |
| 4.8 | TR Limiter | | | |
| 4.9 | Other spare parts | | | |
| | Sub Total | | | |

Table 8. Maintenance Tools and Test Equipment

| S/N | Item | Units | Unit Price | Total |
|---|---|---|---|---|
| 5.1 | Field test equipment (air temperature and humidity, pressure) | | | |
| 5.2 | Field test equipment (solar radiation) | | | |
| 5.3 | Field test equipment (data logger) | | | |
| 5.4 | Laptop for field applications | | | |
| 5.5 | Tool set for maintenance (Cutter, allen set, screwdriver, crescent wrench, open ended wrench, wrench set, cable stripper, etc.) | | | |
| 5.6 | Multimeter | | | |
| 57 | Ground Resistance Meter | | | |
| | Sub Total | | | |

Table 9. Operation and Maintenance of Observing Network

| S/N | Item | Number of items | Unit Price | Total Cost |
|---|---|---|---|---|
| 1 | Maintenance staff | ## staff (provide breakup across sites) | (annual cost per staff) | |
| 2 | Staff for discharge measurements | ## staff (provide breakup across sites) | (annual cost per staff) | |
| 3 | Observers in the manual stations | ## staff (provide breakup across sites) | (annual cost per staff) | |
| 4 | IT expert | ## staff (provide breakup across sites) | (annual cost per staff) | |
| 6 | AWS Network | ## visits/station × ## staff × ## days | ## USD per visit | |
| 7 | Hydro Network | ## visits/station × ## staff × ## days | ## USD per visit | |
| 8 | Radar Network | ## visits/station × ## staff × ## days | ## USD per visit | |
| 9 | Upper Air Network | ## visits/station × ## staff × ## days | ## USD per visit | |
| 10 | Site visits for corrective maintenance | ## visits/station × ## staff × ## days | ## USD per visit | |
| 11 | Discharge measurements | ## visits/station × ## staff × ## days | ## USD per visit | |
| 12 | hydrological stations | ## visits/station × ## staff × ## days | ## USD per visit | |
| 13 | Calibration of the sensors | ## visits/station × ## staff × ## days | ## USD per visit | |
| 14 | ICT Equipment for observing network management | ## visits/station × ## staff × ## days | ## USD per visit | |
| 15 | Training of the staff for O&M | ## staff × ## days | ## USD per day | |
| | Total | | | |

## Annex 2: Staff requirement

Table 10.Staff requirement for O&M of observation networks

| Name of Centre: | Existing | Additional Requirement |
|---|---|---|
| Observer | | |
| Staff for Maintenance | | |
| Staff for stream flow measurements | | |
| Staff for ICT | | |
| Total for staff | ` | |

## Test and control form for automatic weather stations

Table 11.Test and control form for automatic weather stations

| S/N | Sensors | Reference Device | | | | | Test Sensor | | | | Deviation | Maintenance Action | Remark |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Brand | Model | Sl. No. | Uncertain | Measure | Brand | Model | Sl. No. | Measure | | | |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | ty | ment value | | | | ment value | | | |
| 1 | Air Temperature | | | | | | | | | | | | |
| 2 | Relative Humidity | | | | | | | | | | | | |
| 3 | Precipitation | | | | | | | | | | | | |
| 4 | Wind Speed | | | | | | | | | | | | |
| 5 | Wind Direction | | | | | | | | | | | | |
| 6 | Air Pressure | | | | | | | | | | | | |
| 7 | Soil Moisture (20 cm) | | | | | | | | | | | | |
| 8 | Soil Moisture (50 cm) | | | | | | | | | | | | |
| 9 | Soil Temperature (5 cm) | | | | | | | | | | | | |
| 10 | Soil Temperature (10cm) | | | | | | | | | | | | |
| 11 | Soil Temperature (20 cm) | | | | | | | | | | | | |
| 12 | Soil Temperature (50 cm) | | | | | | | | | | | | |
| 13 | Soil Temperature (100 cm) | | | | | | | | | | | | |
| 14 | Global Solar Radiation | | | | | | | | | | | | |
| 15 | Snow Depth | | | | | | | | | | | | |
| 16 | Other | | | | | | | | | | | | |

## Annex 3: Maintenance form for automatic weather stations

Table 12.Maintenance form for automatic weather stations

| | Equipment/Unit | Activity | Finding/Status | Remark/Action |
|---|---|---|---|---|
| 1 | Data Collection Unit | 1. Check the operational status | | |
| | | 2. Check the data availability from the sensors | | |

| | Equipment/Unit | Activity | Finding/Status | Remark/Action |
|---|---|---|---|---|
| | | 3. Check all cable connections and connectors | | |
| 2 | Air temperature and humidity sensor | 1. Check the availability of the sensor data | | |
| | | 2. Clean the sensor filter | | |
| | | 3. Clean the radiation shield | | |
| 3 | Precipitation | 1. Check the availability of the sensor data | | |
| | | 2. Emptying the collecting bucket | | |
| | | 3. Check the position and alignment of the sensor | | |
| | | 4. Check the anti-freeze for winter conditions | | |
| | | 5. Check the heaters (if available) | | |
| 4 | Pressure | 1. Check the position of the sensor in the DCU | | |
| | | 2. Check the availability of the sensor data | | |
| 5 | Wind speed and direction | 1. Check the availability of the sensor data | | |
| | | 2. Check the position and alignment of the sensor | | |
| | | 3. Check any foreign matter or obstacle in the cavity of the sensor | | |
| 6 | Solar radiation | 1. Check the availability of the sensor data | | |
| | | 2. Check the position and alignment of the sensor | | |
| | | 3. Check and clean the glass dome (any moisture inside glass dome) | | |
| | | 4.Check the silicagel (white or pink) | | |
| 7 | Soil temperature | 1. Check the availability of the sensor data | | |
| | | 2. Check the position and alignment of the sensor | | |
| 8 | Soil moisture | 1. Check the availability of the sensor data | | |
| | | 2. Check the position and alignment of the sensor | | |
| 9 | Snow depth | 1. Check the availability of the sensor data | | |
| | | 2. Check the position and alignment of the sensor | | |
| 10 | Snow-water equivalent | 1. Check the availability of the sensor data | | |

| | Equipment/Unit | Activity | Finding/Status | Remark/Action |
|---|---|---|---|---|
| | | 2. Check the position and alignment of the sensor | | |
| 11 | Road condition sensor (remote sensing) | 1. Check the availability of the sensor data | | |
| | | 2. Check the position and alignment of the sensor | | |
| | | 3.Check and clean the optic surface of the sensor | | |
| 12 | GSM Antenna and communication equipment | 1. Check the antenna and position | | |
| | | 2. Check the data transmission | | |
| 13 | Mains | Check the mains voltage and connections | | |
| 14 | Solar Panel | Check the conditions and position of the solar panels | | |
| 15 | Batteries | Check the battery voltage | | |
| 16 | Obstruction light | Check the obstruction light | | |
| 17 | Wind mast and tilting unit | 1. Check the wind mast and connection stay wires | | |
| | | 2.Check the tilting unit, lubricate if needed | | |
| 18 | Grounding resistance | 1.Check the grounding rod and cabling | | |
| | | 2. Measure the grounding resistance | | |
| 19 | Environmental conditions | 1. Observe the siting exposure | | |
| | | 2. Observe ground of observing garden | | |
| 20 | Other | | | |

## Annex 4: Calibration schedule for sensors

Table 13.Calibration schedule for sensors

| | SENSORS/INSTRUMENTS | FIELD CALIBRATION (YEAR) | LABORATORY CALIBRATION (YEAR) |
|---|---|---|---|
| 1 | Air temperature and humidity | 1 | 3 |
| 2 | Pressure | 1 | 5 |
| 3 | Wind speed | N.A | 2 |
| 4 | Wind direction | N.A. | 2 |
| 5 | Precipitation | 1 | 5 |
| 6 | Solar radiation | 1 | 5 |
| 7 | UVA/B radiation | 1 | 5 |
| 8 | Soil temperature | N.A. | 3 |
| 9 | Snow depth | 1 | 5 |
| 10 | Mercury barometer | 1 | 5 |
| 11 | Mercury thermometer | 1 | 3 |

| | SENSORS/INSTRUMENTS | FIELD CALIBRATION (YEAR) | LABORATORY CALIBRATION (YEAR) |
|---|---|---|---|
| 12 | Data Collection Unit (Data Logger) | 3 | 10 |

## Annex 5: Maintenance form for hydrological stations

Table 14.Maintenance form for hydrological stations

| S/N | Equipment/Unit | Activity | Finding/Status | Remark/Action |
|---|---|---|---|---|
| 1 | Data Collection Unit | 1. Check the operational status | | |
| | | 2. Check the data availability from the display | | |
| | | 3. Check all cable connections and connectors | | |
| 2 | Water Level Sensor | 1. Check the operational status | | |
| | | 2. Check the alignment and position | | |
| 3 | GSM Antenna and communication equipment | 1. Check the antenna and position | | |
| | | 2. Check the data transmission | | |
| 4 | Solar Panel | Check the conditions and position of the solar panels | | |
| 5 | Batteries | Check the battery voltage | | |
| 6 | Grounding resistance | 1.Check the grounding rod and cabling | | |
| | | 2. Measure the grounding resistance | | |
| 7 | Environmental conditions | 1. Observe the siting exposure | | |
| | | 2. Observe if any deformation in the river bed | | |
| 8 | Other | | | |

## Annex 6: Maintenance form for upper air observing stations (radiosonde)

Table 15.Maintenance form for upper air observing stations (radiosonde)

| S/N | Equipment/Unit | Activity | Finding/Status | Remark/Action |
|---|---|---|---|---|
| 1 | Hydrogen Generator | 1. Cleaning electrolytic residue with hot water, vinegar or lemon juice | | |
| | | 2. Checking electrolytic liquid, adding or changing if necessary | | |
| | | 3. Checking the humectant unit, changing or adding it if necessary | | |
| | | 4. Checking the humectant unit tube valves | | |
| | | 5. Adjusting the balancing and compensating membranes as | | |

| S/N | Equipment/Unit | Activity | Finding/Status | Remark/Action |
|---|---|---|---|---|
| | | needed | | |
| | | 6.Checking the de-mineralised water filters and resin, changing them if needed | | |
| | | 7.Cleaning of external and internal cooling units | | |
| | | 8. Checking the hydrogen gas line and safety valves (check valves) | | |
| | | 9.Cleaning the Hydrogen and Oxygen discharge cans with hot water, lemon juice or vinegar | | |
| | | 10.Measurement and control of the grounding resistance of balloon inflator room grounding knob and balloon inflator adapter | | |
| 2 | Ground Receiving System | 1. Checking antennas, cables and connector connections | | |
| | | 2. Measuring the grounding resistance value of the antennas | | |
| | | 3. Checking ground test equipment | | |
| | | 4. Checking computer and system functionality | | |
| 3 | Gas detection and fire extinguishing system | 1.Checking connections and sockets on the gas detection panel | | |
| | | 2.Checking the battery of the gas detection panel | | |
| | | 3.Testing the gas detection sensor | | |
| | | 4.Checking the gas detection alarm system | | |
| | | 5. Checking connections and sockets on the fire detection and extinguishing panel | | |
| | | 6.Checking the battery of the fire detection and extinguishing system | | |
| | | 7.Control and cleaning of fire detection sensors | | |
| | | 8. Checking the fire detection alarm system | | |
| | | 9.Checking fire detection and extinguishing panel grounding | | |
| | | 10.Cleaning the discharge nozzle | | |
| | | 11.Testing the solenoid valve on the carbon dioxide tubes | | |
| | | 12.Checking the connections and expiration dates in carbon dioxide tubes | | |
| | | 13.Checking the emptiness or fullness of carbon dioxide tubes | | |

| S/N | Equipment/Unit | Activity | Finding/Status | Remark/Action |
|---|---|---|---|---|
| | | 14.Checking the manual discharging latch on the carbon dioxide tubes | | |
| 4 | Helium system | 1. Checking the regulator and regulator inlet-outlet valves | | |
| | | 2.If necessary, adjusting the outlet pressure | | |
| | | 3.Checking the manometers | | |
| | | 4.Checking the seals at the whips | | |
| | | 5.Checking the tightness in gas lines and whips | | |
| | | 6.Checking the cylinder head valves | | |
| | | 7.Checking the tube expiration dates | | |
| 5 | Other | | | |

## Annex 7: Form for maintenance of weather radar

Table 16.Maintenance form for weather radar

| S/N | Equipment/Unit | Activity | Finding/Status | Remark/Action |
|---|---|---|---|---|
| 1 | Radome | 1. Visual check of radome panels from inside and outside | | |
| | | 2. Visual check of the obstruction light | | |
| | | 3.Visual check of the lightning rods on the radome | | |
| | | 4. Visual check of the waveguides through radar tower | | |
| 2 | Antenna | 1. Visual check of the antenna | | |
| | | 2. Check the antenna pedestal panel | | |
| | | 3. Check the oil level of the antenna | | |
| | | 4. Check the BITE information of the antenna | | |
| | | 5. Make the LED indicator tests | | |
| | | 6.Check the rotation bearings and make the grease lubrication | | |
| | | 7.Check the azimuth and elevation gear box, and make the lubrication | | |
| | | 8.Check the servo motors functions and voltage values | | |
| | | 9. Check the antenna position and implement the sun tracking test and calibration | | |
| | | 10. Make the antenna speed tests | | |

| S/N | Equipment/Unit | Activity | Finding/Status | Remark/Action |
|---|---|---|---|---|
| 3 | Transmitter | 1. Visual check of the transmitter cabinet, indicators and warnings | | |
| | | 2. Check the BITE information of the transmitter | | |
| | | 3. Check the voltage and current values of the test points, and power generating units in the transmitter | | |
| | | 4. Measure the RF Power | | |
| | | 5. Check the ventilators | | |
| | | 6. Check the air filters | | |
| 4 | Receiver | 1. Visual check of the receiver, display, indicators and warnings | | |
| | | 2.Check the BITE information of the receiver | | |
| | | 3.Measure the voltage and current values of the test points | | |
| | | 4.Measure the receiver gain | | |
| | | 5. Measure the RF signal and RF Power | | |
| | | 6. Determine the receiver response curve | | |
| | | 7. Measure the minimum detectable signal | | |
| | | 8.Measure the voltage and current values of the test points | | |
| | | 9.Make the ZAUTO calibration | | |
| 5 | Signal processor | 1. Visual check of the signal processor, display, indicators and warnings | | |
| | | 2. Check the configuration values of the signal processor | | |
| 6 | Environmental Equipment | 1. Check the oil generators | | |
| | | 2. Check the uninterrupted power supplies | | |
| | | 3. Check the air conditioners | | |
| 7 | Grounding and lightning protectors | 1. Check the lightning protection system | | |
| | | 2. Measure the grounding resistance | | |
| 8 | Other | | | |

## Annex 8: Maintenance form for ICT equipment

Table 17.Maintenance form for ICT equipment

| S/N | Activity | Finding/Status | Remark/Action |
|---|---|---|---|
| 1 | Visual check of the ICT system | | |

| S/N | Activity | Finding/Status | Remark/Action |
|---|---|---|---|
| | room | | |
| 2 | General cleaning of the system | | |
| 3 | Visual check of the hardware | | |
| 4 | Occupancy check of the system hard disk | | |
| 5 | Check if any unit in fail | | |
| 6 | Check the CPU workload | | |
| 7 | Check the system memory (RAM) | | |
| 8 | Check the KVM switch and monitors | | |
| 9 | Check the network devices and connections | | |
| 10 | Check the software for the performance | | |
| 11 | Check the log files | | |
| 12 | Take the back-up of the log files | | |
| 13 | Take the back-up of the system software and data files | | |
| 14 | Check and change the passwords | | |
| 15 | Other | | |

## Annex 9: Basic steps to be followed during the radiosonde observation process

1. Touch hands to the copper plate for electrostatic discharge in the entrance of the hydrogen generator and balloon inflating room.
2. Check the safety and security precautions in the hydrogen generator room.
3. Wear the personal protective equipment.
4. Run the hydrogen generator by following the instructions defined in the user manual of the manufacturer.
5. Check the balloon for any tear and hole, and if found in good condition, inflate the balloon with hydrogen by following the instructions in the user manual of the manufacturer. Helium can be used as a back-up in the event of a problem with the hydrogen generation.
6. Prepare the radiosonde, activate the computer of ground receiving system for observation.
7. Make the ground test of radiosonde with the air temperature, humidity and pressure data from the meteorological station, and activate the radiosonde. If the radiosonde has failed, prepare failure report and use another radiosonde.
8. Check the data of radiosonde, ensure the data transmission on the computer.
9. Connect the radiosonde and parachute to the balloon.
10. Take out launching module (radiosonde, balloon and parachute) and wait for 2 minutes at the outside for the adaption of the radiosonde to environmental conditions.
11. Release the launching module to the atmosphere at the observation time (generally 30 minutes before exact observation time; i.e. 23.30 and 11.30 UTC).
12. Enter the air temperature, humidity, pressure, wind and cloud coverage data to the computer.
13. Monitor the launching from the computer.
14. Terminate the launching in normal conditions at 10 hPa level (if launching is terminated before 400 hPa, repeat the launching by using a new launching module).
15. Generate the TEMP code and BUFR code on the computer.
16. Send the TEMP and BUFR messages to the NMHS centre by the computer.

Check if the messages received by the NMHS centre.

## Annex 10: List of basic precautions to be taken while operating a radiosonde

1. The hydrogen generator and balloon inflation room will be equipped with hydrogen gas detectors, flame detectors, automatic fire extinguishing system, audio and visual alarm generating equipment.
2. There will be a cooper plate for electrostatic discharge in the entrance of the hydrogen generator and balloon inflation room
3. No one but on-duty staff must enter the hydrogen generator and balloon inflation room.
4. The staff on duty will touch their hand the copper plate for discharging the static electric on him/her before entering the room.
5. The staff on duty should not enter the balloon inflating room with flammable, burning and explosive materials such as mobile phones, lighters, cigarettes and matches.
6. The staff on duty will wear the personal protection equipment before starting to inflate the balloon.
7. Hydrogen generator should be operated by following the instructions defined in the user manual of the manufacturer.
8. There should be no intervention while there energy and pressure are available in the system during the preventive and corrective maintenance of the hydrogen generator. If intervention is required, energy should be cut and pressure should be relieved.
9. In case of leakage (liquid, gas, melt etc.) in the hydrogen generator and gas lines, the system should not be operated, the environment should be ventilated and the maintenance team should be informed for the intervention.
10. Balloon inflation adaptor should be grounded and ground resistance, which must be less than 5 ohms, should be measured periodically.
11. Balloons with tears and holes should never be used and if the balloon is inflated, it should be left outside in a controlled manner.
12. If there is any alarm from the gas detection system, the room should be ventilated, the main switch should be turned off from the hydrogen generator panel and the maintenance team should be informed.
13. In case of any false alarm generated by the gas detection system, the maintenance team should be informed.
14. The fire extinguishing system will be activated automatically in the event of a fire in the hydrogen generator room. Staff in the room must immediately vacate and go to a designated safe area to avoid exposure to the fire and fire extinguishing gas. The maintenance team should be informed.
15. When making connection to the helium tubes, the gaskets should be renewed and the tubes should be put into operation one by one. Empty tube valves should be closed.
16. Valves should be opened slowly as the helium tubes are under high pressure (200 bars).
17. Helium tubes should be mounted vertically in place, the heads of unused tubes should be attached.
18. Helium Tubes must be fitted with protection chains and protection whips.
19. Helium tubes beyond the expiration date should not be used.
20. Since it is not safe to keep the balloon inflated, the balloon should be inflated close to the observation hour.
21. After the balloon is released to the atmosphere, the room must be locked and kept closed.
22. Explosion protection document and Material Safety Data Sheet should be prepared.
23. The staff should be aware of the precautions and implement them for all flammable-explosive (hydrogen) and chemical substances (sodium hydroxide).
24. In the event of contact of the electrolyte with the staff, the instructions in Material Safety Data Sheet should be implemented.
25. Electrical infrastructure should be checked periodically by the technical staff.
26. Balloon inflating room should not be used for storage.
27. Waste electrolyte should be disposed correctly after neutralisation.
28. Fire extinguishers should be placed within easy reach.
29. Emergency exits should not be blocked as they may prevent escape in case of fire.
30. Fire extinguishers must not be used past their expiration dates.

31. Hydrogen-related hazard and warning signs and instructions should be posted where staff can see them.
32. A warning sign should be placed to prevent accidental operation of faulty systems.