Annex 16. Technical Specifications for the Procurement of Automated Weather Observing Systems

1 Introduction

An Automated Weather Observing Systems (AWOS) or more commonly known as an automatic weather station (AWS) is defined as a "meteorological station at which observations are made and transmitted automatically" (WMO CIMO Guide, 1998, 2018[1]). Measurements are processed and transmitted through a central data-acquisition unit. The collected data from the autonomous measuring devices can be processed locally at the AWS or at a central processing server. These stations may be designed as an integrated concept of various measuring devices in combination with the data-acquisition and processing units (WMO CIMO Guide, 1998). According to the WMO CIMO Guide (1998) AWS are used for increasing the number and reliability of surface observations and achieved through the following:

i. Increasing the density of an existing network by providing data from new sites and from sites that are difficult to access and inhospitable;
ii. Supplying, for manned stations, data outside the normal working hours;
iii. Increasing the reliability of measurements by using sophisticated technology and modern, digital measurement techniques;
iv. Ensuring the homogeneity of networks by standardizing the measuring techniques;
v. Satisfying new observational needs and requirements;
vi. Reducing human errors;
vii. Lowering operational costs by reducing the number of observers;
viii. Measuring and reporting with high frequency or continuously.

AWS can be used for several applications targeting different meteorological needs. The types of AWS chosen to improve Liberia's capacity are agro-meteorological (AMS) and hydro-meteorological stations (AHS). These types of AWS are most common in surface observations and required for successful climate adaptation planning purposes. This document will describe the cost estimates, technical specifications required for procuring and installing an AMS and an AHS in Liberia.

Currently, the observing station distribution in Liberia is sparse (as shown below Figure A16.1) and requires a considerable amount of expansion to support a better understanding of weather and climate as well as monitoring of hazards at community, county and national level. Increasing the observing network will also be useful for data assimilation into and verification of numerical weather prediction model. The Simplified Approval Process Funding proposal (SAP FP) will strengthen the existing hydromet observing as well as enhance environmental monitoring as defined in the Output 2.2.2 of Component 2. The AWSs will be deployed in the most populated areas with major focus on the agricultural and coastal areas. The stations will be interconnected via the internet and data retrieved will be collect at localized and central data management systems for storage, processing, analysis and sharing via the WMO global telecommunication system.

[1] https://library.wmo.int/doc_num.php?explnum_id=10179

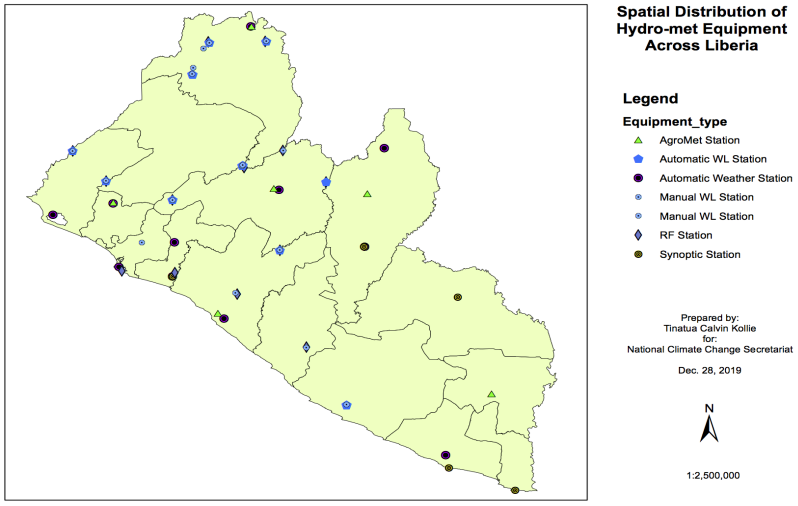

Figure A16.1: Spatial distribution of existing hydrometeorological observing networks (same as Figure B 1.4 in the SAP FP)

2 Hydro-Meteorological Stations (HMS)

2.1 System Overview

The Hydro-Meteorological Station (HMS) allows for the automatic collection, storage and distribution of local meteorological data and conditions to a centralized data server. The observational data should be formatted in the standard WMO SYNOP code for distribution through the WMO networks. Procedures, accuracy and other standards are given in the WMO Manual on the GOS (WMO-No. 494) and in the WMO Guide to Instruments and Methods of Observation (WMO-No. 408). These HMSs are used for applications in the hydrological sector, more specifically for use in flood prevention, climatology and weather forecasting.

The AMS system should include the following:

i. The remote unit that contains the data loggers, communication interfaces and solar power technology.
ii. Structures for the placement of the cabinet and the rain gauge. The structure should allow for a wind sensor to be placed at a height of 10m.
iii. Sensors positioned on masts designed to prevent interference between the different elements.
iv. The system should be Upgradable from a single base dependant on system requirements.
v. Communication between the HMS and central data hub performed via GSM and/or radio and/or satellite networks.

2.1.1 Remote Unit

The HMS remote unit contains the crucial data logging and communications hardware. It is imperative that the housing is waterproof and that the contents are kept dry. The data logger should be equipped with waterproof connectors that allow a quick and easy replacement of sensors (e.g. in case of defect or malfunction) without the need to open the remote unit. The remote unit collects data from the various sensors at the frequency provided by each sensor. The data logger should convert this raw data into weather data (including minimums, maximums, averages) on an hourly basis, and stores the data in its memory. Given a 15-minute logging interval the logger needs to provide enough memory to store data of a standard ETo station for at least 6 months. The raw data is sent to the central data server on a user-defined schedule (minutes, hourly, daily) where the data can be analysed in terms of evapotranspiration (ETP), temperature and used in preventing plant disease. In case of communications failures, the raw data is stored on the logger until the problem is resolved. The data logger should have on-board or removable memory so that data transfer to a remote terminal can be done quickly and easily. The base station should be designed to run on solar power and provide

sufficient power to the station and associated sensors. The size of the solar power system required should be calculated as appropriate for the country location and amount of sunshine. A battery should be provided to accommodate continuous measurements when solar power is unavailable, but last for at least 10 days with a standard weather station configuration.

Lastly, the remote unit should be designed to be completely automated and human presence is only required through routine maintenance. The remote unit should also be designed to be secure from damage or theft.

2.1.2 Sensors

All sensors should fit at least the minimum technical requirements and regulations outlined by the WMO. The HMS system should be comprised of the following sensors:

a. Data Logger & Telemetry (1 combined unit preferred)

Logger: Protection class IP-67

i. Input/Output:

- 12 x analogue (0-1V/ 0-2,5V / 3 x 0 -150mV) with 16-bit resolution across a temperature range of at least -20°C to +°65°C
- 4 x pulse counters (2 x 50Hz, 2 x 500Hz)
- 4 x Digital ports (0 / 3V TTL), configurable as either inputs or outputs
- 40 SDI-12 values via on-board adapter (option of ModBus Adapter)
    - The logger must provide WMO compliant wind gust monitoring (4 readings per second, with a running average of 12 values calculated 4 times per second);
    - The logger must provide WMO compliant wind vector monitoring;
    - The logger must provide WMO compliant methods to record rain intensity and provide adequate correction information;
    - The logger must be able to store date and time of every pulse, plus wind speed and direction at the time of the pulse;

ii. **Integrated Power Supply,** using a NiMH battery, supporting charge and discharge temperatures of up to 60°C:

- Integrated charging circuit;
- Programmable sensor excitation to provide either stabilized voltage (with an accuracy of +/- 0,1V) or unstabilized battery voltage to the attached sensors;

iii. Monocristalline Solar Panel/s:

- Adequate size to run the defined system, being no larger than approximately DIN A5 to reduce wind pressure and the risk of theft or vandalism;
- Shielded Wiring;
- Metal Connectors with IP67 protection class;
- Integrated mast Mounting;

iv. Integrated Modem

- Quad band GSM/GPRS enabled;
- SIM cards must be PIN protected to prevent abuse in case of theft;
- Option to upgrade to UMTS (without factory intervention);
- Antenna;

b. Rain Gauge

- Weighing Precipitation Gauge System;
- Signal filter to eliminate wind influence;
- Temperature calibrations for dirt-free operation;
- Accuracy: 0,1mm;
- Intensity: 0,1mm ~ 1800mm/hr;
- Bucket Capacities: 750mm at 400cm2; 1500mm at 400cm2;
- Orifice: 200cm2 and 400cm2;
- Resolution: ± 0,1mm

c. Pyranometer

- Wavelength Range: 300nm – 2800nm;
- Solar Irradiance Range: 0 – 2000 W/m2;
- Directional Error: ± 2% at 80° at 1000 W/m2;
- Non-Linearity: (0 - 1000 W/m2) ± 1%;

- Non-Stability per year: ± 1 %;
- Daily uncertainty: ± 5%;

d. Vane anemometer (measuring both wind speed and direction)

- Sensor made of anodized aluminium or stainless steel to provide proper stability under temperature variation;
- Direction Range: 0 - 360°;
- Direction Accuracy: < ± 3°;
- Speed Range: 0 – 234km/h;
- Speed Accuracy: < ± 0,4m/s;
- Starting speed of speed and direction < 0,4m/s;
- Cups and vane easily changeable in the field;
- Expected lifetime > 15 years

e. Thermometer and Hygrometer (inside an auto-ventilated radiation shield)

- Capacitance relative humidity (rH) sensor with protective coating against dust;
- Measuring Range: - 40 °C to 60°C (Thermometer); 0 to 100% rH (Hygrometer);
- Accuracy: < ± 0,2 °C (Temperature); 0 – 90%: < ± 2%; 90 – 100 %: < ± 3%;
- Maximum deviation of 1% rH per year within the first 5 years
- Each sensor must be provided with a factory calibration certificate

f. Barometer

- Measuring Range: 500hPa – 1500hPa;
- Accuracy: 0,05% Full Scale;
- Long term stability: 1hPa over 5 years;
- Housing should ensure protection against wind interference;

3 Agro-Meteorological Stations (AMS)

3.1 System overview

The AMS are specifically used in the measuring of parameters associated with the agriculture sector and include variables such as solar radiation, temperature, rainfall, wind speed and soil moisture. The AMS allows for the collection, storage and distribution of local data automatically to a server where they are stored. The AMS system should be designed to have a central node that is easily connected to a number of different sensors measuring different parameters for application in meteorology, climatology and agricultural studies. The system should have at least 10 sensor inputs allowing for easy installation of additional sensors. The AWS should be designed for data transmission and communications using Global System for Mobile Communications (GSM) or General packet radio services (GPRS) networks. Additionally, the instruments should be autonomous, have very low power consumption using solar power technology and have the appropriate protection technology for sustainable use under harsh agricultural conditions with low maintenance. Nonetheless the useful service life of a station should typically exceed 7 years (consumables like batteries, relative humidity sensors and leaf wetness sensor elements, which usually have a shorter life-time, excluded). Therefore, manufacturers need to warrant the availability of spare parts and compatible components for a minimum duration of 10 years after the purchase of equipment.

The AMS system should include the following:

i. The base station that contains the data loggers, communication interfaces and solar power technology.
ii. Sensors, individually placed on masts designed to prevent interference between the different elements, and allowing application-specific selection of mounting position.
iii. A web interface that provides online information and the ability to access data via mobile technologies and smart-phones.
iv. Software multi-user, multi-language (English, French) that is capable of early warning (disease modelling and irrigation, alarms and events).
v. The system should be Upgradable from a single base.
vi. Communication between the AMS and central data hub is performed via GSM/GPRS networks;

3.1.1 Remote Unit

The remote unit contains the crucial data logging and communications hardware. It is imperative that the housing is waterproof and that the contents are kept dry. The data logger should be equipped with waterproof connectors that allow a quick and easy replacement of sensors (e.g. in case of defect or malfunction) without the need to open the remote unit. The remote unit collects data from the various sensors at the frequency provided by each sensor. The data logger should convert this raw data into weather data (including minimums, maximums, averages) on an hourly basis, and stores the data in his memory. The raw data is sent to the central data server on a user-defined schedule (hourly, daily). In case of communications failures, the raw data is stored on the logger until the problem is resolved. Given a 15-minute logging interval the logger needs to provide enough memory to store data of a standard ETo station for at least 6 months. The data logger should have on-board or removable memory so that data transfer to a remote terminal can be done quickly and easily. The remote unit should be designed to run on solar power and provide sufficient power to the station and associated sensors. The size of the solar power system required should be calculated as appropriate for the country location and amount of sunshine. A battery should be provided to accommodate continuous measurements when solar power is unavailable, but last for at least 10 days with a standard weather station configuration.

Lastly, the remote unit should be designed to be completely automated and human presence is only required through routine maintenance. The remote unit should also be designed to be secure from damage or theft.

3.1.2 Data logger, Telemetry and Sensors

All hardware should offer "Plug & Play" use and designed to have very low power consumption. Sensors should be positioned on a 2m mast at appropriate positions as to avoid any interference or corruption to the measurements. Each sensor needs to come with its own mounting arm to provide freedom of choice regarding its mounting position. The AMS should have the following hardware and associated minimum specifications:

a. Data Logger & Telemetry (1 combined unit preferred)

Logger: Protection class IP-67

i. **Input/Output:**
- 12 x analogue (0-1V/ 0-2,5V / 3 x 0 -150mV) with 16-bit resolution across a temperature range of at least -20°C to +°65°C
- 4 x pulse counters (2 x 50Hz, 2 x 500Hz)
- 4 x Digital ports (0 / 3V TTL), configurable as either inputs or outputs
- 40 SDI-12 values via on-board adapter (option of ModBus Adapter)
  - The logger must provide WMO compliant wind gust monitoring (4 readings per second, with a running average of 12 values calculated 4 times per second);
  - The logger must provide WMO compliant wind vector monitoring;
  - The logger must provide WMO compliant methods to record rain intensity and provide adequate correction information;
  - The logger must be able to store date and time of every pulse, plus wind speed and direction at the time of the pulse;

ii. **Integrated Power Supply**, using a NiMH battery, supporting charge and discharge temperatures of up to 60°C:
- Integrated charging circuit;
- Programmable sensor excitation to provide either stabilized voltage (with an accuracy of +/- 0,1V) or unstabilized battery voltage to the attached sensors;

iii. **Monocristalline Solar Panel/s**:
- Adequate size to run the defined system, being no larger than approximately DIN A5 to reduce wind pressure and the risk of theft or vandalism;
- Shielded Wiring;
- Metal Connectors with IP67 protection class;
- Integrated mast Mounting;

iv. Integrated Modem
- Quad band GSM/GPRS enabled;
- SIM cards must be PIN protected to prevent abuse in case of theft;

- Option to upgrade to UMTS (without factory intervention);
- Antenna;

b. Rain Gauge

- Made of durable aluminium to withstand large temperature fluctuations
- Double-Tipping Bucket System;
- 200cm2 orifice at 0,2mm Resolution or 400cm2 at 0,1mm;
- Filter for funnel & Poison Box for insect repellent integrated;
- Intensity Correction Software;
- Accuracy: ± 1% up to 100mm/h;

c. Thermometer and Hygrometer (inside an auto-ventilated radiation shield)

- Capacitance relative humidity (rH) sensor with protective coating against dust;
- Measuring Range: - 40 °C to 60°C (Thermometer) 0 to 100% rH (Hygrometer);
- Accuracy: < ± 0,2 °C (Temperature) 0 – 90%: < ± 2%; 90 – 100 %: < ± 3%;
- Maximum deviation of 1% rH per year within the first 5 years
- Each sensor must be provided with a factory calibration certificate
- Multi-Level Soil Temperature probes placed at (10cm, 20cm, 50cm and 1 m buried in the soil);

d. Vane anemometer (measuring both wind speed and direction)

- Sensor made of anodized aluminum or stainless steel to provide proper stability under high temperature variation;
- Direction Range: 0 - 360°;
- Direction Accuracy: < ± 3°;
- Speed Range:0 – 200km/h;
- Speed Accuracy: < ± 0,5m/s;
- Cups and vane easily changeable in the field;
- Starting speed of direction and speed: < 0,4m/s;

e. Barometer

- Measuring Range: 500hPa – 1500hPa;
- Accuracy: 0,05% Full Scale;
- Long term stability: 1hPa over 5 years;
- Housing should ensure protection against wind interference;

f. Pyranometer (Solar Irradiance)

- Wavelength Range: 400nm – 1100nm;
- Solar Irradiance Range: 0 – 2000 W/m2;
- Temperature Dependance: ± 0,15%;
- Directional Error: ± 1% at 80° at 1000 W/m2;
- Non-Linearity: 0 - 1000 W/m2 < 1%;
- Non-Stability per year: < 2%;
- Hardened, scratch resistant crystal lense;

4 Agricultural Decision Support System Software (Agricultural Advisory Support Services)

The DSS should have the following:

i. Data Delivery functionality:

- Web based PC access;
- WAP based mobile access to most current data
- SMS/E-Mail warnings;
- Server-to-server data replication;
- A2A ASCII export server;
- XML connectivity;
- OPC-DA Server;

- Automatic data export;

ii. Data storage and analysis capability:

- Data Storage in embedded Database
- Data Visualisation: tables, graphs, instruments diagnostics and alarms
- Data Processing:
  - Disease Models
  - Irrigation Models
  - Statistics
  - Alarms & Events
  - Control

4. Base Station:

To maintain full control over the remote units and the data collected by them all data must be transferred to a base station that can be installed at any site of choice, with such site requiring no more than stable mains power and a solid and fast internet connection. The Base Station must meet at least the following requirements:

i. Supports 24/7 operation;
ii. Runs on an embedded Linux operating system;
iii. Supports at least 100 remote units of various sensor configurations, and be upgradeable to support up to 500 remote units;
iv. Autonomously collects data from all stations in the preset intervals;
v. Converts raw data into engineering units and stores it until retrieved with a SCADA software by XML commands;
vi. Retrieves automatically diagnostic data to judge the remote units' status;
vii. Provides full functionality through an Internet connection;
viii. Interfaces with the user via a standard web browser;
ix. Provides an integrated data viewer;
x. Provides remote access to all remote units in order to perform manual configuration changes, retrieve data, or diagnose the station;
xi. Provides multi-user access;
xii. Supports off-line configuration;
xiii. Supports at least 10 parallel GPRS ports;

5. **Cost Estimates**

This project seeks to expand the existing hydrological, meteorological and environmental observing networks by procuring and installing AWSs (at least 20 sets of AMSs, HMSs and AQSs) with localized data management systems (DMS) at the county level and central DMS at national level. The project will also procure manual weather station comprising a range of conventional instruments housed in a Stevenson Screen to enable basic weather data to be collected daily. This will be useful for calibration and field comparison purpose. A breakdown of the sensors to be procured are given in the below table.

Table A16.1: Proposal for the Supply of Meteorological, Hydrological and Environmental Systems

ID	Code	Description	Unit	Quantity	Unit Price (USD)	Total Price (USD)

1	AWS-1000	AWS1000 automatic meteorological station comprising 5 sensors for measuring; wind speed, wind direction, air temperature, relative humidity, global solar radiation, barometric pressure and rainfall. Supplied complete with datalogger, battery, solar charging unit and all necessary accessories.	1	20	12,537.56	250,751.20
2	AQS-1	Air quality sensor for measuring common pollutants; NO2, NO, O3 as well as particulates PM1, PM2.5 and PM10. Operates a replacement cartridge system, online dashboard visualisation and DC / solar power supply.	1	20	6,750.00	135,000.00
3	AWS-2000	AWS2000 automatic agrometeorological station comprising 7 sensors for measuring; soil moisture, soil temperature, leaf wetness, wind speed, wind direction, air temperature, relative humidity, global solar radiation, barometric pressure and rainfall.Supplied complete with datalogger, battery, solar charging unit	1	20	13,732.31	274,646.20

		and all necessary accessories.				
4	EN44-296	Manual Weather Station comprising a range of conventional instruments housed in a Stevenson Screen to enable basic weather data to be collected daily. Consists of a rain gauge, max/min thermometer, hygrometer, anemometer and Stevenson Screen.	1	20	2,490.75	49,815.00
5	AWSMS	AWS Management Software for meteorological data visualisation (INCLUDED IN AWS SYSTEMS)	1	20	0.00	0.00
6	AWS-SOLAR	Solar solutions for meteorological systems (INCLUDED IN AWS SYSTEMS)	1	20	0.00	0.00
7	AWS-SVR	Localised data management server for AWSMS	1	20	4,050.00	81,000.00
8	BS-CDMS	Base Station-Centralized data Management system to maintain full control over the remote units and the data collected.	1	1		8,787.60
Total Value						**800,000.00**