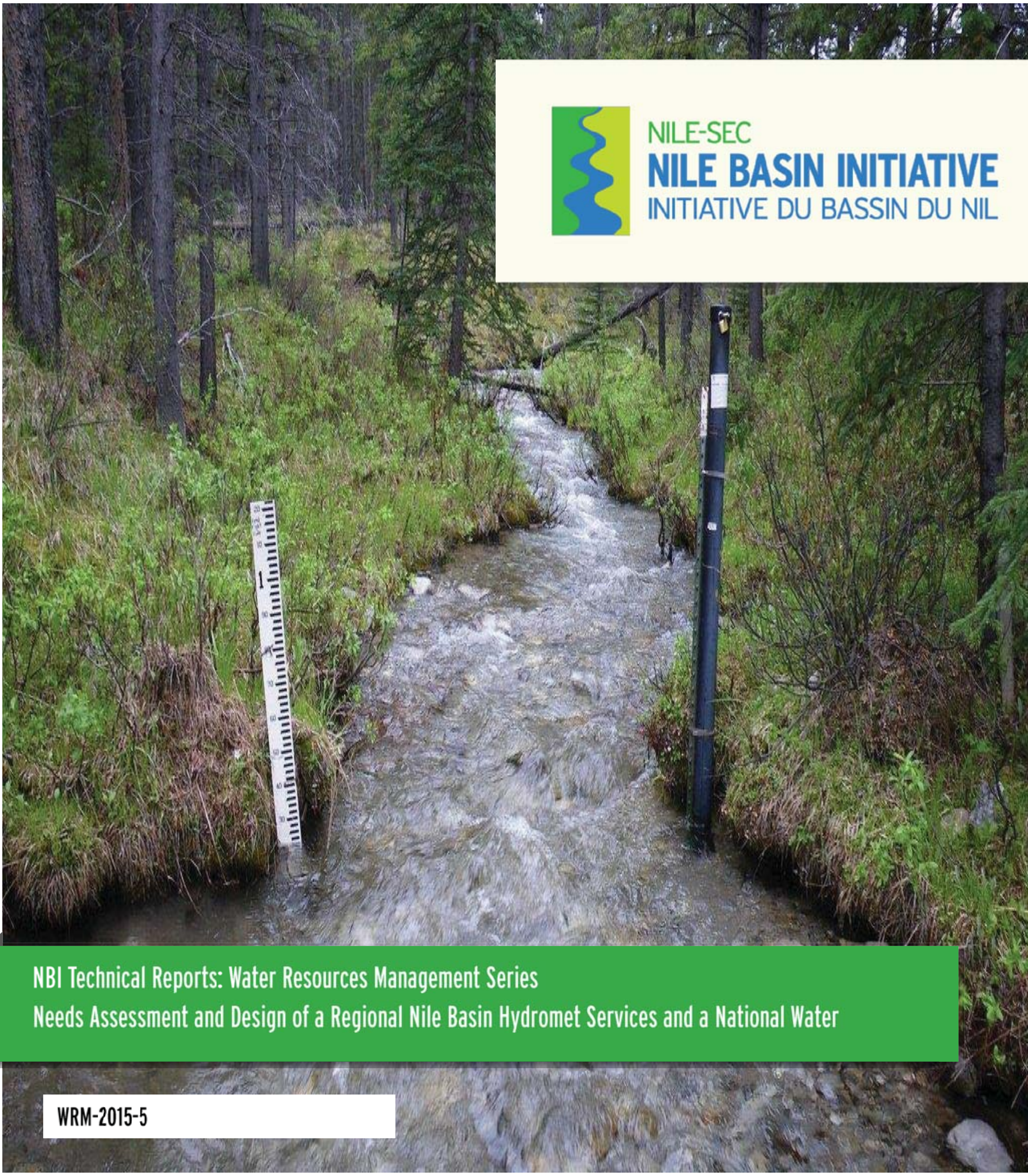

NILE-SEC
NILE BASIN INITIATIVE
INITIATIVE DU BASSIN DU NIL

# NBI Technical Reports: Water Resources Management Series
# Needs Assessment and Design of a Regional Nile Basin Hydromet Services and a National Water

WRM-2015-5

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

On behalf of:
Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
of the Federal Republic of Germany

## Document Sheet

This Technical Report series publishes results of work that has been commissioned by the member states through the three NBI Centers (Secretariat based in Entebbe- Uganda, the Eastern Nile Technical Regional Office based in Addis Ababa - Ethiopia and the Nile Equatorial Lakes Subsidiary Action Program Coordination Unit based in Kigali - Rwanda. The content there-in has been reviewed and validated by the Member States through the Technical Advisory Committee and/or regional expert working groups appointed by the respective Technical Advisory Committees.

The purpose of the technical report series is to support informed stakeholder dialogue and decision making in order to achieve sustainable socio-economic development through equitable utilization of, and benefit from, the shared Nile Basin water resources.

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### Disclaimer

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# 1 NBI Background

The Nile Basin Initiative (NBI) is a partnership of the 10 riparian countries of the Nile River Basin (Figure 1-1) that seek to develop and manage the shared water resources of the Nile in a cooperative manner, catalyze economic development, share substantial socio-economic benefits, and promote regional peace, security and integration so as to fight poverty. This partnership is guided by a shared vision: "*to achieve sustainable socioeconomic development through the equitable utilization of, and benefit from, the common Nile Basin water resources*". The policy guidelines which provide a basin-wide framework for moving forward with co-operative action set forth the primary objectives of the Nile Basin Initiative as to:

A. Develop the water resources of the Nile Basin in a sustainable and equitable way to ensure prosperity, security, and peace for all its peoples.

B. Ensure efficient water management and the optimal use of the resources.

C. Ensure cooperation and joint action between the riparian countries, seeking win-win gains.

D. Target poverty eradication and promote economic integration.

The NBI is a transitional arrangement providing a unique forum for the countries of the Nile Basin to move towards a cooperative process of realizing tangible benefits in the basin and build a solid foundation of trust and confidence. Through a series of legal instruments adopted at meetings of the Nile Council of Ministers of Water Affairs (Nile COM) in the Nile Basin between 1999 and 2002, institutional mechanism of the Nile Basin Initiative (NBI) for cooperation and the Nile Basin Initiative Secretariat [Nile Sec] were established on a transitional basis until a permanent institution within the basin wide framework is developed. Overall, the process of setting a permanent institution of the Nile Basin Initiative is progressing well, and will be achieved as soon as a permanent legal and institutional framework is finalized. Thus the NBI was established with the following governance structure and a secretariat as follows:

1. Council of Nile Ministers (Nile COM), the highest decision making organ;
2. Technical Advisory Committee (Nile TAC) for policy preparation and implementation;
3. Secretariat (Nile Sec) to support Nile COM and Nile TAC.

NBI is managed from three Centers. The first Centre at Entebbe, Uganda, forms the NBI Secretariat (Nile-SEC) and was launched in September 1999. It has a coordinating role across the Basin, supports the platform for Basin-wide dialogue, and provides and manages an interactive, intelligent, basin knowledge base. Another Centre at Addis Ababa, Ethiopia (ENTRO) and a third Centre at Kigali, Rwanda (NELSAP-CU) both manage the facilitation of cooperative water resources development in their respective sub-regions.

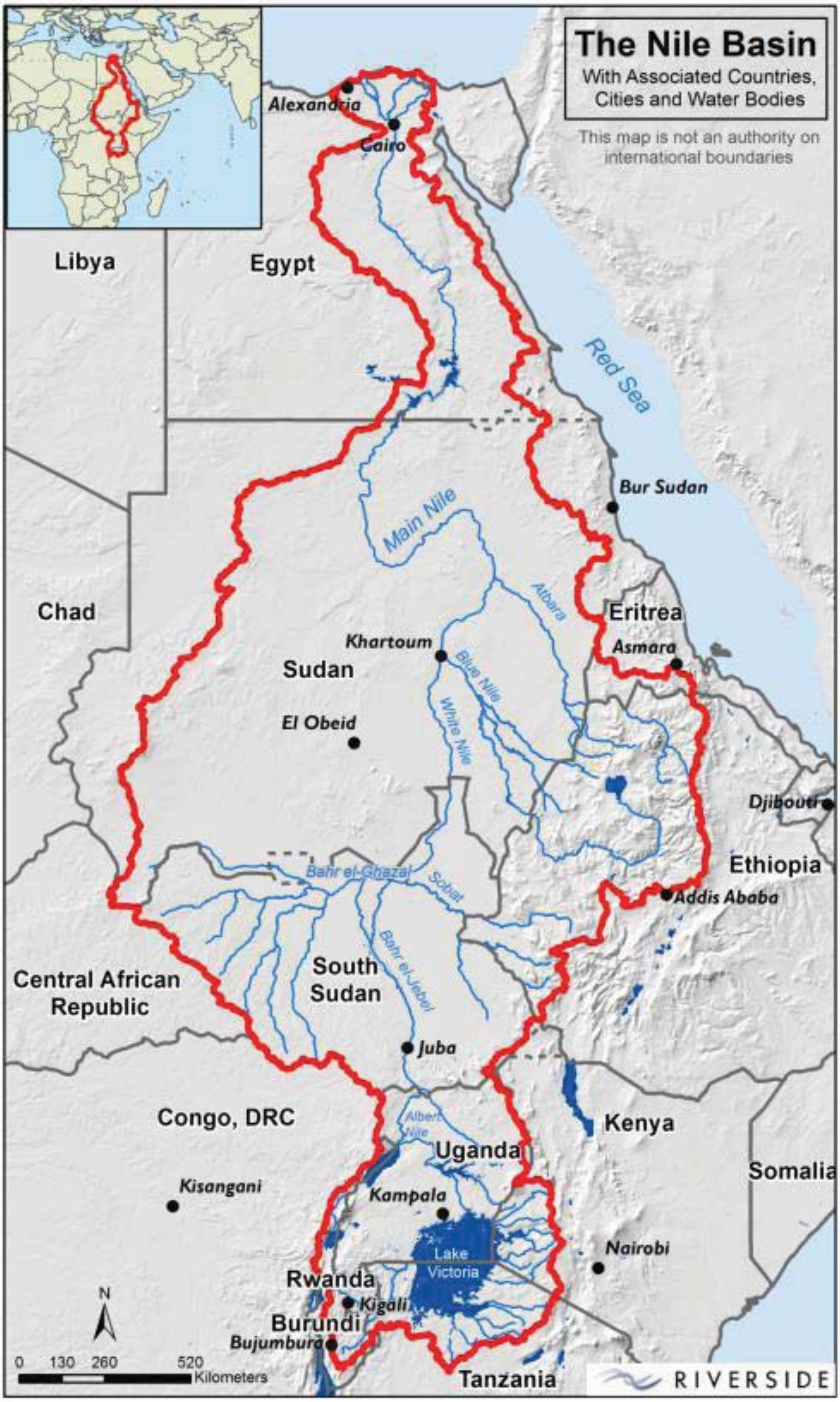


Figure 1-1. Nile Basin with associated countries, cities, and water bodies

# 2 Introduction to the Study

## 2.1 River basin monitoring in the Nile Basin

River basin monitoring is essential for knowledge based water resources planning, efficient water resources management, socio-economic development, and environmental sustainability. The current system of Nile Basin monitoring is far from adequate. An assessment conducted under the NBI-Water Resources Planning and Management project shows that many significant hydrologic portions of the Nile Basin are either un-gauged or very sparely gauged even with respect to basic hydrological parameters. In some countries, data collection and maintenance of previously installed stations has lapsed for an extended period of time.

Data collected from the operational stations often exhibit breaks in the records, which makes the data unsuitable for many purposes. Measurements of water quality and sediment transport are rare in all but a few countries. Moreover, there is a lack of necessary infrastructure for water quality monitoring (certified labs, field sampling and laboratory testing equipment, trained personnel, standards and guidelines). Generally, the degree of automation of the hydrometric networks is still very low, and telemetry is not used in most countries. Most recorders are out of order, and real time data are not available.

Gaps in spatial coverage and time series in key catchments result in an incomplete understanding and knowledge of bio-physical conditions, setbacks in strategic assessment and water resources planning, suboptimal water management decisions, and delays in planning and execution of investment projects.

The water resources monitoring network within South Sudan is in need of immediate review, rehabilitation, and modernization. Many stations in the country are not functional and few are reliable as incidences for early warnings and forecasting measures associated with droughts and floods. In the absence of the real time monitoring network needed for flood warning, parts of the country have been frequently impacted by unexpected flooding resulting in loss of property and life. South Sudan needs a robust, cost effective solution that will operate over a wide range of river and general environmental conditions.

## 2.2 The Nile River Basin monitoring strategy

The critical gap in data in the Nile Basin has been recognized early during the preparation of the first set of cooperative projects under NBI. As a result, NBI developed the Nile river basin monitoring strategy to guide its activities for enhancing the monitoring system in the Nile Basin. The strategy was endorsed by the NBI governance and remains the guiding document for the design of the regional monitoring network.

The primary objective of the strategy was to have a comprehensive suite of river basin monitoring programs in place that supports decision makers, professionals and other stakeholders in the development, management and protection of the shared Nile Water Resources to achieve the Shared Vision of the Nile Basin Countries. The NBI basin-wide Monitoring Strategy is meant to provide the data required to facilitate the implementation of the various projects and programs of the Nile Basin Initiative.

The strategy identified core issues, priority information requirements, spatial and time series data requirements by issue, monitoring strategy framework, and strategic programs and actions. Data archiving and dissemination, linkages between monitoring strategy and analytical tools such as Nile DSS, mechanisms for data availability and quality assurance, institutional development and capacity building, and cost and financing as well as implementation arrangements were also addressed.

## 2.3 Regional Nile Basin Hydromet Services Design

In May, 2014 NBI contracted with Riverside Technology to develop design specifications and an implementation plan for the Nile Basin Regional hydro-meteorological monitoring system (this assignment), including a national water resources monitoring system for South Sudan. The assignment aims to enhance Nile River basin monitoring. Enhancing the basin-wide monitoring typically addresses coverage, equipment, techniques, data acquisition and dissemination, sampling and testing, standard procedures, capacity development, cost estimates, and implementation planning. The consultancy services will contribute to the persistent NBI efforts to address the interlinked challenges of poverty and a deteriorating natural resource base in the Nile Basin to reduce the process of environmental degradation and improve the productive potential of natural resources.

The overall objective of this assignment is to strengthen the Knowledge-based analysis of transboundary options for cooperative planning and management of Nile Basin shared water resources. The specific objectives of this assignment are to:

1. Develop the design of a Nile Basin regional hydro-meteorological monitoring network based on needs and requirements for the sustainable management and development of the shared Nile Basin water resources.
2. Develop the implementation plan for a systematic and expedited implementation of the monitoring network.

The overall work plan for the assignment, which is documented in detail in the Approach and Work Plan submitted to NBI in April, 2014, includes the following elements.

***Phase I: Project Inception***

- Launch Workshop
- Information collection and review
- Establish Hydromet Services Requirements
- Determine Systems needs
- Outline Innovative Technical Options
- Compile Preliminary Situation Assessment
- Prepare Inception Report
- Regional Consultation Workshop

***Phase II: Analyses and Design***

- Consultations and Field Visits
- Review Current Hydromet Services
- Compile Hydromet Services / Network Database
- Examine Data exchange and Dissemination
- Preliminary Conceptual Services Design
- South Sudan Conceptual Hydrologic Information System (HIS) Design
- Institutional and Capacity Development
- Facilitate articulation of a common vision for Regional Hydromet Services
- Interim Report
- Regional Review Workshop 1
- Regional Hydromet System Design
- Regional Review Workshop 2

***Phase III: Implementation Planning***

- Develop quantity and cost estimates

- Develop phased implementation packaging
- Prepare Tender Documents
- Develop Implementation Plan
- Assist in Preparing Project Proposals
- Regional Review Workshop 3

Phase I: Project Inception culminated in an inception workshop held in Entebbe, Uganda during 4-5 August 2014 and the delivery of an updated inception report that laid the groundwork for establishing hydromet services based on data requirements to address water resources management issues with a bearing on socioeconomic development.

Activities of Phase II: Analyses and Design have included national consultations and field visits, with ongoing information collection and review and follow-up with countries and NBI centers. Riverside compiled a hydromet network database that reflects the status of known monitoring stations in the basin, including both active and inactive stations. The database has now been expanded to identify proposed stations for the current monitoring network design. An interim report was delivered in preparation for a workshop held in Nairobi, Kenya from October 8-10. At the workshop Riverside presented a conceptual design for a monitoring network and related information systems and received feedback from NBI and the riparian countries. This report presents the final design of the system, incorporating feedback from the countries and including material developed during the inception phase describing the basis for the network. A separate section is provided detailing more specifically the design for South Sudan.

# 3 Situation Assessment

This situation assessment describes the current status of monitoring programs, data management, and application at both national and regional levels in the Nile Basin in relation to the data requirements to support the water management issues. A situation assessment report was prepared in 2009 as part of the Nile Basin monitoring strategy development effort (Wright, 2009). The current assessment expands on that effort with more focused attention to monitoring and data management programs in each country and data coordination in the region, and highlights specific gaps in relation to the identified data requirements. A preliminary assessment was first conducted based on reports provided from the project Launch Workshop in Addis Ababa, Ethiopia May 12-14, 2014. This assessment was refined following an Inception workshop in Entebbe, Uganda, August 4-5, 2014 and national consultations and field visits to respective countries shortly after. An important part of the refined assessment was the compilation of a complete list of historical stations and preparation of map layers that permit a spatial assessment of station distributions. Emphasis was placed on obtaining metadata from countries regarding parameters, frequency, and operational status of stations in the individual national networks.

## 3.1 Country Assessments

Country Assessment reports were completed by national staff and presented by the countries at the project Launch Workshop in Addis Ababa, Ethiopia May 12-14, 2014. The following sections coalesce the information provided from each report, presenting a summary of information on the following topics:

- Overview of responsible Ministries
- Data collection networks, monitoring practices, and data processing/management with respect to river stage/discharge, precipitation, other meteorological parameters, water quality (including labs) and sediment sampling, groundwater, and use of spatial datasets
- Data dissemination and application
- Gaps in the context of a regional network

Where applicable, supplemental information based on country feedback from workshops and consultations was added to the summaries. In addition, key metadata regarding station locations, parameters, frequency and operational status were obtained to create the database necessary for utilizing the existing network for the regional design. Country assessment reports describing the consultation and field visits are provided in Appendix A. These reports offer greater depth of national assessments beyond the summaries provided below.

Following the completion of the Design Workshop in Addis Ababa, Ethiopia December 19-20, 2014, an additional situation assessment was prepared for Egypt. Information was gathered from available sources but did not include direct communication or reporting from Egyptian ministries. The Egypt assessment is provided in Section 3.1.3.

### 3.1.1 Burundi

<u>*Overview of responsible ministries*</u>

- The directorate of Water resource Management and Sanitation (DGREA), which is under the Ministry of Water, Environment, Land Management and Urban Planning, is responsible for water resources management through the department of Integrated Water Resource Management and the department of Sanitation and Water Quality Control.

- The Institut Géographic of Burundi (IGEBU) - which falls under the same Ministry, is responsible for water resources monitoring through the Department of Hydrometeorology and Agro-meteorology. This department comprises of four technical services namely: 1) Meteorological Assistance to Air Navigation Service, 2) Agro-climatology Service, 3) Hydrology Service, and 4) Database Management Service.

- The Department of Hydrometeorology and Agro-meteorology at IGEBU is also responsible for monitoring weather and climate and providing forecasts and advisories to government and other stakeholders.

<u>*Data collection networks, monitoring practices, and data processing/management*</u>

- *River Stage/Discharge*
    - The river-gauging network in Burundi consists of 54 stations. About 70% of the network is currently operational. Equipment utilized includes staff gauges and chart-type (6) and automatic (6) water level recorders. IGEBU is responsible for operation and maintenance, with assistance from local observers.
    - Water levels are read six times a day at key stations and twice a day for other stations. The Data is transmitted to IGEBU on a monthly or three-monthly basis. No telemetry systems for data transmission are currently used in Burundi.
    - Every three months, a discharge measurement campaign is organized and river-discharge is measured at each station at least 4 times per year. Flow velocities are measured using a conventional current meter and discharge is computed using the area-velocity method.
- *Precipitation and Other Meteorological Parameters*
    - The meteorological network in Burundi consists of 139 rainfall stations, 19 classic weather stations, and 4 automatic synoptic stations. Out of the total network of 161 stations, 36 are operational (2014). The network is maintained and operated by IGEBU, with assistance from local observers. Data from the weather and synoptic stations are transmitted twice a day to IGEBU by mobile telephone. Rainfall data is transmitted to IGEBU on a monthly basis. The main constraints include 1) insufficient funds for operation & maintenance, 2) equipment shortages, 3) insufficient number of qualified staff, and 4) inadequate database and data dissemination systems.
- *Water Quality (including Labs) & Sediment Sampling*
    - Water Quality monitoring and Pollution control activities are considered to be of medium importance in Burundi. These activities are under the Institute Nationale de la Conservation de la Nature as the lead institution. The other supporting institution is IGEBU.
    - The national central WQ water testing lab at Bujumbura is well equipped with vital basic equipment such UV-Vis spectrophotometer and AAS, but lacks a GLC. However, it was established that the equipment is not in use at the moment, as the manuals need to be translated to English and French. A GLC needs to be procured so the lab can effectively carry out tests that satisfy both national and the minimum regional/transboundary requirements for water quality monitoring. There is need to decentralize WQM activities. This lab is manned by few trained staff and more should be recruited.
    - No on site Automatic Sondes and no national Mobile Calibration Labs are in use. Laboratory Information Management System (LIMS) is not used, and Burundi urgently needs to apply and register for accreditation.
- *Groundwater*
    - Apart from 13 observation wells recently established, no operational groundwater monitoring network exists.
    - IGEBU is implementing a project to improve the knowledge of local and national groundwater resources.
- *Spatial Datasets*
    - No mention of the use of spatial datasets within the country assessment reports.

The Burundi assessment report states that all hydrologic and climatic data are processed and archived at IGEBU in a Microsoft Access database.

*Data dissemination and application*

Hydrological yearbooks and basin reports are published periodically. Data are made available without fee for engineering, research, and various operational purposes.

*Gaps in context of Regional Network*

- The hydro-meteorological monitoring network in Burundi has a good country-wide coverage but a limited number of stations are operational. This is a result of insufficient equipment and inadequate funds for operation and maintenance. Only a few stations are equipped with modern electronic instruments, and no real-time data transfer occurs. Long delays in data transfer from station to central database are experienced, reducing the value of the information for operational purposes such as flood forecasting or drought monitoring.
- Water quality and sediment monitoring is not conducted on a regular basis.

### 3.1.2 Democratic Republic of Congo

*Overview of responsible ministries*

- The National Agency for Meteorology and Remote Sensing (METTELSAT – Agence Nationale de Meteorologie et de Teledetection par Satellite) is responsible for the provision of hydrologic and meteorological services. The Agency is placed under the supervision of the Transport and Communications Ministry. As an agency METTELSAT has legal and financial autonomy.
- METTELSAT is responsible for monitoring and the provision of climatic and weather forecasts, operational hydrology, remote sensing, and environmental monitoring. The scope of activities includes synoptic meteorology, aeronautical meteorology, climatology, solar radiation, maritime meteorology, and hydrology as well as general geophysics (magnetism, seismology, gravimetry, study of ionosphere) and satellite remote sensing with regards to the physical environment.
- A Board of Directors manages METTELSAT. The organizational structure follows the monitoring and service functions with a General Directorate and eleven main directorates at Headquarters. Each province has a provincial directorate with parallel functional directorates to that of Headquarters.

*Data collection networks, monitoring practices, and data processing/management*

- Only 2% of the land surface within the DRC lies within the Nile Basin. This region is drained by the Semliki River in the northeastern Albertine Rift along the Uganda border, and includes lakes Edward and Albert. Despite its relatively small size, the Semliki watershed contributes up to 4.6 $km^3$ or 20 per cent of White Nile flows. The Semliki catchment covers a network of protected areas (national parks, wildlife reserves, forest reserves), some of which are also UN World Heritage Sites and Ramsar sites (Wetlands of International Importance).
- *River Stage/Discharge*
    - Currently the measurement of hydrology parameters is almost none existent in DRC. Historically there were a large number of river stations, but over the decades, due to war attrition and a lack of operation and maintenance, these have been reduced to only a few remaining stations on the main stem of the Congo River.
    - METTELSAT operates nine hydrological stations under the SADC-HYCOS program. However, the data collection is limited to manual observations with limited quality control.

    - There is a significant amount of hydrologic data stored in paper form for the stations operated in the past.

- *Precipitation and Other Meteorological Parameters*
    - METTELSAT operates 47 manual meteorological stations, with over 40 of these stations located at airports.
    - During 2014 METTELSAT is expected to receive 50 Automatic Weather Stations (AWS) from China.

- *Water Quality (including Labs) & Sediment Sampling*
    - Water quality monitoring and pollution control activities have been ranked highly in DRC. The activities are under the Ministry of Environment as the lead institution. The other supporting institutions are METELSAT, RVF, RVA, SNEL, and REGIDESO. The National Central Laboratory in DRC is far removed from the Nile Basin portion of the DRC and it would be ideal if a laboratory such as REGIDESO in Goma, which NBI NTEAP had identified as DRC's NBI Focal Laboratory, is strengthened and used to serve the NBI WQ monitoring regional data needs.
    - The laboratory at Goma needs to be upgraded by procuring basic and advanced laboratory equipment such as AAS and GLC, if it has to meet its national and regional WQ data needs. Butembo and Beni, being in the Nile Basin, could also be considered as alternative sites to Goma to set up laboratories.

- *Groundwater*
    - The country institutional survey notes that there is no ground water level program but that there is a limited ground water quality program.

- *Spatial Datasets*
    - METTELSAT has access to remote sensing products via a LANDSAT downlink and has several SYNERGIE meteorological workstations. However a lack of capacity limits the utilization of this information and tools.
    - There is no mention of the use of spatial datasets within the country assessment reports.

*Data dissemination and application*

- Given that METTELSAT operates as an agency suggests that a fee is levied for services and access to hydro-meteorological data and forecasts.

*Gaps in context of Regional Network*

- There is no hydro-meteorological, water quality, nor groundwater monitoring conducted by DRC in the Nile portion of the basin.
- DRC notes that a significant challenge is the aging workforce and the need to improve the skills of existing staff in basic and modern monitoring data analysis and forecast techniques.

### 3.1.3 Egypt

*Overview of responsible ministries*

- The Ministry of Water Resources and Irrigation (MWRI) is responsible for the management of water resources in Egypt.
- The lead institution responsible for the collection of surface water level and discharge within the Nile Basin is the Nile Water Sector at the MWRI.

- Groundwater monitoring is under the Groundwater Research Institute at the National Water Research Center of the MWRI.
- Water quality monitoring is performed by the National Water Research Center (NWRC) for surface water and groundwater, the Egyptian Environmental Affairs Agency (EEAA) at the Ministry of Environment for the protection of the Nile River from industrial pollution and for the protection of the coastal waters and the marine environment, and the Ministry of Health for the safety of drinking water and water quality.
- The Nile Water Sector is in charge of collection of rainfall and evaporation data within the Nile Basin. The Egyptian Meteorological Authority (EMA) collects meteorological data nationwide. The Ministry of Agriculture and the agricultural research stations collect agro-climate data.

*Data collection networks, monitoring practices, and data processing/management*

- *River Stage/Discharge*
  - Numbers of stream gauge and water level stations were unavailable. Equipment utilized includes staff gauges and current meters. Operation and maintenance is the responsibility of the Nile Water Sector. Frequency of data: Readings are taken three times a day for the manual stations.
  - Data transmission is mostly manual. Telemetric data transmission is being progressively introduced for the automatic stations.
  - Hard copy data and electronic copy are available.
- *Precipitation and Other Meteorological Parameters*
  - Number of stations operated by the Nile Water Sector and EMA were unavailable. EMA stations provide information mainly for aviation, marine services, and weather forecasts.
- *Water Quality (including Labs) & Sediment Sampling*
  - The Nile River Institute (NRI) at the NWRC operates around 230 water quality monitoring stations that are sampled at least twice a year. The stations in Lake Nasser, Nile River and its branches are sampled twice a year during minimum and maximum flows approximately in February and August. Some reference stations are sampled every month. Analysis takes places at the Central Laboratory for Environmental Quality Monitoring (CLEQM) at NWRC. It includes physical parameters, oxygen budget, nutrients, major ions, metals and microbiological parameters in addition to biocides for sites along Rayahs and Upper Nile and pesticides for sites in Upper Egypt.

  - The NRI water quality monitoring network includes automatic stations equipped with sondes for measurement of pH, EC, dissolved oxygen, temperature, turbidity, color and N-compounds. Data are transmitted via the GSM network and by satellite to the central database center at NWRC in Cairo. This may serve as a model for its implementation in the Nile countries at selected regional stations.
  - The two focal labs within Egypt include the Central water Quality Testing Unit at the NWRC in Cairo and the High Dam Laboratories at Aswan. Both labs are well equipped with modern equipment and qualified experienced professionals.

  - The Drainage Research Institute (DRI) at NWRC operates 48 water quality stations in the delta for irrigation and 115 for drainage canals that are sampled on a monthly basis.
  - EEAA monitors approximately 70 sampling points for environmental conditions and pollution four times a year and about 100 industrial discharges once a year. Samples are analyzed at the EEAA central laboratory in Cairo and its 8 regional laboratories for physical parameters, oxygen, major ions, nutrients, metals, microbiology and pesticides.

  - The water quality monitoring programs in Egypt are adequate for the purposes of each organization; however, mainstreaming may be needed to avoid potential overlaps between mainly the NRI and EEAA programs.
  - Sediment monitoring is focused mainly at Lake Nasser where comprehensive surveys are conducted on a routine basis.
- *Groundwater*
  - Groundwater is monitored once a year in 223 wells across Egypt, with focus on salinity in the Delta area and pollution of the groundwater system within the Nile Basin in Egypt.
- *Spatial Datasets*
  - EMA utilizes satellite cloud cover imagery to assist in forecasting. The MWRI institutions including the NWRC and the Nile Water Sector use remote sensing and various spatial data sets for GIS analysis and hydrologic modeling.

*Data dissemination and application*

- Surface water, water quality, and sediment data are shared among MWRI institutions, and are being provided to project developers, research institutions, and relevant stakeholders upon request.
- For meteorological data, forecasts are generally produced and disseminated via the media or internet. The primary users of meteorological data include the public, government institutions, project developers, farmers, universities and research institutions, and NGOs.

*Gaps in context of Regional Network*

- The hydromet and water quality network with the Nile Basin in Egypt is quite comprehensive. The water quality monitoring system may need mainstreaming to avoid potential overlaps.

*Sharing best practices in context of Regional Network*

The water quality database management system including the automated water quality monitoring system that NWRC operates may serve as an example for data generation and sharing between organizations within the country and region.

### 3.1.4 Ethiopia

*Overview of responsible ministries*

- The Hydrology and Water Quality Directorate under the Ministry of Water, Irrigation and Energy is the directorate responsible for surface water, groundwater, and water quality monitoring and data processing. Additional activities include flood forecasting and early warning systems, reservoir monitoring and management, and workshop and laboratory activities. Under the Hydrology and Water Quality Directorate nine regional hydrology offices exist. River basin authorities responsible to the ministry have been established, and are beginning to undertake hydrological monitoring operations within their areas.
- The National Meteorology Agency (NMA) is the agency responsible for precipitation and meteorological monitoring within Ethiopia. There are a total of 11 NMA Branch Offices located throughout the country.

*Data collection networks, monitoring practices, and data processing/management*

- *Surface Water Monitoring (River Stage/Discharge and Lake/Reservoir)*
  - “There are three types of water level monitoring stations, including staff gage observation stations, stations with automatic water level recorder using a data logger, and telemetry stations. Almost all of these are “water level recording station” and at

most observations are carried out manually twice a day. Continuous measurement (using automatic recorders) is gradually being introduced on 30 stations with an Automatic Water Level Recorder using a chart recorder, 45 stations are equipped with data loggers and 4 stations are equipped with a telemetry system. At present, these stations with chart recorders are mostly not working properly, as the instrument needs manual paper replacement on a regular basis to maintain its functioning, and the data needs to be read and reported manually rather than collected automatically."

- Data transmission is primarily conducted by sending a "gauge book" recording every 4 months. This data is then transferred manually. There are a few automatic stations where data is transferred through GPRS coverage. Sites important for flood management include transmissions from observers to the Ministry of Water, Irrigation and Energy via High Frequency radio band.
- The current data management software in use is the HYDATA software. The system stores daily and monthly data but only conventional hydrologic data (water level and flow) are stored. Updates and upgrades for the software have not been provided and a need exits for software that can handle more volume and different types of data.
- Data processing is conducted using the HYDATA software, spreadsheets, and Surfer for bathymetric surveys. Quality control procedures are conducted on the data before archiving and disseminating to users.

- *Precipitation and Other Meteorological Parameters*
    - Meteorological stations within Ethiopia are categorized based on WMO standards. WMO Class I includes multiple meteorological parameters that record observations in three hour intervals five times a day (74 within Nile Basin). Class 2 often referred to as synoptic stations includes similar meteorological parameters as Class II but also record atmospheric pressure with data recorded every three hours (7 within Nile Basin). Class III stations record just precipitation and atmospheric temperature twice a day (215 stations within the Nile Basin). Class IV stations record only accumulated precipitation once a day (180 within the Nile Basin). There are also a reported 36 Automatic Weather Stations (AWS) within the Nile Basin collecting multiple meteorological parameters every 15 minutes.
    - Most transmission of Class I and II stations are done with Single-Side-Band (SSB) voice radio with a few also utilizing telephone. Other conventional station data is sent via postal carrier and reaches the NMA head office generally months after observation. Data from very remote stations is collected during station inspections twice a year. AWS stations transmit via GPRS directly to the NMA head office
    - For data processing and management the NMA utilizes the climate data management system CLIDATA from the Czech Republic. This uses Oracle for background and VB based front ends. The NMA is planning to implement a Wide Area Network (WAN) for its eleven Branch Offices that will allow for simple login to the database for data entry, quality control, and extraction. However, currently all offices use MS-Excel for data processing and then email files to the NMA headquarters for entry to CLIDATA
    - Ethiopia is preparing to commission a weather radar in the Blue Nile watershed west of Lake Tana and has a master plan for a total of 7 weather radar to cover basins in the country.
- *Water Quality (including labs) & Sediment Sampling*

  - Water quality monitoring and pollution control activities have been ranked to be of low priority. This function is managed by MoWIE, MoFE (Forest Conservation and Environment) as the sole lead institution. Water quality monitoring activities are decentralized. The management of WQ labs falls under MoWIE; Regional Water Bureaus and National and Regional Water Works Enterprise, which serves private customers. There is a central laboratory in Addis Ababa and nine regional laboratories, which can undertake limited analysis. The laboratories are only able to undertake simple physico-chemical and microbiological analysis, and they collaborate with the central laboratory in Addis Ababa. MOWIE plans to standardize lab procedures, which are currently not harmonized and coordinated. Ethiopian Standards Agency is also adopting ISO standards.
  - The national central Water Laboratory at Addis Ababa has only some basic equipment and lacks vital equipment such UV-Vis, AAS and GLC. This compromises the ability of the laboratory to meet its national and regional data management needs.
  - Microsoft Excel is used as a database for sediment and water quality data.

- *Groundwater*
  - Groundwater monitoring is fairly recent with abstractions being measured at 7 stations. Due to only recent developments in groundwater monitoring, no relationship between aquifer responses to abstraction or recharge have been defined.
  - Groundwater data are stored in databases labeled as “ENGDA” and “EGRAP”

- *Spatial Data Sets*
  - A GIS database exists of operating stations, proposed new stations, and those recommended for rehabilitation.

<u>*Data dissemination and application*</u>

- For the Ministry of Water, Irrigation, and Energy, dissemination of real time and historical data is carried out through cellular and radio transmission for flood management purposes. Offline dissemination for historical data via CD, DVD, or hard copies is generally provided for water resources development, management, and research activities.
- NMA’s data dissemination policy provides data free to certain users and implements cost recovery payments for others. Basic data for public safety are disseminated via public media such as television, radio, and internet.

<u>*Gaps in context of Regional Network*</u>

- Identified challenges from the Ministry of Water, Irrigation, and Energy include locating stable and suitable river gauging locations; siltation; rating curve development for high flows; calibration/condition of monitoring equipment; and data retrieval frequency, processing, and quality control. Each of these are also important with respect to a regional monitoring system. Defining stable sections of channel where rating curves can be established through the measurement of various flow ranges is of particular importance for Ethiopia which contributes a significant portion of annual flow to the system but at highly variable ranges seasonally. Sedimentation sampling is also a significant priority for both Ethiopia and downstream users within the basin and monitoring of this parameter appears to be lacking. Improved transmission and processing protocols along with potential database software upgrades will allow for both Ethiopia and a regional monitoring network to receive and analyze data in a more efficient and timely matter.

### 3.1.5 Kenya

*Overview of responsible ministries*

- After the attainment of independence, the collection of the water resources data was a mandate of the ministry in charge of water, and the weather data collection was under the mandate of Kenya Meteorological Department (KMD). In 2013, the KMD became the Kenya Meteorological Service (KMS).
- Water Resources Management Authority (WRMA), was established after the water sector reforms and mandated to do the water resources management that included the monitoring and assessment. The WRMA has the overall responsibility of ensuring the good management of the country's water resources.
- The Ministry of Environment, Water and Natural Resources, is the main custodian of water resources in Kenya, and has the responsibility for policy formulation and regulation of the water sector activities. The Ministry is also responsible for water resources management which includes coordination, collection, analysis, and maintenance of water resources data.

*Data collection networks, monitoring practices, and data processing/management*

- *River Stage/Discharge*
  - Kenya has historically had as many as 900 water-monitoring stations. Many of these stations use automatic flow recorders or staff gauges. However, many of these stations are inoperable due to neglect or funding issues.
  - Flow measuring stations have been severely neglected during the 1990's due to lack of funds for maintenance and expansion. Even where stations were operational, there were insufficient funds to obtain readings. By the year 2001, 78% of the registered river gauging stations were not in operation.
- *Precipitation and Other Meteorological Parameters*
  - Approximately 36 manual (hourly reading) and 72 telemetric (10 minute sampling) meteorological stations are operated under the KMS for purposes of weather forecasting, to inform water resources situation and allocation plans, design of water infrastructure, climate projections, and provision of early warnings on occurrences of floods and droughts.
  - The Flood Diagnostics and Forecasting Centre (FDFC) operates 19 (soon to be 46) hydro-meteorological stations (10 minute sampling) in the Nzoia and Tana River basins.
  - KMS operates 500 rainfall gauges (a reduction from over 3000) through a volunteer network of individuals, companies, research institutions, schools, and colleges.
  - KMS operates 3 upper-air radiosonde stations (KMS HQs, Garissa and Lodwar), and Airport Meteorological Stations at the main airports (JKIA, MSA, Kisumu, Eldoret and Wajir).
  - KMS operates a manual agrometeorological network at 36 sites, including crop phenology and all meteorological parameters.
  - KMS operates a 4-station marine meteorological network (JKIA, MSA, Kisumu, Eldoret and Wajir), and a network of moored buoys in Lake Victoria.
  - KMS operates meteorological satellite receiving stations at – JKIA, MSA, Kisumu, Eldoret and Wajir.
- *Water Quality (including Labs) & Sediment Sampling*
  - A nationwide Water Quality Monitoring Program was initiated by the Kenyan Ministry of Water in 1980, through which a number of monitoring stations were established.

- Water quality is monitored by the Kenyan Ministry of Water and Irrigation at 136 sites. Temp, Sp. Cond, Cond, Rest, TDS, pH, Turbidity, DO, $NH_4$, $NH_3$, $NO_2$, TDN, TN, Orth $PO_4$, TDP, TP, and TSS are monitored 4 times a year.
- Within the Nile Basin/ Lake Victoria basin, there are two laboratories, in Kisumu and Kakamega. These Laboratories are supervised by the Water Resources Management Authority (WRMA), under the Ministry of Environment Water and Natural Resources. Both laboratories in Kakamega and Kisumu are capable of testing for most of the physico-chemical parameters but are only able to partially meet both national and regional water quality data needs and are not accredited, but are considering accreditation. A new laboratory has been established in Nyalenda Kisumu, and if commissioned will carry out advanced Water Quality analysis as it is equipped with AAS and GLC.
- Surface Water Quality monitoring including data management in Kenya is decentralized from national to regional and sub regional levels based on river basin units. Technical standards for water quality monitoring are harmonized. Currently, capability to analyze for minimum regional parameters is low and, needs to be boosted by additional instrumentation and staffing. Automatic Sondes, LIMS and Mobile Calibration Labs are not in use.

- *Groundwater*
  - From 1992 onwards, water resources monitoring has almost come to a standstill. In most cases, District-based staff are idle because there are no funds to allow them to go to the field. Without updated information, it becomes impossible to plan and manage the water resources development.
  - Limited groundwater survey equipment and non-existent groundwater monitoring network.
- *Spatial Datasets*
  - WRMA activities need data from other agencies such as KMD, Regional Center for Mapping Resources for Development (RCMRD), IGAD Climate Prediction, and Application Centre (ICPAC). These data include: Land cover from RCMRD; Weather satellite imageries from KMD; Flood inundation from KMD; and Climate Change models from KMD and others.

*Data dissemination and application*

The available data comes from a number of different sources, including the NAWARD database, from which the majority of the historical data originates. This has been further updated by WRMA. Listed below are the types of data that are available at the various regional data centers (regional offices);

- Water levels
- Measured discharges
- Weather parameters
- Water quality
- Groundwater levels

Data quality checks are done at the sub-region office, where data are checked manually when being entered into the computers. At the regional office, the data is further quality controlled by analyzing it using software which identifies data outliers. Furthermore, regional staff make surprise visits to stations to check observed data and the state of the instruments. Any inconstancies are identified and rectified as appropriate before sending it to the headquarters.

Kenya has many uses for the hydro-meteorological data. But, for water resources, the collected data are useful in the Mike Basin model to generate various products including development of scenarios that are used to inform the preparation of water resources products and reports such as water situation and allocation plans, design of water infrastructure, climate projects, and other research outputs. The data is also very useful in the current effort of developing climate projections and provision of early warnings on occurrences of floods and droughts.

Meteorological data is exchanged globally through the Global Telecommunication System (GTS), for most synoptic stations. Regional exchange of meteorological data is arranged through the IGAD Climate Prediction and Application Centre in 10 States: Burundi, Eritrea, Ethiopia, Kenya, Rwanda, Somalia, South Sudan, Sudan, Tanzania, and Uganda. These are used in the Greater Horn of Africa (Regional) Seasonal Climate Outlook Forums (COFs).

*Gaps in context of Regional Network*

- Kenya has had an extensive existing national hydro-meteorological network that covers all potential parameters of interest for regional network data collection. However, it has been noted in the country assessment that the sustainability of operating and maintaining all stations has at times been limited to funding constraints. As such, establishing a sustainable network that provides the highest priority national and transboundary data locations will require investigation.
- Much of Kenya's hydro-meteorological monitoring infrastructure has been neglected, making it challenging to carry out water resources planning and operations. Consequently, water allocation and abstraction decisions are made based on inadequate data.
- Equipment is archaic and cannot capture rainfall intensity for modeling; Lack of rainfall intensity observing equipment.
- Lack of continuous data collection system; Transmission is mainly manual, which results to induced high cost of collecting data and errors in data.
- Use of less knowledgeable staff at the observing stations or in data management.
- Lack of regular maintenance and repairs of instruments and equipment, due to lack of readily available capable technicians, transport, spares e.g. gauge plates;
- Insufficient data collection and storage equipment, e.g. field laptops; and weak computer servers which frequently breakdown.
- Data is currently recorded in multiple databases in different formats. Establishing a single repository and format will aid in data transfer to an NBI regional center.
- Establishing closer collaboration and data transfer with the WRMA will allow for additional precipitation and meteorological parameters to aid in water resource management at both the national and regional level.

### 3.1.6 Rwanda

*Overview of responsible ministries*

- The Ministry of Natural Resources through the Rwanda Natural Resources Authority has responsibility for water resources management.
- The Rwanda Meteorology Agency, also called Meteo Rwanda, is the National Meteorological and Hydrological Service of the Republic of Rwanda. Rwanda Meteorology Agency (Meteo Rwanda) was established in 2011 by transforming the Rwanda Meteorological Service.
- The mission of Meteo Rwanda is to monitor, observe, record, and analyze weather and climate data within Rwanda and to generate information as well as provide weather and climate forecasts as a "public good". Meteo Rwanda is responsible for international obligations in relation to data exchange.

*Data collection networks, monitoring practices, and data processing/management*

- *River Stage/Discharge*
    - There are 41 hydrometric stations of which 12 are automatic stations. The manual stations are equipped with staff gauges, which are read three times per day. They have an ADCP and current meters for the conduct of discharge measurements.

- *Precipitation and Other Meteorological Parameters*
  - The available surface observation data follows WMO guidelines for meteorological instruments and methods of observation. For stations designated as climatological of which there are 72 operating, maximum and minimum temperatures and rainfall data is collected. For Agro-meteorological of which there are 9 stations and for synoptic stations of which there are 4 stations, maximum and minimum temperatures, rainfall, humidity, wet bulb and dry bulb temperatures, evaporation, atmospheric pressure, sunshine, radiation, soil temperatures, wind data, and cloud information is observed. Rainfall is also measured at hydrometric stations. Meteo Rwanda reports having 32 operational Automatic Weather Stations (AWS).
  - The country assessment reports notes that there is at least one rainfall station per 10 km by 10 km and references 71 manual and 5 automatic rainfall stations.
  - Data is transmitted by SMS, telephone, and mail. Much of data is digitized and stored in a database. Data is quality controlled, documented, and errors are flagged. The database system currently in use is Climsoft. Data is available to users in both electronic and hard copy formats.
  - There are a number of other manual and AWS stations operated by other stakeholders in agriculture, biodiversity and conservation, tourism, energy for example
- *Water Quality (including Labs) & Sediment Sampling*
  - Rwanda conducts a water quality monitoring program at the 40 some hydrometric sites as well as at water supply intakes, and for drilled wells. The sampling is done quarterly, however it is noted as being a challenge due to limited resources.
  - Water quality and Pollution control activities have been ranked highly in Rwanda. These activities are under the Ministry of Natural Resources. The other supporting institution is Ministry of Infrastructure. A central national Laboratory under the Ministry is set up in Kigali. Other support laboratories are at the National University of Rwanda, and Butare National University. Both laboratories at the 2 universities collaborate with the Laboratory of the Ministry of Natural Resources at Kigali. The national university, of Rwanda has a collaboration agreement with the Ministry of Natural Resources.
  - The national water laboratory carries out basic physico-chemical analysis. It does not test for pesticides and heavy metals. It lacks UV-VIS, AAS and GLC and Incubators. The laboratory is not able to meet most of the national and regional WQ data needs. There is also need to put up other support laboratories and to decentralize water quality monitoring activities.
  - Technical standards for water quality monitoring are not harmonized. Field Portable Kits are mainly used by the two universities. No Automatic Sondes, Mobile Calibration Labs and LIMS are in use and neither is the lab accredited.
  - There is no sediment monitoring conducted within Rwanda.
- *Groundwater*
  - Rwanda does not have an active groundwater monitoring program.
- *Spatial Datasets*
  - The country assessment report does not make reference to the availability of spatial data sets.

*Data dissemination and application*

- Meteo Rwanda is responsible for storing, quality controlling and managing all meteorological data in Rwanda under its governing Law and making the data and products available to users:

*Gaps in context of Regional Network*

- Meteo Rwanda notes that a significant challenge is the need to improve the skills of existing staff in modern monitoring data analysis and forecast techniques.
- Other identified challenges include rating curve development; calibration and condition of monitoring equipment; the fragmentation of data and information amongst different institutions and agencies, gaps in the data record; and limited budgets to maintain stations and operate the network.
- There is no monitoring dedicated to sediment sampling or groundwater within Rwanda.

### 3.1.7 South Sudan

*Overview of responsible ministries*

- The responsible government agency for surface water monitoring in South Sudan currently resides under the Directorate of Hydrology and Survey (DHS) under the Ministry of Electricity, Dams, Irrigation and Water Resources (MEDIWR). Prior to the independence of South Sudan in July 2011, but after the Comprehensive Peace Agreement (CPA) of 2005, this responsibility was under the Ministry of Water Resources and Irrigation (MWRI).
- The South Sudan Meteorological Department (SSMD) under the department of South Sudan Civil Aviation Authority is responsible for meteorological monitoring. This institution resides within the Ministry of Transport, Roads and Bridges.

*Data collection networks, monitoring practices, and data processing/management*

- *River Stage/Discharge*
  - There are currently only 5 operational river gauging stations within South Sudan but a total of 71 historic locations that could potentially be rehabilitated. During consultations with South Sudan representatives, 37 hydrometric station locations were identified for the national network.
  - Data collection activities are carried out by river technicians with gauge readers recording stage on a daily basis. Data transmission is completed manually by phone and email and hard copies of recordings are sent to Juba.
  - Microsoft Excel used for data archiving and analysis.
- *Precipitation and Other Meteorological Parameters*
  - Currently there are five operational synoptic stations used for climate and aviation purposes. Parameters observed include visibility, temperature, atmospheric pressure, sunshine hours, wind speed and direction, cloud type and height, relative humidity, precipitation, and soil temperatures and various levels.
  - Data is collected by meteorologist observers. Currently SSMD does not have a National Meteorological Telecommunication Network for data transmission to regional and global centers. SSMD uses email for data transmission.
  - Data is first typed manually into a spreadsheet by observers and then manually typed again into the meteorological database CLIMSOFT.
- *Water Quality (including Labs) & Sediment Sampling*

  - Currently no water quality or sediment sampling is being conducted but concerns exist at transboundary locations, urban environments, and oil exploration regions. MEDIWR has water quality lab facility which is used for testing the quality of drinking water. The lab does own some portable field kits and other equipment for testing some of the physical, chemical and microbiological parameters.

- *Groundwater*
  - Currently no groundwater monitoring is being conducted but the former MWRI had established a basic database of groundwater data such as borehole coordinates, drilling depth, dates, static and dynamic water levels, well yield, pump type, and pump setting depth. However, it is noted that several fields and entries are incomplete.

- *Spatial Datasets*
  - SSMD notes the utilization of satellite data observation products from EUMETSAT and Sat 24.

*Data dissemination and application*

- Products disseminated by the SSMD include raw meteorological data (rainfall, temperature, humidity, wind speed, etc.) as well as "Metar (actual weather) and TAF (forecast weather and segment)" products. In addition, severe weather forecasts are disseminated when applicable and seasonal rainfall forecasts are generated every 3 months. Primary benefits were listed as "agriculture and livestock, food security, transportation (land and aviation), health, tourism and wildlife management, construction industry, water resource management, environment, and student research." Rainfall and temperature data are sent to Climate Prediction and Applications Center (ICPAC) of IGAD for climate watch bulletin in Nairobi and weather forecasts are sent to Singapore Met center for transmission to the global network.
- Although a central database known as WIMS ([WASH] information management system) was created under the MWRI, there is a lack of systematic procedures for monitoring, assessment, and dissemination of water resources data.
- There is no formal hydromet data sharing mechanism in place both at the ministry and meteorological department, but users can make written requests to get available digital data and hard copy form. Users are not charged on any data receipt. The SSMD is, however, working on the formulation of data sharing policy and planning to charge data users.

*Gaps in context of Regional Network*

- Identified gaps at the national level that also have implications for a regional network include capacity building among staff, rehabilitation of monitoring infrastructure, quality control of existing data, and provision of acceptable monitoring technologies.
- Existing operational network for river stage/discharge and precipitation/meteorological monitoring would need to be expanded for not only national but also regional monitoring purposes.
- There is no monitoring dedicated to water quality, sediment sampling, or groundwater within South Sudan.
- Substantial investment in both infrastructure and institutional development is necessary to create a national institution capable of contributing data to a regional monitoring network. The need to develop South Sudan's capabilities is magnified by its overall hydrologic significance to the entire Nile Basin.

### 3.1.8 Sudan

*Overview of responsible ministries*

- The Sudan Ministry of Water Resources and Electricity (MWRE), is responsible for water resources and electricity management.
- The lead institution responsible for the collection of rivers water level and discharge within the Nile Basin is the Nile Water Directorate at the MWRE, while the surface water level and discharges for wadis are monitored by the General Directorate of Groundwater and Wadis at the MWRE.
- The lead institution responsible for the surface water quality monitoring is General Directorate of Groundwater and Wadis of the MWRE. Other supporting institutions that monitor water quality include the Ministry of Health, States drinking water corporations, the Ministry of Agriculture and Irrigation, and UNICEF.
- The General Directorate of Groundwater and Wadis at the MWRE, is the lead institution in the monitoring of groundwater level and groundwater quality.
- The Hydraulic Research Center of the MWRE at Wed Medani is the lead institution in sediment monitoring.
- The Sudan Meteorological Authority (SMA), is the lead institution responsible for providing meteorological, agro-climate, and rainfall data. The MWRE and Ministry of Agriculture and Irrigation are two other support institutions in the collection of rainfall and climate data. .

*Data collection networks, monitoring practices, and data processing/management*

- *River Stage/Discharge*
  - Currently, Sudan has 15 operational river flow discharge stations and 53 water level gauges, including gauges for monitoring water level for dams. Equipment utilized includes staff gauges, and current meters. Operation and maintenance is the responsibility of the MWRE. Most of these gauges are manual. Automatic water level radar and bubbler type gauges are being progressively introduced as part of the upgrade of hydrometric network.
  - Frequency of data: Readings are taken three times a day for the manual stations.
  - Data transmission is mostly manual. Telemetric data transmission is being progressively introduced for the automatic stations.
  - In most cases hard copy data are available for the complete period of record for a station, while in a few cases electronic copy is available.
  - *Wadi level/discharge* - Monitoring of the wadis (intermittent streams) is carried out by the Directorate General of Groundwater, and Wadis of the MWRE. There are few wadis that discharge in the Nile River. Wadi level/discharge stations within the Nile Basin are currently idle due to limited financial resources. The Directorate General of Groundwater and Wadis is a planning to re-activate these stations.
- *Precipitation and Other Meteorological Parameters*
  - Approximately 18 meteorological stations are operated under the SMA to provide information for aviation and marine services, weather forecast and agro-climate as well as strengthening the early warning systems for flood and drought prevention, environmental conservation, and adaptation to climate change.
- *Water Quality (including Labs) & Sediment Sampling*
  - The water quality monitoring network consists of 13 stations located at river gauging stations. Analysis takes place in the MWRE laboratory run by the General Directorate of Groundwater and Wadis, and includes water Color, Turbidity, Conductivity, pH, SS, TDS, Hardness, $CaCO_3$, $Na_2CO_3$, $HCO_3$, Cl, $SO_4$, Ca, Mg, Na, F, $NO_2$, $NO_3$, $NH_4$.
  - Water quality monitoring and Pollution control activities have been ranked highly in Sudan. A Central Water Testing Laboratory is based in Khartoum. The Laboratory is

supervised by the Ministry of Water Resources and Environment, General Directorate of Ground Water and Wadis. The laboratory is equipped with basic laboratory equipment and has no advanced equipment such as AAS and GLC, and is not able to meet its national and regional WQ data needs. The laboratory is not accredited. No routine sampling and analysis of ground water is done. The Directorate General of Groundwater and Wadis has had financial difficulties; as a result groundwater quality monitoring has stalled for a few years. This function unlike surface water is not decentralized to the river basins.

  - Technical standards for water quality monitoring are not harmonized and no Automatic Sondes and Mobile Calibration laboratory are used. However, laboratory is using LIMS.
  - Because sedimentation is a critical transboundary problem in the Nile basin, Sudan has established a fully equipped Sediment monitoring laboratory at Medani.
  - Sediment concentrations are being measured at selected stations scattered along the Nile and its tributaries in addition to selected canals in the Gezira Scheme.
- *Groundwater*
  - There was an active groundwater level and water quality monitoring network in the 50's. The program has been idle during the past few years due to limited financial resources. Monitoring is only carried sporadically by water supply offices, groundwater investigation projects, and NGOs such as UNICEF
- *Spatial Datasets*
  - SMA utilizes satellite cloud cover imagery to assist in forecasting. The MWRE utilizes various spatial data sets for GIS analysis. The National Remote Sensing Center based at Khartoum University uses satellite data for flood impact assessment and land use mapping.
- There are plans to expand and upgrade the current hydrology monitoring network through automating som*e of the manual g*auges, adding additional gauges for better coverage, and building a data telemetry network.

*Data dissemination and application*

- Surface water, water quality, and sediment data are being provided to project developers, research institutions, and relevant stakeholders upon request.
- For the meteorological data, forecasts are generally produced and disseminated via the media or internet. The primary users of meteorological data include the public, government institutions, project developers, farmers, universities and research institutions, and NGOs.

*Gaps in context of Regional Network*

- Gaps are mainly in the monitoring of groundwater level, and quality, which needs financial support and capacity development to progressively reactivate and upgrade the old network.
- Sudanese authorities are committed to rehabilitate and modernize the hydro-meteorological observation networks. This requires support in strengthening their human resource capacity in order to embrace technological developments.

*Sharing best practices in context of Regional Network*

- Sudan has acquired extensive experience in sediment monitoring and analysis. The hydraulic research center at Wad Medani is a pioneer institution in this field, and their experience can be shared with riparian countries.

### 3.1.9 Tanzania

*Overview of responsible ministries*

- In Tanzania, the Directorate of Water Resources under the Ministry of Water is responsible for surface and groundwater data collection and processing. The water resources management is divided into nine river/lake basins with associated offices. The Lake Victoria Basin Water Office (LVBWO) is responsible for the region of Tanzania that directly contributes to the Nile Basin.
- The Tanzania Meteorological Agency (TMA) is the government institution with the mandate to provide meteorological data and information to users. The meteorological products issued to users include processed data (i.e. analyzed trends of rainfall, temperature and rainfall intensities), weather forecasting and early warnings against meteorological disasters like floods, tsunamis, tropical cyclones and droughts. In addition to the TMA met stations, there are rainfall and climatic stations managed by other institutions including the Ministry of Water, and the Ministry of Agriculture.
- There is a collaborative Memorandum of Understanding (MOU) in its final stages of preparation between the Ministry of Water and TMA for data exchange.

*Data collection networks, monitoring practices, and data processing/management*

- *River Stage/Discharge*
  - The majority of hydrologic stations within the country have not been operational but monitoring equipment has been procured and installations are in progress. The Tanzania country assessment report notes 320 monitoring stations have been either rehabilitated or newly installed within each of the 9 basin water boards. There are currently a total of 410 operational monitoring stations that includes manual and automatic recording capabilities.
  - For manual recording, readers record water levels at 9:00 AM and 5:00 PM from staff gauges. Personal Digital Assistance (PDA's) and laptops are used to download data recorded on an hourly basis in the field from automatic stations. Types of automatic water level recorders include float with stilling wells and pressure transducers. The majority of data is collected from the field by basin staff.
  - Data collected from the field is processed, quality controlled and entered into a database at the local basin office and then sent to the headquarters in Dar es Salaam in a spreadsheet via email. This data is then archived in the national database at the Ministry of Water headquarters. Software tools used for data processing include HYDATA, NBDSS, and GIS.
  - The ministry is in its final stages with the service provider (contract process) to provide special SIM Cards to allow GPRS transmission for selected automatic stations.
- *Precipitation and Other Meteorological Parameters*
  - "Currently, there are 500 operating rainfall stations in the country, 60 climatic stations, 12 agro-meteorological stations, 7 AWS, 2 Marine weather stations and 2 Radars that are not yet operational."
  - Data recorded from observation stations are transmitted to the TMA head office in Dar es Salaam via telephones and emails. It is currently done manually by staff at the station. Data is then further transmitted to the regional center in Nairobi via GTS or email.

  - Data received at the TMA head office are stored as raw data in repositories labeled "archives".

- *Water Quality (including Labs) & Sediment Sampling*
  - Water quality tests are conducted at several sites within the Lake Victoria basin ranging from a monthly basis to bi-annual frequency of testing. Several of the tests are driven by the mining industry within the region. The Ministry of Water laboratory within Mwanza can perform basic water quality tests and only lacks the capabilities to monitor pesticides and heavy metals which are contracted out to a private company. The lab is in the process of becoming accredited.
  - Only total suspended solids sampling is being conducted within the Lake Victoria basin but equipment at the local basin office does exist to conduct sediment transport sampling.

- *Groundwater*
  - Tanzania has a number of groundwater monitoring stations but none currently exist within the Lake Victoria basin. However, there are plans to establish 15 groundwater monitoring sites with digital recording capabilities in the basin.

- *Spatial Datasets*
  - TMA utilizes satellite cloud cover imagery to assist in forecasting. The Ministry of Water utilizes various spatial data sets for GIS analysis.

*Data dissemination and application*

- For surface water measurements, data are being provided to research institutions, project developers, and stakeholders upon request.
- For the meteorological data, forecasts are generally produced and disseminated via the media or internet. Products produced include daily, ten-day, monthly, and seasonal forecasts along with Agromet advisories. The primary users of meteorological data include the public, government, private institutions, NGOs, UN agencies, and researchers.
- Data sharing between government institutions such as TMA and the Ministry of Water currently requires a formal written request between institutions that may be improved with aforementioned MOU.

*Gaps in context of Regional Network*

- Currently data exchange between ministries requires a formal request. In addition, there are multiple isolated databases being used at both the national and local basin level. Establishing a single repository of subset data to be transmitted to an NBI regional monitoring network could be a challenge.
- Noted challenges at the national level that would also effect a regional network include inadequate funds for station operations, lack of continuity in automatic data recording, limited capacity of staff in operating automatic stations, limited software tools for processing, and vandalism of station equipment.

### 3.1.10 Uganda

*Overview of responsible ministries*

- The Uganda Ministry of Water and Environment is responsible for water resources management, through the Directorate of Water Resources Management (DWRM). The

Directorate of Water Resources Management (DWRM) comprises of three departments namely, Water Resources Monitoring and Assessment, Water Resources Planning and Regulation, and Water Quality Management. Monitoring in DWRM has been decentralized to four Water management zones namely; Albert, Victoria, Kyoga and the Upper Nile.

- The Uganda National Meteorological Authority (UNMA) is responsible for monitoring weather and climate and providing forecasts and advisories to government and other stakeholders for use in sustainable development.

*Data collection networks, monitoring practices, and data processing/management*

- *River Stage/Discharge*
  - Currently Uganda reports utilizing 69 operational streamflow stations. Equipment utilized includes staff gauges, and mechanical and automatic water level recorders. Operation and maintenance is the responsibility of the DWRM, with support from local hired observers.
  - "Two daily readings are taken from which the average level is established for the particular day. The water levels are recorded in a Gauge register or in strip charts or downloaded in data loggers, checked for basic errors in the field itself; brought by inspectors to surface water data center after every field visit, entered in HYDATA 4.1 version, manually checked for data quality, flagged if doubtful, and added to time series and stored in MS Access database. Surface observations are primarily manual and data transfer from the field to the processing center is slow and irregular." The HYDATA 4.1 is the principle database for time series of hydrometric data. A separate MS Access database is maintained in parallel for some stations, but has much lower status.
  - "Discharge measurements are carried out periodically to determine the stage-discharge relationship at a stable cross section of the water course. Velocity measurements using current meter (ADCP for large rivers- 3 units available) are made by inspectors when visiting field, converted to mean velocity and discharge, and rating curve generated at surface water Data processing center."
- *Precipitation and Other Meteorological Parameters*
  - Approximately 25 rainfall/meteorological stations are operated under the DWRM for purposes of enhancing quantification of rainfall over Lake Victoria in water balance calculations. These are operated under a memorandum of understanding with the Uganda National Meteorological Authority (UNMA). The Uganda assessment report notes that "meteorological data collection is affected by lack of observers, delayed transfer to data center, incomplete computerization, and poor data access." It is also noted that improved collaboration and capacity-building activities need to take place between UNMA and DWRM.
  - The UNMA is reported to operate several Automated Weather Stations and approximately 100 rain gauges.
- *Water Quality (including Labs) & Sediment Sampling*
  - The water quality monitoring network consists of 119 stations located at river, lake, groundwater, and "impact" sites. However, sampling frequency and parameters measured have varied due to budgetary and logistic constraints.
  - Uganda has a Central Water Testing Laboratory at Entebbe. The Laboratory is supervised by the Directorate of Water Resources Management (DWRM). The DWRM, as a lead institution on water quality monitoring and pollution control is

supported by NEMA Uganda. The Entebbe laboratory is well equipped with basic laboratory equipment and advanced equipment such as AAS and GLC and is one of the most advanced laboratories in the Nile Basin. It is able to carry out most of the physico-chemical parameters. The laboratory meets most of the national and regional water quality data needs. The Laboratory is however not accredited but is in the process of accreditation.

  - Sampling has typically been carried out once a year for turbidity and suspended solids but has not been synchronized with discharge measurements at surface water locations.

- *Groundwater*
  - 30 operational groundwater stations exist with 18 monitoring groundwater level trends and 12 sites monitoring abstraction. 21 sites also include rain gauges.
  - "Groundwater level is observed once a day, by water level meter or automatic water level recorder, and the field data is data brought by Inspectors, entered in Excel sheets at GW Data processing center; validated against rainfall record by senior hydro geologists, flagged when doubtful, and stored in national database in MS Access. The database includes data on site construction, investigation, well installation, spring construction, shallow well construction, bore logs, and water quality." Water quality samples are typically collected and analyzed once a year.
- *Spatial Datasets*
  - No mention of the use of spatial datasets within the country assessment reports.

The Uganda assessment report notes that "currently water resources data is held across a number of different databases in different software, formats. The ideal situation is to store the data in a single information system, with tools for data access, processing and analysis, and user-friendly dissemination."

*Data dissemination and application*

"The current policy is to levy a fee for accessibility of data for any commercial use. Government institutions and Agencies and any use for research purposes are exempted. The policy has proved difficult to implement because the various categories of users cannot be differentiated and it is proposed to allow free access to data and information during DWRM open days and annually published hydrological year books."

*Gaps in context of Regional Network*

- Uganda has a fairly broad existing national hydro-meteorological network that covers all potential parameters of interest for regional network data collection. However, it has been noted in the country assessment that the sustainability of operating and maintaining all stations has at times been limited due to funding constraints. As such, establishing a sustainable network that provides the highest priority national and transboundary data locations will require investigation.
- Data is currently recorded in multiple databases in different formats. Establishing a single repository and format will aid in data transfer to an NBI regional center.
- Establishing closer collaboration and data transfer with the UNMA will allow for additional precipitation and meteorological parameters to aid in water resource management at both the national and regional level.

### 3.1.11 Country Assessment Summary

Table 3-1 summarizes the existing hydro-meteorological capabilities of each country based on the aforementioned country assessments and consultations. For each identified process, an "N" signifies that it is not being carried out while a "Y" signifies a yes, or that the process is being performed.

**Table 3-1. Existing hydro-meteorological capabilities for each country**

| | Burundi | DRC | Ethiopia | Kenya | Rwanda | South Sudan | Sudan | Tanzania | Uganda |
|---|---|---|---|---|---|---|---|---|---|
| **Hydrometric** | | | | | | | | | |
| Automated stations | Y | N | Y | Y | Y | N | Y | Y | N |
| Telemetry | N | N | Y* | N | N | N | N | Y* | N |
| Water level | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| Discharge | Y | N | Y | Y | Y | Y | Y | Y | Y |
| Reservoir/Lake level | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| **Meteorological** | | | | | | | | | |
| Automated stations | Y | N | Y* | Y | Y | Y | Y | Y | Y |
| Telemetry | N | Y | Y | Y | N | N | N | N | N |
| Precipitation | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| Temperature | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| Relative humidity | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| Evaporation | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| **Water Quality/Sediment** | | | | | | | | | |
| Basic WQ | N | N | Y* | Y | Y | N | Y | Y | Y |
| Special WQ | N | N | N | Y | N | N | Y | N | N |
| Sediment Sampling | N | N | Y | N | N | N | Y | Y | Y |
| **Groundwater** | | | | | | | | | |
| Water level | N | N | Y* | Y | N | N | N | N | Y |
| Water quality | N | N | Y* | N | Y | N | N | N | N |
| **Spatial** | | | | | | | | | |
| Wetlands | N | N | Y+ | N | N | N | N | Y | N |
| Landcover | N | N | Y+ | Y | N | N | N | Y | N |
| Erosion | N | N | Y+ | N | N | N | N | Y | N |
| Meteorological | N | N | Y | Y | N | Y | N | Y | N |
| **Data Management/Comm** | | | | | | | | | |
| Coop-data systems | N | N | N | Y | N | N | N | N | N |
| Auto-access | N | N | N | N | N | N | N | N | N |

**These capabilities just recently introduced*

*+Ethiopia notes that internal spatial data needs to be updated*

## 3.2 Regional Assessment and Summary

### 3.2.1 National Summary

Based on the individual country assessments presented above, it is clear that each of the riparian countries has the requisite institutions established for monitoring, but that the level of professional depth and breadth of training and staffing varies, as do the hardware and software available for collecting and managing the data, as well as the actual parameters being measured.

All countries report limited staff and financial resources available to operate and maintain the complete national network of stations. As a result, the number of stations available in the current, active national networks is well below its historical maximum. In all countries the potential use of data for real-time water resources management is not realized because of a lack of telemetry and data processing and management systems. In some countries telemetry systems are in use at a limited number of stations, and in other countries there are no telemetered stations at all.

Pivotal elements of the regional monitoring system are the individual national water resources data management and information systems. These provide the link between data monitored in the field and transmitted to a regional information system. Not only do these systems need to have the appropriate capability for receiving, processing, and transmitting data for the regional network, but they also need to meet national needs in such a way that increases the overall value of the national monitoring program to keep it sustainable. It does not appear that the countries are using modern water resources data management systems to maximize the value of their monitoring programs. Many countries report dissatisfaction with their current systems. The systems that are currently employed will require either extensive customization or replacement to serve as the required links between the monitoring networks and the regional information system. While the NBDSS has been made available to each of the riparian countries, it was not developed as a data management solution for operational monitoring networks. Some countries have adopted it for data analysis and modeling and it could be enhanced to allow it to serve as an operational water information system.

Monitoring of sediment, water quality, and groundwater is lacking in most of the Nile Basin countries. In several countries there have been initiatives associated with measurement of these parameters, but in only one or two countries are there ongoing stable monitoring programs for these aspects of water resources.

While there is not a demonstrated history of water resources data exchange among the Nile Basin countries, the limitations associated with data collection and management described above would present a barrier to data sharing even if the protocols for such exchange existed, so this outcome is not surprising. In this context it is encouraging to note that inter-agency data exchange is actively taking place in some countries in spite of the limitations of the networks and data management systems.

### 3.2.2 Data Rescue

The discussion of water resource management issues presented in Section 1 of this report makes it clear that both historical data and real-time data must be readily accessible to support water management. For this reason, one of the factors that was evaluated in selecting stations for the regional network as described in Section 6 was the existence of a long historical period of record at an existing station. Applying this data for analysis and water management will require that data for the regional system be available and stored in a common digital format to populate the regional historical database, and it follows that that data for the national stations in each country also be available in a digital format for retrieval and analysis to meet national needs. Many of the countries lack data management systems of sufficient capacity to store and manage the volume of historical data that exist in paper records. Others have data management systems that do not integrate with telemetered data from modern data collection systems. One of the primary limiting factors in data availability, however, is that few countries have computerized the majority of their hydro-meteorological information in any format. A quick scoping assessment was therefore conducted of the extent of computerization of paper records (also known as 'data rescue' because of the vulnerability and limited usability of paper records).

To assess the existing status of data digitization/rescue efforts, a simple questionnaire was presented to the countries. Questions focused on whether procedures existed for digitizing historical or manual records, what percentage of data was archived in a digital format, and whether these data were readily available for query and retrieval in a database. Both a summary table of all country responses and complete answers to questions are provided in Appendix I.

In some countries, paper records have been digitized and stored in spreadsheets and other off-line digital sources, so there is already initial progress toward digitizing paper records for use in the regional system. Several of the countries however, reported less than a third of data archived in digital format and few countries having programs or quality control procedures for digital archiving. It is clear, therefore, that a substantial amount of data will need to be digitized to meet regional and national requirements and that the design needs to facilitate this data rescue task, both in terms of digitizing the data as well as providing a data management system appropriate for capture, retrieval, and analysis.

### Data Rescue Status Summary

The following summarizes the results of the questionnaire for the countries that responded:

- Ongoing programs for digitizing historical data exist in only about half of the countries. Some countries with no formal program, however, do have large percentages of their historical data records already digitized.
- Where no formal program for digitizing historical data exist, there are generally no current, established procedures to assure and control the quality of the digitizing process (although some quality control processes may have been used in digitizing data in the past).
- Many countries do have an ongoing program to record *current* manual observations in a digital form.
- The degree of digitization of historical meteorological data ranges from quite low (20%) in some countries to quite high (greater than 70%) in others.
- The degree of digitization of historical hydrological data ranges from low (30%) to very high (90%).
- There is not necessarily a close correlation within countries between having high meteorological data capture rates and having high hydrological data capture rates.
- Once data are captured, they are generally made available for query and retrieval within the ministry that captured the data.
- While the maturity of data rescue efforts varies between countries and between meteorological and hydrological services within countries, all countries identify a need for support and improvement in data rescue efforts.

Because of the vulnerability and limited accessibility of historical paper records for use and consultation, data rescue should be a priority for every country, and digitizing must be prioritized based on utility of the various data records and ease of capture. Although a full program may not be feasible initially, a small effort should be possible immediately as a start.

### Data Rescue Programs

The most basic efforts can be focused on the direct manual key entry of paper records into spreadsheets for immediate digital storage, validation, quality control, and retrieval. Subsequent efforts to digitize large quantities of data for storage in a water resources data management system can benefit from a systematic initiative that begins with entry of paper records into spreadsheets. Digitization of both historical and current data require procedures for quality control. Graphical procedures for quality control of historical data can be applied on monthly, annual, and period of record bases. The WMO has prepared guidelines for both hydrologic and climate data rescue (WMO-No. 1210, 2004) (WMO-No. 1146, 2014). These are described in more detail in Appendix H.

While data rescue encompasses both the preservation of paper records as well as the entry of data into a digital database for subsequent electronic query and analysis, the focus of discussion here is on the latter activity. It should be noted, however, that the capture of images of paper records may be an effective immediate approach to rapidly preserving paper records that can subsequently be entered into a digital database. One way to facilitate data rescue with limited resources is to solicit and engage the assistance of users of the data outside of the organization who may be willing to contribute labor resources in exchange for access to the data. In these instances it is essential to have an organized program and standard procedures so that complementary efforts can be sequenced over time to develop a continuous, consistent record. With proper systems and controls the internet can facilitate recruitment and use of volunteers for data entry and validation from scanned records.

Following are key concepts that should guide data rescue as part of an NBI regional monitoring network in the Nile Basin Countries (many of these concepts are elaborated in the WMO guidelines):

1. It is vital to establish a program with priorities, procedures, staff, and leadership to proceed in an organized fashion.
2. A search of what is available is required as a prerequisite to setting priorities for data rescue
3. An inventory of available data that have not yet been transferred to digital values must be created based on the search results.
4. Priority should be given to the stations identified in the regional monitoring network. These have been selected for their long period of record and strategic importance for both the countries and the region.
5. Priority should be given to capturing daily discharge at streamflow stations, daily precipitation and evaporation at climate and meteorologic stations, and water level, discharge, and evaporation data at reservoirs.
6. It is also vital to capture and store metadata about stations in addition to time series data. These include station history, type of equipment used over time, rating curves, discharge measurements, bathymetric surveys at sections, etc.
7. Clear file naming conventions must be established and followed when creating historical data files
8. Quality control procedures must be followed to assure accuracy in the transfer of data from paper or scanned images to data values. This is discussed in more detail below.
9. Quality controlled data must be transferred to a data management and dissemination database for application and the further quality checks that occur when data are applied in analysis and modeling.
10. A process needs to be in place to allow feedback from the users of the data to inform ongoing quality control and corrections.

### *Data Capture and Quality Control Procedures*

In the program planning process the formats chosen for data capture must take into account the formats, metadata, and import capability of subsequent data management tools to facilitate the ultimate destination and use of the data. Data entry and quality control procedures must be established individually in each country as part of its overall data rescue program and procedures. The WMO data rescue guidelines include suggestions and links to documents and procedures. The same procedures that govern quality control of real-time observed data also generally apply to data captured as part of a historical data rescue effort. The following are examples of common errors in data capture:

- digits are transposed
- a line (day) of data has been omitted
- a sheet (month) of data has been omitted

- months or years of data are repeated in place of actual data;
- data from one station are mistakenly recorded for a different station;

The following concepts will provide important guidance and standards:

1. Someone with basic knowledge of hydromet data measurement should undertake keying of data. The name of the technician and date of capture should be recorded.
2. A scientist or engineer should review the data capture results and quality control procedures followed. The name of the scientist and date of review should be recorded.
3. Clear distinction must be made between zero and missing values
4. Multiple “spot” checks of digital data against original paper records should be made
5. Range checks on acceptable values of parameters can quickly identify problems.
6. Data should be graphed and checked following digitization. This is a highly efficient and effective way to target data for spot checks and to identify errors. Discontinuities in continuous variables such as streamflow or reservoir elevation are readily detected. Potentially outlying precipitation values can be quickly spotted and checked.
7. Data should be summarized and checked following digitization. Comparisons with long term historical trends at a given station can be made by comparing monthly and annual means between years and at nearby stations to find outliers. Duplicate monthly or annual totals can be spotted in summarizing complete time series data for a given station.
8. Compare monthly summaries recorded on paper data sources with monthly summaries from the digital capture to identify and resolve discrepancies

The WMO guidelines state:

> With the help of the metadata the data series should be analyzed, as soon as possible in the digitizing process, on their meaning and reliability. Next, if possible, the data series should be tested with standardized homogeneity tests, preferably on the basis of monthly aggregations.
>
> Once the data rescued are found to be of good quality and integrity, standard climate products such as tables, climate averages and graphs should be made such as those mentioned in the Guide to Climatological Practices. This not only makes good use of the data but is a way to make sure that the data are in good shape and lets other groups (such as universities) know that these newly rescued data are available for their use as well. (WMO-No. 1210, 2004, pg. 9)

These concepts should provide helpful guidance to the countries in preparing data for incorporation in both national and regional (NBI) data management systems.

### 3.2.3 Regional initiatives

The Lake Victoria Basin Commission (LVBC) has developed a water resources information system (WRIS) that combines data from the countries in the Lake Victoria basin. The focus of this development, however, has been on the data management and dissemination system and software, so that the means of regular, consistent updating of data in the database is not yet established. Doing so will require infrastructure, training, and policy development and investment. Such investment in the implementation of the NBI regional monitoring system designs will be of parallel value to the LVBC system.

In many countries, including the Nile riparian states, there is a longer history of cooperation in the sharing of meteorological data. Examples of meteorological data exchange include the use of the GTS and the IGAD Climate Prediction and Application Centre regional arrangements.

ENTRO and NELSAP have each undertaken projects that required compilation of datasets from multiple countries, and have even initiated pilot efforts associated with operational products that utilize and demonstrate the value of data shared among countries, but these efforts have not resulted in permanent operational data sharing systems. A need remains for a regional or river-basin entity with capacity and responsibility to develop and support the complete process of water resources data collection, management and dissemination.

### 3.2.4 Summary

Following is a summary of the most important gaps that will need to be addressed in the development of a regional monitoring network:

1. Stations that are outdated and out of service due to lack of funding and personnel for operations, maintenance, and upgrades (including for equipment calibration).
2. Limited or non-existent telemetry systems for timely availability of data for operational use and for automated processing as part of a regional network.
3. Lack of adequate or modern data acquisition and management systems for receiving, processing, storing, disseminating, and transmitting water resources data and information.
4. Insufficient number and qualifications/training of staff for field measurement, field equipment maintenance, and data management system operation.
5. Limited or non-existent national water quality monitoring programs
6. Limited or non-existent national groundwater monitoring programs
7. Limited or non-existent national sediment monitoring programs
8. Limited institutional funding for operation and maintenance of current and future systems
9. Lack of demonstrated practices and procedures for transboundary sharing of operational water resources observations
10. Need for a regional authority with responsibility for water resources data collection, management, and dissemination.

# 4 Water Resource Management Issues

Specific water resources management issues with direct bearing on socioeconomic development and outcomes were first identified at the Launch Workshop in Addis Ababa, Ethiopia May 12-14, 2014. The selected management issues were drawn from those identified in the previous NBI study *Monitoring Strategy for the Nile River Basin* (NBI & Wright, 2010) and in the terms of reference (TOR) for the present study (see Table 4-1).

**Table 4-1. Evolution of Water Resources Management issues linked to Socio-economic outcomes**

| TOR for current study, February 2014 | Monitoring Strategy for the Nile River Basin July 2010 | Launch Workshop May 2014 |
|---|---|---|
| Improved water resources planning & management | Water resources development | Improved water resource planning & management |
| | Optimal water resources utilization | |
| Flood management | Coping with floods | Flood management |
| Agricultural services | Rainfed and irrigated agriculture | Rainfed agricultural management |
| | | Irrigated agricultural management |
| Drought management | Coping with droughts | Drought management |
| Soil erosion and sediment transport | Watersheds, wetlands, and sediment management | Soil erosion and sediment transport |
| Water quality management & pollution control | Water quality | Surface water quality |
| Groundwater management | | Groundwater management |
| | Energy development (hydropower) | Hydropower |
| | Navigation | Navigation |
| | Fisheries | Fisheries |
| | | Watershed management |
| | | Wetlands management |
| | Climate change | Climate change |

These issues have been outlined in subsequent sections 4.1-4.14 describing: the specific water resource management concerns; locations of these concerns within the Nile Basin; a brief summary of data requirements to address these concerns; and conceptual narratives that demonstrate the value of data for socio-economic benefit and decision support. Supporting material for these sections was based on a combination of a thorough literature review of existing national and regional reports related to the water resources management issues of the Nile Basin (see References on page 257); and consultations with country representatives during both the Inception Workshop and visits to ministries.

These consultations included country representatives providing feedback on the spatial extent and location of water management issues within their respective countries on working hard copy maps. The maps included background global data sets related to wetlands, irrigated areas, roads, rivers, navigable channels, and protected areas. Additional point data related to existing and potential hydro-power, as well as mining sites was also displayed. Country representatives were able to use their local knowledge to supplement the initial layers by noting additional areas of concern as well as expressing their perspectives on priorities. Figure 4-1 shows an example of the working map for South Sudan.

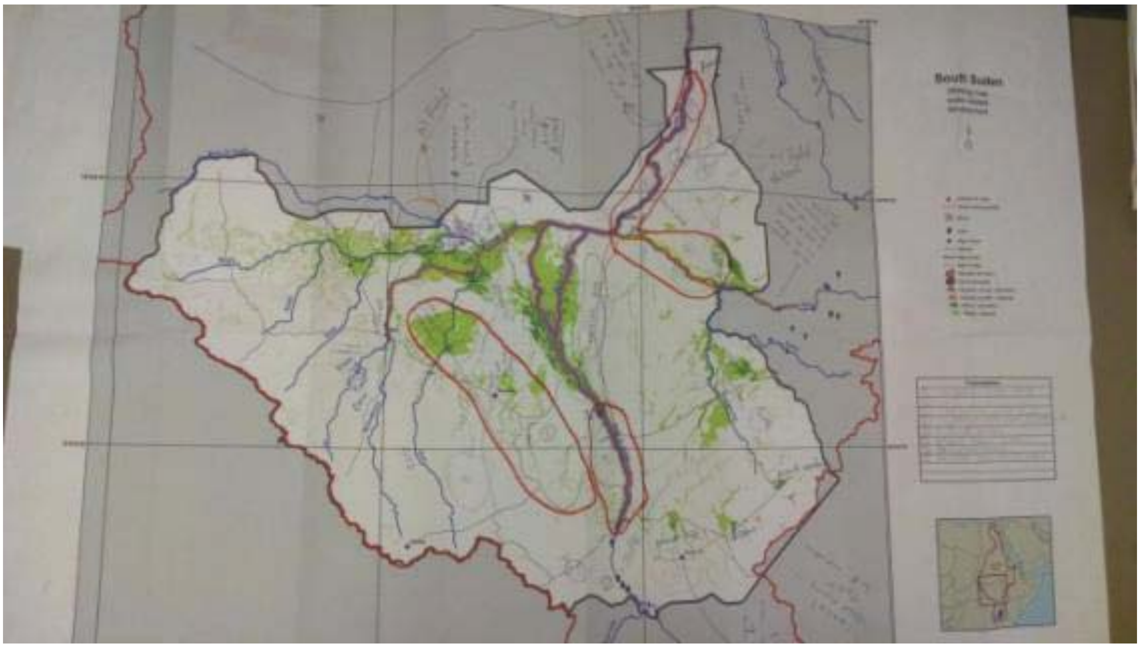

**Figure 4-1. South Sudan working map for water resource management issues**

From these working maps, the features labeled by country representatives could be digitized and labeled for use in ArcGIS. These new layers along with the initial set allow for the assessment of where water management issues exist and how the network design can provide monitoring benefits.

Water resource management issues requiring data for transboundary and collaborative regional management and decisions provide the basis for requirements for specific stations, parameters and frequency of monitoring discussed in Section 6.

The regional or transboundary nature of water resource management has multiple dimensions, including:

1. National water management issues that have an impact on the socioeconomic well-being of the region because of socio-economic interrelationships among countries and peoples of the Nile Basin (**Socioeconomic Interactions - SI**). It should be clear that this dimension is a factor for all water management issues in all countries.
2. National water management issues that require data from other Nile Basin countries for effective analysis, planning, and operations (**Data Dependency - DD**). This is the case whenever a downstream country is dependent on data from an upstream country for planning, analysis, or operational decision making, or for example when an upstream country needs downstream data for planning and operations to assess and address impacts from upstream management decisions.
3. Transboundary water information needs that are required to monitor compliance with water quality or discharge agreements or to establish baselines for defining such agreements (**Transboundary Agreements - TA**);
4. Basin-wide water management issues where data are required for cooperative planning and operation of transboundary water resources infrastructure or to achieve transboundary

benefits. The key to this dimension is transboundary cooperation beyond data sharing (**Cooperative Action - CA**). This dimension represents the most important justification supporting a regional water resources monitoring and information program. It is applicable whenever resources in one or more countries can be managed alone or in connection with resources in another country for an overall increase in benefits.

The aforementioned dimensions noted above (SI, DD, TA, and CA) are used in the following Sections 4.1-4.14 to label how a specific water resources management issue relates to regional or transboundary concerns. This is followed by section 4.15 which presents a table of the primary regional water resource management issues where the hydro-meteorological design will provide opportunities for substantial transboundary benefits. These regional issues were reviewed, revised and agreed upon by country representatives during the Conceptual Design Workshop in Nairobi Kenya, October 9-10, 2014.

## 4.1 Improved Water Resource Planning and Management

**Socio-Economic Concern:**

The Nile Basin exhibits considerable untapped potential for improving energy, water and food security, navigation, and environmental management. Each distinct sub-basin in the large Nile basin is characterized by uneven distribution of water resources with a different hydrologic regime and water- related development potential. In addition, there is great potential in the Nile Basin for enhanced coordinated management of water storage infrastructure for optimized or improved mutual benefits among the riparian countries. The importance of coordinated management will progressively increase when new irrigation schemes and water infrastructure are established across the basin, and it may no longer be possible to meet all system demands at 100% reliability level, in particular during periodic drought years. A significant proportion of the untapped development potential lies in the areas of the basin with poor monitoring infrastructure.

Wherever dams and reservoirs exist or are planned monitoring can assist downstream countries in assessing the impact of reservoir operations (DD). Upstream countries can coordinate reservoir planning and operations with downstream country officials for overall improvement in water management (CA).

**Example Locations:**

- Ethiopia
  - Constructing a dam on the Baro River which could reduce overbank spillage and increase storage but may impact the downstream region around the Baro – Akobo confluence (SI, DD, CA)
- Uganda
  - Regulating Lake Victoria/Lake Albert outflows (SI, DD, CA)
  - Managing soil fertility to improve agricultural yield (SI)
- Kenya
  - Expanding water harvesting (SI)
  - Improving food security using drought-tolerant and early-maturing crops (SI)
- South Sudan
  - Improved monitoring for water resource management throughout the country (Bahr El-Jebel Basin, Sobat Basin, Bahr El-Ghazal Basin, and Upper White Nile Basin). (SI, DD, CA)
- Tanzania
  - Improved monitoring of precipitation and water quality for water resource management within the transboundary Mara Basin (SI, DD, CA)

**Data Requirements:**

- Precipitation – Daily monitoring at key locations
- Temperature, RH, Wind, Pan Evaporation – Monthly monitoring
- River Stage/Discharge – Daily monitoring at key locations
- Lake/Reservoir Levels – Daily monitoring at key locations
- Groundwater Levels – Monitored quarterly at key locations
- Groundwater Yields – Annual
- Irrigation Demands – Weekly for major schemes
- Urban Domestic Demands and Industrial Demands – monthly
- Groundwater Use for Irrigation, Urban Domestic Use, and Industry – weekly at key locations
- Sediment Sampling – Monthly
- Water quality monitoring – Monthly
- Land Cover/Use analysis - Annual

**Socio-Economic Value of Data:**

Optimizing or improving total system benefits in a system with multiple reservoirs and objectives will require coordinated management. An example of coordinated operation concerns the interplay between the possible water storage facilities in the Blue Nile gorge and downstream irrigation. The Blue Nile dams in Ethiopia are primarily intended for hydropower production but may also facilitate multiple cropping seasons in the downstream irrigation schemes in Sudan. Coordinated release policies would lead to considerable food security and socio-economic benefits for the downstream communities. The coordination process is typically informed by a comprehensive Decision Support System (DSS) that serves to assess the benefits and trade-offs of various reservoir release rules and water use policies.

Development, validation, and real-time operation of the DSS require diverse hydro-meteorological information including precipitation, temperature, relative humidity, wind, and pan evaporation data. The hydrologic models use these data for flood forecasting and developing flood warning systems. In case of hydropower plants, monitoring reservoir levels are important to ensure maximum power generation. Water levels in lakes and reservoirs also help to determine total water storage available for human use and the environment. Monitoring flow in the river helps to manage water for anthropogenic uses. Without such information, operation of the complex Nile system will be sub-optimal, and potential socio-economic benefits may be lost.

## 4.2 Flood Management

**Socio-Economic Concern:**

Several areas within the Nile Basin are prone to frequent flooding which can cause loss of life and damage to property and agricultural goods. Flooding can be the result of both slow rising rivers, lakes, and wetlands as well as flash floods for concentrated areas of population. Mitigation measures to reduce the economic, social and environmental losses due to flooding include not only the construction of reservoirs and dikes, but also utilizing forecast data and models to optimize the operation of existing flood control infrastructure. Further benefits can be achieved by coupling flood forecast and warning systems with community awareness and preparedness.

Wherever flooding is generated by rainfall and runoff in upstream countries, data dependencies exist for the downstream countries (DD). Wherever dams and reservoirs in upstream countries can be operated to reduce downstream flooding, cooperative action can be planned (CA).

**Example Locations:**

- Ethiopia
  - Lake Tana Region of the Blue Nile headwaters. (SI)

    - Gambela region along the Baro and Akobo Rivers upstream of the confluence with the Sobat River. (SI, DD, CA)
- Sudan
    - Central Sudan near Khartoum at the confluence of the White and Blue Nile experienced significant flooding in 2013 and 2007. (SI, DD, CA)
    - Flooding along main-stem and tributaries of White and Blue Nile upstream of Khartoum. (SI, DD, CA)
    - Prevalent flooding also occurs along the Atbara River. (SI, DD, CA)
- South Sudan
    - Seasonal flooding within the Sudd wetlands. (SI, DD, CA)
    - October 2013 floods impacted the majority of the northern half of the country cutting off roadways and flooding fields and homes. (SI, DD, CA)
- Rwanda
    - Significant floods in north western Rwanda in 2012 for the Musanze Northern Province, and Nyabihu and Rubavu districts in the Western Province. (SI)
- Kenya
    - Occasional flooding for major rivers that outlet to Lake Victoria (Sio, Nzoia, Yala, Nyando, Sondu Miriu, Mogusi, and Gucha-Migori) (SI)
- Tanzania
    - Occasional seasonal flooding for rivers that outlet to Lake Victoria (Simiyu, Grumeti, Mbalageti, Kagera at Kyaka) (SI)
- Uganda
    - Significant floods in Kasese district in May of 2013.
    - Significant floods in Amuria and Katakwi districts in 2007. (SI)

**Data Requirements:**

- River Stage/Discharge – 10 minute or continuous for flash flood monitoring; hourly or daily for basin forecasting
- Precipitation – 10 minute or continuous for urban flash flood forecasting; hourly or daily for basin forecasting
- Reservoir/Lake Level – Daily and potentially hourly during flood operations for assessing storage and release
- Temperature, Wind, Relative Humidity, Pan Evaporation – Monthly (important for calibrating hydrologic models but real time information not necessary)

**Socio-Economic Value of Data:**

*Development Planning* – Knowledge of the location and extent of flooding of various return periods can allow planners and government agencies to assess vulnerability of land parcels subject to flooding and to plan development to avoid such locations or to assign agricultural or other activities that result in an appropriate level of risk in connection with flooding probabilities. Establishing this knowledge requires historical streamflow records (water level coupled with rating curves) and/or precipitation records coupled with watershed spatial characteristics for hydrologic simulation and terrain data to determine extent of flooding. Where the flooding is the result of runoff from upstream watersheds located in other countries, the planning takes on a transboundary character, and downstream countries are dependent on data collected from upstream countries to be able to accurately assess vulnerability and risk.

*Flood preparedness* – Similar to development planning, flood preparedness can incorporate knowledge of the location and extent of flooding of various return periods, together with the correlation of expected flood extent with river stage at monitoring locations to plan for timing and routes for evacuation and protection of property. Data requirements are similar to those for development planning.

*Flood warning* – Hydrologic forecast and flood warning systems can be developed to provide specific warning of potential flooding in downstream areas based on river stages and hydrologic simulation of runoff using precipitation forecasts and observations. In large river basins with sufficient lead time, regional and international disaster agencies can plan for timely delivery of relief. Where upstream countries have the flexibility and willingness to operate reservoirs in such a way as to limit downstream flood damages, knowledge of downstream tributary flows can permit operation of reservoirs in a manner that avoids combining peak discharges below a confluence. Protocols for sharing of provisional real-time data can be established to collaborate for the protection of life and property.

Data requirements include both the real time-data for operation of systems as well as the historical data needed to calibrate models.

## 4.3 Rainfed Agricultural Management

**Socio-Economic Concern:**

The agricultural sector is of immense importance to all Nile Basin countries in terms of contribution to GDP (between 12% and 43%), employment (between 32% and 94% of the labor force), and food production. Rainfed agriculture accounts for over 87 percent of cultivated land within the Nile Basin, most of which occurs in the Ethiopian highlands, upper Nile and Equatorial Nile area (NBI, BMZ, & GIZ, 2012).

Rapid population growth combined with food security concerns point to further expansion of agricultural activities. Rainfed agriculture – including rainfed pastoral land - will remain dominant in the upstream Nile basin countries in the foreseeable future, in spite of development of irrigation potential.

Rainfall over the Nile basin is characterized by high temporal variability, also within the seasons. Potential evaporation rates are high and exceed annual rainfall in most of the basin. This makes the basin particularly vulnerable to drought events, and periodic moisture deficits at critical points for crop growth are among the principle reasons for low crop yields, and associated low standards of living in rural areas. The rainfed agricultural sector may further be affected by the increased frequency of extreme precipitation events because of global warming, which could cause crop losses and associated socio-economic strain.

Rainfed agriculture is by nature a national issue whose regional significance is related to socioeconomic interactions between countries. This issue does not usually appear to have important transboundary data requirements associated with it because it is not dependent on river discharge. During periods of drought, however, this issue can take on a regional dimension due to the potential spatial extent of drought that can impact multiple countries simultaneously. This aspect is discussed under the Drought Management topic in Section 4.5.

**Example Locations:**

Figure 4-2 presents the main agricultural systems in the Nile Basin.

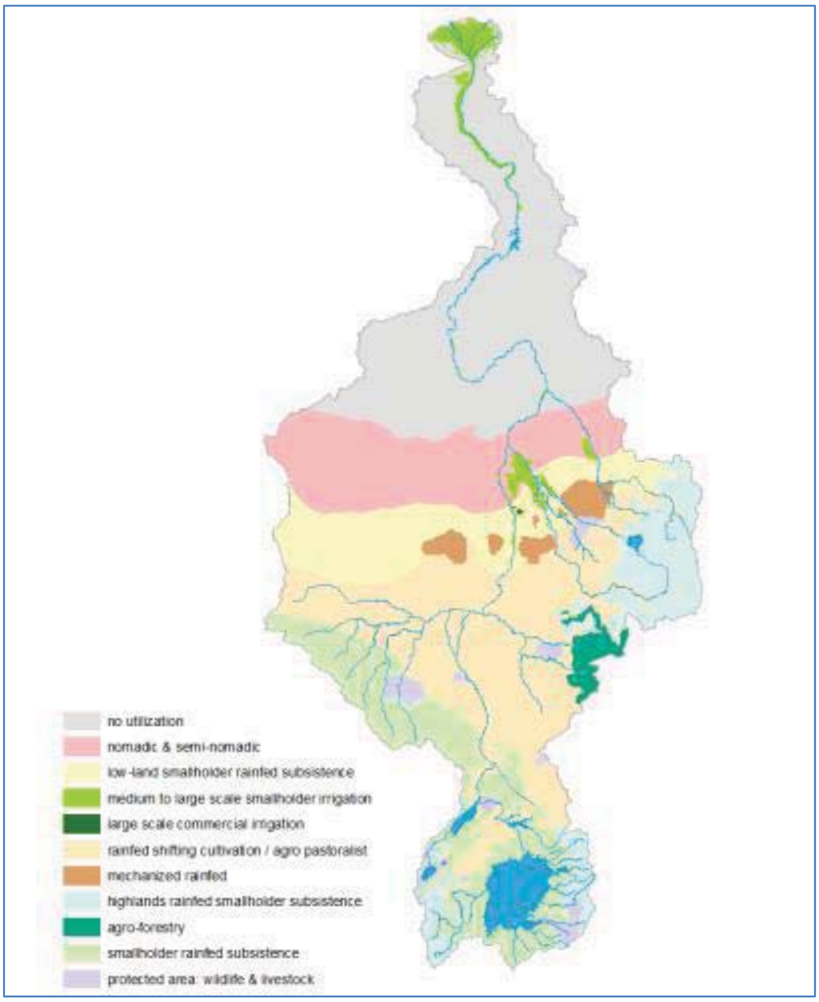


**Figure 4-2. Main Agricultural System in the Nile Basin**

The most important rainfed production systems are as follows:

*Mixed smallholder subsistence rainfed:* This is found in the sub-humid and humid parts of the Nile basin at altitude between 500 and 1500 m above sea level. Farmers grow cereals and legumes primarily for household consumption, and some minor crops for cash. Usually, they also keep a few livestock. Productivity for most crops is low – less than 2 ton/ha (NBI et al., 2012). This system is found in the DRC, Kenya, Rwanda, South Sudan, Tanzania, and Uganda.

*Mixed highland smallholder subsistence rainfed:* This is found in areas above 1500 m altitude where rainfall usually exceeds 1,000 mm/yr. Deeply entrenched traditional crop and livestock practices under temperate climate conditions produce a wide range of fruits, vegetables, cereals, and pulses. Productivity for most crops is low and poverty is high. The average human population density is high, and land has become fragmented with average farm size of less than 0.5 ha (NBI et al., 2012). This system is found in Burundi, Eritrea, Kenya, Ethiopia, Rwanda, and Uganda.

*Mechanized rainfed*: Production, which targets local and export markets, is dominated by industrial crops notably coffee, tea, oil palm, and rubber, as well as cereals and fruits. This production system consists of consolidated farms larger than 1000 ha. Farm operations are largely mechanized (NBI et al., 2012). This system is confined to Sudan and South Sudan, with isolated occurrence in the upper Nile countries.

Livestock-centered production systems are found in the less productive areas of the Nile region. The most important pastoralist systems are:

*Nomadic and semi-nomadic:* This describes the transhumance pastoralist livelihood practiced in areas under arid and semi-arid climatic conditions and sparse population (NBI et al., 2012). This system is found predominantly in Sudan.

*Lowland smallholder subsistence rainfed*: This system is found in the savannah belt where annual rainfall ranges from 300 to 500 mm/year. It combines traditional extensive rainfed cultivation with livestock keeping and is vulnerable to drought (NBI et al., 2012). This system is found in Eritrea, Ethiopia, South Sudan, and Sudan.

*Shifting rainfed cultivation/agro-pastoral:* This system combines the keeping of livestock and cultivation of crops for subsistence. The livestock graze on communal land near the permanent cropping areas, on fallow land during the dry season, and throughout the area after crops have been harvested (NBI et al., 2012). This system is found in Ethiopia, Kenya, South Sudan, Sudan, Tanzania, and Uganda.

**Data Requirements:**

A wide range of data is needed to support decision making in rainfed agriculture. This includes data on soils, markets, diseases, crop type and yields, climate, etc. However, only agro-climatic information will be discussed in this study.

- Precipitation – Daily and sub-daily measurements for key locations
- Other meteorological/agro-climatic parameters including temperature, relative humidity, air temperature, soil temperature, air pressure, wind speed and direction, incoming solar radiation, sunshine duration, pan-evaporation, and surface (leaf) wetness – Daily and sub-daily measurements for key locations

**Socio-Economic Value of Data:**

It is important to note that in addition to providing information for operational decisions for local rainfed agriculture, the above stated agro-climate data can be used for the following important regional applications:

*Drought Monitoring*- The aforementioned climatic data is necessary to assess the spatial extent and severity of droughts in order to initiate drought relief and inform local and regional food security analysis. It enables government and humanitarian actors to quickly recognize a (potential) crisis and take action. The Palmer Drought Severity Index is an example of a widely used climate-based drought indicator most effective for un-irrigated cropland. See Section 4.5 on “Drought Management” for further detail.

*Seasonal Climate Forecasting*- The aforementioned climatic data is necessary to monitor, understand, and ultimately predict seasonal climate variability. This includes the effects of the ENSO and Indian Ocean Dipole phenomena, which are relevant for the Nile region. Farmers will be able to adjust planting decisions to the anticipated weather conditions in order to take advantage of good years (high rainfall) while minimizing losses during periodic drought years. It will reduce the risks associated with agricultural production, increase food security, and provide better economic outcomes for rural communities. The dynamic seasonal climate models are highly data intensive.

*Agricultural Research*- A good regional coverage of climatic data supports a wide range of agricultural research activities. This includes *inter alia* breeding of drought resistant and higher yielding crop (and animal) varieties specifically adapted to local and regional environmental conditions, development of specific pest and disease control measures, etc.

Data requirements for enhancing the adaptation of rainfed agriculture to the changing weather patterns are discussed in section 4.14 “Climate Change”. Data requirements related to small-scale supplementary irrigation are discussed in the next Section 4.4 of “Irrigated Agriculture Management”.

## 4.4 Irrigated Agricultural Management

**Socio-Economic Concern:**

Demand for agricultural produce in the Nile Basin is steadily rising because of population growth, economic development, and changes in dietary patterns. While the production levels of food crops have been rising, food production in the Nile countries falls short of local demand, and all countries are currently net food importers (NBI et al., 2012). Irrigation provides reliable water supply for crop production and is key to increasing agricultural yields. It is the only way to grow a crop in the arid and semi-arid zones of the Nile basin, while it is essential to supplement periodic moisture deficits in other parts of the basin subject to high temporal variability of rainfall. Irrigation thus supports improved standards of living of the rural population in the semi-arid and arid areas and erratic rainfall areas and is critical to attaining food security in the basin.

Irrigated agriculture is the largest consumer of renewable resources in the Nile Basin. Approximately 4.9 million hectares of land is under irrigation in the basin. An additional 0.7 million hectares is not irrigated but is equipped for irrigation, bringing the total irrigable land in the basin to 5.6 million hectares. A large part – 97 percent – of this land is located in Egypt and Sudan, while the remaining 3 percent is located in the upstream countries (NBI et al., 2012).

Many upstream countries now plan to expand their irrigated areas. This issue can have important data dependencies when downstream countries depend on data from upstream countries to assess reliability of supplies (DD). Cooperation is vital when upstream irrigation can potentially reduce downstream water availability or when upstream resource development or management can be undertaken to improve downstream reliability of supplies (CA). Where agreements about water quality between countries are needed to assure suitability for irrigation, monitoring also takes on a transboundary dimension (TA).

**Example Locations:**

Figure 4-3 presents the main existing irrigation areas in the Nile Basin.

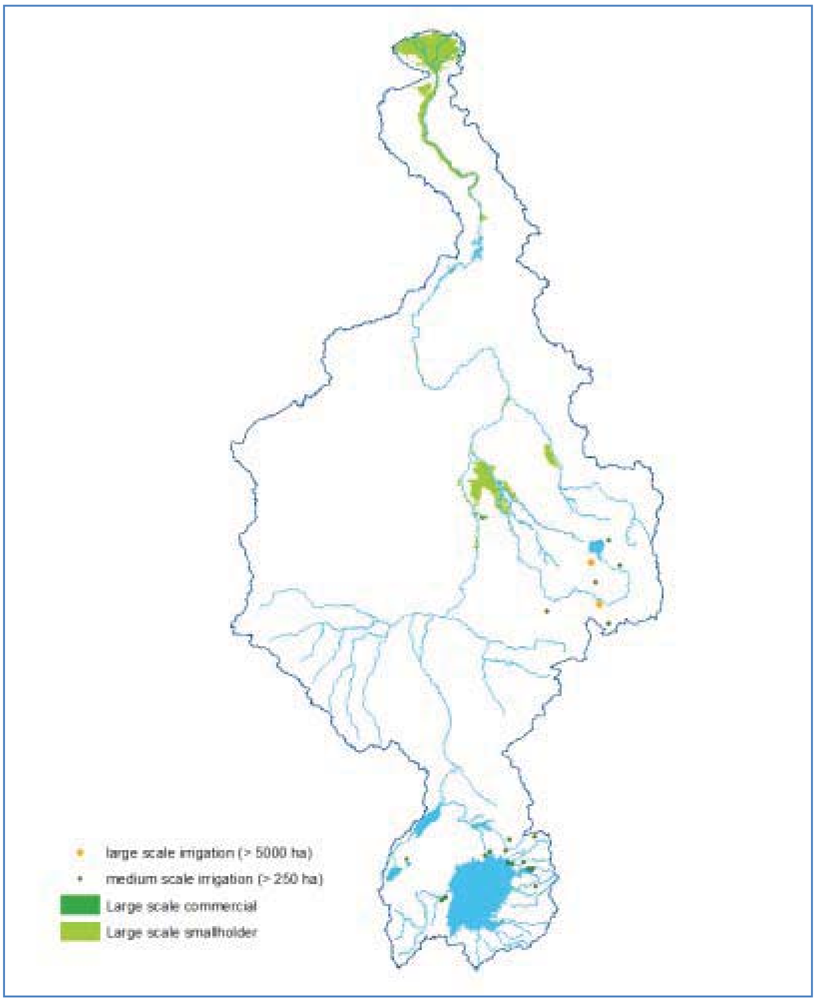


**Figure 4-3. Existing Irrigation within the Nile Basin**

The most important irrigated farming systems are:

*Medium- to large scale smallholder irrigation:* This consists of traditional river diversion and gravity supply schemes, which can be very large (e.g. the Gezira in Sudan). Pump irrigation (from water source to main canal) is increasing. Water is distributed to the fields via earth canals. Holdings vary from less than 1 ha per household to 20 hectares.

*Medium- to large scale commercial irrigation:* These are commercially owned holdings typically exceeding 1,000 ha. They are managed by private companies and produce high-value crops. Almost all operations are mechanized and use of fertilizers and other yield-enhancing inputs is relatively high.

*Small-scale supplementary irrigation:* This has not been mapped as an independent production system and is in fact an extension of rainfed cultivation. Occasional moisture deficits are supplemented with irrigation water through a whole range of practices such as treadle pumps, drip systems, sprinkler systems, etc. The choice of technology and water source depends on local conditions. Solutions are very much local and mostly implemented for single farms (households).

As discussed above, plans exist to expand the irrigated area in the Nile basin. Long-term development plans of the water-related productive sectors (such as irrigation, hydropower, navigations, etc.) are a key input when designing an effective basin-wide hydro-meteorological monitoring network.

A map of the irrigation potential of Uganda is presented in Figure 4-4. It was obtained from the National Water Resources Assessment for Uganda, which is in the public domain. It is noted that the map excludes upland and small-scale supplementary potential.

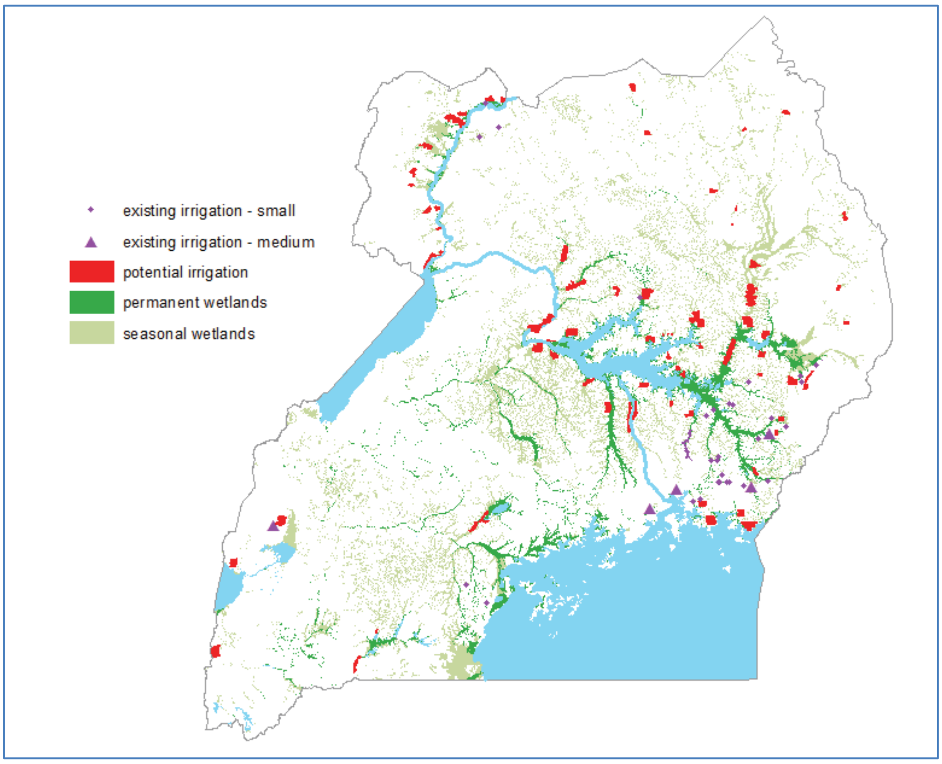


Figure 4-4. Existing and potential irrigation in Uganda

**Data Requirements:**

- Daily climate data (rainfall, and all meteorological parameters to calculate Penman reference evaporation) to estimate crop water demand and daily, 10-day, and monthly irrigation requirements. It is assumed that spatial information such as the location of irrigation areas and distribution of crop types is available. Network density depends on the size of the irrigation scheme.
- Soil data to assess infiltration capacity and soil moisture capacity and content to determine irrigation and drainage scheduling. Daily data on the soil-moisture balance is required. It is noted that local soil conditions can vary substantially. Preferably, farmers need to know soil water availability field by field. Daily monitoring of groundwater levels assists in reducing risks of water logging.
- Daily river discharge in order to calculate base flow and sustainable water off-take rates. This information is also required for low-flow analysis and drought risk assessment.
- Daily information on the water intake to the scheme. Similarly, the return flow of drainage water to the river needs be measured (daily aggregated volume).
- Information on salinity and other relevant water quality parameters is needed to assess if the water source is safe/suitable for crop production. The temporal resolution of these data depends on the characteristics of the water source. For instance, surface water quality can be affected on a daily (even hourly) basis by upstream activities.
- Daily data on sediment rate of the water source in order to determine irrigation scheduling and reduce canal sedimentation and associated scheme operation and maintenance costs. Whether or not this information is required depends on local conditions.

- Sustainable groundwater yields (taking into account safety factors and environmental water requirements) need to be assessed on a monthly and annual basis for irrigation systems supplied by groundwater. As discussed above, the quality of the groundwater source need to be monitored.

**Socio-Economic Value of Data:**

Adequate climate and soil data will lead to a more accurate assessment of irrigation requirements and increase crop yields, reduce water losses and associated salinization risks, and result in lower water abstraction (and thus lower energy costs in case of pumping schemes). It will provide better economic outputs for the scheme and the communities depending on it, and thus support the local and regional economy. Potential surplus production because of higher yields could assist in addressing (regional) food security concerns.

Lower irrigation losses could make a contribution to reduce basin-wide water stress, given that irrigated agriculture is the single largest water-consuming sector in the Nile Basin. Further, accurate climate and soil data will facilitate deficit irrigation in times of occasional (or periodic) basin-wide water stress. In a system with multiple objectives (such as the Nile basin), coordinated operation of all system elements (e.g. hydropower facilities, irrigation schemes. etc.) would maximize total benefits. Deficit irrigation maximizes crop water productivity rather than yield. The water saved can be used for other high-value purposes. It is noted that maximizing total system benefits requires high levels of cooperation and clear mechanisms for benefit sharing across riparians and stakeholders.

Daily sediment data could reduce operation and maintenance costs of some irrigation schemes. The excessive sedimentation of some gravity irrigation schemes in the Eastern Nile cause great difficulties and consume a very substantial percentage (e.g., up to 50% for the Gezira in Sudan) of the annual budget for operation and maintenance. Relatively short periods of high sediment concentration (from mid-July to the end of August) are believed to result in about 80% of sediment deposits in the major and minor canals. Hence daily knowledge of sedimentation rates in the river reaches upstream of the intake point could assist in minimizing sediment inflow.

The benefits of data on nutrient and pesticide levels of drainage water are discussed in Section 4.7 on "Water Quality Management".

## 4.5 Drought Management

**Socio-Economic Concern:**

Drought is an extended period of below normal precipitation or water supply for a given region. Depending on the duration and intensity, drought can have significant social, economic and environmental impacts. High potential evaporation rates within the Nile Basin make the region particularly vulnerable to drought. With over 87 percent of the cultivated land in the Nile Basin being rainfed agriculture, farmers who depend on normal precipitation patterns may be the most susceptible demographic. An improved understanding and forecasting of climatological conditions can lead to enhanced preparation for drought mitigation measures and efficient use of available water supply.

Because of the potential for a regional drought to cover multiple countries, and because of the potential impact on regional food supplies, drought may be considered a regional issue with potential for cooperative resource management to mitigate its effects (CA). Early detection of drought requires a continuous and broad spatial sampling of rainfall data in connection with streamflow data at key locations, all of which can be expected to cross some national boundaries for a particular drought region. This represents a special case of data dependency (DD) where any national or regional analysis of drought conditions will require data from multiple countries.

**Example Locations:**

- Sudan - Regions of Darfur and Western Sudan are historically vulnerable to drought but the entire country of Sudan is susceptible. (SI, DD, CA)
- South Sudan - Warap Province experienced drought in 2010. Concerns are generally greatest for larger towns (Renk, Kopeta, Malakal, Wau, Awesi, Juba, Bor) (SI, DD, CA)
- Tanzania – Mwanza Region (Kwimba district), Simiyu Region (Maswa District), Mara Region (Rorya District and Bunda District). (SI, DD)
- Uganda - Eastern Ugandan district of Bulambuli experienced drought in 2011. (SI, DD, CA)

**Data Requirements:**

- Precipitation – Daily monitoring at key locations
- Temperature, Relative Humidity, Wind, Pan Evaporation – Monthly monitoring
- River Stage/Discharge – Daily monitoring at key locations
- Lake/Reservoir Levels – Daily monitoring at key locations
- Groundwater Levels, Yield, Quality – Monitored monthly or quarterly at key locations

**Socio-Economic Value of Data:**

Indexing historical drought events to precipitation, other meteorological parameters, and streamflow records can allow for regional analysis of areas vulnerable to famine based on current conditions and seasonal forecasts. This can allow for early mobilization of potential aid or decision support on how crises could best be averted.

One possibility of supplementing drought losses of rain fed agriculture could be increased irrigated agriculture production. If sufficient storage of water is available from upstream reservoirs, increased releases could be made to amplify agriculture production or recharge groundwater aquifers. This data may also lead to studies that analyze where irrigated agriculture is currently underutilized to complement expansion and resiliency for future drought events as briefly described in Section 4.4 "Irrigated Agricultural Management."

Groundwater is often the last water resource available during a drought event. Monitoring groundwater yield, quality, withdrawal, and potential for recharge during drought conditions will further supplement decisions to mitigate disasters.

## 4.6 Soil Erosion and Sediment Transport

**Socio-Economic Concern:**

Soil erosion and sediment transport are major issues in many of the upstream catchments of the Nile Basin. Upstream catchments in the Nile Basin face a range of degradation challenges associated with natural occurring processes and human activities, such as over grazing and deforestation.

Resource degradation processes have impacts not only locally, but far downstream within and beyond the borders of the country within which they occur. The most significant impacts of land degradation in the Nile Basin are:

- Loss of soil productivity because of accelerated erosion of the topsoil.
- Increased siltation of reservoirs for hydropower and irrigation as well as siltation of diversion works and irrigation canals.
- Deteriorating water quality due to increased suspended load and sedimentation.

Soil erosion and sediment transport is the main cause of sedimentation issues at downstream hydraulics infrastructures such as dams, diversion structures, and irrigation canals. Inappropriate use of land for agriculture and poor management lead to environmental problems such as land degradation through soil erosion and increased sediment deposition into the water bodies and streams. The consequences are that nutrients and chemicals from cropland are transported into water systems. Aquatic systems are modified by increased deposition of sediments and by the absorbed nutrients and chemicals carried by sediments. These nutrients often result in eutrophication, which in turn negatively influences aquatic habitat for fish and other organisms. Climate change, which enhances major climatic events such as flooding, can also accelerate soil erosion

Investments in water related infrastructure are adversely affected. Reservoirs established for hydroelectric power, urban water supply, and agriculture accumulate alarmingly higher levels of sediment than expected. The consequences for reservoir sedimentation include increased hydro-equipment maintenance and repair, decline in water quality, cost of removing sediment, blockage of inland water systems, and loss of recreation opportunities.

The impact of soil erosion and degradation has not only economic, but also social and political consequences. The absence of adequate integrated watershed management interventions, soil erosion and degradation of natural resources will continue at accelerating rates, reducing agricultural productivity and affecting household economies.

The impact of soil erosion and degradation also has some benefits. The sedimentation in Lake Nubia is not seen as a negative impact in Sudan. Here the sedimentation contributes to the development of fertile agricultural land in the new delta that is forming in the Lake Nasser/Nubia (Staub & Seman, 2012). However the use of fertilizers and/or pesticides in connection with agricultural activities close to the river will impose a risk to the water quality downstream.

Soil erosion and sediment transport clearly have a dimension of data dependency (DD) in which downstream regions require information on upstream sediment levels that can be expected, and even upstream countries may benefit from downstream sediment data to characterize and manage erosion. Moreover, collaboration in erosion management and reservoir operation may produce benefits for both upstream and downstream countries (CA).

The problems related to soil erosion and sedimentation vary greatly from one area to another as the two main tributaries have very distinct hydrologic regimes. The Blue Nile (Abay) and the other rivers coming from the Ethiopian Highlands contribute between 80 and 90 percent of the Nile’s flow, but are highly seasonal and carry high sediment loads that affect downstream dams and irrigation canals in Sudan (SI, DD, CA). The White Nile, by contrast, has a steady flow, with low sediment content, and contributes some 10 to 20 percent to the annual Nile discharge.

In Ethiopia, with high and heavy rainfall, steep slopes and erodible soils, the problem of soil erosion and sedimentation is dominating. Several new dam projects are planned in Ethiopia and their associated reservoirs will have to deal with the high sedimentation rates and the associated bank erosion.

A problem that is specific to Sudan is the sand encroachment of Nile. Wind-blown sand settles within the river cross-section and enters into the sediment balance of the river. Sand encroachment creates problems locally, by enhancing local flooding and changing the river regime and eventually contributes to the sedimentation in Lake Nubia/Nasser (SI). However, it has been estimated that the total wind-blown sand constitutes only 1 to 2 percent of the total sediment load entering the lake (ENTRO (CRA Consortium), 2007). The most damaging effects from wind-blown sand are due to impacts on canal and irrigation schemes.

**Data Requirements:**

Accurate prediction of soil erosion and sediment transport under different land use and management practices, and the associated impact on water quality is a key to solutions in terms of sound watershed plans that will reduce soil erosion in critical areas, thereby reducing downstream impacts. However, available data in the basin is scanty and whenever this is available it is reported to be of poor quality making planning at a larger scale difficult. Thus, there is a need to accurately document the level of erosion and sedimentation both in time and space and to establish relationship between land use and management practices and soil erosion and sediment transport.

The quantification of soil erosion is based on empirical formulas supported with local research that need to be tuned to each geographical location. The quantification of sediment transport rates in flowing water is still a semi-empirical science that relies more on measurements than hydrological and hydraulic relationships and principles.

The uncertainties in sediment transport measurements are far higher than for measurements of hydrometric parameters, such as discharges. Hence, the accuracies of sediment transport predictions are bound to be relatively low, but still very useful in the evaluation and assessment of the effect of watershed management interventions and development options.

The monitoring of soil erosion of suspended sediment loads throughout the basin at the outlets of sub-catchments and catchments of varying size will provide input to a more complete understanding of the linkages between catchment size, geomorphology, soils and land use, and the dynamics within the sub-catchments. Since it may not be feasible to undertake this across the whole basin, a number of representative sub-catchments may be selected and monitored to support a greater understanding of the impacts of watershed management interventions as well as natural processes. The importance of cooperative data and information collection in the Nile Basin is essential to maximize the return on the data collection and monitoring investment as well as for capacity building and institutional strengthening.

**Socio-Economic Value of Data:**

Soil erosion leads to increased sediment loads of rivers. As a result, there is increased siltation of major reservoirs for irrigation and hydropower generation reducing their efficiency and useful life. The useful life of reservoirs is sometimes mitigated through costly desilting operations and may be extend through operational procedures that enable high sediment loads to be passed or flushed.

The high sediment loads have considerable negative impacts including reservoir storage loss, increased costs for removal of sediment for domestic water supplies, damage to hydro-electric turbines and irrigation pumps, higher irrigation-system operation and maintenance costs, increased dredging in front of turbines in-takes, higher cost of water purification, pump damage, river bed aggradations, lost hydroelectricity production, and losses in agricultural production. Sustainability of this infrastructure depends on availability of reliable and representative sediment data for design and operation.

Measurement and monitoring of soil erosion and sediment transport will:

- provide information on the sediment sources
- provide information on soil erosion and sedimentation rates and their variability in the Nile basin
- provide information on the quality and type of sediments
- provide an understanding on the basin-scale sediment processes
- assist in predicting sediment response to changes and interventions in land management
- be used for model verification to support cost-benefit and risk analysis

A basin-wide soil erosion and sediment transport monitoring program is necessary to support effective watershed management planning, monitoring, and evaluation as well as to support the undertaking of environmental, social, and economic impact studies.

## 4.7 Surface Water Quality

**Socio-Economic Concern:**

Surface water is the primary domestic water supply source for many people in the Nile Basin. Poor surface water quality from untreated or poorly treated municipal and industrial discharges causes health problems for the people living downstream. There is also pollution from non-point sources in agricultural areas. Poor water quality is reducing the fish populations in many areas, such as Lake Victoria and Lake Kyoga. This is causing a serious loss of income for fishermen and reducing a valuable source of food.

Water hyacinths are quite literally choking out many shorelines in lakes. The problems in Lake Victoria are particularly severe and have been extensively studied. A fundamental cause of excessive hyacinth growth is excessive nutrients (nitrogen and phosphorous). The water hyacinth problems are also caused by excessive nutrients from the watersheds discharging to the lakes.

For policy and decision-making it is important to measure water quality in conjunction with streamflow. Excessive nutrients are a problem in many areas, especially lakes. Decision-making in terms of prioritizing pollution reductions by watershed requires knowledge of the nutrient loads from each watershed.

Because of the capacity of rivers, lakes and marshes to buffer and mitigate pollutants, water quality concerns are most acute at the point of pollution and decrease with distance from the source, making water quality an immediate national concern. It also concerns downstream countries who wish to monitor quality at the border (TA) or have some warning of pollutants that enter waterways through spills (DD). At confluences of rivers with sources in multiple countries and on lakes whose shores span multiple countries water quality becomes an issue with potential collaboration for effective management (CA).

**Example Locations:**

Common water quality problems throughout the Basin include declining fisheries, soil erosion/sedimentation, and discharge of untreated domestic and industrial effluents. Below are documented specific issues for several locations in the Nile Basin.

- Lake Victoria - Major problems include eutrophication (algae blooms) and Water Hyacinths, declining fisheries, soil Erosion and sedimentation, discharge of untreated domestic and industrial effluents, and discharge of agrochemicals. (SI, DD, TA, CA)
- Sio-Malaba Malakisi basins - Agrochemicals and sedimentation (SI, DD, TA, CA)
- Mara, Gucha-Migori, Isiukhu, Middle Nzoia, Nyando (Kenya)- Mining and Sugar factories (SI, DD, TA, CA)
- Lake Kyoga - Water Hyacinths, declining fisheries, soil erosion/sedimentation, discharge of untreated domestic and industrial effluents, and agrochemicals. (SI, DD)
- Lake Cyohoha (Rwanda) - Soil erosion/sedimentation, agrochemicals and declining fisheries (SI, DD, CA)
- River Kagera (Rwanda) - Soil Erosion and Sedimentation, discharge of untreated domestic and industrial effluent and agrochemicals (SI, DD, TA, CA)
- White Nile at Juba/Malakal (South Sudan) - Untreated domestic and industrial wastes, pollution from oil wells, and soil erosion/sedimentation (SI, DD)
- Blue Nile(Ethiopia &Sudan) - Soil Erosion/sedimentation, discharge of untreated domestic and industrial effluent and agrochemicals (SI, DD, CA)

- Lake Tana (Ethiopia) - Declining Fisheries, soil erosion/ sedimentation, discharge of untreated domestic and industrial effluents (SI)
- Mara River (transboundary between Kenya and Tanzania) - Agrochemicals and soil erosion/sedimentation (SI, DD, TA, CA)
- White Nile at Khartoum - Agrochemicals, discharge of untreated domestic and industrial effluents, soil erosion/sedimentation (SI)
- The Nile River North of Cairo - Agrochemicals, discharge of untreated or poorly treated domestic and industrial effluents, sedimentation (SI)
- Nile Delta in Egypt suffers from high water salinity (SI)
- Wetlands of the Nile Basin - Agrochemicals, untreated sewage and industrial wastes, soil erosion/sedimentation (SI, CA)

**Data Requirements**

The first tier of WQ parameters that need to be monitored include temperature, pH, dissolved oxygen (DO), turbidity and total suspended solids (TSS), bacteria (fecal coliforms), and nutrients (phosphorous and nitrogen). This monitoring, except for TSS, bacteria and nutrients, can be done on site. The second tier of parameters requires more sophisticated sample collection and laboratory capabilities and includes Biochemical Oxygen Demand (BOD), heavy metals and hydrocarbons. Sampling for these parameters will be most useful in urbanized areas. In addition, monitoring for pesticides will be useful to quantify pesticide runoff from agricultural areas.

WQ sampling in large lakes, for example Lake Victoria, needs to be done on a regular basis. Sampling in lakes needs to be done at several locations and measurements of DO and temperature profiles at these locations is necessary to understand lake stratification. Lakes can tend to have different layers of flow and WQ primarily due to different temperatures. It is possible for the inflows to a lake to not mix completely, and the inflows can in effect flow only on a layer a few meters deep. The surface layers can be healthy, while deeper layers can become severely oxygen depleted, which can severely diminish fish habitat and useful vegetative growth. In addition, understanding the lake stratification patterns will improve the understanding of the lake hydrology, especially time-of-travel through the lake.

**Socio-Economic Value of Data:**

Improved WQ monitoring will enable the countries to improve the WQ for domestic use, identify the major "hot spots" of WQ problems, and support pollution abatement. WQ monitoring will provide fundamental support for pollution control policies, prioritizing pollution control measures, and tracking the success of pollution control. It is essential for decision-makers and the people to understand what the issues are, where they are, and what needs to be done to improve their health, increase and protect valuable fisheries, support tourism, and maintain and improve the biological conditions for wildlife.

Monitoring in urban areas will help to quantify the most serious issues and develop pollution control priorities. This will help to develop industrial pollution requirements and support the economic justification for the construction of domestic wastewater treatment plants.

Monitoring at key watershed outlets will quantify the major pollutant levels and help to determine what measures are most important for point and nonpoint source controls. It will also be fundamental in understanding and improving the problems in lakes, especially the water hyacinth, eutrophication and declining fishery problems.

Furthermore water quality monitoring of rivers and lakes in the rural areas, will inform government decision makers on the suitability of the water sources for drinking purposes, as most of the rural populations within the basin directly drink from the rivers and lakes. In so doing they can fore-warn residents of any dangers that may be posed by grossly contaminated or polluted water bodies.

Transboundary water quality is important for all of the riparian countries. The importance is threefold. First, it is directly related to pollution control between the countries. Second, it helps the downstream countries to determine their own WQ control decision-making. Third, it is important for the upstream countries in providing a fundamental baseline for how best to prioritize controls within their country.

## 4.8 Groundwater Management

**Socio-Economic Concern:**

Groundwater is the only source of water supply in many areas of the Nile Basin, particularly the arid and semi-arid pastoral areas and communities that do not have access to surface water. Groundwater has also been considered by the Intergovernmental Authority on Development (IGAD) and NBI as a vital resource for drought disaster resilience and climate change resilience to ease the pressure on surface water during severe water shortage periods. Over-exploitation and contamination of groundwater resources are major issues in groundwater resources management. Over-abstraction of groundwater can cause significant draw down of the groundwater table that would lead to reduction of rivers base flow, drying up of springs, and depletion of aquifers. This in turn can engender water shortage for the people and livestock and can stimulate local and cross-borders conflicts. On the other hand, groundwater quality deterioration as a result of uncontrolled disposal of domestic and industrial wastewater and solid waste can be a major threat to human health; especially children under the age of five[1]. Thus, groundwater monitoring is essential to its safe and sustainable use. The establishment of a lean and effective groundwater monitoring network, which can be expanded over time as groundwater use increases, would bring valuable information to the regional and national decision makers, planners, and developers for the development and sustainable use of Nile Basin Groundwater basin.

Because of their typically slow response to change factors (pumping, climatic variability, pollution), management of groundwater aquifers is primarily a concern of individual countries (SI) where impacts of changes in content and quality are most likely to be observed and felt. At the current level of groundwater development in the Nile Basin a limited regional groundwater monitoring network could provide initial baseline information to permit countries and regional stakeholders to determine the current sensitivity of their individual resources to conditions and actions in other countries and regions, thereby better defining the need for additional monitoring and action (DD, TA, CA).

**Example Locations:**

- Northeastern Uganda and Northwestern Kenya (SI, possible DD, TA, CA)
- Northeastern Ethiopia and Southeastern Sudan (SI)
- South Sudan and Sudan (SI, possible DD, TA, CA)
  - Nubian Sandstone formation
  - Umm Ruwaba formation
  - Basement Complex formation

**Data Requirements:**

- Aquifers safe yield
- Water level (monthly).
- Water Quality (monthly water quality including PH, T, TDS, Total Nitrates, Fecal coliform, pollution due to oil extraction).
- Monthly groundwater abstraction
- Precipitation to assess recharge potential

[1] poor water quality is a major cause of diarrhea and mortality of children under five.

**Socio-Economic Value of Data:**

Aquifers safe yields are essential for national and regional decision makers to assess the sustainable rate of abstraction of renewable groundwater to ease pressure on the Nile Basin surface water in area of conjunctive use of surface and groundwater resources. Knowledge of aquifer safe yield is very important in transboundary aquifers. It is essential for guiding informed collaborative sustainable development and management of the groundwater resources. It also helps planners and managers in improving groundwater management, particularly in pastoral areas to reduce internal and cross-borders conflicts over water.

Groundwater level monitoring will provide the actual status of the overall behavior of the groundwater system in response to abstraction and recharge. Downward trends in groundwater level is an alert to groundwater managers that the system is under stress of groundwater depletion due to over-abstraction or reduced recharge during extended periods of drought. Thus, monitoring of groundwater level is essential at the national and regional level for collaborative sustainable use of this strategic resource.

Similarly, groundwater quality monitoring will allow early identification of trends in time in the variation of groundwater quality as a result of contamination at the local or regional scale. This in turn will provide opportunities for early control groundwater pollution.

## 4.9 Hydropower

**Socio-Economic Concern:**

Electricity is an important factor for economic growth and industrial expansion in the Nile countries. Electricity supply in most of the Nile countries is inadequate, unreliable and expensive. With hydropower potential of more than 20 GW in the Nile basin, its long economic life and low per unit energy costs, it is the preferred energy option for most of the Nile countries. There are additional benefits associated with hydropower such as flood control and river flow regulation, irrigation, transport and navigation, aqua farming, recreation, industrial and domestic water supply. A sustainable development and optimized use of hydropower potential in the region requires enhanced coordinated planning and reservoir operations across the basin.

Because of the importance of electricity to economic growth and because of the potential for hydropower at a single location to support regional electricity requirements, hydropower has clear cooperative aspects (CA). These are highlighted in regions where hydropower potential (and existing projects) crosses borders with the potential for coordinated hydropower operations. Where hydropower is dependent on upstream rainfall and runoff, data dependencies (DD) may exist.

**Example Locations:**

- Uganda (SI, CA)
    - Estimated capacity of over 4,000 MW between Lake Victoria and Lake Albert of which 380 MW is currently operational
    - Estimated capacity of 250 MW for Bujagali
    - Estimated total potential capacity of 4,723 MW in Nile basin of which 380 MW is currently operational
- Ethiopia (SI, CA)
    - Estimated capacity of over 8,000 MW between Lake Tana and the border of Sudan
    - Estimated capacity of 2,300 MW along the Baro River
    - Estimated total potential capacity of the Nile basin exceeds 20,000 MW, of which about 26% is currently operational (alternate estimates suggest that Ethiopia alone has 45,000 MW of potential, with most of that in the Nile basin portion of the country)

- Sudan (SI, DD, CA)
    - Estimated capacity of 130 MW along the Atbara River
    - Estimated capacity of 1250 MW for Merowe
    - Estimated total potential capacity of 4,873 MW in Nile basin of which 380 MW is currently operational
- Burundi, Rwanda, Tanzania (SI, DD, CA)
    - Regional Rusumo Falls Hydroelectric Project to provide 80 MW

**Data Requirements:**

- Reservoir Inflow/Outflow, Reservoir Level – Daily monitoring
- Precipitation for forecasting reservoir inflows – Daily monitoring
- Sediment Load at key locations upstream of reservoirs – Monthly monitoring
- Sediment distribution in the reservoir – Monthly to Annual monitoring
- Energy Supply/Demands – Daily monitoring

**Socio-Economic Value of Data:**

The change in the downstream flow regime due to reservoir construction depends on the outflows from the reservoir which in turn depend on energy demands and also downstream riparian and/or environmental demands in some cases. A daily monitoring of energy demands is required to maintain reservoir level and release reservoir outflows.

Balancing reservoir levels so as to generate maximum hydropower energy is important. In an international river with multiple reservoirs, coordinated reservoir operating rules are necessary to optimize hydropower generation and maximize benefit to all involving countries. Operating these rules involve monitoring reservoir levels and inflows. For example, Lake Victoria serves as the principal reservoir of the cascade of hydropower facilities along the White Nile in Uganda, which are essentially operated on a run-of-the-river basis. Because the reservoirs created by the respective dams are relatively small, coordinated operation is needed in order to optimize electricity generation and meet other system objectives. It requires a dedicated Decision Support Tool with modules for: 1) long-term planning to determine mid- and long-term Lake Victoria release policies, 2) short-term release models to forecast the implications of the proposed release volumes for the coming 12-month period, 3) general hydraulic modeling tools to analyze routing times, and 4) short-term power generation optimization tools, which plan hourly dam releases and power production. All models are data intensive.

Sedimentation in reservoirs decrease the reservoir storage capacity decreasing head required for power generation and hence should be monitored to optimize power generation.

## 4.10 Navigation

**Socio-Economic Concern:**

Transportation of people and goods by boat, as well as navigation for fishing and other commercial activities such as tourism is an important economic activity in many parts of the Nile basin. Transport links create opportunities for inter-basin trade and regional economic integration. Good transport links are essential to achieving the goals of poverty reduction and sustainable development. Improved water resources management is required in some parts of the basin because navigation is being threatened by declining water levels, construction of water control structures, and proliferation of aquatic weeds such as water hyacinth. While navigation related issues are widespread across the basin, they are of greatest importance in the Sudd, where water provides the most prevalent form of transportation of people and goods, as well as for fishing, and in the Nile below Aswan High Dam where navigation is an important element of tourism in Egypt.

Navigation is dependent on upstream flow and therefore has an important element of data dependency (DD) from upstream countries. Where upstream countries have potential to maintain minimum navigation flows through reservoir releases, or where navigation crosses country borders, cooperative potential exists (CA).

**Example Locations:**

Figure 4-5 shows the navigable river stretches in the Nile Basin.

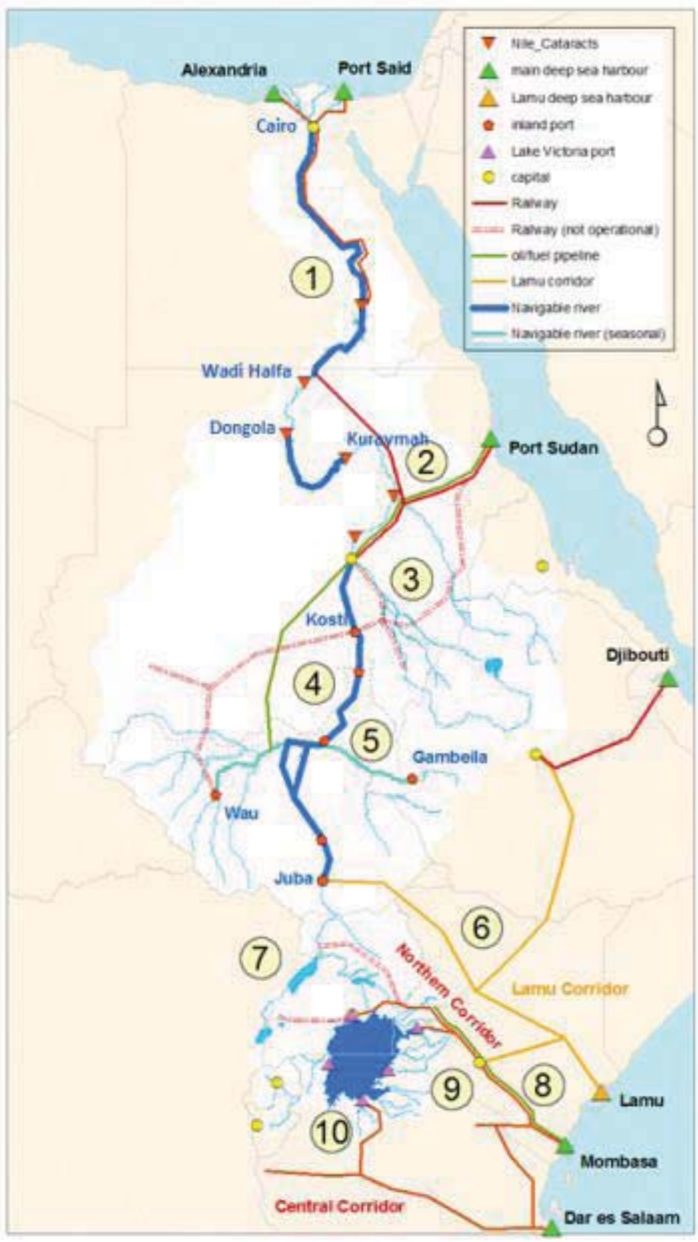


**Figure 4-5. Existing and potential navigable rivers in the Nile Basin**

- South Sudan (SI, DD, CA)
  - Khartoum to Juba inland navigation on the White Nile River (South Sudan to Sudan)
  - Lake No to Wau inland navigation on the Jur River (seasonal)
  - Sobat river from mouth to Gambeila (seasonal, South Sudan to Ethiopia)
- Ethiopia (SI, CA)

  - Sobat Mouth to Gambeila inland navigation on the Baro River (seasonal, South Sudan to Ethiopia)
- Sudan (SI, DD, CA)
  - Dongola to Kuraymah inland navigation on the Main Nile River
  - Khartoum to Juba (Sudan to South Sudan)
  - Cairo to Wadi Halfa on Main Nile River (Sudan to Egypt)
- Egypt (SI, DD, CA)
  - Cairo to Wadi Halfa inland navigation on the Main Nile River (Egypt to Sudan)

**Data Requirements:**

- River Levels – Daily monitoring
- Lake/Reservoir Levels – Monthly monitoring
- Precipitation for forecasting river and lake levels – Daily monitoring
- River morphology (variation due to sediment deposition and bank erosion) – Annual monitoring

**Socio-Economic Value of Data:**

Developing the inland navigation potential of the River Nile – in particular the 'southern reach' from Kosti (Sudan) to Juba (South Sudan) on the White Nile - may provide a low-cost transport route for bulk cargo from South Sudan and the Nile Equatorial Lakes region to Sudan and Egypt, and would thus encourage inter-basin trade and regional integration. The main types of goods and services using this transport mode comprise agricultural produce, livestock, fish, and passengers. Establishing the 'southern reach' would in effect connect the land-locked areas of South Sudan and northern Uganda to the global transportation system, with considerable socio-economic benefits.

Although seasonal variations of the White Nile flows are limited, water levels in the dry season may drop below the level of 1.2 m necessary for barges to operate. This indicates the need for regionally coordinated water resources management and operation of the Lake Victoria reservoir (the principle source of White Nile flows). Lake Victoria release policies should include the additional objective to maintain minimum water levels in the respective navigation corridors. It requires real-time data on water levels of the respective navigable White Nile reaches, but also of river discharge of the White Nile tributaries downstream of Lake Victoria such as the Torrents, Aswa, and Semliki.

## 4.11 Fisheries

**Socio-Economic Concern:**

Fisheries are an important economic activity in the Nile Basin. Poor management of water and land resources has a significant impact on these fisheries. Stakeholders have identified two main issues that impact fisheries in a number of the sub-basins, namely pollution and the destruction of fish habitats.

Fisheries management is primarily a local issue for individual countries (SI), but may be dependent on water quality and volume from upstream countries (DD). Where multiple countries border a common lake, important potential for cooperative fisheries management exists, similar to water quality management (CA).

**Example Locations:**

- Lake Victoria (SI, DD, CA)
- Lake Tana (SI)
- Lake Albert (SI, DD, CA)

- Lake Edward (SI, DD, CA)
- Lake Kyoga (SI)
- Lake Nubia (SI)
- Sudd Wetlands (SI, DD, CA)
- Aquaculture fish farms in the Nile Delta (SI)
- Potential fisheries in all reservoirs (SI, DD, CA)

**Data Requirements:**

- River Levels – Monthly monitoring
- Lake/Reservoir Levels – Monthly monitoring
- Water Temperature – Weekly monitoring
- Dissolved Oxygen, Nutrients – Monthly monitoring
- Pesticides, Turbidity – Monthly monitoring
- Numbers of commercial fish per species - Annual

**Socio-Economic Value of Data:**

River/Stream/Lake/Wetland levels can be used in combination with rating curves to assess fish habitat associated with instream flows and lake water levels at specific locations.

High levels of nutrients in water form atmospheric deposition, nutrient runoff from agricultural areas, and urban and industrial effluents because water pollution and can lead to problems such as algal blooms and fish deaths. Also, high BOD levels resulting from untreated waste waters and runoff cause the dissolved oxygen (DO) depletion in water required for aquatic life. Low DO level in water body can also lead to an increase in anaerobic bacteria that leads to the production of foul smelling and toxic gases. Hence, nutrients and DO levels in water body should be monitored and regulated to ensure healthy aquatic environment.

Agricultural drainage water from irrigation schemes in Sudan and Egypt is contaminated with fertilizers and pesticide residues causing serious pollution of receiving waters. For example, contaminated drainage water from the Gezira irrigation scheme drains to Lake Nubia at the border of Sudan and Egypt contaminating fish in Lake Nubia with high concentration of pesticide residues.

## 4.12 Watershed Management

**Socio-Economic Concern:**

The health of the Nile River watersheds is threatened in certain areas by the degradation of productive agricultural and grazing lands through inadequate cropping and range management practices; erosion and sedimentation due to deforestation and inappropriate land use practices; stress of water dependent ecosystems (wetlands, lakes) due to pollution, overfishing and natural disasters (floods, droughts); inadequate protection of plant and animal species; and spread of exotic and invasive water weeds. Monitoring of rainfall, flow discharges, levels and water quality of major natural, catchment erosion and sedimentation; land cover and extent including forests; lakes for major watersheds are important for the management and protection of these watersheds. The main benefits of watershed management include:

- Improved safe water supply
- Improved soil and water conservation
- Improved Sedimentation Control
- Improved water quality and pollution control
- Improved wetland protection
- Enhanced biodiversity protection
- Improved protection of pastoral areas

- Improved livelihood and health

Watershed management is inherently an upstream action that has vital local benefits (SI) as well as important downstream (CA) benefits (see previous topic on Soil Erosion and Sediment Transport). A minor component of data dependency (DD) may exist when downstream sediment monitoring can provide insight into effectiveness of ongoing watershed management practices. All of the examples below reflect these elements.

**Example Locations:**

- Kagera Basin
- Mara Basin
- Lake Victoria Basin
- Nzoia Basin
- Nyando Basin
- Bahr el Ghazal Basin
- Bahr el Jebel
- Baro-Akobo Sobat Basin
  - Southwest Ethiopian Highlands (ENTRO (CRA Consortium), 2007)
- Blue Nile Basin
  - Mount Choke Mountain Chain (ENTRO (CRA Consortium), 2007)
- Atbara Basin

**Data Requirements:**

- Rainfall and Rainfall Intensity(daily and hourly)
- Discharge (daily).
- Evaporation (daily)
- Sediment load (daily at key stations, monthly at other stations)
- Soil Erosion
- Water quality (monthly)
- Lake level (monthly)
- Earth observation data

**Socio-Economic Value of Data:**

Rainfall data is essential for national and regional decision makers to assess rainfall impact on soil conservation, rainfed agriculture, pastoral areas, and natural ecosystems including lakes and wetlands.

River discharges will assist in determining water yields for each watershed, and estimating sediment transport, and environmental flow for protection of downstream ecosystems. Evaporation data will help in determining water losses from reservoirs, lakes, and wetlands. Water quality monitoring will provide fundamental information for identification of pollution hotspots and support for pollution control for safe water supply, and protection of fisheries and natural ecosystems. Satellite earth observation data provide additional information on precipitation, soil moisture, evapotranspiration (ET) including evaporation losses from rivers, lakes, reservoirs, and wetlands, river flow, and land cover to improve estimation of catchment consumptive water use, especially for irrigation.. It also provides capabilities to survey water bodies on a regular basis and provide detailed mappings of the water extent within each catchment.

A *Cooperative Regional Assessment (CRA) for Watershed Management* study for the Eastern Nile was carried out by ENTRO in 2007. This study provides long-term cooperative watershed activities to ensure protection and rehabilitation of vulnerable areas. This includes a detailed cost-benefit analysis related to environmental, social, and economic impacts of an overall watershed management program, which is partially dependent on monitoring and an associated network to provide a thorough assessment.

## 4.13 Wetlands Management

**Socio-Economic Concern:**

Some of the major socio-economic benefits of wetlands include erosion control, flood control, groundwater recharge, improved fisheries, and natural filtering of excess nutrients and sediments. Wetland vegetation reduces erosion along lakes and stream banks by minimizing the forces associated with waves. During flood events, wetlands can help absorb and slow runoff that may otherwise achieve catastrophic levels further downstream. Some wetlands can serve as points of groundwater recharge for surrounding communities or points of groundwater discharge to reduce the impact of short-term droughts on rivers and streams. Many species of fish will utilize wetland habitats for spawning and food sources. In addition, wetlands will absorb excess runoff nutrients that produce algae blooms and reduce oxygen levels killing fish and other aquatic life. As a result, protected wetlands can improve fish yields for surrounding communities. Tragically, these benefits are often not fully appreciated or recognized until a wetland is drained or flows are routed around the natural setting in an effort to "conserve" water. Characterizing and preserving benefits of wetlands then becomes a priority for countries with wetlands as well as for surrounding countries. With this in mind, wetlands management becomes an important issue for cooperative investment and action (CA) for upstream countries whose impacts are mitigated, riparian countries whose wetlands are preserved (SI), and downstream countries whose water quality is improved. Management of wetlands will also require upstream data for appropriate planning and downstream data to assess benefits of wetlands (DD). Because of the upstream and downstream relationships associated with wetlands management, all of the examples below reflect these elements.

**Example Locations:**

The primary wetlands for the Nile Basin noted in the NBI, NTEAP report "*The Wetlands of the Nile Basin: Baseline Inventory and Mapping*" (NBI, 2009) include the following:

- Sio Malaba Malakisi watersheds
- Mara wetlands
- Sudd Swamps
- Nile Delta
- Sobat–Machar/Gambela Marshes
- Bahr el Ghazal Ghazal swamps
- Bahr el Jebel
- Lake Kyoga swamps
- Albert Nile Swamps
- Winam Gulf (Kisumu Bay)
- Kagera swamps
- Lake Tana Wetlands Complex

**Data Requirements:**

- River or Lake Stage/Discharge for both upstream and downstream ends of the wetland. Monitored daily or at a minimum, monthly basis.
- Sediment load upstream and downstream of wetland (daily at key locations, monthly at other stations).
- Water Quality analysis of key parameters conducted at both the upstream and downstream ends of the wetland. Monitored on a monthly basis.

- Groundwater monitoring at key locations surrounding or within a wetland to observe potential recharge or discharge effects associated with seasonal wetland fluctuations. Monitored on a monthly basis.
- Precipitation, Temperature, Relative Humidity, Pan Evaporation to assess water losses and direct gains of the wetland system. Monitored on a monthly basis.
- Bio-diversity of key aquatic species inventoried on a seasonal or annual basis.
- Remote sensing analysis of land cover to observe extent and changes of wetlands in the region conducted on a seasonal or annual basis.

**Socio-Economic Value of Data:**

*Sudd Wetlands* - The Sudd wetlands in South Sudan are among the largest tropical wetland areas in the world and have a permanent and seasonal component, the extent of which various from year to year following local and regional climatic variations, and the flow regime of the Bahr el Jebel (as the White Nile is known in South Sudan). The seasonal fluctuations in the wetlands are essential for the livelihood of the pastoralist people in South Sudan, who graze their cattle on the pastures emerging immediately adjacent to the receding wetlands during the dry season.

The extent of the seasonal wetlands determines the grazing capacity of the area. Both periodic drought and flood years result in a much smaller seasonal grazing areas with associated economic losses, and could lead to fierce competition over grazing lands.

Coordinated management of the outflow from Lake Victoria would reduce excess flooding during wet years and maintain seasonal wetlands during drought years, and is part and parcel of managing the seasonal grazing lands in order to optimize their benefits for the local population. It would require real-time data on the seasonal extent of the wetlands, the Bahr el Gazal level, and the flows of the White Nile and the various upstream tributaries. Information is also needed on the Sudd outflow while rainfall data and information on evapotranspiration from the swamp vegetation is needed in order to establish the water balance of the area.

*Improved Water Quality* – Strategic monitoring of water quality and sediment loads at upstream and downstream ends of a wetland will reveal their associated value. Furthermore, thoughtful evaluation of effluent water quality data combined with seasonal bio-diversity inventories and remote sensing extents can lead decision makers to assess the overall health of the wetland eco-system and take associated action. The same analyses applied to water quality assessment can also be applied to fish yields within lakes or rivers to draw correlations with the physical conditions of a surrounding wetland.

## 4.14 Climate Change

**Socio-Economic Concern:**

Climate change is real and is happening now with severe and diverse impacts. Climate change impacts have the potential to undermine development and even undo progress made in reducing poverty and improving the socio-economic wellbeing of broad parts of the population. Rising temperatures and changed rainfall patterns are expected to increase climate variability and both the number and intensity of extreme weather events such as heat waves, droughts, storms, and floods, resulting in water contamination, vector-borne diseases and food shortages. A lack of long-term hydro-meteorological data in the Nile Basin, coupled with the region's high natural variability in precipitation and sensitivity to climate effects makes the precise projection of climate change impacts difficult.

Through direct effects on temperature and water availability, climate change will have a number of additional cascading effects on agriculture, fisheries, energy, health, disasters, and freshwater ecosystems.

The above points highlight that climate change exacerbates impacts of existing challenges such as human-induced land-use changes, poverty, high population growth, and rising demand for natural resources. Further to this, most parts of the Nile region have a very low level of economically developed infrastructure. There is low water-storage capacity, few water-control systems, and the transport, energy, information, and communication systems still need further improvement. Combined with the exposure and sensitivity of the basin countries to climate change, this contributes to the basin's vulnerability and low adaptive capacity.

The Nile Basin is highly vulnerable to the impacts of global warming owning to a multiplicity of factors, and the basin communities have limited ability to cope with the negative impacts of climate change. Nile countries have prepared National Adaptation Plans for Action (NAPA). However, while many efforts have been made at understanding the future climate in the Nile region, at this point in time it is not possible to draw firm conclusions on how exactly the climate in the Nile Basin or a particular sub-basin will develop. This obviously reduces the effectiveness of the respective NAPAs while increasing their costs. As a regional issue in the context of water resources monitoring, climate change will be an acute national problem (SI) that will require climatic information across the basin (DD) and regional analysis and cooperation (CA) to track evolving climate indicators, assess impacts, and identify regionally appropriate responses. While the locations noted below represent a cross-section of issues, the nature of climate change requires a distributed climate information network with consistent standards more than location-focused monitoring.

**Example Locations:**

The following climate changes impacts in the Nile Basin seem likely (from the NBI Climate Strategy):

- Sea-level rise will seriously threaten the delta. The problem of flooding is compounded by land subsidence.
- Warming of water and changes in water level pose a threat to fisheries, resulting in widespread negative impacts on economies and food security.
- The hydropower potential of the Nile is large, but it is also vulnerable to changes in river flows driven by climate change. The vast majority of existing infrastructure as well as projects under planning or construction have not been designed for climate resilience and could experience serious harm.
- Wetlands, which provide beneficial water filtration, are highly vulnerable to climate change, calling into question the continued quality of water in the basin.
- Negative influences on agriculture and livestock are expected, with strong implications for food security and future economic growth. Degradation of livelihoods through climate change may accelerate and intensify cross-border and rural-urban migration.
- High rates of urbanization that are triggered by the above factors are placing increased pressure on already stressed urban and peri-urban ecosystem services, health systems and food security.

**Data Requirements:**

A wide range of data is needed to support decision making for climate change adaptation. This includes data on diseases, crop type and yields, climate, meteorology, groundwater, lake-levels, water quality, water demand, etc. However, only climatic information will be discussed in this study.

- Daily and sub-daily measurement of climate parameters (rainfall, water discharge, relative humidity, air temperature, and evapotranspiration) to support climate adaptation decision making. This includes agriculture, industrial management, urban planning, disaster mitigation, and long-term infrastructure planning (such as dams, dykes, and canals).
- Daily and sub-daily measurement of climate parameters (as above) in order to establish daily, seasonal, and annual variations in order to support effective agricultural techniques, water management, and hazard planning.

- Provision of hydro-meteorological earth observations, including satellite, and modeled assessments as well as future projections of climate change.
- Daily climate parameters to support short, medium, and long range forecasts that are required to support disaster preparedness and avoid catastrophe, and ultimately improve the food and water security situation. This includes the information requirements for Early Warning Systems for El Nino/La Nina and/or the Indian Ocean Dipole, which are associated with extreme weather events in the Nile region.

**Socio-Economic Value of Data:**

Uncertainties about the pace and extent of climate change and the impacts on different sub-regions and sectors in the basin make policy decisions difficult, and magnify the need for the region to improve its hydro-meteorological knowledge and monitoring base. Whilst the national level information and analysis on climate change risks, vulnerability and impacts has improved substantially over the past decade, well-synthesized information and an established knowledge base, at a basin, sub basin or even national level, is often absent. This is particularly critical to decision-making processes, providing policy guidance and considering transboundary responses to climate change.

In order to better inform policy making at local and regional level, improved climate models are required. It requires intensified data collection of all climatic parameters. These data serve to validate the climate models and to improve the scientific understanding of the climate change phenomena. Better understanding of the threat of climate change would allow for specific investments in infrastructure and/or targeted adaptation measures, with obvious socio-economic benefits.

Accurate information about the weather and hydrological variables is a starting point when assessing the direction, pace, and magnitude of climate change. Data gaps now exist for significant parts of the basin, and for a number of critical sections of the river network. This lack of knowledge makes it difficult to validate climate models and predict possible climate change. Data acquisition is complicated by the vastness of the Nile basin and the sometimes difficult terrain. Modern electronic monitoring equipment, fortunately, will both drastically reduce operating expenses and make real-time data available. Re-establishing a comprehensive data acquisition network in the basin needs to be a key priority of the Nile riparian states.

## 4.15 Regional Water Resource Management Opportunities

Following the Inception Workshop and country consultations, Riverside met with NBI to discuss the primary regional water resource management issues where the hydro-meteorological design should provide opportunities for substantial transboundary benefits. These were reviewed, revised and agreed upon by country representatives during the Conceptual Design Workshop. The final list is presented in Table 4-2 and plays a key role in the methodology of station selection. A map of the cooperative issues follows the table in Figure 4-6.

**Table 4-2. Nile Basin Primary Regional Issues**

| # | Cooperative issue | Socio-economic benefits | Key system and data requirements |
|---|---|---|---|
| **1** | Uganda and South Sudan need to coordinate the release policy of Lake Victoria and the operation of the (future) hydropower facilities along the Victoria Nile, Kyoga Nile, and Bahr el-Jebel.<br><br>Lake Victoria is the principle reservoir of the Nile system in Uganda and South Sudan. Lake releases are controlled at the outlet in Jinja and fairly stable over the year. The reservoirs of the (potential) downstream hydropower facilities along the Nile system in Uganda and South Sudan are small and barely modify river flows. The seasonal component of the Bahr el Jebel is provided by the Semliki, Aswa, Torrents, and other small tributaries.<br><br>The seasonal Bahr el-Jebel component combined with local climate conditions determines the fluctuation and extent of the seasonal wetlands in South Sudan. Lake Victoria release policies can attenuate the Bahr el Jebel regime and modify the flooding patterns. | • optimizing hydropower production of the cascade of (future) run-of-river hydro-facilities along the Victoria Nile, Kyoga Nile, and Bahr el-Jebel between Nimule and Juba (S SUD, UGA);<br>• facilitating navigation on the river reach from Kosti to Juba by maintaining minimum water depth on the Bahr el-Jebel (S SUD, SUD);<br>• supporting the pastoralist economy along the Bahr el-Jebel through floodplain and seasonal wetland management (S SUD);<br>• preserving important environmental value in the Sudd wetlands by managing the extent and fluctuation of the seasonal and permanent wetlands (S SUD). | • data sharing policies between Uganda and South Sudan;<br>• data transmission facilities;<br>• lake Victoria level; Lake Albert level;<br>• river discharge at key locations along the Victoria, Kyoga, and Albert Nile, and Bahr el-Jebel;<br>• river discharge of Semliki;<br>• river discharge of Aswa and Torrents (which provide the seasonal component of the Bahr el-Jebel);<br>• over-lake rainfall and evaporation estimates of Lake Albert;<br>• Sudd topography in order to assess (seasonal) wetland dynamics;<br>• Sudd wetland evapotranspiration and rainfall<br>• detailed river profile of the Bahr el Jebel (to asses water depths);<br>• data processing, storage, and dissemination facilities |

| # | Cooperative issue | Socio-economic benefits | Key system and data requirements |
|---|---|---|---|
| **2** | Ethiopia and Sudan need to coordinate the release policies of the Tekezze dam and the downstream facilities on the Atbara.<br><br>The Tekezze (or Setit as the river is called in Sudan) is a highly seasonal river. The bulk of runoff occurs between July and September while dry season flows are very low.<br><br>Coordinated operation of the dams on the Tekezze/Atbara (Tekezze, Upper Atbara Complex, Kashm el Girba) can increase dry season flows and attenuate the flood-wave. | • optimizing hydropower production on the Atbara / Tekezze (ETH, SUD);<br>• flood & drought management along the rivers, but also of parts of the main Nile in Sudan upstream of Merowe (ETH, SUD);<br>• irrigation scheduling of New Halfa scheme and planned intensification(SUD);<br>• management of spate irrigation along the lower Atbara reaches in Sudan (SUD);<br>• minimizing evaporation losses at Kashm el Girba and Upper Atbara Complex reservoirs (SUD);<br>• minimizing siltation of all reservoirs including Merowe and Lake Nubia (EGY,ETH, SUD);<br>• minimizing siltation of New Halfa irrigation scheme (and planned extension) (SUD);<br>• maintaining in-stream flow requirements and WQ standards (SUD);<br>• Improved watershed management and reduction of erosion. | • Data sharing policies between Ethiopia and Sudan;<br>• data transmission facilities;<br>• River discharge at key locations along the Atbara/Tekezze;<br>• water levels at key locations along the Atbara/Tekezze and Main Nile;<br>• reservoir levels of Tekezze, Upper Atbara Complex, and Kashm el Girba;<br>• H-V relations for the above reservoirs;<br>• open-water evaporation of the above reservoirs;<br>• sediment load at key locations upstream and downstream along the Atbara/Tekezze;<br>• data processing, storage, and dissemination software.<br>• Catchment (field) soil erosion monitoring. |

| # | Cooperative issue | Socio-economic benefits | Key system and data requirements |
|---|---|---|---|
| **3** | Ethiopia and Sudan need to coordinate the release policies of the future Grand Ethiopian Renaissance Dam (GERD) on the Blue Nile, which is under construction.<br><br>The Blue Nile provides the greater part (around 60%) of the flow of the Main Nile. The river has a pronounced seasonal flow distribution with very high sediment loads in the flood season. The flood potential of the Blue Nile is high, while flows in the period between January to May are reduced to a trickle. The river serves as the primary water source for a group of irrigation schemes in Sudan, the largest of which is the Gezira.<br><br>GERD can potentially mitigate flood risks, increase hydropower production, and provide water for irrigation during the dry season in Sudan. | • optimizing hydropower production on the Blue Nile (GERD, Roseires, Sennar) and the Main Nile (Merowe and future dams) (ETH, SUD);<br>• irrigation scheduling and intensification in the Gezira irrigation scheme in Sudan, and other schemes along the Blue and Main Nile (SUD);<br>• flood & drought management along the Blue Nile, at the Blue-White Nile confluence, and the Main Nile (ETH, SUD);<br>• flood management of the Rahad and Dinder (which are affected by Blue Nile levels) (SUD);<br>• minimizing siltation of all reservoirs, including Merowe and Lake Nubia/Nasser (EGY,ETH, SUD);<br>• minimizing siltation of Gezira scheme and other gravity schemes in Sudan (including Rahad extension) (SUD);<br>• maintaining in-stream flow requirements and WQ quality standards at the urban centers along the Blue and Main Nile (Sennar, Wad Medani, Khartoum, Atbara) (SUD);<br>• minimizing reservoir evaporation losses (Roseires, Sennar, Merowe, planned facilities, but also of Lake Nasser/Nubia) (SUD, EGY);<br>• Improved navigation on the Main Nile, Blue Nile, and on the Abbay between planned reservoirs. | • Data sharing policies between Ethiopia and Sudan, and possibly Egypt;<br>• data transmission facilities;<br>• River discharge at key locations along the Blue Nile and Main Nile;<br>• Reservoir level of GERD, Roseires, Sennar, and Merowe;<br>• H-V relations of all reservoirs;<br>• open-water evaporation of the above reservoirs;<br>• sediment load at key locations along the Blue Nile;<br>• detailed river profile of the downstream reaches of the Blue Nile to assess flood extent and associated return periods;<br>• water quality parameters around the urban centers in Sudan (Sennar, Wad Medani, Khartoum, Atbara)<br>• data processing, storage, and dissemination software.<br>• Catchment (field) soil erosion monitoring. |

| # | Cooperative issue | Socio-economic benefits | Key system and data requirements |
|---|---|---|---|
| **4** | Uganda and South Sudan need to exchange water quality information on Lake Albert and the Albert Nile.<br><br>Commercially viable oil deposits have been discovered in the Albertine Graben in Uganda. The water quality implications of oil exploration are potentially large and possible oil spills could adversely affect the downstream Bahr el-Jebel and adjacent wetland areas in South Sudan. | • to mitigate possible WQ implications from oil production in the Albertine Graben in Uganda (and DR Congo in the future) (UGA, DRC, SOUTH SUD);<br>• to protect the environmental value of the Sudd wetlands (SOUTH SUD);<br>• to protect the pastoralist economy in the Bahr el Jebel floodplain in South Sudan (SOUTH SUD);<br>• to protect drinking water facilities in Juba and other downstream towns and settlements (SOUTH SUD) | • data sharing policies between Uganda and South Sudan;<br>• data transmission facilities;<br>• water quality information at key locations in the Albertine Graben and along the Albert Nile and Bahr el-Jebel;<br>• data processing, storage, and dissemination software. |
| **5** | Burundi, Rwanda, and Tanzania need to coordinate water resources development upstream of Rusumo hydropower facility (under construction) and protect the upstream watersheds in order to mitigate siltation of the reservoir and preserve dry season flows. | • to optimize hydropower production at Rusumo Falls (BUR, RWA, TAN);<br>• to increase base-load by maintaining minimum flows (BUR, RWA, TAN);<br>• to minimize reservoir siltation (BUR, RWA, TAN); | • data sharing policies between Burundi, Rwanda, and Tanzania;<br>• data transmission facilities;<br>• river discharge at key locations on the Nyabarongo and Ruvubu;<br>• earth-observation products to design, plan, and monitor watershed protection projects;<br>• data processing, storage, and dissemination software. |

| # | Cooperative issue | Socio-economic benefits | Key system and data requirements |
|---|---|---|---|
| 6 | Ethiopia and South Sudan need to coordinate the release policies of the potential dams on the Baro river.<br><br>The Baro is a highly seasonal river that originates almost entirely in Ethiopia, and is the principle tributary of the Sobat river.<br><br>Overbank spills of the Baro and Sobat during the flood season contribute to the extensive seasonal wetlands in the area (including the Machar marshes), which represent important ecological value and sustain the pastoralist economy. The Baro, Gilo and lower reaches of the Sobat are navigable during part of the year.<br><br>Coordinated management of the future Baro dams can attenuate the Baro-Sobat regime and modify the flooding and low-season flow patterns. | • optimize hydropower production on the Baro reservoirs (ETH);<br>• manage flood-flows to reduce overbank spills on the Baro-Sobat in order to protect the pastoralist economy and decrease wetland evaporation losses (SOUTH SUD – SUD);<br>• preserving important environmental value in wetlands such as the Machar marshes by managing the extent and fluctuation of the seasonal and permanent wetlands (ETH, SOUTH SUD);<br>• support the pastoralist economy by managing the extent and seasonal fluctuation of the seasonal and permanent wetlands (SOUTH SUD);<br>• maintain minimum water levels for navigation on the Baro (up to Gambella), Gilo and the Sobat and for drought management and maintaining minimum flows (ETH, SOUTH SUD, SUD).<br>• future irrigation along the Baro and downstream rivers (ETH, SOUTH SUD)<br>• maintain minimum discharge and water levels for navigation, minimum flows, and irrigation (pumping) on the White Nile, and limiting releases for flood control on the White Nile. (SUD, SOUTH SUD). | • data sharing policies between Ethiopia, South Sudan, and Sudan;<br>• data transmission facilities;<br>• river discharge at key locations along the Baro, Sobat, Pibor, and Akabo;<br>• levels and H-V curves for the future Baro reservoirs;<br>• wetland area topography in order to assess (seasonal) wetland dynamics;<br>• wetland evapotranspiration and rainfall;<br>• detailed river profile of the lower reach of the Sobat up to Gambeila (to asses water depths for navigation purposes);<br>• data processing, storage, and dissemination facilities |

| # | Cooperative issue | Socio-economic benefits | Key system and data requirements |
|---|---|---|---|
| **7** | Sudan and South Sudan need to coordinate the release policies of Jebel Aulia reservoir for irrigation, navigation, flood control, fisheries, and tourism, both in Sudan and South Sudan. | • maintain water levels in order to facilitate use of (fixed) pump installations for the irrigation schemes along Jebel Aulia reservoir and White Nile, and minimize pumping head; (SOUTH SUD, SUD);<br>• flood management at the Blue-White Nile confluence (i.e. Khartoum) and Main Nile (SUD);<br>• maintaining navigation and in-stream flow requirements and WQ quality standards for fisheries, tourism and hyacinth control along the White and Main Nile and for the urban centers (Khartoum, Atbara) (SUD);<br>• minimize reservoir evaporation losses of Merowe reservoir (and other future R-o-R hydro-facilities along the Main Nile in Sudan) (SUD) | • data sharing policies between South Sudan and Sudan;<br>• data transmission facilities;<br>• White Nile flows at Malakal;<br>• Sobat flows at outlet;<br>• Jebel Aulia levels (at various points along the lake in order to assess wind setup at the dam);<br>• data processing, storage, and dissemination facilities. |
| **8** | Egypt and Sudan need to exchange information on water quality and sand encroachment of the Main Nile; maintaining water quality standards of the Main Nile is a joint undertaking of the two riparians. | • maintain WQ standards along the main Nile and in the respective reservoirs (including Lake Nasser and Lake Nubia) (SUD, EGY);<br>• reduce contamination by hazardous chemicals from industries and agriculture;<br>• reduce water treatment costs and protect drinking water facilities along the Main Nile<br>• Maintain positive or improved environment for fisheries at Lake Nasser and Lake Nubia<br>• Manage impacts of sand encroachment along the Main Nile and in the reservoirs. | • data sharing policies between Egypt and Sudan;<br>• data transmission facilities;<br>• water quality monitoring at key locations along the Main Nile and near the urban centers (such as Khartoum, Atbara, Aswan, etc.);<br>• data processing, storage, and dissemination facilities. |

| # | Cooperative issue | Socio-economic benefits | Key system and data requirements |
|---|---|---|---|
| **9** | The Lake Victoria riparians (Kenya, Tanzania, and Uganda) need to exchange information on the water quality of Lake Victoria. | • maintain WQ standards in Lake Victoria and along the downstream White Nile reaches (KEN, TAN, UGA, SOUTH SUDAN);<br>• reduce Eutrophication that can cause algal blooms that may lead to oxygen deficits and fish kills, or promote the excessive growth of weeds such as water hyacinth;<br>• reduce contamination by hazardous chemicals from industries and agriculture;<br>• reduce water treatment costs, and protect drinking water facilities along Lake Victoria. | • data sharing policies between Kenya, Tanzania, and Uganda;<br>• data transmission facilities;<br>• water quality monitoring at key locations on Lake Victoria and near the urban centers (such as Kisumu, Mwanza, and Kampala, etc.)<br>• data processing, storage, and dissemination facilities. |
| **10** | Uganda and DR Congo need to coordinate Lake Edward release policies and levels (in case a regulator is built).<br><br>Lake Edward is the principle reservoir of the Semliki river, which has considerable hydropower potential. The river has a seasonal component and drains into Lake Albert.<br><br>In case a regulator is constructed at the Lake Edward outlet, Semliki flows can be modified in order to maximize the productive use of the river. | • to optimize hydropower production (and base-load) on the future facilities on the Semliki (DRC, UGA);<br>• support wetland management in the Sudd and along the Jebel Aulia (see 1) (SOUTH SUD) | • data sharing policies between DR Congo and Uganda;<br>• data transmission facilities;<br>• water level of Lake Edward;<br>• river discharge at key locations along the Semliki;<br>• data processing, storage, and dissemination facilities. |

| # | Cooperative issue | Socio-economic benefits | Key system and data requirements |
|---|---|---|---|
| **11** | Monitor transboundary water quality and quantity flows between Kenya and Tanzania in the Mara basin.<br><br>Notable concerns include soil erosion and sediment loads; deforestation of the watershed; degradation of water quality due to poor agricultural, sanitation, and mining practices. | • basin has significant environmental and biodiversity conservation interests. This includes eco-tourism benefits for both countries resulting from the world famous Masai Mara-Serengeti ecosystem.<br>• improve agricultural, mining, and watershed management practices to sustain the long term environmental health and production of the basin | • data sharing policies between Kenya and Tanzania;<br>• data transmission facilities;<br>• river discharge, sediment loads, and water quality at key locations along the Mara river;<br>• data processing, storage, and dissemination facilities |
| **12** | Monitor transboundary water quality and quantity flows between Kenya and Uganda in the Malaba basin<br><br>Notable concerns of watershed degradation leading to increased levels of suspended sediment as well as potential water quality issues. This affects downstream irrigation and wetlands eco-systems. | • maintain water quality standards for existing and potential irrigation along the Malaba River.<br>• maintain water quality standards of flows entering the wetlands of Lake Kyoga<br>• improve upstream watershed management practices to sustain the long term environmental health and production of the basin | • Data sharing policies between Kenya and Uganda<br>• River discharge, sediment loads, and water quality at key locations along the Malaba River<br>• Data processing, storage, and dissemination facilities |
| **13** | Monitor water quality of transboundary lakes Cyohoha Sud and Rweru between Rwanda and Burundi | • maintain WQ standards in the transboundary lakes (BUR, RWA)<br>• reduce eutrophication that can cause algal blooms that may lead to oxygen deficits and fish kills, or promote the excessive growth of weeds such as water hyacinth;<br>• reduce contamination by agriculture<br>• protect drinking water facilities along transboundary lakes. | • data sharing policies between Rwanda and Burundi;<br>• data transmission facilities;<br>• water quality monitoring at key locations on Lake Rweru and Lake Cyohoha Sud<br>• data processing, storage, and dissemination facilities. |

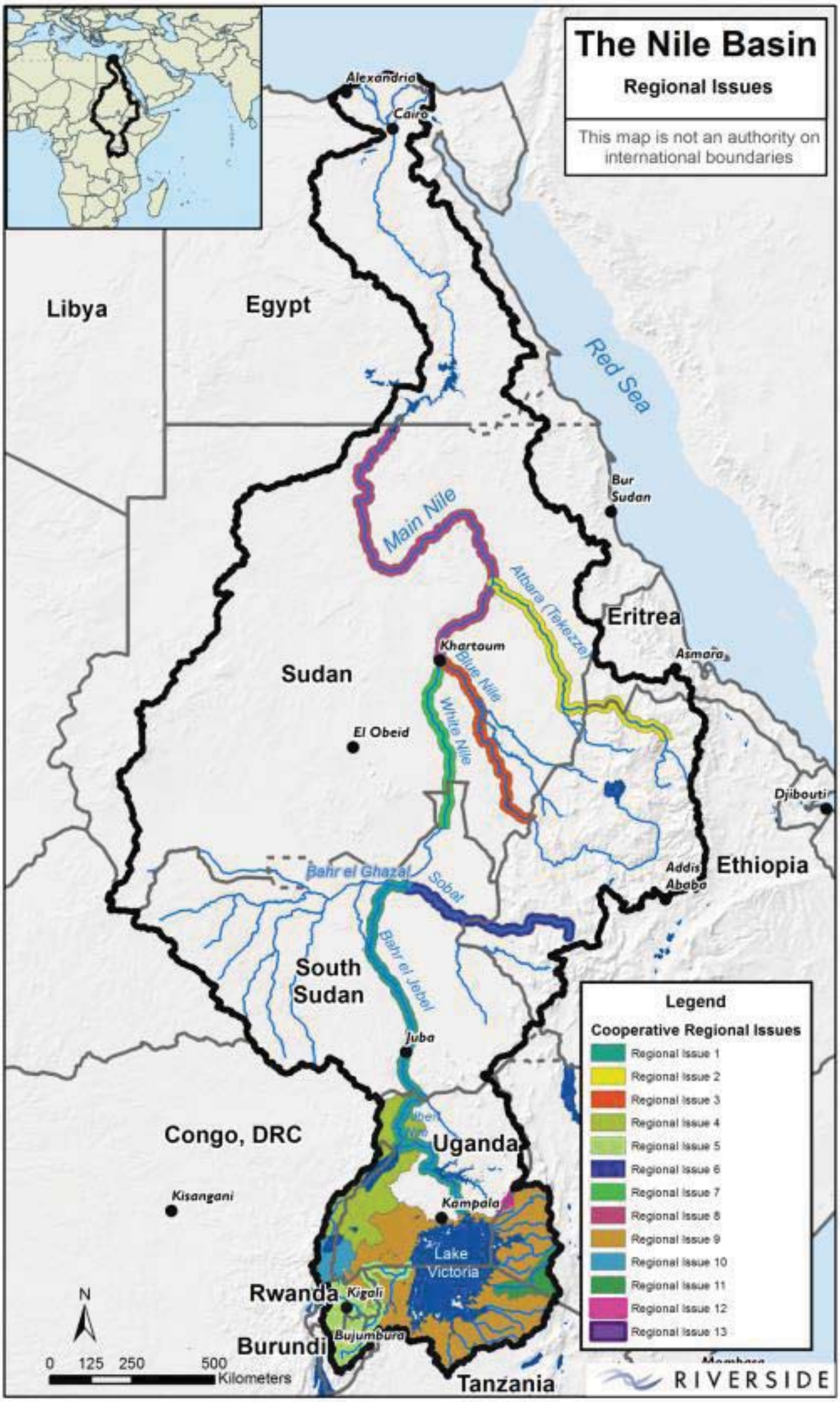


**Figure 4-6. Map of 13 regional water resource cooperative issues**

# 5 Design Overview

The design presented in the following sections responds to the water resources management opportunities identified previously and includes the following primary components:

1. Field Monitoring Network comprised of station locations and measurement parameters for collecting the required ongoing field data. This includes the specification of field monitoring equipment and station telemetry at each site.
2. Water Quality Labs and Standards to be used in developing consistent approaches for water quality monitoring at sites identified in the field monitoring network.
3. Earth Observation and Regional modeling data products that can be obtained, organized and applied at a regional level and disseminated to countries for further analysis and application.
4. Data Management Systems, consisting of data acquisition management systems for collecting data from the field monitoring network, national data management systems, a regional data management system, and tools for communications between national and regional systems. Specific regional products are identified as part of these systems as a focal point for the overall system development and operation.
5. Institutional Design and Development, outlining the factors, staffing, and training requirements for long term system implementation and operation.

# 6 Field Monitoring Network

## 6.1 Data Specification

The preceding sections have outlined data requirements for addressing specific water resources management issues in the Nile Basin. The design of a water resources monitoring network can address a subset of the complete data requirements (population and economic data, for example, are needed for some assessments but are not part of a monitoring network). The following section outlines the data specification for the development of a regional hydro-meteorological monitoring network within the Nile Basin. Based on the assessment of water resources management issues presented in Section 1, a summary of the monitoring data needs for each water resource management issue is presented in Table 6-1.

**Table 6-1. Summary of data needs for water management issues**

| Data Needs for Water Management Issues | IWRM | Flood Management | Rain Fed Agriculture | Irrigated Agriculture | Drought Management | Soil Erosion and Sediment Transport | Surface Water Quality | Groundwater Management | Hydropower | Navigation | Fisheries | Watershed Management | Wetlands Management | Climate Change | # |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| River Stage/Discharge | ● | ● | | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | 13 |
| Lake/Reservoir Level | ● | ● | | ● | ● | | ● | ● | ● | ● | ● | ● | ● | ● | 12 |
| Precipitation | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | | ● | ● | ● | 13 |
| Temp, RH, Evap. | ● | ● | ● | ● | ● | | | | | | | ● | ● | ● | 8 |
| Groundwater | ● | | | ● | ● | | | ● | | | | | ● | ● | 6 |
| Sediment Sampling | ● | | | ● | | ● | | | ● | | | ● | ● | | 6 |
| Surface Water Quality | ● | | | ● | | | ● | | | | ● | ● | ● | | 6 |
| Land Use/Cover | ● | | | | | ● | | | | | | ● | ● | ● | 5 |

The last column in Table 6-1 represents the number of water resource management issues where the data parameter is needed to address that issue. This demonstrates that of the 14 water resource management issues river stage/discharge, lake/reservoir level, and precipitation are needed the most frequently. Other meteorological parameters, groundwater, sediment sampling, and water quality parameters are necessary for about half the issues and land use/cover for about a third. Although this summary is somewhat simplified by not distinguishing relative importance of each data parameter for each sector, it still provides a basis for assessing the data priorities of a regional network.

The following sub-sections describe the broad spatial and temporal requirements of each data parameter to address water resource management issues on a regional scale.

### 6.1.1 River Stage/Discharge

*Spatial:*

A regional network requires river gauges placed at key locations upstream and/or downstream of channel confluences in order to monitor the flow contributions from various sub-basins. Where possible, the defined locations take advantage of current or previous station locations with historic data. Key locations also include stations near country borders to assess transboundary flows. Ultimately, the number of stations depends on a balance between regional monitoring needs and capacity to sustain the network.

*Temporal:*

The requirement for monitoring frequency of river stage (or water level) observations varies between 10 minutes for flash flood warning to daily for many water resources planning activities.

Discharge measurements should be recorded and incorporated into rating curve development on a monthly basis where possible, and seasonally at a minimum. Measurements should represent a range of discharge zones including peak flows when possible. Consequently, the frequency of discharge measurements can be highly variable and site specific depending on the seasonality and stability of the river. The frequency of measurement is an operational decision to be made according to local site conditions by managers and technicians who conduct the monitoring program. More detail on the frequency of discharge measurements is provided in Section 6.2.9.

### 6.1.2 Lake/Reservoir Level

*Spatial:*

Water level recordings are made for any major lakes or reservoirs that have regional significance.

*Temporal:*

Daily instantaneous water level reported on a daily basis for moderate sized lakes/reservoirs will only be necessary for benefits related to flood forecasting and hydropower generation. Most large lakes with minimal fluctuation in surface water level will only need monitoring to be conducted on a weekly or monthly basis and reported on a similar interval to the regional database.

### 6.1.3 Precipitation

*Spatial:*

Precipitation monitoring should extend over the entire basin, should be well distributed spatially, and needs to respond to depth and variability of rainfall in the several sub-regions, with increasing network density in areas with higher rainfall and greater spatial variability. Lower network density is typically required to represent larger areas, such as those required for a regional network. These considerations are factored into the design criteria discussed in more detail in Section 6.3. Beyond spatial extent, stations should be distributed throughout the elevation range of the basin to represent orographic variation throughout a basin.

*Temporal:*

Hourly precipitation accumulations transmitted by telemetry in real-time will provide optimal analysis for real-time dependent benefits such as hydrologic forecasting. Daily precipitation monitoring is sufficient for many planning applications. 10 minute measurement frequency is required for subsequent analysis of depth-duration-frequency relationships needed for many hydraulic designs.

### 6.1.4 Temperature, Relative Humidity, Evaporation

*Spatial:*

Temperature, Relative Humidity, and Evaporation are parameters that generally experience a more uniform distribution of expected resultants for a given area compared with precipitation which can be highly variable. This fact may be best understood when considering a weather forecast which is generally quite accurate for temperature but harder to predict for rainfall. Due to this fact a network of these additional meteorological parameters can often be of a lower density for assessing hydrological characteristics. However, the network should be well distributed vertically in order to characterize elevation differences in modeling and forecasting procedures.

*Temporal:*

Temperature, Relative Humidity, and Evaporation vary in predictable ways throughout the course of a day but are generally more consistent from day to day than precipitation. Measurements at a three-hour frequency are generally sufficient to capture daily patterns and clearly serve to meet longer term characterization of these parameters.

### 6.1.5 Groundwater

*Spatial:*

Groundwater monitoring of both levels and quality will depend on where the resource is currently being abstracted or where potential exists to develop its use for water resources.

*Temporal:*

A typical groundwater monitoring program will involve monthly analysis of both level and quality at key locations.

### 6.1.6 Sediment Sampling

*Spatial:*

Key locations for sediment sampling are upstream of irrigated agriculture, wetlands, and hydropower sites that have regional importance and downstream of areas with high erosion rates. These locations coincide with pertinent river stage/discharge locations, including relevant transboundary sites.

*Temporal:*

Sediment sampling should generally be carried out monthly, but the frequency is an operational decision to be made according to local site conditions by managers and technicians who conduct the monitoring program. For some rivers, such as the Blue Nile, seasonal sampling may be adequate during low flow periods, with weekly or bi-weekly sampling during periods of high flow and high sediment load.

Measurements will be conducted at varying sediment load and flow levels to establish an understanding of sediment transport and its relationship with discharge and seasonal impacts.

### 6.1.7 Surface Water Quality

*Spatial:*

Similar to sediment sampling, surface water quality will be conducted for sites upstream of irrigated agriculture, wetlands, or fisheries with regional significance or downstream of pollutant generating areas. This includes large regional lakes such as Lake Victoria. These locations will coincide with pertinent river stage/discharge locations and lake-level stations, including relevant transboundary sites. The type of specific parameters to be measured will depend on the needs of each location.

*Temporal:*

Water quality monitoring for key regional locations should generally be recorded and reported on a monthly basis. However, the frequency is an operational decision to be made according to local site conditions by managers and technicians who conduct the monitoring program. Some sites may require a higher frequency of testing due to known harmful upstream impacts while others may require only routine testing.

### 6.1.8 Land Use/Cover

*Spatial:*

Land use/cover analysis can be conducted with earth observation products for the entire basin. Specific focus may be given to regions impacted by poor watershed management practices to assess the changes of land cover and observed effects of other parameters such as sediment and water quality.

*Temporal:*

Monitoring should be conducted on a seasonal, or at a minimum annual basis. Imagery and associated land cover data should be recorded during similar times of different years to consistently track the effects of changes on an annual basis. It is likely that this work can be carried out within the regional office and disseminated out to respective country representatives on a monthly or seasonal timeframe.

### 6.1.9 Conclusion

River level, precipitation, temperature, relative humidity, and evaporation monitoring can be conducted using automated station sensors connected to data loggers and transmitters that facilitate a 10-minute frequency of observations and reporting. This will support all of the frequency requirements outlined above for these parameters. For purposes of network operation and maintenance, data management, and ultimate data analysis flexibility, a single standard using 10 minute observations and hourly telemetric reporting for all stations in the regional network is specified and outlined in the following section. This will also facilitate effective reporting of data to the regional system on a daily basis.

The remaining monitoring system observation parameters (discharge, sediment, water quality, groundwater, and land cover) do not rely on automated station sensors and will depend on staff initiated measurement and data collection efforts for the specified monitoring frequency to be carried out.

## 6.2 Monitoring Station Specifications

### 6.2.1 Hydrometric Stations

Table 6-2 outlines the infrastructure and instrumentation requirements for a typical hydrometric site. In general, a hydrometric site will be equipped with a five-meter tower; weatherproof NEMA 6 (IP67) rated instrument enclosure for housing the data logger, batteries, and solar regulator; a water level sensor being either a radar, pressure transducer, or shaft encoder; and a solar power supply system. Water temperature will be observed if an in-situ water level pressure transducer is used.

A shaft encoder will only be installed if the existing stilling well infrastructure is functional.

The data logger will have a display enabling the on-site observer to record manually the parameters measured using auto-sensors. This functionality will ensure that the auto observations reflect the conditions at the site.

The frequency of the observations by the auto-sensors will be every 10 minutes.

A series of staff gauges will be installed for the manual observation of water level as well as three benchmarks tied to the local datum.

Periodic streamflow measurement is required for hydrometric sites. For sites where permanent and trained observers are stationed and the existing infrastructure to support the conduct of streamflow measurements is functional, mechanical rotary cup type current meters will be provided.

Hydro acoustic streamflow measurement profilers will be used by trained mobile monitoring teams to conduct streamflow measurements for all other hydrometric sites. Infrastructure to support the use of hydro acoustic Doppler profilers may consist of a bank-operated cableway or boat, if a suitable measurement platform does not exist at the site.

Sediment measurements for selected hydrometric sites will be conducted using standard manual methods and mechanical sediment samplers.

Table 6-2: Requirements for a Typical Hydrometric Site

| Major Component | Quantity | Description |
|---|---|---|
| 1. Site Infrastructure | 1 | Five-meter freestanding tower with foundation designed according to building code requirements with a method for accessing the top of the tower. |
| | 1 | Weatherproof NEMA 6 (IP67) rated enclosure for data logger, communications device, battery, etc. |
| | 1 | Mounting bracket for radar sensor, or in-water mount for pressure transducer, or shelf mount for shaft encoder including conduit. |
| | 1 | Underground conduit with inspection pits for placement of cables. |
| | 1 | Flexible metal conduit with fire resistant protection for all above-ground cables with connectors, as required |
| | 1 | Set of Staff gauge posts |
| | 1 | Grounding system for lightning protection |
| | 3 | Benchmarks (Numbered) |
| 2. Instrumentation | 1 | Data logger with GPS and communications device |
| | 1 | Solar charging system with batteries |
| | 1 | Water level sensor (Radar, Pressure Transducer, or Shaft Encoder) |
| | 1 | Set of staff gauge plates |
| | 1 | Cabling, connectors, and mounting hardware for all sensors, as required |

### *Water Level Sensors*

The preferred water level sensor technologies are radar or pressure transducer. Each sensor will have certified documentation of performance.

For a limited number of field sites where the existing stilling well is operational, shaft encoders may be used or a pressure sensor installed in the stilling well.

The pressure transducer will have the capability to output water temperature.

The water level sensor will be connected to a data logger for automatic data storage and transmission.

The preferred communications protocol of the selected water level sensor is SDI-12. Following are the specifications for the different types of water level sensors:

*Water Level Sensor - Pressure Transducer*

| | |
|---|---|
| Measuring Range | 0 to 1.5m, 0 to 5m, 0 to 10m and 0 to 30m ranges, User programmable offset and scale range |
| Measurement Parameters | Water level in mm and water temperature in °C |
| Typical Measurement Range | 0 to 20 m |
| Resolution - Water Level | 0.001 m |
| Resolution - Water Temperature | 0.1°C |
| Accuracy - Water Level | 0.05% F.S. |

| | |
|---|---|
| Accuracy – Water Temperature | 0.1°C |
| Long Term Stability | ± 0.1% / year FS |
| Temperature Compensated Range | 0°C to 45°C |
| Safe Pressure Overload | Minimum twice the measuring range |
| Output Signal | SDI-12 preferred |
| Material | Stainless Steel DIN 1.4539 |
| Protection | IP 68 |
| Operating Voltage | 10.0 to 16.0 VDC |
| Power Consumption | < 15 mA in active mode |
| Operating Temperature | -10°C to 60°C |
| Cable | Integral vented cable with pull strength of 100 kg minimum and suitable for placement under ground |
| Lightning Protection | Required: Shunts 20,000 Amperes, response time <10 nsecs |
| Vented Tube - Moisture Protection | Supplied with desiccant and desiccant chamber or humidity absorber |

*Water Level Sensor - Radar*

| | |
|---|---|
| Measuring Range | Typical range of 1.5 to 30 m, User programmable offset and scale range |
| Measurement Output | Water level in mm |
| Typical Measurement Range | 0 to 15 m |
| Beam width | < ± 15° |
| Resolution | 1 mm |
| Maximum dead range | 1.5 m |
| Accuracy | 0.05% F.S. |
| Output Signal | SDI-12 preferred |
| Operating Temperature | -10°C to 60°C |
| Environment Protection | IP67 |
| Operating Voltage | 10.0 to 16.0 VDC |
| Power Consumption | < 15 mA in active mode |
| Cabling | Must be UV resistant and suitable for placement under ground |
| Lightning Protection | Required |

*Water Level Sensor – Shaft Encoder (float)*

| | |
|---|---|
| Measuring Range | 0 to 30 m |
| Measurement | Absolute |
| Resolution | 0.001 m |
| Accuracy | 0.001 m |
| Reporting Resolution | User selectable with range of 7 decimal digits |
| Display | Built-in 8 character LCD display with backlight |
| Battery | Externally accessible, internal back-up battery |
| Output Signal | SDI-12 |
| Protection | over voltage and reverse voltage protected |
| Operating Voltage | 10.0 to 16.0 VDC |
| Power Consumption | < 2.5 mA @ 12 VDC |
| Operating Temperature | -10°C to 60°C |
| Float Size | Between 100 to 160 mm |

| | |
|---|---|
| Float Material | Sealed float of plastic or painted corrosion resistant metal |
| Float Wire | Geometrically wound, non-twisting, 1.0 mm diameter, stainless-steel cable with beads crimped on at uniform intervals which match the recesses in the float pulley for non-slip operation |
| Lightning Protection | Required |

### *Direct Water Level Gauges*

A series of standard staff gauges will be used for the manual determination of the water level for each hydrometric site. The standard staff gauges will be composed of a concrete staff post with staff gauge plates mounted on the concrete post. Following are the specifications for the staff gauge plate:

*Staff Gauge Plate*

| | |
|---|---|
| Manufactured from 18-gauge or 2 mm plate steel, porcelain coated to resist rust and discoloration with clear dark markings on a white or yellow background | |
| Length | 1.0 m |
| Wide | 80 mm, ± 10 mm |
| Markings | Minimum centimeter markings with labeled decimeters, supply with separate meter number plates |

### 6.2.2 Meteorological Stations

The meteorological stations will consider of two distinct types: Automatic Weather Station (AWS) and Automatic Rain Gauge (ARG). Automatic weather stations include measurement of parameters not specifically listed in the data specification but that are required to calculate evaporation and also to maintain consistency with monitoring practices and requirements of national meteorological agencies.

Table 6-3 outlines the infrastructure and instrumentation requirements for a typical automatic weather station, and Table 6-4 outlines the requirements for a typical automatic rain gauge. The basic configuration for the Automatic Weather Station will be a 20 x 20 meter fenced observing park with a ten-meter tower for placement of wind sensors and the weatherproof NEMA 6 (IP67) rated instrument enclosure. The instrument enclosure will house the data logger, batteries, and solar regulator. The fence will be one-meter in height, with a gate for access. Galvanized chain link is preferred for the fence. The precipitation gauges will be mounted on a separate pedestal to place the lip of the precipitation gauge at a one-meter height.

The typical suite of sensors located at an Automatic Weather Station will be: wind speed and wind direction at a ten-meter height, barometric pressure, air temperature and relative humidity housed in a radiation shield mounted on an arm from the ten-meter tower at a two meter height, solar radiation, an auto-accumulation precipitation gauge with a shield, a tipping bucket rain gauge, and a manual rain gauge. The solar radiation sensor will be mounted on an arm at two meters extending to the south at least one meter from the ten-meter tower.

The frequency of the automatic observations using sensors will be every 10 minutes. Evapotranspiration will be calculated from the sensor data using the Penman-Monteith method.

WMO guidelines regarding meteorological instruments and methods of observation (WMO-No. 8, 2008), and technical regulations for meteorological standards (WMO-No. 49, 2012) have been provided as supplemental resources with summaries of each provided in Appendix H.

Table 6-3: Requirements for a Typical Met - Automatic Weather Station

| Major Component | Quantity | Description |
|---|---|---|
| 1. Site Infrastructure | 1 | One meter high fence of galvanized chain link, with posts, gate, and post foundations. Typical compound will be 20 by 20 meters |
| | 1 | Ten-meter free standing tower with foundation designed according to building code requirements with a method for accessing the top of the tower |
| | 1 | Weatherproof NEMA 6 (IP67) rated enclosure for data logger, communications device, battery, etc. |
| | 1 | Foundation and pedestal for auto accumulation rain gauge |
| | 1 | Foundation and pedestal for tipping bucket rain gauge |
| | 1 | Foundation for manual rain gauge |
| | 1 | Mounting arm from the ten-meter tower for the radiation shield and barometric pressure sensor |
| | 1 | Mounting arm from ten-meter tower for solar radiation sensor |
| | 1 | Underground conduit with inspection pits for placement of cables |
| | 1 | Flexible metal conduit with fire resistant protection for all above-ground cables with connectors, as required |
| | 1 | Grounding system for lightning protection |
| | 1 | Benchmark |
| 2. Instrumentation | 1 | Data logger with GPS and communications device |
| | 1 | Solar charging system with batteries |
| | 1 | Wind speed and wind direction sensor |
| | 1 | Temperature sensor with radiation shield |
| | 1 | Humidity sensor |
| | 1 | Barometric Pressure sensor |
| | 1 | Solar Radiation sensor |
| | 1 | Auto-accumulation rain gauge with shield |
| | 1 | Tipping Bucket rain gauge |
| | 1 | Manual rain gauge (at stations where an observer is available) |
| | 1 | Cabling, connectors, and mounting hardware for all sensors, as required |

The basic configuration for the Automatic Rain Gauge station will be typically a 3 x 3 meter fenced observing park with a five-meter tower for placement of the weatherproof NEMA 6 (IP67) rated instrument enclosure. The instrument enclosure will house the data logger, batteries, and solar regulator. The fence will be one-meter in height, with a gate for access. Galvanized chain link is preferred for the fence.

The typical suite of sensors located at the Automatic Rain Gauge station will be a tipping bucket rain gauge. The tipping bucket rain gauge will be mounted on an arm from the five-meter tower to place the lip of the rain gauge at a one-meter height.

The frequency of the automatic observations using sensors will be every 10 minutes.

Table 6-4: Requirements for a Typical Met - Automatic Rain Gauge

| Major Component | Quantity | Description |
|---|---|---|
| 1. Site Infrastructure | 1 | One meter high fence of galvanized chain link, with posts, gate, and post foundations. Typical compound will be 3 by 3 meters |
| | 1 | Five-meter free standing tower with foundation designed according to building code with a method for accessing the top of the tower |
| | 1 | Weatherproof NEMA 6 (IP67) rated enclosure for data logger, communications device, battery, etc. |
| | 1 | Mounting arm from five-meter tower for tipping rain gauge |
| | 1 | Flexible metal conduit with fire resistant protection for all above-ground cables with connectors, as required |
| | 1 | Grounding for lightning protection |
| | 1 | Benchmark |
| 2. Instrumentation | 1 | Data logger with GPS and communications device |
| | 1 | Solar charging system with batteries |
| | 1 | Tipping Bucket rain gauge |
| | 1 | Cabling, connectors, and mounting hardware for all sensors, as required |

### *Precipitation Sensors*

Reliable precipitation measurement is critical to water management and flood forecasting and, as a result, highly reliable and suitable technologies that can record intense rainfall events as well as low rainfall amounts are required. Auto-accumulation precipitation gauges complete with a shield will be installed at all Automatic Weather Stations as well as a tipping bucket rain gauge and a manual rain gauge. The redundancy in rain gauges allows for comparisons of the auto-accumulation with tipping buckets which are known to under catch. This allows for measurement from the broader network of tipping bucket gauges to be corrected based on the differences observed at the smaller number of sites with both types of gauges. Both of the automatic stations are then further checked against the manual rain gauge which provides no automatic reporting but can be included at minimal additional cost.

The Automatic Rain Gauge stations will use a tipping bucket rain gauge.

The proposed precipitation gauge must have successfully passed WMO laboratory inter-comparison tests or be recognized by the WMO. The 2005 WMO report on the Intercomparison of Rainfall Intensity Gauges (Lanza, L., et al., 2005) is noted as a supplemental resource with a summary provided in Appendix H.

The sensor is to be connected to a data logger for automatic data storage and transmission.

The precipitation gauges will be capable of providing reliable observations for both low and high intensity rain events.

In general, the precipitation sensors must be made of non-corrosive material.

The standard manual rain gauges must be recognized by WMO. Following are the specifications for precipitation sensors:

*Precipitation – Auto Accumulation*

| | |
|---|---|
| Collecting Area | 200 or 400 cm² |
| Collection Volume | 1500 0r 700 mm minimum |
| Intensity | 0 to 300 mm/hr |
| Sensitivity/Resolution | 0.2 mm |
| Accuracy – Intensity | ± 3 % or better |
| Accuracy – Accumulated | ± 3 % or better |
| Operating Voltage | 10.0 to 16.0 VDC |
| Power Consumption | <12 mA |
| Output Signal | SDI-12 preferred |
| Operating Temperature | -10°C to 60°C |
| Housing Material and Mounts | Must be UV resistant and of non-corrosive material |
| Cabling | Minimum of 8 of cable and must be UV resistant and suitable for placement under ground |
| Lightning Protection | Required |

*Precipitation – Tipping Bucket*

| | |
|---|---|
| Collecting Area | 200 cm² |
| Intensity | 0 to 700 mm/hr |
| Sensitivity/Resolution | 0.2 mm |
| Accuracy – Intensity<br>Accuracy – Accumulated | ± 3 % or better<br>± 3 % or better |
| Operating Voltage | 10.0 to 16.0 VDC |
| Power Consumption | < 3 mA |
| Output Signal | Switch close/open |
| Operating Temperature | 0°C to 60°C |
| Housing Material and Mounts | Must be UV resistant and non-corrosive materials |
| Cabling | Minimum 8 m of cable and must be UV resistant and suitable for placement under ground |
| Lightning Protection | Required |

*Precipitation Sensor - Standard Rain Gauge (manual)*

| | |
|---|---|
| Collecting Area | 200 cm² or greater |
| Reading Accuracy | 0.2 mm |
| Collecting Bottle Capacity | 300 mm |
| Operating Temperature | 0°C to 60°C |
| Housing Material | Must be UV resistant and non-corrosive materials |

## Wind Sensors

Wind speed and wind direction is required at each of the Automatic Weather Stations. The sensor is to be an industry standard ultrasonic sensor and will be mounted on a tower at a height of 10 meters. The sensor must be recognized by the WMO.

The sensor should output instantaneous, average 10 minute, and 1 minimum, and maximum values.

The sensor is to be connected to a data logger for automatic data storage and transmission. The preferred communications protocol of the sensor is SDI-12. Following are the specifications for wind sensors:

*Wind Speed Sensor – Ultrasonic*

| | |
|---|---|
| Measuring Range | 0 to 60 m/s |
| Maximum gust | 60 m/s |
| Resolution | 0.1 m/s |
| Accuracy | ± 5% or better for V > 5 m/s |
| Operating Voltage | 10.0 to 16.0 VDC |
| Power Consumption | < 10 mA |
| Operating Temperature | -10°C to 60°C |
| Output Signal | SDI-12 preferred |
| Cabling | Minimum 10 m of cable and must be UV resistant |
| Lightning Protection | Required |

*Wind Direction Sensor – Ultrasonic*

| | |
|---|---|
| Measuring Range | 0 to 359° no dead band |
| Resolution | Better than 5° |
| Accuracy | ± 5% or better for V > 5 m/s |
| Operating Voltage | 10.0 to 16.0 VDC |
| Power Consumption | < 10 mA |
| Operating Temperature | -10°C to 60°C |
| Output Signal | SDI-12 preferred |
| Cabling | Minimum 10 m of cable and must be UV resistant |
| Lightning Protection | Required |

## Air Temperature Sensors

Air temperature is required at each of the Automatic Weather Stations. The sensor is to be an industry standard electronic sensor mounted within a naturally aspirated radiation shield. The sensor must be recognized by the WMO.

The sensor is to be connected to a data logger for automatic data storage and transmission. The preferred communications protocol of the sensor is SDI-12. Following are the specifications for air temperature sensors:

*Air Temperature*

| | |
|---|---|
| Sensing Element | Platinum resistor Pt-100 |
| Accuracy | ±0.1°C |
| Measuring Range | -10°C to 60°C |
| Resolution | 0.1°C |
| Operating Voltage | 10.0 to 16.0 VDC |
| Power Consumption | < 3 mA |
| Operating Temperature | -10°C to 60°C |
| Output Signal | 4 wire Pt-100, SDI-12 preferred |
| Cabling | Minimum 8 m of cable and must be UV resistant and suitable for placement under ground |
| Lightning Protection | Required |

## Humidity Sensors

Humidity is required at each of the Automatic Weather Stations. The sensor will be an industry standard electronic sensor mounted within a naturally aspirated radiation shield. The sensor must be recognized by the WMO.

The sensor is to be connected to a data logger for automatic data storage and transmission. The preferred communications protocol of the sensor is SDI-12. Following are the specifications for humidity sensors:

*Relative Humidity*

| | |
|---|---|
| Measuring Range | 0 to 100% RH |
| Resolution | 0.1% RH |
| Accuracy | Better than ± 2.0% against factory references |
| Long Term Stability | Better than 1% RH a year |
| Temperature Dependence | Compensated for temperature |
| Operating Voltage | 10.0 to 16.0 VDC |
| Power Consumption | < 3 mA |
| Output Signal | SDI-12 preferred |
| Cabling | Minimum 8 m of cable and must be UV resistant and suitable for placement under ground |
| Lightning Protection | Required |

### Vented Enclosure

The temperature and humidity sensors will be placed in a vented enclosure to shield the sensors from direct sunlight, wind, and precipitation. The enclosure is to be vented on all sides and bottom to provide exposure to ambient conditions while excluding direct sunlight and precipitation. Following are the specifications for vented enclosures:

*Vented Radiation Shield*

| | |
|---|---|
| Material | Non-metal |
| Color | White |
| Mounting | Bracket for mounting on a mast |
| Shield | Naturally aspirated standard meteorological cage with at least five elements |

### Barometric Pressure Sensor

Barometric pressure is required at each of the Automatic Weather Stations. The sensor will be an industry standard electronic sensor and mounted within a vented enclosure. The sensor must be recognized by the WMO.

The sensor is to be connected to a data logger for automatic data storage and transmission. The preferred communications protocol of the sensor is SDI-12. Following are the specifications for barometric pressure sensors:

*Barometric Pressure*

| | |
|---|---|
| Measuring Range | 600 to 1100 hPa |
| Resolution | 0.1 hPa |
| Accuracy | ±0.5 hPa |
| Long Term Stability | 0.1 hPa drift per year |
| Temperature Dependence | Compensated for -10°C to +70°C range |
| Measurement | Within a vented enclosure |
| Operating Voltage | 10.0 to 16.0 VDC |
| Power Consumption | < 5 mA |
| Operating Temperature | -10°C to 60°C |
| Output Signal | SDI-12 preferred |

| | |
|---|---|
| Cabling | Minimum 8 m of cable and must be UV resistant and suitable for placement under ground |
| Lightning Protection | Required |

### Solar Radiation Sensor

Net solar radiation is required at each of the Automatic Weather Stations. The sensor will be mounted on a tower. The sensor must be recognized by the WMO.

The sensor is to be connected to a data logger for automatic data storage and transmission. The preferred communications protocol of the sensor is SDI-12. Following are the specifications for solar radiation sensors:

*Solar Radiation Global (Net Radiometer)*

| | |
|---|---|
| Measuring Range | -2000 to +2000 W/m² radiation balance within a range of 0.2 to 100 µm |
| Sensitivity | 10 µV/W/m² |
| Field of View | 180 ° |
| Response Time | < 60 secs |
| Operating Voltage | 10.0 to 16.0 VDC |
| Power Consumption | < 5 mA |
| Operating Temperature | -10°C to 60°C |
| Output Signal | SDI-12 preferred |
| Cabling | Minimum 8 m of cable and must be UV resistant and suitable for placement under ground |
| Mounting | Bracket for mounting on a mast |
| Lightning Protection | Required |

### Evaporation

Information on evaporation and potential evapotranspiration is required to estimate water losses for agro-meteorological purposes and is critical to perform water balance analyses. The Penman-Monteith method will be used to estimate evapotranspiration using an appropriate configuration of meteorological sensors at each of the Automatic Weather Stations. Data from a suite of sensors, including wind speed and direction, air temperature, radiation, air humidity, and barometric pressure will be processed using a standard algorithm at the data center to estimate evapotranspiration.

The suite of required sensors required for the determination of evaporation will be connected to a data logger for automatic data storage and transmission. The preferred communications protocol for the suite of sensors is SDI-12.

### Compact Multi Weather Sensor

A fully integrated and compact multi sensor is the preferred designed for the Automatic Weather Stations due to its simplicity in interfacing to the data logger, its low power consumption, as well as its preprogrammed functions for determine derived parameters such as dew point using standard algorithms. The multi sensor incorporates all the required measurement parameters such as wind, temperature, humidity, barometric pressure, and solar radiation. The multi sensor will have a built in GPS and compass. The multi sensor must conform to international standards, be easy to use, and have minimum maintenance.

The multi-sensor will be of a design that enables the measurement of wind at 10 meters and the other parameters at 1.5 to 2.0 meters.

The multi sensor will satisfy the specification for each of the above noted meteorological sensors as well as the following requirements:

| | |
|---|---|
| **Power Supply** | |
| Operating Voltage | 10.0 to 16.0 VDC |
| Power Consumption | < 25 mA |
| **Physical Environment** | |
| Protection Class | IP65 |
| Operating Humidity | 0 to 100% humidity |
| Operating Temperature | -10°C to 60°C |
| Color | White |
| Material | Non-metal |
| Output | SDI-12 |
| All necessary cabling, connections, and mounting hardware to be supplied. Mounting is to be on a mast. Cabling must be UV resistant and suitable for placement underground. | |
| Software and a communications cable required to configure the multi sensor and for the display of real-time and logged data must be supplied. | |

### 6.2.3 Groundwater Stations

Groundwater stations will be equipped with a pressure transducer, data logger, and a solar power supply system. The data logger will be housed in a weatherproof NEMA 6 (IP67) rated instrument enclosure with the required batteries and solar regulator system. A five-meter tower will be required to support the instrument enclosure, solar panel, and communications antenna

The data logger will have a display enabling the on-site observation of the groundwater level.

The frequency of the observations will be every 60 minutes.

The specifications for the pressure transducer are the same as those used for the hydrometric stations as noted in Section 6.2.1.

A contact gauge will be required for the manual measurement of depth to water, temperature, and conductivity in groundwater. The contact gauge will consist of measured tape with a probe placed on a drum held by a stable frame, which is easy to carry. Once the probe touches the water surface a signal is produced and the distance to water can be read. The contact gauge is suitable for depths of 15 to 100 m. The contact gauge can be equipped with a conductivity sensor and display to show values of temperature, conductivity and TDS (Total Dissolved Solids).

A bailer will be required to collect a groundwater sample for laboratory analysis. The bailer is to be a long-life reusable bailer constructed of virgin high density white PVC or Teflon for environmental sampling and bailing applications. The bailer must be 50mm in diameter and 1000m in length with recess check. The bailer must be designed to have a trouble free rigid tethering attachment and to have accurate pouring capability. Each bailer is to be provided with a roll (at least 150m) of 18 Nylon braid bailer cord.

### 6.2.4 Data Loggers

The data loggers will be able to perform the following functions:

- Automatic acquisition of hydro-meteorological data: the data logger shall make it possible to set acquisition intervals independently for each acquisition channel, and configure the sensors as required.
- Data processing: the data logger shall be capable of doing local conversion of measured variables in order to provide reliable data in standard hydro-meteorological engineering units.
- Data storage: the data logger shall make it possible to store in memory at least twelve (12) months of 10-minute data for each parameter (precipitation, wind direction, wind speed,

barometric pressure, air temperature, soil temperature, humidity solar radiation, water level, and station health parameters such as battery voltage).

- Self-diagnosis and supervision: the data logger shall be able to gather and report alarm conditions upon exceeding specified precipitation and water level warning levels, or upon detecting failures with connected devices.
- Programming and display: staff shall be able to program the data logger at the field site and display live as well as stored data readings using a remote device. The data logger is to have an integrated display to allow information to read on site by the field observer without the need for a computer and/or tablet. An integrated keyboard is optional.

*Data Logger*

The data logger must meet or exceed these specifications:

**Inputs:** Supports ten sensors with a minimum of two analog channels, one SDI-12 port, and a tipping bucket event counter
**On-site and Data Download Interface:** Standard RS232 or USB port. USB port preferred for on-site access
**Remote Communication Interface:** Communication port to interface with GSM/GPRS modem and/or EUMETSAT Satellite transmitter
**Microprocessor:** 16 or preferred 32-bit
**Logging Memory:** 8 Mb
**Data storage:** Non-Volatile
**Time synchronization:** GPS antenna for time synchronization
**Time Stamp:** Individually with 1 sec resolution
**Display:** 8 digit LCD display with backlight or equivalent for bright exposure environments
**Battery:** Internal back-up battery and external power supply
**Enclosure:** Weatherproof NEMA 6 (IP66 or 67) rated
**Protection:** Lighting, over voltage, and reverse voltage
**Operating Voltage:** 10.0 to 16.0 VDC
**Power Consumption:** < 3 mA quiescent
**Operating Temperature:** -10°C to 60°C
**Programmable Functions:** Supports mathematical equation editor, averaging, and customize calculations

The programming environment of the data logger has to be simple, flexible, with built-in data quality control functionality and availability of integrated calculations of derived variables such as minimum, maximum. There must also be an option to convert the input data detected in electrical units into engineering units using conversion formulas.

Data loggers must be based on a widely used model, tested in a large number of installations, and must have been in production for at least 2 years. All data loggers must have programmable data acquisition rates, a large and expandable data storage capability and low power consumption. The data logger must log both the battery level and the solar panel voltage level in addition to the basic hydro-meteorological parameters.

The data logger must be installed in an instrument enclosure. The instrument enclosure is to be complete with wiring and terminal block for the connection of all required sensors as well as provide the required grounding (earthing) and protection from lightning. The external cabling from the sensors are to have a single entry point to the instrument enclosure with appropriate environmental protection.

All necessary cables, connectors, surge protection, and mounting hardware are to be supplied including the communications cable for laptop to data logger communications.

One complete set of technical documentation with user manual in both hard and soft copy in English.

The Instrument Enclosure must meet or exceed these specifications:

**Type:** Weatherproof NEMA 6 (IP67) rated enclosure with a key log sized to house the data logger, batteries, solar regulator, and GSM/GPRS modem or EUMETSAT Satellite transmitter.

### 6.2.5 Communications – Telemetry

Today's modern hydro-meteorological networks rely on real-time reporting of data and field conditions to operate effectively. In addition to making the field data readily available for operational decisions, the real-time information is used to monitor the operational state of the network as well as the quality of data being collected.

In the Nile Basin the feasible options for data communications from the field sites to a data center include the following:

- Satellite Communications – Geostationary
- Global System for Mobile Communications (GSM) with GPRS (3G and 4G)

The preferred option for the transmission of field observations to a data center(s) is the geostationary satellite telemetry option. It provides a cost effective and sustainable solution, supports data security using a simple encryption protocol, can support multi-point access, is proven technology, has readily available commercial and open source with standardized data acquisition and telemetry management software, and has proven to be more reliable in adverse environmental conditions.

The most suitable geostationary satellite telemetry solution for the Nile basin is METEOSAT, which is supported by the European Union. The METEOSAT satellite is operated by the European Organization for the Exploration of Meteorological Satellites (EUMETSAT) whose primary goal is to collect and disseminate weather imagery. However, the system of METEOSAT satellites supports low-rate data transmission through their on-board Data Collection System (DCS).

Information from a Data Collection Platform (DCP) located at the field can be transmitted to one of the geostationary METEOSAT satellites in two different ways. The first method is the self-timed option, which transmits a message to the satellite at fixed timeslots. These timeslots normally are once every hour, but other intervals are possible. The second method of communication is an alert option in which the DCP transmits when a threshold level for a parameter has been exceeded.

Satellite communications are one-way to EUMETSAT's main control center. The user may access data at the main control center via Internet. As well, EUMETSAT offers a EUMETCAST system, which enables the user to acquire real-time data using a simple and cost effective satellite reception system installed at the country's data collection center(s).

The satellite based telemetry systems support hourly data collection from a large number of stations. Satellite telemetry is not affected by environmental issues such as flooding or power cuts and has been proven to work during the most adverse environmental conditions.

The Global System for Mobile Communication (GSM) option uses the General Packet Radio Service (GPRS). GPRS is an enhanced protocol that allows for transmission of data on the Global System for Mobile Communication (GSM). GPRS is a much more robust communications service that enables for error checking and automated two-way communications. However the GPRS requires that reliable cellular service, which supports the GPRS protocol, be available at the field site. In addition, the mobile network is shared with the general population which can limit reliability during periods of heavy load. As a result, GPRS would not be a suitable telemetry option for stations that are intended to provide early flood warning. Another key consideration in using the GSM-GRPS approach is that there will be monthly telecommunication charges. These charges depend on the local service provider's fee structure.

Based on feedback from the workshop, the design calls for satellite based telemetry and communications from field stations as the standard, and this is proposed for the pilot/demonstration stations in Implementation Phase I. There are some countries that are still unsure about adopting satellite telemetry. It is therefore proposed that the design and implementation plan offer the option for individual countries to select GPRS transmissions if they choose, after they have evaluated the satellite based telemetry implemented for demonstration stations in Phase I. If a country chooses

GPRS for subsequent stations, the satellite radios at the Phase I stations can be replaced with GPRS radios. Additionally, where national policy imposes constraints on allowable telecommunications technologies, an exception may be required to this design to permit GPRS to be used also for the demonstration stations.

### *Satellite Communications – Geostationary*

The satellite transmitter must conform to EUMETSAT requirements and must a have an EUMETSAT

"Data Collection Platform/Radio Set" Certificate. The transmitter will be designed to operate without degradation under the dusty and wet conditions experienced at exposed sites and will enclosed in a watertight case conforming to IP65. The equipment will function satisfactorily between -10°C and +60°C.

The satellite transmitter must be programmable by an external terminal without modification of the equipment for METEOSAT and GOES international and regional channels, have a GPS interface for auto-synchronization of time and a RS232/V28 serial interface for data transmission and control from the data logger. The antenna is to be either a Yagi or UB6 antenna, but the UB6 antenna is preferred.

The transmitter should have the following minimum features:

- Transmitting performance of 5W directional
- Power consumption in idle mode <10 mA and during transmission <1.4 A
- Data transmission time set by PRC/PMU according to EUMETSAT time allocation
- The input voltage to the system shall be nominal +12 volt DC (from 10.8 to 16V), polarity and surge protected.
- Self-timed and emergency frequencies should be available.
- The desired baud rate is 1200 baud (EUMETSAT sets baud rates in assigning IDs for satellite transmitter at 100, 300, or 1200).

### *GSM with GPRS*

The GSM-GPRS modem must meet or exceed these specifications:

**Module:** Band GSM 900/1800/1900 Mhz Quad band GSM 850/900/1800/1900 MHz

**Output Power:** < 2W (ideally < 1W)

**SIM: Interface:** External standard SIM 1.8V and 3V

**SMS:** Support Text and PDU mode

**Data:** Data circuit Asynchronous and non-transparent up to 14.4 kbps

**GPRS Packet Data Feature:** Coding Scheme CS1 to CS4, Embedded TCP/IP Stack

**Radio Modem:** Work with VHF and UHF user adjustable ranges

**AT Commands Interface:** GSM /GPRS

**Connectors/Switches:** RS-232 Serial or USB, SIM Card Holder, DC power connector, Antenna connector

**Power Supply:** Input 6 - 30V DC with reverse connection protection

**Enclosure:** Water proof and heat resistant material

**Mounting:** Poll, Wall Mounting

**Temperature:** Operating: - 10°C ~ +70°C

**Software:** The software should be in English, compatible with Windows

**Antenna:** High gain with rubber cover or standard for tropical countries

All necessary cables, connectors, surge protection, and mounting hardware are to be supplied including the communications cable. One complete set of technical documentation must be supplied with user manual in English in both hard and soft copy.

### 6.2.6 Base Station

The Base Station will be equipped with software to manage the acquisition of hourly data from both the EUMETSAT Satellite system as well as the GSM-GPRS communications system. The Base Station will be composed of a PC-Based Central Receiving Station.

The basic requirement for the data communications is one-way, scheduled transmission with a non-redundant transition system on a minimum of an hourly schedule from the field station to the Data Center.

To allow future system up-grade and maintenance, the telemetry data format shall be based on well know international industrial standards (not proprietary protocols).

The entire system for the automatic transmission and reception of data from the remote field stations must ensure the permanent operation of the entire network, with virtually no loss of data under all weather conditions, including significant rainfall and storm events. The reception level of data must meet or exceed 98% of the data transmitted. The delay in the reception of data from remote field stations as viewed from the Data Centre must not be greater than one (1) hour.

### 6.2.7 Power Supply System

All electrical power to operate the sensors, data logger, and the communication system at the field stations will be provided from a solar charging system. The power supply system will consist of a solar panel and back-up batteries with the appropriate power and protection circuits. The power supply system will be capable of satisfying all power requirements of the field station, considering site and meteorological conditions, guaranteeing uninterrupted operation and data transmission.

Solar panel will be capable of charging 12 V DC batteries to guarantee full charge of the batteries under normal operating conditions. The solar panels must be resistant to any adverse weather condition, ultraviolet radiation, wind, mechanical impacts, and penetration of dust and humidity. The solar panel will be installed in such a way as to defer vandalism and be identifiable in case of theft.

Battery will be rechargeable, suitable for service in solar powered systems and have sufficient capacity to satisfy normal operational loads for a period of at least 60 days without recharging. The batteries will require little or no maintenance and must be available in the region. The expected lifetime of the battery is to be not less than sixty (60) months.

The power and protection circuit will guarantee that the battery is not over-charged and receives the correct voltage, and the circuit will prevent power discharge during low solar radiation conditions.

*Solar Power Supply*

The Bidder will be required to design and size the solar charging and battery system considering the Bidders proposed suite of sensors and communication method, according to the following:

| | |
|---|---|
| Solar panel(s) | Sized as required. Certified for damp heat applications (sealed for use in an outdoor environment) |
| Battery | Sized for 60 days of power supply without a charge |
| Charge controller | Temperature compensated; with status lights; disable and able low voltage cut-off |

### 6.2.8 Station Autonomy

The conditions and constraints of station operations in the Nile River Basin require long periods of station autonomy. Therefore, the measuring stations shall offer capability for unattended operations with at least one year of data logging capacity. Telemetry will be support the real-time monitoring of all sites.

All sites will be solar powered and must operate 60 days without recharging. The solar panel will be placed on the main tower so as not to shade or interfere with the sensors. The antenna to support the telemetry system will be placed on the main tower at the required height.

The tower and all sensors are to be appropriately grounded according to the country's code for lightning protection. The free standing towers and tower foundations are to be designed to comply with the required standards and country building codes.

All underground cable runs will be placed in protective PVC conduit of at least 80 mm in diameter. All exposed cable runs will be placed in flexible polyolefin coated galvanized steel conduit.

All sensors, data loggers, and other equipment shall be surge protected as required. Equipment for lightning protection, such as conductors and ground rods, are part of the station infrastructure.

Appropriate signage will be installed at each site indicating the general purpose of the site and promoting the responsible agency or Ministry.

### 6.2.9 Discharge Measurements

Discharge measurements are required to develop a stage-discharge relation for each flow site as well as provide confirmation of peak flows values. Once developed the stage-discharge relations must be validated at a frequency to assess whether the channel conditions have changed and whether the stage-discharge relations requires updating. The frequency of the confirmation measurements depends on the stability of the stage-discharge relation, which is governed by the stability of the channel at the station, or the occurrence of backwater effects from downstream conditions.

For flow sites with an existing stage-discharge relation a series of confirmation measurements are required over the range of stages. For example; a discharge measurement at the low, medium and high flow ranges are required to confirm the validity of the stage discharge relation within these flow ranges. Discharge measurements should also be taken on the rising and falling limbs of the hydrograph to assess the degree of hysteresis at the site. It is important that a series of discharge measurements be taken at the time of the peak flow.

For flow sites requiring the development of a stage-discharge relation an intense discharge measurement program is required during the runoff period. The discharge measurement program must cover the low, medium, and high ranges of stage and multiple measurements are required at each range to minimize uncertainty in the stage-discharge relation for each range of stage. It is important that discharge measurements be made during the peak flow period.

The frequency of regular discharge measurement at a site is governed by the stability of the channel conditions of the site and the existence of variable backwater, and hence the stability of the stage-discharge relation. As well, the expected range of flows during the runoff season governs the frequency of discharge measurement.

Typically, monthly discharge measurements are required at the initiation of the runoff period and should proceed to weekly discharge measurement during the high to peak flow period. It is important to follow the recession limb of the hydrograph with discharge measurements. During the low runoff period discharge measurements should be conducted once every two months.

For sites affected by regulation a discharge measurement is required when there is a change in the regulated release, in addition to the discharge measures required to develop and validate the stage-discharge relation.

The discharge measurement program for a site can be customized as the knowledge of the stability of the stage-discharge relation for a site grows.

The WMO manual on stream gauging (WMO-No. 1044, 2010) and a white paper on rating curve development (Hamilton, S, 2014) have been included as supplemental resources with summaries of each provided in Appendix H.

### *Acoustic Doppler Current Profiler*

A number of Acoustic Doppler Current Profilers (ADCPs) with ancillary accessories are required to measure current velocity (surface and depth), flow discharge both in rivers and canals, and furnish cross section and velocity profiles. The ADCPs will come complete with a tethered boat, communications to shore radios, and field-ruggedized laptop.

The ADCPs technology shall be based on the most recent available series of Acoustic Doppler Current Profilers that can profile depths of up to 30 meters with high levels of suspended sediment.

The ADCP measurement systems are to include measurement platform, measurement computer and software, differential GPS, all cabling, and power supply. The software must handle both moving boat and discrete panel measurements.

A manual on *Measuring Discharge with Acoustic Doppler Current Profilers from a Moving Boat* (Environment Canada, 2013) has been provided as a supplemental resource with a summary given in Appendix H.

| The Acoustic Doppler Current Profiler (ADCP) is to be used for automated discharge measurements on rivers and canals. The ADCP will be deployed in a roving mode, being transported from the one site of interest to the other.<br>Functionally is required to measure discrete river discharges in conditions ranging from streams with cross sections up to 10 m wide and 1 m deep to rivers with cross sections up to 400 m wide and 40 m deep. In addition, the ADCP must be able to measure streams and rivers with very high sediment loads.<br>Measurements are based on the measurement of three dimensional water velocity vectors and platform position using acoustic bottom tracking. The ADCP software must handle moving boat and discrete panel type measurements.<br>ADCP measurement systems are to be complete and fully functioning including ADCP, GPS, power system, measurement controller (laptop or PDA complete with software), and measurement platform or boat. | |
|---|---|
| Depth Profiling Range | 0.3 m to 40 m |
| Velocity Profiling Range | ±10 m/s |
| Measurement Profiling Range (minimum effective depth of water required to obtain a valid velocity profile including the draft of the instrument as mounted on the operational floating platform, blanking distances, and one valid depth cell) | Minimum required depth 0.4 m.<br>Maximum required depth 40 m. |
| Velocity Measurement Accuracy | 0.3% of relative velocity with a minimum of 3 mm/s |
| Velocity Resolution | 1 mm/s |
| Maximum Number of Depth Cells | 100 |
| Minimum Cell Size | 20 cm |
| Depth Profiling | Independent vertical beam |
| Depth Profiling Range | 0.3 m to 70 m |
| Depth Profiling Accuracy | 1% of measured depth |
| Depth Profiling Resolution | 1 mm |
| Temperature Measurement Range | 1°C - 50°C |
| Temperature Measurement Accuracy | ± 0.5°C |
| Temperature Measurement Resolution | 0.01°C |
| Tilt Sensor Measurement Range | ±15° |
| Tilt Sensor Accuracy | ±1° |

| | |
|---|---|
| Tilt Sensor Resolution | .05° |
| Compass Measurement Range | 0 - 360° |
| Compass Measurement Accuracy | ± 2° |
| Compass Measurement Resolution | 0.1° |
| Measurement Control | PDA, lap top or equivalent using Bluetooth, Wi-Fi, or spread spectrum radio. |
| Moving Platform Software | Intuitive software including ship track, measured velocity profile, velocity contour plot, measurement statistics and quality assurance parameters. |
| Stationary Position, Velocity Area, based Measurement Software. | Intuitive stationary position software including measurement position, measurement progress, measured velocity profile, velocity contour plot, total discharge, measurement statistics and quality assurance parameters. |
| Positioning | Primary high precision platform positioning using bottom track (without GPS).<br>Secondary positioning using GPS with VTG and GGA options under moving bed conditions. |
| GPS | Integrated RTK GPS with accuracy 0.04 m or better.<br>DGPS positioning with accuracy of 1.5 m or better. |
| Floating Platform | Rugged, stable platform or trimaran from non-corrosive material, as needed for ADCP operation |
| Power System | Rechargeable with reverse polarity and over voltage protection. Built-in waterproof battery housing with charger. Battery to have minimum 8 hours of continuous operation between charges. |

For sites where the existing infrastructure does not allow for the tethering of an ADCP from a bridge or deployment using a boat, an un-manned permanent bank-operated cableway may be installed. The bank-operated cableway is a simple structure using a light cable, as it is unmanned and is not required to support the use of sounding weights for the conduct of the discharge measurement. The measurement platform (tethered boat) with the ADCP is towed back and forth across the measurement section using either a manual crank or a motorized drive. A number of remote control motorized rovers are available, which can be used to tow the tethered boat and ADCP across the measurement section. The rovers can be used with existing cableways as well as un-manned bank operated cableways. These rovers can be carried from one streamflow-gauging station to another and, once mounted on the cableway, can be used to winch up the tethered boat as well as tow it across the measurement section.

The typical specifications for a 40 m span are 2000mm by 200mm hot galvanized I-beams mounted on a 400mm by 400mm by 800mm deep reinforce concrete foundation placed on opposite sides of the river. The cable lines between the two I-beams are to be 3mm high tensile stainless steel cable placed on a dual pulley system. The pulley system is to have a hand operated crank for moving the cable and the tethered boat with the ADCP back and forth across the river. The pulley system and hand operated crank winch are to be pre-fabricated or purchased.

### *Acoustic Doppler Current Meters*

The use of acoustic Doppler current meters as a substitute for mechanical current meters has become acceptable for the measurement of stream discharge in low to medium to high flow situations. The acoustic Doppler current meter will be used to measure flow velocity for determining river flow using the velocity area method by wading and suspended measurement techniques.

| Measurement system required to measure flow velocity for determining river flow using the velocity area wading measurement technique, and is to be complete including meter and top setting wading rod. | |
|---|---|
| Sensor Configuration | Minimum 2 dimensional vector measurement (typically referenced as x and y dimensions) |
| Velocity Measurement | -0.1 m/s to 2.5 m/s |
| Velocity Measurement Accuracy | ± 1% of measured value, ± 0.25 cm/s |
| Velocity Measurement Resolution | 0.001 m/s |
| Discharge Measurement Software | Intuitive on-board software using linear programming to step through the velocity area measurement process. Discharge measurement software based on ISO mid-section measurement procedures. |
| Measurement download and QA/QC software | Measurements shall be downloadable through direct connect cable and processed using stand-alone quality assurance software. QA software to include measurement assessment and instrument diagnostics in an intuitive format. |
| Internal data storage | Record space for up to 50 discharge measurements on-board. |
| Power | Batteries to support 20 hours of continuous operation between charging. |
| Electronics | System shall be capable of 1 m submersion for short periods of time. |
| Storage Temperature | -5 to 50°C. |
| Wading Rod | Instrument to come complete with high quality top setting wading rod and all necessary operational and instrument mounting hardware. Wading rod to be available in up to 2 m lengths marked in minimum of 2 cm increments. |

### *Mechanical Flow Meters*

A number of mechanical flow meters complete with all accessory equipment and materials are required for the conduct of discharge measurements in low to medium to high flow situations. The metering equipment will be used to measure flow velocity for determining river flow using the velocity area method by wading and suspended measurement techniques. The mechanical flow meters will include a rotary cup type meter where the cups are to be glass filled nylon buckets to be more resistant to damage.

Accessories are to include wading and suspension rods, weights, sounding reels, and cranes.

The mechanical flow meters units are to be supplied with a keypad and display as well as have the ability to manually determine velocity by counting audio beeps.

| |
|---|
| The mechanical measurement system is to be complete and include meter, a stabilizer tail fin, top setting wading rod, sounding reel, hanger bar, sounding weights, and tagline to take measurements from a bridge, cableway, or by wading. |

| | |
|---|---|
| Sounding weights for carrying out discharge measurements by suspension will include weights of 15 kg, 25 kg, and 35 kg.<br>Sounding reels are to have metric counters for use with weights up to 50 kg with and at least 20 m of armoured signal cable. Crank is to be removable. The reel is to be equipped with a ratchet and pawl to hold metering equipment in place. | |
| Sensor Configuration | Cup-type meter with interchangeable buckets with durable tungsten tip pivot. Bucket configuration to be six (6) durable glass filled nylon buckets. Reed switch to be encapsulated. |
| Construction | Cast brass body, nickel plated with stainless steel bucket wheel frame |
| Velocity Measurement | 0.025 m/s to 8.0 m/s |
| Velocity Measurement Accuracy | ± 1% of measured value |
| Velocity Measurement Resolution | 0.001 m/s |
| Output Signal | Voltage free digital signal, with one (1) full revolution of the bucket assembly producing one pulse. |
| Standard Kit | 3.0 meters connecting lead, calibration certificate, 30 mls of current meter oil, and screw driver, heavy-duty case with durable molded foam.<br>Instrument to come complete with all necessary operational and instrument mounting hardware. |
| Counter | Basic counter that can be set to count pulses for a specific time period (10-200 secs). The counter stops when the time period has elapsed and shows a digital reading for the number of pulses. A rating table is to be used to convert the number of pulses to velocity. |
| Wading Rod | Instrument to come complete with high quality top setting wading rod. Wading rod to be available in up to 2 m lengths marked in minimum of 2 cm increments. |

### 6.2.10 Sediment Monitoring Field Kit

Sediment measurement involves sampling the water-sediment mixture to determine the mean suspended sediment concentration, particle size distribution, specific gravity, temperature of the water sediment mixture, and other physical and chemical properties of the transported solids. Suspended sediment concentration in a natural stream varies from the water surface to the streambed and laterally across the stream. Concentration generally increases from a minimum at the water surface to a maximum at or near the streambed.

The recommended samplers for the collection of suspend sediment samples have been designed by the U.S. Federal Interagency Sedimentation Project (FISP).

Depth Integrating Samplers - Depth integrating samplers are designed to continuously extract a sample as they are lowered from the water surface to the streambed and returned at a constant rate of travel. Ascending and descending speeds need not be the same, but the rate of travel must be constant in each direction. As the sample is collected, air in the container is compressed so that the pressure balances the hydrostatic pressure at the air exhaust and the inflow velocity is approximately equal to the stream velocity.

Point Integrating Samplers - Point integrating samplers are equipped with an electrically controlled rotary valve, which opens and closes the sampler on command. They are designed to take a sample at any point in a stream over a short time interval. With the control valve fixed in the open position, these samplers are also used to obtain depth integrated samples. One-way depth integrated samples may be obtained by opening the valve with the sampler at the water surface and lowering it to the streambed at a constant speed. This permits sampling to greater depths.

Suspended-sediment samplers should be used only with the specified nozzle to give a truly representative sample. All US-series samplers are designed to sample isokinetically, which means that water is entering the nozzle at the same speed as the water would be traveling if the sampler wasn't there.

### *Depth-integrating Wading Type - DH-48 Sampler*

This is a lightweight sampler for collection of suspended-sediment samples where wading rod sampler suspension is used. The sampler consists of a streamlined aluminum casting, 13 inches (33 cm) long, which partially encloses a 0.5-liter sample container. The sampler weights 2 kg including sample container. A standard 1.27 cm wading rod is threaded into the top of the sampler body for suspending the sampler. The wading rods come in 1 m long sections. The wading sampler is supplied with one 0.635 cm yellow color-coded, calibrated, nylon nozzle.

The sampler can be supplied with a special epoxy coating for chemical and trace metal sampling applications.

In the sampling operation, the intake nozzle is orientated into the current and held in a horizontal position while the sample is lowered at a uniform rate from the water surface to the bottom of the stream, instantly reversed, and then raised again to the water surface at a uniform rate. The sampler continues to take its sample throughout the time of submergence.

### *Depth-Integrating Hand Line Type - Model US DH-59 and DH-76*

These are medium-weight suspended-sediment samplers for hand line or sounding reel suspension. The DH-59 sampler comprises a streamlined bronze casting, 38 cm long, which partially encloses a 0.5-liter sample container. This sampler weighs approximately 10 kg, and is equipped with a tail vane assembly to orient the intake nozzle of the sampler into the approaching flow as the sampler enters the water.

The DH-76 is 17 43 cm long, partially encloses a 1.0-liter sample container and weighs approximately 11 kg. The DH-76 comes with an adapter sleeve and can be used with a 0.5 -liter sample containers.

The sampler's nozzles are calibrated and are supplied in 0.64 cm, 0.48 cm, and 0.32 cm red color-coded nylon sizes. Each sampler is shipped in a hinged, wooden box suitable for storing and transporting.

The samplers can be supplied with a special epoxy coating for chemical and trace metal sampling.

The operation of these samplers is identical to the operation of the DH-48.

### *Depth-Integrating Reel Type, US D-74 and US D-74AL*

This is a 28 kg sampler for suspension by cable, reel, and crane to take suspended-sediment samples in streams up to 5.5 meters in depth. The sampler has a cast bronze streamlined body 61 cm long, in which a 0.5 or 1.0-liter sample container is enclosed. These samplers also can be cast in aluminum instead of bronze. In this case, the sampler weigh is 13.6 kg, and is designated as the US D-74AL.

The instrument is suspended on a hanger bar attached to a stainless steel cable and is lowered and raised by means of a sounding reel mounted on a crane, cable car or boat.

Each nozzle is calibrated and supplied in 0.64 cm, 0.48 cm, and 0.32 cm green color-coded nylon sizes.

The samplers can be supplied with a special epoxy coating.

Shipment is made in a hinged, wooden box suitable for storing and transporting. T

The sampling operation is identical to that of the DH-48.

### *Point-Integrated Samplers- US P-72*

This is a 19 kg electrically operated sampler for collection of suspended sediment samples at any point beneath the surface of a stream, or for taking a sample continuously over a range of depth. The sampler is made of cast aluminum and is 71 cm long. The sampler head is hinged to provide access for a 1.0-liter size sample container or, with adapter, a 0.5-liter size container.

An electrically actuated valve mechanism, to start and stop the sampling process, is located in the sampler head.

The compression chamber in the body of the sampler permits operation to depths of 55 meters. A battery source of about 36 volts is required to operate the solenoid. More voltage is required if a long suspension cable is used.

Each sampler is shipped in a hinged, wooden box suitable for storing and transporting and the sampler can be epoxy-coated for water quality sampling.

### *USGS Type E Heavy-Duty Crane and Truck - Model 4400*

The Type E crane is used with the Type E truck when making discharge measurements of large rivers where heavy weights or sediment samplers are required. The Type E crane is collapsible for compact storage, and is made from aluminum stock with stainless steel bolts and stainless steel shafts. The reel mount is drilled to install a Type A-55, B-56 or E-53 sounding reel. The power drive unit for the sounding reel clamps to the crane assembly.

This crane may be used for any of the sounding weights or samplers, but it is usually used for those from 45 kg and up.

The crane is complete with a colored protractor to measure the vertical angle of the sounding line. The protractor measures angles from -25 to +90 degrees. A USGS stream velocity correction chart based on the measured angle is included with the protractor.

The approximate weight of the crane is 27 kg.

The Type E truck is intended to be used with the Type E crane. It does not have adjustable curbside wheels as the Type A crane does. The truck has a handle, which folds underneath the crane for storage and holds up to five 27 kg counterweights. The truck is made from aluminum stock, and has a width of 86 cm and a length of 106 cm. The approximate weight of the truck is 45 kg.

### 6.2.11 Water Quality Field Kit

A water quality program will be conducted at the field level for both surface and groundwater sites. The objective of the program is to characterize the ambient water quality at the site and to identify water quality ‘hot spots of concern’. The ‘hot spots of concern’ sites will require an intense water quality monitoring and assessment program, which is beyond the scope of the regional network design.

Accordingly, the approached used for the water quality program is structured on the use of portable water quality field kits. The field kit will be designed to withstand harsh environmental and rugged conditions.

The field kits will consist of a versatile portable laboratory kit, which includes a full complement of instruments and reagent sets for more than 20 water quality parameters. The portable laboratory kit will include DR 900 Colorimeter, HQ40d multimeter, PHC201 pH electrode (1 meter cable), CDC401 conductivity probe (1 meter cable), Digital Titrator, reagent set, illustrated instrument manual, and procedure manual CD with all required apparatus in a rugged carrying case.

The basic water quality parameters covered include temperature, pH, Conductivity, TDS, Dissolved oxygen, Turbidity, BOD, and Nutrients (N, P). Whereas advanced parameters that will require further analysis at the laboratory include pesticides, heavy metals and hydrocarbons.

Specific discussion on equipment for advanced monitoring within a laboratory is provided in Section 7.1.5 with specifications for laboratory equipment provided in Appendix G.

### 6.2.12 Additional Field Accessories

Field-ruggedized laptops or tablets will be required for the field service crews. Surveyor's levels are also required for establishing and maintaining the reference datum for the staff gauges and water level sensors.

A complete tool kit with accessories, equipment, and materials is required to calibrate and service the instrumentation and equipment previously identified. The field kits will include tools and instruments for conducting routine servicing of the data loggers, sensors, and the power supply system.

All related technical user manuals, operational guides, and reference material are to be supplied in English.

#### *Field Laptop or Tablet*

The laptop must meet or exceed the detailed specifications that follow.

| | |
|---|---|
| Housing | IP65 rating with metal with rubber bumpers, covers on ports, and carry handle |
| LCD | LCD 13" Sunlight readable WXGA |
| Processor, RAM, Hard Drive | 2.8 GHz Intel; 2 GB (RAM), 100 GB shock resistant (hard drive) |
| Communications | 802.11 a/b/g Wireless, Bluetooth, built in modem |
| I/O ports | 3 USB 2.0, 1 DB9 serial, PCMCIA type II, RJ45 Ethernet, RJ11 phone, PS/2 mouse |
| Media | DVD reader, CD-ROM writer, smart card |
| Keyboard | Waterproof full QWERTY |
| Pointing device | Touchpad or track point |
| OS | Windows XP Pro or latest |
| Battery Life | 4 hours |
| Operating Condition | 0 to 50 °C, 95% humidity |
| Power Supply | Nominal 220VAC, Africa socket |

The tablet must meet or exceed the detailed specifications that follow.

| | |
|---|---|
| Housing | IP65 rating with metal with rubber bumpers, covers on ports, and hand/ carrying straps |
| LCD | 10.1 inch outdoor full HD, sunlight viewable, color LCD with circular polarizer for up to 800cd/$m^2$ brightness |

| | |
|---|---|
| Processor; RAM; Hard Drive | Intel Core i5 VPro Processor); 8GB SDRAM; 120 GB shock resistant solid state (hard drive) |
| Communications | Dual Band Wireless, Bluetooth, and LAN port for minimum of 10Base-T |
| I/O ports | one USB 3.0, one DB9 serial |
| Touch Screen | 10 finger capacity multi touch screen |
| OS | Windows 8.1 Pro or latest |

### *Surveyors Auto-level*

Professional grade surveyors level suitable for rugged conditions with magnetically-dampened, wire-hung compensator for optimum range and accuracy, compensator lock to protect instrument during transport or storage, large effective aperture withal least 28x magnification and minimum focus of 0.4 m, top-mounted optical peep-sight for quick reference, large, easy-to-use precise focusing knob, Penta prism for easy bubble viewing, sealed, dust-protected leveling screws, water-resistant, sealed construction plus sunshade for use in various weather conditions, fine motion knobs on left and right sides with friction-braked rotation, endless horizontal drive, 1:100 stadia for distance estimation, 5/8" x 11 threads to fit standard tripods, manufacturers five year warranty.

Surveyors level to be complete with tripod, four (4) meter aluminum rod, hard-shell carrying case with dual latches, plumb bob, Allen wrench, adjusting pin, and instruction manual.

### *Field Tool Kits*

Basic tool kit with a range of tools to service and maintain the field instrumentation provided, including multi-meters. The tool kit is to include:

Minimum of 100-piece kit of combination wrenches in metric, adjustable wrenches, construction grade vice grips, a full range of construction grade drive sockets, a full range of construction grade screw drivers, a good selection of construction grade pliers, a construction grade hammer, a construction grade hacksaw, 25 m tape measure, and other needed tools with tool case.

Industrial Grade cordless power drill and impact driver with Li-on batteries and charger complete with carrying case, range of drill bits for wood and metal, a range of screwdriver bits, and a range of nut drivers.

Digital multi-meter and voltage tester combo kit includes heavy-duty alligator clips, industrial test probe set, silicone test leads, and tool storage box.

Heavy-duty 35-watt soldering iron and hot cover, a 10-18 AWG wire stripper, electrician's grade wire cutters, and a combo stripper/crimper for attaching wire terminals.

### 6.2.13 Data Schema

The proposed data schema for the regional monitoring network is summarized in Table 6-5.

**Table 6-5. Proposed data schema for regional monitoring network**

| Station Type | Data Parameters | Method | Frequency |
|---|---|---|---|
| **Hydrometric** | Water level | Staff Gauge | Daily |
| | | Radar | 10 minute |
| | | Pressure Transducer | 10 minute |
| | | Shaft Encoder | 10 minute |
| | Water Temperature | Pressure Transducer | 60 minutes |
| | Discharge | Mechanical Current Meter | Time of visit |
| | | ADCPs | Time of visit |
| | Sediment | Manual Depth integrated | Time of visit |
| | | Manual Grab sample | Daily |
| | Water Quality | Field kit – On site | Time of visit |
| | | Samples - Laboratory | Time of visit |
| | | | |
| **Met - AWS** | Wind Direction and Speed | Ultra Sonic sensor | 10 minute average and gusts |
| | Air Temperature | Sensor | 10 minutes |
| | Humidity | Sensor | 10 minutes |
| | Net Solar Radiation | Sensor | 10 minutes |
| | Barometric Pressure | Sensor | 10 minutes |
| | Rain - Accumulation | Auto weighting type gauge | 10 minutes |
| | Rain - Automatic | Tipping bucket type gauge | 10 minutes |
| | Rain - Manual | Manual rain gauge | Daily |
| | Evaporation | Calculated - Penman Monteith method | Daily |
| | | | |
| **Met - ARG** | Rain - Automatic | Tipping bucket type gauge | 10 minutes |
| | | | |
| **Groundwater** | Level | Pressure transducer | 60 minutes |
| | | Contact gauge | Time of visit |
| | Quality | Field Kit – On site | Time of Visit |
| | | Samples - Laboratory | Time of visit |

## 6.3 Design Criteria and Methodology

A key element of the system design is the layout of specific stations and measurement parameters in the monitoring network. These locations must respond to data requirements to address water resources management issues, which in turn support socio-economic objectives. The process for establishing monitoring locations includes several elements.

The primary impetus for the current effort to coordinate and subsequently invest in a regional network for the Nile Basin is the potential to realize specific benefits from transboundary data sharing and cooperation in water resource planning and management. It has also been widely noted that the regional network must be built on the successful operation of individual national networks, which in turn are justified based on the potential for the data obtained to provide national benefits from improved water resource planning and management. A key aspect of the network design, therefore, is to monitor water resources parameters at locations that will facilitate the realization of these benefits.

The first step in the network design, therefore, has been to identify locations of specific water resources management issues. These were clarified during both the Inception Workshop and country consultation visits and are thoroughly presented in Section 1. Major regional water management issues, including specific locations or river reaches of importance, have been identified in collaboration with NBI based on hydrologic significance and potential regional benefits. Additional feedback from NBI and country representatives on these regional issues was received during the Conceptual Design Workshop with a final list of issues presented in Table 4-2.

Second, required station locations for basic hydrologic monitoring of the basin were identified, including precipitation and streamflow monitoring based on hydrologic features of the basin and historical occurrence and variability of precipitation. Existing station locations in the respective countries were selected where possible. Stations with an extended period of record, superior monitoring equipment, and active operational status were preferred. A uniform spatial distribution of precipitation stations that satisfies network density, elevation distribution and rainfall variability was achieved. This resulted in defining the core hydrologic monitoring network.

Third, using the core hydrologic monitoring network as a foundation, location-specific water management issues were used to identify requirements for any additional monitoring locations and parameters required to properly inform those issues. These locations were identified on the developing map of the monitoring network. As the iterative process unfolded of identifying station locations to meet specific information needs, previously identified station locations in the proposed monitoring network were preferred. Where additional stations were required, impacts to the spatial and elevation distribution of the network were reviewed, with appropriate adjustments to the design. As much as possible, the purposes for each proposed station were noted in the meta-database for future reference. Elements of the final design thus respond to the specific water resource management issues and their location, and can be connected by category to those issues later for prioritization of network implementation in the third phase of this project.

### 6.3.1 Data Retrieval and Assessment

#### *Station Metadata*

Utilizing existing and established monitoring locations within the Nile Basin is a significant priority for the design. This allows for the regional monitoring to leverage past investments already implemented within countries and efficiently optimize the network to either expand or upgrade infrastructure depending on the needs. As such, it was important to retain station metadata with regards to locations, parameters, period of record, operational status, recording frequency, transmission, and any other pertinent information such as if the station is to be used in another regional network design (i.e. IGAD HYCOS).

The first set of metadata received came during the Launch Workshop. This allowed for Riverside to assess what was received (or not received) and make inquiries for additional information during the Inception Workshop and country consultations. The Conceptual Design workshop allowed for the countries to once again review the metadata received and assess whether the first draft of proposed stations for the network were appropriate and if supplemental metadata could enhance the design. Specific updates to the network design based on country feedback at the Conceptual Design workshop are provided in Appendix B. In addition to metadata received from countries, water quality monitoring and groundwater monitoring data sets were retrieved from past projects and reports.

A database has been developed which provides the country, agency, ID, name, latitude, longitude, altitude, parameters, start date, end date, status, recording frequency, equipment type, transmission, and any notable references related to expected upgrades or use in other projects. It should be noted that not all metadata fields listed have data provided from every country. In addition, several assumptions were necessary to standardize the database from the multiple formats received. One example being that when not explicitly defined the operational status of stations was assumed based on an end date.

### *Additional Data Sets*

Additional data sets are necessary in the design to provide context to the water management issues and existing station network. This includes shapefiles for rivers, lakes, roads, towns, basins, and country borders. A DEM for the entire Nile Basin was obtained for identifying station elevations and the area-elevation distribution for the network design. The DEM was also useful for creating or confirming basin boundaries and stream networks. Isohyetal and rainfall variability grids were used for assessing the precipitation network density based on rainfall distribution. This allows for visual inspection of where additional monitoring may be necessary to capture highly variable events.

### 6.3.2 Sub-Basin Selection

In order to monitor hydrologic characteristics on a regional scale, a network should be designed based on the natural delineation of sub-catchments that comprise the watershed. This involves recognizing the primary points of flow accumulation and assessing where a sub-division would provide benefit for analysis of flow contribution from different reaches. These points are often established based on existing hydrometric gauging locations or natural hydrologic endpoints such as an outlet to a lake or ocean.

Riverside utilized the 11 primary sub-basins presented in Figure 6-1. These sub-basins were altered to align with existing hydrometric station locations to be used in the design and sub-divided further to address water resource management needs. An example of additional subdivision involves the Lake Victoria basin which includes multiple smaller sub-basins that that require monitoring of several reaches to account for the total flow contribution to the lake. For reporting and graphical display these were subdivided to include the Kagera basin, Tanzania-Mara sub-basin, Kenya-Mara sub-basin, and Uganda sub-basin that contribute to Lake Victoria as demonstrated in Section 6.4.3.

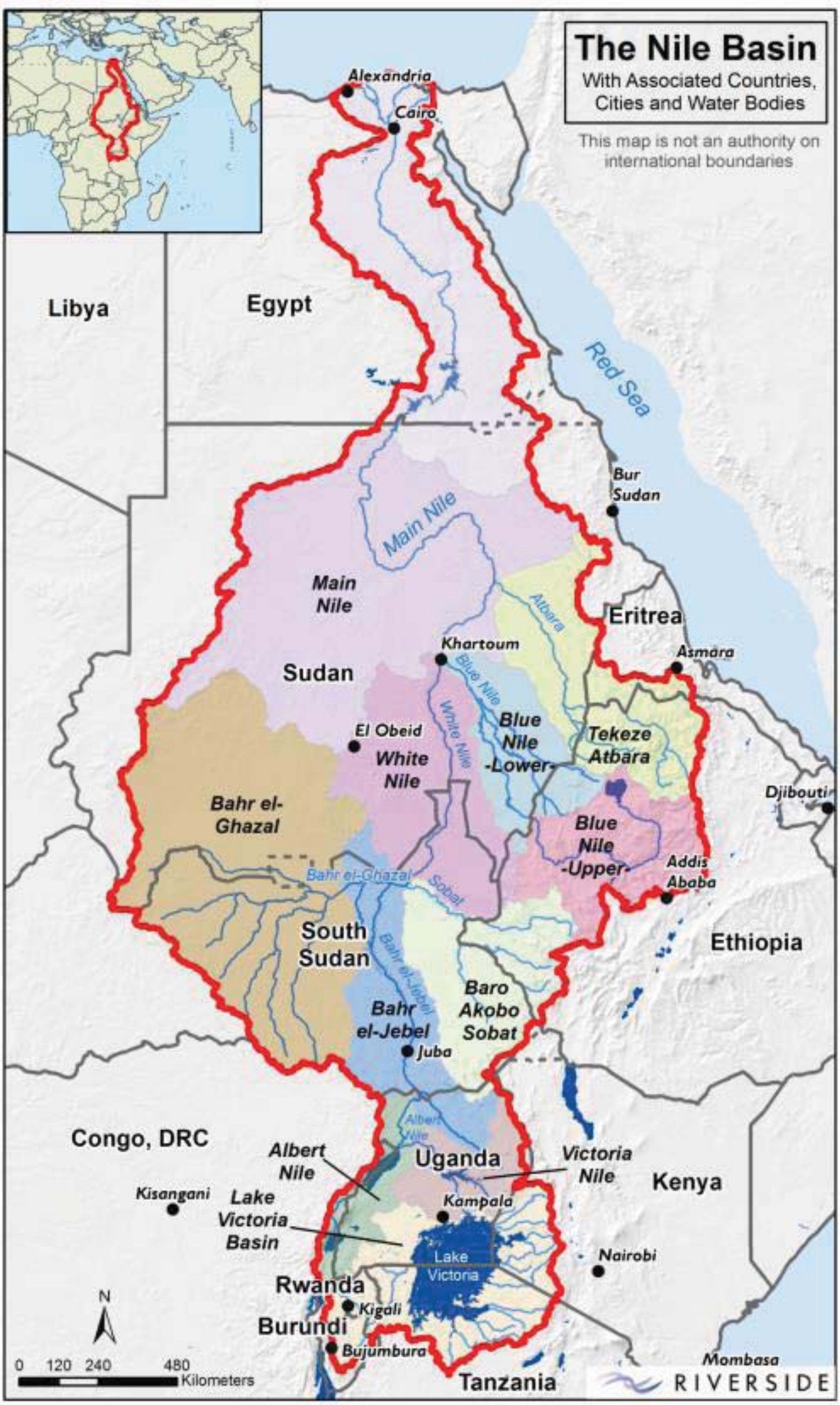


Figure 6-1. Primary Nile Sub-basins

### 6.3.3 Hydrometric Design Criteria

Hydrometric stations typically measure both streamflow and precipitation. However, in most instances the existing network indicated that the majority of locations only measured streamflow (via water level recording and corresponding rating curve). As such, it was assumed that the primary purpose of the existing hydrometric stations for the regional design would be for measuring streamflow at rivers and water level at lakes. In addition, the hydrometric design also includes where water quality and sediment monitoring should be implemented, which typically aligns with streamflow gauging locations.

WMO guidelines are often used as a starting point for assessing an existing hydro-meteorological network for water resources applications. Table 6-6 displays the minimum number of stations necessary for specific parameters for seven distinct physiographic zones.

**Table 6-6. WMO Recommended minimum densities of stations (area in KM$^2$ per station) (WMO-No. 168, 2008)**

| *Physiographic unit* | *Precipitation* | | *Evaporation* | *Streamflow* | *Sediments* | *Water quality* |
|---|---|---|---|---|---|---|
| | *Non-recording* | *Recording* | | | | |
| Coastal | 900 | 9 000 | 50 000 | 2 750 | 18 300 | 55 000 |
| Mountains | 250 | 2 500 | 50 000 | 1 000 | 6 700 | 20 000 |
| Interior plains | 575 | 5 750 | 5 000 | 1 875 | 12 500 | 37 500 |
| Hilly/undulating | 575 | 5 750 | 50 000 | 1 875 | 12 500 | 47 500 |
| Small islands | 25 | 250 | 50 000 | 300 | 2 000 | 6 000 |
| Urban areas | – | 10–20 | – | – | – | – |
| Polar/arid | 10 000 | 100 000 | 100 000 | 20 000 | 200 000 | 200 000 |

A limitation of the WMO standards is that they are based on the overall area of a physiographic region of interest as opposed to considering sub-basins of interest that make up the entire watershed. In addition, these standards cannot give an indication as to where these locations would provide the most benefit for monitoring and analysis based on hydrologic orientation or water resource management issue.

Water quality and sediment monitoring are being proposed at hydrometric stations that address regional issues as outlined in Table 4-2. The regional design proposes monitoring both basic and advanced water quality parameters. Basic parameters are being defined as temperature, pH, Conductivity, TDS, Dissolved oxygen, Turbidity, BOD, and Nutrients (N, P). Whereas advanced parameters include pesticides, heavy metals and hydrocarbons. The level of monitoring for each station is distinguished based on the need of the issue identified at the site. More detail on the water quality monitoring program is provided in Section 1 with specifics for parameters and equipment at each proposed water quality station provided in Appendix E. It is worth noting that sediment monitoring of suspended sediment load is being classified independently of water quality based on its importance for specific regional needs.

The Nile Basin hydrometric design will focus on achieving the monitoring of water management issues defined in the Section 1 through the following methodology:

1. Defining streamflow and lake level stations that provide regional monitoring of core hydrologic characteristics in the Nile Basin. These characteristics include simple water balance analyses of primary sub-catchments. An understanding of the basic hydrology at a regional scale has been the basis for the establishment of long standing historical stations and subsequent studies that result in overarching benefits.
2. Identify how the core hydrologic monitoring stations achieve regional and national benefits based on the defined water management issues. Supplement the design to fill gaps for

regional monitoring issues which includes defining locations with water quality and sediment monitoring needs.

3. Review and revise stations based on internal and external discussion with regards to how the design achieves the objectives of the study.

Within the design meta-database, the benefits and purpose for each proposed station are noted with regards to regional monitoring benefits and national benefits based on the defined water management issues. This tracking allows for a future scoring system to be established for prioritization and implementation. A write-up on the overview of the hydrometric network design is provided in Section 6.4.1 with specifics for each sub-basin provided in Sections 6.4.3 through 6.4.13. A table of all 79 proposed hydrometric stations is provided in Appendix C.

### 6.3.4 Meteorological Design Criteria

The meteorological network design differs from the hydrometric in the sense that the specific location of monitoring is of less significance compared with a good spatial distribution that will capture the meteorological variability necessary for hydrologic monitoring.

As is done with the hydrometric station network, the WMO guidelines defined in Table 6-6 are first reviewed. These represent initial guidelines for national climatic networks. The regional network for the Nile Basin should support basic hydrologic monitoring for water management, and should therefore address the required network density specifically for the size of individual catchments of interest. A useful station-to-area relationship for detecting and quantifying precipitation for a catchment of a given size is presented as Equation 6-1 (Schaake, 1981).

**Equation 6-1**

$$N = (0.8) \times \left(\frac{A}{2.59}\right)^{0.3}$$

Where *N* equals the number of rain gauges and *A* equals the catchment area in square kilometers. Unlike the WMO guidelines, which defines the number of gauges necessary based on a fixed area, Equation 6-1 defines the number based on the catchment area to be analyzed. It is worth noting that Equation 6-1 represents an idealized network density which is often unachievable due to costs. On the other hand, the total catchment area of sub-basins presented may be sub-divided further by the need for additional hydrometric monitoring beyond the outlet. This would result in Equation 6-1 underestimating the monitoring necessary as the number of catchments would technically increase. As a result, Riverside utilized the number of stations calculated from Equation 6-1 as an initial reference but further assessed density needs for precipitation monitoring based on isohyetal and rainfall variability grids as further described below.

Precipitation is the primary meteorological parameter for not only general hydrologic monitoring but also for achieving the monitoring needs of the defined water resource management issues (Table 6-1). However, additional meteorological parameters also provide some benefit to specific water management issues and their density requirements also necessitate consideration. As is demonstrated in Table 6-6 the density requirements for evaporation parameters are significantly less for most physiographic regions. This is primarily a result of less spatial and temporal variability for these parameters compared with rainfall. As is further explained below, the scoring system used for selecting stations will naturally favor those that monitor multiple meteorological parameters, but a secondary check is conducted after establishing the precipitation needs to ensure that an adequate number of proposed stations monitor other meteorological parameters in the sub-basin. Any proposed station that currently monitors all meteorological parameters is proposed to continue with automation upgrades where necessary. Additional full meteorological upgrades were proposed at stations that currently just monitor precipitation in order to achieve the WMO guidelines for evaporation outlined in Table 6-6.

As noted previously, the primary drivers of the design included meeting the necessary density for hydrologic monitoring but this also includes distributing the stations both spatially and with regards to elevation to capture orographic effects. The spatial distribution involved simply looking at the available network of stations on a map and visually selecting meteorological stations that resulted in an even distribution, using the number estimated from Equation 6-1. For some countries the number of available stations far exceeds the amount necessary for monitoring hydrology at the sub-basin scale. As a result, a scoring system within the database was established to give a higher rank to higher quality stations as presented in Table 6-7. A total score was given based on each field and then the higher quality stations could be filtered and viewed spatially for selection within ArcGIS.

**Table 6-7. Scoring for selection prioritization of meteorological stations**

| Field | Score of 1 | Score of 0 |
|---|---|---|
| **Status 1*** | Active | Inactive, New, Proposed, (blank) |
| **Status 2*** | op | (blank) |
| **Parameters** | Full Met, (R, T, RH, W, etc.) | Rainfall, or Rainfall & T |
| **Recording Frequency** | Sub Daily | Daily |
| **Equipment** | AWS, Agromet, Synoptic, Logging | Manual, Manual RG |
| **Transmission** | Automatic | Manual |
| **Other** | Other Network Design, Notable Upgrade, Notable remark on Importance | |

**Status 1 is sometimes implicitly defined based on period of record ending date where Status 2 is explicitly defined as operational if ending date was used for Status 1.*

After the initial spatial selection and scoring prioritization from Table 6-7 is complete, the elevation distribution within the sub-basin is checked. Distributing the stations based on elevation was important to ensure that orographic variation in precipitation would be properly represented by the network. This involved developing an area-elevation curve for the sub-basin and then plotting the stations on the curve at their respective elevations to assist in visualizing the resulting elevation distribution. This is an iterative process involving defining stations spatially and then ensuring the elevation distribution was also adequate. The elevation distribution of the proposed network in each basin is presented, beginning with the curve for the Kagera basin shown in Figure 6-9 on page 120. Note that colors are used to define *Active* (green), *Inactive* (yellow), and *New* (red) for proposed stations while grayed stations represent those not proposed but included in the database. Both the maps and area-elevation plots utilize this color scheme.

The last check in the meteorological network design is overlaying the proposed network on top of the annual rainfall depth and variability grids to ensure no significant gaps in coverage exist. In order to estimate the rainfall variability, 15 years (2000-2014) of average monthly ¼° x ¼° Global Land Data Assimilation System (GLDAS, Rodell et al., 2004) precipitation data was used to analyze the spatial coherence structure across the Nile basin. GLDAS precipitation data is derived from a blend of satellite, gauge, and model-based precipitation estimates. Satellite precipitation estimates are most accurate in areas with strong convection and cold cloud top temperatures.

Figure 6-2 shows the average annual precipitation in mm on the left and the average monthly precipitation time series spatial correlation on the right. The spatial correlation gridded map is based on comparing each grid point's precipitation time series with the surrounding 24 grids. With a grid size of roughly 25 x 25 km, this represents a spatial correlation distance of about 75 km around each grid point. Higher spatial correlations indicate areas that have less precipitation variability, and therefore require a relatively less dense network to quantify measurements spatially. Areas with less spatial correlation have more variability, requiring larger relative measurement densities to quantify precipitation.

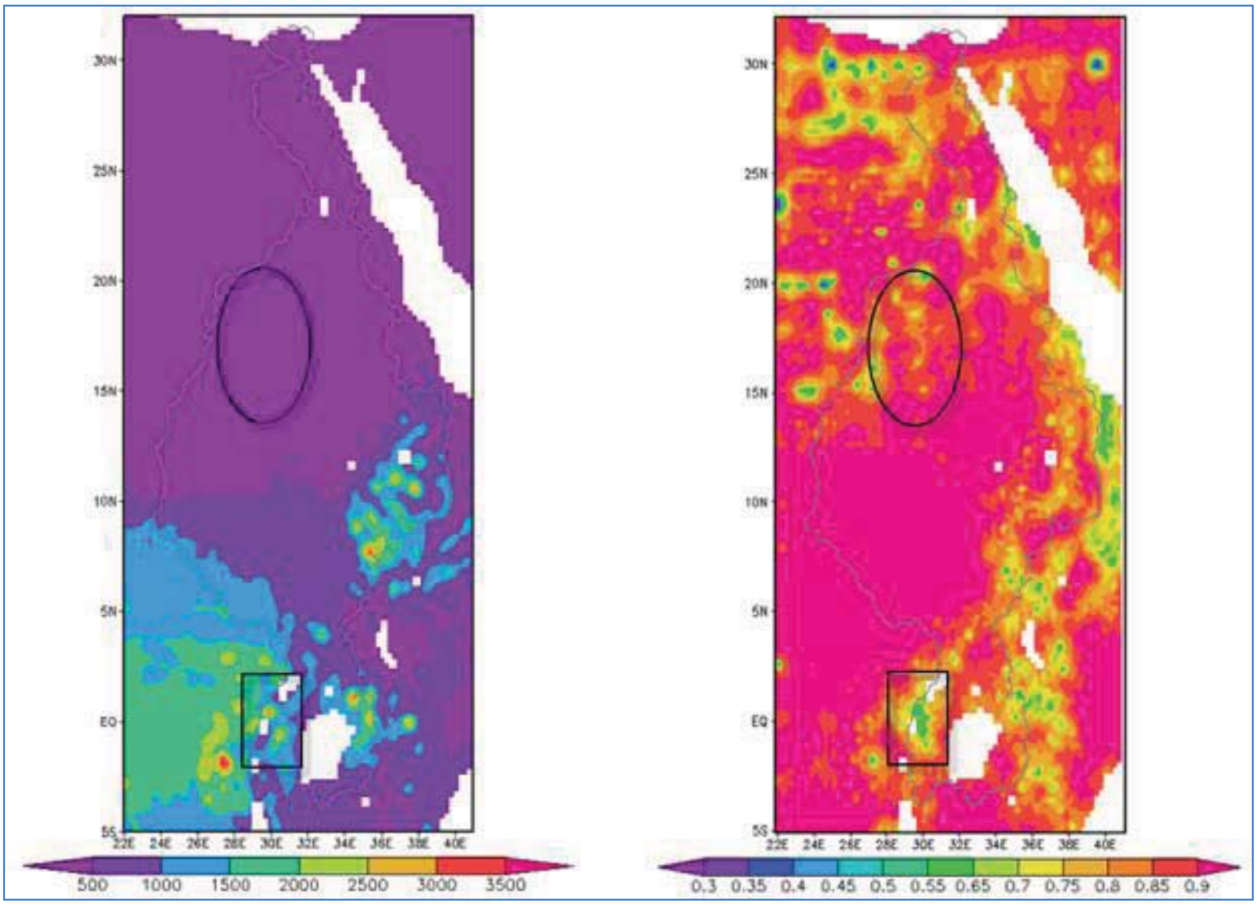


**Figure 6-2. Average annual precipitation in mm (left) and 75 km spatial correlation of precipitation time series (right) for Nile Basin derived from NASA-GLDAS**

In general, areas with larger precipitation amounts also have less spatial structure. However, there are several regions that do not follow this general pattern which is why both gridded maps were utilized in the analysis. For example, the southwestern portion of the basin outlined by a rectangle demonstrates a region with both high annual rainfall and high rainfall variability requiring a more dense station network along the Lake Edward and Albert regions. However, the area outlined in the northwest of the basin shows high rainfall variability but almost no annual precipitation as result of being located in the southern Sahara desert. In this instance a dense network to capture this variability would not be justified due to the minimal precipitation that could be recorded. These are two basic examples that demonstrate how the annual rainfall and variability grids were utilized as a final step in assessing the network density for each sub-basin.

The general methodology for defining the meteorological network is an iterative process that is summarized by the following steps:

1. Assess general number of stations necessary for hydrologic monitoring dependent on the basin area to analyze.
2. Spatially distribute approximate number of proposed stations based on (1) utilizing scoring prioritization to identify the highest quality stations for use.
3. Plot initial proposed set of stations on area-elevation curves to ensure a proper elevation distribution exists.

4. Overlay proposed design onto isohyetal and rainfall variability grids to further assess network density and any gaps in coverage.
5. Check that the density of stations measuring meteorological parameters beyond precipitation is sufficient for regional monitoring.
6. Review and revise stations based on internal and external discussion with regards to how the design achieves the objectives of the study.

This overall meteorological design methodology is a highly iterative process. Unlike the hydrometric network, meteorological benefits to monitoring the water management issues are more spatially encompassing as opposed to site specific. The prioritization for implementation will be based on the scoring system already established in Table 6-7. A write-up on the overview of the meteorological network design is provided in Section 6.4.2 with specifics for each sub-basin provided in Sections 6.4.3 through 6.4.13. A table of all 323 proposed meteorological stations is provided in Appendix D.

### 6.3.5 Groundwater Considerations

Groundwater throughout the Nile Basin is used for a variety of purposes but its most common use is for drinking water supply for rural and urban communities (NBI, BMZ, and GIZ 2012). Monitoring of groundwater sources is important to assess over-abstraction, which can lead to draw down of the groundwater table or reduction in surface water sources (reduced river base flow, drying up of springs, and depletion of aquifers). Groundwater quality is also an important consideration and monitoring is necessary to assess the impact of pollution sources (urban, industrial, mining, agricultural, etc.) for groundwater uses.

Abiye and Mmayi provide an overview of groundwater conditions and the underlying geology that defines the groundwater setting of the basin (Abiye, T. A. and Mmayi, P. 2014). Groundwater is of definite regional significance in the Nile Basin. It appears, however, that groundwater monitoring programs are not mature or widespread in the basin and that there is a need for preliminary activity to lay the groundwork for the establishment of groundwater monitoring and assessment programs at national and regional levels.

Before establishing a regional groundwater monitoring network, an assessment of the transboundary implications must first be understood. Attributes of groundwater systems that require transboundary analysis, defined by Scheumann and Alker, include: (Scheumann, W. & Alker, M., 2009):

- Geographical location of one riparian state in relation to another;
- Location of transboundary aquifer in relation to national border(s);
- Recharge, flow and discharge of groundwater in relation to the national border(s);
- Possible hydraulic links between aquifers and surface water bodies; and
- Whether or not aquifers are confined

These attributes can then be applied to situational challenges to depict transboundary implications (Eckstein, Y. and Eckstein G.E., 2005):

A. Unconfined aquifer hydraulically linked to a river, both of which flow along an international border formed by the river.
B. Unconfined aquifer intersected by an international border and linked hydraulically to a river intersected by the same international border.
C. Unconfined aquifer flowing across an international border and hydraulically linked to a river totally located in the territory of one State. Transboundary implications rely on distribution of the hydraulic potential within the aquifer.
D. Unconfined aquifer entirely in one state but connected hydraulically to an international river flowing from another state.
E. Confined transboundary aquifer that is only linked hydraulically to one state.
F. Any transboundary aquifer that is not linked to the hydrologic cycle and can therefore not be recharged naturally (fossil aquifer).

In order to assess the noted transboundary implications and to develop a regional groundwater monitoring network, initial baseline data must be obtained. This includes mapping of groundwater aquifers, assessing aquifer properties from well and pumping tests, and gathering water use inventories and population data. Also required are supporting data such as hydrological and meteorological observations, geological maps, and satellite land-use surveys to assess the hydraulic connectivity with surface water.

Much of this information is unavailable at the country level. However, hydrologic and meteorological data produced from the proposed regional network will support the assessment of the groundwater resource and assist in identifying monitoring needs. At the time of preparing this report, there are only two countries with ongoing groundwater monitoring stations (Uganda and Kenya), which limits the available data, infrastructure, and institutional knowledge to draw from for a regional network design.

Groundwater monitoring was initially stated as a priority for the regional design during the Launch Workshop in Addis Ababa, Ethiopia May 12-14, 2014. However, after conducting country consultations and field visits, groundwater monitoring has only been noted as a national priority for a few countries. As a consequence, the demand for groundwater monitoring at a regional scale is unclear. The majority of interest in groundwater is on abstraction monitoring to support irrigation projects and community water supply. There is some interest in groundwater quality for site-specific areas. It is noted that none of the 13 primary regional issues outlined in Table 3-1 identify groundwater monitoring as being critical.

Furthermore regional/transboundary groundwater monitoring priorities and benefits are not clearly defined due to a lack of supporting data to establish needs.

It is suggested that national groundwater assessments can help identify transboundary concerns. These national assessments will involve the collection of baseline data associated with aquifer properties from well records, pumping tests, water use inventories, and population statistics.

Based on the above discussion it is recommended that a regional groundwater assessment be conducted as a prerequisite to the preparation of a regional groundwater network design.

While there appears to be a higher priority for establishing a regional hydrometric and meteorological network, data from these proposed networks will support the development of a regional groundwater design through analysis of hydraulic connectivity with surface water.

Although a detailed regional groundwater design is not proposed at this time, it is recommended that the Nile countries begin to establish capacity in groundwater monitoring. As such, it is proposed that each country not currently conducting groundwater monitoring be provided with at least one monitoring well to be located at a site of national interest with ease of access. This approach will build experience and encourage capacity development in the conduct of groundwater level and quality monitoring and assessment within each Nile Basin country. It will also establish a basic foundation for design and implementation of a regional/transboundary groundwater monitoring network when the requisite data are available and the demand for such data at a regional level becomes more evident.

## 6.4 Hydro-Meteorological Network Design

The following section presents the hydro-meteorological design for the Nile Basin. This begins with an overview of the hydrometric and meteorological network designs in Sections 6.4.1 and 6.4.2 and is then followed by a detailed discussion of the design for each of the 11 primary sub-basins in Sections 6.4.3 through 6.4.13. Each sub-basin section presents the following:

- brief summary of the sub-basin orientation and hydrology
- map of the proposed regional hydro-meteorological network in the sub-basin area
- hydrometric design discussion for sub-basin

- table of proposed hydrometric stations for associated sub-basin
- meteorological design discussion for sub-basin
- area-elevation distribution curve for proposed network in sub-basin
- table of proposed meteorological stations for associated sub-basin

Supplemental information related to the hydro-meteorological network design can be found in the following Appendices:

- Appendix B - Station Location and Parameter Updates from Workshop Feedback
- Appendix C - Table of All Proposed Hydrometric Stations
- Appendix D - Table of All Proposed Meteorological Stations
- Appendix E - Water Quality Station Specifications for Parameters and Equipment

### 6.4.1 Hydrometric Network Design Overview

A total of 79 hydrometric stations are proposed for the regional network of the Nile Basin. The design is driven by the need to capture the core hydrologic characteristics of the Nile Basin as well as provide monitoring of the regional issues outlined in Table 4-2 of Section 4.15. In addition to these two main objectives, the design also provides national monitoring benefits to respective countries and seeks to leverage existing operational locations or sites with historical monitoring significance.

The symbology used for the hydrometric network in the following sub-basin maps is shown in

Figure 6-3. Note that hydrometric stations to include sediment monitoring, water quality monitoring, or both sediment and water quality monitoring are defined by smaller triangles within the larger green (active), yellow (inactive), and red (new) triangles that define the status of the proposed stations. Stations in grey are part of current or past national monitoring networks but are not proposed for the regional design.

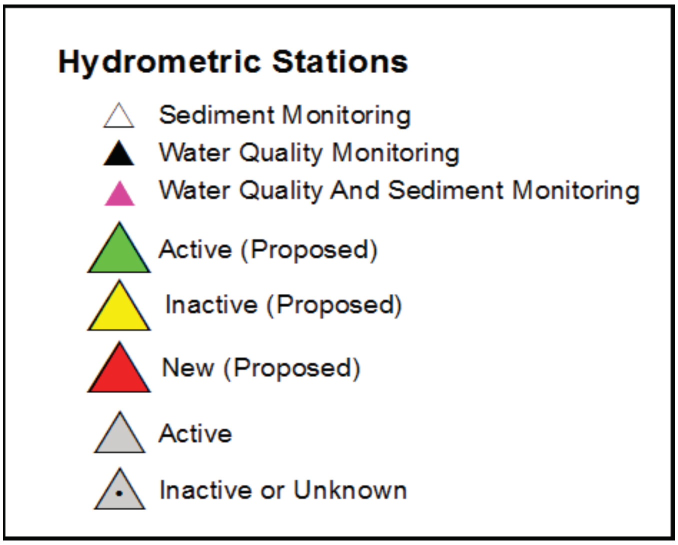


Figure 6-3. Hydrometric network symbology

Figure 6-4 shows the complete hydrometric monitoring network and associated sub-basins for the entire Nile Basin. Note that only the proposed stations and their existing status are shown in Figure 6-4 while more detail is provided in the sub-basin maps in the following sections. As can be seen from Figure 6-4 the design leverages the existing operational network within the countries as the majority of proposed sites are active (green).

The following sections that describe the network by sub-basin provide tables displaying proposed station attributes. Explanation and abbreviations for identifiers in the hydrometric network tables are as follows:

- **Regional ID –** *3 letter Country Abbreviation_3 digit regional ID number_Hyd (for hydrometric)*
- **Name** – As defined by metadata received from countries
- **Lat** – Latitude coordinates in decimal degrees
- **Long –** Longitude coordinates in decimal degrees
- **Status –** *Active, Inactive, New*
- **Parameters –** *WL (Water Level), D (Discharge), WQ (Water Quality), S (Sediment)*
- **Eq (Equipment) –** *Rad (Water Level Radar), PS (Pressure Sensor), SE (Shaft Encoder)*
- **Tel (Telemetry) –** *GPRS (GSM/GPRS cellular telemetry), Sat (Satellite telemetry via EUMETSAT)*

The Regional ID was developed as a way to easily identify a station for the regional network and know the associated country in a single field. This compliments the national identifiers provided by the countries which are included in the complete meta-database. The Name, Lat, Long, and Status are fields that were all provided by the countries with the exception of where assumptions were made for Inactive status when no indication was provided. The Parameters, Equipment, and Telemetry fields are the proposed properties to be included at the associated site and may or may not be correlated with the current conditions of the station. The Parameters to be measured are explained in the discussion for each sub-basin section.

The proposed Equipment is based first on whether the site was reported to have the existing equipment installed. The design proposes water level radars for any suitable rivers with bridge crossings, pressure sensors for any other locations, and shaft encoders with floats where this technology is currently installed and working. See Section 6.2.1 for further specifications on these technologies.

For Telemetry the primary technology proposed is satellite utilizing EUMETSAT. However, stations that are already using or planning to have upgrades in the near future with GPRS are proposed to continue with cellular transmission. See Section 6.2.5 for further specification on these technologies.

A complete table of all hydrometric stations within the proposed Nile Basin design can be found in Appendix C.

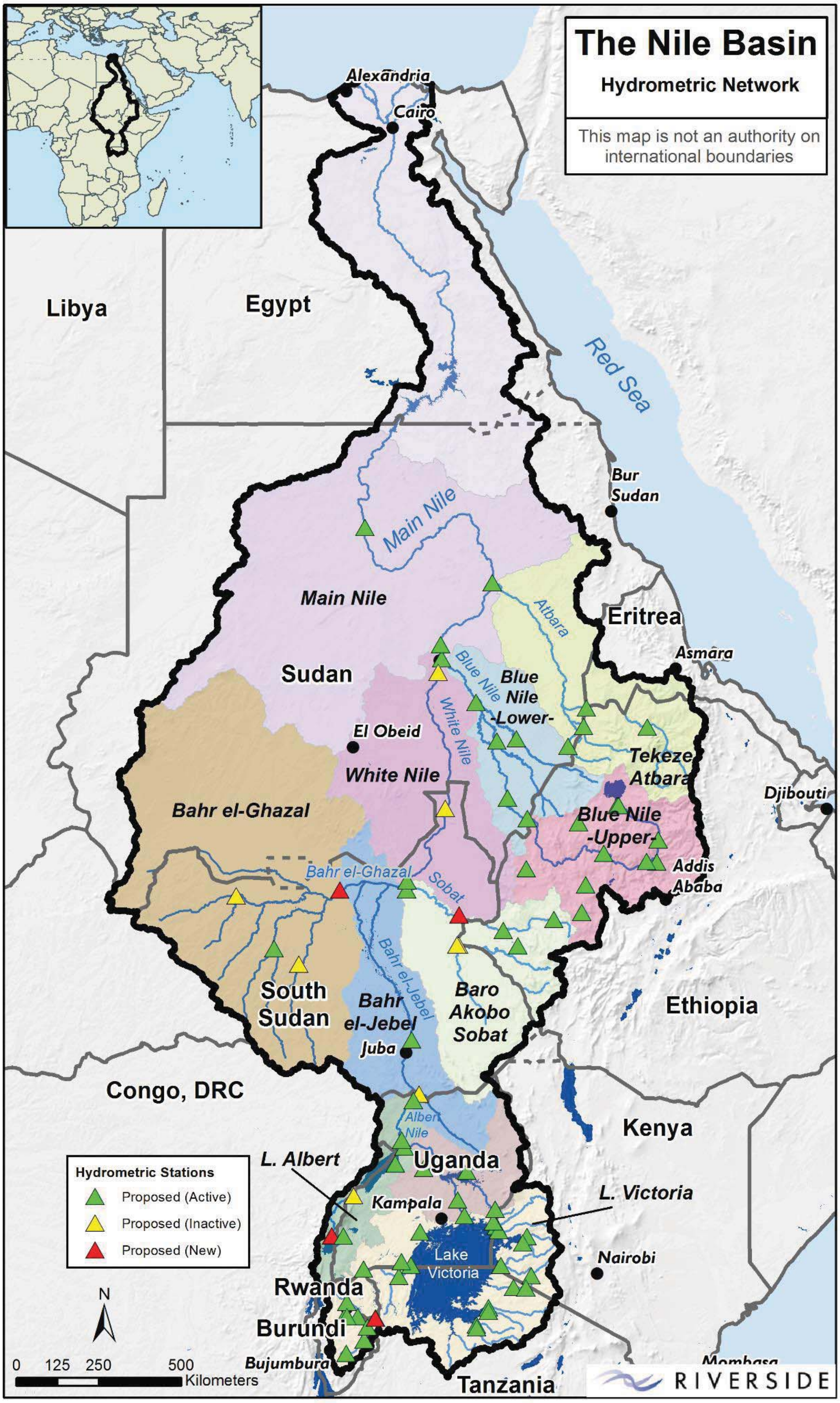


**Figure 6-4. Proposed hydrometric network map**

Table 6-8 provides a summary of the number of hydrometric stations proposed in the regional design by sub-basin and associated area. These are listed in hydrologic order and provide a summary of the total upstream area and number of stations for non-headwater basins. Note that the area for the Main Nile (sub-basin and total) only extends to Lake Nubia/Nasser.

**Table 6-8. Summary of regional hydrometric network by sub-basins**

| Sub-Basin | Sub-Basin Area ($KM^2$) | Regional Gauges in Sub-Basin | Total Upstream Area ($KM^2$) | Regional Gauges in Total Upstream Area |
|---|---|---|---|---|
| Lake Victoria - Kagera | 197,181 | 12 | - | - |
| Lake Victoria - Kenya | 49,737 | 6 | - | - |
| Lake Victoria - Tanzania | 71,305 | 6 | - | - |
| Lake Victoria - Uganda | 27,660 | 3 | - | - |
| Victoria Nile | 85,521 | 6 | 431,404 | 33 |
| Lake Albert | 74,819 | 5 | 506,223 | 38 |
| Bahr el Jebel | 185,364 | 5 | 691,587 | 43 |
| Bahr el Ghazal | 604,746 | 3 | - | - |
| Baro Akobbo Sobat | 204,288 | 7 | - | - |
| White Nile | 258,803 | 2 | 1,759,424 | 55 |
| Blue Nile - Upper | 175,374 | 10 | - | - |
| Blue Nile - Lower | 132,344 | 6 | 307,718 | 16 |
| Tekeze Atbara | 232,374 | 5 | - | - |
| *Main Nile | 592,637 | 3 | 2,892,153 | 79 |

**Main Nile basin areas only extend to Lake Nubia/Nasser*

Table 6-9 provides a summary of the number of proposed stations by country. This includes the number of stations in each status category (active, inactive and new), as well as the number of stations that are specified to include water quality or sediment monitoring.

**Table 6-9. Summary of proposed regional hydrometric network by country**

| | Proposed Regional Hydrometric Network | | | | | |
|---|---|---|---|---|---|---|
| Country | Active | Inactive* | New | Total | # of Stations w/ WQ | # of Stations w/ Sediment |
| Burundi | 2 | 0 | 0 | 2 | 1 | 2 |
| DRC | 0 | 0 | 1 | 1 | 1 | 0 |
| Ethiopia | 15 | 0 | 0 | 15 | 4 | 14 |
| Kenya | 6 | 0 | 0 | 6 | 6 | 1 |
| Rwanda | 6 | 0 | 1 | 7 | 6 | 5 |
| South Sudan | 4 | 6 | 2 | 12 | 5 | 2 |
| Sudan | 12 | 1 | 0 | 13 | 9 | 12 |
| Tanzania | 8 | 0 | 0 | 8 | 8 | 6 |
| Uganda | 14 | 1 | 0 | 15 | 12 | 1 |
| **Total** | **67** | **8** | **4** | **79** | **52** | **43** |
| **% of Total** | **85%** | **10%** | **5%** | **100%** | **66%** | **55%** |

**Inactive Stations also include unknown or "blank" status entries originally received*

### 6.4.2 Meteorological Network Design Overview

A total of 322 meteorological stations are proposed for the regional network of the Nile Basin. This includes 227 stations to measure a full suite of meteorological parameters and 95 to monitor rainfall only. The full meteorological (Full Met) stations include instruments to measure precipitation, wind, air temperature, humidity, barometric pressure and solar radiation which allows for the calculation of evaporation (more detail explained in Section 6.2.2).

The meteorological network design was driven by the spatial distribution necessary to capture the meteorological variability within the basin. This involved utilizing a sub-basin to station relationship defined in Equation 6-1; selecting stations spatially based on a scoring criteria defined from operational status and equipment; plotting proposed stations along area-elevation curves to ensure adequate elevation distribution; and checking and refining the proposed network based on annual rainfall depth and rainfall variability grids. The details of the aforementioned steps are more thoroughly covered in Section 6.3.4.

The symbology used for the meteorological network is shown in Figure 6-5. Stations proposed to include full meteorological monitoring are noted with a cross while those monitoring only rainfall are open. The status of the proposed station is defined by the same color scheme as the hydrometric stations: green (active), yellow (inactive), and red (new). Those stations not proposed for the regional network are defined in gray with those that are inactive having a dot in the center.

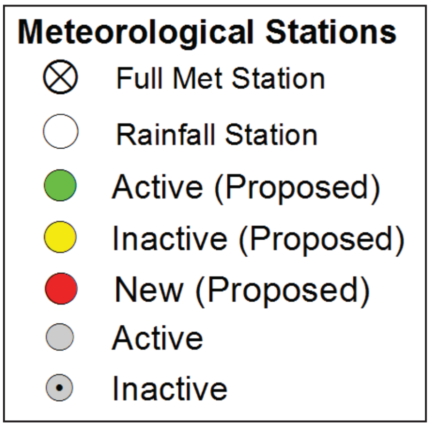


Figure 6-5. Meteorological station symbology

The rain gauge to sub-basin area relationship developed by Schaake and defined in Equation 6-1 was used as a starting point for assessing the number of meteorological stations to include for each sub-basin. These values were then modified based on the subsequent design steps previously outlined with a heavy emphasis on assessing the regional rainfall variability. Table 6-10 provides a comparison of the calculated number of rainfall gauges for each sub-basin based on the WMO, Schaake equation and the actual number in the design.

Table 6-10. Meteorological stations per sub-basin area for WMO, Schaake, and Design

| Sub-Basin | Area (KM$^2$) | WMO | Schaake Equation 6-1 | Regional Design |
|---|---|---|---|---|
| Lake Victoria - Kagera | 197,181 | 34 | 23 | 30 |
| Lake Victoria - Kenya/Mara | 49,737 | 9 | 15 | 31 |
| Lake Victoria - Tanzania/Mara | 71,305 | 12 | 17 | 22 |
| Lake Victoria - Uganda | 27,660 | 5 | 13 | 13 |
| Victoria Nile | 85,521 | 15 | 18 | 28 |
| Lake Albert | 74,819 | 13 | 17 | 28 |
| Bahr el-Jebel | 185,364 | 32 | 23 | 14 |
| Bahr el-Ghazal | 604,746 | 105 | 33 | 23 |
| Baro Akobo Sobat | 204,288 | 36 | 24 | 17 |
| White Nile | 258,803 | 45 | 25 | 17 |
| Blue Nile - Upper | 175,374 | 30 | 23 | 41 |
| Blue Nile - Lower | 132,344 | 23 | 21 | 13 |
| Tekeze Atbara | 232,374 | 40 | 24 | 35 |
| Main Nile | 592,637 | 103 | 32 | 10 |
| | **Total** | **503** | **309** | **322** |

When comparing the values in Table 6-10 there are some stark differences between the calculated WMO values (utilized density of one station per 5,750 $km^2$) versus those from the Schaake Equation 6-1. The most noticeable differences are for the Bahr el-Ghazal sub-basin with 105 WMO stations versus 33 from Schaake, and the Main Nile sub-basin with 103 WMO, versus 32 for Schaake. The difference here is related to the Schaake equation requiring a smaller density for a larger area rather than the linear relationship established by the WMO guideline. Conversely when comparing the smallest sub basin area of the Ugandan Lake Victoria basin the number of Schaake stations at 13 is more than double the number of WMO at 5, again due to the exponential rather than linear relationship between basin area and number of stations.

It is also worth noting from Table 6-10 that there are instances where the number of stations for the design is less or more than the number calculated from Schaake Equation 6-1. This is a result of sub-basins having greater or lesser orographic effects, rainfall depth, and/or rainfall variability. An example of the design having more stations than those calculated from Equation 6-1 is for the Lake Albert sub-basin with 28 versus 17. This is due to the Lake Albert sub-basin having a high level of both rainfall depth and rainfall variability requiring a denser network to capture the spatial variability. This is demonstrated in Figure 6-6 and Figure 6-7 which show the annual rainfall depth and variability for the entire Nile basin along with the proposed meteorological network. When viewing these maps it should be clear why sub-basins like Lake Albert and the Upper Blue Nile have greater station densities while sub-basins like the Bahr el-Ghazal and Main Nile have lower station densities. Further explanation for the design of each sub-basin is provided in the following sections and often makes reference to Figure 6-6 and Figure 6-7.

The following sections that describe the network by sub-basin provide tables displaying proposed station attributes. Explanation and abbreviations for identifiers in the meteorological network tables are as follows:

- **Regional ID –** *3 letter Country Abbreviation_3 digit regional ID number_Met*
- **Name** – As defined by metadata received from countries
- **Lat** – Latitude coordinates in decimal degrees
- **Long –** Longitude coordinates in decimal degrees
- **Status –** *Active, Inactive, New*
- **Parameters –** *Full Met (precipitation, wind, temperature, humidity, barometric pressure, solar radiation), Rainfall (precipitation only)*
- **Eq (Equipment) –** *AWS (Automatic Weather Station), ARG (Automatic Rain Gauge)*
- **Tel (Telemetry) –** *GPRS (GSM/GPRS cellular telemetry), Sat (Satellite telemetry via EUMETSAT)*

The Regional ID was developed as a way to easily identify a station for the regional network and know the associated country in a single field. This compliments the national identifiers provided by the countries which are included in the complete meta-database. The Name, Lat, Long, and Status are fields that were all provided by the countries with the exception of where assumptions were made for Inactive status when no indication was provided. The Parameters, Equipment, and Telemetry fields are the proposed properties to be included at the associated site and may or may not be correlated with the current conditions of the station.

Stations to have Full Met parameters were assigned to sites that already had these existing at proposed locations. In most cases these were manual synoptic-like stations and a proposed AWS is recommended to compliment the current equipment. There were nine stations between South Sudan and Sudan that were proposed to be upgraded to Full Met from existing rainfall only in order to achieve WMO guidelines for evaporation monitoring on one station per 50,000 $km^2$ (Table 6-6). There was also an additional nine stations proposed for Full Met upgrades at locations along major lakes in order to evaluate evaporation. All other stations not defined as Full Met were proposed to monitor just rainfall to achieve the necessary spatial variability previously described.

For equipment, all Full Met stations were proposed to have AWS's while Rainfall stations utilize ARG's. See Section 6.2.2 for further specifications on sensor technologies. Similar to the hydrometric stations, the primary technology proposed for telemetry is satellite utilizing EUMETSAT but any existing stations that currently use GPRS are proposed to continue with cellular telemetry. See Section 6.2.5 for further specification on telemetry technologies.

A complete table of all meteorological stations within the proposed Nile Basin design can be found in Appendix D.

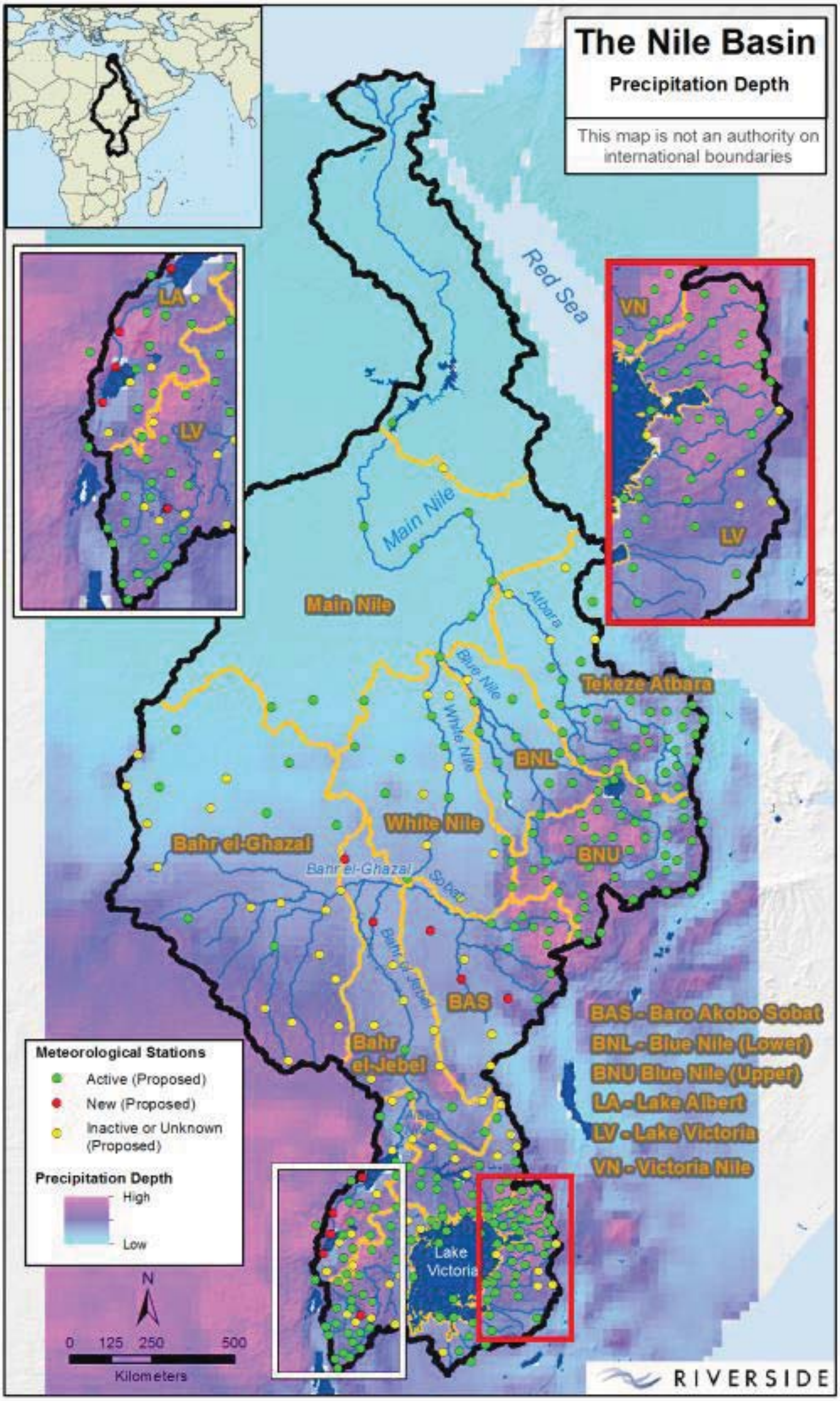


Figure 6-6. Annual rainfall depth and proposed meteorological network for the Nile Basin

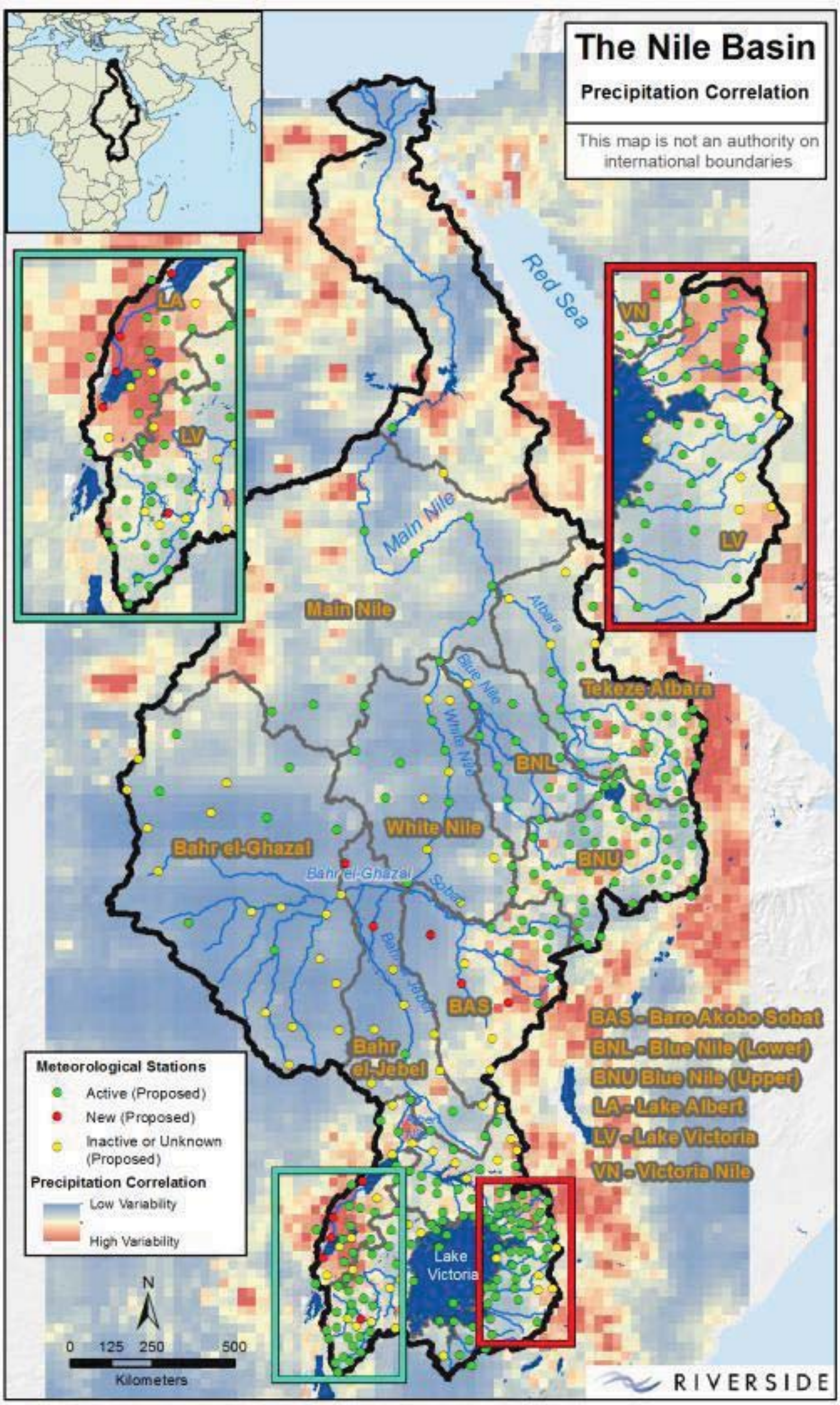


Figure 6-7. Rainfall variability and proposed meteorological network for the Nile Basin

Table 6-11 provides a summary of the number of proposed meteorological stations by country. This includes the number of stations in each status category (active, inactive and new), as well as the number of Full Met versus Rainfall only stations being proposed.

Table 6-11. Summary of proposed meteorological network by country

| | Proposed Meteorological Network | | | | | |
|---|---|---|---|---|---|---|
| Country | Active | Inactive* | New | Total | # of Stations w/ | |
| | | | | | Full Met | Rain Only |
| Burundi | 9 | 1 | 1 | 11 | 10 | 1 |
| DRC | 3 | 2 | 4 | 9 | 7 | 2 |
| Ethiopia | 82 | 1 | 0 | 83 | 74 | 9 |
| Kenya | 28 | 5 | 0 | 33 | 21 | 12 |
| Rwanda | 10 | 1 | 0 | 11 | 11 | 0 |
| South Sudan | 5 | 22 | 5 | 32 | 18 | 14 |
| Sudan | 33 | 18 | 0 | 51 | 29 | 22 |
| Tanzania | 21 | 6 | 0 | 27 | 22 | 5 |
| Uganda | 48 | 17 | 0 | 65 | 35 | 30 |
| **Total** | **239** | **73** | **10** | **322** | **227** | **95** |
| **% of Total** | **74%** | **23%** | **3%** | **100%** | **70%** | **30%** |

**Inactive Stations also include unknown or "blank" status entries originally received*

### 6.4.3 Lake Victoria

When considering the complete watershed of Lake Victoria, about 195,200 km$^2$ (74%) consists of land while 68,800 km$^2$ (26%) is made up of the lake's water surface area. This is a relatively large fraction of area that will receive direct precipitation but is even greater when considering that only a percentage of overland precipitation will actually reach the lake. It has been estimated that on average 85% of the lake input is a result of direct precipitation (Sutcliffe, J.V. & Parks, Y.P., 1999). As a result, it is important to consider meteorological stations that would help monitor the direct precipitation to the lake. This will include the need for stations located within the lake itself based on following excerpt from *The Hydrology of the Nile* (Sutcliffe, J.V. & Parks, Y.P., 1999):

> *The problem of the estimation is complicated because evidence from the timing of rainfall on different shores supported by rainfall observations from island stations, suggest that rainfall over the lake itself is higher than at the lakeside stations…The impact of the lake has been illustrated by measurement of rainfall near its centre, which indicated rainfall some 30% higher than observed at any lakeshore station.*

Although this network design does not include the use of weather radar stations, these can be powerful instruments for assessing direct precipitation to areas difficult to monitor such as Lake Victoria. It should be noted that Tanzania is in the process of establishing a weather radar station in Mwanza that could provide significant monitoring coverage for rainfall over Lake Victoria. Further information is available in the Tanzania consultation report in Appendix A.

The design for Lake Victoria is presented by the Kagera sub-basin, Tanzania-Mara sub-basins, Kenya-Mara sub-basins, and Uganda sub-basins with the last three demonstrating emphasis for monitoring direct precipitation to the lake with meteorological stations located along shorelines and islands.

#### *Kagera*

With approximately 33% of the total overland flow contribution to Lake Victoria, the Kagera is by far the lake's largest tributary (LVBC, 2007). The Kagera Basin has a total drainage area of approximately

59,500 km$^2$. The main tributaries of the Kagera River include the Ruvubu with headwaters beginning in the highlands of Burundi and the Nyabarongo developing in Rwanda. The confluence of these two rivers meet to form the Kagera just upstream of Rusumo Falls, which is the planned site for a major hydro-electric run of the river dam and power plant. From Rusumo Falls the Kagera runs north forming the border between Rwanda and Tanzania before making a sharp turn east to form a partial border between Tanzania and Uganda. The river then passes through northwest Tanzania and the oldest gauging site of any tributary to Lake Victoria, Kyaka Ferry, with records dating back to 1940. From Kyaka Ferry the Kagera heads northeast where it empties into Lake Victoria just after passing the Tanzania-Uganda border.

The design for the Kagera basin is presented in Figure 6-8 and helps achieve the required monitoring to address Regional Issues 5 (Rusumo hydropower coordination) and 9 (Lake Victoria inflows) from Table 4-2.

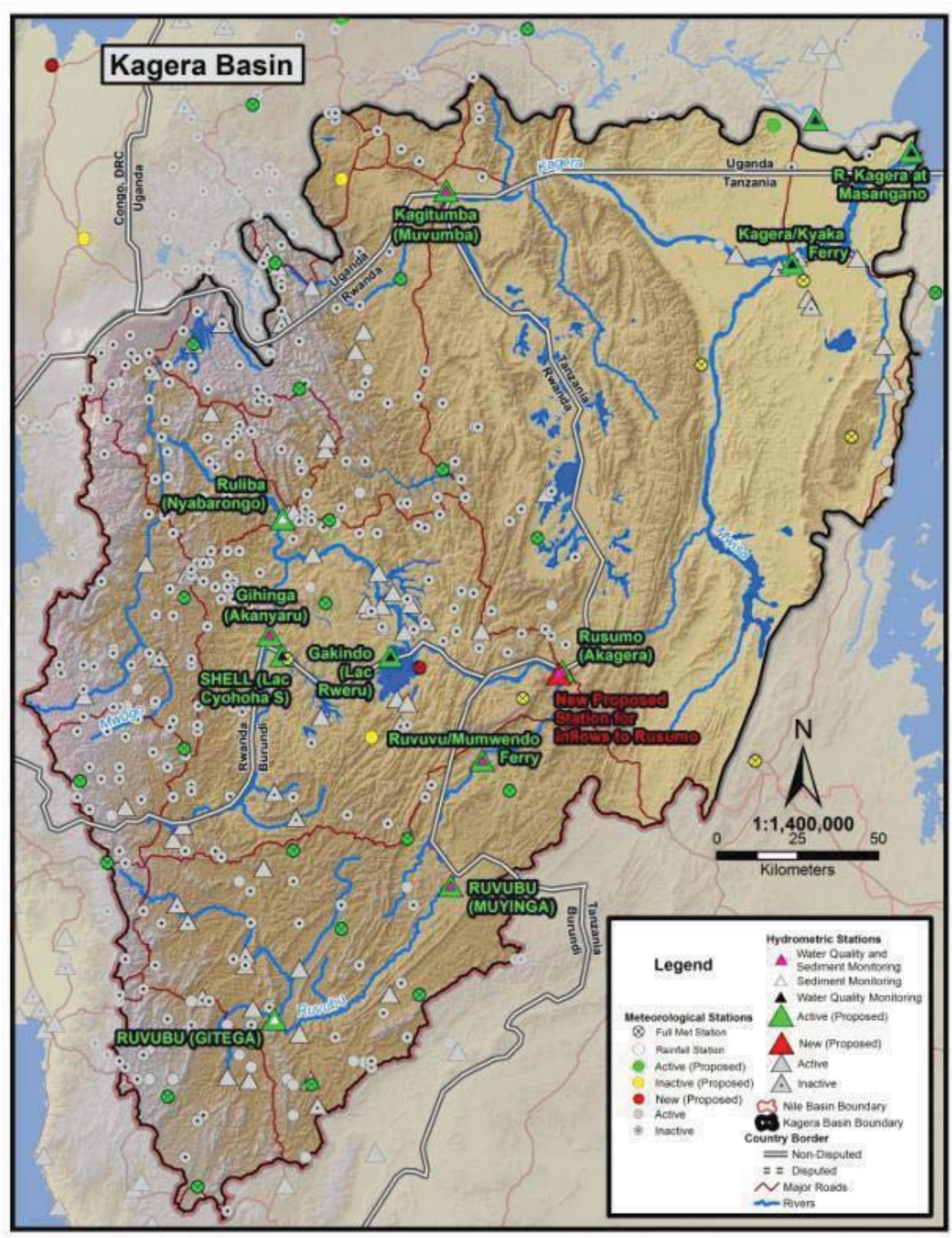


**Figure 6-8. Kagera proposed hydro-meteorological network design**

***Hydrometric Design***

Beginning with the RUVUBU (GITEGA) station in Burundi this gauge will help provide the total flow contribution from the three main tributaries of the Ruvubu just after the confluence. Combined with the national network, real-time flow data at this site could provide benefits for planned irrigation and flood monitoring for downstream communities along the Ruvubu. The Ruvuvu/Mumwendo Ferry gauge within Tanzania is the last active site for monitoring the Ruvubu before the confluence with the Nyabarongo. This site allows for monitoring the majority of contribution from the Ruvubu to both the Kagera and the hydropower site at Rusumo.

Three stations are proposed from the Nyabarongo upstream of the Kagera confluence. The Ruliba (Nyabarongo) allows monitoring of the upstream watershed in Rwanda while the Gihinga (Akanayaru) site will monitor an upstream watershed from both Rwanda and Burundi near the border. An additional new site is proposed just upstream of Rusumo Falls to monitor the total flows from the Nyabarongo before the confluence and dam site. These coordinates are tentative and a stable and accessible site will need to be found that will not experience backwater effects from the downstream dam. It was worth noting that all the proposed hydrometric locations upstream of the Rusumo Falls hydropower project are recommended to include sediment transport monitoring in order to mitigate siltation of the reservoir and isolate which upstream watershed may be contributing the greatest load. In addition, water quality monitoring was proposed at key transboundary locations.

The Rusumo (Akagera) station is currently situated near the proposed dam site. It is proposed that the monitoring for this site be moved downstream of the project to monitor the outflow and assess the suspended sediment and water quality that is released from the dam.

Two hydrometric stations were proposed by Rwanda representatives at the Conceptual Design Workshop to monitor the transboundary lakes Cyohoha and Rweru between Burundi and Rwanda defined as Regional Issue 13 in Table 4-2. Each of these locations is to include water quality monitoring.

Downstream of the Rusumo the next monitoring site is the Kagitumba (Muvumba). This leaves a long un-gauged section of the Kagera but the majority is wetlands and would be difficult to find a suitable site for monitoring as evident from the lack of historical gauges on the river. The Muvumba River was noted as a significant tributary to Kagera requiring both sediment and water quality monitoring to assess the upstream basin that straddles the Uganda-Rwanda border.

The next proposed downstream site is Kyaka Ferry in Tanzania. Kyaka Ferry is the longest standing monitoring site of any tributary to Lake Victoria with records extending back to 1940. As such, it is an important gauge to maintain for future hydrologic studies. It also provides benefit in accounting for the majority of contributing flows from the watershed including the Mwisa River which is the main Kagera tributary in Tanzania. Water quality monitoring is proposed at this site due to a Sugar Factory upstream and the capability to isolate pollution sources from the mouth to Lake Victoria.

The last proposed hydrometric site is the Masangano gauge in Uganda. This site will monitor the entire flow contribution of the Kagera basin to Lake Victoria. Like all main tributaries to Lake Victoria it is also proposed to include water quality monitoring for assessing impacts to the lake. Table 6-12 presents the proposed hydrometric stations in the Kagera basin.

**Table 6-12. Kagera hydrometric stations**

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| BUR_001_Hyd | RUVUBU (MUYINGA) | -2.980 | 30.470 | Active | WL, D, WQ, S | Rad | Sat |
| BUR_002_Hyd | RUVUBU (GITEGA) | -3.350 | 29.980 | Active | WL, D, S | PS | Sat |
| RWA_001_Hyd | Gakindo (Lac Rweru) | -2.341 | 30.302 | Active | WL, WQ | PS | Sat |
| RWA_002_Hyd | Gihinga (Akanyaru) | -2.283 | 29.967 | Active | WL, D, WQ, S | PS | Sat |

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| RWA_003_Hyd | Kagitumba (Muvumba) | -1.049 | 30.458 | Active | WL, D, WQ, S | Rad | Sat |
| RWA_004_Hyd | Ruliba (Nyabarongo) | -1.960 | 30.003 | Active | WL, D, S | PS | Sat |
| RWA_005_Hyd | Rusumo (Akagera) | -2.382 | 30.780 | Active | WL, D, WQ, S | PS | Sat |
| RWA_006_Hyd | SHELL (Lac Cyohoha S) | -2.339 | 30.002 | Active | WL, WQ | PS | Sat |
| RWA_007_Hyd | New Proposed Station for inflows to Rusumo | -2.391 | 30.769 | New | WL, D, WQ, S | PS | Sat |
| TAN_005_Hyd | Kagera/Kyaka Ferry | -1.250 | 31.419 | Active | WL, D, WQ | PS | Sat |
| TAN_006_Hyd | Ruvuvu/Mumwendo Ferry | -2.631 | 30.558 | Active | WL, D, WQ, S | SE | Sat |
| UGA_002_Hyd | R. Kagera at Masangano | -0.940 | 31.750 | Active | WL, D, WQ | SE | Sat |

### *Meteorological Design*

30 meteorological stations are proposed for monitoring the Kagera basin with an additional 4 providing benefits just outside the basin. Of these 30 stations 22 are currently active, 7 are inactive requiring some kind of rehabilitation, and one is new. The new station is located on the east bank of Lake Rweru in Burundi to monitor evaporation of the lake for Regional Issue 13. Overall the number of stations exceeds the initial guideline calculated from Equation 6-1. However, there are significant orographic effects in the mountainous areas of Rwanda and Burundi, high annual rainfall depth as shown in Figure 6-6, and considerable rainfall variability in the northern end of the sub-basin as shown in Figure 6-7. All of these factors contribute to the need for a denser network. The spatial distribution is evident from Figure 6-8, while the elevation distribution is demonstrated in Figure 6-9. Table 6-13 provides a list of meteorological stations and associated attributes for the Kagera basin.

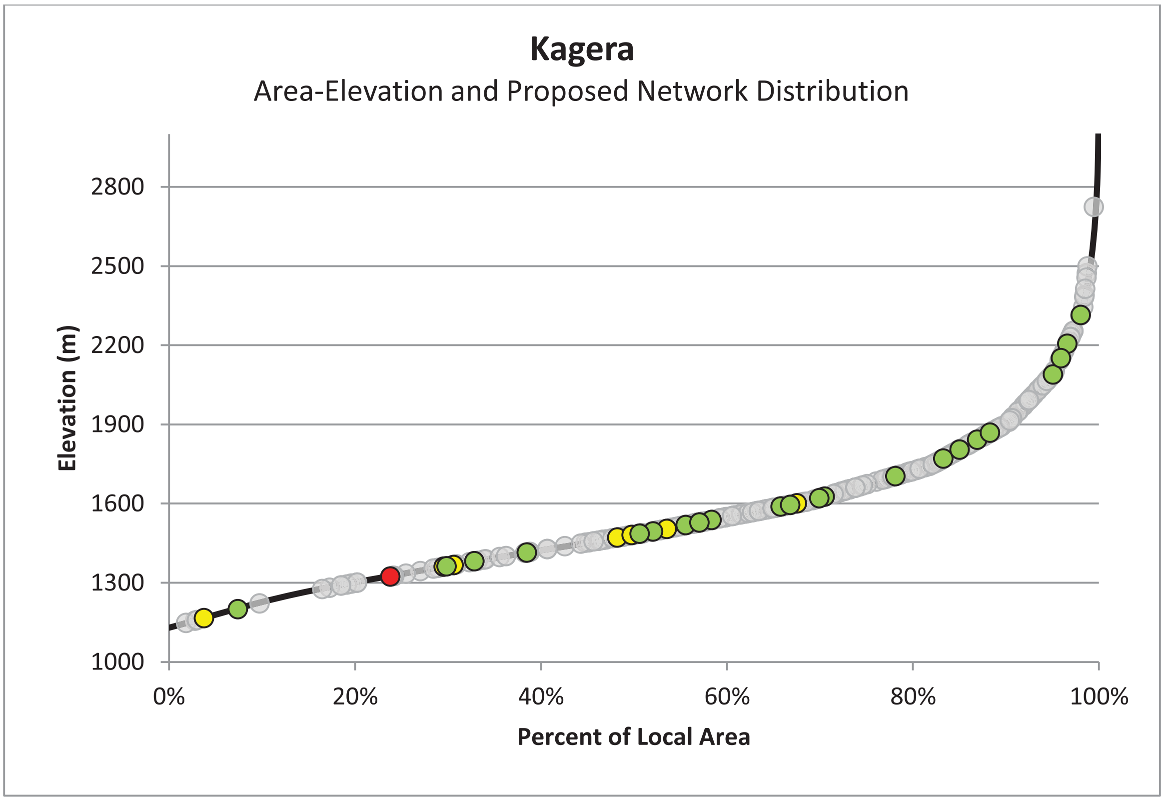


Figure 6-9. Kagera elevation distribution for meteorological network

**Table 6-13. Kagera meteorological stations**

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| BUR_001_Met | CANKUZO (Projet) | -3.283 | 30.383 | Active | Full Met | AWS | Sat |
| BUR_002_Met | MUYINGA | -2.850 | 30.350 | Active | Full Met | AWS | Sat |
| BUR_003_Met | KARUZI | -3.100 | 30.167 | Active | Full Met | AWS | Sat |
| BUR_004_Met | GITEGA (Aero) | -3.417 | 29.917 | Active | Full Met | AWS | Sat |
| BUR_005_Met | GISOZI | -3.567 | 29.683 | Active | Full Met | AWS | Sat |
| BUR_006_Met | MURIZA | -3.533 | 30.083 | Active | Full Met | AWS | Sat |
| BUR_007_Met | RUVYIRONZA | -3.817 | 29.767 | Active | Full Met | AWS | Sat |
| BUR_008_Met | RWEGURA | -2.917 | 29.517 | Active | Full Met | AWS | Sat |
| BUR_009_Met | NYAMUSWAGA | -2.883 | 30.033 | Active | Full Met | AWS | Sat |
| BUR_010_Met | MULEHE | -2.567 | 30.250 | Inactive | Rainfall | ARG | Sat |
| BUR_011_Met | Lake Rweru | -2.375 | 30.384 | New | Full Met | AWS | Sat |
| RWA_001_Met | BYIMANA | -2.180 | 29.730 | Active | Full Met | AWS | Sat |
| RWA_002_Met | KAWANGIRE | -1.824 | 30.448 | Active | Full Met | AWS | Sat |
| RWA_003_Met | KIGALI AERO | -1.965 | 30.133 | Active | Full Met | AWS | Sat |
| RWA_004_Met | Ntaruka | -1.476 | 29.756 | Active | Full Met | AWS | Sat |
| RWA_005_Met | NYAGATARE | -1.295 | 30.331 | Active | Full Met | AWS | Sat |
| RWA_006_Met | BUTARE AERO | -2.600 | 29.730 | Active | Full Met | AWS | Sat |
| RWA_007_Met | BYUMBA MET | -1.600 | 30.050 | Active | Full Met | AWS | Sat |
| RWA_008_Met | Mayange | -2.196 | 30.122 | Active | Full Met | AWS | Sat |
| RWA_009_Met | Ndego | -2.014 | 30.711 | Active | Full Met | AWS | Sat |
| RWA_010_Met | Nyabimata | -2.689 | 29.440 | Active | Full Met | AWS | Sat |
| RWA_011_Met | RUHUHA | -2.350 | 30.017 | | Full Met | AWS | Sat |
| TAN_012_Met | Rulenge Met. Station | -2.717 | 30.633 | Active | Full Met | AWS | Sat |
| TAN_019_Met | Kayanga Met. Station | -1.533 | 31.167 | Inactive | Full Met | AWS | Sat |
| TAN_020_Met | Kishanda met. Station | -1.733 | 31.583 | Inactive | Full Met | AWS | Sat |
| TAN_021_Met | Kyakakera Met. Station | -1.300 | 31.450 | Inactive | Full Met | AWS | Sat |
| TAN_022_Met | Ngara | -2.460 | 30.670 | Inactive | Full Met | AWS | Sat |
| UGA_031_Met | Kabale Met Station | -1.250 | 29.983 | Active | Full Met | AWS | Sat |
| UGA_063_Met | Kibanda WDD | -0.867 | 31.367 | Active | Rainfall | ARG | Sat |
| UGA_065_Met | Rubale | -1.017 | 30.167 | | Rainfall | ARG | Sat |

### *Tanzania-Mara*

The portion of Tanzania (outside of the Kagera sub-basin) draining to Lake Victoria constitutes approximately 71,305 km$^2$. This includes the entire Mara basin of which about half resides in Kenya. The primary tributaries include the Mara, Grumeti, Mbalageti, and Simiyu. Combined these rivers contribute approximately 12% of overland flow contribution to Lake Victoria (LVBC, 2007). The proposed design for the Tanzania-Mara sub-basin within the Lake Victoria watershed is shown in Figure 6-10. This design helps achieve the required monitoring to address Regional Issues 9 (Lake Victoria inflows) and 11 (Mara Basin transboundary flows) from Table 4-2.

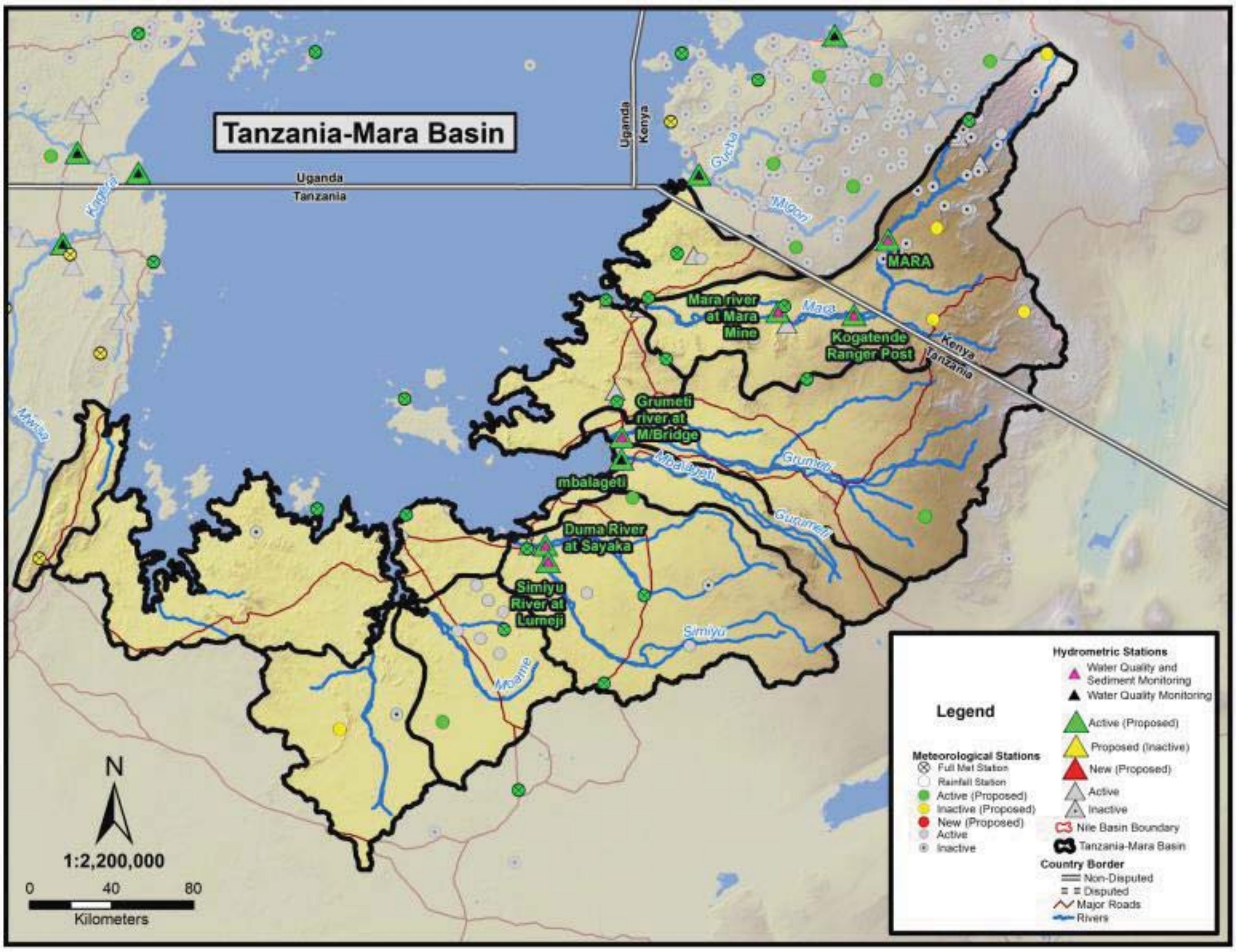


**Figure 6-10. Tanzania-Mara proposed hydro-meteorological network design**

***Hydrometric Design***

A total of 7 hydrometric stations are proposed for monitoring the inflows of the Tanzania-Mara sub-basin. This design includes three hydrometric stations along the important transboundary Mara basin. The first site proposed is an upstream location in Kenya simply named "MARA" that captures the flows from the northern and mountainous portion of the basin. The next proposed station is the "Kogatende Ranger Post" located just downstream of the border with Kenya and Tanzania. This is an important location for monitoring transboundary flows as well as a logical hydrologic monitoring location for assessing the contributing flows from tributaries in the eastern end of the basin from Kenya. The last downstream point on the Mara where discharge measurements can be made before the river enters wetlands is the "Mara river at Mara Mines" location. This station was visited during the field visits and more information about the site can be found in Appendix A. Each location along the Mara river is proposed to conduct sediment and water quality monitoring as concerns for both exist within the transboundary basin (NBI & NELSAP, 2008).

Other monitoring locations within the region include existing stations for the Grumeti, Mbalageti, and Simiyu rivers. Initially a single location downstream location was proposed for the Simiyu River but it was discovered this site was susceptible to backwater effects from the lake requiring upstream monitoring for the two main branches of the Simiyu and Duma tributary. The Simiyu and Grumeti rivers have notable issues with sediment that require monitoring while all proposed locations are planned to conduct water quality for assessment of inflows to Lake Victoria.

Other notable basins without proposed regional monitoring include the Magogo-Moame and Isanga at the southern end of the basin in Figure 6-10 due to limited inflows and wetland areas making suitable sites for discharge measurement difficult if not impossible to locate. All other sub-basins consist of very small and isolated tributaries unpractical for monitoring in a regional network. Table 6-14 presents the proposed hydrometric stations for the Tanzania-Mara sub-basin area.

Table 6-14. Tanzania-Mara hydrometric stations

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| KEN_006_Hyd | MARA | -1.233 | 35.036 | Active | WL, D, WQ, S | PS | Sat |
| TAN_001_Hyd | Mara river at Mara Mine | -1.549 | 34.554 | Active | WL, D, WQ, S | PS | Sat |
| TAN_002_Hyd | Grumeti river at M/Bridge | -2.098 | 33.869 | Active | WL, D, WQ, S | PS | Sat |
| TAN_003_Hyd | mbalageti | -2.196 | 33.868 | Active | WL, D, WQ | PS | Sat |
| TAN_004_Hyd | Duma River at Sayaka | -2.572 | 33.533 | Active | WL, D, WQ, S | SE | Sat |
| TAN_007_Hyd | Simiyu River at Lumeji | -2.647 | 33.546 | Active | WL, D, WQ, S | PS | Sat |
| TAN_008_Hyd | Kogatende Ranger Post | -1.563 | 34.887 | Active | WL, D, WQ, S | PS | Sat |

***Meteorological Design***

27 meteorological stations are proposed for monitoring the Tanzania-Mara basin. Of these 27 stations 21 are Active, and 6 are Inactive requiring some kind of rehabilitation. The number of proposed stations is more than the initial guideline calculated in Equation 6-1. This is a result of high annual rainfall and moderate rainfall variability as shown in Figure 6-6 and Figure 6-7 respectively. In addition, there is a need to for stations along the shoreline and islands of Lake Victoria to estimate direct rainfall to the lake. These factors contribute to the need for a denser network. The spatial distribution is evident from Figure 6-10, while the elevation distribution is demonstrated in Figure 6-11. Table 6-15 provides a list of the proposed meteorological stations and associated attributes for the Tanzania-Mara basin.

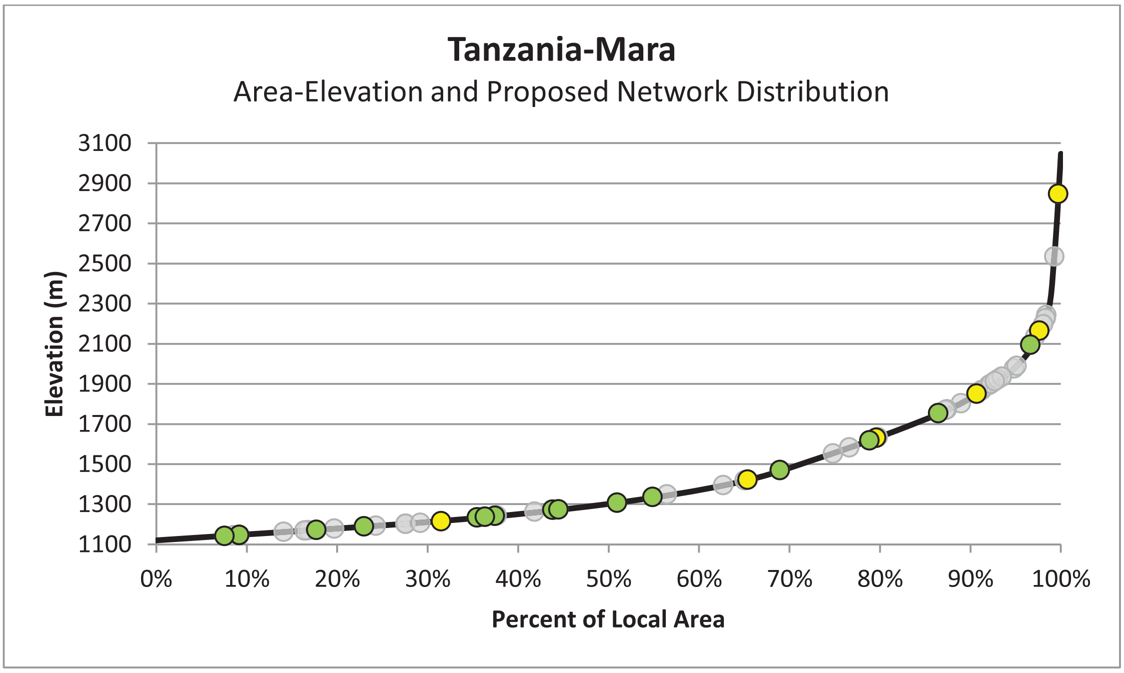


Figure 6-11. Tanzania-Mara elevation distribution for meteorological network

**Table 6-15. Tanzania-Mara meteorological stations**

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| KEN_004_Met | Bomet | -0.712 | 35.391 | Active | Full Met | AWS | Sat |
| KEN_030_Met | ELBURGON, BARAGET FOREST STATION | -0.417 | 35.733 | | Rainfall | ARG | Sat |
| KEN_031_Met | SOTIK, AITONG VET. HOUSE | -1.183 | 35.250 | | Rainfall | ARG | Sat |
| KEN_032_Met | NAROK,KEEKOROK GAME LODGE | -1.583 | 35.233 | | Rainfall | ARG | Sat |
| KEN_033_Met | NAIKARA AFRICA GOSPEL CHURCH | -1.550 | 35.633 | | Rainfall | ARG | Sat |
| TAN_001_Met | Bunda/ Bitaraguru Met. Station | -1.947 | 33.848 | Active | Full Met | AWS | Sat |
| TAN_002_Met | Kidinda Met. Station | -2.797 | 33.967 | Active | Full Met | AWS | Sat |
| TAN_003_Met | Magu Met. Station | -2.592 | 33.454 | Active | Full Met | AWS | Sat |
| TAN_004_Met | Maswa Met. Station | -3.182 | 33.791 | Active | Full Met | AWS | Sat |
| TAN_005_Met | Randa Met. Station | -1.295 | 34.112 | Active | Full Met | AWS | Sat |
| TAN_006_Met | Ukerewe Met. Station | -1.933 | 32.917 | Active | Full Met | AWS | Sat |
| TAN_007_Met | Kahunda Met. Station | -2.417 | 32.533 | Active | Full Met | AWS | Sat |
| TAN_008_Met | Buhemba met. Station | -1.759 | 34.064 | Active | Full Met | AWS | Sat |
| TAN_009_Met | Kuruya met. Station | -1.489 | 33.986 | Active | Full Met | AWS | Sat |
| TAN_010_Met | Mugumu met. Station | -1.846 | 34.681 | Active | Full Met | AWS | Sat |
| TAN_011_Met | Nyabusara met. Station | -1.527 | 34.583 | Active | Full Met | AWS | Sat |
| TAN_013_Met | Ngudu Met. Station | -2.946 | 33.354 | Active | Full Met | AWS | Sat |
| TAN_014_Met | Bukoba | -1.333 | 31.817 | Active | Full Met | AWS | Sat |
| TAN_015_Met | Musoma | -1.500 | 33.800 | Active | Full Met | AWS | Sat |
| TAN_016_Met | Mwanza | -2.442 | 32.925 | Active | Full Met | AWS | Sat |
| TAN_017_Met | Shinyanga | -3.650 | 33.417 | Active | Full Met | AWS | Sat |
| TAN_018_Met | Biharamulo | -2.633 | 31.317 | Inactive | Full Met | AWS | Sat |
| TAN_023_Met | Busweta P/School | -1.267 | 34.633 | Active | Rainfall | ARG | Sat |
| TAN_024_Met | Bwai P/school | -2.367 | 33.917 | Active | Rainfall | ARG | Sat |
| TAN_025_Met | Kikubiji P/School | -3.350 | 33.083 | Active | Rainfall | ARG | Sat |
| TAN_026_Met | Mugumu P/School | -2.450 | 35.200 | Active | Rainfall | ARG | Sat |
| TAN_027_Met | Kharumwa P/School | -3.383 | 32.633 | Inactive | Rainfall | ARG | Sat |

### *Kenya-Mara*

The portion of Kenya that drains directly to Lake Victoria, which also includes the entire Mara transboundary basin consists of approximately 49,700 km$^2$. The major rivers and sub-basins within Kenya include the Sio, Nzoia, Yala, Sondu, Gucha Migori, and Mara. When combined the contribution from these rivers is estimated to be approximately 41% of the total overland flow contribution to Lake Victoria which is more than the Kagera (LVBC, 2007). The proposed design for the Kenya-Mara sub-basin within the Lake Victoria watershed is shown in Figure 6-12. This design helps achieve the required monitoring to address Regional Issues 9 (Lake Victoria inflows) and 11 (Mara Basin transboundary flows) from Table 4-2.

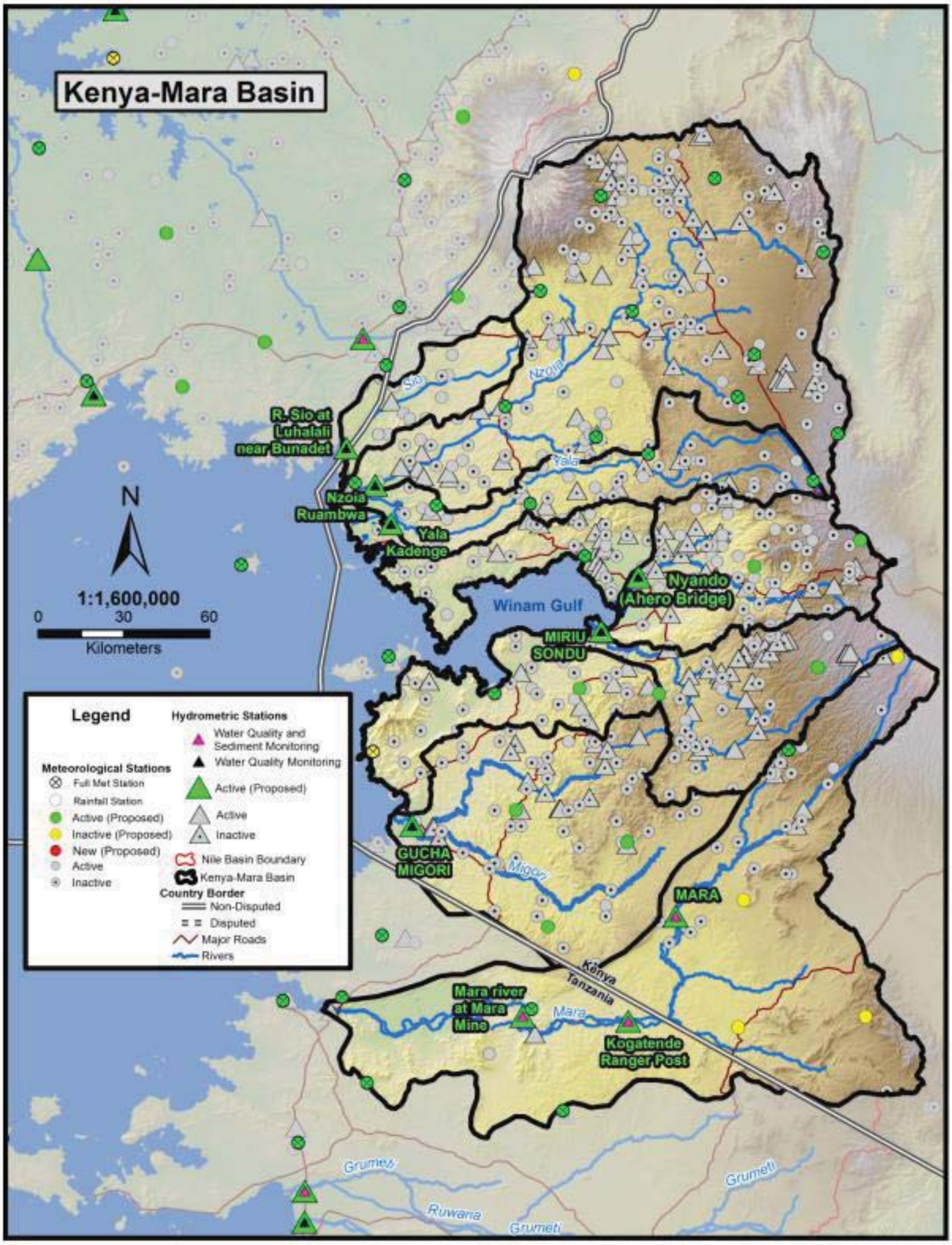


Figure 6-12. Kenya-Mara proposed hydro-meteorological network design

### *Hydrometric Design*

A total of 9 hydrometric stations are proposed for monitoring the inflows of the Kenya-Mara sub-basin. This design includes three hydrometric stations along the important transboundary Mara basin.

The first site proposed is an upstream location in Kenya simply named “MARA” that captures the flows from the northern and mountainous portion of the basin. The next proposed station is the “Kogatende Ranger Post” located just downstream of the border with Kenya and Tanzania. This is an important location for monitoring transboundary flows as well as a logical hydrologic monitoring location for assessing the contributing flows from tributaries in the eastern end of the basin from Kenya. The last downstream point on the Mara where discharge measurements can be made before the river enters wetlands is the “Mara river at Mara Mines” location. This station was visited during the field visits and more information about the site can be found in Appendix A. Each location along the Mara river is proposed to conduct sediment and water quality monitoring as concerns for both exist within the transboundary basin (NBI & NELSAP, 2008).

All additional stations within Kenya are proposed to monitor discharge and water quality of inflows to Lake Victoria. It should be noted that the Sio River outlet station is located and operated within Uganda but the majority of the basin is within Kenya as shown in Figure 6-12.

Other notable basins without proposed hydrometric monitoring include the North and South Awach surrounding Winam Gulf. Both of these basins contain only small localized tributaries that do not contribute enough overland flow to justify an investment for regional hydrometric monitoring. Table 6-16 presents the proposed hydrometric stations for the Kenya-Mara sub-basin area.

Table 6-16. Kenya-Mara hydrometric stations

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| KEN_001_Hyd | Nzoia Ruambwa | 0.124 | 34.090 | Active | WL, D, WQ | Rad | Sat |
| KEN_002_Hyd | Yala Kadenge | 0.002 | 34.140 | Active | WL, D, WQ | Rad | Sat |
| KEN_003_Hyd | NYANDO (Ahero Bridge) | -0.164 | 34.919 | Active | WL, D, WQ | Rad | Sat |
| KEN_004_Hyd | MIRIU SONDU | -0.336 | 34.802 | Active | WL, D, WQ | Rad | Sat |
| KEN_005_Hyd | GUCHA MIGORI | -0.947 | 34.207 | Active | WL, D, WQ | PS | Sat |
| KEN_006_Hyd | MARA | -1.233 | 35.036 | Active | WL, D, WQ, S | PS | Sat |
| TAN_001_Hyd | Mara river at Mara Mine | -1.549 | 34.554 | Active | WL, D, WQ, S | PS | Sat |
| TAN_008_Hyd | Kogatende Ranger Post | -1.563 | 34.887 | Active | WL, D, WQ, S | PS | Sat |
| UGA_004_Hyd | R. Sio at Luhalali near Bunadet | 0.240 | 34.000 | Active | WL, D, WQ | SE | Sat |

### *Meteorological Design*

34 meteorological stations are proposed for monitoring the Kenya-Mara basin. Of these 34 stations 29 are Active, and 5 are Inactive requiring some kind of rehabilitation. The number of proposed stations is more than the initial guideline calculated in Equation 6-1. This is a result of high annual rainfall and high rainfall variability as shown in Figure 6-6 and Figure 6-7 respectively. In addition, there is a need to capture orographic effects from the mountainous headwater regions of the east as well as estimate direct precipitation to Lake Victoria with shoreline and island stations. These factors contribute to the need for a denser network. The spatial distribution is evident from Figure 6-12, while the elevation distribution is demonstrated in Figure 6-13. Table 6-17 provides a list of the proposed meteorological stations and associated attributes for the Kenya-Mara basin.

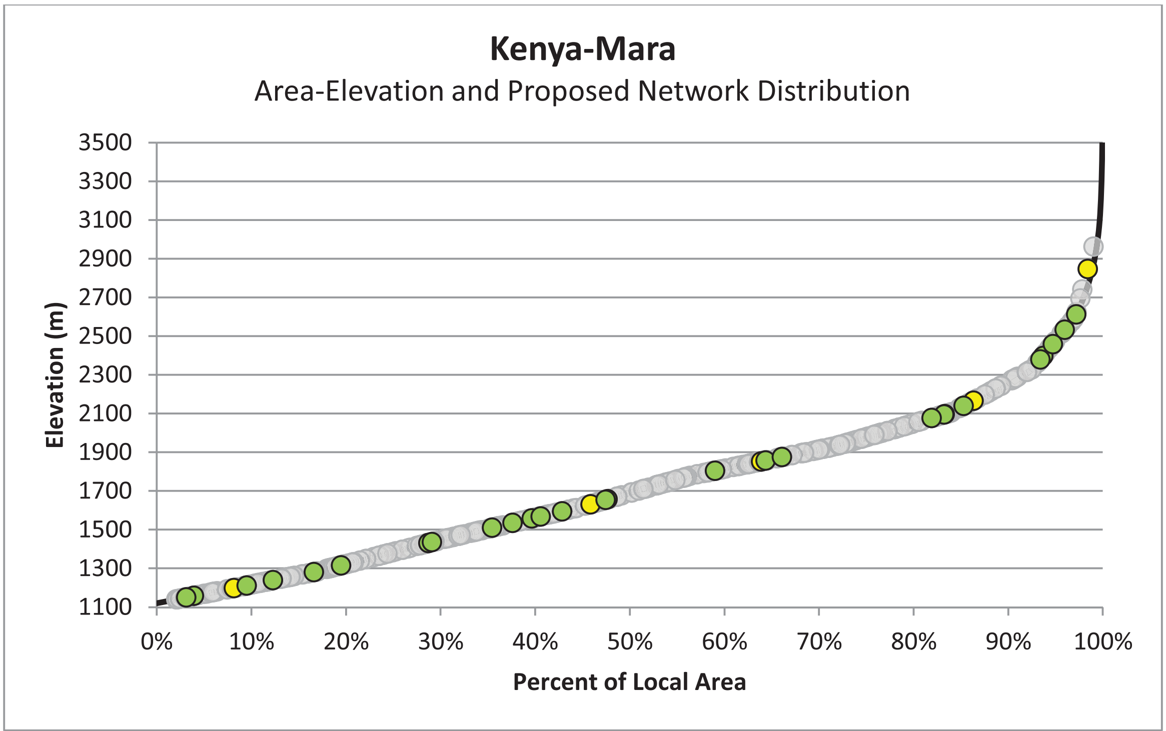


**Figure 6-13. Kenya-Mara elevation distribution for meteorological network**

**Table 6-17. Kenya-Mara meteorological stations**

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| KEN_001_Met | Siaya ATC | 0.058 | 34.283 | Active | Full Met | AWS | Sat |
| KEN_003_Met | Chwele | 0.734 | 34.610 | Active | Full Met | AWS | Sat |
| KEN_004_Met | Bomet | -0.712 | 35.391 | Active | Full Met | AWS | Sat |
| KEN_005_Met | Kisumu Airport Met | -0.100 | 34.750 | Active | Full Met | AWS | Sat |
| KEN_006_Met | Eldoret Airport | 0.400 | 35.230 | Active | Full Met | AWS | Sat |
| KEN_007_Met | Eldoret Kapsoya Met | 0.533 | 35.283 | Active | Full Met | AWS | Sat |
| KEN_008_Met | Suba Met, RUSINGA ISLAND KASWANGA HDR. STN | -0.417 | 34.133 | Active | Full Met | AWS | Sat |
| KEN_009_Met | Nganyi Community RANET | 0.064 | 34.578 | Active | Full Met | AWS | Sat |
| KEN_010_Met | Kakamega Airport | 0.274 | 34.785 | Active | Full Met | AWS | Sat |
| KEN_011_Met | Mumias Sugar Factory | 0.370 | 34.500 | Active | Full Met | AWS | Sat |
| KEN_012_Met | Kaimosi Farmers Training Centre | 0.220 | 34.950 | Active | Full Met | AWS | Sat |
| KEN_013_Met | Lugari Forest Station | 0.670 | 34.900 | Active | Full Met | AWS | Sat |
| KEN_014_Met | Kapsara Tea Factory | 1.088 | 35.159 | Active | Full Met | AWS | Sat |
| KEN_015_Met | CHORLIM ADC | 1.033 | 34.800 | Active | Full Met | AWS | Sat |
| KEN_016_Met | CHEPTONGEI CHIEF's Office | 0.855 | 35.501 | Active | Full Met | AWS | Sat |
| KEN_017_Met | KIPKABUS FOREST STATION | 0.284 | 35.546 | Active | Full Met | AWS | Sat |
| KEN_018_Met | NABKOI FOREST STATION | 0.136 | 35.469 | Active | Full Met | AWS | Sat |
| KEN_019_Met | Bunyala RANET FM | 0.130 | 34.027 | Active | Full Met | AWS | Sat |
| KEN_021_Met | OYUGIS AGRICULTURAL STATION | -0.517 | 34.733 | Active | Rainfall | ARG | Sat |
| KEN_022_Met | HOMABAY FARMERS TRAINING CENTRE | -0.533 | 34.467 | Active | Full Met | AWS | Sat |
| KEN_023_Met | KEBABE PRIMARY SCHOOL | -0.533 | 34.983 | Active | Rainfall | ARG | Sat |
| KEN_024_Met | SOUTH NYANZA SUGAR FACTORY | -0.900 | 34.533 | Active | Rainfall | ARG | Sat |

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| KEN_025_Met | LONDIANI MAKUTANO FOREST STATION | -0.050 | 35.617 | Active | Rainfall | ARG | Sat |
| KEN_026_Met | NDOINET FOREST STATION | -0.450 | 35.483 | Active | Rainfall | ARG | Sat |
| KEN_027_Met | KORU, COFFEE BOARD SUB-STATION | -0.133 | 35.283 | Active | Rainfall | ARG | Sat |
| KEN_028_Met | KILGORIS DIVISSIONAL AGR.OFFICE | -1.000 | 34.883 | Active | Rainfall | ARG | Sat |
| KEN_029_Met | GOD BURA SCHOOL,S.D.A. | -0.717 | 34.083 | | Full Met | AWS | Sat |
| KEN_030_Met | ELBURGON, BARAGET FOREST STATION | -0.417 | 35.733 | | Rainfall | ARG | Sat |
| KEN_031_Met | SOTIK, AITONG VET. HOUSE | -1.183 | 35.250 | | Rainfall | ARG | Sat |
| KEN_032_Met | NAROK,KEEKOROK GAME LODGE | -1.583 | 35.233 | | Rainfall | ARG | Sat |
| KEN_033_Met | NAIKARA AFRICA GOSPEL CHURCH | -1.550 | 35.633 | | Rainfall | ARG | Sat |
| TAN_008_Met | Buhemba met. Station | -1.759 | 34.064 | Active | Full Met | AWS | Sat |
| TAN_010_Met | Mugumu met. Station | -1.846 | 34.681 | Active | Full Met | AWS | Sat |
| TAN_011_Met | Nyabusara met. Station | -1.527 | 34.583 | Active | Full Met | AWS | Sat |

### *Uganda Lake Victoria*

The portion of Uganda that drains directly to Lake Victoria consists of approximately 27,600 km$^2$. The main tributaries for this basin consist of the Bukora and Katonga Rivers. As a result of the wetlands at the downstream end of these rivers their estimated total overland flows contribution to Lake Victoria is quite minimal at less than 2% (LVBC, 2007). The proposed design for the Uganda Lake Victoria sub-basin is shown in Figure 6-14. This design helps achieve the required monitoring to address Regional Issue 9 (Lake Victoria inflows) from Table 4-2.

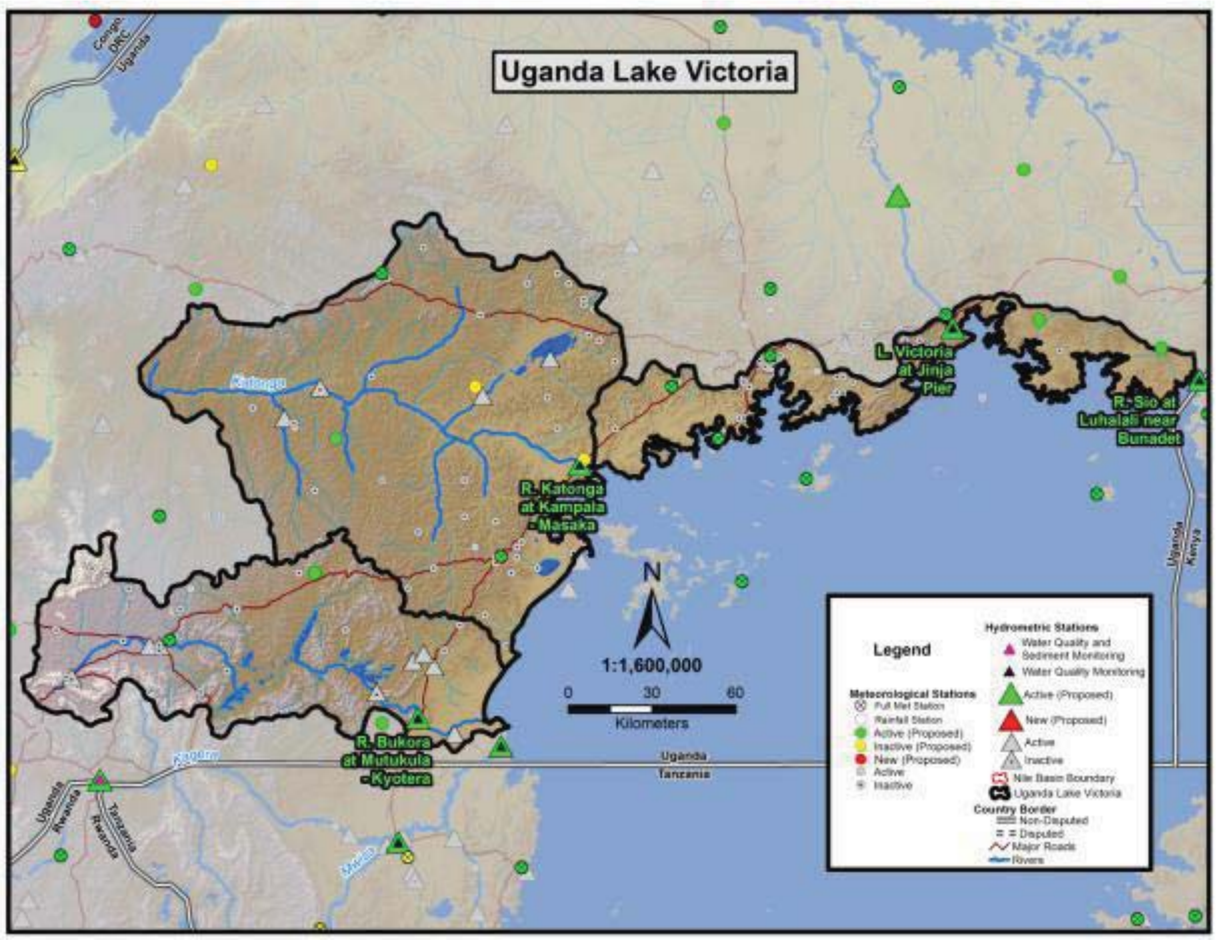


Figure 6-14. Uganda Lake Victoria proposed hydro-meteorological network design

### *Hydrometric Design*

4 hydrometric stations are proposed for monitoring the Uganda Lake Victoria sub-basin. This includes the operational water level monitoring site for Lake Victoria at Jinja Pier. The data from this site is very important on a regional basis for assessing the total water balance on the lake and the releases from the dam that affect downstream countries. The other three proposed locations include the Bukora River at Mutukula-Kyotera, Katonga River at Kampala-Masaka, and Sio River outlet at Luhalali to monitor the quantity and quality of flows from the main tributaries. As noted previously the Katonga and Bukora sites contribute very minimal overland flow and there may be concerns with conducting discharge measurements due to associated wetlands. This is of particular concern for the downstream Katonga site. The outlet to the Sio River is within the Ugandan border but the majority of the watershed is within Kenya.

No monitoring is proposed for the small local tributaries of the Northern Shore streams sub-basin that do not contribute enough overland flow to justify an investment for regional hydrometric monitoring. Table 6-16 presents the proposed hydrometric stations for the Uganda Lake Victoria sub-basin area.

**Table 6-18. Uganda Lake Victoria sub-basin hydrometric stations**

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| UGA_001_Hyd | L. Victoria at Jinja Pier | 0.409 | 33.205 | Active | WL, WQ | SE | Sat |
| UGA_003_Hyd | R. Katonga at Kampala - Masaka | -0.034 | 32.004 | Active | WL, D, WQ | Rad | Sat |
| UGA_004_Hyd | R. Sio at Luhalali near Bunadet | 0.240 | 34.000 | Active | WL, D, WQ | SE | Sat |
| UGA_005_Hyd | R. Bukora at Mutukula - Kyotera | -0.850 | 31.483 | Active | WL, D, WQ | Rad | Sat |

### *Meteorological Design*

13 meteorological stations are proposed for monitoring the Uganda Lake Victoria basin. Of these 13 stations 11 are Active, and 2 are Inactive (or unknown) requiring some kind of rehabilitation. The number of proposed stations is just slightly more than the initial guideline calculated in Equation 6-1. This is a result of high annual rainfall and moderate rainfall variability as shown in Figure 6-6 and Figure 6-7 respectively. The spatial distribution is evident from Figure 6-14, while the elevation distribution is demonstrated in Figure 6-15. Table 6-19 provides a list of the proposed meteorological stations and associated attributes for the Uganda Lake Victoria basin.

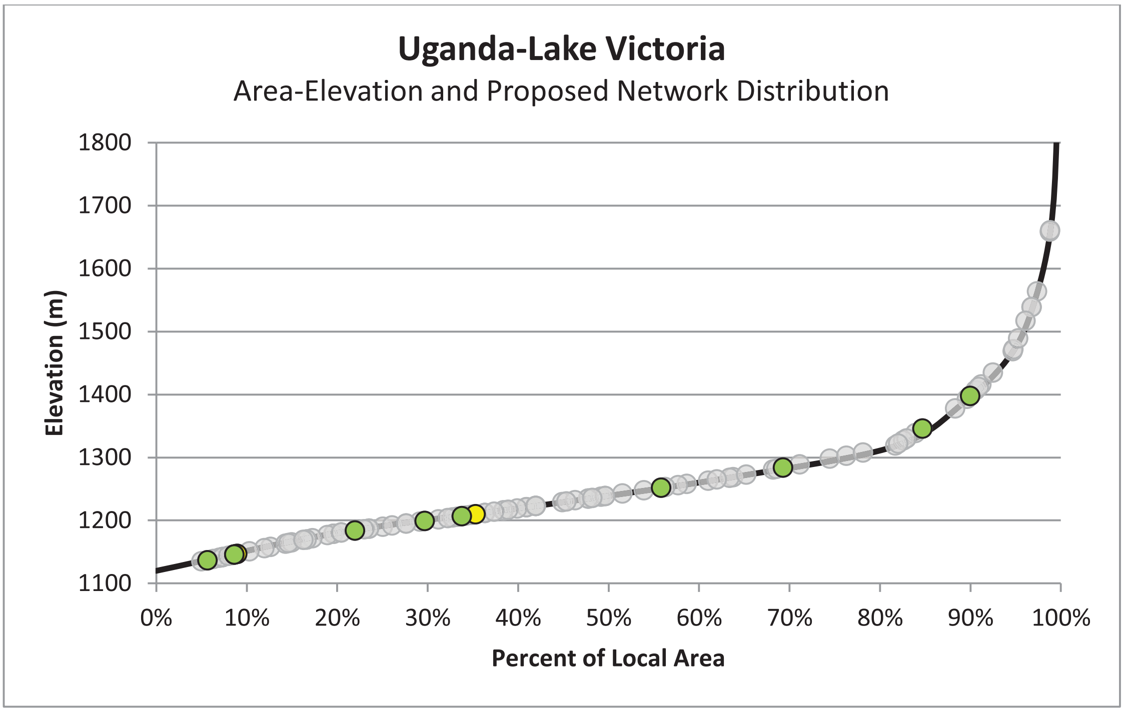


Figure 6-15. Uganda Lake Victoria elevation distribution for meteorological network

Table 6-19. Uganda Lake Victoria meteorological stations

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| UGA_008_Met | Masaka | -0.330 | 31.750 | Active | Full Met | AWS | Sat |
| UGA_009_Met | Bukasa | -0.411 | 32.526 | Active | Full Met | AWS | Sat |
| UGA_010_Met | Lolui | -0.129 | 33.669 | Active | Full Met | AWS | Sat |
| UGA_011_Met | Kome | -0.080 | 32.733 | Active | Full Met | AWS | Sat |
| UGA_019_Met | Mbarara Met Station | -0.600 | 30.683 | Active | Full Met | AWS | Sat |
| UGA_021_Met | Kampala Sewerage Works | 0.317 | 32.617 | Active | Full Met | AWS | Sat |
| UGA_022_Met | Mpanga Forest statio | 0.217 | 32.300 | Active | Full Met | AWS | Sat |
| UGA_024_Met | Entebbe Intl Airport | 0.050 | 32.450 | Active | Full Met | AWS | Sat |
| UGA_054_Met | Ntusi | 0.050 | 31.217 | Active | Rainfall | ARG | Sat |
| UGA_055_Met | Madu | 0.217 | 31.667 | | Rainfall | ARG | Sat |
| UGA_058_Met | Ikulwe Farm Institute | 0.433 | 33.483 | Active | Rainfall | ARG | Sat |
| UGA_062_Met | Lyantonde Dispensary | -0.383 | 31.150 | Active | Rainfall | ARG | Sat |
| UGA_064_Met | Nkozi Exp Farm | -0.017 | 32.017 | | Rainfall | ARG | Sat |

### 6.4.4 Victoria-Kyoga Nile

The entire area of the Victoria-Kyoga Nile sub-basin is approximately 85,500 km$^2$. The majority of flow through the basin is a result of releases from Lake Victoria at Jinja with some minor local seasonal contributions. Based on estimates from *The Hydrology of the Nile* the releases from Jinja account for approximately 87% with local flows accounting for 13% of the total flow on an annual basis (Sutcliffe, J.V. & Parks, Y.P., 1999). All flows that pass through Lake Kyoga experience significant attenuation as result of surrounding swamps and a topography of moderate relief (Sutcliffe, J.V. & Parks, Y.P., 1999). The proposed design for the Victoria-Kyoga Nile sub-basin is shown in Figure 6-16. This design helps achieve the required monitoring to address Regional Issues 1 (releases from Jinja) and 12 (Malaba transboundary flows) from Table 4-2.

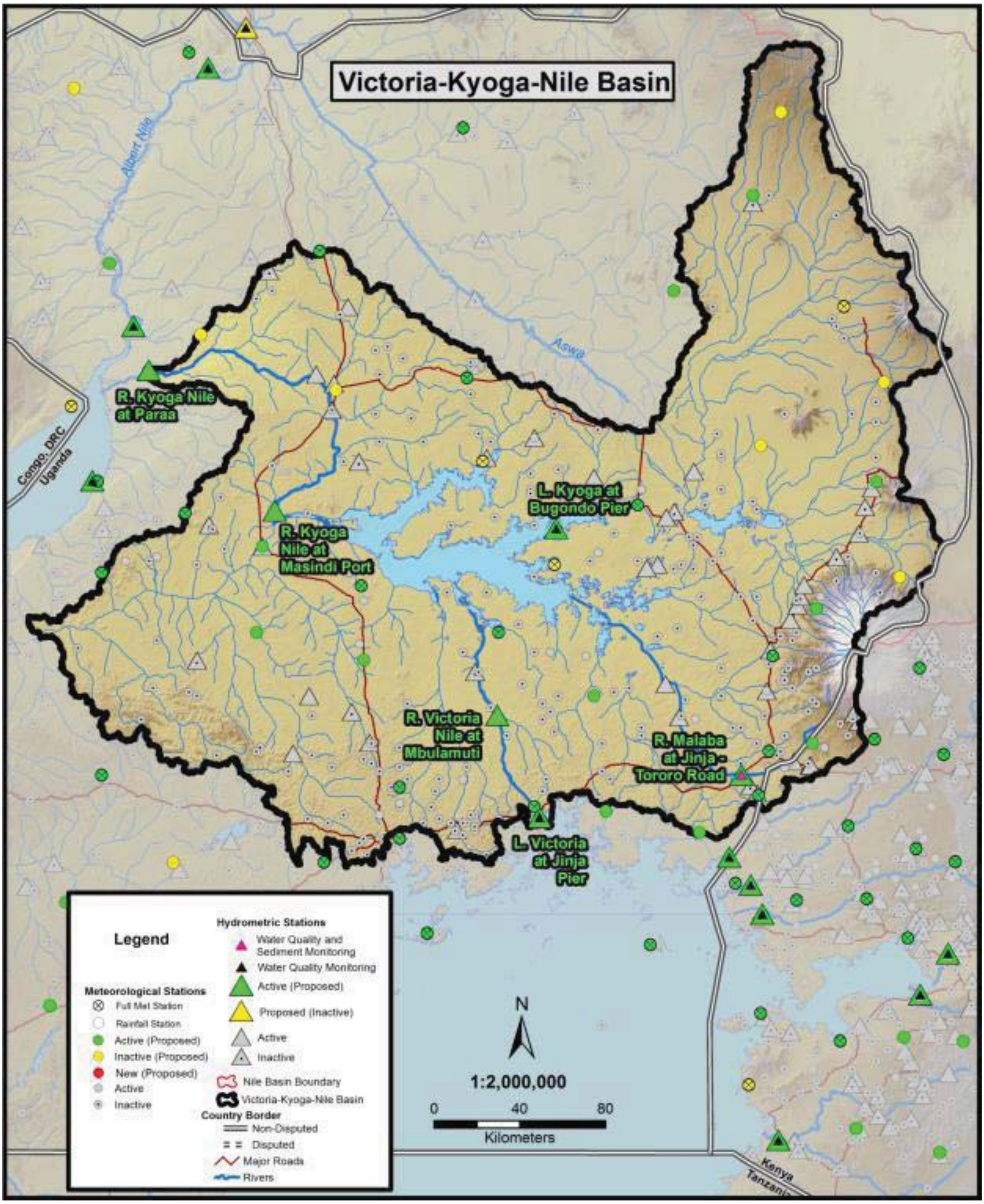


Figure 6-16. Victoria-Kyoga Nile proposed hydro-meteorological network

### *Hydrometric Design*

6 hydrometric stations are proposed for monitoring the Victoria-Kyoga Nile sub-basin. The two most important for regional purposes are the Lake Victoria water level at Jinja pier and the associated releases from Jinja at the Mbulamuti gauge. The total local contributions passing through Lake Kyoga

can be assessed between the difference of monitoring at Masindi Port and Mbulamuti. Additional local contributions or losses can be observed from assessment of the Paraa flows before entering Lake Albert. All of these sites with the exception of the Paraa were visited during consultations and further details are available in Appendix A.

Additional regional locations include monitoring the level and water quality of Lake Kyoga at Bugondo Pier and assessing the transboundary sediment and water quality of the Malaba basin between Kenya and Uganda at the Jinja-Tororo road gauging location. Table 6-20 presents the proposed hydrometric stations for the Victoria-Kyoga Nile sub-basin area.

Table 6-20. Victoria-Kyoga Nile hydrometric stations

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| UGA_001_Hyd | L. Victoria at Jinja Pier | 0.409 | 33.205 | Active | WL, WQ | SE | Sat |
| UGA_006_Hyd | L. Kyoga at Bugondo Pier | 1.620 | 33.274 | Active | WL, WQ | SE | Sat |
| UGA_007_Hyd | R. Victoria Nile at Mbulamuti | 0.835 | 33.028 | Active | WL, D | SE | Sat |
| UGA_008_Hyd | R. Malaba at Jinja - Tororo Road | 0.585 | 34.052 | Active | WL, D, WQ, S | Rad | Sat |
| UGA_009_Hyd | R. Kyoga Nile at Masindi Port | 1.695 | 32.093 | Active | WL, D | SE | Sat |
| UGA_010_Hyd | R. Kyoga Nile at Paraa | 2.283 | 31.564 | Active | WL, D | PS | Sat |

### *Meteorological Design*

28 meteorological stations are proposed for monitoring the Victoria-Kyoga Nile basin. Of these 28 stations 20 are Active, and 8 are Inactive (or unknown) requiring some kind of rehabilitation. The number of proposed stations is more than the initial guideline calculated in Equation 6-1. This is a result of high annual rainfall and portions of the basin with high rainfall variability as shown in Figure 6-6 and Figure 6-7 respectively. These factors contribute to the need for a denser network. The spatial distribution is evident from Figure 6-16, while the elevation distribution is demonstrated in Figure 6-17. Table 6-21 provides a list of the proposed meteorological stations and associated attributes for the Victoria-Kyoga Nile basin.

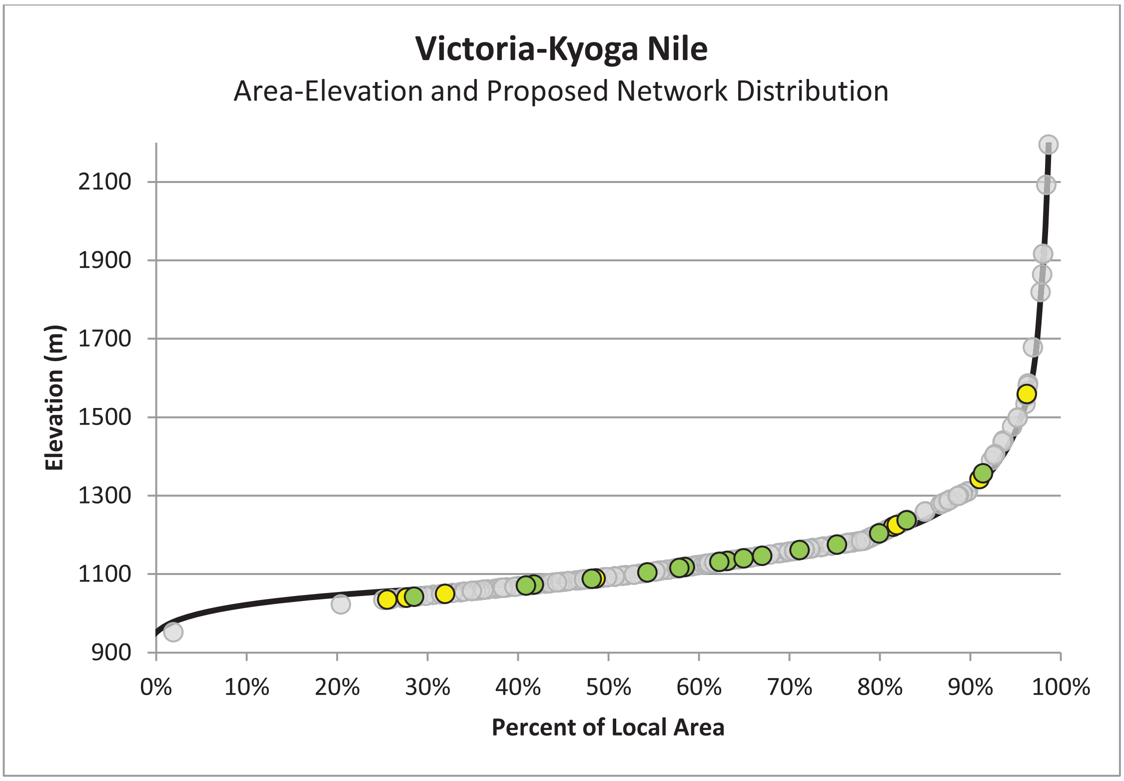


Figure 6-17. Victoria-Kyoga Nile elevation distribution for meteorological network

Table 6-21. Victoria-Kyoga Nile meteorological stations

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| KEN_002_Met | Alupe KARI | 0.500 | 34.124 | Active | Full Met | AWS | Sat |
| KEN_020_Met | ANGORAI CHIEF'S CENTRE | 0.717 | 34.350 | Active | Rainfall | ARG | Sat |
| UGA_001_Met | Mbale | 1.083 | 34.183 | Active | Full Met | AWS | Sat |
| UGA_003_Met | Lira | 2.250 | 32.900 | Active | Full Met | AWS | Sat |
| UGA_005_Met | Nakasongola | 1.378 | 32.456 | Active | Full Met | AWS | Sat |
| UGA_014_Met | Bugiri Hospital | 0.573 | 33.743 | Active | Rainfall | ARG | Sat |
| UGA_015_Met | Namayingo Health Centre | 0.343 | 33.876 | Active | Rainfall | ARG | Sat |
| UGA_016_Met | Kafu (Masindi) | 1.543 | 32.042 | Active | Rainfall | ARG | Sat |
| UGA_017_Met | Moroto | 2.550 | 34.483 | | Full Met | AWS | Sat |
| UGA_023_Met | Namulonge Res Station | 0.533 | 32.617 | Active | Full Met | AWS | Sat |
| UGA_025_Met | Jinja Met. Station | 0.450 | 33.183 | Active | Full Met | AWS | Sat |
| UGA_026_Met | Tororo Met.Station | 0.683 | 34.167 | Active | Full Met | AWS | Sat |
| UGA_029_Met | Masindi Met Station | 1.683 | 31.717 | Active | Full Met | AWS | Sat |
| UGA_030_Met | Soroti Met Station | 1.717 | 33.617 | Active | Full Met | AWS | Sat |
| UGA_036_Met | Kotido | 3.017 | 34.100 | Active | Rainfall | ARG | Sat |
| UGA_037_Met | Loyoro [County Dodoth] | 3.367 | 34.217 | | Rainfall | ARG | Sat |
| UGA_040_Met | Jaber Verona Fathers | 2.200 | 32.350 | | Rainfall | ARG | Sat |
| UGA_042_Met | Nakapiripirit | 2.233 | 34.650 | | Rainfall | ARG | Sat |
| UGA_043_Met | Kachung Port KUR | 1.900 | 32.967 | | Full Met | AWS | Sat |
| UGA_044_Met | Kakoge Gombolola | 1.067 | 32.467 | Active | Rainfall | ARG | Sat |
| UGA_045_Met | Ngoma | 1.183 | 32.017 | Active | Rainfall | ARG | Sat |

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| UGA_046_Met | Kiige WDD | 1.183 | 33.033 | Active | Full Met | AWS | Sat |
| UGA_047_Met | Labori Irrigation | 1.467 | 33.267 | | Full Met | AWS | Sat |
| UGA_048_Met | Namalu W.D.D. | 1.817 | 34.617 | Active | Rainfall | ARG | Sat |
| UGA_049_Met | Greek River Police Post | 1.417 | 34.717 | | Rainfall | ARG | Sat |
| UGA_050_Met | Buginyanya Coffee Res | 1.283 | 34.367 | Active | Rainfall | ARG | Sat |
| UGA_051_Met | Nariam Tractor Hire Unit | 1.967 | 34.133 | | Rainfall | ARG | Sat |
| UGA_057_Met | Namukooge | 0.917 | 33.433 | Active | Rainfall | ARG | Sat |

### 6.4.5 Albert Nile

The entire area of the Albert Nile sub-basin is approximately 74,819 km$^2$. The majority of flow through the basin is still a result of releases upstream made from Lake Victoria at Jinja. However, there are some considerable local annual flow contributions of approximately 13% of the total outflow based on estimates of historical recorded flow on the Semliki River at Bweramule (Sutcliffe, J.V. & Parks, Y.P., 1999). Unlike the Victoria-Kyoga Nile sub-basin, there is considerable topographic relief from surrounding mountains but attenuation effects for flows passing through Lakes Edward and Albert are prevalent. The proposed design for the Albert Nile sub-basin is shown in Figure 6-18. This design helps achieve the required monitoring to address Regional Issues 1 (releases from Jinja), 4 (Lake Albert and Albert Nile water quality), and 10 (Lake Edward releases) from Table 4-2.

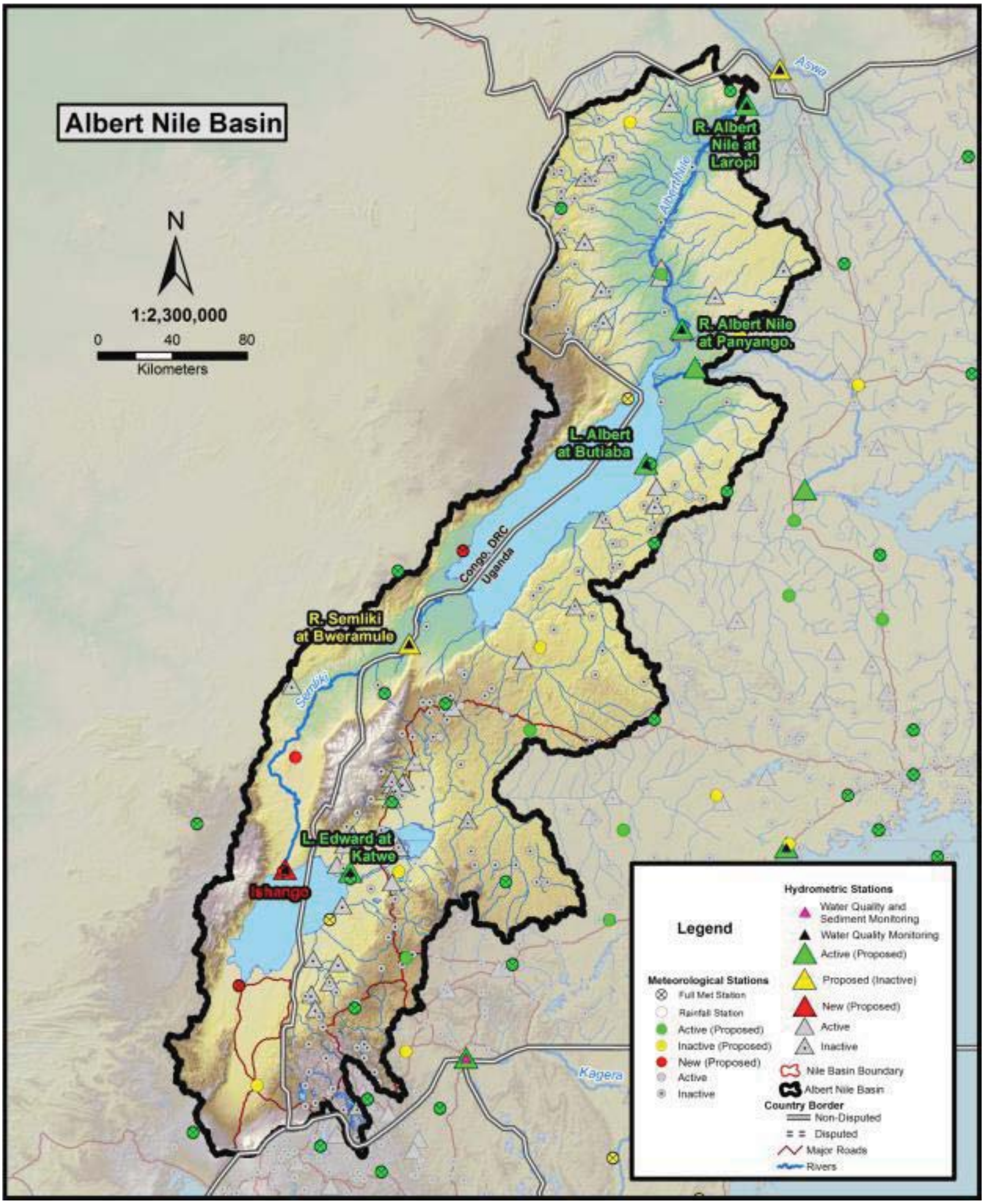


Figure 6-18. Albert Nile proposed hydro-meteorological network design

### *Hydrometric Design*

6 hydrometric stations are proposed for monitoring the Albert Nile sub-basin. All stations are proposed to include water quality monitoring to assess both impacts from oil exploration activities in the region and transboundary impacts between the DRC, Uganda, and downstream South Sudan. Two existing stations within Uganda are proposed to monitor Lakes Edward and Albert at Katwe and Butiaba respectively. An important newly proposed hydrometric station is proposed to monitor the outflows of Lake Edward at Ishango in the DRC. The inflows to Lake Albert are proposed at the inactive

but long standing historical record site of Bweramule on the Semliki River. Outflows from Lake Albert are proposed at Panyango. Transboundary quantity and quality flows along the Albert Nile leaving Uganda and entering South Sudan are recommended at the established and operational Laropi gauging site. Table 6-22 presents the proposed hydrometric stations for the Albert Nile sub-basin.

Table 6-22. Albert Nile hydrometric stations

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| DRC_001_Hyd | Ishango | -0.137 | 29.584 | New | WL, D, WQ | PS | Sat |
| UGA_011_Hyd | L. Edward at Katwe | -0.150 | 29.900 | Active | WL, WQ | PS | Sat |
| UGA_012_Hyd | L. Albert at Butiaba | 1.820 | 31.327 | Active | WL, WQ | SE | Sat |
| UGA_013_Hyd | R. Semliki at Bweramule | 0.950 | 30.183 | Inactive | WL, D, WQ | PS | Sat |
| UGA_014_Hyd | R. Albert Nile at Laropi | 3.552 | 31.813 | Active | WL, D, WQ | PS | Sat |
| UGA_015_Hyd | R. Albert Nile at Panyango. | 2.470 | 31.500 | Active | WL, D, WQ | SE | Sat |

### *Meteorological Design*

28 meteorological stations are proposed for monitoring the Lake Albert basin. Of these 28 stations 17 are Active, 7 are Inactive requiring some kind of rehabilitation, and 4 are New. The number of proposed stations is more than the initial guideline calculated in Equation 6-1. This is a result of high annual rainfall and high rainfall variability as shown in Figure 6-6 and Figure 6-7 respectively. In addition, there are considerable orographic effects from surrounding mountains and a need to monitor the direct precipitation and evaporation with shoreline stations for Lakes Edward and Albert. These factors contribute to the need for a denser network. The spatial distribution is evident from Figure 6-18, while the elevation distribution is demonstrated in Figure 6-19. Table 6-23 provides a list of the proposed meteorological stations and associated attributes for the Lake Albert basin.

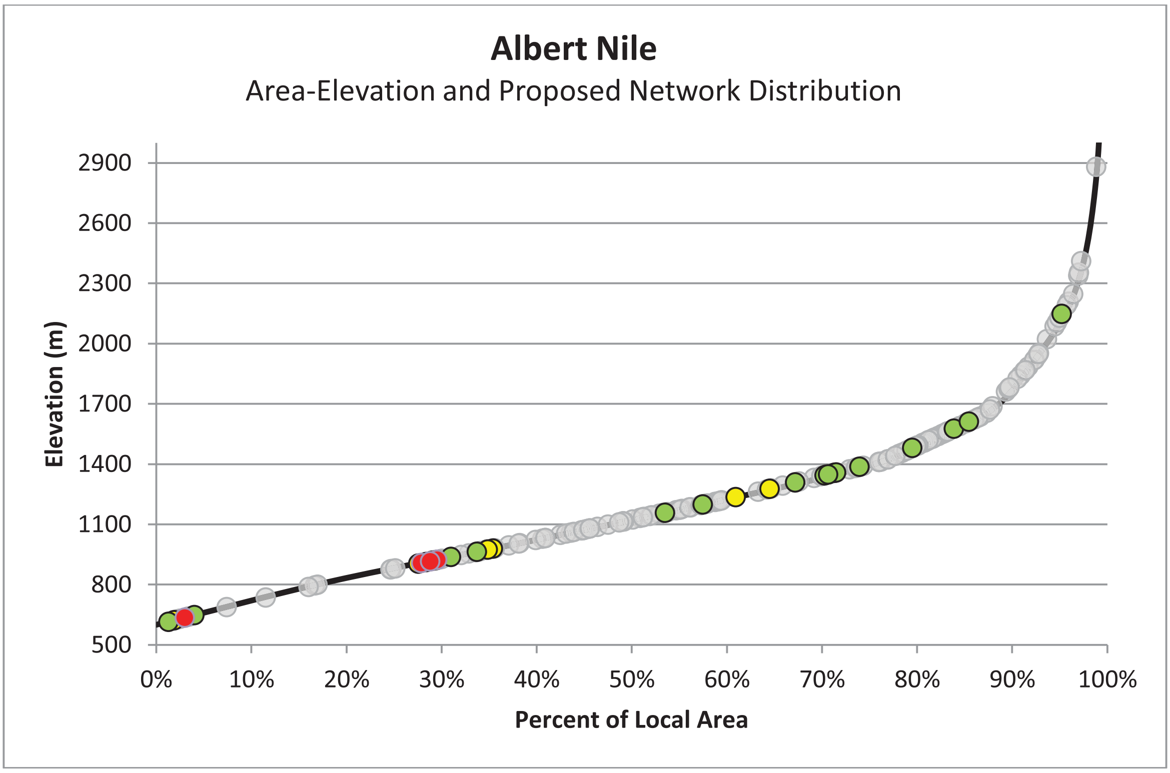


Figure 6-19. Albert Nile basin elevation distribution for meteorological network

**Table 6-23. Albert Nile basin meteorological stations**

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| DRC_001_Met | BUNIA | 1.300 | 30.130 | Active | Full Met | AWS | Sat |
| DRC_002_Met | BUTEMBO | 0.080 | 29.160 | Active | Full Met | AWS | Sat |
| DRC_003_Met | GOMA | -1.410 | 29.140 | Active | Full Met | AWS | Sat |
| DRC_004_Met | Tumbula | 0.402 | 29.634 | New | Rainfall | ARG | Sat |
| DRC_005_Met | Bwera | -0.702 | 29.362 | New | Full Met | AWS | Sat |
| DRC_006_Met | Kasenyi | 1.397 | 30.443 | New | Full Met | AWS | Sat |
| DRC_007_Met | Mahagi Port | 2.131 | 31.240 | Inactive | Full Met | AWS | Sat |
| DRC_008_Met | Lake Edward Outlet | -0.150 | 29.576 | New | Full Met | AWS | Sat |
| DRC_009_Met | Rutshuru | -1.182 | 29.451 | Inactive | Rainfall | ARG | Sat |
| UGA_004_Met | Moyo | 3.617 | 31.733 | Active | Full Met | AWS | Sat |
| UGA_006_Met | Kasese | 0.660 | 30.360 | Active | Full Met | AWS | Sat |
| UGA_007_Met | Mbarara | -0.200 | 30.650 | Active | Full Met | AWS | Sat |
| UGA_012_Met | Bushenyi District Headquarters | -0.810 | 29.920 | Active | Full Met | AWS | Sat |
| UGA_013_Met | Bundibugyo Headquarters | 0.710 | 30.065 | Active | Full Met | AWS | Sat |
| UGA_018_Met | Kasese Met Station | 0.183 | 30.100 | Active | Full Met | AWS | Sat |
| UGA_020_Met | Mubende 2nd Order Station | 0.583 | 31.367 | Active | Full Met | AWS | Sat |
| UGA_027_Met | Butiaba HM | 1.817 | 31.350 | Active | Full Met | AWS | Sat |
| UGA_028_Met | Hoima | 1.433 | 31.367 | Active | Full Met | AWS | Sat |
| UGA_032_Met | Arua Met Station | 3.050 | 30.917 | Active | Full Met | AWS | Sat |
| UGA_034_Met | Yumbe Hospital (Aringa) | 3.467 | 31.250 | | Rainfall | ARG | Sat |
| UGA_038_Met | Wangkwar Camp | 2.433 | 31.783 | | Rainfall | ARG | Sat |
| UGA_039_Met | Wadelai WDD | 2.733 | 31.400 | Active | Rainfall | ARG | Sat |
| UGA_052_Met | Kagadi Gombololo | 0.933 | 30.817 | | Rainfall | ARG | Sat |
| UGA_053_Met | Matiri | 0.533 | 30.767 | Active | Rainfall | ARG | Sat |
| UGA_059_Met | Rwenshama Police Post | -0.383 | 29.800 | | Full Met | AWS | Sat |
| UGA_060_Met | Uganda Institute of Ecology - Kasese | -0.183 | 29.900 | Active | Full Met | AWS | Sat |
| UGA_061_Met | Bushenyi Agromet Station | -0.567 | 30.167 | Active | Rainfall | ARG | Sat |
| UGA_066_Met | Rwomuhororo - Mbarara | -0.150 | 30.133 | | Rainfall | ARG | Sat |

### 6.4.6 Bahr el-Jebel

The entire area of the Bahr el-Jebel sub-basin which includes the Aswa River tributary is approximately 185,500 km$^2$. The Bahr el-Jebel is considered to be the most complex of Nile reaches due to the Sudd wetlands and seasonal spill of flows from the river to adjacent flood plains. These wetlands provide significant benefits to the grazing pastoral population but result in losses of approximately half of the inflows measured from Mongalla to outflows monitored at Malakal (Sutcliffe, J.V. & Parks, Y.P., 1999). The Bahr el-Jebel basin is situated between the Bahr el-Ghazal and Baro-Akobo-Sobat basins receiving flows from each. The proposed design for the Bahr el-Jebel sub-basin is shown in Figure 6-20. This design helps achieve the required monitoring to address Regional Issue 1 (releases from Jinja) from Table 4-2.

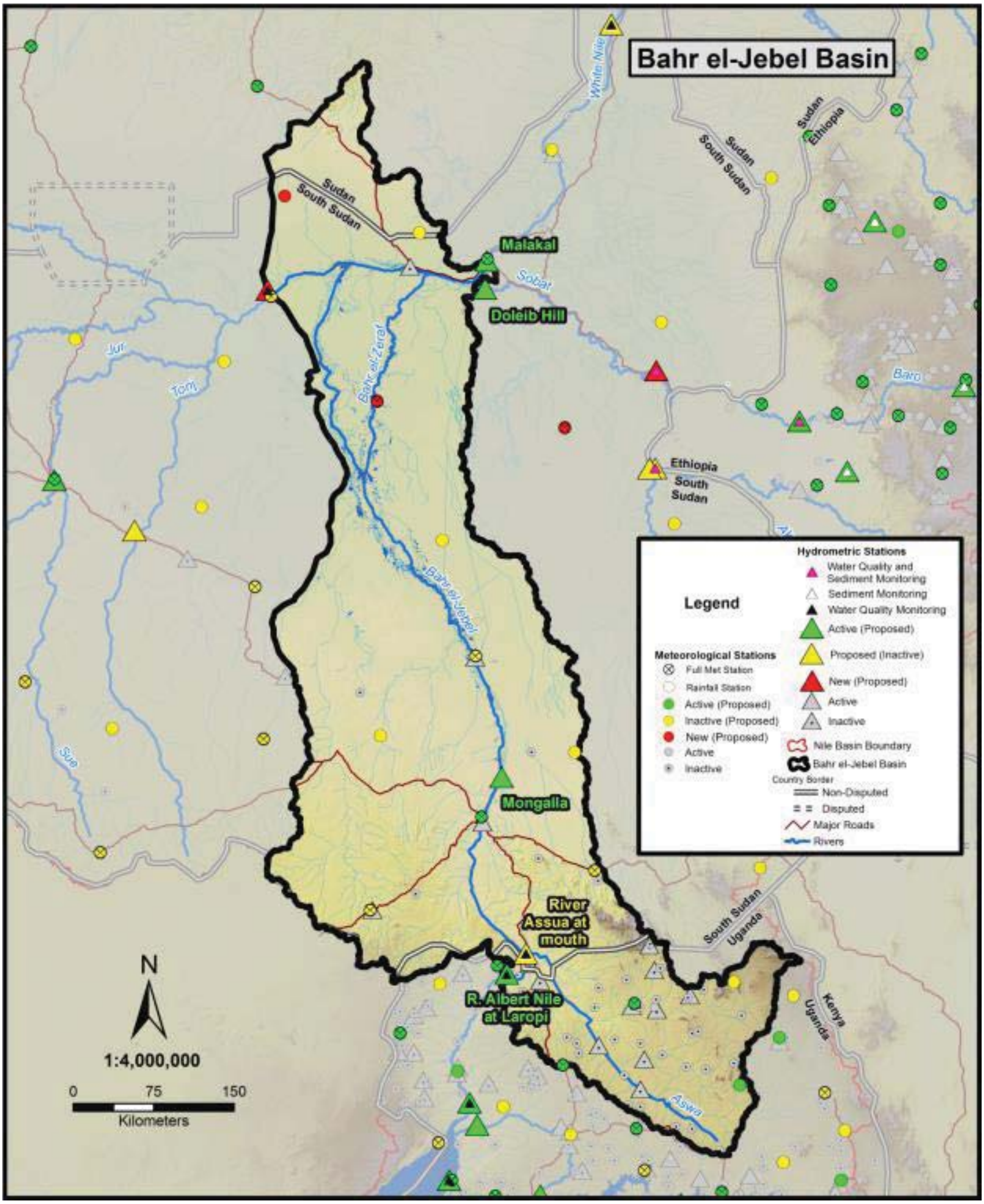


Figure 6-20. Bahr el-Jebel proposed hydro-meteorological network design

### *Hydrometric Design*

3 key hydrometric sites are proposed for monitoring the Bahr-Jebel sub-basin. This consists of transboundary water quantity and quality at the Aswa mouth (labeled as "Assua" in database and Figure 6-20). Additional monitoring of flows on the main stem Nile from Uganda are proposed for the active Laropi gauge as noted in Section 6.4.5.

The Mongalla site is a key location with data records extending back to 1905 (Sutcliffe, J.V. & Parks, Y.P., 1999). The site is the last suitable location for monitoring discharge of the Bahr el-Jebel (White Nile) enters the Sudd. This location also allows for monitoring the effect from most of the upstream seasonal torrents entering the system.

Just as important as Mongalla if not more so is the Malakal hydrometric site. Records for this location also extend back to 1905 and are some of the most complete within the entire Nile Basin (Sutcliffe, J.V. & Parks, Y.P., 1999). From Malakal the entire outflow from the Sudd (including the contribution from the Bahr el-Ghazal) can be monitored based on the difference from the upstream contribution of the Sobat River measured at Doleib Hill. Table 6-24 presents the proposed hydrometric stations for the Bahr el-Jebel sub-basin.

Table 6-24. Bahr el-Jebel hydrometric stations

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| SSD_004_Hyd | Malakal | 9.536 | 31.644 | Active | WL, D | PS | Sat |
| SSD_005_Hyd | Mongalla | 5.202 | 31.768 | Active | WL, D | PS | Sat |
| SSD_009_Hyd | River Assua at mouth | 3.723 | 31.972 | Inactive | WL, D, WQ | Rad | Sat |

### *Meteorological Design*

14 meteorological stations are proposed for monitoring the Bahr el-Jebel basin. Of these 14 stations 4 are Active, 8 are Inactive requiring some kind of rehabilitation, and 2 are New. The number of proposed stations is less than the initial guideline calculated in Equation 6-1. This is a result of moderate annual rainfall but also very low rainfall variability as shown in Figure 6-6 and Figure 6-7 respectively. These factors result in a less dense network required to achieve adequate spatial coverage to capture rainfall. The spatial distribution is evident from Figure 6-20, while the elevation distribution is demonstrated in Figure 6-21. Table 6-25 provides a list of the proposed meteorological stations and associated attributes for the Bahr el-Jebel basin.

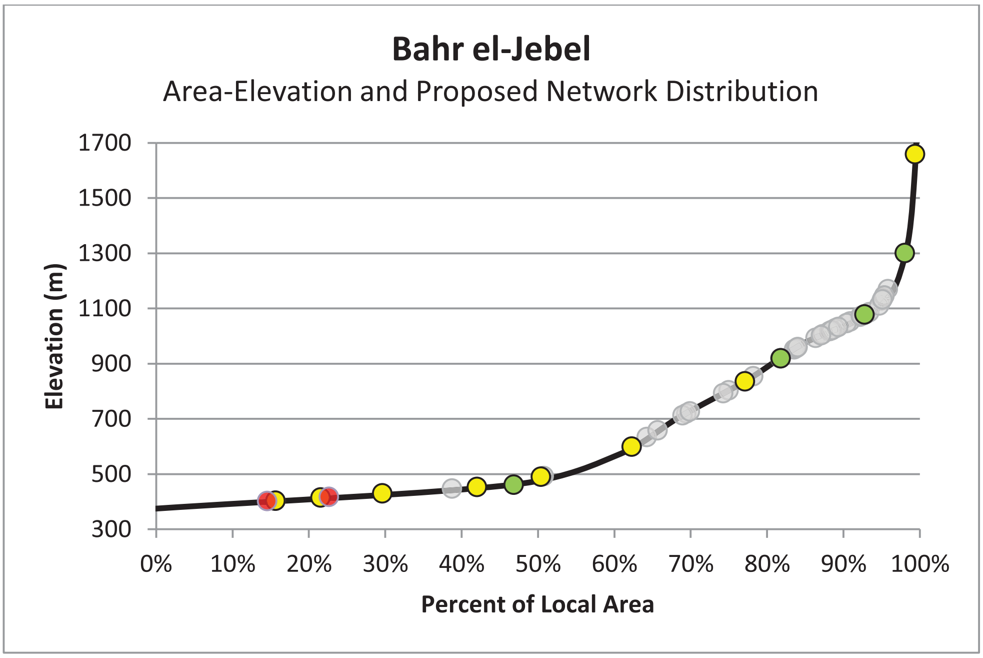


Figure 6-21. Bahr el-Jebel elevation distribution for meteorological network

Table 6-25. Bahr el-Jebel meteorological stations

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| SSD_002_Met | Juba | 4.867 | 31.600 | Active | Full Met | AWS | Sat |
| SSD_008_Met | TORIT | 4.417 | 32.550 | Inactive | Full Met | AWS | Sat |
| SSD_010_Met | YEI | 4.083 | 30.667 | Inactive | Full Met | AWS | Sat |
| SSD_011_Met | BOR | 6.217 | 31.550 | Inactive | Full Met | AWS | Sat |
| SSD_016_Met | TONGA | 9.770 | 31.080 | Inactive | Rainfall | ARG | Sat |
| SSD_019_Met | SHAMBE | 7.190 | 31.270 | Inactive | Rainfall | ARG | Sat |
| SSD_022_Met | LUI | 5.550 | 30.750 | Inactive | Rainfall | ARG | Sat |
| SSD_023_Met | MONGALLA | 5.410 | 32.380 | Inactive | Rainfall | ARG | Sat |
| SSD_028_Met | Fakwak | 8.355 | 30.724 | New | Full Met | AWS | Sat |
| SSD_032_Met | Pachua | 10.080 | 29.947 | New | Rainfall | ARG | Sat |
| UGA_002_Met | Gulu Met Station | 2.783 | 32.283 | Active | Full Met | AWS | Sat |
| UGA_033_Met | Kitgum Centre VT | 3.300 | 32.883 | Active | Full Met | AWS | Sat |
| UGA_035_Met | Karenga | 3.483 | 33.717 | | Rainfall | ARG | Sat |
| UGA_041_Met | Morulem | 2.617 | 33.767 | Active | Rainfall | ARG | Sat |

### 6.4.7 Bahr el-Ghazal

The entire area of the Bahr el-Ghazal sub-basin is approximately 605,000 $km^2$. The northern half of the basin in Sudan experiences almost no flow due minimal annual rainfall. The southern half located in Southern Sudan receives significant annual rainfall but the majority of seasonal runoff is intercepted by downstream wetlands that results in only about 3% of the basin's total flow reaching the Nile (Sutcliffe, J.V. & Parks, Y.P., 1999). These losses to evaporation are similar to the hydrologic processes of the Bahr el-Jebel but become even greater due to the more seasonal nature of inflows and greater number of shallow channels flooding over into unrestricted clay plains. The proposed design for the Bahr el-Ghazal sub-basin is shown in Figure 6-22. This design primarily helps achieve an understanding of hydrologic accounting but also provides some benefits that address Regional Issue 1 (releases from Jinja) from Table 4-2 based on the assessment of contributing flow to the Main Nile.

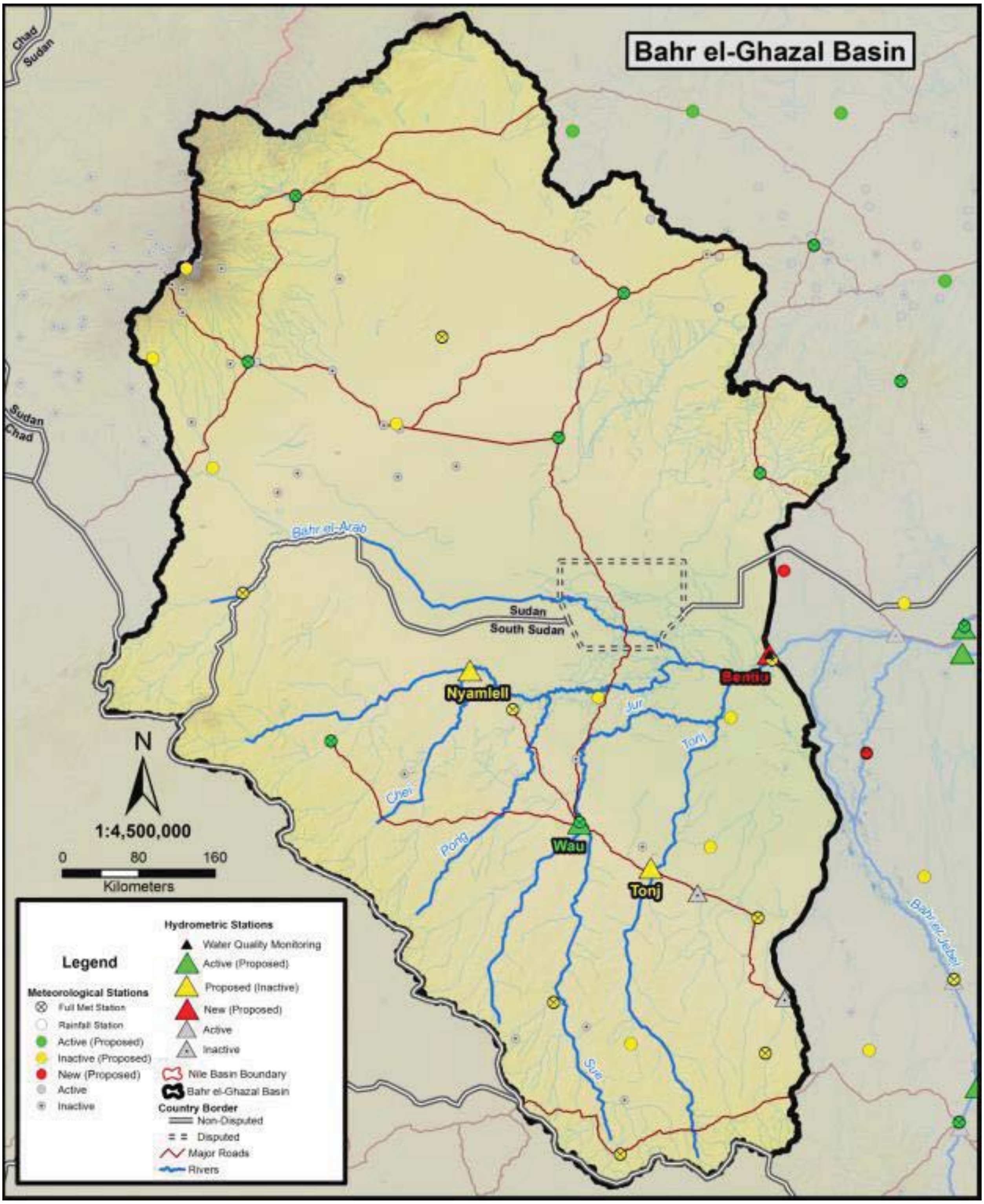


Figure 6-22. Bahr el-Ghazal proposed hydro-meteorological network design

### *Hydrometric Design*

4 hydrometric stations are proposed for monitoring the Bahr el-Ghazal sub-basin. Based on historical findings it may be difficult to justify regional monitoring for a basin that contributes almost no flow to the Nile system. However, this would not be known without the historical data that led to this understanding and therefore continued monitoring on a regional basis should be continued to better understand the complex hydrology of the Bahr el-Ghazal.

The proposed network includes monitoring of Lol River at Nyamlell, Jur River at Wau, and Tonj River at Tonj. These tributaries are estimated to account for approximately 80% of the total flow in the Bhar el-Ghazal (Sutcliffe, J.V. & Parks, Y.P., 1999). In addition, a new hydrometric site is proposed at Bentiu. It is believed by representatives of South Sudan that the proposed location offers a stable channel that captures the majority of outflow from the basin. Monitoring of flows at Bentiu may allow for a better understanding the evaporative losses before or after this point based on the flows at downstream Malakal. It is also proposed that water quality monitoring be conducted at Bentiu to assess potential upstream oil exploration activities within the Abyei region. Table 6-26 presents the proposed hydrometric stations for the Bahr el-Ghazal sub-basin.

Table 6-26. Bahr el-Ghazal hydrometric stations

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| SSD_007_Hyd | Nyamlell | 9.139 | 26.978 | Inactive | WL, D | PS | Sat |
| SSD_010_Hyd | Wau | 7.694 | 28.014 | Active | WL, D | Rad | Sat |
| SSD_011_Hyd | Tonj | 7.272 | 28.687 | Inactive | WL, D | Rad | Sat |
| SSD_012_Hyd | Bentiu | 9.292 | 29.804 | New | WL, D, WQ | PS | Sat |

***Meteorological Design***

23 meteorological stations are proposed for monitoring the Bahr el-Ghazal basin. Of these 23 stations 7 are Active, and 16 are Inactive requiring some kind of rehabilitation. The number of proposed stations is less than the initial guideline calculated in Equation 6-1. This is primarily a result of very low rainfall variability as shown in Figure 6-7 but also very low annual rainfall in the northern half of the basin as shown in Figure 6-6. These factors result in a less dense network required to achieve adequate spatial coverage to capture rainfall. The spatial distribution is evident from Figure 6-22, while the elevation distribution is demonstrated in Figure 6-23. Table 6-27 provides a list of the proposed meteorological stations and associated attributes for the Bahr el-Ghazal basin.

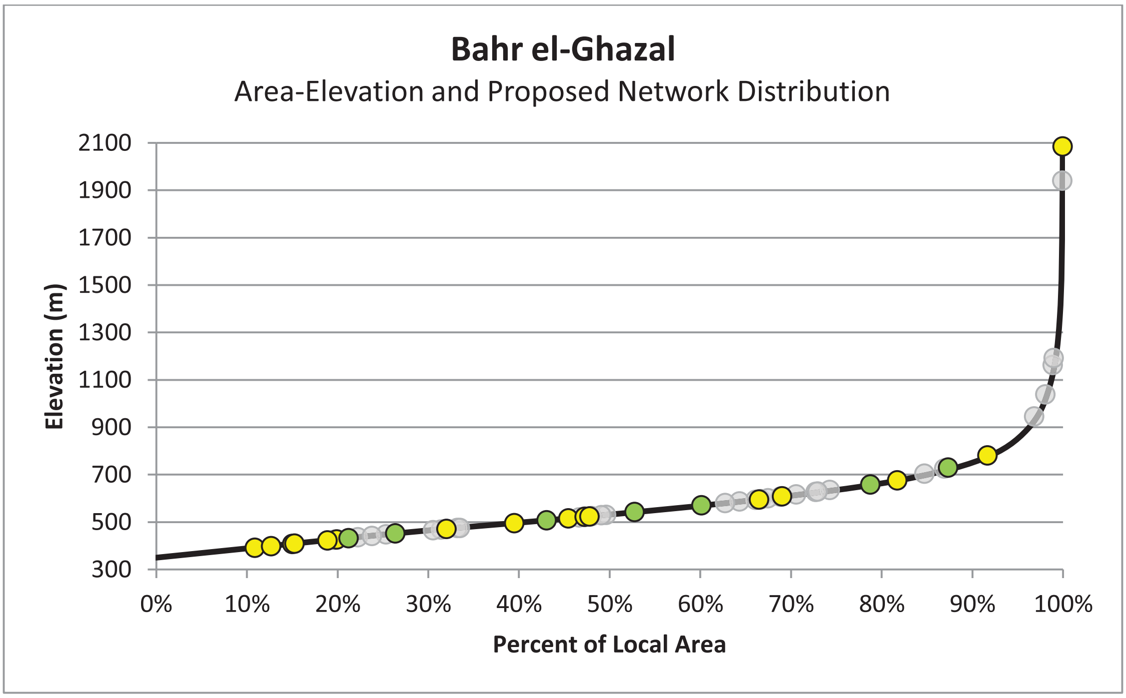


Figure 6-23. Bahr el-Ghazal elevation distribution for meteorological network

**Table 6-27. Bahr el-Ghazal meteorological stations**

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| SSD_003_Met | Wau | 7.700 | 28.017 | Active | Full Met | AWS | Sat |
| SSD_005_Met | Raga | 8.467 | 25.667 | Active | Full Met | AWS | Sat |
| SSD_006_Met | BENTIU | 9.233 | 29.833 | Inactive | Full Met | AWS | Sat |
| SSD_007_Met | RUMBEK | 6.800 | 29.700 | Inactive | Full Met | AWS | Sat |
| SSD_009_Met | YAMBIO | 4.567 | 28.400 | Inactive | Full Met | AWS | Sat |
| SSD_012_Met | AWEIL | 8.767 | 27.383 | Inactive | Full Met | AWS | Sat |
| SSD_017_Met | GOGREIAL | 8.880 | 28.190 | Inactive | Rainfall | ARG | Sat |
| SSD_018_Met | MESHRAERREQ | 8.690 | 29.440 | Inactive | Rainfall | ARG | Sat |
| SSD_020_Met | TONJ | 7.470 | 29.250 | Inactive | Rainfall | ARG | Sat |
| SSD_024_Met | MARIDI | 5.520 | 29.770 | Inactive | Full Met | AWS | Sat |
| SSD_025_Met | NA'ANDI | 5.610 | 28.500 | Inactive | Rainfall | ARG | Sat |
| SSD_027_Met | TUMBURA | 6.000 | 27.770 | Inactive | Full Met | AWS | Sat |
| SUD_009_Met | El Fasher | 13.617 | 25.333 | Active | Full Met | AWS | Sat |
| SUD_016_Met | Kadugli | 11.000 | 29.717 | Active | Full Met | AWS | Sat |
| SUD_017_Met | Babanusa | 11.333 | 27.817 | Active | Full Met | AWS | Sat |
| SUD_018_Met | En Nahud | 12.700 | 28.433 | Active | Full Met | AWS | Sat |
| SUD_022_Met | Nyala | 12.050 | 24.883 | Active | Full Met | AWS | Sat |
| SUD_033_Met | DANKOG | 12.083 | 23.983 | Inactive | Rainfall | ARG | Sat |
| SUD_034_Met | EL-TEWAISHA | 12.283 | 26.717 | Inactive | Full Met | AWS | Sat |
| SUD_035_Met | Gazala gawazat | 11.467 | 26.283 | Inactive | Rainfall | ARG | Sat |
| SUD_036_Met | RADOM | 9.867 | 24.833 | Inactive | Full Met | AWS | Sat |
| SUD_037_Met | TORA TONGA | 12.933 | 24.300 | Inactive | Rainfall | ARG | Sat |
| SUD_038_Met | tulus | 11.050 | 24.550 | Inactive | Rainfall | ARG | Sat |

### 6.4.8 Baro-Akobo-Sobat

The total area for the Baro-Akobo-Sobat sub-basin is approximately 204,000 $km^2$. The total flow contribution is almost half of the White Nile or about one sixth of the whole Nile (Sutcliffe, J.V. & Parks, Y.P., 1999). This is almost equal to the total outflow of the Sudd. The majority of runoff results from the Ethiopian highlands in the east portion of the basin with the main tributaries consisting of the Baro, Gilo, and Akobo Rivers. The Gilo combines with the Akobo which then converges with the Pibor River out of southeastern South Sudan. The Pibor continues north forming the border between South Sudan and Ethiopia before converging with the Baro to form the Sobat River. The confluence of the Sobat and White Nile occurs just upstream of Malakal gauging location. The proposed design for the Baro-Akobo-Sobat sub-basin is shown in Figure 6-24. This design helps achieve the required monitoring to address Regional Issue 6 (releases of potential dams on the Baro) from Table 4-2 as well as general hydrologic accounting.

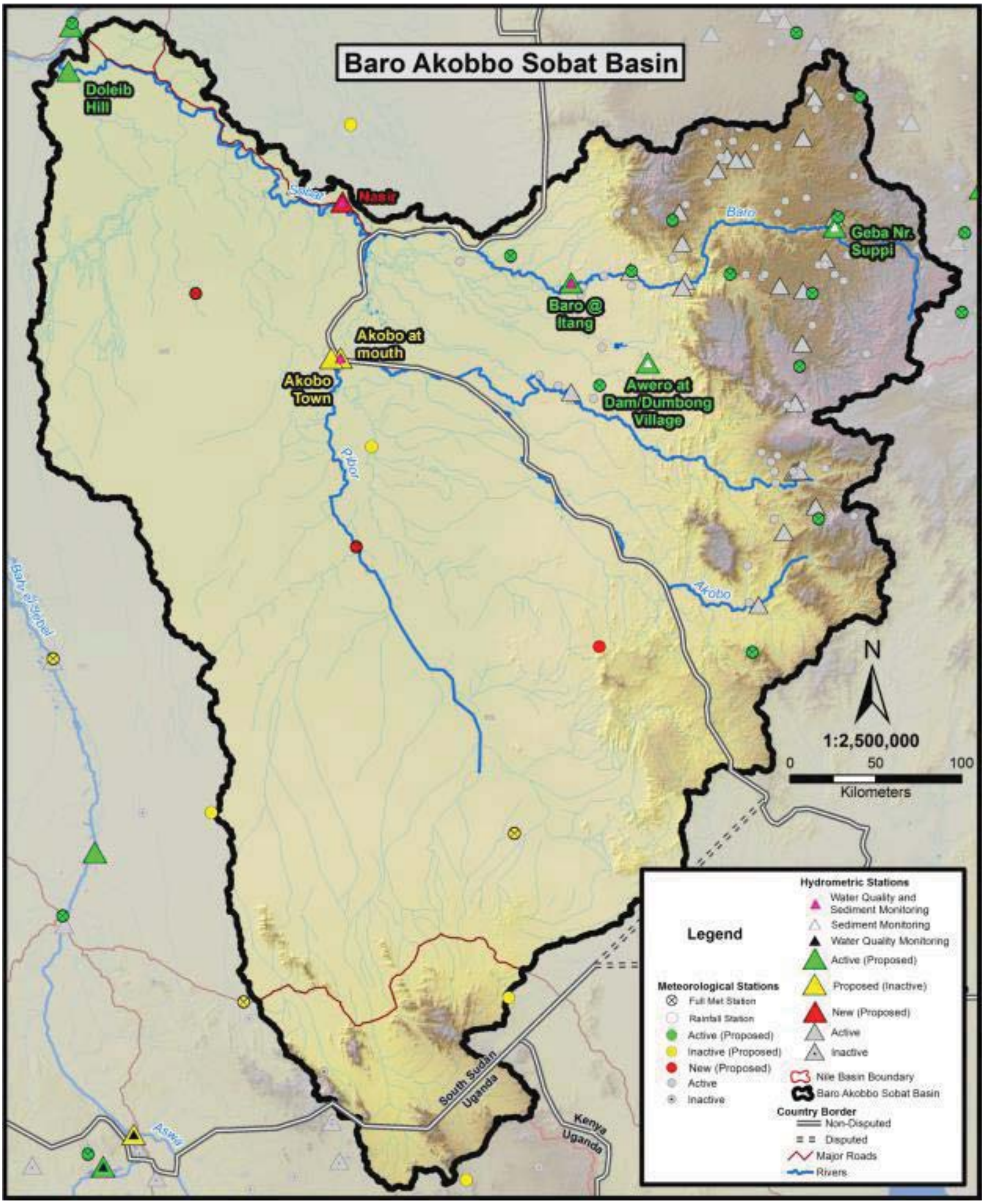


Figure 6-24. Baro-Akobo-Sobat proposed hydro-meteorological network design

### *Hydrometric Design*

7 hydrometric stations are proposed for monitoring the Baro-Akobo-Sobat sub-basin. This consists of the Geba near Suppi gauge for monitoring the upstream contribution of the Baro. The Baro at Itang site is proposed as the last downstream location capable of conducting discharge measurements before the Gambeila/Machar Marshes. This site is also downstream of a proposed dam near Gambeila adding to its importance to assess releases. The Awero at Dam/Dubong Village is also a proposed

location within Ethiopia to monitor the downstream releases of a new dam. All of the sites in Ethiopia are proposed to conduct sediment monitoring as this is a notable issues within the Ethiopian highlands, while the Baro at Itang is also proposed to monitor water quality for transboundary purposes.

Within South Sudan the Akobo at Mouth gauges is proposed to monitor the flow, suspended sediment and water quality resulting from the Akobo River before the confluence with Pibor. Upstream of the confluence the Akobo Town gauge will monitor the total flow of the Pibor before the confluence with Akobo. Further downstream the total flow, suspended sediment, and water quality is proposed at Nasir along the Sobat to assess the full impact of the three main tributaries just downstream of the confluence of the Pibor and Baro Rivers. The last proposed regional station is Doleib Hill before the confluence with the White Nile. This gauge contains records dating back to 1905 and provides the total flow contribution of the Baro-Akobo-Sobat basin. Table 6-28 presents the proposed hydrometric stations for the Baro-Akobo-Sobat sub-basin.

**Table 6-28. Baro-Akobo-Sobat hydrometric stations**

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| ETH_001_Hyd | Geba Nr. Suppi | 8.483 | 35.650 | Active | WL, D, S | Rad | Sat |
| ETH_002_Hyd | Baro @ Itang | 8.190 | 34.267 | Active | WL, D, WQ, S | PS | Sat |
| ETH_011_Hyd | Awero at Dam/Dumbong Village | 7.770 | 34.670 | Active | WL, D, S | PS | Sat |
| SSD_001_Hyd | Akobo at mouth | 7.795 | 33.057 | Inactive | WL, D, WQ, S | PS | Sat |
| SSD_002_Hyd | Akobo Town | 7.794 | 33.009 | Inactive | WL, D | PS | Sat |
| SSD_003_Hyd | Doleib Hill | 9.300 | 31.630 | Active | WL, D | PS | Sat |
| SSD_006_Hyd | Nasir | 8.615 | 33.067 | New | WL, D, WQ, S | PS | Sat |

### *Meteorological Design*

17 meteorological stations are proposed for monitoring the Baro-Akobo-Sobat basin. Of these 17 stations 11 are Active, 3 are Inactive requiring some kind of rehabilitation, and 3 are New. The number of proposed stations is slightly less than the initial guideline calculated in Equation 6-1. This is a result of high annual rainfall in the northeast but moderate to low in the rest of the basin as shown in Figure 6-6. Similarly, more rainfall variability existing in the eastern portion of the basin in the Ethiopian highlands compared with the low variability throughout majority of the western half of the basin as shown in Figure 6-7. These factors contribute to the need for a denser network for the eastern half of the basin versus the western which requires fewer stations to provide adequate spatial coverage for less variability. The spatial distribution is evident from Figure 6-24, while the elevation distribution is demonstrated in Figure 6-25. Table 6-29 provides a list of the proposed meteorological stations and associated attributes for the Baro Akobo Sobat basin.

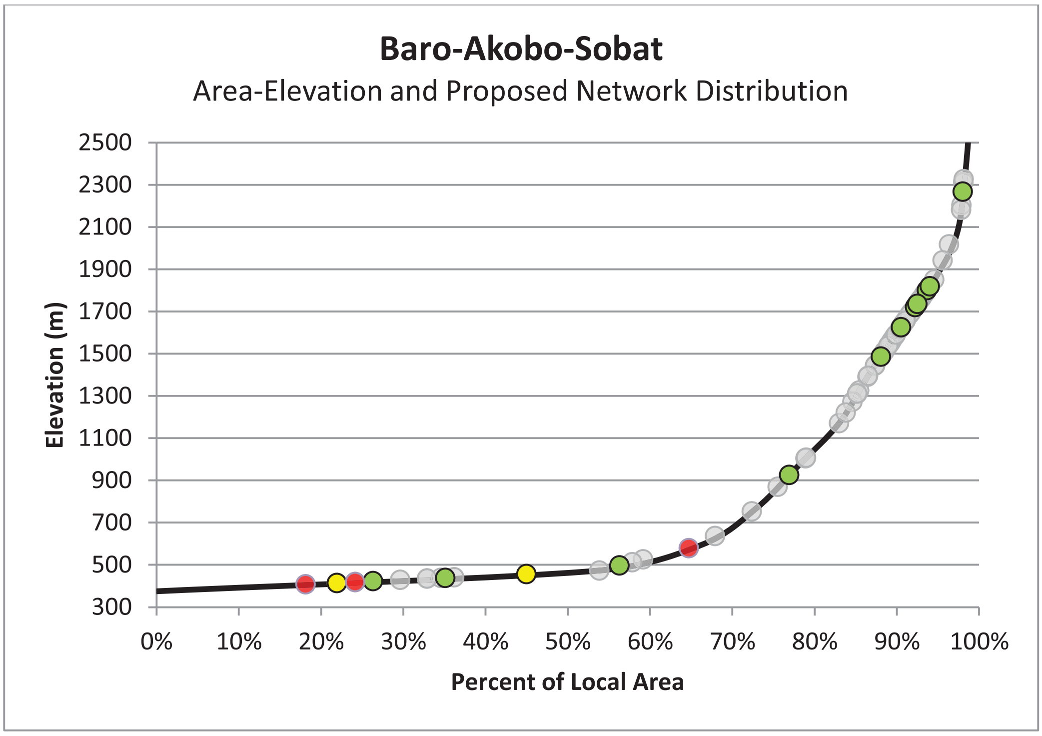


Figure 6-25. Baro-Akobo-Sobat elevation distribution for meteorological network

Table 6-29. Baro-Akobo-Sobat meteorological stations

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| ETH_020_Met | Alge | 8.533 | 35.667 | Active | Full Met | AWS | GPRS |
| ETH_022_Met | Bure | 8.233 | 35.100 | Active | Full Met | AWS | GPRS |
| ETH_023_Met | Fugnido | 7.650 | 34.417 | Active | Full Met | AWS | GPRS |
| ETH_024_Met | Gambela | 8.250 | 34.583 | Active | Full Met | AWS | GPRS |
| ETH_025_Met | Jikawo (Lare) | 8.330 | 33.950 | Active | Full Met | AWS | Sat |
| ETH_026_Met | Masha | 7.750 | 35.467 | Active | Full Met | AWS | Sat |
| ETH_027_Met | Aman | 6.950 | 35.567 | Active | Full Met | AWS | GPRS |
| ETH_028_Met | Jeba | 6.250 | 35.218 | Active | Full Met | AWS | Sat |
| ETH_042_Met | Dembidolo | 8.517 | 34.800 | Active | Full Met | AWS | Sat |
| ETH_044_Met | Gimbi | 9.167 | 35.783 | Active | Full Met | AWS | Sat |
| ETH_057_Met | Gore | 8.133 | 35.533 | Active | Full Met | AWS | GPRS |
| SSD_015_Met | PIBOR | 7.330 | 33.220 | Inactive | Rainfall | ARG | Sat |
| SSD_021_Met | KAPOETA | 5.300 | 33.970 | Inactive | Full Met | AWS | Sat |
| SSD_026_Met | NAGI SHOT | 4.440 | 33.940 | Inactive | Rainfall | ARG | Sat |
| SSD_029_Met | Pibor Post | 6.804 | 33.140 | New | Full Met | AWS | Sat |
| SSD_030_Met | Boma | 6.281 | 34.415 | New | Rainfall | ARG | Sat |
| SSD_031_Met | Faddoi | 8.133 | 32.298 | New | Full Met | AWS | Sat |

For logistical reasons, only 7 of the proposed 11 meteorological stations in Ethiopia will be included in the regional network for the Baro-Akobo-Sobat basin. Appendix B includes the final list, consistent with the implementation plan.

### 6.4.9 White Nile

The total area for the White Nile sub-basin is approximately 259,000 $km^2$. The majority of flow is a result of upstream contributions from the Sudd outflow and Sobat River with minimal and sporadic inflows from small tributaries. The Jebel Aulia dam is 40 km upstream of the confluence with the Blue Nile in Khartoum and controls the water level of the “reservoir” in the White Nile through northern South Sudan. This has allowed for increased irrigation and control of the White Nile to delay releases during the low flow season of the Blue Nile. As a result this has also increased the total losses of the reach which are on average about 12-14% less at the confluence with the Blue Nile than what is monitored at Malakal (Sutcliffe, J.V. & Parks, Y.P., 1999). The proposed design for the White Nile sub-basin is shown in Figure 6-26. This design helps achieve the required monitoring to address Regional Issue 7 (releases of Jebel Aulia) from Table 4-2.

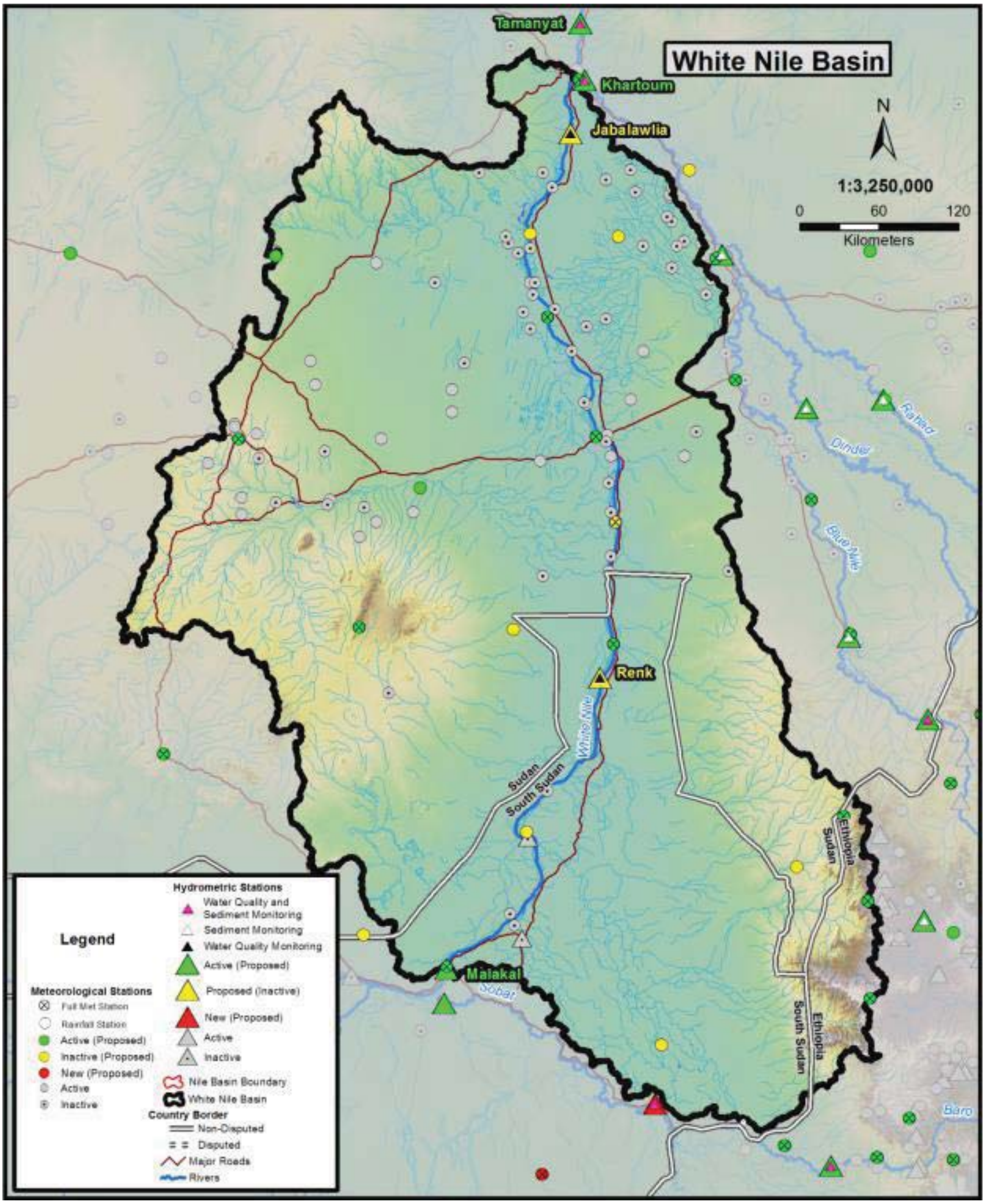


**Figure 6-26. White Nile proposed hydro-meteorological network design**

### *Hydrometric Design*

Only 3 hydrometric stations are proposed for monitoring the White Nile sub-basin. These are the Renk station in northern South Sudan, the Jabalawlia on the Jebel Aulia reservoir, and the Tamanyat station on the Main Nile downstream of the Blue and White Nile confluence in Khartoum. The Renk station is proposed to assess the water level from the Jebel Aulia reservoir as well as the water quality due to potential oil exploration in the region and the associated transboundary implications between Sudan and South Sudan. Further downstream, the Jabalawlia gauge in Sudan will provide water level and water quality on the Jebel Aulia reservoir just upstream of the dam. The Tamanyat station allows for the total White Nile flow to be calculated based on the difference with the Blue Nile flows provided at Khartoum. As a result, additional gauges necessary to calculate the total White Nile flow and potential local gains and losses include the Blue Nile gauge at Khartoum and inflows from the Malakal station. Table 6-30 presents the proposed hydrometric stations for the White Nile sub-basin. Note that the Tamanyat station is provided in both Table 6-30 and Table 6-38 for the Main Nile sub-basin due to its importance for each.

Table 6-30. White Nile hydrometric stations

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| SSD_008_Hyd | Renk | 11.520 | 32.690 | Inactive | WL, WQ | PS | Sat |
| SUD_008_Hyd | Tamanyat | 15.985 | 32.559 | Active | WL, D, WQ, S | PS | Sat |
| SUD_013_Hyd | Jabalawlia | 15.233 | 32.490 | Inactive | WL, WQ | PS | Sat |

### *Meteorological Design*

17 meteorological stations are proposed for monitoring the White Nile basin. Of these 17 stations 10 are Active, and 7 are Inactive requiring some kind of rehabilitation. The number of proposed stations is less than the initial guideline calculated in Eq 6-1. This is a result of low annual rainfall and low rainfall variability as shown in Figure 6-6 and Figure 6-7 respectively. These factors result in a less dense network required to achieve adequate spatial coverage to capture rainfall. The spatial distribution is evident from Figure 6-26, while the elevation distribution is demonstrated in Figure 6-27. Special attention was given to capturing the evaporative losses along the Jebel Aulia reservoir with Full Met stations distributed along the reach. Table 6-31 provides a list of the proposed meteorological stations and associated attributes for the White Nile basin.

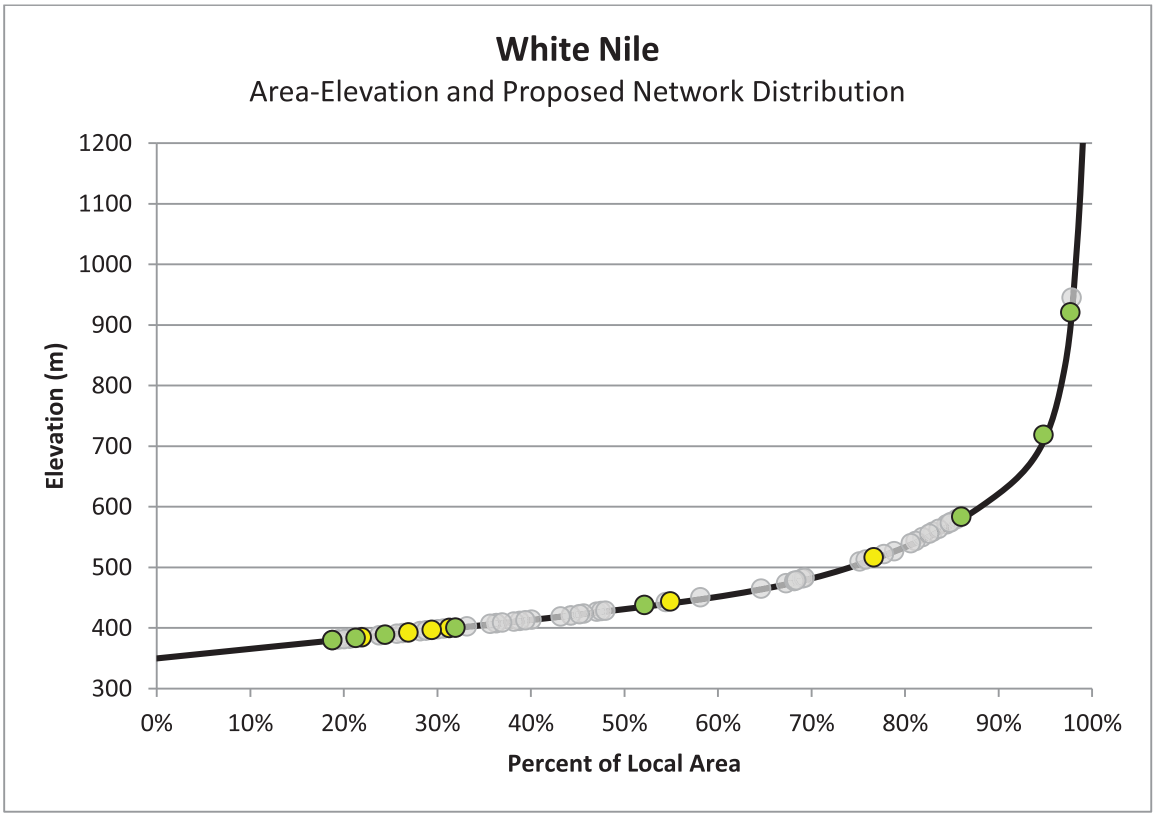


Figure 6-27. White Nile elevation distribution for meteorological network

Table 6-31. White Nile meteorological stations

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| ETH_040_Met | Assosa | 10.000 | 34.517 | Active | Full Met | AWS | GPRS |
| ETH_041_Met | Begi | 9.333 | 34.533 | Active | Full Met | AWS | GPRS |
| ETH_046_Met | Kurmuk | 10.577 | 34.354 | Active | Full Met | AWS | Sat |
| SSD_001_Met | Malakal | 9.550 | 31.650 | Active | Full Met | AWS | Sat |
| SSD_004_Met | Renk | 11.750 | 32.783 | Active | Full Met | AWS | Sat |
| SSD_013_Met | KODOK | 10.470 | 32.190 | Inactive | Rainfall | ARG | Sat |
| SSD_014_Met | NASIR | 9.020 | 33.110 | Inactive | Rainfall | ARG | Sat |
| SUD_008_Met | Ed Dueim | 13.983 | 32.333 | Active | Full Met | AWS | Sat |
| SUD_012_Met | Kosti | 13.167 | 32.667 | Active | Full Met | AWS | Sat |
| SUD_021_Met | Rashad | 11.867 | 31.050 | Active | Full Met | AWS | Sat |
| SUD_024_Met | Elobeid | 13.150 | 30.230 | Active | Full Met | AWS | Sat |
| SUD_026_Met | Aldali | 10.233 | 34.033 | Inactive | Rainfall | ARG | Sat |
| SUD_039_Met | EL NEIMA | 14.533 | 32.817 | Inactive | Rainfall | ARG | Sat |
| SUD_040_Met | Fatisa | 14.550 | 32.217 | Inactive | Rainfall | ARG | Sat |
| SUD_041_Met | J Megeneis | 11.850 | 32.100 | Inactive | Rainfall | ARG | Sat |
| SUD_044_Met | Shirkela Um aush | 12.817 | 31.467 | Active | Rainfall | ARG | Sat |
| SUD_051_Met | Jebelein | 12.583 | 32.800 | Inactive | Full Met | AWS | Sat |

### 6.4.10 Upper Blue Nile

The entire area of the Upper Blue Nile sub-basin is approximately 175,000 km$^2$. It is estimated that the Blue Nile River contributes 60% of the total flow to the Nile but the contribution is highly seasonal with approximately 85% of that volume occurring between the months of July and October (Sutcliffe, J.V. & Parks, Y.P., 1999). This can result in significant flooding along both the main stem and major tributaries. In addition, there are considerable concerns with erosion and sedimentation both within the Upper Blue Nile and other Ethiopian headwaters. It is estimated that the Eastern Nile sub-basin which consists of the Blue Nile, Tekeze-Atbara, and Baro-Akobo Sobat contribute 97% of the total sediment load to the Nile River (NBI et al., 2012). The proposed design for the Upper Blue Nile sub-basin is shown in Figure 6-28. This design helps achieve the required monitoring to address Regional Issue 3 (releases and management of GERD) from Table 4-2.

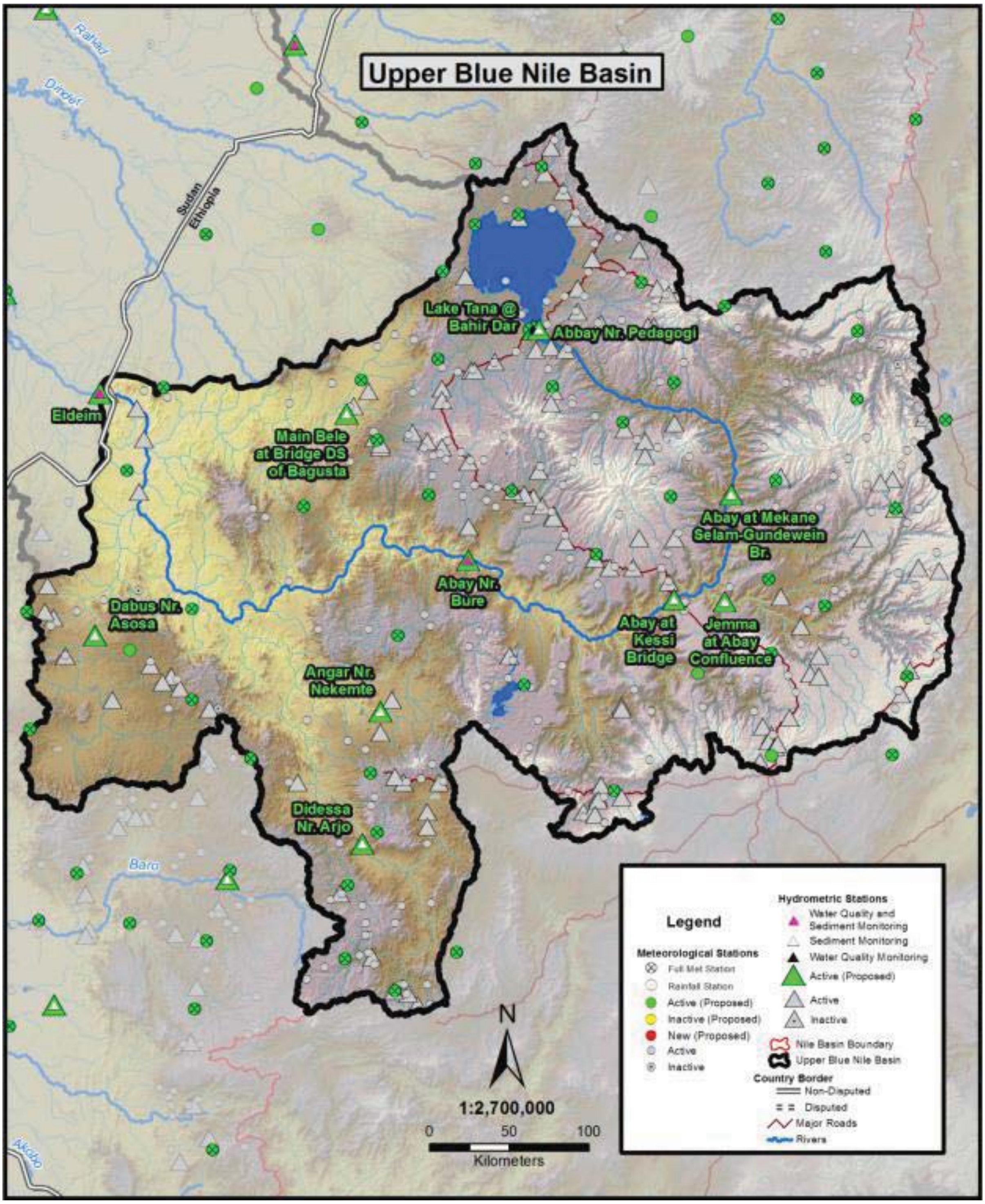


Figure 6-28. Upper Blue Nile proposed hydro-meteorological network design

***Hydrometric Design***

11 hydrometric stations are proposed for monitoring the Upper Blue Nile sub-basin. 5 of the 11 stations are located directly on the Blue Nile (or Abay) River, 5 are on major tributaries, and one is proposed to monitor Lake Tana. All of these locations with the exception of the Lake Tana water level station at Bahir Dara are proposed to include sediment monitoring in order to address and identify the sources of major soil erosion. Many of the proposed sites were discussed with Ethiopian representatives at the Conceptual Design Workshop to identify the best downstream accessible

locations of primary tributaries. Several of these locations are not ideal but are the best sites based on existing major roads.

The last downstream site before the proposed Grand Ethiopian Renaissance Dam (GERD) near the Sudan-Ethiopia border is the Abay Nr. Bure. In addition to sediment monitoring this location is proposed to include water quality monitoring for inflows to the GERD. A site further downstream was proposed by Ethiopian representatives but it is believed these existing locations will be inundated by the GERD reservoir (see Appendix B) and no other current accessible roads and locations were found along the main river this far downstream. Other water quality monitoring locations include the water level station for Lake Tana and the outlet of the basin downstream of the GERD at the Eldeim gauge in Sudan for transboundary implications.

The design is believed to capture the majority of the main tributaries or enough points along the main Blue Nile to conduct basic regional hydrologic modeling to gain a better understanding of the expected quantity and timing of flows at specified hydrometric sites and overall inflows to the future GERD. It is believed that monitoring of additional tributaries would be beneficial in the regional design but key downstream locations on these tributaries are currently inaccessible due to a lack of existing roads in the vicinity of these rivers. Unlike meteorological stations, which can be conveniently located to represent a broad spatial area of interest and require only infrequent visits to provide maintenance, hydrometric stations are constrained to be on the river network, often coincide with challenging terrain, and require more frequent visits to conduct discharge and sediment monitoring, especially during the flood season. It may be valuable for NBI and Ethiopia to consider the expansion of both the regional and national networks as future transportation developments facilitate accessibility for monitoring. Table 6-32presents the proposed hydrometric stations for the Upper Blue Nile sub-basin.

**Table 6-32. Upper Blue Nile hydrometric stations**

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| ETH_003_Hyd | Lake Tana @ Bahir Dar | 11.600 | 37.383 | Active | WL, WQ | PS | Sat |
| ETH_004_Hyd | Didessa Nr. Arjo | 8.683 | 36.417 | Active | WL, D, S | Rad | Sat |
| ETH_005_Hyd | Angar Nr. Nekemte | 9.433 | 36.517 | Active | WL, D, S | Rad | Sat |
| ETH_006_Hyd | Dabus Nr. Asosa | 9.867 | 34.900 | Active | WL, D, S | Rad | Sat |
| ETH_009_Hyd | Abay Nr. Bure | 10.292 | 37.013 | Active | WL, D, WQ, S | Rad | Sat |
| ETH_010_Hyd | Abbay Nr. Pedagogi | 11.600 | 37.417 | Active | WL, D, S | PS | Sat |
| ETH_012_Hyd | Jemma at Abay Confluence | 10.056 | 38.466 | Active | WL, D, S | Rad | Sat |
| ETH_013_Hyd | Abay at Kessi Bridge | 10.070 | 38.180 | Active | WL, D, S | Rad | Sat |
| ETH_014_Hyd | Abay at Mekane Selam-Gundewein Br. | 10.664 | 38.503 | Active | WL, D, S | Rad | Sat |
| ETH_015_Hyd | Main Bele at Bridge DS of Bagusta | 11.120 | 36.326 | Active | WL, D, S | Rad | Sat |
| SUD_001_Hyd | Eldeim | 11.238 | 34.928 | Active | WL, D, WQ, S | PS | Sat |

It has been noted that five of the above stations have been upgraded recently with monitoring equipment and telemetry. Five additional hydrometric monitoring stations were requested by Ethiopia representatives for monitoring needs in the Tekeze-Atbara (3) and Baro-Akobo-Sobat (2) basins. These are identified in Appendix B and in the complete table of hydrometric stations in Appendix C.

### *Meteorological Design*

41 meteorological stations are proposed for monitoring the Upper Blue Nile basin. All of these 41 stations are currently active. The number of proposed stations is significantly more than the initial value calculated in Eq 6-1. This is a result of high annual rainfall and high rainfall variability as shown

in Figure 6-6 and Figure 6-7 respectively. In addition, there are considerable orographic effects within the Ethiopian highlands and some additional shoreline stations necessary to monitor Lake Tana. These factors contribute to the need for a denser network. The spatial distribution is evident from Figure 6-28, while the elevation distribution is demonstrated in Figure 6-29. Table 6-33 provides a list of the proposed meteorological stations and associated attributes for the Upper Blue Nile basin.

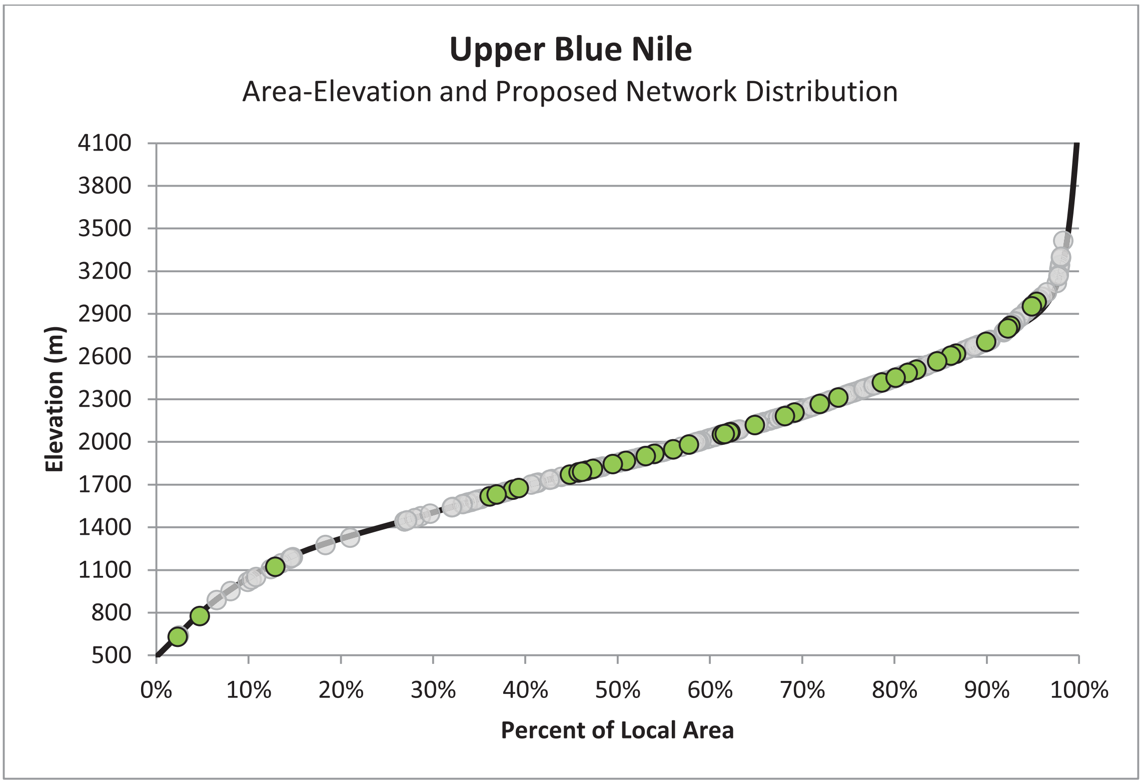


Figure 6-29. Upper Blue Nile elevation distribution for meteorological network

Table 6-33. Upper Blue Nile meteorological stations

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| ETH_003_Met | Debre Tabor | 11.867 | 37.995 | Active | Full Met | AWS | Sat |
| ETH_009_Met | Shahura | 11.929 | 36.874 | Active | Full Met | AWS | GPRS |
| ETH_010_Met | Adet | 11.274 | 37.493 | Active | Full Met | AWS | Sat |
| ETH_011_Met | Ayehu | 10.661 | 36.793 | Active | Full Met | AWS | Sat |
| ETH_012_Met | Bullen | 10.596 | 36.082 | Active | Full Met | AWS | Sat |
| ETH_013_Met | Chagni | 10.974 | 36.499 | Active | Full Met | AWS | Sat |
| ETH_014_Met | Dangila | 11.434 | 36.846 | Active | Full Met | AWS | Sat |
| ETH_015_Met | Debre Work | 10.651 | 38.162 | Active | Full Met | AWS | Sat |
| ETH_016_Met | Finoteselam | 10.682 | 37.263 | Active | Full Met | AWS | Sat |
| ETH_018_Met | Motta | 11.074 | 37.890 | Active | Full Met | AWS | Sat |
| ETH_019_Met | Pawe | 11.312 | 36.410 | Active | Full Met | AWS | Sat |
| ETH_021_Met | Bedele | 8.450 | 36.333 | Active | Full Met | AWS | Sat |
| ETH_029_Met | Alem Ketema | 10.033 | 39.033 | Active | Full Met | AWS | GPRS |
| ETH_030_Met | Ambo Agriculture | 8.985 | 37.840 | Active | Full Met | AWS | GPRS |
| ETH_031_Met | Debre Berhan | 9.633 | 39.500 | Active | Full Met | AWS | Sat |
| ETH_032_Met | Fiche | 9.767 | 38.733 | Active | Full Met | AWS | GPRS |

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| ETH_033_Met | Gunde Meskel | 10.183 | 38.717 | Active | Full Met | AWS | Sat |
| ETH_039_Met | Arjo | 8.750 | 36.500 | Active | Full Met | AWS | GPRS |
| ETH_043_Met | Gidayana | 9.867 | 36.617 | Active | Full Met | AWS | GPRS |
| ETH_045_Met | Kamashe | 10.017 | 35.450 | Active | Full Met | AWS | GPRS |
| ETH_047_Met | Nedjo | 9.500 | 35.450 | Active | Full Met | AWS | Sat |
| ETH_048_Met | Amba Mariam | 11.203 | 39.217 | Active | Full Met | AWS | GPRS |
| ETH_051_Met | Mekane Selam | 10.743 | 38.757 | Active | Full Met | AWS | Sat |
| ETH_052_Met | Wegel Tena | 11.590 | 39.221 | Active | Full Met | AWS | Sat |
| ETH_053_Met | Wereilu | 10.579 | 39.437 | Active | Full Met | AWS | Sat |
| ETH_054_Met | Gondar A.P. | 12.521 | 37.432 | Active | Full Met | AWS | Sat |
| ETH_055_Met | Bahir Dar New | 11.600 | 37.360 | Active | Full Met | AWS | GPRS |
| ETH_056_Met | Debre Markos | 10.326 | 37.739 | Active | Full Met | AWS | Sat |
| ETH_060_Met | Nekemte | 9.083 | 36.463 | Active | Full Met | AWS | GPRS |
| ETH_063_Met | Gorgora | 12.250 | 37.300 | Active | Full Met | AWS | Sat |
| ETH_066_Met | Agaro | 7.850 | 36.600 | Active | Full Met | AWS | GPRS |
| ETH_067_Met | Siadebr | 9.650 | 38.317 | Active | Rainfall | ARG | Sat |
| ETH_068_Met | Sululta | 9.183 | 38.733 | Active | Rainfall | ARG | Sat |
| ETH_071_Met | Mendi | 9.783 | 35.100 | Active | Rainfall | ARG | Sat |
| ETH_072_Met | Sherekole | 10.800 | 35.083 | Active | Full Met | AWS | GPRS |
| ETH_074_Met | Delgi | 12.193 | 37.055 | Active | Full Met | AWS | Sat |
| ETH_075_Met | Setema | 8.033 | 36.317 | Active | Full Met | AWS | GPRS |
| ETH_076_Met | Shola Gebeya | 9.191 | 39.416 | Active | Full Met | AWS | Sat |
| ETH_077_Met | Simada | 11.300 | 38.180 | Active | Full Met | AWS | Sat |
| ETH_078_Met | Combolcha | 11.086 | 39.720 | Active | Full Met | AWS | Sat |
| ETH_083_Met | Limu Genet | 8.070 | 36.950 | Active | Full Met | AWS | GPRS |

For logistical reasons, only 19 of the proposed 41 meteorological stations in Ethiopia will be included in the regional network for the Upper Blue Nile basin. Appendix B includes the final list, consistent with the implementation plan.

### 6.4.11 Lower Blue Nile

The entire area of the Lower Blue Nile sub-basin is approximately 132,000 km$^2$. This sub-basin was sub-divided from the Upper Blue Nile to primarily provide an improved visual display of the network in each associated map. There is minimal flow contribution to the main Blue Nile downstream of the Ethiopian border but there are significant seasonal flows in the two main tributaries of the Dinder and Rahad from July through October. However, these two rivers typically become completely dry at the mouths from January through May (Sutcliffe, J.V. & Parks, Y.P., 1999). The proposed design for the Lower Blue Nile sub-basin is shown in Figure 6-30. This design primarily helps achieve an understanding of hydrologic accounting but also provides benefits that address Regional Issues 3 (releases and management of GERD) and 8 (Nile water quality) from Table 4-2.

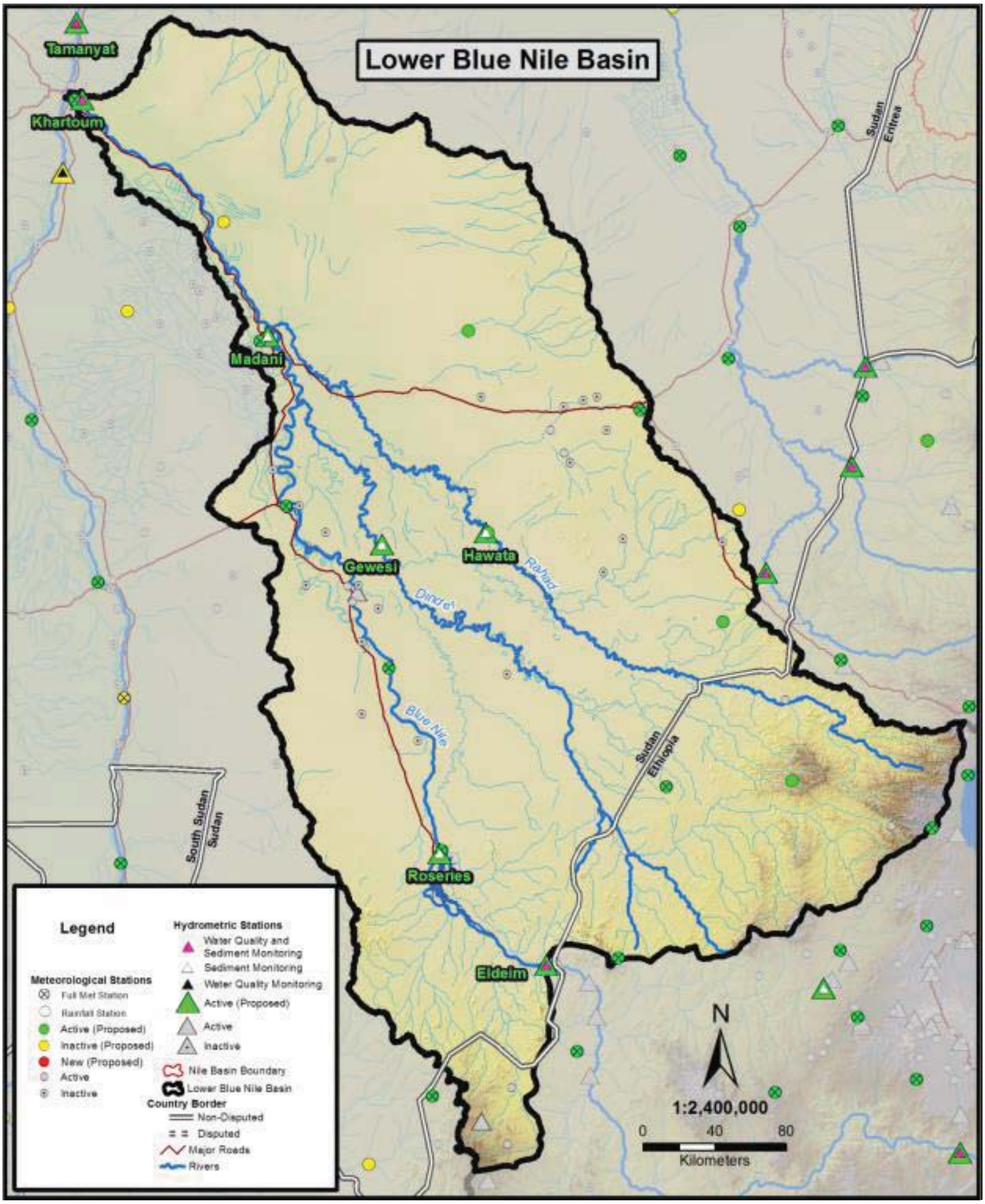


Figure 6-30. Lower Blue Nile proposed hydro-meteorological network design

### *Hydrometric Design*

5 hydrometric stations are proposed for the Lower Blue Nile sub-basin. All of these locations include sediment monitoring to continue to track the loads from upstream headwaters in Ethiopia all the way to the confluence with the Main Nile. The Roseries station is proposed to monitor the regulated outflows the Roseires dam which has an impact on downstream users. Similarly, the Madani station allows for the assessment of the releases from the upstream Sennar dam when taking the difference of the Gwesi gauge that monitors the Dinder flows. The Hawata gauge monitors the flows on the Rahad.

The last downstream gauge for the entire Blue Nile is at Khartoum. This is a very important location for assessing the total quantity and quality of flow contribution from the Blue Nile before the confluence with the White to form the Main Nile. In addition, monitoring of this gauge allows for the entire White Nile contribution to be assessed based on the difference calculated from the total flow at Tamanyat. Table 6-34 presents the proposed hydrometric stations for the Lower Blue Nile sub-basin.

Table 6-34. Lower Blue Nile hydrometric stations

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| SUD_002_Hyd | Roseries | 11.800 | 34.389 | Active | WL, D, S | Rad | Sat |
| SUD_003_Hyd | Madani | 14.406 | 33.523 | Active | WL, D, S | Rad | Sat |
| SUD_004_Hyd | Khartoum | 15.599 | 32.588 | Active | WL, D, WQ, S | Rad | Sat |
| SUD_005_Hyd | Gewesi | 13.357 | 34.099 | Active | WL, D, S | PS | Sat |
| SUD_006_Hyd | Hawata | 13.416 | 34.623 | Active | WL, D, S | PS | Sat |

***Meteorological Design***

13 meteorological stations are proposed for monitoring the Lower Blue Nile basin. Of these 13 stations 12 are Active, and 1 is Inactive requiring some kind of rehabilitation. The number of proposed stations is less than the initial guideline calculated in Eq 6-1. This is a result of low annual rainfall and low rainfall variability as shown in Figure 6-6 and Figure 6-7 respectively. These factors contribute to the need for a less dense network. The spatial distribution is evident from Figure 6-30, while the elevation distribution is demonstrated in Figure 6-31. Table 6-35 provides a list of the proposed meteorological stations and associated attributes for the Lower Blue Nile basin.

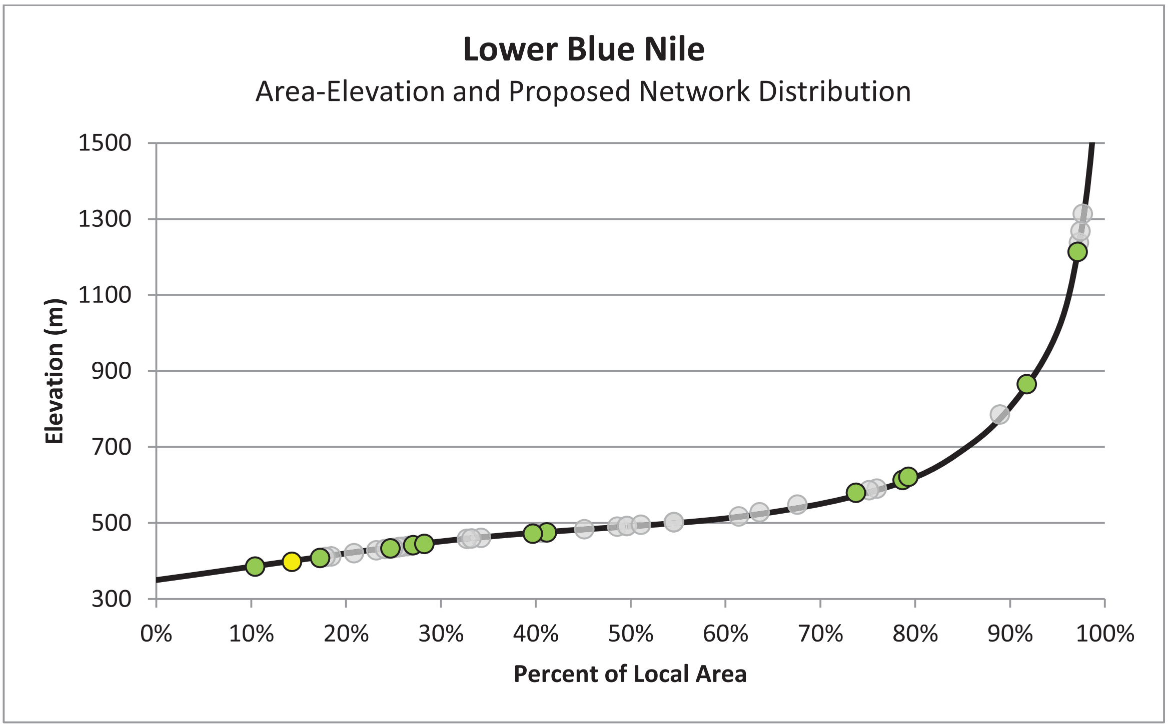


Figure 6-31. Lower Blue Nile elevation distribution for meteorological network

Table 6-35. Lower Blue Nile meteorological stations

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| ETH_007_Met | Quara | 12.137 | 35.532 | Active | Full Met | AWS | Sat |
| ETH_017_Met | Mankush | 11.273 | 35.291 | Active | Full Met | AWS | GPRS |
| ETH_065_Met | Kunzila | 12.167 | 36.167 | Active | Rainfall | ARG | Sat |
| SUD_001_Met | Abu Naama | 12.733 | 34.133 | Active | Full Met | AWS | Sat |
| SUD_002_Met | Sennar | 13.550 | 33.617 | Active | Full Met | AWS | Sat |
| SUD_003_Met | Wad Medani | 14.383 | 33.483 | Active | Full Met | AWS | Sat |
| SUD_006_Met | Ed Damazine | 11.817 | 34.400 | Active | Full Met | AWS | Sat |
| SUD_010_Met | Khartoum | 15.600 | 32.550 | Active | Full Met | AWS | Sat |
| SUD_015_Met | El Gadaref | 14.033 | 35.400 | Active | Full Met | AWS | Sat |
| SUD_042_Met | Wd alkali | 14.983 | 33.300 | Inactive | Rainfall | ARG | Sat |
| SUD_047_Met | Basunda | 12.967 | 35.817 | Active | Rainfall | ARG | Sat |
| SUD_049_Met | ElFaw | 14.433 | 34.533 | Active | Rainfall | ARG | Sat |
| SUD_050_Met | ElHawata | 13.417 | 34.633 | Active | Rainfall | ARG | Sat |

### 6.4.12 Tekeze-Atbara

The entire area of the Tekeze-Atbara sub-basin is approximately 232,000 km$^2$. The seasonal nature and variability of flows in the Blue Nile is similar to those for the Tekeze-Atbara basin. However, the total volume of the Tekeze Atbara basin is only about 20-25% of the total Blue Nile flow (Sutcliffe, J.V. & Parks, Y.P., 1999). Never the less this is still a considerable 12-15% contribution of the total Nile volume. The primary rivers of the basin include the Tekeze (or Setit), Angareb and Atbara. The Atbara converges first with the Angereb and then the Tekeze at confluences west of the Sudan-Ethiopia border. The Atbara River continues northwest until it meets the Main Nile at the town of Atbara. The proposed design for the Tekeze-Atbara sub-basin is shown in Figure 6-32. This design primarily helps address Regional Issues 2 (releases and management of Tekeze dam) and 8 (Nile water quality) from Table 4-2 but also provides hydrologic accounting.

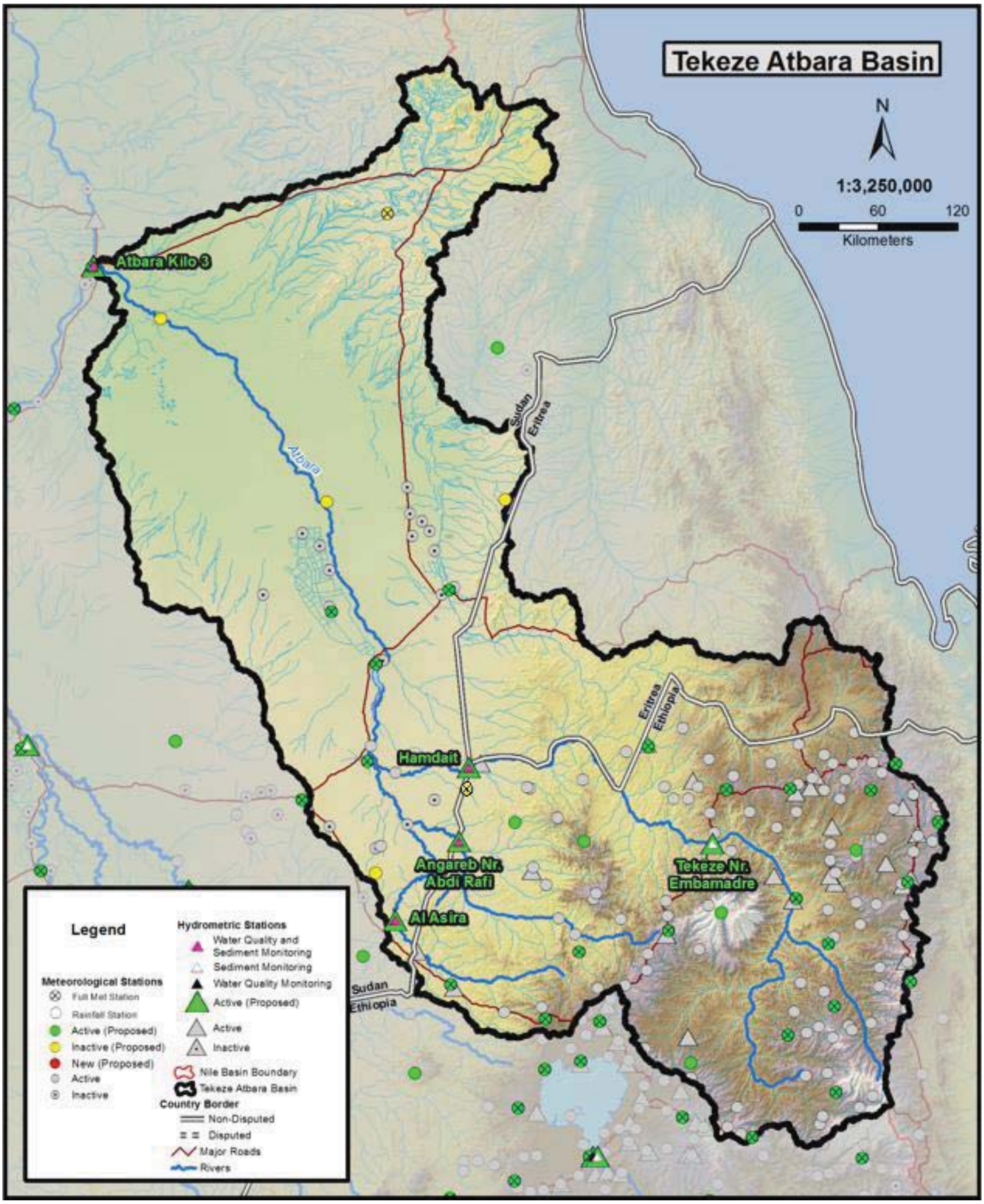


Figure 6-32. Tekeze-Atbara proposed hydro-meteorological network design

### *Hydrometric Design*

5 hydrometric stations are proposed for monitoring the Tekeze-Atbara basin. All of these locations include sediment monitoring in order to track the loads from upstream headwaters in Ethiopia all the way to the confluence with the Main Nile. In addition water quality monitoring is proposed at Hamdait, Angareb Nr. Abdi Rafi, and Al Asira stations to assess the transboundary implications of the main rivers. Water quality is also proposed at the downstream station Atbara Kilo 3 to assess the impact on the Main Nile before the confluence.

The furthest upstream proposed gauge is the Tekeze Nr Embamadre to assess the outflows from the Tekezze dam and the large watershed downstream of the dam. It is situated at a very accessible main road. Early design proposals included at site near Yechila believed to be just downstream of the Tekezze dam but it was later discovered the location was fully inundated and no accessible site between Embamadre and the dam was found. Similar to the recommendation of the Upper Blue Nile basin, the Tekezze Basin regional design could benefit from gauges on downstream reaches of main tributaries but most of these locations appear to be currently inaccessible. These matters were discussed at the Final Design workshop and it is recommended that Ethiopia and NBI remain in close communication to assess the expansion of both the regional and national network as future transportation developments facilitate accessibility for monitoring.

As noted previously the Hamdait, Angareb Nr. Abdi Rafi, and Al Asira stations are proposed to monitor transboundary flows between Ethiopia and Sudan but also provide rational hydrologic dividing points to assess the total contribution of from each main river before the confluences that form the complete Atbara. Likewise, the Atbara Kilo 3 provides the total flow contribution of the Atbara before the confluence with the Main Nile. Table 6-36 presents the proposed hydrometric stations for the Tekeze-Atbara sub-basin.

**Table 6-36. Tekeze-Atabara hydrometric stations**

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| ETH_007_Hyd | Tekeze Nr. Embamadre | 13.733 | 38.200 | Active | WL, D, S | Rad | Sat |
| ETH_008_Hyd | Angareb Nr. Abdi Rafi | 13.750 | 36.467 | Active | WL, D, WQ, S | Rad | Sat |
| SUD_007_Hyd | Atbara Kilo 3 | 17.679 | 33.974 | Active | WL, D, WQ, S | Rad | Sat |
| SUD_011_Hyd | Al Asira | 13.213 | 36.034 | Active | WL, D, WQ, S | PS | Sat |
| SUD_012_Hyd | Hamdait | 14.254 | 36.537 | Active | WL, D, WQ, S | PS | Sat |

***Meteorological Design***

35 meteorological stations are proposed for monitoring the Tekeze-Atbara basin. Of these 35 stations 31 are Active, and 4 are Inactive requiring some kind of rehabilitation. The number of proposed stations is more than the initial guideline calculated in Eq 6-1. This is a result of moderate annual rainfall in the southeast but low annual rainfall in the northwest as shown in Figure 6-6. Similarly, more rainfall variability exists for the southeastern portion of the basin in the Ethiopian highlands compared with the low variability in the northwest of the basin as shown in Figure 6-7. These factors contribute to the need for a denser network for the southeast versus the northwest. The spatial distribution is evident from Figure 6-32, while the elevation distribution is demonstrated in Figure 6-33. Table 6-37 provides a list of the proposed meteorological stations and associated attributes for the Tekeze-Atbara basin.

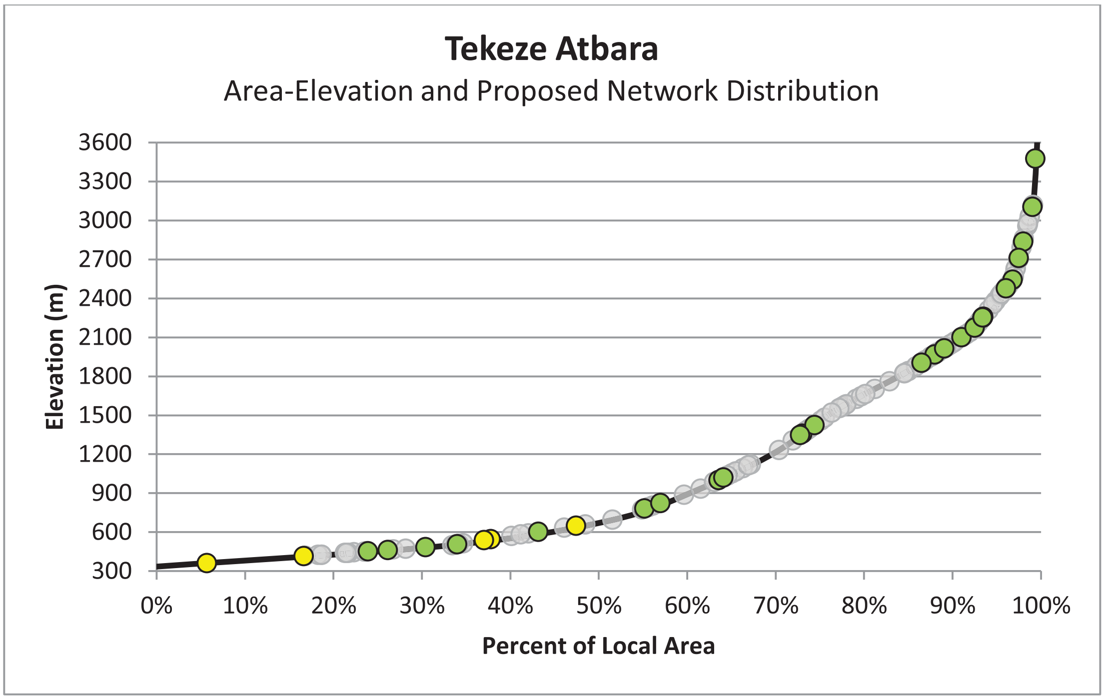


Figure 6-33. Tekeze-Atbara elevation distribution for meteorological network

Table 6-37. Tekeze-Atbara meteorological stations

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| ETH_001_Met | Aykel | 12.540 | 37.059 | Active | Full Met | AWS | Sat |
| ETH_002_Met | Debark | 13.142 | 37.898 | Active | Full Met | AWS | GPRS |
| ETH_004_Met | Humera | 14.104 | 36.522 | Inactive | Full Met | AWS | GPRS |
| ETH_005_Met | Metema | 12.775 | 36.414 | Active | Full Met | AWS | GPRS |
| ETH_006_Met | Nefas Mewcha | 11.730 | 38.468 | Active | Full Met | AWS | GPRS |
| ETH_008_Met | Sanja | 12.998 | 37.289 | Active | Full Met | AWS | Sat |
| ETH_035_Met | Atsebi | 13.883 | 39.741 | Active | Full Met | AWS | Sat |
| ETH_036_Met | May Tsebri | 13.589 | 38.145 | Active | Full Met | AWS | Sat |
| ETH_037_Met | Nebelet | 14.100 | 39.280 | Active | Full Met | AWS | Sat |
| ETH_038_Met | Shire Endasilasse | 14.102 | 38.294 | Active | Full Met | AWS | GPRS |
| ETH_049_Met | Amde Work | 12.428 | 38.714 | Active | Full Met | AWS | Sat |
| ETH_050_Met | Lalibela | 12.039 | 39.040 | Active | Full Met | AWS | GPRS |
| ETH_058_Met | Axum Air Port | 14.110 | 38.730 | Active | Full Met | AWS | Sat |
| ETH_059_Met | Mekele Air Port | 13.471 | 39.531 | Active | Full Met | AWS | GPRS |
| ETH_061_Met | Baeker | 13.880 | 36.850 | Active | Rainfall | ARG | Sat |
| ETH_062_Met | Chenek | 13.262 | 38.259 | Active | Rainfall | ARG | Sat |
| ETH_064_Met | Guhala | 12.240 | 38.050 | Active | Rainfall | ARG | Sat |
| ETH_069_Met | Adiremets | 13.750 | 37.321 | Active | Rainfall | ARG | Sat |
| ETH_070_Met | Guroro | 13.690 | 39.180 | Active | Rainfall | ARG | Sat |
| ETH_073_Met | Sekota | 12.626 | 39.031 | Active | Full Met | AWS | GPRS |
| ETH_079_Met | Adigrat | 14.280 | 39.450 | Active | Full Met | AWS | Sat |
| ETH_080_Met | Maichew | 12.790 | 39.550 | Active | Full Met | AWS | Sat |
| ETH_081_Met | Shiraro | 14.401 | 37.760 | Active | Full Met | AWS | Sat |

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| ETH_082_Met | Tekeze Hydro power | 13.360 | 38.770 | Active | Full Met | AWS | GPRS |
| ETH_084_Met | Niruaq | 13.050 | 38.990 | Active | Full Met | AWS | GPRS |
| SUD_019_Met | Kassala | 15.467 | 36.400 | Active | Full Met | AWS | Sat |
| SUD_020_Met | New Halfa | 15.317 | 35.600 | Active | Full Met | AWS | Sat |
| SUD_023_Met | Khashm Elgirba | 14.961 | 35.903 | Active | Full Met | AWS | Sat |
| SUD_025_Met | Elshwak | 14.294 | 35.846 | Active | Full Met | AWS | Sat |
| SUD_027_Met | Hamsh Koreab | 17.117 | 36.733 | Active | Rainfall | ARG | Sat |
| SUD_028_Met | Goz Ragab | 16.067 | 35.567 | Inactive | Rainfall | ARG | Sat |
| SUD_029_Met | Sidon | 17.317 | 34.433 | Inactive | Rainfall | ARG | Sat |
| SUD_030_Met | Togan | 16.083 | 36.783 | Inactive | Rainfall | ARG | Sat |
| SUD_031_Met | Barbar | 18.033 | 35.983 | Inactive | Full Met | AWS | Sat |
| SUD_048_Met | Doka | 13.533 | 35.900 | Inactive | Rainfall | ARG | Sat |

For logistical reasons, only 10 of the proposed 25 meteorological stations in Ethiopia will be included in the regional network for the Tekeze-Atbara basin. Appendix B includes the final list, consistent with the implementation plan.

### 6.4.13 Main Nile

The entire area of the Main Nile sub-basin up to Lake Nasser/Nubia is approximately 593,000 km$^2$. Losses are experienced for the entire stretch of Tamanyat to Lake Nasser/Nubia with the exception of considerable seasonal gains from the Atbara tributary. In general, the total losses attributed to channel evaporation, losses to bank storage with subsequent evapotranspiration, and irrigation abstraction have continued to steadily rise over time (Sutcliffe, J.V. & Parks, Y.P., 1999). The proposed design for the Main Nile sub-basin is shown in Figure 6-34. This design primarily addresses Regional Issue 8 (Nile water quality) from Table 4-2 but also provides hydrologic accounting for the downstream segment of the entire basin.

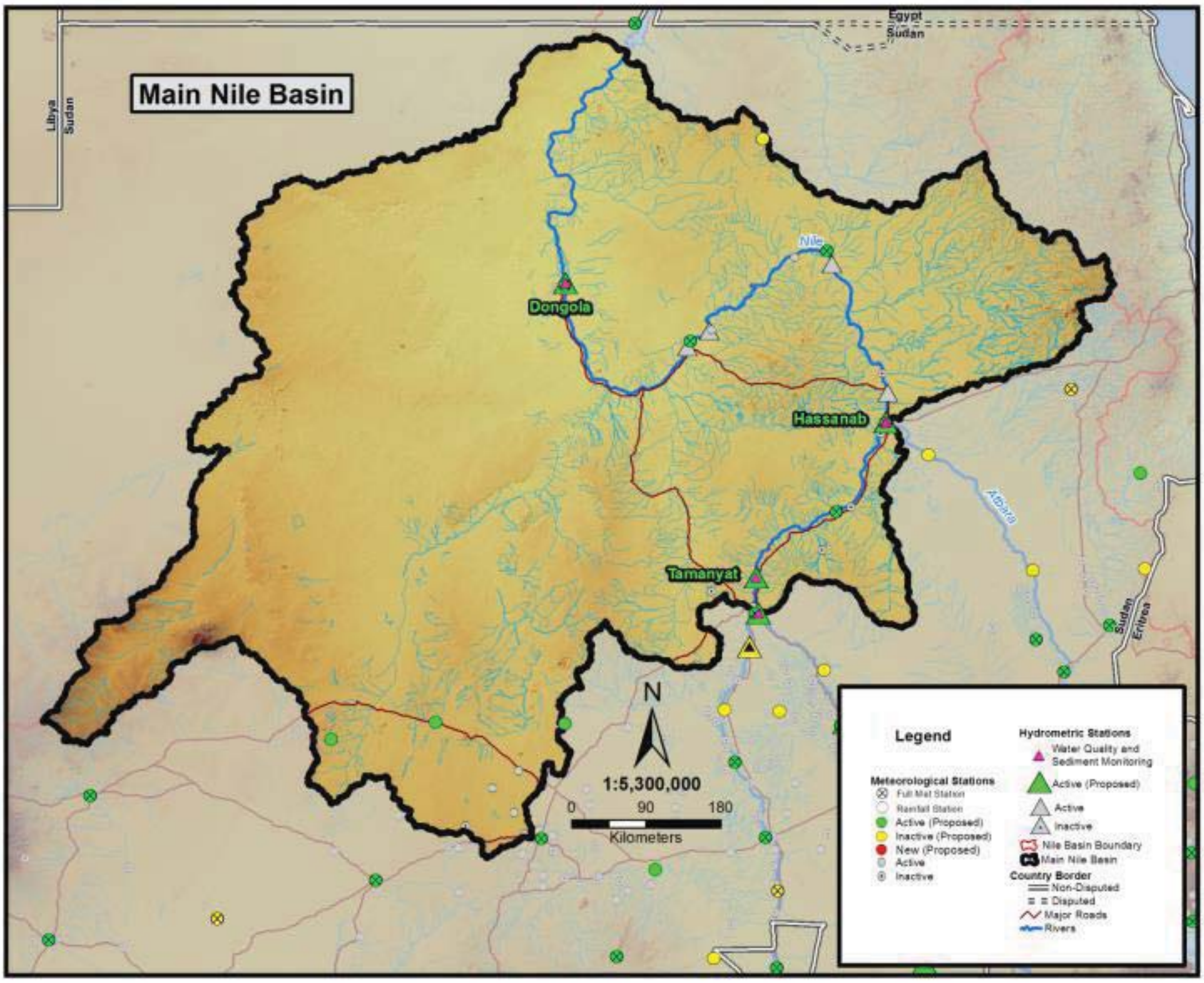


Figure 6-34. Main Nile proposed hydro-meteorological network design

### *Hydrometric Design*

3 hydrometric stations are proposed to monitor the flows within the Main Nile Sub-Basin. All of these sites are proposed to monitor both sediment and water quality along the Nile in order to address Regional Issue 8 (Nile water quality) from Table 4-2. This includes the long standing and stable Tamanyat gauge downstream of Khartoum. This site allows for water accounting of the total White Nile flow contribution from the difference with the Blue Nile Khartoum station. It also provides a starting assessment of total Main Nile flow from the two primary tributaries of the White and Blue. The Hassanab station allows for the accounting of both water quantity and quality before the confluence with Atbara. The Dongola station is the last existing station and stable cross-section to conduct discharge measurements before Lake Nasser/Nubia. This provides the best estimate of delivered quantity and quality of flows to Egypt.

Table 6-38. Main Nile hydrometric stations

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| SUD_008_Hyd | Tamanyat | 15.985 | 32.559 | Active | WL, D, WQ, S | PS | Sat |
| SUD_009_Hyd | Hassanab | 17.676 | 33.973 | Active | WL, D, WQ, S | Rad | Sat |
| SUD_010_Hyd | Dongola | 19.181 | 30.494 | Active | WL, D, WQ, S | Rad | Sat |

***Meteorological Design***

10 meteorological stations are proposed for monitoring the Main Nile basin. Of these 10 stations 9 are Active, and 1 are Inactive requiring some kind of rehabilitation. The number of proposed stations is less than the initial guideline calculated in Eq 6-1. This is a result of very low annual rainfall and moderate rainfall variability as shown in Figure 6-6 and Figure 6-7 respectively. In addition, the majority of the basin is considered desert, which limits accessibility but more importantly offers little justification for establishing a vast meteorological network. The spatial distribution is evident from Figure 6-34, while the elevation distribution is demonstrated in Figure 6-35. Table 6-39 provides a list of the proposed meteorological stations and associated attributes for the Main Nile basin.

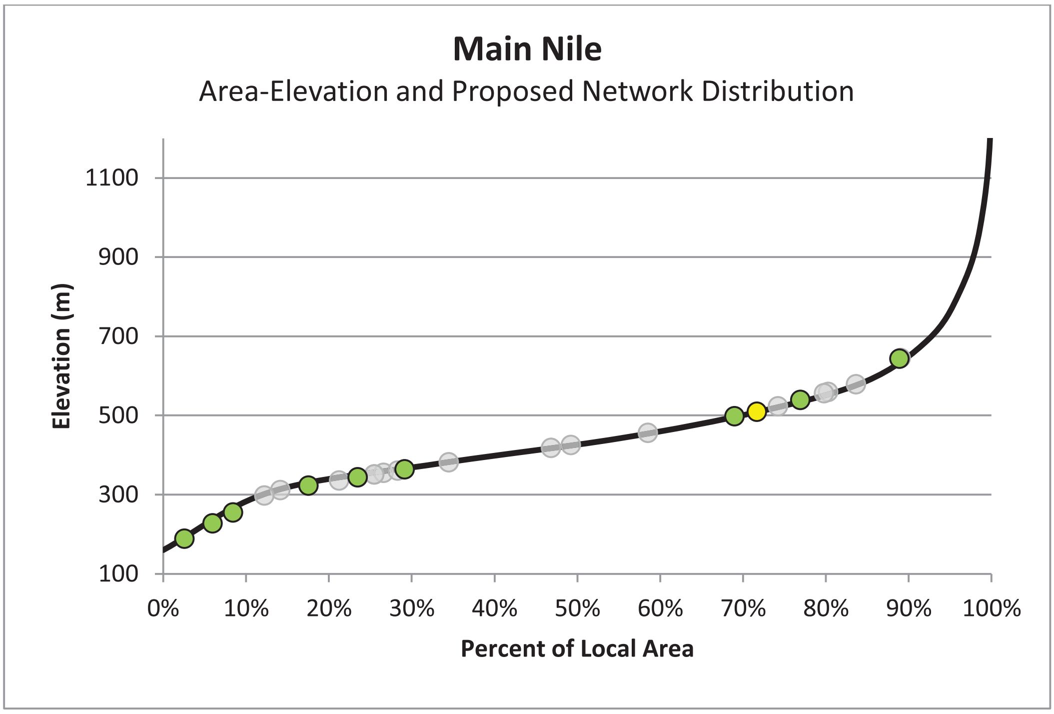


Figure 6-35. Main Nile elevation distribution for meteorological network

Table 6-39. Main Nile meteorological stations

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| SUD_004_Met | Abu Hammad | 19.533 | 33.333 | Active | Full Met | AWS | Sat |
| SUD_005_Met | Atbara | 17.667 | 33.967 | Active | Full Met | AWS | Sat |
| SUD_007_Met | Dongola | 19.167 | 30.483 | Active | Full Met | AWS | Sat |
| SUD_011_Met | Karima | 18.550 | 31.850 | Active | Full Met | AWS | Sat |
| SUD_013_Met | Shendi | 16.700 | 33.433 | Active | Full Met | AWS | Sat |
| SUD_014_Met | Wadi Halfa | 22.000 | 31.250 | Active | Full Met | AWS | Sat |
| SUD_032_Met | Station no.6 | 20.750 | 32.633 | Inactive | Rainfall | ARG | Sat |
| SUD_043_Met | kogmer | 14.400 | 30.483 | Active | Rainfall | ARG | Sat |
| SUD_045_Met | Sodari | 14.417 | 29.083 | Active | Rainfall | ARG | Sat |
| SUD_046_Met | Um bader | 14.233 | 27.950 | Active | Rainfall | ARG | Sat |

# 7 Water Quality Standards and Labs

The goal of water quality monitoring is to verify if the observed water quality satisfies intended purposes of water usage. Monitoring has been used to identify the current status of the river system, and to detect any signs of deterioration in water quality. It has been used for the identification of sections of a river system that do not meet the desired water quality standards and also to point out any grossly contaminated areas and hot spots. Monitoring also assists in the estimation of the pollution load carried by the river, provides information on the effectiveness of pollution control measures put in place, generates data for water research and provides data for decision making in Water Resources Management and Planning (WRMP). In the Nile Basin countries water quality monitoring is of great significance as it assists in the evaluation of a water body and warns users of problems, since most inhabitants draw water directly from lakes, rivers and streams for their domestic uses.

The following section presents the water quality standards associated with sampling, laboratory testing and equipment, quality control and management, staffing, and training necessary to achieve an ideal water quality monitoring program. This will in turn support the regional water quality monitoring network presented as part of the hydrometric design in Section 6.4. As previously described in the hydrometric design criteria of Section 6.3.3, the proposed water quality monitoring addresses regional issues outlined in Table 4-2. The regional design proposes monitoring both basic and advanced water quality parameters. Basic parameters are being defined as temperature, pH, Conductivity, TDS, Dissolved oxygen, Turbidity, BOD, and Nutrients (N, P). Whereas advanced parameters include pesticides, heavy metals and hydrocarbons. Specifics for parameters and equipment at each proposed water quality station are provided in Appendix E. It is worth noting that the advanced parameters presented in Appendix E represent an ideal monitoring protocol for each location but it is recognized that this may not initially be achievable for many countries. As a result the implementation and planning activities in phase 3 of this project will prioritize achieving basic water quality monitoring first and later be supplemented by advanced monitoring once benchmarks in capacity development and retrieval of specialized equipment have been achieved. These principles also coincide with the proposed water quality program standards that follow.

## 7.1 Water Quality Monitoring Standards

### 7.1.1 Sampling and Sample Storage

The aim of sampling is to collect a representative portion of water from a sampling station and convey it to the laboratory for testing. Samples must be properly labeled at the time of sampling. Most samples collected are grab samples which are taken from a given location at a given time. Composite samples may be taken over say a period of 24 hours to capture the flux of pollution discharged through a point source. Other types of samples are integrated samples and in-situ samples.

Sample Containers must be chosen carefully to avoid contamination from the container. They may be of plastic or glass. A wide range of samplers are available depending on the type of sample to be collected and the sample source which may be a river, a lake or a borehole. Samples may be collected manually, or by use of automated samplers. It is also important to record field conditions in addition to carrying out field measurements. Samples may need preservation (often with acid solution) as they are transported to the laboratory. It is general practice to keep samples in a cool box before transferring them to cold storage in the laboratory. On arrival at the laboratory the samples are received and entered in the sample register before storage.

### 7.1.2 Frequency of Sampling

Sampling should have a seasonal bias, but will also depend on a number of other factors such as nature and type of sampling station. It may be quarterly, bi-monthly, monthly, weekly or daily depending on the data needs and also as agreed in the sampling program. Often sampling programs are disrupted due to poor financing for the program and even lack of transport to go the field. The NBI NTEAP had recommended quarterly sampling from the transboundary stations. Nationally sampling frequency is variable from country to country and it also depends on the type of station. Preliminary sampling frequencies for the stations in the regional monitoring network are provided in Appendix E but it is recognized that this is an operational decision to be made according to local site conditions by managers and technicians who conduct the monitoring program.

### 7.1.3 Water Quality Index

An integral part of any environmental monitoring program is the reporting of results to both managers and the general public. This poses a particular problem in the case of water quality monitoring because of the complexity associated with analyzing a large number of measured variables. The traditional practice has been to produce reports describing trends and compliance with official guidelines or other objectives on a variable-by-variable basis. This approach provides a wealth of data and information. However in many cases, managers and the general public have neither the inclination nor the training to study these reports in detail. Rather, the general public and decision makers require statements concerning the general health or status of the system of concern.

One solution to the problem is to reduce the multivariate nature of water quality data by employing an index that will mathematically combine all water quality measures and provide a general and readily understood description of water. The index can be used to assess water quality relative to its desirable state as defined by water quality objectives and to provide insight into the degree to which water quality is affected by human activity. An index is a useful tool for describing the state of the water column, sediments and aquatic life and for ranking the suitability of water for use by humans, aquatic life, wildlife, and for assessing water quality changes. As well a water quality index provides a convenient means of summarizing complex water quality data and facilitating its communication to a general audience.

The Water Quality Index incorporates three elements:

- scope - the number of variables not meeting water quality objectives;
- frequency - the number of times these objectives are not met; and
- amplitude - the amount by which the objectives are not met.

The index produces a number between 0 (worst water quality) and 100 (best water quality). These numbers may be divided into descriptive categories to simplify presentation.

The specific variables, objectives, and time period used in the index are not specified and indeed, could vary from region to region, depending on local conditions and issues. It is recommended that at a minimum, four variables sampled at least four times be used in the calculation of index values. It is also expected that the variables and objectives chosen will provide relevant information about a particular site.

The index can be used both for tracking changes at one site over time, and for comparisons among sites. If used for the later purpose, sites can only be compared directly if the same variables and objectives are used.

The index can be used to reflect the overall and ongoing condition of the water. As with most monitoring programs, an index will not usually show the effect of spills, and other such random and transient events, unless these are relatively frequent or long lasting.

Two references regarding water quality indexing have been provided as a supplemental resource with a summary given in Appendix H. These include the Canadian Council of Ministers of the Environment (CCME) user's manual on water quality index (CCME, 2001) and an application of the CCME procedures for deriving guidelines for a water quality index (Khan, A., et. al., 2005).

### 7.1.4 Laboratory Testing

Laboratory Analysis shall be carried out using carefully chosen and agreed Standard Methods of Testing, such as the American Water Works Association (AWWA), American Public Health Association (APHA), which are currently in use in several countries. Where applicable harmonized water quality testing Manuals developed from the Standard methods, can be used uniformly across the Nile Basin. The selected methods should be well validated, and selective for the parameter to be analyzed.

### 7.1.5 Laboratory Equipment

Equipment for Laboratories can be placed into 3 categories: Field Water Test Kits as described in Section 6.2.11, Standard Basic Laboratory Equipment and Advanced Laboratory Equipment. Most of the Laboratories within the Nile Basin have both Field Test Equipment and Standard basic laboratory equipment to undertake Physico-chemical analysis. Only a few laboratories have procured advanced instrumentation. A list of recommended Basic and Advanced Laboratory equipment is presented in Table 7-1 with specifications for equipment provided in Appendix G.

**Table 7-1. Basic and Advanced Laboratory equipment**

| | | | | |
|---|---|---|---|---|
| **Basic** | UV/Vis Spectrophotometer | Analytical balance | Top-pan balance | pH meter |
| | Conductivity Meter | DO Meter | Water still | Water Bath |
| | Hot plate | Refrigerator | Flame photometer | Turbidimeter |
| | Desiccators | Computer (Desktop) | Printer | Fuming cupboard |
| | Titration equipment | Oven | Centrifuge | Incubator |
| **Advanced** | AAS | GLC | HPLC | ICP_MS |

### 7.1.6 Water Quality Standards

The purpose of water quality monitoring and testing is to check its conformity with existing national Water Quality Standards or Guidelines, as well as specifications for the different water uses. Many of the Nile Basin countries have formulated and established national water quality standards for drinking water against which test results are interpreted. Where national water quality standards have not been formulated the WHO Guidelines for Drinking Water Quality are used. Where applicable, international standards should be used, or if not applicable, local standards should be developed and used. For the Nile Basin, it is important that if regional standards cannot be formulated, then the national standards developed by each country should be able to produce data that is comparable for purposes of future data exchange. It is also important to use uniform and harmonized standard methods of sampling and testing in all countries.

In order to protect rivers and downstream water users, some countries have also established Effluent discharge Standards into water bodies for the regulation of industries, although enforcement of these standards is often a challenge.

### 7.1.7 Quality Control

The main objective of quality control of a process such as water quality monitoring and assessment is to have full control of the processes involved and to be in a position to determine the effectiveness and efficiency of the various processes, from sampling, sample handling, through laboratory analysis, data quality control management up to information production. The recommended use standard and harmonized methods of sampling and water quality testing are a primary quality control requirement which should be embraced by all countries.

A Quality Control/Quality Assurance System is designed to ensure that all activities/processes involved provide the desired good quality of the product, in this case, sound and reliable water quality data.

### 7.1.8 Quality Management System (QMS)

Such a system documents all the relevant interactions between the different but related activities of the WQM cycle. The system also documents the responsibilities with regard to each procedure or activity or decision making. Such activities are approval of sampling program, receipt of samples in the laboratory, completion of analysis etc. Procedures should be followed as much as possible and checked for compliance and consistency.

Various QMS have been proposed:

**ISO 9000 Series:** Is a generic name given to a family of standards developed to provide a framework around which a QMS can be implemented. It generally applies to manufacturing companies that design and make their own products. Other related QMS Standards in this series are **ISO 9001, ISO 9002, ISO 9003** and **ISO 9004,** each of which applies and focuses on specific business organizational processes

**ISO 1400 Series:** is also a generic name given to a series of standards that deal with management of environmental practices within industries. The **ISO 14001** It is often called the environmental standard, while the other 14000 series of standards support it by providing guidelines and tools for its implementation.

**ISO 17025:** Is the most appropriate standard applicable to Laboratories. It stipulates the General Requirements for Competency of Testing and the Calibration of Laboratories. It further states that all measurements and decisions should be based on accurate, repeatable, verifiable, cost effective, timely and believable measurements, opinions and recommendations.

This ISO 17025 standard assures that this happens all the time and on time. Without these assurance, the data, opinions and recommendations become suspect, questionable, risky and of reduced value and usability. Data produced based on ISO 17025 is deemed to be reliable and acceptable. It is the most popular quality standard for all laboratories, whether they are in local data production or international business. It controls all aspects of how laboratories conduct their business (Who, what, when, where, how, how much, why, which) of measurements, testing, certifying, recommending and reporting.

### 7.1.9 Laboratories and Competence/Accreditation

The Standard against which laboratories are formally recognized for Competence /Accredited is ISO/IEC 17025:2005. It is entitled: General Requirements for the Competence of Testing and Calibration Laboratories. Competence is defined as demonstrated ability to apply knowledge and skills, taking into consideration the fact that the scientific understanding behind a measurement or a test is important. This standard gives comprehensive criteria that a laboratory needs to implement, for an effective quality system that serves the laboratory needs.

Unfortunately Laboratories can only be accredited through registration with an accrediting body or an accredited lab, and it is a process which takes time, and often labs are accredited for some specific and not all the parameters. All laboratories should however aim to be ISO accredited in the long term.

### 7.1.10 Method Validation/Proficiency testing

Analytical methods validation will ensure that performance requirements for accuracy, recovery, precision and detection limit are met. For this, Reference samples, test samples and spiked test samples are used.

Under NTEAP in 2008, the same water test samples and reference samples were sent to the 9 Nile Basin Focal Laboratories. The results obtained showed a lot of variance between the labs, underscoring the need to use harmonized and standardized methods of testing.

### 7.1.11 Staffing for Water Quality Laboratories

Staffing laboratories with trained professional and dedicated staff is a major constraint in many Nile Basin countries and needs urgent attention. Most laboratories have indicated a high staff turn-over citing low wages as the cause. In general a water laboratory should have a mix of professionals, who should preferably be trained up to graduate level including the following basic 3 cadres:

- Analytical Chemists (Organic/Inorganic Chemistry)
- Laboratory Technologists
- Biologists/microbiologist

Other staff may be recruited as the need arises. The proposed staffing levels at each country for the proposed network follow.

#### *Burundi*

Burundi has adequate well trained staff manning its WQ Laboratory and no additional staffing is proposed.

#### *DRC*

DRC does not have trained staff to perform all surface water and groundwater quality testing. DRC needs to recruit at least 4 officers for its WQ Lab to undertake regional WQM. This would include 1 Analytical Chemist, 3 Lab. Technologists, and 1 Micro-biologist.

#### *Ethiopia*

Current establishment for the WQM Lab in Addis stands at 3 officers**.** In view of the proposed number of regional WQM stations, Ethiopia should recruit as a minimum, 6 officers to undertake regional WQM. This would include 1 Analytical Chemists 4 Lab. Technologists, and 1 Micro-biologist.

#### *Kenya*

The Kisumu WQ Laboratory is manned by 4 Laboratory Technologists and 1 Chemist. Ideally this Lab should be manned by 1 Analytical Chemist, 3 Laboratory Technologists and 1 Micro-biologist. The staffing appears adequate. The Kakamega WQ Laboratory is manned by 3 Laboratory Technologists. Ideally this Lab should be manned by 1 Analytical Chemist and 3 Laboratory Technologists and 1 Micro-biologist

#### *Rwanda*

Rwanda has adequate well trained staff manning its WQ Laboratory at Kigali, and no additional staffing is proposed.

#### *South Sudan*

South Sudan does not have trained staff to perform all surface water and groundwater quality testing. In view of the proposed number of regional and national WQM stations South Sudan needs to recruit as a minimum, 9 officers for its WQ Lab at Juba. This would include 2 Analytical Chemists, 6 Lab. Technologists, and 1 Micro-biologist.

#### *Sudan*

Sudan has adequate well trained staff manning its WQ Laboratory at Khartoum, and no additional staffing is proposed.

### Tanzania
Tanzania has adequate well trained staff manning its WQ Laboratory at Mwanza, and no additional staffing is proposed.

### Uganda
Uganda has adequate well trained staff manning its WQ Laboratory at Entebbe and no additional staffing is proposed.

### 7.1.12 Training
Trained and qualified technical staff is the backbone of an effective and efficient WQM program. The following are some of the areas identified by the countries for technical capacity building:

- Laboratory Management
- Laboratory Instrumentation
- Laboratory Analysis
- Laboratory Operations and maintenance
- Water Quality Management
- Data Management
- Quality Assurance
- Use of Automatic Sondes LIMS and other Field Equipment

Training Modules featuring training themes or units, and indicating training duration are attached as Appendix F. The proposed training modules/themes are based on the needs proposed by the countries

## 7.2 Proposed Upgrades of Country Laboratories
The following represents an ideal upgrade of improved laboratory capabilities for each country. It is based primarily on the assessment of the existing capabilities and measures necessary for each country to achieve the high standards noted in Section 7.1.

### 7.2.1 Burundi
Currently, the ability for the Burundi National Laboratory to meet the minimum regional and national data needs is average. However, Burundi urgently needs to procure GLC/HPLC for its laboratory in order to meet regional data requirements. The manuals for the new equipment need to be translated to English and French and staff trained on use of equipment. There is a need to participate in technical capacity building, use of new equipment, data management, QA and on use of Sondes and LIMS. Recruitment of new staff should be considered to augment current establishment. Decentralize surface water monitoring activities to the districts or river basins. Introduce and mainstream the use of Mobile Calibration Labs and LIMS in order to improve WQM services. Finally introduce systems quality control (QMS/QA) and register for accreditation. Funds for WQM are low and should be increased, by the by creation of awareness on importance of WQM and the socio-economic benefits of WQ data.

### 7.2.2 DRC
The capacity of DRC labs to meet the minimum regional and national data needs is low. The labs need to be equipped with Field Test Kits, Basic Lab and advanced lab equipment such as AAS and GLC. There is need to participate in technical capacity building, on use of new equipment, data management, QA and on use of Sondes and LIMS. Recruitment of new staff should be considered to augment current establishment. Introduce and mainstream the use of modern technology such as Sondes, LIMS and Mobile Calibration Labs, in order to improve WQM services. Adapt use of QMS/QA and plan to register for eventual accreditation of the labs. All these upgrades can be possible if funding for WQM is

increased by creating awareness on importance of WQM and the socio-economic benefits of WQ data. Consider the establishment of a WQ Lab in either Beni, Butembo or Goma.

### 7.2.3 Ethiopia

The ability of the National Laboratory in Addis Ababa to meet minimum regional and national data needs is low. The following equipment needs to be urgently acquired: GLC/HPLC, AAS and Flame Photometer, to upgrade level of service delivery. The country needs to participate in all the 5 areas of capacity strengthening identified in the Institutional Questionnaire, and additional staff needs to be recruited. Decentralization of WQM activities to the regions is strongly recommended. Staff should be properly motivated to take WQM activities seriously. There is need to introduce the use of Automatic Sondes, Mobile Calibration Labs and LIMS. Finally, gradually introduce systems quality control (QMS/QA) with a view to register for accreditation of the labs. Creation of awareness on the importance of WQM and its socio-economic benefits will ensure that more funds are set aside for WQM activities.

### 7.2.4 Kenya

The capacity of the Labs in Kisumu and Kakamega to meet minimum regional and national data needs is average. The new Lab at Nyalenda Kisumu should be commissioned and handed over to WRMA.
Upgrade the lab in Kakamega with the purchase of additional equipment such as GLC and HPLC. The country also needs to participate in all the 5 areas of capacity strengthening identified, and additional qualified staff needs to be recruited. There is need to introduce the use of Automatic Sondes, Mobile Calibration Labs and LIMS. Finally, gradually introduce systems quality control (QMS/QA) with a view to apply and register for accreditation of the labs. Creation of awareness on the importance of WQM and its socio-economic benefits will ensure that more funds are set aside for WQM activities.

### 7.2.5 Rwanda

The ability of the national Laboratory in Kigali to meet minimum regional and national data needs is average. The following equipment needs to be urgently acquired: UV-Vis, GLC/HPLC, AAS and more Field Kits to upgrade level of service delivery. The country needs to participate in all the 5 areas of capacity strengthening identified in the Institutional Questionnaire, and additional staff needs to be recruited. Decentralization of WQM activities to the districts is advisable. There is need to introduce the use of Automatic Sondes, Mobile Calibration Labs and LIMS. Finally, gradually introduce systems quality control (QMS/QA) with a view to apply and register for accreditation of the lab. Creation of awareness on the importance of WQM and its socio-economic benefits, should be enhanced, to ensure that more funds are set aside for WQM activities.

### 7.2.6 South Sudan

Currently, the ability of the National lab at Juba to meet minimum regional and national data needs is very low. The following equipment needs to be urgently procured: Field Kits, Basic Lab Equipment including UV-Vis, AAS, and GLC, in order to upgrade level of service delivery. The country needs to participate in all the 5 areas of capacity strengthening identified in the Institutional Questionnaire, and additional qualified staff needs to be recruited. Decentralization of WQM activities to the States is recommended. There is need to introduce the use of Automatic Sondes, Mobile Calibration Labs and LIMS. Finally, gradually introduce systems quality control (QMS/QA) with a view to apply and register for accreditation of the labs. Creation of awareness on the importance of WQM and its socio-economic benefits will ensure that more funds are set aside for WQM activities.

### 7.2.7 Sudan

The capacity of the national Laboratory in Khartoum to meet minimum regional and national data needs is average. The following equipment needs to be urgently procured: GLC/HPLC and AAS to upgrade level of service delivery. The country needs to participate in all the 5 areas of capacity strengthening identified in the Institutional Questionnaire, and additional qualified staff needs to be recruited. The Lab is already using LIMS, but there is need to introduce the use of Automatic Sondes and Mobile Calibration Labs. Finally, gradually introduce systems quality control (QMS/QA) with a view to apply and register for accreditation of the Lab. Creation of awareness on the importance of WQM and its socio-economic benefits will ensure that more funds are set aside for WQM activities.

### 7.2.8 Tanzania

The ability of the Lab in Mwanza to meet minimum regional and national data needs is average. The purchase of additional advanced equipment such as GLC /HPLC and AAS will enhance the laboratory's capability. The country needs to participate in all the 5 areas of capacity strengthening identified in the Institutional Questionnaire, and additional staff, needs to be recruited. There is need to introduce the use of Automatic Sondes, Mobile Calibration Labs and LIMS. Finally, gradually introduce systems quality control (QMS/QA) with a view to apply and register for accreditation of the labs. Creation of awareness on the importance of WQM and its socio-economic benefits will ensure that more funds are set aside for WQM activities. Also involve the private sectors, such as the Tourism Industry who are direct beneficiaries of WQM data and information to support WQM activities.

### 7.2.9 Uganda

The ability of the National Lab in Entebbe to meet minimum regional and national data needs is above average. The purchase of additional advanced equipment such as Inductively Coupled Plasma Mass Spectrometry will highly enhance the laboratory's capability. The country needs to participate in all the 5 areas of capacity strengthening identified, and additional qualified staff, needs to be recruited. Introduce the use of Automatic Sondes, Mobile Calibration Labs and LIMS. Finally, follow-up and pursue and conclude the accreditation process already initiated. Uganda should play a leading role in Regional WQM activities, and assist other countries such as DRC and South Sudan.

## 7.3 Sustainability of Water Quality Monitoring Activities

***Institutional Factor -*** Different Institutional arrangements (decentralized or centralized) are being used by different countries. For sustainability, whatever institutional arrangement has been chosen, it should be functional, if the regional and national water quality data needs have to be met.

***Management Factor -*** Laboratory management systems differ from country to country. Some countries use a mix of Field Equipment and basic laboratory equipment to carry out water quality testing. A few laboratories however have procured advanced equipment and are able to meet minimum regional water quality data needs. Only two Laboratories have embraced the use of LIMS. For sustainability and also to ensure future data integrity, all laboratories should embrace LIMS and introduce QMS/ QA programs and be internationally accredited. Staff carrying out WQ monitoring activities should be well remunerated so that their services can be retained in order to enhance sustainability of water quality monitoring activities.

***Financial Factor -*** All Nile Basin countries have highlighted low financing to the water sector in general as compared to other similar sectors such as agriculture. This means that funds for water quality monitoring are even lower. This not only affects the level of service delivery but also compromises the integrity of the data generated It has been cited that decision makers do not seem to be aware of the socio-economic benefits of water quality data. To be able to meet the data requirements of the various water-related sectors, then sensitization and awareness creation on the socio-economic benefits of water quality data has to be made as well as lobbying for funding has to be carried out. Nile Basin countries must strive to provide funds for WQ monitoring and to sustain the institutions carrying out the activity. Governments could also approach the private sector, donors, and other WQ data local beneficiaries to assist in funding to sustain the WQ monitoring activities.

***Technical Factor -*** Training is a very important element for the upgrade of laboratory facilities. Whereas the great technical expertise within the Nile Basin countries' laboratories is noted, further training in all aspects of water quality management is recommended. Countries ranked the need for proposed training options very highly in the institutional questionnaire. They also indicated that lack of spare parts and maintenance is a major problem in many laboratories. The following proposed trainings are supported in order to enhance and sustain the Nile Basin countries capacity to undertake effective water quality monitoring:

- Improved capacity building/strengthening for data analysis and modeling tools to support water quality management and pollution control.
- Capacity building/strengthening needs on automatic water quality monitoring technology.
- Capacity building/strengthening needs on water quality laboratory technology
- Capacity building needs on mobile calibration laboratory technology.
- Capacity building needs on LIMS

***Behavior Change -*** Goodwill exists in the countries, especially among the technical officers, who have been working together on transboundary and cross-border projects for many years. In order to sustain and give impetus to the sustainability of regional water quality monitoring activities, it is necessary that all the technical officers in the water sectors in the region realize the importance and value of water quality data and its socio-economic benefits. The same goes for leaders and decision makers. If need be awareness and sensitization programs on the need to sustain WQM activities can be initiated to effect behavior change. The timely compensation of staff is a strong motivating factor, and this will further enhance sustainability of the WQ monitoring activities.

**General Recommendations:**

1. Laboratories need to be well equipped and adequately staffed to meet the data needs of the identified WQM stations
2. Many countries have indicated their preferred areas for technical training. Regional trainings on the areas indicated in the training modules are recommended as they would be cost-effective.
3. The quarterly and monthly sampling programs proposed must be well planned, and where applicable joint field visits made with the hydro met teams, in order to reduce field measurements and sampling costs.

# 8 Earth Observation and Regional Modeling Data Products

Earth observation data can bring high benefits to the Nile Basin hydro-metrological services to complement ground based monitoring systems. Earth observation satellite global coverage also helps to address the problems of data continuity in transboundary basins where complete, consolidated, and consistent information may be difficult to obtain. Integrating ground and satellite observational networks with modeling data products offers maximum benefits to local environments, communities, and economies. Integration enables data and service providers to maximize the benefits derived from Earth observations, develop more robust decision-support systems, reduce the uncertainties in resource management decisions made in data-sparse areas, and facilitate the sharing of data, information, and data-processing tools across all systems and sectors. The SERVIR-Africa and FEWS-NET projects have been developed to help access to these products directly. This section presents hydro-meteorological satellite observation and integrated data product examples and summarizes their socio-economic benefit.

The design of the earth observation products system is based on the regional data requirement and the maturity of the earth observation technology for the various hydromet parameters. Precipitation, evaporation, surface water level, surface water discharge, water quality, and sediment load are the main hydromet parameters required to address the regional cooperative issues as shown in Table 4-2. Among the latter parameters only precipitation, evaporation, soil moisture, water level for large reservoirs, and land cover have mature earth observation products. Earth observation products for river water level and water discharge are still at the research level. Water quality earth observation is adequate for chloroform in large water bodies such as Lake Victoria to track algae and vegetation. Satellite data provide many opportunities to increase information on precipitation, evapotranspiration (ET), land cover and soil moisture. The SERVIR-Africa, FEWS-NET, and Tiger programs have been developed to help access to earth observation products directly. This section presents the recommended most mature and currently available earth observation products which can be integrated in the design of the hydromet monitoring system. Other products can be integrated in the future when they become more mature and can be adapted to the Nile Basin regional information requirements.

Riverside recommends the creation of a Regional Nile Earth Observation Center to process and disseminate the earth observation products relevant to the Nile Basin. A description of each of the recommended products is shown below with details about spatial resolution, temporal resolution, download procedures, and references.

## 8.1 Precipitation

While rain gauges give accurate on site rainfall measurements, the spatial variability of precipitation leads to considerable uncertainty in precipitation for areas without dense gauge networks. Integrated measurements, derived from combinations of microwave, infrared, and gauge data, give more reliable areal estimates in data-sparse areas, and in regions of high rainfall variability in the Blue and White Nile headwater regions. The precipitation radar (PR) on the joint National Aeronautics and Space Administration (NASA)/Japan Aerospace Exploration Agency (JAXA) Tropical Rainfall Measuring Mission (TRMM) satellite provides precise but infrequent measurements. The recently launched NASA/JAXA Global Precipitation Measurement (GPM) Mission will help to remedy these limitations. Precipitation forecasts are also available from operational forecasting systems at the European Center for Medium Range Forecasting (ECMWF), the U.S. National Oceanographic and Atmospheric Administration (NOAA), the Japan Meteorological Agency, the Australian Bureau of Meteorology (BoM). An example of TRMM satellite based precipitation estimates for the Nile River Basin is shown in Figure 8-1.

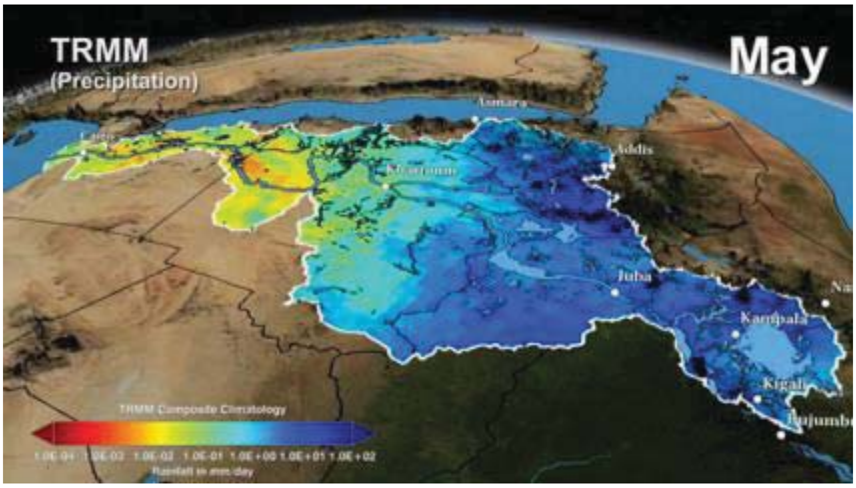


Figure 8-1. TRMM satellite-based precipitation estimates for the Nile Basin

Knowledge of precipitation is important for improved Nile River Basin water resource planning and management; daily monitoring at key locations are critical to inform comprehensive Decision Support Systems (DSS) about water and land cover distribution changes serve to assess the benefits and trade-offs of various reservoir release and water use policies. Sub-daily near-real-time precipitation is essential for urban flash flood forecasting, and historical precipitation records are important inputs to determine and mitigate flood risk. Precipitation is also a key input for rainfed agricultural management, where it can inform drought monitoring and agricultural research. Large scale precipitation monitoring and seasonal model forecasts can alert regional and basin-wide managers to areas vulnerable to drought and famine, enabling the mobilization of aid or crisis avoidance decision support. Precipitation observations and forecasts are also critical inputs for hydropower planning and optimization, as well as navigation. Operating rules in the Nile basin are complex due to transboundary issues; accurate regional precipitation data can ease this issue by providing critical upstream water resource information. In what follows are two recommended earth observation products: 1) Tropical Rainfall Measurement Mission (TRMM) Multi-satellite Precipitation Analysis (TMPA) and 2) CMORPH (CPC MORPHing technique). TRMM is the most mature precipitation earth observation product. The CMORPH product has a higher resolution, but it is less accurate than the TRMM product. Both products are free of charge.

| Tropical Rainfall Measurement Mission (TRMM) Multi-satellite Precipitation Analysis (TMPA) | |
|---|---|
| Data Description | TMPA is a combination of the passive microwave product (PMW) and the PMW-calibrated geostationary infrared (IR) Variable rain rate (VAR) product. The PMW product is a merger of the Special Sensor Microwave Imager (SSM/I) and TRMM precipitation estimates, where the SSM/I data are calibrated to the TRMM Microwave Imager (TMI) before combination. Combined geostationary IR satellite data are also corrected to the microwave data. Finally, the combined product is scaled to fit gauge estimated data to obtain the main product.<br>**Web Link:** http://disc.sci.gsfc.nasa.gov/gesNews/trmm_v7_multisat_precip |
| Grid Size and Temporal Resolution | **Data domain:** Available between 60°N-60°S latitude<br>**Spatial resolution:** ¼° x ¼° degree latitude/longitude, equivalent to ~25km x ~25km grids<br>**Temporal resolution:** 3 hours |
| References | *Huffman, Bolvin, Nelkin, Wolff, Adler, Gu, Hong, Bowman, and Stocker, 2007: The TRMM Multisatellite Precipitation Analysis (TMPA): Quasi-Global, Multiyear, Combined-Sensor Precipitation Estimates at Fine Scales. J. Hydrometeor, 8, 38–55.* |

| Tropical Rainfall Measurement Mission (TRMM) Multi-satellite Precipitation Analysis (TMPA) | |
|---|---|
| Download Protocol | • **FTP download:** ftp://disc2.nascom.nasa.gov/data/TRMM/Gridded/3B42RT/<br>• Change to most recent directory (YYYYMM)<br>• Download desired file(s), 3B42RT.YYYY.MM.DD.HHz.bin<br>• Data Format: binary<br>• Data subsetting: data is available between 60°N to 60°S latitude; data will need to be subsetted for the Nile Basin after downloading. |

| CMORPH (CPC MORPHing technique) | |
|---|---|
| Data Description | High quality passive microwave (PMW) derived precipitation estimates are used exclusively to construct this high-resolution product. The intensity and shape of precipitation amounts are estimated by interpolating the microwave-derived satellite precipitation estimates between available time-steps (this part of the technique is referred to as 'morphing').<br>**Web Link:**<br>http://www.cpc.ncep.noaa.gov/products/janowiak/cmorph_description.html |
| Grid Size and Temporal Resolution | **Data domain:** Available between 60°N-60°S latitude<br>**Spatial resolution:** 8km x 8km grids<br>**Temporal resolution:** 30 minutes |
| References | *Joyce, R. J., J. E. Janowiak, P. A. Arkin, and P. Xie, 2004: CMORPH: A method that produces global precipitation estimates from passive microwave and infrared data at high spatial and temporal resolution.. J. Hydromet., 5, 487-503.* |
| Download Protocol | • **FTP download:** ftp://ftp.cpc.ncep.noaa.gov/precip/global_CMORPH/30min_8km<br>• Download desired file(s): advt-8km-interp-prim-sat-spat-2lag-2.5+5dovlp8kmIR-YYYYMMDDHH<br>• Data Format: flat binary big-endian<br>• Data subsetting: data is available between 60°N to 60°S latitude; data will need to be subsetted for the Nile Basin after downloading. |

## 8.2 Evapotranspiration

Evapotranspiration (ET) measurements in the Nile Basin can be used to estimate consumptive water use, especially irrigation water use, and non-productive evaporative losses from rivers, lakes, reservoirs, wetlands and pastoral land. Knowledge of evaporation dynamics is an important input for Nile River Basin flood forecasting as well as water resource planning and water management Decision Support Systems (DSS). Evaporation data directly benefits socio-economic issues at the regional and national level linked to issues such as water resources planning and management, floods, drought, climate change resilience, rainfed agriculture, irrigation, soil erosion, wetland management, etc. For example, coordinated management of the outflow from Lake Victoria would reduce excess flooding during wet years and maintain seasonal wetlands during drought years, and is part and parcel of managing the seasonal grazing lands in order to optimize their benefits for the local population; rainfall data and information on evapotranspiration from the swamp vegetation is needed in order to establish the water balance of the area.

Accurate flux values at a particular location can be derived from onsite lysimetric, pan, or Penman-Monteith ET measurements. Evapotranspiration is generally estimated from satellite data using a range of models, with model inputs from the visual and thermal bands which are available from many different satellite sensors. Hydrometeorological models and data assimilation systems are excellent sources of continuous ET fields. Operational forecasting systems at the European Center for Medium Range Forecasting (ECMWF), the U.S. National Oceanographic and Atmospheric Administration (NOAA), the Japan Meteorological Agency, the Australian Bureau of Meteorology (BoM), can provide baseline ET data. However, specialized Land Data Assimilation Systems (LDAS) can offer value-added products that integrate land surface models with satellite and surface observations to provide consistent hydrological data over large regions.

Among the ET earth observation products, we recommend the Moderate Resolution Imaging Spectroradiometer (MODIS) Evapotranspiration (MOD16A3) for the Nile Basin Earth Observation system, as the most mature and free product available.

| Moderate Resolution Imaging Spectroradiometer (MODIS) Evapotranspiration (MOD16A3) | |
|---|---|
| Data Description | The MOD16 global evapotranspiration (ET), latent heat flux (LE), potential ET (PET), and potential LE (PLE) datasets are estimated based on the Penman-Monteith equation.<br>**Web Link:** http://www.ntsg.umt.edu/project/mod16 |
| Grid Size and Temporal Resolution | **Data domain:** Available globally, 5 parameters available<br>**Spatial resolution:** 1km x 1km grids<br>**Temporal resolution:** 8 days |
| References | *Mu, Q., M. Zhao, S. W. Running, 2007: A Remotely Sensed Global Terrestrial Drought Severity Index. Remote Sensing of Environment, Volume 115, pages 1781-1800 (doi:10.1016/j.rse.2011.02.019)* |
| Download Protocol | • **FTP download:** ftp://ftp.ntsg.umt.edu/pub/MODIS/NTSG_Products/MOD16/MOD16A3.105_MERRAGMAO/<br>• Change to most recent directory (yyyy)<br>• Download desired file(s),<br>• Data Format: HDF<br>• Data subsetting: data is available globally; data will need to be subsetted for the Nile Basin after downloading. |

## 8.3 Soil Moisture

Soil moisture is a critical input for Nile country agricultural management, where it can both inform drought monitoring and agricultural research, as well as provide critical initial conditions for seasonal climate forecasting. Soil moisture knowledge is also critical for irrigation planning and scheduling, resulting in improved crop performance, reduced water use, and maximizing total system benefits. Soil moisture is also a critical parameter for detecting and monitoring drought conditions, enabling improved decision support and crisis management.

Uncertainties about the pace and extent of climate change and the impacts on different sub-regions and sectors in the basin make policy decisions difficult, and magnify the need for the region to improve its hydro-meteorological knowledge and monitoring base. In order to better inform policy making at local and regional level, improved climate models are required. This requires intensified data collection of all climatic parameters; however it has been found that soil moisture is one of the most critical climate parameters due to its relatively long memory. These data serve to validate the climate models and to improve the scientific understanding of the climate change phenomena. Better understanding of the threat of climate change would allow for specific investments in infrastructure and/or targeted adaptation measures, with obvious socio-economic benefits.

Soil moisture plays an important role in weather, climate and water resource management. In particular, it modifies the partitioning of incoming radiative energy into sensible and latent heat fluxes and in partitioning precipitation between infiltration, runoff, and evaporation. Both active and passive space-based microwave systems have been used to estimate soil moisture. Currently, the European Space Agency's (ESA) Soil Moisture and Ocean Salinity mission (SMOS) provides operational soil moisture products at a 30-km resolution and repeat coverage of one to three days. Active remote sensing data will soon be available from NASA's Soil Moisture Active-Passive (SMAP) mission (to be launched in early 2015) for use in estimating soil moisture at up to 10km resolution. Upscaling techniques and water balance assessments are needed to effectively use on site soil moisture to validate and develop new integrated soil moisture products. While limited integration with weather forecasting models is being pursued, the most benefit of these soil moisture products will be realized when integrated with a Land Data Assimilation System (LDAS) that integrates land surface models with satellite and surface observations to provide consistent hydrological data over large regions.

The European Space Agency (ESA), Soil Moisture Ocean Salinity (SMOS) is a currently available soil moisture related satellite observation product that is recommended for the Nile Basin Earth Observation system.

| European Space Agency (ESA), Soil Moisture Ocean Salinity (SMOS) | |
|---|---|
| Data Description | The Level 2 SSMOS soil moisture product comprises soil moisture measurements geo-located in an equal-area grid system. The product contains not only the retrieved soil moisture, but also a series of ancillary data derived from the processing (nadir optical thickness, surface temperature, roughness parameter, dielectric constant and brightness temperature retrieved at top of atmosphere and on the surface) with the corresponding uncertainties. The pixels are consolidated in a pole-to-pole product file.<br>**Web Link:** https://earth.esa.int/web/guest/-/level-2-soil-moisture-6900 |
| Grid Size and Temporal Resolution | **Data domain:** Available globally, 15 different parameters<br>**Spatial resolution:** 30-50km x 40-50km variable resolution<br>**Temporal resolution:** Daily |
| References | *Kerr, Y.H., et al., Soil moisture retrieval from space: The soil moisture and ocean salinity (SMOS) mission. IEEE Trans. Geosci. Rem. Sens., 2001. 39(8): p. 1729-1735.* |
| Download Protocol | Data access requires registration at https://earth.esa.int/web/guest/pi-community/myearthnet<br>Download the Level 2 Soil Moisture product.<br>• Note that SMOS data are in Earth Explorer Ground Segment File Format Standard format. |

## 8.4 Water Level

Beginning in the early 1990s, satellite remote sensing of water level in large reservoirs and lakes was made possible through satellite radar altimetry. Available radar altimeters include GEOSAT (1986-1988), Topex/Poseidon (1992-2002), ERS-1 (1991-1996), ERS-2 (1995-2003), GFO (2000-2008), ENVISAT (post 2002), JASON-1 (2002-2008), and JASON-2 (post 2008). For very large lakes the altimeter measurement error can be a few cm, while smaller lakes or lakes with low surface roughness will all have larger errors. Estimates of lake and reservoir water storage and water storage variation requires additional measurements of surface water area and bathymetry.

The following LEGOS product is recommended for the Nile Earth Observation system. This product is free of charge.

| Water Levels from Satellite Altimetry | |
|---|---|
| Data Description | Water level from large water bodies can be observed from space using radar altimeters on board the Topex–Poseidon, GFO, ERS-2, Jason-1, Jason-2 and Envisat satellites. Satellite radar altimetry measures the time required for a microwave pulse to travel from the satellite antenna to the earth's surface and back to the satellite receiver. Altimetry on inland lakes generally shows some deviation from in situ level measurements. The deviation is attributed to the geographically varying corrections applied to account for atmospheric effects on radar waves. Temporal resolution depends on the respective orbits of the satellites. The level of a number of large lakes and reservoirs can be actively monitored from space, including Lake Victoria, Lake Tana (Ethiopia), Roseires (Sudan), Lake Nasser (Egypt), etc.<br>**Web Link:** http://www.legos.obs-mip.fr/fr/soa/hydrologie/hydroweb/Objets.html http://www.pecad.fas.usda.gov/cropexplorer/global_reservoir/ |
| Grid Size and Temporal Resolution | **Data domain:** Available globally for large lakes (error decreases with lake size)<br>**Spatial resolution:** One lake level estimate, with an accuracy of 2-3cm depending on lake size.<br>**Temporal resolution:** Approximately Monthly |
| References | *J-F. Crétaux , W. Jelinski , S. Calmant , A. Kouraev , V. Vuglinski , M. Bergé Nguyen , M-C. Gennero , F. Nino, R. Abarca Del Rio , A. Cazenave , P. Maisongrande, SOLS: A Lake database to monitor in Near Real Time water level and storage variations from remote sensing data, J. Adv. Space Res. (2011), doi:10.1016/j.asr.2011.01.004* |
| Download Protocol | **Download:** http://www.legos.obs-mip.fr/fr/soa/hydrologie/hydroweb/Objets.html<br>• Click on lake of interest<br>• Download desired data in text or Google Earth format. |

## 8.5 Land cover & water bodies

The Nile Basin surface water bodies such as lakes, floodplains, wetlands, river channels are home to aquatic ecosystems. Knowledge of land cover and water body status is important in the Nile Basin for improved water resource planning and management; annual land cover/water body assessments are critical to inform comprehensive Decision Support Systems (DSS) about water and land cover distribution changes that serve to assess the benefits and trade-offs of various reservoir release and water use policies. Monitoring of land cover and extent including forests, lakes for major watersheds, and wetlands in combination with rainfall, flow discharges, levels and water quality of major natural, catchment erosion and sedimentation are important for the management and protection of these watersheds.

Although they are important ecosystems, standing water bodies are particularly poorly monitored. Although effective monitoring of wetlands and manmade reservoirs present different challenges, the demands for data on water storage create special needs for a strategy combining surface data with new sources of satellite data. High-resolution imaging sensors, particularly the visible and near-infrared spectrums, provide capabilities to survey water bodies on a regular basis and provide detailed mappings of the water extent. Visible and infrared sensors provide images on a daily basis at moderate spatial resolution ranging from 250m to 1,000m, have been used to map open water bodies. High-resolution sensors also fit under this category of sensors. The Shuttle Radar Topography Mission (SRTM) Water Bodies Database (SWBD) provides con-tour lines of water bodies (lakes, reservoirs, major rivers) derived from visible and infrared images covering the SRTM domain (approximately +/- 60° latitudes). Passive microwave sensors have demonstrated capabilities to measure water extents. The following two land cover and water body earth observation products are recommended for the Nile Earth Observation system. The Moderate Resolution Imaging Spectroradiometer (MODIS) Land

Cover (MCD12Q1) is free of charge. European Space Agency (ESA) Land Cover Products are available at higher resolution and accuracy, but they are not free of charge.

| Moderate Resolution Imaging Spectroradiometer (MODIS) Land Cover (MCD12Q1) | |
|---|---|
| Data Description | The MODIS Land Cover Type product contains five classification schemes, which describe land cover properties derived from observations spanning a year's input of Terra- and Aqua-MODIS data. The primary land cover scheme identifies 17 land cover classes defined by the International Geosphere Biosphere Programme (IGBP), which includes 11 natural vegetation classes, 3 developed and mosiaced land classes, and three non-vegetated land classes. The product incorporates five different land cover classification schemes, derived through a supervised decision-tree classification method.<br>**Web Link:** https://lpdaac.usgs.gov/products/modis_products_table/mcd12q1 |
| Grid Size and Temporal Resolution | **Data domain:** Available globally<br>**Spatial resolution:** 500m x 500m grids<br>**Temporal resolution:** Annual |
| References | *Friedl, M. A., Sulla-Menashe, D., Tan, B., Schneider, A., Ramankutty, N., Sibley, A., andHuang, X. (2010). MODIS Collection 5 global land cover: Algorithm refinements and characterization of new datasets. Remote Sensing of Environment, 114, 168–182.* |
| Download Protocol | • **FTP download:** http://e4ftl01.cr.usgs.gov/MOTA/MCD12Q1.051/<br>• Change to most recent directory (YYYY.MM.DD)<br>• Download desired file(s), MCD12Q1…hdf<br>• Data Format: HDF<br>• Data subsetting: data is available globally; data will need to be subsetted for the Nile Basin after downloading. |

| European Space Agency (ESA) Land Cover Products | |
|---|---|
| Data Description | The Climate Change Initiative Land Cover (LC) team provides 5 key land cover products, including (1) the full archive (2003-2012) of MERIS Full Resolution time series pre-processed in 7-day composites, (2) three global LC maps representative for the 1998-2002, 2003-2007 and 2008-2012 epochs,(3) three global land cover seasonality products describing the vegetation greenness, the snow and the burned areas occurrence dynamics, (4) a global map of open and permanent water bodies at 300m spatial resolution, and (5) a user tool for sub-setting, re-projecting and re-sampling the products.<br>**Web Link:** http://www.esa-landcover-cci.org/?q=node/156 |
| Grid Size and Temporal Resolution | **Data domain:** Available globally<br>**Spatial resolution:** 300m x 300m grids<br>**Temporal resolution:** 7 days |
| Download Protocol | All products are available via the Land Cover CCI Climate Research Data Package (CRDP). Registration is required.<br>http://maps.elie.ucl.ac.be/CCI/viewer/download.php |

## 8.6 Near-Real Time Atmospheric Analysis

Global forecasts of precipitation, evapotranspiration, and soil moisture can be used to complement remotely sensed observations of these and other parameters. Several international organizations operate global models and make their data available publicly. We recommend two sources of near-real time atmospheric analysis products that can be integrated in the Nile Earth Observation system. The first is the Global Forecast System (GFS) & Global Data Assimilation System (GDAS) which is a mature and free product. The second is the Integrated Forecast System (IFS) of the European Centre for Medium-Range Weather Forecasts (ECMWF) which is the most mature product in this field. It is adequate in real time, less accurate in forecasting, but can predict El Nino and drought scenarios. The IFS is available at an expensive cost.

| Global Forecast System (GFS) & Global Data Assimilation System (GDAS): | |
|---|---|
| Data Description | The Global Forecast System (GFS) is a weather forecast model produced by the National Centers for Environmental Prediction (NCEP) in the United States. Dozens of atmospheric and land-soil variables are available through this dataset, from temperatures, winds, and precipitation to soil moisture and atmospheric ozone concentration. The GFS model is a coupled model, composed of four separate models (an atmosphere model, an ocean model, a land/soil model, and a sea ice model), which work together to provide an accurate picture of weather conditions. Changes are regularly made to the GFS model to improve its performance and forecast accuracy.<br>**Web Link:** http://www.ncdc.noaa.gov/data-access/model-data/model-datasets/global-forcast-system-gfs |
| Grid Size and Temporal Resolution | **Data domain:** Available globally, with 116 land surface parameters<br>**Spatial resolution:** T1534 spectral resolution, equivalent to ~13km x ~13km grids<br>**Temporal resolution:** 6 hours, and 384 hour forecast |
| References | *Environmental Modeling Center, 2003: The GFS Atmospheric Model. NCEP Office Note 442, Global Climate and Weather Modeling Branch, EMC, Camp Springs, Maryland.*<br>*Zheng, W., H. Wei, Z. Wang, X. Zeng, J. Meng, M. Ek, K. Mitchell, and J. Derber, 2012: Improvement of daytime land surface skin temperature over arid regions in the NCEP GFS model and its impact on satellite data assimilation. J. Geophys. Res., 117, D06117, doi:10.1029/2011JD015901.* |
| Download Protocol | • **FTP download:** ftp://hydro1.sci.gsfc.nasa.gov/data/s4pa/GLDAS_V1/GLDAS_NOAH025SUBP_3H<br>• Change to most recent directory (..gfs.YYYYMMDDHH)<br>• Download desired file(s): gfs.tCCz.sfluxgrbfFF.grib2<br>• Data Format: GRIB2<br>• Data subsetting: data is available globally; data will need to be subsetted for the Nile Basin after downloading. |

| European Centre for Medium-Range Weather Forecasts (ECMWF): Integrated Forecast System (IFS) | |
|---|---|
| Data Description | European Centre for Medium-Range Weather Forecasts (ECMWF) is an independent intergovernmental organization supported by 20 European Member States and 14 Co-operating States. The ECMWF is best known for its global operational forecast model, known officially as the "Integrated Forecast System". The model runs both in a "deterministic forecast" mode and as an ensemble. The ECMWF model is proprietary and copyrighted, so only a limited amount of output |

| European Centre for Medium-Range Weather Forecasts (ECMWF): Integrated Forecast System (IFS) | |
|---|---|
| | from the model has been publicly released through both the ECMWF and various sites. IFS assimilates a wide variety of in-situ and remotely-sensed land, ocean, atmospheric sounding and wind data. Of particular note, IFS assimilates remotely sensed snow, soil moisture, and precipitation and assimilates surface station temperature and humidity observations.<br>**Web Link:** http://www.ecmwf.int/en/forecasts/datasets |
| Grid Size and Temporal Resolution | **Data domain:** Available globally, with 74 land surface parameters<br>**Spatial resolution:** 1/8° x 1/8° degree latitude/longitude, equivalent to ~16km x ~16km grids<br>**Temporal resolution:** 6 hours, and seasonal ensemble forecasts |
| Download Protocol | Data is not freely available. A specific download arrangement is needed with ECMWF. |

## 8.7 Product Integration

Integrating ground and satellite observational networks and systems as well as water research, planning, and water management offers maximum benefits to local environments, communities, and economies. Integration enables data and service providers to maximize the benefits derived from Earth observations, develop more robust decision-support systems, reduce the uncertainties in resource management decisions made in data-sparse areas, and facilitate the sharing of data, information, and data-processing tools across all systems and sectors. Examples of water cycle model integration, aside from the operational forecast systems at the European Center for Medium Range Forecasting (ECMWF), the U.S. National Oceanographic and Atmospheric Administration (NOAA), the Japan Meteorological Agency, the Australian Bureau of Meteorology (BoM), to name a few, include the community Earth system models developed by the U.S. Department of Energy, NASA/GSFC, and the Water Cycle Integrator, under development at the University of Tokyo. An example of data-model integration is the Land Data Assimilation System (LDAS) concept that integrates land surface models with satellite and surface observations to provide consistent hydrological data over large regions. Operational LDAS systems are currently available for the Nile Basin from the Global LDAS and the Middle East North Africa (MENA) LDAS.

## 8.8 Regional Earth Observation Center for the Nile Countries

A Regional Earth Observation System based at the Nile-Secretariat (Figure 8-2) is proposed as part of the water resources monitoring system design. The regional center will be highly responsive to the earth observation needs of managers and stakeholders in the region, and can serve as a focal point for the distribution of Earth Observation products to the Nile countries. The center will gather Earth Observation products from international weather and climate modeling centers, as well as from various space agencies. The products will be spatially subsetted and processed for use in a particular Nile basin region. The center will also enable product visualization and access for managers and stakeholders across the basin. An archive will be maintained to study past events and learn how to better manage future issues.

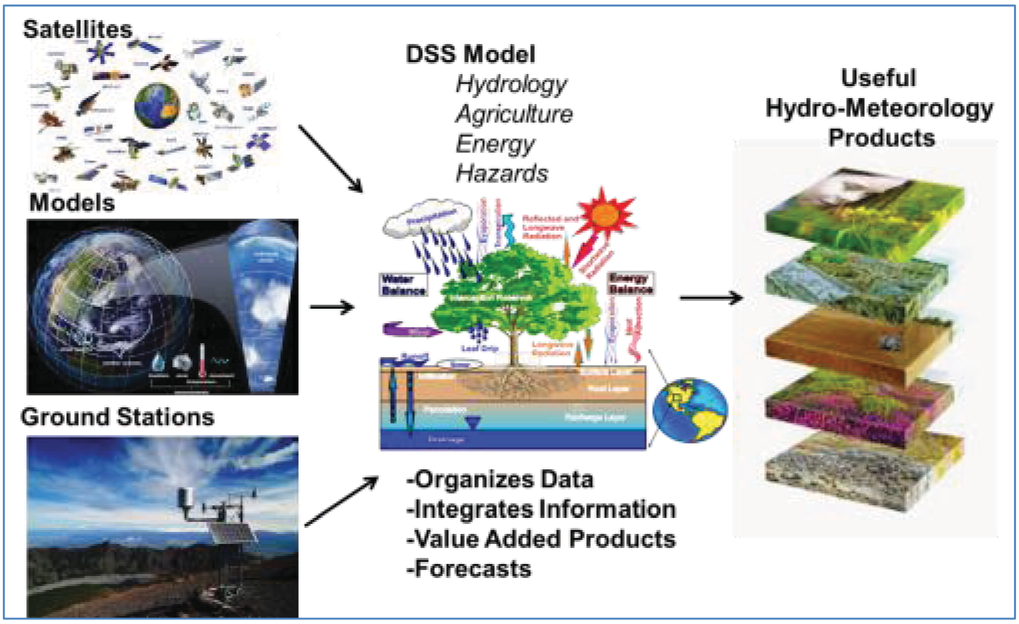


Figure 8-2. Data flowchart for the proposed Nile Basin Earth Observation System

In the future the Nile Basin Earth Observation center could also engage in on-site product integration by developing its own model forecast and assimilation capabilities. The system could also provide a framework for the regional integration of hydrologic, agricultural, energy, and extreme event DSSs, such as the NBDSS. A Nile Basin Hydro-meteorological Data Assimilation System could be developed using established software and models to create value-added regional integrated hydro-meteorology products. Integration enables data and service providers to maximize the benefits derived from Earth Observations, develop more robust decision-support systems, reduce the uncertainties in resource management decisions made in data-sparse areas, and facilitate the sharing of data, information, and data-processing tools across all systems and sectors.

At its baseline functionality, a Nile Basin Earth Observation center will gather, process, archive, visualize and distribute satellite and earth observation products from internationally-available satellites and models. The Nile Basin Earth Observation center could be enhanced by adding:

- On-site integration and modeling capabilities in the form of hydro-meteorological models, DSSs, and data assimilation capacities, and
- Integration of local *in-situ* observations from national and regional networks (as available).

The earth observation products described in the foregoing sections will be integrated as part of the Regional data management system, discussed in Section 1, below, which will constitute the earth observation system, among other functions.

# 9 Data Management System

The NBI monitoring strategy emphasizes a regional system in the context of national operations. Thus, NBI hopes to support and encourage individual countries in regards to their national systems, and in particular regarding the elements of monitoring networks and communications systems that will facilitate the data collection required for effective contribution to the regional system. In addition, it is anticipated that NBI will bear primary responsibility for the regional aspects of the system, including developing and implementing tools that permit national data to be transmitted to a regional data management system. NBI will also be responsible for the regional data management system that will permit storage, retrieval, and analysis of the data and encourage use of the data through appropriate web interfaces to the database. At its most basic level, the data management system design will recognize three conceptual elements: data acquisition management, the national data management systems, and the regional data management system. Embedded within the national and regional data management systems will be a national-regional data communications component as well as information products and stakeholder communications.

While the data collection networks are essential to providing the raw data for the system, it is the data management systems that will be the visible component to bring water resources data and information to potential users. Moreover, the data collection network design is comprised of many components that are already in place, if only in a manual operation mode, while the data management infrastructure is largely absent. Therefore, development of the data management systems will be one of the highest leverage activities that NBI can take to begin making water resources information available to achieve the potential benefits outlined in this study.

## 9.1 Data Acquisition Management

The data acquisition management system is an optional system that bridges the gap between a base station receiving raw data from the monitoring network and a national data management system that provides data analysis and modeling for water management. The acquisition management system performs the following functions:

- compiling field observations from automated station networks
- compiling field observations from manually observed station networks
- maintaining and managing network infrastructure, using databases, feedback mechanisms, and reporting tools to assist in network equipment monitoring and maintenance
- Short term data storage for observed field data
- basic quality control of input data using standardized filtering techniques
- analysis of input data for purposes of monitoring network performance
- editing observations and logging edits
- transmitting quality controlled data to data management applications

Many of the listed functions can be handled by the Base Station, as described in Section 6.2.6, which will be used to acquire and filter hourly data from the field sites. The entry of data from manually observed stations may be done using either the acquisition management system or the national data management application. Which application is used for entering manually observed data depends on the particular software applications chosen.

While management of the monitoring network can be attempted by countries manually using a collection of methods that have been used historically, software systems that have been designed specifically to perform these functions can be employed to great advantage. Where the national network is large enough to justify a dedicated staff for managing the monitoring network, a dedicated tool to assist in this task is justified. Costs for such software include license costs plus configuration and training costs.

To be a complete solution with flexibility to meet the needs of all Nile Basin countries, this sub-system will have capability that overlaps with some of the capabilities of the national data management system described below, and in some cases one system or the other might be selected to be used alone by a country depending on data management priorities and needs. The specification for either the data acquisition system mentioned above or the National Data Management system described below will provide for data ingest to the system. This data may come from automated stations in national networks (including designated regional stations) and from manually entered station data. These systems can be centralized at the national level or distributed to individual river-basin offices. For example, Tanzania may wish to implement the systems only at its Lake Victoria Basin office to meet the specific needs of the Nile Basin monitoring system.

## 9.2 National Data Management

The National Data Management systems do or will exist under the operational responsibility of the individual countries. The hydro-met system design will provide tools and options that may be adopted by the countries. While the identification of these options is informed by existing practice in the basin as gathered during the consultation process, their implementation will be carried out by the individual countries. At a minimum it will be necessary for the countries to implement tools that permit communication of agreed data with the regional system. It is also noted that each country has a unique institutional structure and the source data that comprise the input to the regional system will likely come from multiple disparate ministries, so that a uniform approach among countries would not be feasible in any case. The National Data Management system as described below in terms of objectives and requirements is recommended for upgrading from the HYDATA systems that exist in many of the Nile Basin countries.

The overall objective of the National Data Management system and supporting GIS database is to:

1. Manage the hydro-met network data and meet national hydromet services needs in terms of data analysis, reporting, execution of models, data ingest and information dissemination for the sustainable management and development of national water resources, and
2. Permit and facilitate the exchange of approved and quality assured data with the Regional Data Management system

Implementation of the national data management systems will require:

1. Installing and initiating operations of the system in each of the NBI countries, including establishment of the necessary data flows, and
2. Conducting capacity building and training for the system.

One of the challenges that will exist at the national level will be integrating meteorological and hydrometric station networks. The National DMS is targeted for the water management institutions, and policies and procedures will be needed in those countries that lack them for sharing data from MET agencies. Features of the national DMS will facilitate data inputs from a variety of sources. These features can be employed to permit automated processes at the meteorological agency to transfer formatted data files to the national DMS for ingest. Another critical feature of the national DMS will be to support data rescue and data consolidation efforts in each country. This will require tools to ingest datasets from a variety of existing sources, including spreadsheets, text files, existing legacy data management systems, and manually-entered data.

NBI has invested heavily in the NBDSS, which already provides many of the functions of both a national and a regional data management system. The present design proposes that the NBDSS be configured and enhanced to include the required capabilities for the water resources monitoring network, as outlined below. It should be noted that the following requirements are intended to provide comprehensive capability in data management that will meet the needs of hydromet services in all countries, though a given country is likely to employ only a subset of the listed functionality. From the standpoint of the regional monitoring system requirement, the most critical function of the national

DMS is the ability to synchronize or send data from stations that comprise the regional monitoring network to the regional data management system. As such, individual countries need not feel compelled to implement the proposed system if they choose not to, as long as they can provide a compatible data communication link to the regional system.

*Specific National Data Management System Requirements*

| Id | Description | Supported in NB DSS |
|---|---|---|
| 1 | The National Data Management system shall support a variety of time series data in the hydro-met network at various observation times and with various periods | Yes |
| 2 | The National Data Management system shall include a GIS component for storing spatial information of various types, e.g., stations and gauges, rivers, catchments, rasters, etc. | Yes |
| 3 | The National Data Management system shall allow time series and GIS data input and editing | Yes |
| 4 | The National Data Management system shall support documents that can be in the form of MS Word, PDF, Spreadsheets and diagrams or images. These can be of general interest but the National Data Management system shall also facilitate the association to stations and gauges | Yes |
| 5 | The National Data Management system shall facilitate data ingest by the following methods:<br>a) Interface with a dedicated data acquisition system. This will be deemed the preferred method for data ingest in a timely fashion to support operational objectives. Where a dedicated data acquisition system is not operating, the alternatives below will be used for data ingest.<br>b) integrate with telemetry systems supporting the acquisition of real time station data<br>c) support manual data acquisition by, e.g., providing a mechanism for uploading of files in agreed file formats for both time series and GIS data, or through a data entry interface | <br>a) No<br>b) No<br>c) Partial |
| 6 | The National Data Management system shall facilitate the integration of data from meteorological agencies using one of the following options:<br>a) support manual data integration/acquisition by, e.g., providing a mechanism for uploading of files in agreed file formats generated by meteorological agencies data management systems, e.g., CLIMSOFT<br>b) Support automated data integration by exposing data integration/acquisition functionality via web services | <br>a) No<br>b) No |
| 7 | The National Data Management system shall permit execution of models with data stored in the system database | Yes |
| 8 | The National Data Management system shall provide mechanisms to generate reports based on pre-defined templates. These reports shall support time series charts (of both observed and simulated data), time series data tables and GIS maps | Yes |

| | | |
|---|---|---|
| 9 | The National Data Management system shall support metadata for time series and GIS data | Yes |
| 10 | The National Data Management system shall provide data processing and analysis functionality for time series data covering:<br>a) Visualization – time series charts and time series tables allowing multiple time series to be displayed. Edit functionality shall also be supported<br>b) Basic statistics – Averaging, Accumulating, Standard Deviation, minimum values, maximum values<br>c) Period statistics – basic statistics calculated based on daily, weekly, monthly or yearly periods<br>d) Monthly statistic – basic statistics calculated on a monthly basis with monthly and yearly summaries<br>e) Advanced statistics – coverage, data quantile auto-correlation, duration curves | Yes |
| 11 | The National Data Management system shall provide data processing and analysis functionality for GIS data covering:<br>a) Visualization – GIS maps of both vector and raster data with support for navigation (zooming, panning, etc) styling and background maps like Google Maps. Attribute tables to visualize attribute data. Coloring of GIS maps according to values for features/stations<br>b) Editing – Possibility of adding, changing or removing vector data supported by edit tools like clip, erase, split and merge. Attribute tables to edit attribute data with synchronization of select features in the GIS maps.<br>c) Query – query GIS data in the GIS maps by using spatial and attribute querying<br>d) Geo processing – dissolve, measure and re-project<br>e) Thiessen Polygons – produce thiessen polygons<br>f) Interpolation – produce raster based on interpolating of attribute values in point data<br>g) Raster Processing – resample, reproject, reclassification and zonal statistics<br>h) Convert – produce rasters based on vector data and vector data based on rasters | Yes |
| 12 | The National Data Management system shall provide functionality to link time series and documents to GIS data | Yes |
| 13 | The National Data Management system shall as well allow dissemination of authorized data (GIS, time series and documents) via a web user interface, including the ability to access time-series, documents and metadata via a spatial display | No |
| 14 | The National Data Management system shall as allow authorized users to input data via the web interface | No |
| 15 | The National Data Management system shall include a light weight component to be used by data loggers with no access to the database to create data sets to be easily imported | No |

| | | |
|---|---|---|
| 16 | The National Data Management system shall provide a web services layer allowing both uploading and downloading of data and information like time series, GIS data, documents and spreadsheets. | No |
| 17 | The National Data Management system shall provide mechanisms to facilitate synchronization of selected approved and quality assured data with the Regional Data Management system | No |
| 18 | National Data Management system shall provide mechanisms to facilitate exchange of data between 2 National Data Management systems where agreements on data exchange are available | No |

It is anticipated that the National Data Management system is composed by the components illustrated in Figure 9-1:

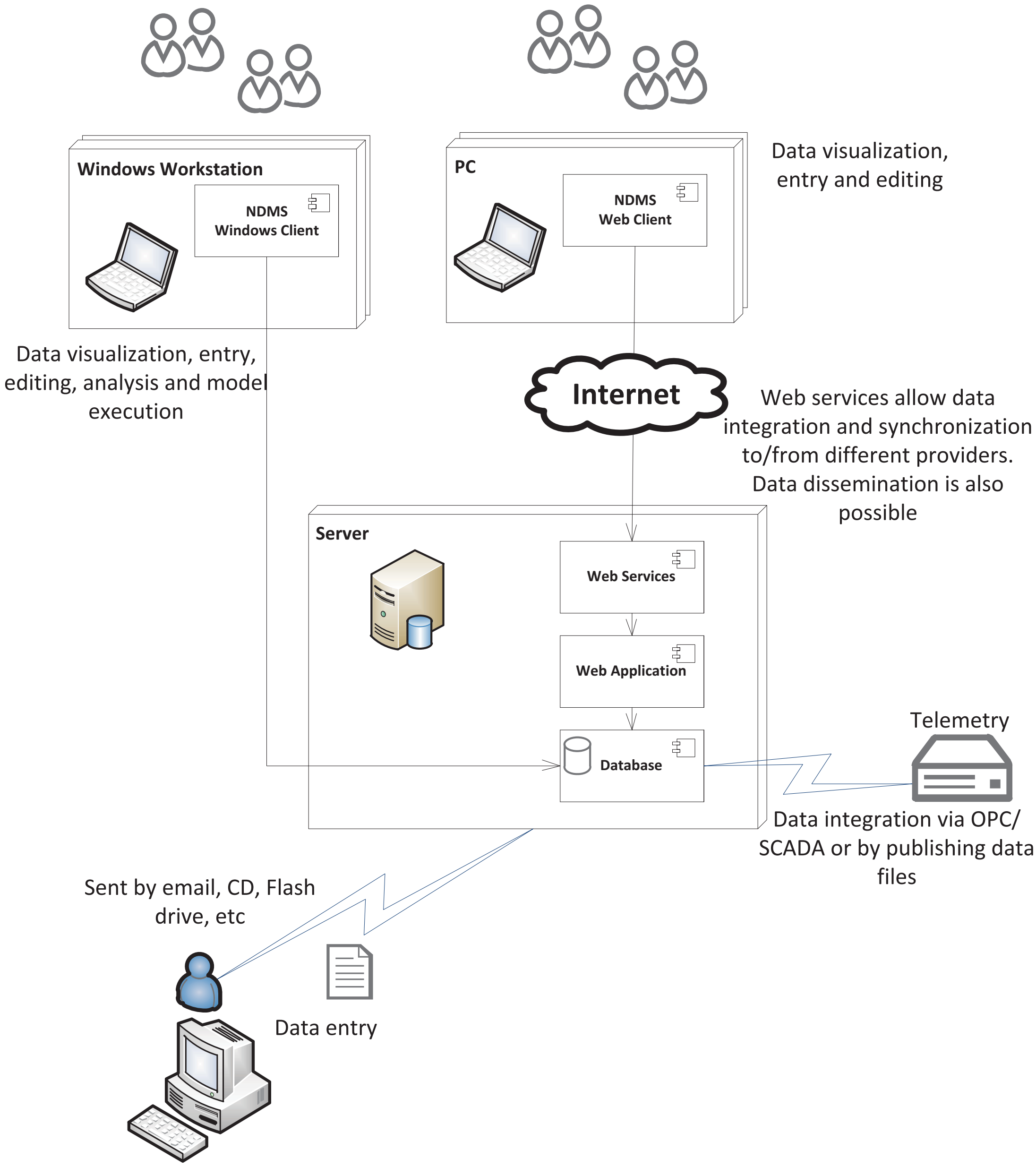


**Figure 9-1. National Data Management System Structure**

Please note from Figure 9-1 that:

- The National Data Management system is composed mainly by 7 components
    a. NDMS Windows Client – rich windows client availing the full set of functionality in the NDMS. This covers data visualization, data entry, data analysis, and model execution. Data entry is supported through agreed file formats produced by Data Entry component
    b. NDMS Web Client – web client for data visualization, data entry and data editing. Data entry is supported through agreed file formats produced by Data Entry component
    c. Database – The database where all data are stored
    d. Web services – functionality available through the Web facilitating data integration and synchronization
    e. Web Application – The web application availing the functionality to the NDMS web client
    f. Automated data ingest – software component for integration with dedicated data acquisition system or telemetry system for real time data acquisition or to load data from files published by a data acquisition or telemetry system
    g. Data Entry – A light weight component to be used by data loggers with no access to the database to create data sets to be easily imported by the NDMS windows client or NDMS web client
    h. Regional Data Management systems synchronization (not shown in the figure) – software component to allow synchronization of data between the National Data Management system in an automated manner that preserves approval authority at the national level.

Data Entry will be based on well-defined file format generated by the Data Entry light weight component. The same format shall be used for automated data ingest by publishing data files to, e.g., an agreed ftp server location.

The details of the file format shall be agreed taking into account what data suppliers can support and what NB DSS can handle but a comma separated format with header information allowing the identification of the data is envisaged:

```
FeatureClass:Rainfall_Stations
FeatureID:ID_OF_FEATURE
DataType:Rainfall
DateTime,Value
2014/01/11 09:00:00, 5
2014/01/11 20:00:00, 0.5
2014/01/11 11:00:00, [illegible]
2014/01/11 12:00:00, 2
2014/01/11 13:00:00, 1
2014/01/11 14:00:00, 0
```

Header

Data

Figure 9-2. Example of Data Format for Exchange

## 9.3 Regional Data Management

The Regional Data Management system will initially be hosted by NBI. This system will house data collected by the individual countries that has been identified as being required for the regional system and will be a sub-set of the full data collected by the countries.

The overall objective of the Regional Data Management system and supporting GIS database is to:

1. Manage regional hydro-met data and meet regional hydromet information needs in terms of data analysis, reporting, execution of models, and information dissemination for the sustainable management and development of national water resources, and
2. Automated ingest of data from countries where National Data Management systems as described in previous section are adopted
3. Manual ingestion of data from countries where the National Data Management system as described in previous section is not adopted

Implementation of the national data management systems will require:

1. Installing and initiating operations of the system at NBI, including establishment of the necessary data flows from national systems, and
2. Conducting capacity building and training for the system.

The Requirements of the Regional Data Management System to meet these objectives are essentially the same as those for the National Data Management System, with several points of difference in emphasis. This should allow the same software to be used for both the National and Regional Systems, with primary differences being the configuration of the systems and that some of the functions will be dormant in one or the other of the systems. The primary points of difference in emphasis for the Regional Data Management System are noted below.

*Specific Regional Data Management System Requirements*

1. The Regional Data Management System shall provide all of the capabilities associated with the National Data Management Systems.
2. The Regional Data Management system shall provide mechanisms to facilitate synchronization of approved and quality assured data with the National Data Management systems, either automated from countries where National Data Management systems as described in previous section are adopted, or manual from countries where the National Data Management system as described in previous section is not adopted
3. Because primary entry point for data in the system is anticipated at the national level, the Regional Data Management system will include data entry, reception, and editing as an alternate and not a primary source of data. The primary source of data for the regional system will be through the synchronization mechanisms noted above.
4. The facility for automated ingest, processing, and dissemination of global and regional spatial data products will be fully developed and configured in the Regional data management system implementation, while national data management systems will generally be configured to receive these products from the regional systems.

It is anticipated that the Regional Data Management system is composed by the components illustrated in the Figure 9-3.

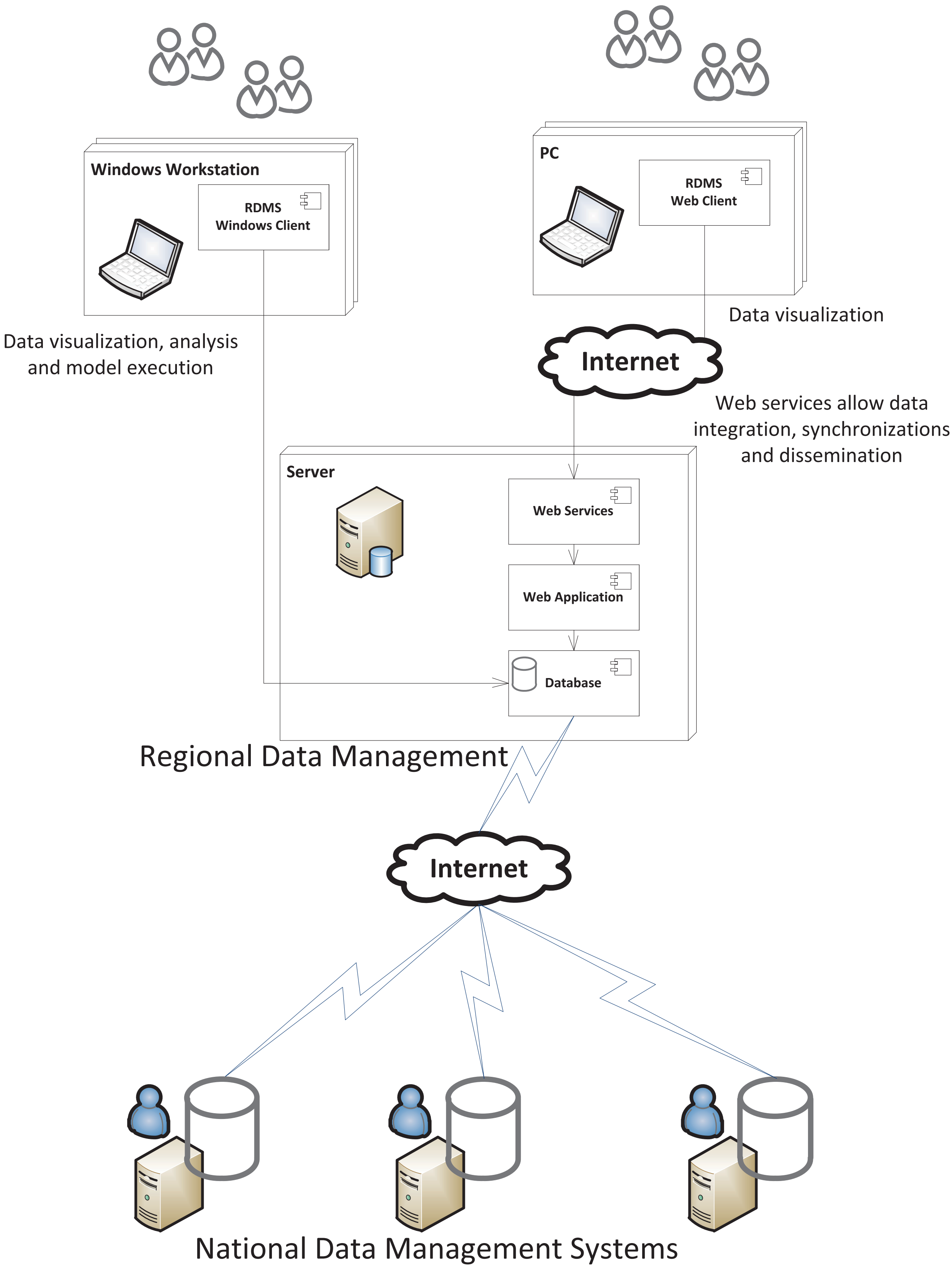


Figure 9-3. Regional Data Management System Structure

Please note from Figure 9-3 that for the Regional Data Management system:

a. National Data Management systems synchronization is emphasized – A software component will allow synchronization of data with the various National Data Management systems. For countries where National Data Management systems (or compatible systems) as described in previous section are adopted the synchronization can be manually initiated or automated. For countries where a compatible National Data Management system is not adopted, the synchronization will be manual. Synchronization will be internet based, as shown in the figure.
b. While the national data management system may contain data for all stations in a country, only a selected subset will be synchronized with the regional system, as agreed in the design, but under the control of the countries. Automated communications configuration should include the ability to fill in missing periods following power or network outages.
c. Global and regional earth observation products will be emphasized
d. Other data entry functions are de-emphasized.

## 9.4 Data and Information Products

While the national and regional data management systems are designed to be configurable so that a wide variety of products could be generated, several specific web-based products will be defined to be configured during system setup. These will include:

- A map display showing the stations in the network
- Pop-up graphics showing charts of current data for regional stations, with options for expanding in a separate window; flexibility for multiple parameters, selection of time periods, and time intervals.
- Spatial data overlays to visualize precipitation and other layers as agreed
- Ability to download spatial data layers
- Ability to download data for one or more stations to a local file

Additional features for regional dissemination and stakeholder communications will include:

- Public pages and stakeholder pages accessible via authentication
- Web services to permit automation of dissemination

### 9.4.1 Web portal design

A number of schematics have been prepared that illustrate the look and feel of a web portal – that is, how the users will experience working with the web portal – and also that give an idea of the available functionality.

Note that the web portal can actually be installed in two versions – at regional level as part of Regional Data Management System and at the various countries as part of the National Data Management Systems.

The user interface will appear similar for the two versions – the main difference will be that data editing will not be available at regional level.

## *General Layout*

Figure 9-4 illustrates the anticipated general layout of the web portal.

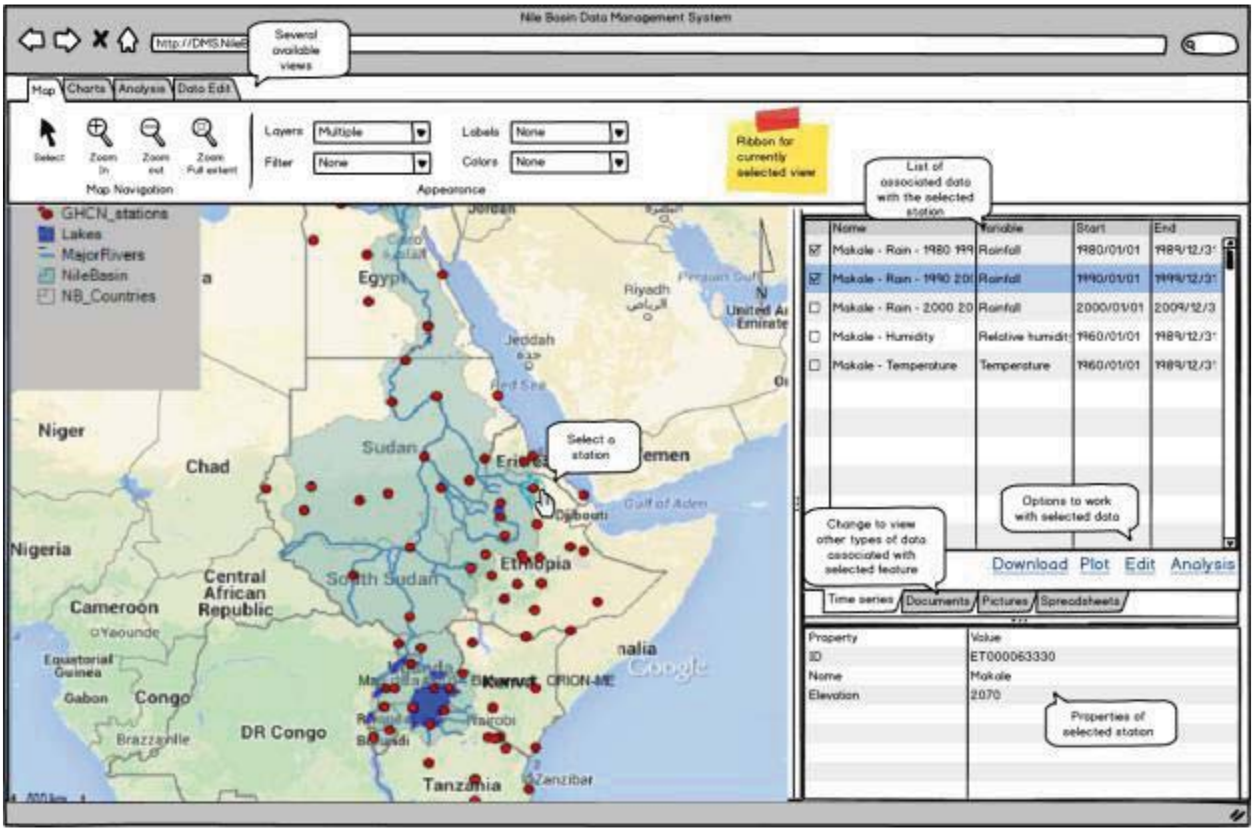


Figure 9-4. Web Portal - General layout

Please note from Figure 9-4 that:

- The user interface is based on a GIS map that can display any of the GIS data stored in the data management system
- It is possible to select the layers to display, labeling style, to filter GIS data and also to display colors according to values for the GIS data
- Upon selection of GIS feature on the map, e.g., a station, not only its properties are displayed but also the data associated to the station
- By clicking on the corresponding tab-leaf it is possible to switch between the lists of the data associated with the selected feature (time series, documents, pictures, spreadsheets)
- Each type of data will have a set of options to work with. In this example, it is possible to download, plot, edit or add the time series to the Analysis component.
- A ribbon displays the available functionality for each of the available components (Map, Charts, Analysis, Data Edit)
- Available functionality can be based on the permissions of a logged-in user

### *Workflow*

Figure 9-5 illustrates the anticipated workflow of the web portal.

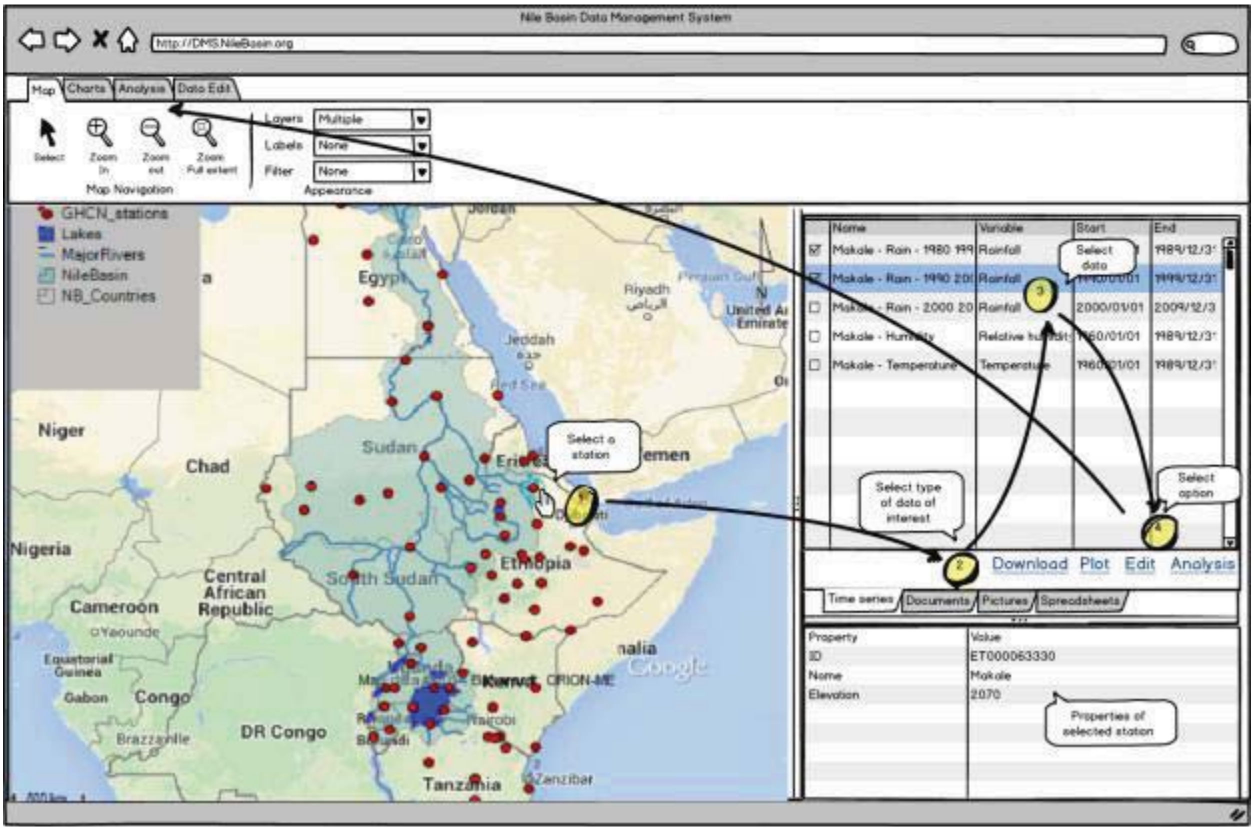


Figure 9-5. Web Portal – Workflow

Please not from Figure 9-5 that:

- The user start by selecting a GIS feature after which properties and associated data are displayed
- The user selects which associated data type (time series, documents, pictures, spreadsheets) to work with
- The user selects the specific data to work with. Depending on the data type, multiple selection may be available
- The user selects what to do with the data. Download, plot, edit and add to analysis will be available for time series data.
- Data are added to the component/tab corresponding to the selected option.

## *Charts*

Figure 9-6 illustrates the anticipated user interface for time series charts.

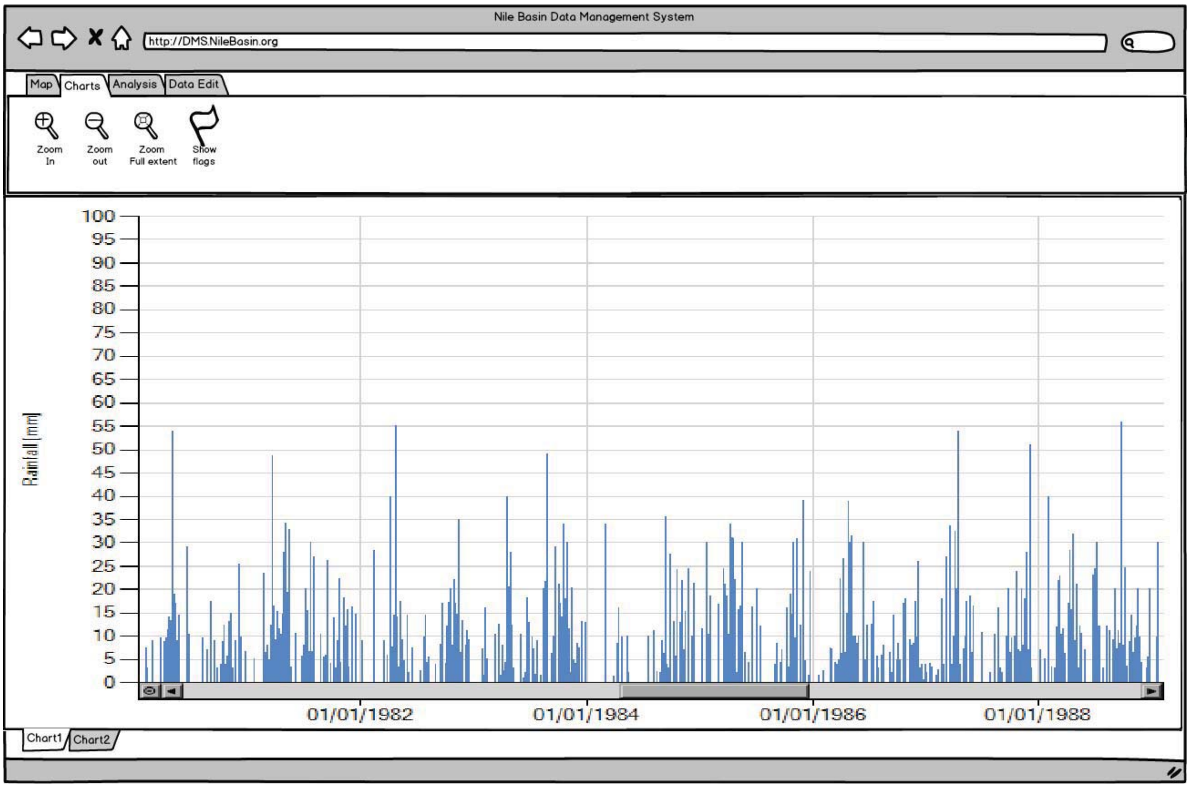


**Figure 9-6. Web Portal - Charts**

Please not from Figure 9-6 that:

- Multiple charts can be handled in the chart component
- It is possible to combine multiple time series in the same chart
- It is possible to zoom on the chart as well as display flags for time step values

## *Analysis*

Figure 9-7 illustrates the anticipated user interface for time series analysis.

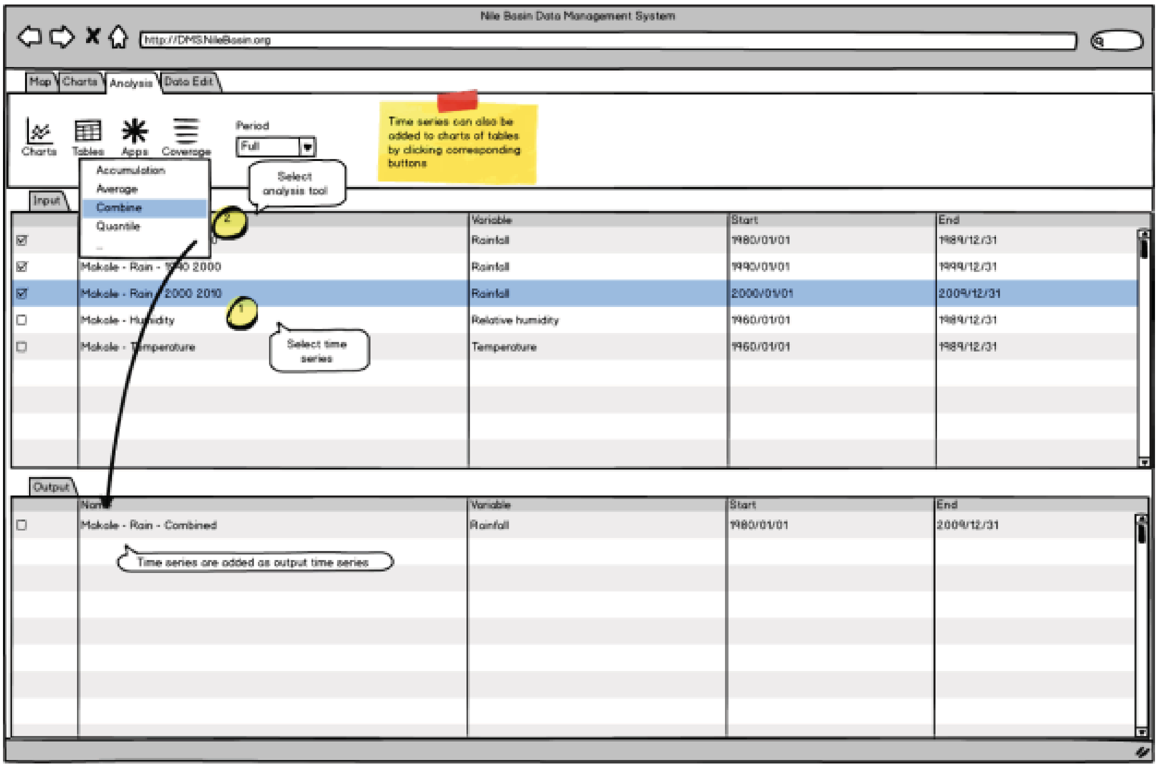


Figure 9-7. Web Portal – Time Series Analysis

Please not from Figure 9-7 that:

- Time series added to the analysis component will be available in the Input section
- The user shall start by selecting which time series to analyze. The number of necessary time series vary for the analysis tools.
- The user shall then select which analysis tool to execute
- Time series generated in the analysis component will be added to the Output section
- Analysis tools can also add time series to charts or tables depending on the type of output from the tools

### *Data Edit*

Figure 9-8 illustrates the anticipated user interface for editing time series data.

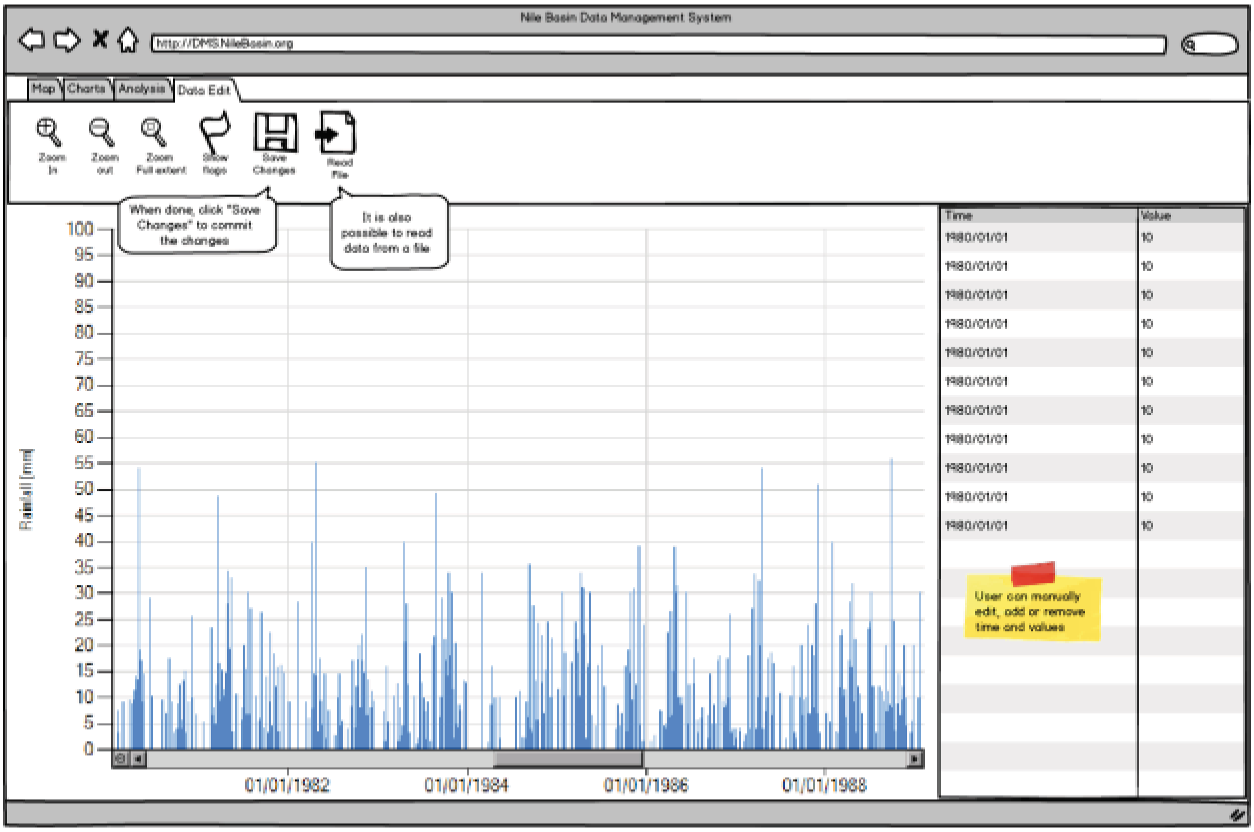


Figure 9-8. Web Portal – Data Edit

Please not from the figure that:

- It is possible to zoom on the chart as well as display flags for time step values
- User can manually edit, delete or remove time steps and values using the table on the right
- User can open a file produced by the data entry with the data to be added
- Access to time series editing functionality will be based on the user roles.
- It is envisaged that time series editing component will only be available in the National Data Management System

## 9.4.2 Data Entry

Data Entry is a light weight component to be used by data loggers with no access to the database to create data sets to be easily imported by the NDMS windows client or NDMS web client. These data sets shall follow the agreed format as previously described.

A number of schematics have been prepared that illustrate the look and feel of the Data Entry – that is, how the users will experience working with it – and also that give an idea of the available functionality.

### *Data definition*

Figure 9-9 illustrates the anticipated user interface for the data definition in Data Entry.

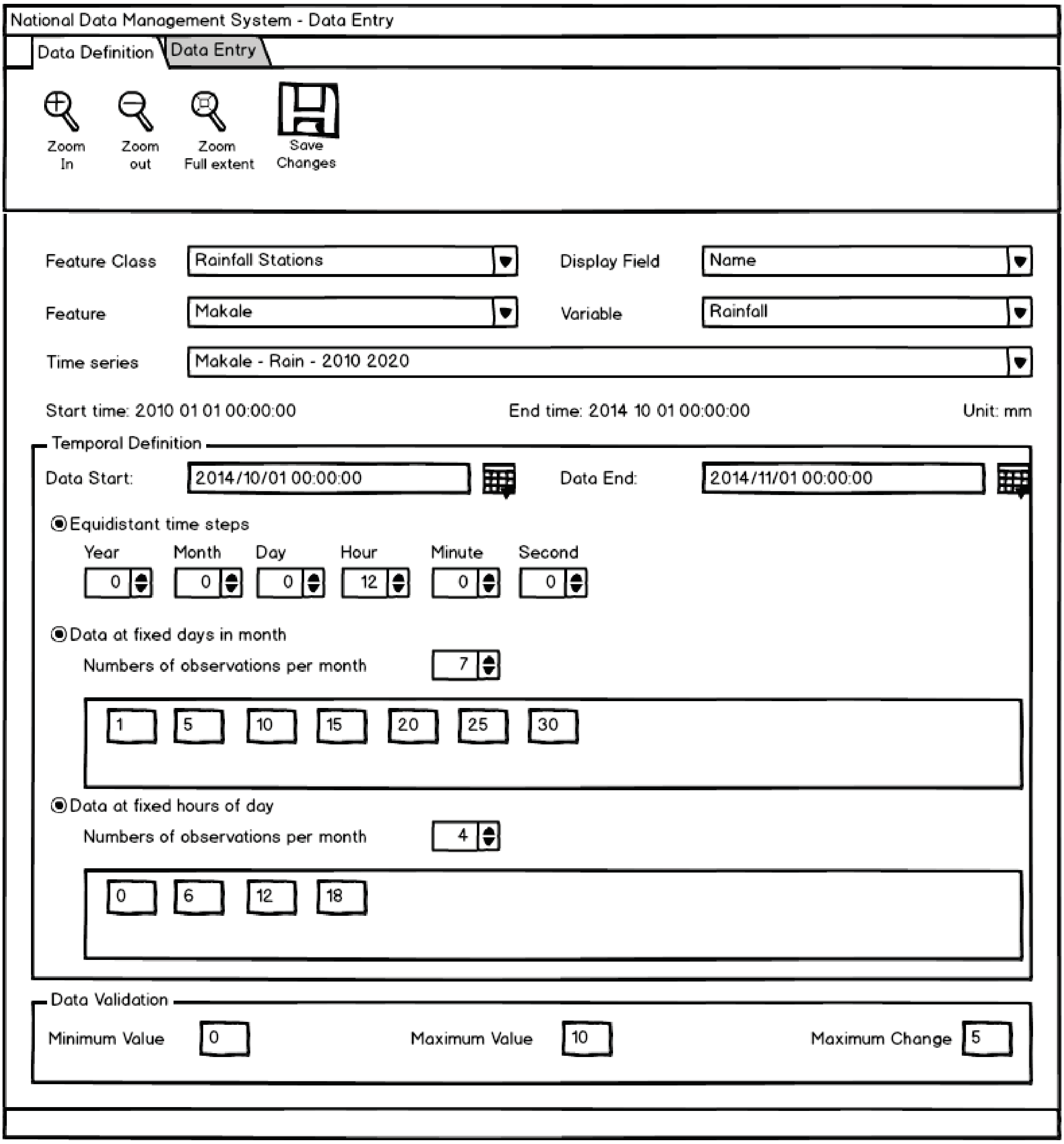


**Figure 9-9. Data Entry– Data Definition**

Please not from Figure 9-9 that:

- User starts by selecting the feature/station and the associated time series to edit data for
- Data Entry will provide information on start and end time of existing data as well as the unit for the selected time series
- User shall then define period and the temporal resolution of the data to be edited. This way, Data Entry can automatically generate new time step values according to the observed data. 3 options are available:
    - Data observed at equidistant intervals

    - Data observed at fixed days per month
    - Data observed at fixed hours every day
- Finally, user can define data validation criteria as a first filter on the quality of the data while typing

### *Data editing*

Figure 9-10 illustrates the anticipated user interface for the data editing in Data Entry.

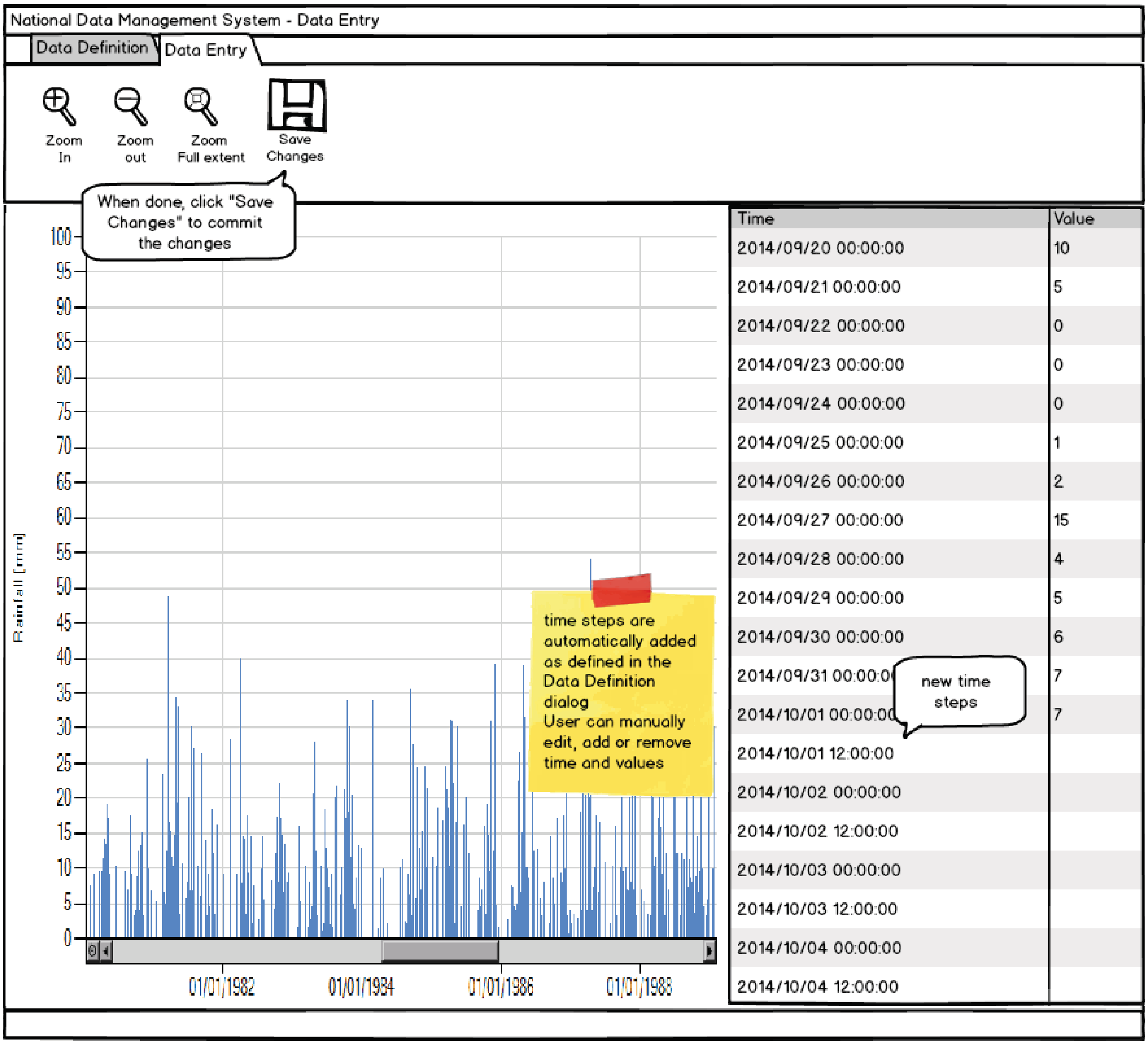


**Figure 9-10. Data Entry– Data Editing**

Please not from Figure 9-10 that:

- It is possible to zoom on the chart as well as display flags for time step values
- User can manually edit, delete or remove time steps and values using the table on the right
- New time steps are added according to Data Definition dialog

## 9.6 Forecasting System

A regional forecasting system is one of a variety of models that can be supported by (and integrated with) the data management components of a water resources monitoring system. Monthly to seasonal water supply forecasts are essential for effective planning and managing water resources particularly for irrigation, operating reservoirs and water distribution networks, and allocating water among competing users. More reliable, timely and understandable forecasts can directly lead to more efficient and sustainable water use and reduced conflict through improved management, conservation and more equitable allocation.

Hydrologic forecast systems generally utilize forecasts and observations of parameters such as precipitation and temperature as inputs to a hydrologic model to generate a forecasted streamflow response. A hydrologic forecast system can be used to forecast long-term water supply on a monthly and seasonal basis as well as river basin flooding on an hourly or daily scale. A flash flood forecast system is generally used to forecast intense rainfall events for a vulnerable urban area. It differs from a hydrologic forecast system in that the nature of a short lead time for “flash” floods may not allow for a hydrologic simulation and instead relies on event based thresholds monitored on fine temporal scales through the use of nowcasting. For a regional forecast system operated at a regional center such as NBI a hydrologic and flood forecasting system may be operated effectively at a daily time step, with ability to aggregate flows to monthly and seasonal volumes as necessary. Sub-daily time step models are better addressed at a national or local scale where observations can be received and processed with sufficient speed to address rapidly responding basins and flash flood phenomenon.

The system should use observed and forecasted data to drive hydrologic and hydraulic models. The functions of the forecast system are to manage the data inputs to the associated models and visually display model outputs in customizable ways for user decision support.

### 9.6.1 Hydrologic Forecast Approach

Hydrological models must be configured, calibrated, and validated to specific basin characteristics and conditions. Hydrological forecasting and simulation software, the core of an operational and predictive modeling system, must include modules for:

- Precipitation estimation,
- Hydrologic simulation,
- Hydrologic and hydraulic flow routing,
- Reservoir and basin simulation modeling; and
- Analysis and adjustment of flood forecasts.
- Ensemble streamflow forecasting and probabilistic analysis

**Precipitation Estimation Module** - The main features of the precipitation estimation module are that it will interpolate rainfall observations provided by the rainfall network and provide results at a spatial scale suitable for hydrologic applications. The module should be able to easily read observed and forecast precipitation data from the data management system and provide resulting precipitation time-series for use in hydrologic simulation.

**Hydrological Module** - The hydrologic simulation module will perform rainfall-runoff modeling and calculate stream-flow hydrographs at required stations. The rainfall-runoff model will be able to perform a continuous simulation of the hydrologic behavior of the catchment. Once the model is calibrated, it should provide a reliable estimate of stream-flow at the required stations with only minor adjustment of the model parameters.

It is proposed that the hydrological model provide a representation of the rainfall-runoff process using physically meaningful model parameters. Preferences will be given to models that have already shown their effectiveness in a daily flood forecasting operation.

The hydrological module will:

- Model the behavior of the main components of the hydrologic cycle, such as infiltration, evapotranspiration, sub-surface drainage, percolation to deeper soil layers, overland flow, and channel flow.
- Be able to provide modeled estimates for ungauged catchments using parameter values derived from elevation, soil characteristics, land use and other relevant information.
- Provide daily information on streamflow and for other hydrological parameters such as soil moisture.
- Provide reliable continuous forecasts on the basis of daily rainfall data collected across the basins, rainfall predictions for days ahead, and actually observed flows and water levels at gauging stations. The latter daily information will be used to continuously fine-tune and update the model to the actual flow conditions, without requiring any significant adjustment to the model parameters.
- Produce output containing time series of stream-flow, observed rainfall, soil moisture, evapotranspiration, and percolation at a sub-basin level.
- Be easily linked to the flow routing module, directly or through data management software.

**Hydrologic and Hydraulic Flow Routing Module** - The flow routing module is crucial for operations and flood forecasting in streams, rivers, and canals. The routing module will be able to receive and integrate stream-flow information from both the data management system and from the hydrological modeling system, and will be able to function in operational and forecast domains.

The routing model will:

- Be based on appropriate hydrologic routing techniques where such models can effectively represent the routing transformation and intermediate flow and stage estimates are not required
- Be based on the complete set of De Saint-Venant equations where backwater conditions require a hydraulic representation or where river stage and discharge estimates are required throughout the length of a given reach. The algorithm must use a robust numerical scheme that simulates channel and overland flow using 1D flow simulations.

**Reservoir and River Basin Simulation Module** – The reservoir and river basin simulation modules will provide a realistic view of the physical river and reservoir system using a map-based schematic complete with a set of drawing tools. The module will be able to build a network capable of representing a single reservoir on a single stream as well as a highly developed and interconnected system. In addition, the module will have the ability to model a range of reservoir outlet types.

**Ensemble streamflow prediction** – The ensemble streamflow prediction module will facilitate seasonal forecasting and short term probabilistic forecasting by drawing from an initial database of model states associated with the forecast system and simulating possible future streamflow traces based on past climate realizations. Probabilistic analysis will be facilitated by analysis tools designed to summarize the streamflow ensembles at various future timescales and flow variables.

# 10 Institutional Design and Development

Institutional strengthening and capacity development are vital to the durability of the operation, management and delivery of the Hydromet services. The following five factors have been identified by the Nile Basin Countries during the project launch workshop as essential to the sustainability of the Nile Basin Hydromet systems:

- Institutional
- Technical
- Management
- Financial
- Behavioral change

A questionnaire, presented in the inception report, was prepared to interview decision makers, field officers and technicians to gain a deep understanding of the current hydromet systems' institutional, technical, management, and financial conditions; and explore opportunities for institutional strengthening and improved capacity to sustain hydromet services. The questionnaire addressed prioritization of the fourteen water resources management/socio-economic issues. It also allowed for identification of geographic priority areas for each issue, confirmation of data requirement, listing of capacity building needs, and exploring ideas for improved financial sustainability and behavioral change to promote hydromet services. The questionnaire was filled during the countries consultation with decision makers and professionals at ministries and during interviews of field staff. Field visits were conducted to key locations to assess current technologies and associated monitoring practices (Appendix A). A description of each of the sustainability factors, key findings based on the countries consultation and field visits, and recommendations for institutional strengthening and improved operation, management, and service delivery are presented below.

## 10.1 Institutional Factor

### 10.1.1 Key concepts

Institutional sustainability of the Hydromet Systems means that institutions at the regional, national and local level are functional and meet the needs of decision makers, professionals and relevant stakeholders in the development, management and protection of the shared Nile Water Resources to achieve the Shared Vision of the Nile Basin Countries. If institutional structures are strong, lead and support institutions at the regional, national, and local level will be clear on their functions, and responsibilities, and will be capable of fulfilling these roles effectively.

### 10.1.2 Key Findings and recommendations

The countries consultation and field visits were a good opportunity for national decision makers, professionals and field staff to gain an understanding of the objectives and tasks of the Nile Basin Hydromet Systems project and be engaged in the design process. This section presents the main findings of the institutional questionnaire related to water management/socio-economic issues and monitoring parameters.

#### *Water Resources Management/Socio-economic issues*

The Nile Basin Ministries of Water Affairs[2] have organized in their premises a participatory session with decision makers and senior staff to discuss and complete the water management/socio-economic section of the questionnaire.

[2] Ministries of Water Affairs are the Ministries in charge of the water sector, and are the NBI focal Ministries on this sector.

- *Lead and Supporting Institutions*

Results of the questionnaires show that, generally, the Ministries of Water Affairs in the Nile Bain lead the majority of the water resources management/socio-economic issues. The number of water resources management/socio-economic issues where the Ministries of Water Affairs have a lead role varies from seven (7) to twelve (12) issues as illustrated in Table 10-1. They also have support role of the majority of the issues that they are not leading. This would help in the regional collaboration towards maximizing the benefit of hydromet systems and allows for leveraging resources in the operation and management of these systems. On the other hand, there is a considerable number of supporting institutions composed of national Ministries representing sectors such agriculture, health, infrastructure, energy[3], fisheries, navigation, environment, interior, and research as well as other entities representing state[4] level government services, NGOs, and local organizations and associations. The number of the supporting government institutions (Ministries and specialized agencies) can be close to twenty (20) for some of the countries. This is a challenge for the effective operation and delivery of the hydromet services, if the roles and responsibilities of the lead and supporting institutions are not clearly defined.

[3] The energy sector, specifically hydropower, is in most countries led by institutions that are separate from the Ministries of Water Affairs.
[4] State can be regional Ministries at the Governorate level.

**Table 10-1. Lead and Support Roles of the Ministries of Water Affairs**

| | Burundi | | DRC | | Ethiopia | | Kenya | | Rwanda | | South Sudan | | Sudan | | Tanzania | | Uganda | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Water Management/ Socio-economic-issues** | Lead | Support | Lead | Support | Lead | Support | Lead | Support | Lead | Support | Lead | Support | Lead | Support | Lead | Support | Lead | Support |
| **WRPM** | √ | | √ | | √ | | √ | | √ | | √ | | √ | | √ | | √ | |
| **Floods** | √ | | √ | | √ | | √ | | | ● | √ | | √ | | √ | | √ | |
| **Rainfed Agriculture** | | ● | | ● | | ● | | ● | | ● | | ● | | ● | | ● | | |
| **Irrigated Agriculture** | | ● | | ● | √ | | | ● | | ● | √ | | √ | | | ● | | ● |
| **Groundwater Management** | √ | | √ | | √ | | √ | | √ | | √ | | √ | | √ | | √ | |
| **Water Quality and Pollution** | √ | | √ | | √ | | √ | | √ | | √ | | √ | | √ | | √ | |
| **Erosion/Sediment** | √ | | √ | | √ | | √ | | √ | | √ | | √ | | | ● | √ | |
| **Energy** | | ● | | ● | √ | | | ● | | ● | √ | | √ | | | ● | | ● |
| **Watershed Management** | √ | | √ | | √ | | √ | | √ | | √ | | √ | | √ | | √ | |
| **Wetland Management** | √ | | √ | | √ | | √ | | √ | | √ | | √ | | | | √ | |
| **Drought** | √ | | √ | | √ | | | ● | | ● | √ | | √ | | √ | | | ● |
| **Climate Change** | √ | | √ | | √ | | √ | | √ | | √ | | | ● | | ● | √ | |
| **Fisheries** | | ● | √ | | | ● | | ● | | ● | | ● | | ● | | | | |
| **Navigation** | | ● | | | √ | | | ● | | ● | | ● | | ● | | | | ● |

- *Prioritization of Water Management/Socio-economic issues*

The questionnaire includes prioritization of the water management/socio-economic issues based on a list of benefits relevant to each issue. Results[5] indicate that the highest priority was given to water resources planning and management, energy, watershed management, flood management, and water quality, followed by climate change, rainfed irrigation, and wetland management. Navigation, erosion and sediment, and drought are relevant to specific geographical areas.

- *Geographical areas of socio-economic issues*

Decision makers and senior staff from the Nile Basin countries have identified, as part of the institutional questionnaire, geographic areas (catchments, sub-catchments) that need hydromet data to address each of the water management/socio-economic issues and generate regional and national benefits for the development, management and protection of the shared Nile Water Resources to achieve the Shared Vision of the Nile Basin Countries. A list of the geographical areas has been compiled in Table 4-2 targeting issues for regional collaboration with defined common benefits and data requirement for each issue. This list was discussed with the Nile Basin countries during the first review workshop for the hydromet systems conceptual design. The list will assist in the design of

[5] These results need to be confirmed and validated after final review of the questionnaire information for DRC and South Sudan.

implementation phase, in defining the functions required to address the selected water management/socio-economic issues and identifying the roles and responsibilities of the lead and supporting institutions relevant to each issue.

### *Institutional responsibilities of hydromet parameters*

Results of the questionnaire and field visits for key hydromet parameters are summarized as follows[6]:

- *Rainfall and Evaporation Parameters*

The National Meteorological Services are the lead institutions responsible for monitoring rainfall and evaporation. Burundi, DRC, Rwanda, and Sudan meteorological services have responsibility of all national meteorological monitoring. Supporting institutions in the other countries include mainly Ministries of Agriculture, water resources departments, and research centers. Meteorological services in Ethiopia and Kenya are under the Ministries of Water Affairs. Kenya meteorological monitoring services are decentralized. For the remaining countries data collection is decentralized, but data processing, validation, storing, and dissemination are centralized. Tanzania Meteorological service has data sharing agreement with the Ministry of Water. Meteorological services in DRC, Kenya, Sudan, Tanzania, and Uganda charges fee for data. Rainfall and evaporation monitoring network in some of the countries witness duplication of monitoring stations due to lack of collaboration between lead and support institutions. Most of the support institutions are currently not sharing data with lead institutions. Streamlining the monitoring responsibilities between the hydromet services and other institutions and organization collecting rainfall and evaporation data will address the monitoring duplication issue.

- *Water discharge/Level*

Water discharge/level monitoring are carried out exclusively by the hydrological services of the Ministries of Water Affairs. Kenya, Tanzania, and Uganda have decentralized these services to regional districts or rivers basins. Kenya has adopted a decentralized system that links the Transboundary Water Directorate to the national office of the Water Resources Management Authority (WRMA) which is responsible of two Regional Offices covering respectively the Northern and Southern Basins of the Kenyan Lake Victoria Basin. Each the regional offices has three sub-regional offices. This institutional model takes into consideration regional (transboundary), national, and basin catchment needs, and may be worth considering by other countries.

- *Groundwater monitoring*

Groundwater monitoring is only carried out for a limited number of sites in Kenya, Sudan and Uganda under by the hydrological services of the Ministries of Water Affairs. Sudan groundwater monitoring program is currently limited to groundwater level and quality for specific projects under the Directorate General of Groundwater and Wadis. Most of the countries have plans to map out groundwater resources and progressively establish groundwater level and quality monitoring systems.

- *Surface water and groundwater use*

Despite the fact that water releases from surface reservoirs and diversion canals are often monitored, the majority of private water diversion and groundwater abstraction are not measured. In addition, responsibilities of monitoring agriculture water use and urban/rural water supply are not clearly defined for most countries.

- *Earth Observations Products*

Most of the Ministries of water Affairs in the Nile Basin do not currently have Earth Observation Products capacities.

[6] Water quality, sediment and water laboratories institutional aspects were supplemented to material in Section 3.1.

### Institutional Conceptual Design

The conceptual design of the institutional component addresses the institutionalization at both the data demand and data supply levels as depicted in Figure 10-1. The demand is driven by the data and information required to address the regional water resources management issues. The lead and supporting national institutions in charge of the various water resources management/socio-economic issues constitute the data demand entities. The various hydromet services are the data supply entities.


Figure 10-1. Data Demand and Supply Concept

The key steps, for the institutionalization of the hydromet systems to meet the data and information needs of decision makers, professionals and relevant stakeholders in the riparian countries to collaboratively address the regional transboundary water resources management issues following the key concepts indicated in Section 10.1.1, are presented below:

- Review and confirm the regional transboundary issues.
- Review and confirm the benefits for addressing each transboundary regional issue.
- Review and confirm water resources management/socio-economic factors[7] (i.e. IWRPM, Flood Management, Erosion and Sediment, Energy, Irrigated agriculture, etc.) for each regional transboundary issue.
- Identify the lead and supporting institution for each of the water resources management issue.
- Define the functions (activities) related to each water resources management issue.
- Identify the roles and responsibilities of the lead institution and supporting institutions for the implementation of each defined function.
- Develop national policies, plans[8], and procedures to support the implementation of the functions based on the roles and responsibilities of each lead and supporting institution.
- Validate the list of data requirements (Demand) for each water resources management/socio-economic factor.

[7] Issues and factors are interchangeably used throughout the report.
[8] The plans can be phased in short, medium, and long term horizons

- Identify for each country the data requirements for the lead institution and supporting institutions based on the above validated list and the functions and responsibilities of each institution.
- Confirm the regional network for each Hydromet parameter.
- Identify for each country the lead and support institutions responsible for providing hydromet services for the required data with clear functions and roles of each institution.
- Develop national policies and procedures to support the functions, roles and responsibilities of each lead and supporting institution providing hydromet services.
- Ensure commitment of Ministries of Water Affairs in each country for sharing Regional Hydromet data through collaborative agreements.
- Identify national institutions responsible for the Regional Hydromet Network Database in their respective countries.
- Identify the NBI functions and responsibilities in supporting (capacity building and promoting enforcement of standards) sustainability of regional Hydromet Network and managing the regional database.
- Develop policies and procedures to support the implementation of the NBI functions.
- Identify NBI personnel needs for the implementation of the NBI functions to support sustainability of regional Hydromet Network and management of the regional database.

## 10.2 Technical Factor

### 10.2.1 Key Concepts

Technical sustainability of the Hydromet Systems services is primarily achieved through the availability of trained and motivated observers and technical staff, clear technical standards and procedures for operation and management of monitoring stations and associated hardware and software, combined with the availability of appropriate technologies that are easy to maintain and upgrade.

### 10.2.2 Key Findings and recommendations

Interviews of the meteorological and hydrologic services and field visits to key monitoring stations show that countries use both manual and automatic monitoring stations. There is a tendency of more use of automatic stations by meteorological services. The majority of water level recorders are manual staff gauges, however, all countries are progressively adopting new technologies for water levels recording and water discharges measurement. Technical standards are more readily available and adopted by meteorological services due to technical support from WMO, but these standards are often not adopted by other national institutions that support monitoring of rainfall and evaporation parameters. Lack of spare parts and lack of maintenance are the main reasons for malfunction of equipment. Tipping bucket, acoustic flow meters, automatic float and bubbler water level recorders, and real time transmission are the most favorable technologies in the basin. Use of these technologies is reflected in the design of the hydromet systems.

Training and capacity building has been requested by the countries, especially in the areas of data collection and maintenance for new monitoring systems technologies and transmission technologies.

## 10.3 Management Factor

### 10.3.1 Key Concepts

Management sustainability of hydromet services is reached when data collection, processing, analysis, validation, storage, and dissemination standard procedures are harmonized and implemented by the lead and support institutions, and when these institutions are able to hire and retain qualified field observers and staff. Sustainable management ensures that hydromet services are aligned with local human and financial resources.

### 10.3.2 Key Findings and recommendations

Around half of the Nile Basin countries have standard procedures for data collection, processing, analysis, validation, storage, and dissemination that are harmonized and implemented. With the exception of Tanzania that has both central and regional meteorological databases, all other countries keep the meteorological data at a central database. Hydrological data are more decentralized, three countries have opted for central and regional databases. Most countries have difficulties hiring and retaining qualified staff due mainly to low wages.

Collection, processing and validation of hydromet data, especially hydrometric data is a tedious job. Hydrologic services have often specialized units of data analysts to process, analyze and validate water level/discharge measurement data and update rating curves. All countries have expressed needs for capacity building in these areas. Riverside has included hands on and formal training in data collection, procession, analysis, and validation in the training program presented in Section 1.

## 10.4 Financial Factor

### 10.4.1 Key Concepts

Financial sustainability means that continuity in the delivery of hydromet services is assured because of the socio-economic benefits that can be gained from the reliable data and information provided by the services for the effective design of the hydraulic infrastructure, productive agriculture for food security, and for reducing risk of losing lives during extreme events. Awareness of decision makers about these benefits and communication for increased demand for these services are essential for securing sustainable funding.

### 10.4.2 Key Findings and recommendations

As mentioned above lack of adequate funding is the main challenge for sustainability of hydromet services. The questionnaire interviews revealed that chief reasons for adequate funding are low priority given to the sector, lack of awareness about the economic value of the hydro-meteorological data, and lack of studies to demonstrate the socio economic benefits of the hydro-meteorological data. Recommendations for options to sustain finding of hydromet services are presented below:

- Conduct a study to show the socio-economic value of hydromet services.
- Develop and conduct an awareness and outreach program based on the results of this study targeted to decision makers and users in the various sectors benefiting from the hydromet services.
- Explore opportunities of funding from Water utilities, Electricity companies, and private sector

## 10.5 Behavioral Factor

Meteorological and hydrological services rely on local field observers to collect rainfall data from manual rain gauges and surface water records from manual staff gauges. Despite the low stipends for these services, manual observers are not compensated on time. Given that for some the countries, manual gauges can represent up to 90% of the stations in the monitoring network, lack of payment often results in failure of the hydromet services. The questionnaire data shows that this issue is a challenge for the majority of the hydromet services. Around half of the countries recognize the lack of awareness of field observers about the national socio-economic benefits of hydromet field data collection. They also support communication and awareness program to change the attitude about compensation of the field observers, raise awareness of field observer about the benefits of the data, and convince decision makers about the added socio-economic national and local benefits. Riverside recommends the development of communication capacity at the lead institutions for meteorological and hydrological services to develop and conduct awareness and communication programs targeted to decisions makers, data users, and observers. This has been included in the training program presented in Section 1.

# 11 Staffing Needs for Sustainable Regional Hydromet Systems

The availability of human resources with the right qualifications and in the right numbers at all levels is vital to the sustainability of the regional hydromet systems. The human resources for the regional hydromet systems are related to the services required to obtain the data and information for the thirteen (13) regional Nile Basin issues indicated in Table 4-2. Table 11-1 presents the key data requirements for the regional cooperative issues:

**Table 11-1. Regional Key Data Requirements**

| Required Hydromet Data | Regional Issues from Table 4-2 |
|---|---|
| Rainfall | 1, 2, 3, 6 |
| Evaporation | 1, 2, 3, 6 |
| Water Level (River, Reservoir, Lake) | 1, 2, 3, 6, 7, 10 |
| Water Discharge | 1, 2, 3, 5, 6, 7, 10, 11, 12 |
| Water Quality | 3, 4, 8, 9, 11, 12, 13 |
| Soil erosion and Sediment Load | 2, 3, 8, 11, 12 |
| River Profile | 1, 3, 6 |
| Earth Observation Products | 5 |

The services associated to the hydromet data for the regional collaboration issues, shown in Table 11-1 include:

- Meteorological services
- Hydrological Services
- Earth Product Services

## 11.1 Meteorological Services

Rainfall and evaporation are the key meteorological parameters that are essential for the majority of the regional issues. The particular functions and human resources required by the national meteorological services of each of the Nile countries to provide accurate data and information about these parameters are described below.

### Monitoring

**Functions:** The monitoring function consists of collection of rainfall and evaporation data from the rainfall stations and automatic weather stations of the regional network in each country. This includes operation and maintenance of the stations and data retrieval on a routine basis as per requirement of the water resources management issues and regional cooperation issues indicated in Table 4-2.

**Staff:**

- A minimum of one or two field technicians are required depending on the number and geographical spread of the stations and the national organizational arrangement of the hydrological monitoring (centralized or decentralized at basin level, regional level). One technician can handle 10 to 12 meteorological sites. The technicians should have a secondary level education and training in operation and maintenance of automatic weather stations.
- One experienced technologist to manage, service, and support the meteorological data communications and data acquisition system at the central/regional country office.

### Data Checking, Validation, and Dissemination

**Functions:** Data checking and validation consist of conducting data quality control (QC) and data quality assurance (QA) to ensure the completeness and correctness of the rainfall and evaporation data downloaded or transmitted from the automatic weather stations. The primary purpose of quality control of observational data is missing data detection, error detection and possible error corrections in order to ensure the highest possible reasonable standard of accuracy for the optimum use of these data by all possible users. This also includes comprehensive evaluation of biases and long-term drifts of sensors and modules, malfunction of sensors, etc. The primary objective of the quality assurance system is to ensure that data are consistent, meet the data quality objectives and are supported by comprehensive description of methodology[9]. This task also covers dissemination of the validated data to public and private users in electronic and hard copies with concise description of data quality.

**Staff:** One to two climatologists or agro-climatologists depending on the number of regional stations in each country. One climatologist can cover at least 15 to 20 stations with adequate automatic processing software. This assumes that this function is handled at the same location, i.e. at headquarters if the function is centralized and at the basin/national regional office level if the function is decentralized. A bachelor degree in meteorology, climatology, geography or equivalent with experience in data verification and validation of automatic rainfall stations and automatic weather stations is required for this task.

### Data Management

**Functions:** This task includes management and administration of meteorological database that includes data of the regional rainfall and automatic weather stations.

**Staff:** One trained staff in database systems management and administration if this function is decentralized. A minimum of one junior and one mid-level staff if this function is centralized.

### Data Analysis and Modeling

**Functions:** This task includes preparation of information for public and private clients. The information would include climate trend analysis (wet and dry periods), rainfall intensity-duration frequency curves, estimated evaporation, etc. This function would be more effective and economically sound when performed at the centralized level.

**Staff:** One mid-level and one senior climatologist/agro-climatologist, preferably with Master Degree and strong experience in statistics.

### Communication and Outreach

**Functions:** This task includes the development of written, audio, and visual educational and awareness material about the meteorological data and information products targeted to public and private users to raise awareness about the socio-economic benefits of meteorological monitoring. This task also includes organizing workshops and outreach programs about the meteorological monitoring services, and exploring opportunities for private sector funding to support development and sustainability of these services.

**Staff:** one (1) communication specialist with strong experience in designing and preparing educational material and outreach programs and familiarity with meteorological or environmental related services. Excellent communication and social marketing skills are highly required.

### Institutional and Policy Support

**Functions:** This task will support creating the enabling institutional and policy environment related to the meteorological service for the implementation of the institutionalization of the hydromet systems.

**Staff:** Head or representative of the national meteorological service.

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[9] Guidelines on Quality Control Procedures for Data from Automatic Weather Stations, Expert team on requirements for data from automatic weather stations, WMO, Geneva, Switzerland, 28 June -2 July 2004.

## 11.2 Hydrological Services

The key hydrological parameters required for addressing the regional collaboration issues shown in Table 10.1 include surface water level/discharge, water quality, sediment transport, and earth observation products[10]. The particular functions and human resources required by the national hydrological services from each of the Nile countries to provide accurate data and information about water level/discharge and sediment transport are described hereafter. WMO guidelines for the role, operation, and management of National Hydrologic Services (WMO-No. 1003, 2006) has been provided as a supplemental resource with a summary given in Appendix H. Functions and staffing related to water quality are presented in Section 7.1.11.

### Monitoring

**Functions:** The monitoring function consists of collection of water level from automatic water level recorders, routine measurement of water discharges to establish (for new stations) or update rating curves, and collecting water samples for water quality and sediment load testing. This includes operation and maintenance of the stations and data retrieval on a routine basis as per requirement of the socio-economic issues/ water management issues (water resources planning and management, flood management, water quality management and pollution control, erosion and sediment control, watershed management, etc.) that are related to the regional cooperation issues indicated in Table 4-2.

**Staff:**

- A minimum of one or two technicians are required depending on the number and geographical spread of the stations and the national organizational arrangement of the hydrological monitoring (centralized or decentralized at basin level, regional level). Approximately one technician is needed for every 7 to 8 hydrometric sites. The technicians should have a secondary level education and training in operation and maintenance of automatic hydrometric stations.
- One experience technologist to manage, service, and support the hydrometric data communications and data acquisition system at the central/regional country office.

### Data Checking, Validation, and Dissemination

**Functions:** This task includes data QC/QA and validation of the water level data downloaded or transmitted from the automatic hydrometric stations, the water discharge measurements and the rating curves for each station. This also includes comprehensive evaluation of biases and long-term drifts and malfunction of the water level sensors and data loggers, and dissemination of the validated data to public and private users in electronic and hard copies with concise description of data quality.

**Staff:** One to two hydrologists depending on the number of regional hydrometric stations in each country. One hydrologist can handle at least 15 stations with adequate automatic processing software. This assumes that this function is handled at the same location, i.e. at headquarters if the function is centralized and at the basin/national regional office level if the function is decentralized. A bachelor degree in civil engineering, agriculture engineering, geography, natural sciences or equivalent with experience in data verification and validation of automatic hydrometric stations is required for this task.

### Data Management

**Functions:** This task includes management and administration of surface water discharge, water quality, and sediment transport database that includes data of the regional hydrometric, water quality, and sediment transport regional stations (if any).

[10] Note that river profile is not included in this section given that it is not a routine monitoring function.

**Staff**: One trained staff in database systems management and administration if this function is decentralized. One junior and one mid-level staff if this function is centralized.

### Data Analysis and Modeling

**Functions:** This task includes preparation of information for public and private clients. The information could include streamflow forecasting, streamflow trend analysis (wet and dry periods), Flow frequency analysis, Flow duration analysis, low flow analyses, inundation duration analyses, etc. This function would be more effective and economically efficient when performed at the centralized level.

**Staff:** One Mid-level and one senior hydrologist, preferably with Master Degree or PhD and strong experience in hydrologic modeling and statistics, and working experience in GIS.

### Communication and Outreach

**Functions:** This task includes the development of written, audio, and visual educational and awareness material about hydrological data and information products targeted to public and private users to raise awareness about the socio-economic benefits of meteorological monitoring. This task also includes organizing workshops and outreach programs about the hydrological monitoring services, and exploring opportunities for private sector funding to support development and sustainability of these services.

**Staff:** one (1) communication specialist with strong experience in designing and preparing educational material and outreach programs and familiarity with hydrological or environmental related services. Excellent communication and social marketing skills are highly required.

### Institutional and Policy Support

**Functions:** This task will support creating the enabling institutional and policy environment related to the hydrological service for the implementation of the institutionalization of the hydromet systems.

**Staff:** Head or representative of the national hydrological department/division.

## 11.3 Earth Observation Product Services

This section describes the functions and staffing need to establish the Nile Basin Earth Observation Products Center for precipitation, evaporation, soil moisture, and land cover earth observation products. Functions and staffing are presented for the Regional Center and for each Nile Basin country.

### 11.3.1 Regional Center

#### *Earth Observation data processing, analysis and modeling*

**Functions:** This task includes extracting, assessing, manipulating, exploiting, analyzing, and integrating digital imagery, geospatial databases, and various sources related to precipitation, soil moisture, evaporation, and land cover. Remote sensing, spatial analysis, and Geographic Information Systems (GIS) skills are used to construct multi-source geospatial databases. This task also covers performing in-depth imagery and model analysis to produce high-quality solutions for specific Nile Basin water resources issues, and conducting QC/QA analysis of the final products to ensure compliance with end-use technical specifications.

**Staff:** The following skills are needed:

- One (1) Earth Observation Specialists at the regional center with strong skills in remote sensing, atmospheric radiative transfer, especially in microwave sensing area, atmospheric scattering, various retrieval methods, and radiometric calibration. Experience with earth observation remote sensing data set related particularly to precipitation, soil moisture, evaporation, and land cover is required, and advanced degree in meteorology /atmospheric sciences, hydrology, oceanography, earth system modeling statistics, or applied mathematics.

- One (1) data processing and analysis specialist Bachelor's Degree with demonstrated academic achievement in Math, Computer Science, Statistics, or a related field. Strong hands-on experience data mining, data analysis, and data visualization in addition to experience in configuration, maintenance and troubleshooting of deployed systems, identification of software upgrade methods, and write software upgrade and deployment plans.

#### *GIS and Database*

**Functions:** This task includes managing GIS and database servers, developing and publishing Open Geo-spatial Consortium (OGC) map services, achieving earth observation products, managing geospatial databases, configuring web servers, developing scripts for data processing automation, and supporting/promoting knowledge exchange within the Nile Basin network.

**Staff:** One (1) GIS-Database specialist with experience working in earth observation products, attention to detail, ability to multi-task in a fast pace work environment, and knowledgeable of basic data format standards and data security functions.

#### *Knowledge Management-Web Portal*

**Functions:** This task covers defining and developing data portals, defining and developing the Earth Observation web tools, incorporating web user functions applicable to all earth observation data products, and supporting development of web data services, including data visualization.

**Staff:** One (1) Web Portal specialist with bachelor degree in Computer Science, Information Science, or equivalent, experience in knowledge management, experience in working with earth observation data and relational databases and developing or supporting software applications.

### 11.3.2 National Offices

#### *Earth Observation Access and Use*

**Functions**: This task includes accessing and making use of the earth observation products from the Nile Basin regional center for solving water resources issues; designing, testing and implementing earth observation data management platforms; producing, validating and maintaining metadata according to accepted standards. This task also covers maintaining Catalog Services for the Web complaint metadata catalog and harvesting procedures.

**Staff:** Earth Observation specialist with very good knowledge of earth observation, remote sensing, geographic information system (GIS), database applications, and web-based applications for data earth observation data access, presentation, and management. Experience with earth observation remote sensing data set related particularly to precipitation, soil moisture, evaporation, and land cover is required, and advanced degree in meteorology /atmospheric sciences, hydrology. Excellent skills and experience in management and manipulation of spatial and tabular data sets (GIS, relational databases, etc).

# 12 Training and Capacity Development

The countries consultations and the institutional questionnaire were an opportunity to map out capacity building needs in the following areas:

- Meteorological and hydrological monitoring
- Meteorological and hydrological data checking, validation and dissemination
- Meteorological and hydrological database development management
- Analysis and modeling tools
- Water quality laboratory technologies and Laboratory Information Management System (LIMS)
- Hydromet services communication and outreach
- Earth Observation Products

Table 12-1, below specifies the main capacity needs for each Nile Country.

**Table 12-1. Capacity building and training needs for Nile Countries**

| | Burundi | DRC | Ethiopia | Kenya | Rwanda | South Sudan | Sudan | Tanzania | Uganda |
|---|---|---|---|---|---|---|---|---|---|
| Installation of hydrometric stations, data acquisition, operation and maintenance | | | * | * | | * | * | | |
| Installation of meteorological stations, data acquisition, operation and maintenance | | | | * | * | * | * | | |
| River discharge measurements | | * | * | | * | * | * | | * |
| Development and maintenance of rating curves | | * | | * | * | * | | | |
| Sediment transport monitoring | | * | * | * | * | * | * | * | |
| Hydromet data checking , validation, and dissemination | * | * | * | * | * | * | * | * | * |
| Meteorological data checking , validation, and dissemination | * | * | * | * | * | * | * | * | * |
| Database Management | * | * | * | * | * | * | * | * | * |
| Hydromet monitoring communication and Outreach | | * | * | * | * | * | * | * | |
| Weather forecasts and predictions | | | * | * | * | * | * | * | |
| Hydrological forecasting | | * | * | * | * | * | * | * | |
| Data Analysis tools | * | * | * | * | * | * | * | * | * |
| Water Resources Planning and management | | * | * | * | * | * | * | * | |
| Erosion and sediment transport modeling | | * | * | * | * | * | * | * | |
| Web and grid services for earth observations | * | * | * | * | * | * | * | * | * |
| Earth Observation-precipitation | * | * | * | * | * | * | * | * | * |
| Earth Observation- evapotranspiration | * | * | * | * | * | * | * | * | * |
| Earth Observation-soil moisture | * | * | * | * | * | * | * | * | * |
| Earth Observation- land cover | * | * | * | * | * | * | * | * | * |

Based on Table 12-1, Riverside is proposing the following list (Table 12-2) of training elements assembled according to the training areas or theme indicated above. Specific training methods such as formal classroom training and demonstration workshops, on the job-training, as well as training duration are presented for each training topic. Training modules specific to water quality are provided in Appendix F. WMO guidelines on the implementation of education and training standards of personnel for both meteorological (WMO-No. 1083, 2012) and hydrological (WMO-No. 258, 2003) services have been provided as supplemental resources with summaries of each given in Appendix H.

**Table 12-2. Proposed list of training needs**

| Training Theme | Training Elements | Training Method |
|---|---|---|
| 1. Installation of meteorological stations, data acquisition, operation and maintenance | a. Automatic weather/agroclimate station site selection and installation standards.<br>b. Automatic weather/agroclimate stations instrumentation (traditional and new technologies)<br>c. Installation of weather/agroclimate Station instrumentation (sensors, data loggers).<br>d. Data Acquisition System - Hardware<br>e. Data Acquisition System - Software<br>f. Data Acquisition System - Diagnostics<br>g. Data Acquisition System operation and maintenance.<br>h. Calibration of sensors and equipment. | • Two day classroom and two day field demonstration.<br>• On-the-job training during implementation. |
| 2. Installation of hydrometric stations, data acquisition, operation and maintenance | a. Automatic hydrometric station site selection and installation standards (including datum benchmark, leveling techniques, site description, etc.).<br>b. Hydrometric stations instrumentation and technologies (water levels recorders, data loggers)<br>c. Data Acquisition System - Hardware<br>d. Data Acquisition System - Software<br>e. Data Acquisition System - Diagnostics<br>f. Data Acquisition System operation and maintenance.<br>g. Calibration of sensors and equipment. | • Two day classroom and two day field demonstration.<br>• On-the-job training during implementation. |

| Training Theme | Training Elements | Training Method |
|---|---|---|
| 3. River discharge measurements | a. Presentation and analysis of flow discharge measurement methods.<br>b. Conduct on site discharge measurements using various methods and proven technologies (current meters, ADCP, Radar, etc.)<br>c. Analyze and compare various methods<br>d. Calibration of current meters, ADCPs, Radar instruments, etc. | • Two day classroom and three day field demonstration.<br>• On-the-job training during implementation. |
| 4. Development and maintenance of rating curves | a. Rating Curve Theory<br>b. Hydraulic Considerations<br>c. Rating Curve Development - Software | • Two day workshop on theory.<br>• Two day workshop on using software application.<br>• On-the-job training during implementation. |
| 5. Sediment transport monitoring | a. Methods for collection of suspended sediment stream samples.<br>b. Laboratory testing of sediment transport load.<br>c. Establishment of a relationship between sediment concentration or load and stream discharge - the sediment rating curve | • One day classroom and two day field and laboratory demonstration.<br>• On-the-job training during implementation. |
| 6. Meteorological data checking, validation, and dissemination | a. Data processing and data quality control (QC) methods and operations.<br>b. Data quality assurance (QA) and data validation methods and operations.<br>c. Evaluation of biases and long-term drifts of sensors and modules, malfunction of sensors of data loggers.<br>d. Dissemination of the validated data with concise description of data quality. | • One day classroom and two day operational training using field data.<br>• On-the-job training during implementation. |
| 7. Hydrometric data checking, validation, and dissemination | a. Data processing and data quality control (QC) methods and operations.<br>b. Data quality assurance (QA) and data validation methods and operations.<br>c. Evaluation of biases and long-term drifts of sensors and modules, malfunction of sensors and malfunction of the water level sensors and data loggers.<br>d. Dissemination of the validated data with concise description of data quality. | • One day classroom and two day operational training using field data.<br>• On-the-job training during implementation. |

| Training Theme | Training Elements | Training Method |
|---|---|---|
| 8. Database Management | a. Database and Data Management Principles<br>b. Time series data processing<br>c. GIS vector data processing<br>d. GIS raster data processing | • One week classroom and demonstration workshop<br>• One week operational training<br>• On-the-job training during implementation |
| 9. Data Entry | a. Using data entry to provide data to database management systems<br>b. Update Database Management Systems with data from Data Entry<br>c. Distributing the Data Entry component | • 2 days formal classroom training<br>• On-the-job training during implementation |
| 10. Automatic update of Database Management Systems with RT data | a. Integration with SCADA systems<br>b. Consuming data automatically published by different providers<br>c. Using Web Services to consume data | • 3 days formal classroom training<br>• On-the-job training during implementation |
| 11. Data analysis tools and applications | a. Flow frequency analysis<br>b. Flow duration analysis<br>c. Trend analysis<br>d. Low flow analyses<br>e. Inundation duration analyses<br>f. Correlation and data comparisons | • A series of one day training sessions for each analytical application with practical demonstrations<br>• On-the-job training during implementation |
| 12. Meteorological monitoring communication and outreach | a. Development of written, audio, and visual educational and awareness material about meteorological data and information products<br>b. Design and implementation of outreach programs to raise awareness about benefit of meteorological monitoring services among field technicians, decisions makers, and public and private data and information users.<br>c. How to explore opportunities for private sector funding to support development and sustainability of meteorological services. | • 2 days of formal classroom and operational training<br>• On-the-job training during implementation |
| 13. Institutional Development for sustainable hydromet systems | a. Factors of sustainability of hydromet services<br>b. Principle of lead and supporting institutions<br>c. Defining functions, roles and responsibilities of hydromet services<br>d. Creating policy and legal environment for sustainable hydromet services | • 2 days of formal classroom and operational training<br>• On-the-job training during implementation |

| Training Theme | Training Elements | Training Method |
|---|---|---|
| 14. Web operations and support | a. Web Design and Applications<br>b. Web Data and Information Applications<br>c. Web Data and Information – Software<br>d. Editing data<br>e. Web services | • One week formal classroom training<br>• One week operational training<br>• On-the-job training during implementation |
| 15. Weather forecasts and predictions | a. Numerical Weather Prediction models<br>b. WMO's Cascade Forecasting system<br>c. Regional supported Imagery system | • One week formal classroom training<br>• One week operational training<br>• On-the-job training during implementation |
| 16. Hydrological forecasting | a. Hydrologic Models and Applications<br>b. Hydraulic Models and Applications<br>c. Reservoir Simulation Models and Applications | • One week formal classroom and operational training for each model<br>• On-the-job training during implementation |
| 17. Water Resources Planning and management | a. Principles of Transboundary water resources planning and management<br>b. IWRM<br>d. Water Demand Models and Applications<br>c. Nile DSS | • Four weeks of theoretical and operational training.<br>• On-the-job training during implementation |
| 18. Soil erosion and sediment transport modeling | a. Soil erosion modeling<br>b. Soil erosion control methods<br>c. Sediment transport modeling<br>d. Management of reservoir sedimentation<br>e. Management of irrigation canal sedimentation. | • Two weeks of theoretical and operational training.<br>• On-the-job training during implementation |
| 19. Hydrological monitoring communication and outreach | a. Development of written, audio, and visual educational and awareness material about hydrological data and information products<br>b. Design and implementation of outreach programs to raise awareness about benefit of hydrological monitoring services among field technicians, decisions makers, and public and private data and information users.<br>c. How to explore opportunities for private sector funding to support development and sustainability of hydrological services. | • 2 days formal classroom and operational training<br>• On-the-job training during implementation |

| Training Theme | Training Elements | Training Method |
|---|---|---|
| 20. Earth Observation Product-Precipitation | a. Sensor capabilities and availability.<br>b. Physical principles of precipitation retrieval<br>c. Processing precipitation from satellite measurements | • One week classroom and demonstration workshop<br>• One week operational training<br>• On-the-job training during implementation |
| 21. Earth Observation-Evapotranspiration | a. Physical principles of evapotranspiration retrieval<br>b. Sensor characteristics and availability<br>c. Processing evapotranspiration from satellite measurements | • One week classroom and demonstration workshop<br>• One week operational training<br>• On-the-job training during implementation |
| 22. Earth Observation-Soil Moisture | a. Physical principles of soil moisture retrieval<br>b. Sensor characteristics and availability<br>c. Processing soil moisture from satellite measurements | • One week classroom and demonstration workshop<br>• One week operational training<br>• On-the-job training during implementation |
| 23. Earth Observation-Land Cover | a. Sensor characteristics and classification methods.<br>b. Physical principles of land cover retrieval<br>c. Processing land cover from satellite measurements | • One week classroom and demonstration workshop<br>• One week operational training<br>• On-the-job training during implementation |
| 24. Web and grid services for earth observation | a. Instrumentation and data acquisition systems<br>b. Methods in instrumentation and computing<br>c. Data and signal processing<br>d. Communication System Installation<br>e. Intelligent information and ontology systems<br>f. Servicing and Maintenance | • One week classroom and demonstration workshop<br>• On-the-job training during implementation. |

# 13 South Sudan HIS Design

South Sudan requires special attention both because of its recent emergence as a new state with a lack of mature hydromet services, and because of ongoing conflicts that complicate both development from within and assistance from outside the country. There is a long history of water resources monitoring in South Sudan, going back to colonial days and continuing to the present with ongoing monitoring by the Egyptian Ministry of Water Resources and Irrigation at key locations on the White Nile. Currently, however, the South Sudan Ministry of Electricity, Dams, Irrigation and Water Resources (MEDIWR) is heavily under-staffed and assistance is required to rehabilitate the national monitoring network, to modernize data management systems, and to develop staff and institutions to perform required functions. NBI is anxious to support South Sudan as a Nile Basin country in need of basic water resources monitoring infrastructure and institutional capacity, and also as an important participant in the regional monitoring network with key monitoring locations that need to be actively contributing to the network.

Implementing, operating, and maintaining a water resources information program, including monitoring networks and data management systems, will require a substantial initial investment and ongoing resources. While donors might be found for the initial investment, ongoing operation and maintenance typically devolves to the country. Moreover, South Sudan must balance a broad range of critical infrastructure and institutional development needs in addition to the question of water resources monitoring and data management. For this reason it is unlikely that sufficient resources will be available from the government in the near term to support the extent and complexity of monitoring that will be desired for the regional monitoring network. Nor will the resources support the degree of monitoring that NBI and the other riparian countries would hope to see in support of South Sudan's national development initiatives. This requires consideration of the need to match the scale, complexity, and cost of the South Sudan national system with the combined, ongoing resources that can be committed by the South Sudan government, NBI, and donor organizations. Because the design is intended to provide data in support of water resources development and management for decades into the future, an appreciation of the long term budget that will be available from South Sudan is an important consideration. The design proposed in SECTION 13.3 represents an ideal national network based on close collaboration and discussion with South Sudan representatives during consultations at workshops and visits to the Ministries. The schedule of implementation to achieve the proposed national design will require staging to permit a gradual increase in system complexity and scale to match the growing capacity of the responsible institutions, together with the capacity of the stakeholders to benefit from the available data.

Full implementation of a national monitoring network will require several external prerequisites to be achieved at the ministries. These include government control and security throughout the country, stable electric power and high speed internet at ministry offices, and an improved national road infrastructure. MEDIWR and SSMD will need to seek budget and training for qualified staff that can be retained as well as budget for typical operation and maintenance including vehicles, fuel, batteries, and station equipment. It will require a great deal of time and resources to fully achieve these goals and several factors may be outside of the ministries control. As a result, several interim approaches may be proposed to allow the ministries to provide some benefits while making the transition to full implementation. These include:

- Use of global data products specific to the Nile region that could be hosted by NBI but have national significance. These products may include precipitation grids and time series from the regional network such as releases of Lake Victoria at Jinja that would have significance on Bahr el-Jebel.

- NBI could host the MEDIWR data management system on an interim basis to allow for technical and infrastructure support with a dedicated MEDIWR web client for accessing all data. This could be coupled with staff training opportunities at NBI offices for future transition of the system to MEDIWR.
- Working with a neighboring country such as Uganda to help establish the water quality monitoring program as well as provide advanced analysis for parameters that require specialized equipment not readily available in South Sudan.
- Using manually observed gauges coupled with internet or cellular transmissions by the observer at some stations during a transition to fully automated network
- Employing a paid "observer" at automated gauges to provide verification of the readings and to establish the importance of the station in the local community as a means of security.

In addition to interim activities, the implementation strategy will need to involve a series of check points to provide motivation for further development as well as ensure sustainability based on what is feasible. This would start with some of the interim activities noted above and the production of basic daily products. The network would first be confined to establishing local key locations that could be monitored adequately and then slowly expanded out as capacity and resources are developed. This incremental development will rely on support from NBI, riparian countries, and contractors. The proposed plans for this implementation will be conducted in the third phase of this project.

## 13.1 National Situation Assessment

The current situation assessment for South Sudan is compiled from multiple reports and consultations with South Sudan representatives. These primarily include:

- National country assessment report provided by South Sudan representatives at Launch Workshop in Addis Ababa, Ethiopia May 12-14, 2014.
- Consultations following Inception Workshop in Entebbe, Uganda on August 7-8, 2014.
- Report on "South Sudan Preliminary Water Information Assessment Study" (MWRI (South Sudan), 2012).
- Consultations and Field Visits conducted in and around Juba, South Sudan September 22-26, 2014.
- Consultations and South Sudan session of Conceptual Design Workshop in Nairobi, Kenya on October 11, 2014.

_Overview of responsible ministries_

- The responsible government agency for surface water monitoring in South Sudan currently resides under the Directorate of Hydrology and Survey (DHS) under the Ministry of Electricity, Dams, Irrigation and Water Resources (MEDIWR). Prior to the independence of South Sudan in July 2011, but after the Comprehensive Peace Agreement (CPA) of 2005, this responsibility was under the Ministry of Water Resources and Irrigation (MWRI).
- The South Sudan Meteorological Department (SSMD) under the department of South Sudan Civil Aviation Authority is responsible for meteorological monitoring. This institution resides within the Ministry of Transport, Roads and Bridges.

_Data collection networks, monitoring practices, and data processing/management_

- *River Stage/Discharge*
    - There are currently only 5 operational river gauging stations within South Sudan but a total of 71 historic locations that could potentially be rehabilitated. During

consultations with South Sudan representatives, 37 hydrometric station locations were identified for the national network.

  - Data collection activities are carried out by river technicians with gauge readers recording stage on a daily basis. Data transmission is completed manually by phone and email and hard copies of recordings are sent to Juba.
  - Microsoft Excel used for data archiving and analysis.
- *Precipitation and Other Meteorological Parameters*
  - Currently there are five operational synoptic stations used for climate and aviation purposes. Parameters observed include visibility, temperature, atmospheric pressure, sunshine hours, wind speed and direction, cloud type and height, relative humidity, precipitation, and soil temperatures and various levels.
  - Data is collected by meteorologist observers. Currently SSMD does not have a National Meteorological Telecommunication Network for data transmission to regional and global centers. SSMD uses email for data transmission.
  - Data is first typed manually into a spreadsheet by observers and then manually typed again into the meteorological database CLIMSOFT.
- *Water Quality (including Labs) & Sediment Sampling*
  - Currently no water quality or sediment sampling is being conducted but concerns exist at transboundary locations, urban environments, and oil exploration regions. MEDIWR has water quality lab facility which is used for testing the quality of drinking water. The lab does own some portable field kits and other equipment for testing some of the physical, chemical and microbiological parameters.
- *Groundwater*
  - Currently no groundwater monitoring is being conducted but the former MWRI had established a basic database of groundwater data such as borehole coordinates, drilling depth, dates, static and dynamic water levels, well yield, pump type, and pump setting depth. However, it is noted that several fields and entries are incomplete.
- *Spatial Datasets*
  - SSMD notes the utilization of satellite data observation products from EUMETSAT and Sat 24.

*Data dissemination and application*

- Products disseminated by the SSMD include raw meteorological data (rainfall, temperature, humidity, wind speed, etc.) as well as “Metar (actual weather) and TAF (forecast weather and segment)” products. In addition, severe weather forecasts are disseminated when applicable and seasonal rainfall forecasts are generated every 3 months. Primary benefits were listed as “agriculture and livestock, food security, transportation (land and aviation), health, tourism and wildlife management, construction industry, water resource management, environment, and student research.” Rainfall and temperature data are sent to Climate Prediction and Applications Center (ICPAC) of IGAD for climate watch bulletin in Nairobi and weather forecasts are sent to Singapore Met center for transmission to the global network.
- Although a central database known as WIMS ([WASH] information management system) was created under the MWRI the web portal is currently offline due to internet connection

problems. There is currently a lack of systematic procedures for monitoring, assessment, and dissemination of water resources data.

- There is no formal hydromet data sharing mechanism in place both at the ministry and meteorological department, but users can make written requests to get available digital data and hard copy form. Users are not charged on any data receipt. The SSMD is, however, working on the formulation of data sharing policy and planning to charge data users.

*Ongoing and Planned Network Expansion*

- There are currently several initiatives running parallel that aim at improving the hydro-meteorological monitoring systems in the South Sudan. These include IGAD-HYCOS, World Meteorological Organization (WMO), and the Egyptian Technical Cooperation. Some of these activities overlap, which calls for coordination to effectively utilize available resources.
    - IGAD-HYCOS – Through the support of the EU, IGAD, and the WMO a joint project is being developed to provide adequate infrastructure for hydrological observations and regional cooperation in information exchange. South Sudan is one of 8 regional countries involved and the project proposes to upgrade 15 hydrometric stations within the country.
    - WMO – The WMO has been assisting in drafting a 5 year strategic plan for the development of SSMD. The plan has outlined the future development in terms of institutional setup, human resource capacity building, weather forecasting, research on climate change, and a hydromet network system including data acquisition, management and dissemination. The draft plan has been finalized and submitted to the WMO for approval.
    - Egyptian Technical Cooperation - In addition to the support provided for the rehabilitation of Malakal, Wau, Juba, Mongalla, and Bor, there is a plan to strengthen water quality assessment and monitoring capability of South Sudan. Delegates from Egypt are expected to have visits with the South Sudan ministries.
    - MEDIWR – MEDIWR through its own means has procured equipment for 5 automatic hydro-meteorological stations but these have never been installed due to budget limitations.

*Gaps, and Challenges*

*Hydrometric*

- Intermittent data records at key locations due to conflict.
- Limitations for rehabilitation due to financial constraints. Budget and transportation are also not available for the staff of the ministry to do the rehabilitation within their technical capacity.
- In addition to budget constraints, the geographic distribution of the gauging stations in the country and the prevailing poor road conditions, pose serious challenges to assess the status of the stations.
- Training needs in the use and maintenance of high-tech instruments like ADCP.
- Lack of data management system that handles hydrological time-series data.
- Lack of water quality, sediment or ground water monitoring.

- No clear institutional arrangement among the different parties responsible for the management of wetlands (Ministry of Environment, Ministry of Wild Life conservation and Tourism, MEDIWR, and other users like Ministry of Animal Resources and Fisheries).

*Meteorological*

- Office space is not sufficient to accommodate the entire staff. All staff members including observers, forecasters, meteorologists, administrator, director and deputy director reside in a small room.
- Limited trained manpower (e.g. for all 10 AWSs implemented in the country, there is only one person who can maintain the system)
- Limitations with regards to vehicles for field visits, computers, and office equipment.
- Insufficient budget to purchase equipment, rehabilitate non-operational stations, and establish new stations.
- Low awareness level in the country on the use of meteorological data.
- Facilities for real-time data collection, processing, and dissemination systems are lacking.

*External Factors*

Because of the long history of conflict in South Sudan, factors that have limited development and establishment of stable and sustainable monitoring environments in the past will take time to be reversed. Indeed, the current conflict is an ongoing barrier to improvement, and its effects will be felt for some time to come. Specific concerns that will need to be factored into the technical and institutional design include:

- Overall government control and security throughout the country;
- Availability of human resources with necessary prerequisites for specific training and development;
- Availability of public infrastructure that is assumed in order to deploy intended technologies (reliability of power supplies; availability of internet connectivity among data sharing partners and for the use of trained experts who will be expected to operate the system; availability of internet among expected stakeholders).
- Capacity among government, business and populace for taking advantage of the information to be made available through a modern water resources monitoring and information system;
- Capacity and determination of the public to protect field monitoring infrastructure from vandalism and theft; and
- Tenure/longevity/turnover of trained government personnel and resulting ongoing training requirements.

Thus, the design for South Sudan will need to be comprehensive in relation to station locations for monitoring of all required parameters; a data management system capable of meeting national and regional requirements; hardware and infrastructure for monitoring, transmission, processing, and dissemination; an institutional plan that identifies staffing requirements as well as training and development requirements; and a financing strategy that addresses both initial and long term investments required for a sustainable monitoring program.

## 13.2 National Water Resource Management Issues

South Sudan is uniquely positioned with four distinct sub-basins (Figure 13-1) of the Nile that together embody the complete range of socio-economic issues that require consistent, effective monitoring for development planning and decision making. The Baro-Akobo-Sobat in the East is characterized by seasonal heavy rainfall giving rise to opportunities in irrigated and rainfed agriculture, reservoir development, and flood loss prevention among others. The Bahr el-Jebel with its multiple swamps and marshes of the Sudd, requires attention to wetlands, navigation, water resources development, and water management. In addition, there are potential hydropower locations at the upstream end of the basin just downstream of the border with Uganda. The Bahr el-Ghazal to the west requires development, is subject to drought, is heavily dependent on rainfed agriculture, could benefit from careful utilization of groundwater, and requires careful watershed management. The White Nile sub-basin experiences moderate rainfall together with the passage of the growing discharge with contributions from the Bahr el-Jebel and Baro-Akobo-Sobat sub-basins. This leads to important opportunities associated with water management, irrigated agriculture, and other development potential. Thus, virtually all of the water resource management/socio-economic issues identified for the Nile Basin as a whole are at play in South Sudan.

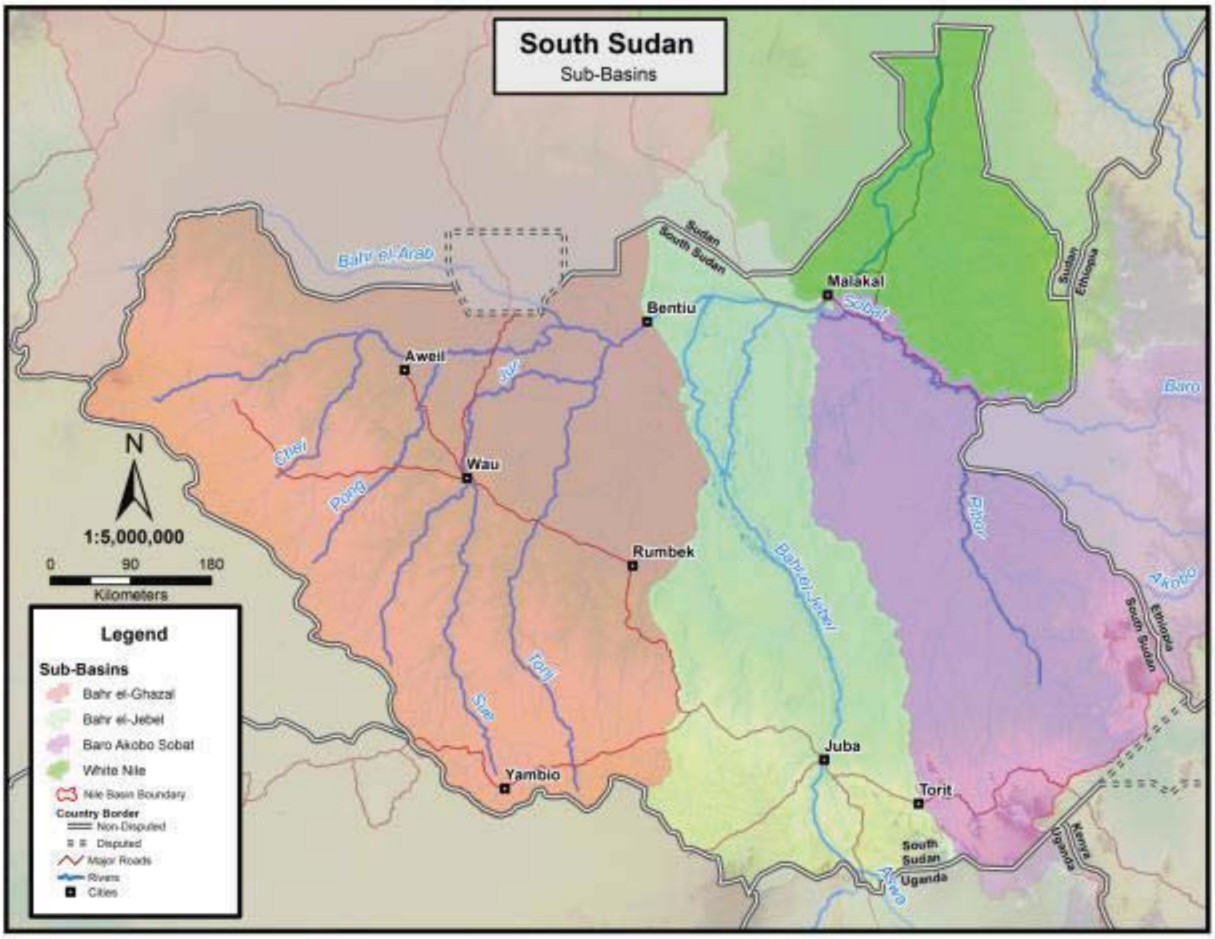


Figure 13-1. Primary sub-basins of South Sudan

Specific locations of water resource management issues within South Sudan were identified with representatives following the inception workshop on August 7-8, 2014. This involved labeling issues spatially on hard copy maps as shown in Figure 13-2. These identified issues were then digitized in ArcGIS to aid in identifying the proposed national South Sudan hydro-meteorological network during the design phase. Data requirements are noted for each issue with specifications to follow the same recommendations for the proposed regional network outlined in Section 6.1.

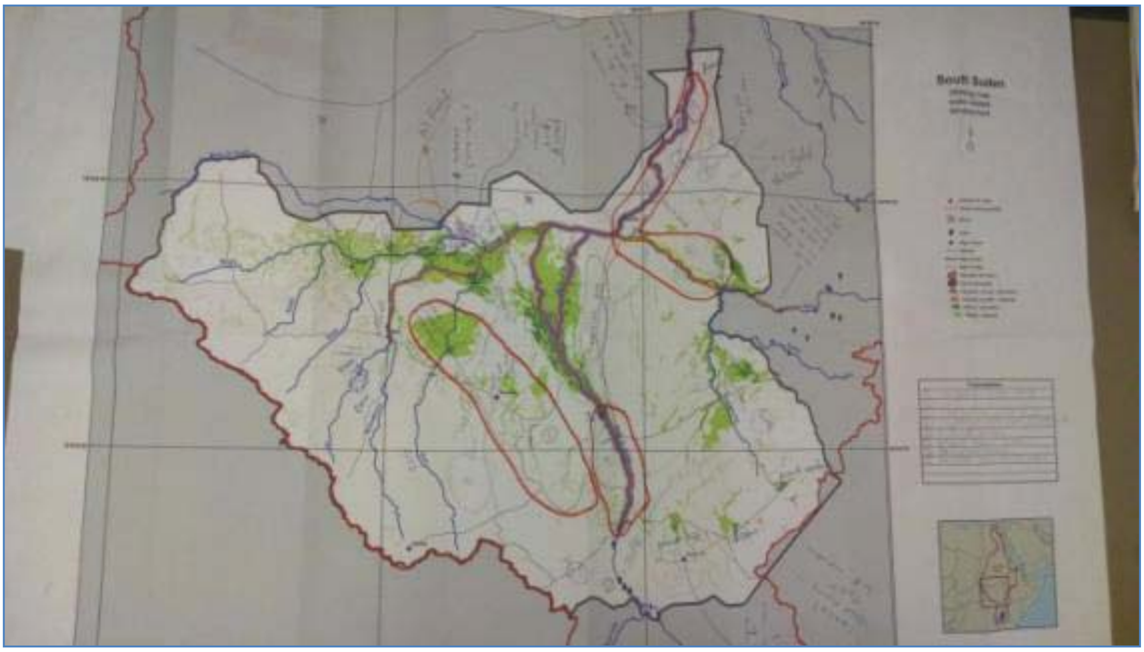

Figure 13-2. South Sudan working map of water resource management issues

The 14 water resource management/socio-economic issues described in Section 1 are covered specifically for South Sudan's national interest below. It is important to note that the level of content presented for each issue is a reflection of the priority at the national level.

### 13.2.1 Improved Water Resource Planning and Management

As South Sudan develops, the need for hydro-meteorological monitoring will increase in order to support decision makers with the best opportunities for socio-economic development through water resource management. Coordination will be essential when new irrigation schemes and water infrastructure are established throughout the country. A significant proportion of the untapped development potential lies in the areas of the country with limited monitoring infrastructure such as the Bahr el-Ghazal.

IWRPM is a broad concern that touches on many of the individual water resources management issues but some examples of improved coordination and management within South Sudan include:

- Planning and management of future irrigation schemes to optimize food production through controlled allocation
- Coordinated management of the Bahr el-Jebel system for potential upstream hydropower, downstream navigation and seasonal livestock grazing along adjacent wetlands for pastoral people.
- Management and monitoring of both surface and groundwater supply for urban domestic use with regards to quality and quantity.

**Data Requirements:**

- Precipitation – Daily monitoring at key locations
- Temperature, RH, Wind, Pan Evaporation – Monthly monitoring
- River Stage/Discharge – Daily monitoring at key locations

- Lake/Reservoir Levels – Daily monitoring at key locations
- Groundwater Levels – Monitored quarterly at key locations
- Groundwater Yields – Annual
- Irrigation Demands – Weekly for major schemes
- Urban Domestic Demands and Industrial Demands – monthly
- Groundwater Use for Irrigation, Urban Domestic Use, and Industry – weekly at key locations
- Sediment Sampling – Monthly
- Water quality monitoring – Monthly
- Land Cover/Use analysis - Annual

### 13.2.2 Flood Management

Notable flood prone regions identified by South Sudan representatives include the following:

- Segments of the Lol and Bahr el-Ghazal rivers upstream of Bentiu
- Seasonal flooding within the Sudd wetlands. The seasonal flooding can be both beneficial and detrimental but the timing is important for both the pastoral people and established communities such as Bor and Shambe.
- October 2013 floods impacted the majority of the northern half of the country cutting off roadways and flooding fields and homes.
- Flash flooding has been noted as a concern for fast responding rivers originating from the Imatong Mountains in the southeast of the country.

**Data Requirements:**

- River Stage/Discharge – 15-minute or continuous for flash flood monitoring; hourly or daily for basin forecasting
- Precipitation – 15 minute or continuous for urban flash flood forecasting; hourly or daily for basin forecasting
- Reservoir/Lake Level – Daily and potentially hourly during flood operations for assessing storage and release
- Temperature, Wind, Relative Humidity, Pan Evaporation – Monthly (important for calibrating hydrologic models but not necessary for real time information)

### 13.2.3 Rainfed Agriculture Management

Like much of the entire Nile Basin, rainfed agriculture accounts for the majority of cultivated land within South Sudan. Rapid population growth combined with food security concerns point to further expansion of agricultural activities. Rainfed agriculture – including rainfed pastoral land - will remain dominant throughout South Sudan in the foreseeable future, in spite of development of irrigation potential.

The most important rainfed production systems in South Sudan include:

- *Mixed smallholder subsistence rainfed:* This is found in the sub-humid and humid parts of southwest of the country along the headwaters of the Bahr el-Ghazal basin. Farmers grow cereals and legumes primarily for household consumption, and some minor crops for cash.

Usually, they also keep a few livestock. Productivity for most crops is low – less than 2 ton/ha (NBI et al., 2012).

- *Shifting rainfed cultivation/agro-pastoral:* This system combines the keeping of livestock and cultivation of crops for subsistence. The livestock graze on communal land near the permanent cropping areas, on fallow land during the dry season, and throughout the area after crops have been harvested (NBI et al., 2012).

**Data Requirements:**

A wide range of data is needed to support decision making in rainfed agriculture. This includes data on soils, markets, diseases, crop type and yields, climate, etc. However, only agro-climatic information will be discussed in this study.

- Precipitation – Daily and sub-daily measurements for key locations
- Other meteorological/agro-climatic parameters including temperature, relative humidity, air temperature, soil temperature, air pressure, wind speed and direction, incoming solar radiation, sunshine duration, pan-evaporation, and surface (leaf) wetness – Daily and sub-daily measurements for key locations

### 13.2.4 Irrigated Agriculture Management

Three areas of South Sudan are currently under investigation for irrigation potential. This includes the majority of surrounding area around the Sobat and White Nile, the Bahr el-Jebel from Juba to Bor, and large downstream portion of the Bahr el-Ghazal basin as shown in Figure 13-3 (digitized layers from working map). Establishing a monitoring network for assessing seasonal flows and modeling potential irrigation schemes will be essential for the future agricultural development of the country.

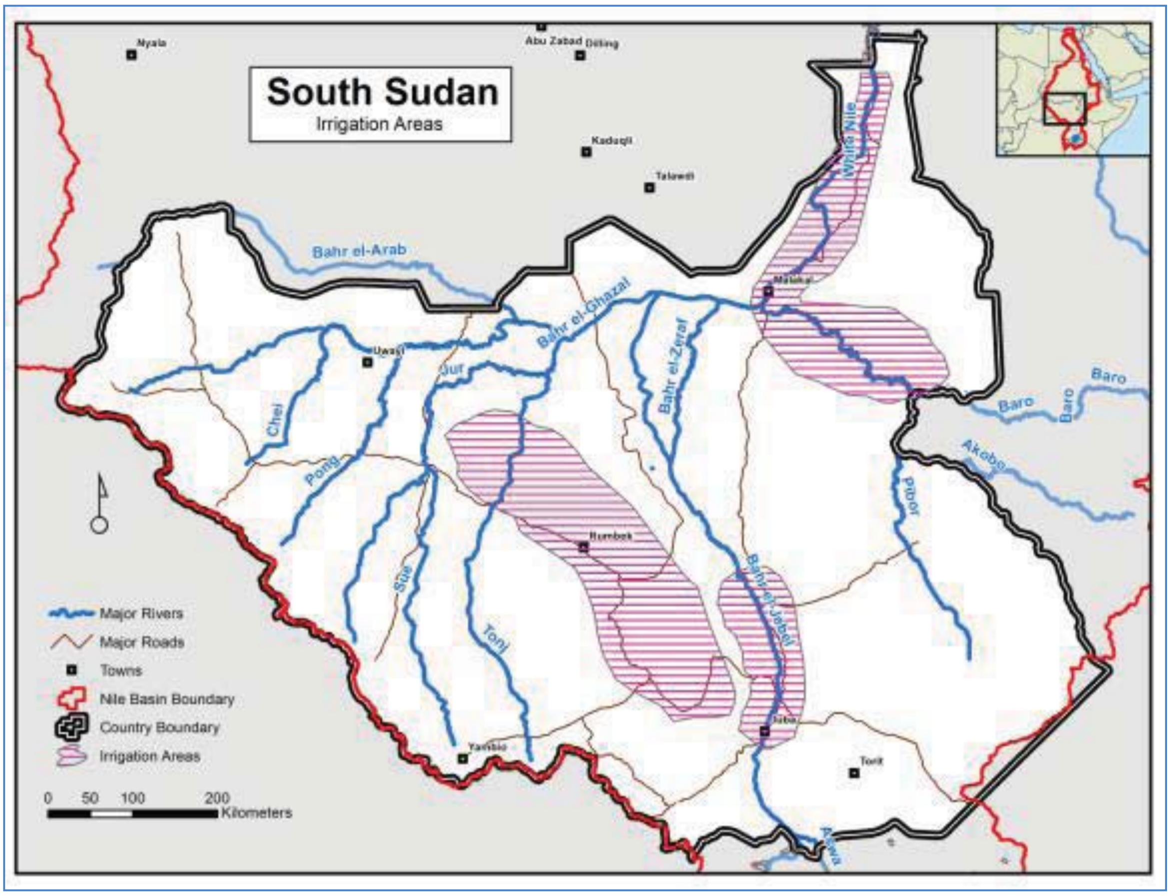


Figure 13-3. South Sudan potential irrigation areas under investigation

**Data Requirements:**

- Daily Climate data (precipitation, meteorological parameters for calculating evaporation)
- Soil data to assess infiltration and soil moisture capacity
- Daily river discharge to determine sustainable water off-take rates
- Salinity and other water quality parameters
- Sustainable groundwater yields if being used for irrigated agricultural purposes

### 13.2.5 Drought Management

High potential evaporation rates within South Sudan make the country particularly vulnerable to drought. With the majority of agriculture production being rainfed, farmers who depend on normal precipitation patterns may be the most susceptible demographic. An improved understanding and forecasting of climatological conditions can lead to enhanced preparation for drought mitigation measures and efficient use of available water supply.

Notable regions of drought concern within the country include the far northeast in the Upper Nile province, the far south around the city of Torit, and a recorded drought in Warap province in 2010 in the north central area of the Bahr el-Ghazal basin. Drought has also been a notable concern for several urban areas such as Renk, Malakal, Wau, Juba, and Bor.

**Data Requirements:**

- Precipitation – Daily monitoring at key locations

- Temperature, Relative Humidity, Wind, Pan Evaporation – Monthly monitoring
- River Stage/Discharge – Daily monitoring at key locations
- Lake/Reservoir Levels – Daily monitoring at key locations
- Groundwater Levels, Yield, Quality – Monitored monthly or quarterly at key locations

### 13.2.6 Soil Erosion and Sedimentation

Sedimentation and erosion was not identified as a high priority national issue for South Sudan. However, there were concerns addressed with potential transboundary sediment load on the Baro and Akobo rivers from Ethiopia. Sediment monitoring of these rivers will be necessary to assess impacts on potential irrigation development of the Sobat River.

**Data Requirements:**

- Monthly to quarterly discharge measurements with suspended sediment load measured at key locations.

### 13.2.7 Surface Water Quality

For South Sudan there are common water quality concerns with respect to bacteria and nutrients effecting domestic, industrial, fisheries, and agricultural use. This is evident from the occurrence of cholera and guinea worm epidemic in 2005-2006. In addition, there is an added threat to watersheds from oil pollution in exploration regions. These areas include Abeyi upstream of Bentiu and the Upper Nile Province near Renk.

For policy and decision-making it is important to measure water quality in conjunction with stream flow. Excessive nutrients are a problem in many areas, especially lakes. Decision-making in terms of prioritizing pollution reductions by watershed requires knowledge of the nutrient loads from each watershed.

**Data Requirements:**

The first tier of water quality parameters that need to be monitored include temperature, pH, dissolved oxygen (DO), turbidity and total suspended solids (TSS), bacteria (fecal coliforms), and nutrients (phosphorous and nitrogen). This monitoring, except for TSS, bacteria and nutrients, can be done on site. The second tier of parameters requires more sophisticated sample collection and laboratory capabilities and includes Biochemical Oxygen Demand (BOD), heavy metals and hydrocarbons. Sampling for these parameters will be most useful in urbanized areas or regions that could experience effects from oil production.

### 13.2.8 Groundwater Management

Groundwater could potentially be an important resource for South Sudan but there is currently very little known about the potential or extent of groundwater aquifers within South Sudan. Presently there is no groundwater monitoring system where real time measurements are regularly taken to assess abstraction and water quality. The report of the South Sudan Preliminary Water Information Assessment Study does note that “Deep boreholes were drilled in Sudd region, Southern parts of Baggara and Eastern Kordofan basins whereas slim shallow wells fitted with hand pumps were drilled in the fractured aquifer of basement and in the alluvial aquifers underlying seasonal Wadis.” With regards to groundwater the assessment report concluded that there is no exact figure regarding how much is abstracted but that it is a “small fraction of the resources available”.

During the consultations conducted October 11th following the conceptual design workshop South Sudan representatives expressed their interest in establishing groundwater monitoring at key urban locations that could benefit from or currently utilize groundwater as a supply source. These included Juba, Rumbek, Yambio, Aweil, and Bentiu.

**Data Requirements:**

- Aquifers safe yield
- Water level (monthly).
- Water Quality (monthly water quality including PH, T, TDS, Total Nitrates, Fecal coliform, pollution due to oil extraction).
- Monthly groundwater abstraction
- Precipitation to assess recharge potential

### 13.2.9 Hydropower

Within South Sudan the primary potential hydropower locations are along the upstream end of the Bahr el-Jebel. These future potential sites would create relatively small reservoirs with run of the river facilities. As such, this would require coordinated operation to optimize electricity generation and meet other system objectives. In addition, upstream release conditions at other potential run of the river hydropower sites in Uganda and direct releases of Lake Victoria at Jinja. This would require a dedicated Decision Support Tool with modules for: 1) long-term planning to determine mid- and long-term Lake Victoria release policies, 2) short-term release models to forecast the implications of the proposed release volumes for the coming 12-month period, 3) general hydraulic modeling tools to analyze routing times, and 4) short-term power generation optimization tools, which plan hourly dam releases and power production. All models are data intensive.

**Data Requirements:**

- Reservoir Inflow/Outflow, Reservoir Level – Daily monitoring (including upstream sites)
- Precipitation for forecasting reservoir inflows – Daily monitoring
- Sediment Load at key locations upstream of reservoirs – Monthly monitoring
- Sediment distribution in the reservoir – Monthly to Annual monitoring
- Energy Supply/Demands – Daily monitoring

### 13.2.10 Navigation

Transportation of people and goods by boat, as well as navigation for fishing and other commercial activities such as tourism is an important economic activity for many parts of South Sudan. Transport links create opportunities for inter-basin trade and regional economic integration. Good transport links are essential to achieving the goals of poverty reduction and sustainable development. Navigation related issues are of greatest importance in the Sudd, where water provides the most prevalent form of transportation of people and goods.

Developing the inland navigation potential of the River Nile – in particular the 'southern reach' from Kosti (Sudan) to Juba (South Sudan) on the White Nile - may provide a low-cost transport route for bulk cargo from South Sudan and the Nile Equatorial Lakes region to Sudan and Egypt, and would thus encourage inter-basin trade and regional integration. The main types of goods and services using this transport mode comprise agricultural produce, livestock, fish, and passengers. Establishing the 'southern reach' would in effect connect the land-locked areas of South Sudan and northern Uganda to the global transportation system, with considerable socio-economic benefits. The primary navigation corridors in South Sudan that would benefit from monitoring include the Nile from Renk to Juba on an annual basis and the Sobat and Bahr el-Ghazal/Jur on a seasonal basis.

**Data Requirements:**

- River Levels – Daily monitoring
- Lake/Reservoir Levels – Monthly monitoring
- Precipitation for forecasting river and lake levels – Daily monitoring
- River morphology (variation due to sediment deposition and bank erosion) – Annual monitoring

### 13.2.11 Fisheries

Fisheries are an important economic activity and subsistence food source within South Sudan. The main rivers and Sudd wetlands are the primary corridors for fisheries within the country. Poor management of water and land resources has a significant impact on these fisheries. Stakeholders have identified two main issues that impact fisheries in a number of the sub-basins, namely pollution and the destruction of fish habitats.

River/Stream/Lake/Wetland levels can be used in combination with rating curves to assess fish habitat associated with instream flows and lake water levels at specific locations. In addition, water quality monitoring is necessary at key locations to assess the status of the aquatic habitat and track pollution sources.

**Data Requirements:**

- River Levels – Monthly monitoring
- Lake/Reservoir Levels – Monthly monitoring
- Water Temperature – Weekly monitoring
- Dissolved Oxygen, Nutrients – Monthly monitoring
- Pesticides, Turbidity – Monthly monitoring
- Numbers of commercial fish per species - Annual

### 13.2.12 Watershed Management

In general, few specific cases of notable land degradation practices resulting in erosion and sedimentation due to deforestation; stress of water dependent ecosystems (wetlands, lakes) due to pollution, overfishing and natural disasters (floods, droughts); inadequate protection of plant and animal species; and spread of exotic and invasive water weeds were noted for South Sudan. This may be due to a lack of current monitoring to identify these concerns, a lack of issues in general, or most likely, a combination of both. Regardless of the case, a national monitoring network is necessary in order to assess the overall health and productivity of watersheds. Benefits to monitoring can include improvements to water supply, soils, sedimentation control, wetlands, biodiversity, and pastoral lands.

**Data Requirements:**

- Rainfall and Rainfall Intensity (daily and hourly)
- Discharge (daily).
- Evaporation (daily)
- Sediment load (daily at key stations, monthly at other stations)
- Soil Erosion

- Water quality (monthly)
- Lake level (monthly)
- Earth observation data

### 13.2.13 Wetlands Management

Some of the major socio-economic benefits of wetlands include erosion control, flood control, groundwater recharge, improved fisheries, and natural filtering of excess nutrients and sediments. Wetland vegetation reduces erosion along lakes and stream banks by minimizing the forces associated with waves. During flood events, wetlands can help absorb and slow runoff that may otherwise achieve catastrophic levels further downstream. Some wetlands can serve as points of groundwater recharge for surrounding communities or points of groundwater discharge to reduce the impact of short-term droughts on rivers and streams. Many species of fish will utilize wetland habitats for spawning and food sources. In addition, wetlands will absorb excess runoff nutrients that produce algae blooms and reduce oxygen levels killing fish and other aquatic life. As a result, protected wetlands can improve fish yields for surrounding communities. Tragically, these benefits are often not fully appreciated until a wetland is drained or flows are routed around the natural setting in an effort to “conserve” water.

The Sudd wetlands in South Sudan are among the largest tropical wetland areas in the world and have a permanent and seasonal component, the extent of which various from year to year following local and regional climatic variations, and the flow regime of the Bahr el-Jebel. The seasonal fluctuations in the wetlands are essential for the livelihood of the pastoralist people in South Sudan, who graze their cattle on the pastures emerging immediately adjacent to the receding wetlands during the dry season.

The extent of the seasonal wetlands determines the grazing capacity of the area. Both periodic drought and flood years result in a much smaller seasonal grazing areas with associated economic losses, and could lead to fierce competition over grazing lands. Figure 13-4 shows the extent of the seasonal and permanent wetlands as well as the primary grazing areas identified by South Sudan representatives during initial consultations.

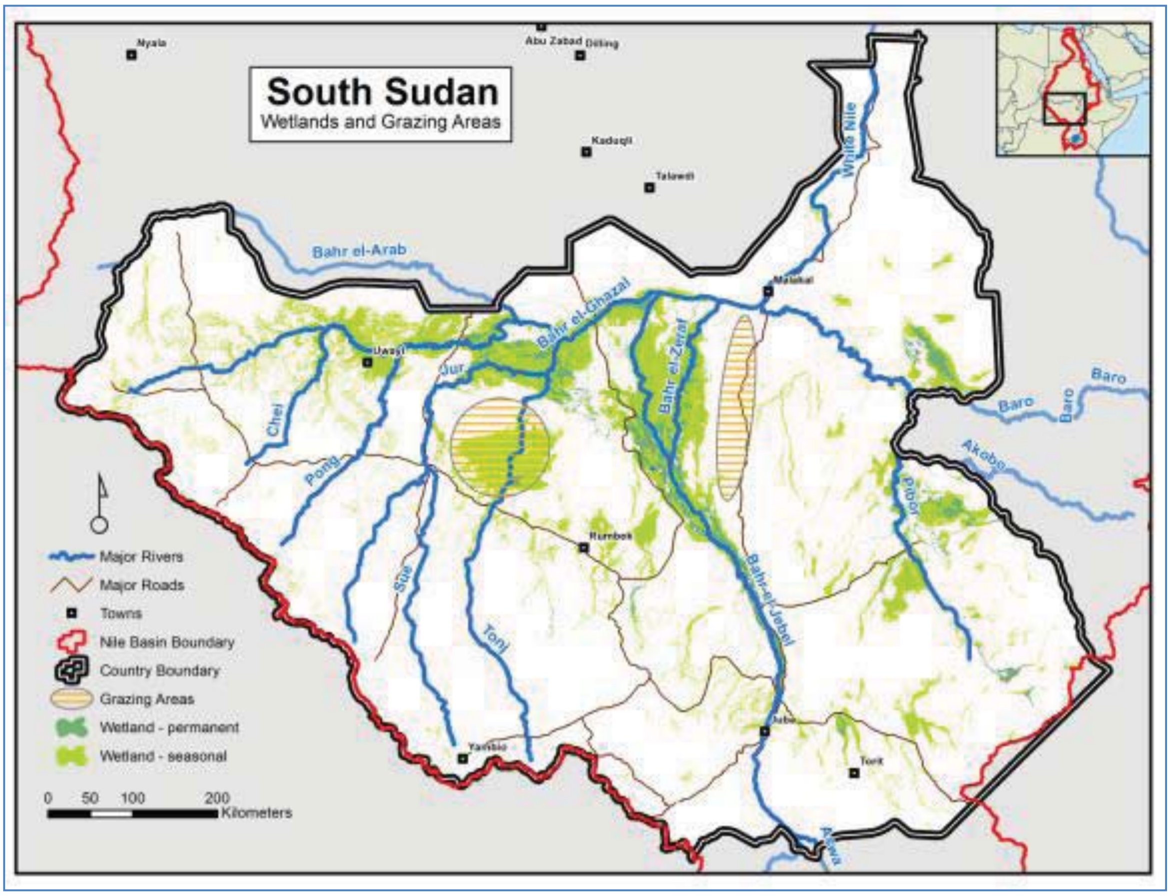


Figure 13-4. South Sudan wetlands and primary grazing areas

Coordinated management of the outflow from Lake Victoria would reduce excess flooding during wet years and maintain seasonal wetlands during drought years, and is part and parcel of managing the seasonal grazing lands in order to optimize their benefits for the local population. It would require real-time data on the seasonal extent of the wetlands, the Bahr el-Ghazal level, and the flows of the White Nile and the various upstream tributaries. Information is also needed on the Sudd outflow while rainfall data and information on evapotranspiration from the swamp vegetation is needed in order to establish the water balance of the area.

**Data Requirements:**

- River or Lake Stage/Discharge for both upstream and downstream ends of the wetland. Monitored daily or at a minimum, monthly basis.
- Sediment load upstream and downstream of wetland (daily at key locations, monthly at other stations).
- Water Quality analysis of key parameters conducted at both the upstream and downstream ends of the wetland. Monitored on a monthly basis.
- Groundwater monitoring at key locations surrounding or within a wetland to observe potential recharge or discharge effects associated with seasonal wetland fluctuations. Monitored on a monthly basis.
- Precipitation, Temperature, Relative Humidity, Pan Evaporation to assess water losses and direct gains of the wetland system. Monitored on a monthly basis.
- Bio-diversity of key aquatic species inventoried on a seasonal or annual basis.

- Remote sensing analysis of land cover to observe extent and changes of wetlands in the region conducted on a seasonal or annual basis.

### 13.2.14 Climate Change

Climate change impacts have the potential to undermine development and even undo progress made in reducing poverty and improving the socio-economic wellbeing of broad parts of the population. Rising temperatures and changed rainfall patterns are expected to increase climate variability and both the number and intensity of extreme weather events such as heat waves, droughts, storms, and floods, resulting in water contamination, vector-borne diseases and food shortages. A lack of long-term hydro-meteorological data within South Sudan, coupled with the region's sensitivity to climate effects makes the precise projection of climate change impacts difficult. However, the biggest climate change concerns for the country may result from a change in seasonal rainfall timing impacting both rainfed agriculture and pastoral grazing patterns.

**Data Requirements:**

- Daily and sub-daily measurement of climate parameters (rainfall, water discharge, relative humidity, air temperature, and evapotranspiration) to support climate adaptation decision making. This includes agriculture, industrial management, urban planning, disaster mitigation, and long-term infrastructure planning (such as dams, dykes, and canals).
- Daily and sub-daily measurement of climate parameters (as above) in order to establish daily, seasonal, and annual variations in order to support effective agricultural techniques, water management, and hazard planning.
- Provision of hydro-meteorological earth observations, including satellite, and modeled assessments as well as future projections of climate change.
- Daily climate parameters to support short, medium, and long range forecasts that are required to support disaster preparedness and avoid catastrophe, and ultimately improve the food and water security situation. This includes the information requirements for Early Warning Systems for El Nino/La Nina and/or the Indian Ocean Dipole, which are associated with extreme weather events in the Nile region.

## 13.3 National Field Monitoring Network Design

The proposed South Sudan hydro-meteorological monitoring network follows the same general methodology for defining stations as was presented in Section 6.3 for the regional network. The major differences include the following:

1. The national design focuses on achieving the priorities of the national South Sudan water resource management concerns as outlined in Section 13.2 rather than the Nile Basin regional issues
2. Due to the limited number of existing stations the national South Sudan design relies more heavily on assessing new suitable monitoring sites. This required more direct collaboration and communication with the South Sudanese representatives than with other countries for the regional design.

The national design is presented in the following sub-sections 13.3.1 through 13.3.3 outlining the proposed hydrometric, meteorological, and groundwater networks. The data and station specifications defined in Sections 6.1 and 6.2 also apply to the South Sudan proposed network designs based tables providing identifiers for station parameters and equipment. In addition, specific water quality monitoring to be conducted at proposed hydrometric and groundwater stations are presented in sub-section 13.3.4.

### 13.3.1 South Sudan Hydrometric Network Design

Following the Inception Workshop, Riverside conducted consultations with South Sudan representatives Simon Otoung Awikjak of the Ministry of Electricity, Dams, Irrigation and Water Resources (MEDIWR), and Edward Andrew Ashiek of the Civil Aviation Authority – Department of Meteorology. Outcomes of the consultations included mapping of national water resource management concerns/projects, an institutional questionnaire, and an initial site selection for the hydrometric station network. Riverside consultants and South Sudan representatives utilized working maps in conjunction with Google Earth to identify potential monitoring locations and record associated coordinates, names, and parameters to be measured. These sites were further reviewed and revised during the special session for South Sudan following the Conceptual Design workshop in Nairobi, Kenya October 11, 2014.

The proposed national hydrometric network for South Sudan is shown in Figure 13-5. The existing "active" stations are shown in green, "inactive" proposed stations (previous monitoring location) are shown in yellow, and "new" proposed sites are shown in red. In addition, stations to include water quality monitoring are defined by smaller black triangles while those to include both water quality and sediment monitoring are defined by smaller pink triangles.

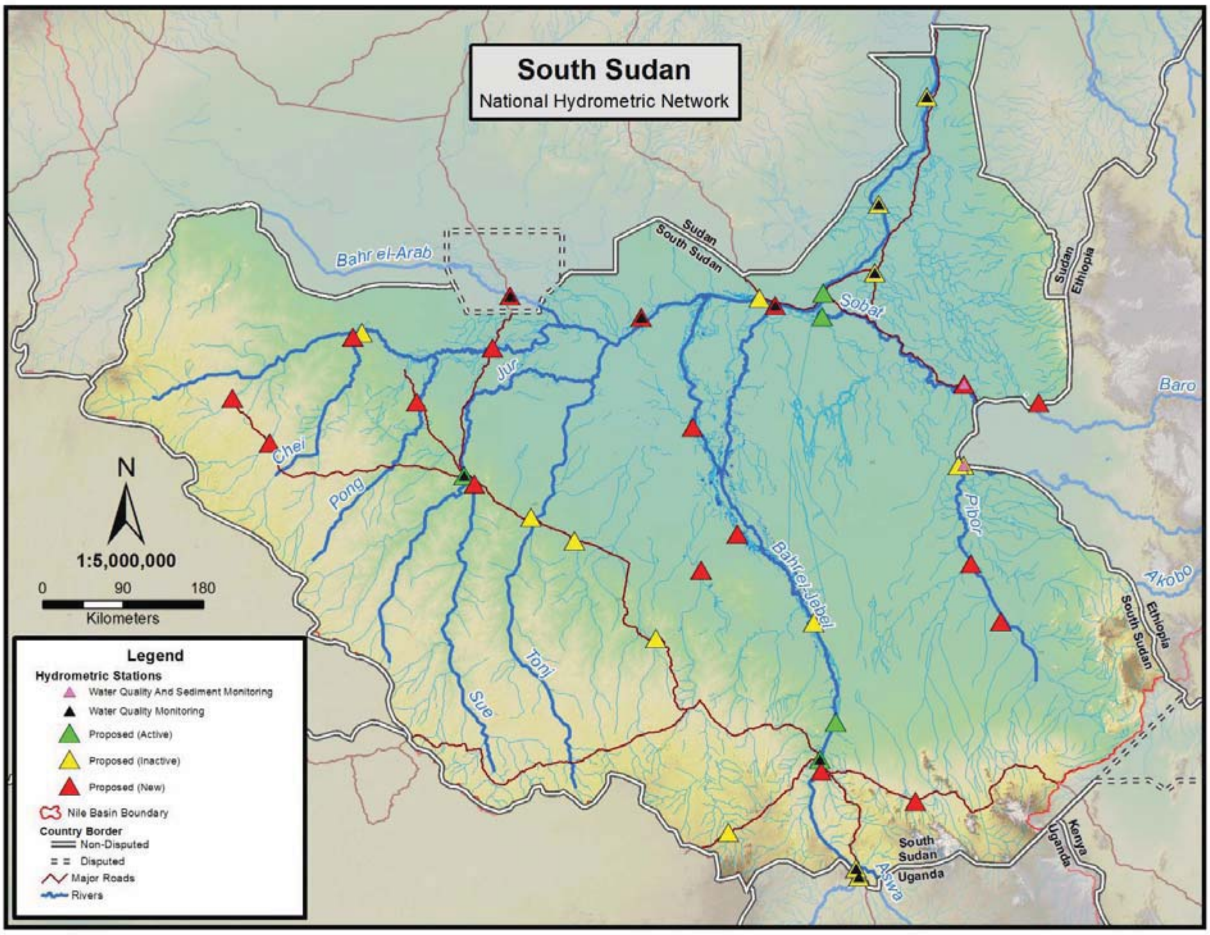


Figure 13-5. National South Sudan hydrometric network design

Table 13-1 presents associated station attributes at each site in the national hydrometric network design. Explanation and abbreviations for identifiers in Table 13-1 follow the same format as those presented in the regional hydrometric design in Section 6.4.1:

- **Name** – As defined by metadata received from countries

- **Lat** – Latitude coordinates in decimal degrees
- **Long –** Longitude coordinates in decimal degrees
- **Status –** *Active, Inactive, New*
- **Par (Parameters –** *WL (Water Level), D (Discharge), WQ (Water Quality), S (Sediment)*
- **Eq (Equipment) –** *Rad (Water Level Radar), PS (Pressure Sensor), SE (Shaft Encoder)*
- **Tel (Telemetry) –** *GPRS (GSM/GPRS cellular telemetry), Sat (Satellite telemetry via EUMETSAT)*
- **Notes –** Specific notes on why the station is incorporated in the national design

Station equipment specifications are provided in Section 6.2.1 while telemetry specifications are provided in Section 6.2.5. Details on specifics for water quality monitoring are provided in Section 13.3.4.

**Table 13-1. National South Sudan hydrometric stations**

| Name | Lat | Long | Status1 | Par | Eq | Tel | Notes |
|---|---|---|---|---|---|---|---|
| Akobo at mouth | 7.795 | 33.057 | Inactive | WL, D, WQ, S | PS | Sat | Monitor total flow contribution from the Akobo before confluence with Pibor |
| Akobo Town | 7.794 | 33.009 | Inactive | WL, D | PS | Sat | Monitor total flow contribution from the Pibor before confluence with Akobo |
| Bor | 6.207 | 31.547 | Inactive | WL | PS | Sat | Monitor water levels within the Sudd |
| Pong at Bridge | 8.437 | 27.532 | New | WL, D | Rad | Sat | Monitor flow contribution from the Pong River before the confluence with the Lol |
| Doleib Hill | 9.300 | 31.630 | Active | WL, D | PS | Sat | Historically significant monitoring location that captures total flow of Sobat before confluence with White Nile |
| Gel at New Road Bridge | 7.037 | 29.130 | Inactive | WL, D | Rad | Sat | Monitor flows from the Gel before entering the Sudd and for irrigation potential |
| Jikou | 8.427 | 33.819 | New | PS | Rad | Sat | IGAD HYCOS proposed station to provide potential benefits for future irrigation |
| Juba | 4.822 | 31.608 | Active | WL, D, WQ | Rad | Sat | Monitor flows at capital city for broad-based national benefits |
| Kennite (at Torit) | 4.401 | 32.572 | New | WL, D | Rad | Sat | Assess flows and runoff effects from events occurring in the mountains in the southeast end of the country and drought prone region. |
| Khor Adar | 9.745 | 32.160 | Inactive | WL, D, WQ | Rad | Sat | Monitor water quality and flows for future irrigation development |
| Kit 1 | 4.702 | 31.620 | New | WL, D | PS | Sat | Monitor flows for tributary that can have impact on Bahr el-Jebel just upstream of Juba |
| Malakal | 9.536 | 31.644 | Active | WL, D | PS | Sat | Historically significant monitoring location that captures total flow of White Nile downstream of Sudd and confluence with the Sobat |
| Melut | 10.434 | 32.203 | Inactive | WL, D, WQ | PS | Sat | Monitor water quality from nearby oil operations and flows for future irrigation development |
| Mongalla | 5.202 | 31.768 | Active | WL, D | PS | Sat | Historically significant monitoring location that captures torrent flows and is the last well defined location for monitoring discharge on the Bahr El Jebel before the Sudd |
| Yei at Yei | 4.087 | 30.683 | Inactive | WL, D | Rad | Sat | Monitor flows for major town of Yei |
| Nasir | 8.615 | 33.067 | New | WL, D, WQ, S | PS | Sat | Proposed new location to measure the total contribution from the Baro and Akobo on the Sobat |
| Nimule | 3.634 | 32.003 | Inactive | WL, D, WQ | PS | Sat | Monitor flows of Bahr el-Jebel from Uganda |

| Name | Lat | Long | Status1 | Par | Eq | Tel | Notes |
|---|---|---|---|---|---|---|---|
| Nyamlell | 9.139 | 26.978 | Inactive | WL, D | PS | Sat | Monitor flow of Lol with a contribution of approximately 30% of total flow from Bahr el-Ghazal basin |
| Pagarau | 6.739 | 30.408 | New | WL, D | PS | Sat | IGAD HYCOS proposed station to provide potential benefits for future irrigation |
| Phom el-zeraf, Tondiak | 9.410 | 31.159 | New | WL, D, WQ | PS | Sat | IGAD HYCOS station to assess split flow from Phom el-Zeraf before confluence with White Nile. Includes WQ to assess upstream oil exploration impacts |
| Pibor | 6.220 | 33.438 | New | WL, D | PS | Sat | IGAD HYCOS proposed station on Pibor River |
| Raga | 8.477 | 25.672 | New | WL, D | Rad | Sat | Monitor flows in town of Raga |
| Renk | 11.520 | 32.690 | Inactive | WL, WQ | PS | Sat | Monitor backflow water level from Jebel Aulia reservoir/White Nile. Important to also assess water quality from upstream oil fields. |
| River Assua at mouth | 3.723 | 31.972 | Inactive | WL, D, WQ | Rad | Sat | Monitor flow contribution from Aswa to Bahr el Jebel |
| Rumbek | 6.047 | 29.951 | Inactive | WL, D | Rad | Sat | Monitor flow near Rumbek for irrigation potential |
| Shambe, Al-Buhayrat | 7.105 | 30.772 | New | WL | PS | Sat | IGAD HYCOS proposed station to monitor water level within the Sudd at major town Shambe |
| Sopo | 8.022 | 26.050 | New | WL, D | Rad | Sat | Monitor flow contribution from Sopo River |
| Tonga at mouth | 9.488 | 30.999 | Inactive | WL, D | PS | Sat | Monitor flows near Tonga before confluence that forms White Nile |
| Wau | 7.694 | 28.014 | Active | WL, D, WQ | Rad | Sat | Monitor flow of Jur at Wau which contributes approximately 40% of total flow from Bahr el Ghazal. Seasonal navigation from Wau along Jur to Bahr el Jebel |
| Tonj | 7.272 | 28.687 | Inactive | WL, D | Rad | Sat | Monitor flow of Tonj which is a significant tributary of Bahr el Ghazal contributing approximately 10% of the basin flow |
| Bentiu | 9.292 | 29.804 | New | WL, D, WQ | PS | Sat | Monitor flow of entire Bahr el Ghazal. Assess WQ impacts from upstream oil fields. Need to determine if discharge measurements are possible and if a main channel constitutes majority of basin flow. |
| Pibor Post | 6.798 | 33.134 | New | WL, D | PS | Sat | Monitor flows on Pibor River at town of Pibor Post |
| Sue | 7.606 | 28.115 | New | WL, D | PS | Sat | Monitor flows of Sue before confluence with Jur at Wau |
| Wunrok | 8.986 | 28.300 | New | WL, D | Rad | Sat | Monitor flows of Lol before confluence with Bahr el-Arab |
| Awolnhom | 9.511 | 28.479 | New | WL, D, WQ | Rad | Sat | Monitor flows of Bahr el-Arab and assess water quality impacts from nearby oil mining operations |
| Adok | 8.185 | 30.321 | New | WL, D | PS | Sat | Monitor water levels within the Sudd |
| Chei at Bridge | 9.091 | 26.891 | New | WL, D | Rad | Sat | Monitor flow contribution from Chei before confluence that forms Lol River |

In summary, the national South Sudan hydrometric network design allows for hydrologic monitoring of the primary rivers and lakes that address the national water management issues presented in Section 13.2. The specific function that each station serves is presented in the notes of Table 13-1. These locations were thoughtfully discussed and reviewed with South Sudan representatives including identifying newly proposed sites at feasible locations using Google Earth Imagery.

The design consists of 37 total hydrometric stations. 12 of these are proposed to monitor water quality and 2 are proposed to conduct sediment monitoring to assess loads from Transboundary Rivers originating in Ethiopia. All of the stations to be included in the IGAD HYCOS network are also proposed in the national design and are labeled within the database.

### 13.3.2 South Sudan Meteorological Network Design

Currently there are only 5 existing manual synoptic meteorological stations that are active within South Sudan. There were an additional 9 Automatic Weather Station coordinates provided that are no longer active. The rehabilitation of these stations is likely given their recent installation from 2009 and 2010. Riverside utilized these existing sites along with a sustainable number of stations distributed throughout the country to provide national monitoring. Figure 13-6 shows the meteorological network with the rainfall variability grid (described in Section 6.3.4) as the background. It is worth noting that the overall rainfall variability is fairly low throughout the entire country when compared to other regions in the Nile Basin. This allows for a less dense meteorological network to still capture the mean areal precipitation that would occur throughout the country. Note also that an extensive road and town layer have been incorporated which provided excellent reference with regards to where additional meteorological stations could be installed and easily maintained.

The symbology used in Figure 13-6 is the same as maps displayed in the regional network with green signifying active, yellow as inactive, and red as new. In addition, stations proposed to have Full meteorological parameters (*precipitation, wind, temperature, humidity, barometric pressure, solar radiation*) at fully automated stations are defined with an "X", those proposed to be automated rain gauges are defined by a half circle, and those proposed as manual rain gauges are defined as open full circles. The difference with the regional symbology defined in Section 6.4.2 is that the South Sudan design includes some stations as manual rain gauges only to provide additional long term climatologically analysis. This was a specific request of the South Sudan representatives and manual rain gauges were added to supplement the automated stations that are considered to be a part of both the national and regional networks.

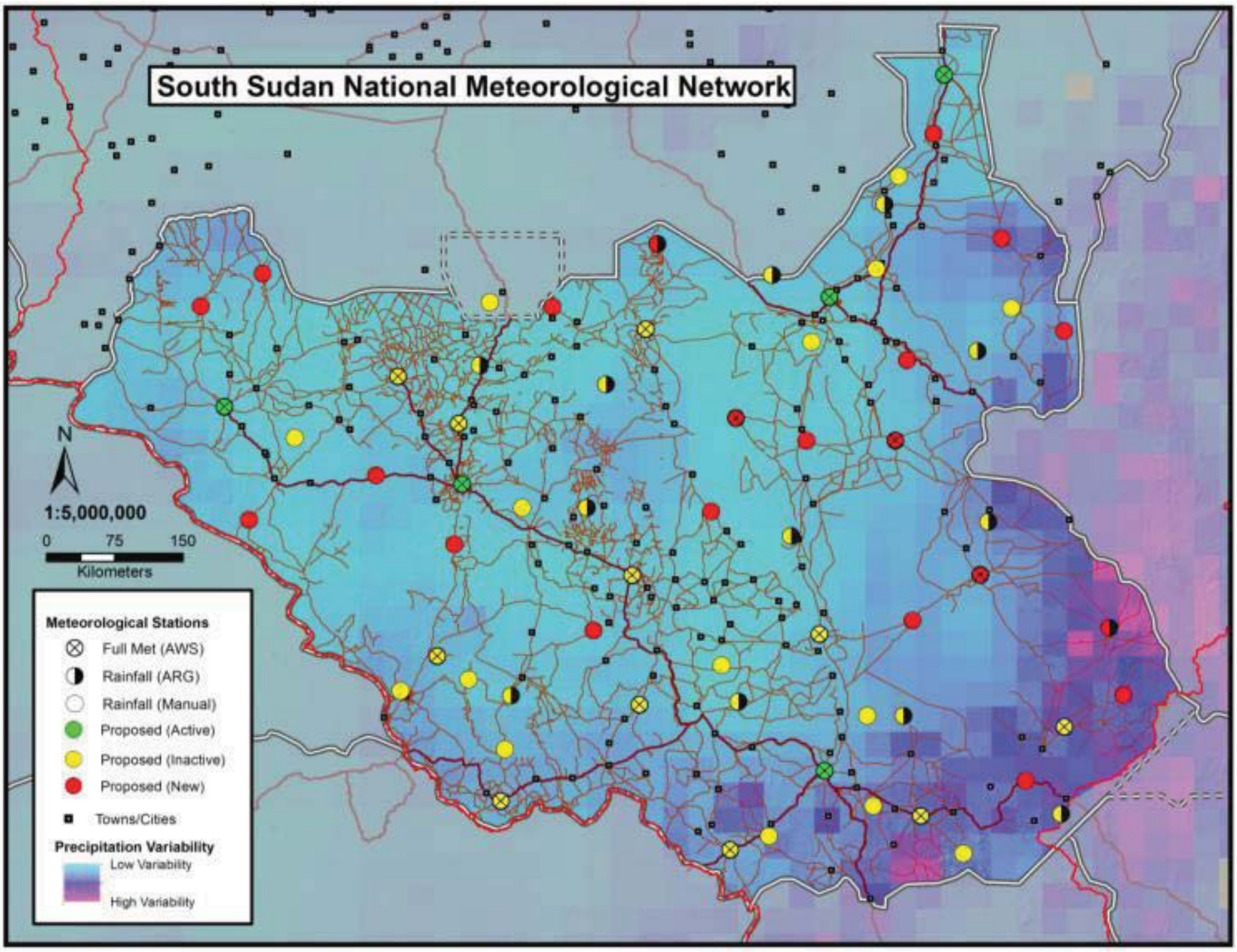


Figure 13-6. National South Sudan meteorological network design

Table 13-2 presents associated station attributes at each site in the national meteorological network design. Explanation and abbreviations for identifiers in Table 13-2 follow the same format as those presented in the regional meteorological design in Section 6.4.2:

- **Name** – As defined by metadata received from countries
- **Lat** – Latitude coordinates in decimal degrees
- **Long –** Longitude coordinates in decimal degrees
- **Status –** *Active, Inactive, New*
- **Parameters –** *Full Met (precipitation, wind, temperature, humidity, barometric pressure, solar radiation), Rainfall (precipitation only)*
- **Eq (Equipment) –** *AWS (Automatic Weather Station), ARG (Automatic Rain Gauge), Manual (Manual Rain Gauge)*
- **Tel (Telemetry) –** *GPRS (GSM/GPRS cellular telemetry), Sat (Satellite telemetry via EUMETSAT), NA (no telemetry at manual rain gauge)*

Station equipment specifications are provided in Section 6.2.2 while telemetry specifications are provided in Section 6.2.5. Newly proposed sites were provided a name based on nearby towns.

Table 13-2. National South Sudan meteorological stations

| Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|
| 50km SW of Biri | 7.350 | 25.909 | New | Rainfall | Manual | NA |
| 60km SSE of Boma | 5.617 | 34.552 | New | Rainfall | Manual | NA |
| 90km SW of Pibor Post | 6.355 | 32.468 | New | Rainfall | Manual | NA |
| Abyei | 9.502 | 28.291 | Inactive | Rainfall | Manual | NA |
| AMADI | 5.910 | 30.580 | Inactive | Rainfall | Manual | NA |
| ANZARA | 5.080 | 28.440 | Inactive | Rainfall | Manual | NA |
| AWEIL | 8.767 | 27.383 | Inactive | Full Met | AWS | Sat |
| Ayod | 8.132 | 31.420 | New | Rainfall | Manual | NA |
| BENTIU | 9.233 | 29.833 | Inactive | Full Met | AWS | Sat |
| Boma | 6.281 | 34.415 | New | Rainfall | ARG | Sat |
| BOR | 6.217 | 31.550 | Inactive | Full Met | AWS | Sat |
| Bunj | 9.445 | 33.445 | Inactive | Rainfall | Manual | NA |
| Daga Post | 9.217 | 33.967 | New | Rainfall | Manual | NA |
| DEIM ZUBEIR | 8.160 | 26.360 | Inactive | Rainfall | Manual | NA |
| Faddoi | 8.133 | 32.298 | New | Full Met | AWS | Sat |
| Fakwak | 8.355 | 30.724 | New | Full Met | AWS | Sat |
| FANGAK | 9.110 | 31.470 | Inactive | Rainfall | Manual | NA |
| FARAJOK | 4.050 | 32.970 | Inactive | Rainfall | Manual | NA |
| GOGREIAL | 8.880 | 28.190 | Inactive | Rainfall | ARG | Sat |
| Gunna | 7.788 | 27.167 | New | Rainfall | Manual | NA |
| IWATOKA | 4.220 | 31.050 | Inactive | Rainfall | Manual | NA |
| Juba | 4.867 | 31.600 | Active | Full Met | AWS | Sat |
| JUBA TOWN | 5.410 | 32.020 | Inactive | Rainfall | Manual | NA |
| Junguls | 10.133 | 33.350 | New | Rainfall | Manual | NA |
| Kambala | 9.463 | 25.433 | New | Rainfall | Manual | NA |
| KAPOETA | 5.300 | 33.970 | Inactive | Full Met | AWS | Sat |
| Kapoeta | 4.770 | 33.588 | New | Rainfall | Manual | NA |
| KODOK | 10.470 | 32.190 | Inactive | Rainfall | ARG | Sat |
| KUAJOK | 8.300 | 27.983 | Inactive | Full Met | AWS | Sat |
| LIYUBU | 5.660 | 27.410 | Inactive | Rainfall | Manual | NA |
| LUI | 5.550 | 30.750 | Inactive | Rainfall | ARG | Sat |
| Malakal | 9.550 | 31.650 | Active | Full Met | AWS | Sat |
| MALAKAL (M. OF A.) | 9.830 | 32.110 | Inactive | Rainfall | Manual | NA |
| MARIDI | 5.520 | 29.770 | Inactive | Full Met | AWS | Sat |
| Mbia | 6.258 | 29.315 | New | Rainfall | Manual | NA |
| MESHRAERREQ | 8.690 | 29.440 | Inactive | Rainfall | ARG | Sat |
| MONGALLA | 5.410 | 32.380 | Inactive | Rainfall | ARG | Sat |
| MULUT | 10.750 | 32.330 | Inactive | Rainfall | Manual | NA |
| MUPOI | 5.770 | 28.080 | Inactive | Rainfall | Manual | NA |
| NA'ANDI | 5.610 | 28.500 | Inactive | Rainfall | ARG | Sat |
| NAGI SHOT | 4.440 | 33.940 | Inactive | Rainfall | ARG | Sat |
| NASIR | 9.020 | 33.110 | Inactive | Rainfall | ARG | Sat |

| Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|
| OPARI | 4.520 | 32.080 | Inactive | Rainfall | Manual | NA |
| Pachua | 10.080 | 29.947 | New | Rainfall | ARG | Sat |
| Peili | 7.106 | 27.939 | New | Rainfall | Manual | NA |
| PIBOR | 7.330 | 33.220 | Inactive | Rainfall | ARG | Sat |
| Pibor Post | 6.804 | 33.140 | New | Full Met | AWS | Sat |
| RAFFILI | 7.470 | 28.610 | Inactive | Rainfall | Manual | NA |
| Raga | 8.467 | 25.667 | Active | Full Met | AWS | Sat |
| Renk | 11.750 | 32.783 | Active | Full Met | AWS | Sat |
| RUMBEK | 6.800 | 29.700 | Inactive | Full Met | AWS | Sat |
| SHAMBE | 7.190 | 31.270 | Inactive | Rainfall | ARG | Sat |
| Thar Nhom | 7.432 | 30.479 | New | Rainfall | Manual | NA |
| TONGA | 9.770 | 31.080 | Inactive | Rainfall | ARG | Sat |
| TONJ | 7.470 | 29.250 | Inactive | Rainfall | ARG | Sat |
| TORIT | 4.417 | 32.550 | Inactive | Full Met | AWS | Sat |
| TUMBURA | 6.000 | 27.770 | Inactive | Full Met | AWS | Sat |
| Turaybah | 11.170 | 32.677 | New | Rainfall | Manual | NA |
| Umm Begago | 9.785 | 26.045 | New | Rainfall | Manual | NA |
| Wau | 7.700 | 28.017 | Active | Full Met | AWS | Sat |
| Wer Ping | 9.458 | 28.911 | New | Rainfall | Manual | NA |
| YAMBIO | 4.567 | 28.400 | Inactive | Full Met | AWS | Sat |
| Yarkwaich | 8.929 | 32.414 | New | Rainfall | Manual | NA |
| YEI | 4.083 | 30.667 | Inactive | Full Met | AWS | Sat |

In summary, the South Sudan national meteorological network benefits from the previous regional network design presented in Section 6.4 with the inclusion of a real-time automated network. This is further supplemented with the inclusion of several proposed manual rain gauge locations. Figure 13-6 demonstrates the relatively low rainfall variability throughout the country with the exception of the southeast region. Here, a denser network has been provided to capture the variability in a region known for flash flood incidences. It is also worth noting that newly proposed stations have been strategically located at towns or along roads to provide accessible sites that provide good spatial coverage for monitoring.

The meteorological design consists of 64 total stations. 19 of these stations are proposed to be AWS with full meteorological monitoring. 14 of the 64 are proposed to be Automated Rain Gauges (ARG) and 31 are proposed to be manual rain gauges. It is also worth noting that 5 inactive stations received from South Sudan representatives were not included in the proposed network due to their close proximity with other proposed stations offering limited benefits for enhanced spatial coverage. These stations are listed in Table 13-3.

**Table 13-3. Inactive meteorological stations not proposed in the design**

| Name | Lat | Long | Status |
|---|---|---|---|
| MALAKAL | 9.910 | 32.080 | Inactive |
| LOA | 4.330 | 32.580 | Inactive |
| Akobo | 7.476 | 33.010 | Inactive |
| Okaru | 4.292 | 32.106 | Inactive |
| Loka | 4.123 | 30.595 | Inactive |

### 13.3.3 South Sudan Groundwater Network Design

During the consultations following the Conceptual Design workshop it was discussed and agreed upon that a few key urban locations which could utilize groundwater for supply purposes would benefit the most from groundwater monitoring. These sites included Juba, Rumbek, Yambio, Aweil and Bentiu. Each location was proposed to monitor both the water level and quality of groundwater. The development of these sites would allow for initial groundwater capacity building while not over extending the initial capabilities of the MEDIWR. After ensuring the initial sustainability of the few proposed groundwater sites the MEDIWR could elect to expand the network.

Specifications for the equipment at each proposed groundwater site are provided in Section 6.2.3. Both water level and water quality are proposed to be sampled on a monthly basis as suggested in the data specification Section 6.1.5 on groundwater. In addition, water quality parameters and equipment necessary are provided in Section 13.3.4 for each location. Figure 13-7 provides a map of the proposed groundwater network followed by Table 13-4 providing specific attributes.

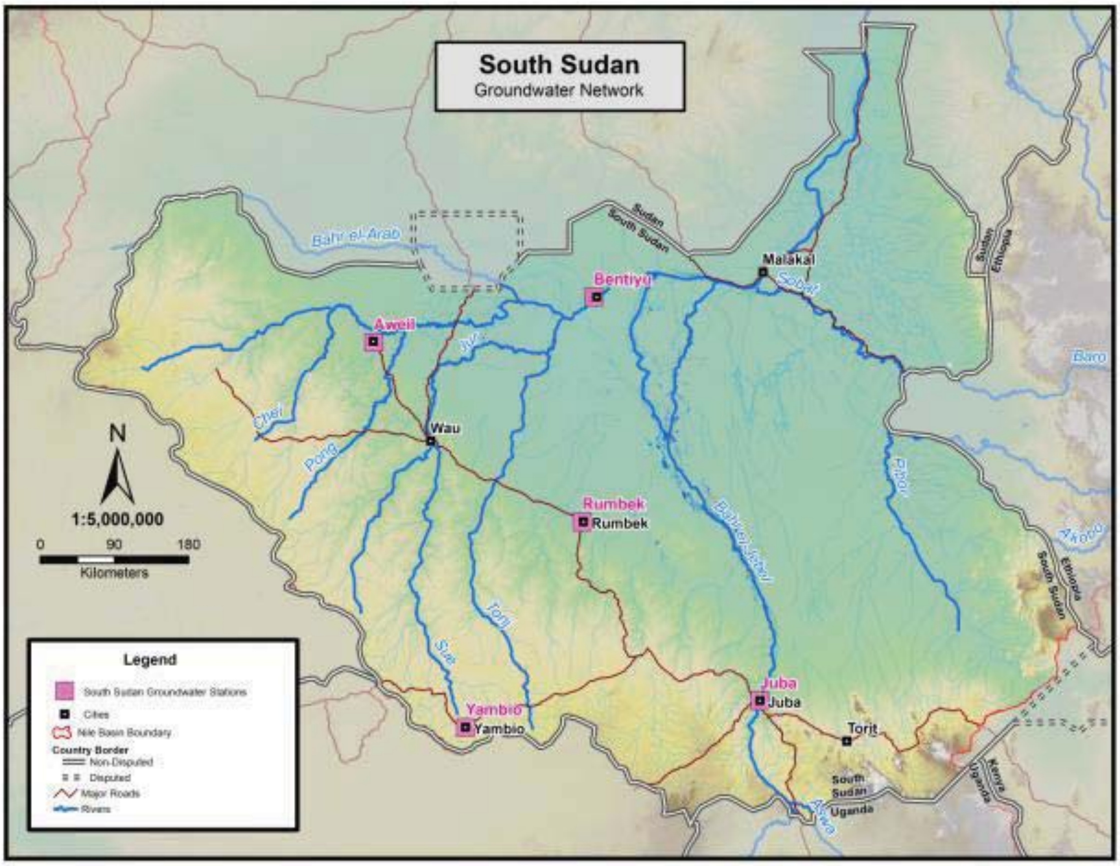


Figure 13-7. National South Sudan groundwater network design

Table 13-4. National South Sudan groundwater stations

| Name | Lat | Long | Status | Parameters* |
|---|---|---|---|---|
| Juba | 4.850 | 31.617 | New | GWL, GWQ |
| Rumbek | 6.805 | 29.676 | New | GWL, GWQ |
| Yambio | 4.560 | 28.403 | New | GWL, GWQ |
| Aweil | 8.767 | 27.400 | New | GWL, GWQ |
| Bentiu | 9.260 | 29.800 | New | GWL, GWQ |

**GWL- groundwater level; GWQ- groundwater quality*

### 13.3.4 South Sudan Water Quality Monitoring

Both the proposed hydrometric and groundwater networks include stations with recommended water quality monitoring. The current water quality monitoring capabilities within the country are very limited as noted in Section 13.1 and 7.2.6. Regardless, the national design represents an ideal monitoring network that may require phasing in additional water quality monitoring once specific benchmarks have been achieved. As such, the proposed national network includes monitoring both basic and advanced water quality parameters at all identified sites. These parameters are defined as follows:

- **Basic Parameters -** Temperature, pH, Conductivity, TDS, Dissolved oxygen, Turbidity, BOD, and Nutrients (N, P)
- **Advanced Parameters -** pesticides, heavy metals and hydrocarbons

Equipment for monitoring these parameters are presented in Table 7-1 of Section 7.1.5. South Sudan will need to establish both the capacity and equipment for monitoring basic parameters before establishing advanced monitoring. However, an opportunity may exist to utilize Uganda's water quality expertise to develop and assist South Sudan's program. During the first consultations with South Sudan representatives following the Inception workshop, a visit was made to Uganda's national water quality lab in Entebbe in early August of 2014. The South Sudan representatives were able to see the extent of the working lab facilities and equipment. There was also a brief discussion with the principal water analyst Simon Etimu regarding the potential collaboration for the Uganda lab to provide advanced parameter analysis services for South Sudan. This could allow South Sudan to begin monitoring water quality at the most important locations of national concern.

Table 13-5 provides specifics on the proposed sites to conduct water quality monitoring including notes on justification.

Table 13-5. National South Sudan water quality monitoring sites

| H/GW | Name | Lat | Long | Notes |
|---|---|---|---|---|
| H | Akobo at mouth | 7.795 | 33.057 | Transboundary WQ monitoring of flows between Ethiopia and South Sudan |
| H | Juba | 4.822 | 31.608 | Monitor WQ of Bahr el-Jebel within the capital city |
| H | Khor Adar | 9.745 | 32.160 | Monitor WQ for irrigation potential and possible impacts from nearby oil fields |
| H | Melut | 10.434 | 32.203 | Monitor WQ for irrigation potential and possible impacts from nearby oil fields |
| H | Nasir | 8.615 | 33.067 | Transboundary WQ monitoring of flows between Ethiopia and South Sudan |
| H | Nimule | 3.634 | 32.003 | Transboundary monitoring of WQ from Uganda |
| H | Phom el-zeraf, Tondiak | 9.410 | 31.159 | WQ monitoring of impacts from upstream oil fields |
| H | Renk | 11.520 | 32.690 | Transboundary WQ monitoring on Jebel Aulia reservoir. Also important for assessing potential affects from nearby oil production facilities. |
| H | River Assua at mouth | 3.723 | 31.972 | Transboundary WQ monitoring of flows between Uganda and South Sudan |
| H | Wau | 7.694 | 28.014 | WQ monitoring of Jur river for major city |
| H | Bentiu | 9.292 | 29.804 | WQ monitoring of potential impacts from upstream oil fields with regional significance due to border uncertainty with Sudan in Abeyi region |
| H | Awolnhom | 9.511 | 28.479 | WQ monitoring of potential impacts from oil fields in Abeyi region |
| GW | Juba | 4.850 | 31.617 | WQ monitoring for potential domestic drinking supply |

| H/GW | Name | Lat | Long | Notes |
|---|---|---|---|---|
| GW | Rumbek | 6.805 | 29.676 | WQ monitoring for potential domestic drinking supply |
| GW | Yambio | 4.560 | 28.403 | WQ monitoring for potential domestic drinking supply |
| GW | Aweil | 8.767 | 27.400 | WQ monitoring for potential domestic drinking supply |
| GW | Bentiu | 9.260 | 29.800 | WQ monitoring for potential domestic drinking supply |

## 13.4 National Data Management System

Currently the Ministry of Electricity, Dams, Irrigation and Water Resources (MEDIWR) in South Sudan does not operate a central database for storing hydrometric data. Any hydrometric data currently collected is stored within Excel Spreadsheets with copies on various staff laptops. In addition, it was made clear from consultations that there is a strong interest to incorporate the NBDSS into the national operations of the MEDIWR. This presents a unique opportunity to propose the national data management system outlined in Section 9.2 that will meet the future needs for hydro-meteorological monitoring in South Sudan as well as tie directly to the regional system.

Although other countries in the region are trending toward mobile networks, the coverage in South Sudan may not support mobile transmission in many of the remote areas where stations will be located, making satellite communications more attractive throughout the country. However, the national network will still include several manual gauges which will require the system to also allow for manual data entry. This will enable South Sudan to gradually develop capacity for new automated stations while restoring active operations at previously existing stations and adding new manual stations. This will establish a data record and experience with observers who may play a future role in sustainability and security.

Several external prerequisites discussed previously will need to be achieved before South Sudan can host data management system within MEDIWR. Some of these include government security throughout the country and stable electricity and high speed internet availability at the ministry offices. One interim approach discussed and proposed at the Conceptual Design workshop was the possibility of that NBI could host the South Sudan national data management system on an interim basis to allow for technical and infrastructure support with a dedicated MEDIWR web client for accessing all data. This could be coupled with staff training opportunities at NBI offices for future transition of the system to MEDIWR.

## 13.5 Institutional Design and Development

The institutional strengthening and capacity development are vital to the durability of the operation, management and delivery of the Hydromet services in South Sudan. The following five factors have been identified by the Nile Basin Countries during the project launch workshop as essential to the sustainability of the Nile Basin Hydromet systems:

- Institutional
- Technical
- Management
- Financial
- Behavioral change

Consultation meetings took place with South Sudan representatives in Entebbe on Aug 6-7, 2014, during field visits in September and November 2014, and during the Conceptual Design workshop in Nairobi, Kenya October 11, 2014. Based on the key findings from these meetings, recommendations for the conceptual design of the institutional and development of South Sudan HIS follow below.

### 13.5.1 Socio-economic issues

- *Lead and Supporting Institutions*

Results of the first south Sudan institutional questionnaire show that, generally, the Ministry of Electricity, Dams, Irrigation and Water Resources (MEDIWR) in South Sudan lead eleven (11) of the fourteen (14) socio-economic issues and has a support role in two (issues). This would help in maximizing the benefit of Hydromet systems and allows for leveraging resources in the operation and management of these systems. On the other hand, the number of supporting institutions is not fully completed in the questionnaire.

- *Prioritization of Socio-economic issues*

Preliminary results for South Sudan show that the highest priority was given to eight (8) issues namely water resources planning, floods, watershed, wetland, drought, climate change, fisheries and navigation. Rainfed agriculture, groundwater and water quality have second priority. Energy and irrigation have third priority, and soil erosion and sediment has the lowest priority[11].

- *Geographical areas of socio-economic issues*

The list of primary regional issues in Table 4-2 shows targeted issues in South Sudan for regional collaboration with other riparian countries. This list was discussed with the Nile Basin countries during the first review workshop for the hydromet systems conceptual design. The list will assist in the design of implementation phase in defining the functions required to address the selected socio-economic issues and identifying the roles and responsibilities of the lead and supporting institutions relevant to each issue in South Sudan. In addition, a working map of national water resource management/socio-economic issues as shown in Figure 13-2 was developed that can assist in identifying the local roles and responsibilities for monitoring.

### 13.5.2 Institutional Responsibilities for Hydromet Parameters[12]

- *Rainfall and Evaporation Parameters*

South Sudan needs to build on lessons learned from the other Nile basin countries to build strong Meteorological Services that take the lead role on all the rainfall and evaporation parameters for meteorological, water resources and agro-climate needs to avoid duplication of efforts and leverage funds for capacity building and effective monitoring technologies. Key functions and staffing for the meteorological services are shown in Section 11.1.

- *Water discharge/Level*

MEDIWR need to exclusively carry out Water discharge/level monitoring and progressively decentralized its service to cater for the large size of the country and the hydrological specifics of the various geographical areas. Key functions and staffing for the hydrometric services are shown in Section 11.2.

- *Groundwater monitoring*

The MEDIWR needs to map out the national and Transboundary groundwater systems and progressively establish a groundwater monitoring system giving priority to the monitoring of groundwater level and quality in oil production areas to control contamination of groundwater and over-abstraction in these areas. The new monitoring network would also include provisions for monitoring shared aquifers and water quality for water supply wells, especially in area of low groundwater table and dense population to control biological contamination of groundwater.

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[11] Priority will be revised following completion and confirmation of the institutional questionnaire.

[12] Water Quality responsibilities noted in Section 1

- *Surface water and groundwater use*

Monitoring of surface and groundwater use is essential for the national water resources management and efficient use of water. Responsibilities of monitoring agriculture water use and urban/rural water supply need be clearly defined.

- *Earth Observations Products*

Riverside has suggested regional and national functions and staffing for earth observation services in the staffing needs Section 11.3 of the institutional design and development component.

### 13.5.3 Institutional Conceptual Design

The institutional concept for addressing the regional Transboundary issues will follow the same approach presented in Section 10.1. The following are the key steps for the institutionalization of the national hydromet systems in South Sudan:

- Identify priority water resources management/socio-economic issues (i.e. WRPM, floods, watershed, wetland, drought, climate change, fisheries and navigation. etc.).
- Identify the lead and supporting institutions for each of the water resources management issue.
- Define the functions (activities) related to each water resources management issue.
- Identify the roles and responsibilities of the lead institution and supporting institutions for implementation of each defined function.
- Develop policies, action plans, and procedures to support the implementation of the functions based on the roles and responsibilities of each lead and supporting institution[13].
- Validate the list of data requirements (Demand) for each water resources management factor.
- Identify the data requirements for the lead institution and supporting institutions based on the above validated list (Demand) and the functions and responsibilities of each institution.
- Confirm the monitoring network for each Hydromet parameter.
- Identify the lead and support institutions responsible for providing hydromet services for the required data with clear functions and roles of each institution.
- Develop national policies, action plans, and procedures to support the roles and responsibilities of each lead and supporting institutions providing hydromet services.

### 13.5.4 Hydromet Services Function and Staffing Need

This section presents the functions and staffing for the key services and institutional enabling environment required for the sustainability of the regional and national hydromet network in South Sudan. The services are associated to the hydromet data requirement for the regional collaboration issues, shown in Table 11-1 and the national hydromet data needs. These services include:

- Meteorological services
- Hydrological Services
- Earth Product Services

### 13.5.5 Meteorological Services

#### *Monitoring*

**Functions:** The monitoring function consists of collection of rainfall and evaporation data from the rainfall stations and automatic weather[14] stations. This includes operation and maintenance of the

[13] Based on the organization structure presented in the Preliminary WIS Assessment Final Report for South Sudan or any later institutional amendment

[14] Synoptic stations are not included given that they mainly serve the transportation sector.

stations and data retrieval on a routine basis as per requirement of the key socio-economic issues/ water management issues in South Sudan (water resources planning and management, flood management, wetland management, watershed management, etc.).

**Staff: -** Three field technicians and a supervisor. The supervisor and one technician at South Sudan Meteorological Department (SSMD) located in Juba, one technician in Wau, and one technician in Malakal. The technicians should have a secondary level education and training in operation and maintenance of automatic weather stations.

- One experienced technologist to manage, service, and support the automatic weather data communications and data acquisition system at the central/regional country office.

### *Data Checking, Validation, and Dissemination*

**Functions:** This includes QA/QC and data dissemination to clients as described in the details of Section 11.1.

**Staff:** Three climatologists and a supervisor. The supervisor and one climatologist at South Sudan Meteorological Department (SSMD) located in Juba, one climatologist in Wau, and one climatologist in Malakal. A bachelor degree in meteorology, climatology, geography or equivalent with experience in data verification and validation of automatic rainfall stations and automatic weather stations is required for this task.

### *Data Management*

**Functions:** This task includes management and administration of meteorological database that includes data of the regional rainfall and automatic weather stations. This function would be initially centralized in Juba.

**Staff:** One junior and one mid-level staff located at SSMD. Both staff should have a computer science or IMS degree with good experience in database management.

### *Data Analysis and Modeling*

**Functions:** This task includes preparation of information for public and private clients. The information would include climate trend analysis (wet and dry periods), rainfall intensity-duration frequency curves, estimated evaporation, etc. This function would be more effective and economically sound when performed at the centralized level at the SSMD in Juba.

**Staff:** One mid-level and one senior climatologist/agro-climatologist, preferably with Master Degree and strong experience in statistics.

### *Communication and Outreach*

**Functions:** This task includes the development of written, audio, and visual educational and awareness material about the meteorological data and information products targeted to public and private users to raise awareness about the socio-economic benefits of meteorological monitoring. More details in Section 11.1.

**Staff:** One communication specialist with strong experience in designing and preparing educational material and outreach programs and familiarity with meteorological or environmental related services. Excellent communication and social marketing skills are highly required.

### *Institutional and Policy Support*

**Functions:** This task will support creating the enabling institutional and policy environment related to the meteorological service for the implementation of the institutionalization of the hydromet systems.

**Staff:** Head or representative of the SSMD.

### 13.5.6 Hydrological Services

WMO guidelines for the role, operation, and management of National Hydrologic Services (WMO-No. 1003, 2006) has been provided as a supplemental resource with a summary given in Appendix H.

#### *Monitoring*

**Functions:** The monitoring function consists of collection of water level from automatic water level recorders, routine measurement of water discharges to establish (for new stations) or update rating curves, and collecting water samples for water quality and sediment load testing. More details in Section 11.2.

**Staff: -** Three routine flow measurement crews of two persons each, one crew in Juba, one in Wau and one in Malakal**.** Three field technicians and a supervisor. The supervisor and one technician at the Directorate of Hydrology and Survey (DHS) located in Juba, one technician in Wau, and one technician in Malakal. The technicians should have a secondary level education and training in operation and maintenance of automatic hydrometric stations. The supervisor should preferable have a bachelor degree or a minimum two year university level in a scientific or technical major.

- One experienced technologist to manage, service, and support the hydrometric data communications and data acquisition system at the central/regional country office.

#### *Data Checking, Validation, and Dissemination*

**Functions:** This task includes data QC/QA and validation of the water level data downloaded or transmitted from the automatic hydrometric stations, the water discharge measurements and the rating curves for each station. More details in Section 11.2.

**Staff:** Three hydrologists and a supervisor. The supervisor and one hydrologist at DHS located in Juba, one hydrologist in Wau, and one hydrologist in Malakal. A bachelor degree in civil engineering, agriculture engineering, geography, natural sciences or equivalent with experience in data verification and validation of automatic hydrometric stations is required for this task.

#### *Data Management*

**Functions:** This task includes management and administration of surface water discharge, water quality, and sediment transport database that includes data of the regional hydrometric, water quality, and sediment transport regional stations.

**Staff**: One junior and one mid-level staff located at DHS. Both staff should have a computer science or IMS degree with good experience in database management

#### *Data Analysis and Modeling*

**Functions:** This task includes preparation of information for public and private clients. The information could include streamflow forecasting, streamflow trend analysis (wet and dry periods), Flow frequency analysis, Flow duration analysis, low flow analyses, inundation duration analyses, etc. This function would be more effective and economically efficient when performed at the centralized level at DHS Juba.

**Staff:** One Mid-level and one senior hydrologist, preferably with Master Degree or PhD and strong experience in hydrologic modeling and statistics, and working experience in GIS.

#### *Groundwater Monitoring Services*

**Functions:** This task includes monitoring of groundwater level and groundwater quality for selected aquifers to build capacity in this field. This function also covers data checking and validation and data analysis.

**Staff**: One junior technician and one hydro geologist located at DHS. The technician should have a secondary level education and training in operation and maintenance of monitoring equipment. The supervisor should preferable have a bachelor degree in geology or a master degree in hydrogeology.

#### *Communication and Outreach*

**Functions:** This task includes the development of written, audio, and visual educational and awareness material about hydrological data and information products targeted to public and private users to raise awareness about the socio-economic benefits of hydrological monitoring. More details in Section 11.2.

**Staff:** one (1) communication specialist with strong experience in designing and preparing educational material and outreach programs and familiarity with hydrological or environmental related services. Excellent communication and social marketing skills are highly required.

#### *Institutional and Policy Support*

**Functions:** This task will support creating the enabling institutional and policy environment related to the hydrological service for the implementation of the institutionalization of the hydromet systems.

**Staff:** Head or representative of the national hydrological department/division.

### 13.5.7 Earth Observation Product Services

The national Earth Observation office for South Sudan would preferably be located at the Ministry of Electricity Dams Irrigation and Water Resources (MEDIWR) headed by an Earth Observation specialist with very good knowledge of earth observation, remote sensing, geographic information system (GIS), database applications, and web-based applications for data earth observation data access, presentation, and management. Experience with earth observation remote sensing data set related particularly to precipitation, soil moisture, evaporation, and land cover is required, and advanced degree in meteorology /atmospheric sciences, hydrology. Excellent skills and experience in management and manipulation of spatial and tabular data sets (GIS, relational databases, etc). The earth observation specialist should be supported by a GIS specialist and Web Portal specialist.

### 13.5.8 Training and Capacity Development

The national situation assessment, the two in- country consultations, and the institutional questionnaire have clearly stressed the need to develop and strengthen the human resources to build and sustain regional and national hydromet systems in South Sudan. Section 13.5.4 presented the functions and staffing for the key services and institutional enabling environment required for the sustainability of the regional and national hydromet networks in South Sudan. Section 7.1.11 highlighted the staffing requirement for the MEDIWR Water Quality Laboratory. Riverside is proposing a national training program tailored to the conditions of South Sudan as a new state that is embarking on the establishment of mature hydromet services within the constraints of ongoing conflicts. The training program objective is to progressively build a solid foundation for the staff of MEDIWR, SSMD and other relevant institutions for the accomplishment of the hydrological, meteorological, and WQ monitoring functions. Staffing of the MEDIWR and SSMD as per staff requirement of the hydrological and meteological services illustrated in section 13.5.4 and staff requirement of the MEWDIWR water quality laboratory in 7.1.11 are a pre-requisite for the South Sudan training program.

The training program will be composed of formal classroom training and demonstration workshops, and on the job-training. The formal training program includes the training modules illustrated in Table 12-2 covering the following areas:

- Meteorological and hydrological monitoring

- Meteorological and hydrological data checking, validation and dissemination
- Meteorological and hydrological database development and management
- Hydromet services communication and outreach
- Earth Observation Products Water quality laboratory technologies and Laboratory Information Management System (LIMS)

Targeted trainees and specific training methods such as formal classroom training and demonstration workshops, as well as training duration are presented for each training topic. The training modules have been prioritized. Priority 1 modules need to start immediately after the launch of the National Hydromet implementation program. The remaining modules need to be completed within the first two years of the National Hydromet program.

Table 13-6. Proposed training modules for South Sudan

| Training Modules | Training Elements | Training Method | Targeted Trainees |
|---|---|---|---|
| 1. Installation of meteorological stations, data acquisition, operation and maintenance (Priority 1) | a. Automatic weather/agroclimate station site selection and installation standards.<br>b. Automatic weather/agroclimate stations instrumentation (traditional and new technologies)<br>c. Installation of weather/agroclimate Station instrumentation (sensors, data loggers).<br>d. Data Acquisition System - Hardware<br>e. Data Acquisition System - Software<br>f. Data Acquisition System - Diagnostics<br>g. Data Acquisition System operation and maintenance.<br>h. Calibration of sensors and equipment. | • 2 day classroom and two day field demonstration.<br>• On-the-job training during implementation. | • Field technicians and field supervisor<br>• Technologist |
| 2. Installation of hydrometric stations, data acquisition, operation and maintenance (Priority 1) | a. Automatic hydrometric station site selection and installation standards (including datum benchmark, leveling techniques, site description, etc.).<br>b. Hydrometric stations instrumentation and technologies (water levels recorders, data loggers)<br>c. Data Acquisition System - Hardware<br>d. Data Acquisition System - Software<br>e. Data Acquisition System - Diagnostics<br>f. Data Acquisition System operation and maintenance.<br>g. Calibration of sensors and equipment. | • 2 day classroom and two day field demonstration.<br>• On-the-job training during implementation. | • Flow measurement crews<br>• Field technicians and field supervisor<br>• Technologist |

| Training Modules | Training Elements | Training Method | Targeted Trainees |
|---|---|---|---|
| 3. River discharge measurements (Priority 1) | a. Presentation and analysis of flow discharge measurement methods.<br>b. Conduct on site discharge measurements using various methods and proven technologies (current meters, ADCP, Radar, etc.)<br>c. Analyze and compare various methods<br>d. Calibration of current meters, ADCPs, Radar instruments, etc. | • 2 day classroom and three day field demonstration.<br>• On-the-job training during implementation. | • Flow measurement crews<br>• Field technicians and field supervisor<br>• Technologist |
| 4. Development and maintenance of rating curves (Priority 1) | a. Rating Curve Theory<br>b. Hydraulic Considerations<br>c. Rating Curve Development - Software | • 2 day workshop on theory.<br>• 2 day workshop on using software application.<br>• On-the-job training during implementation. | • Flow measurement crews<br>• Field technicians and field supervisor |
| 5. Sediment transport monitoring (Priority 2) | a. Methods for collection of suspended sediment stream samples.<br>b. Laboratory testing of sediment transport load.<br>c. Establishment of a relationship between sediment concentration or load and stream discharge - the sediment rating curve | • One day classroom and two day field and laboratory demonstration.<br>• On-the-job training during implementation. | • Flow measurement crews<br>• Field technicians and field supervisor |
| 6. Meteorological data checking, validation, and dissemination (Priority 1) | a. Data processing and data quality control (QC) methods and operations.<br>b. Data quality assurance (QA) and data validation methods and operations.<br>c. Evaluation of biases and long-term drifts of sensors and modules, malfunction of sensors of data loggers.<br>d. Dissemination of the validated data with concise description of data quality. | • One day classroom and two day operational training using field data.<br>• On-the-job training during implementation. | • Climatologists and meteorological data QA/QC supervisor |
| 7. Hydrometric data checking, validation, and dissemination (Priority 1) | a. Data processing and data quality control (QC) methods and operations.<br>b. Data quality assurance (QA) and data validation methods and operations.<br>c. Evaluation of biases and long-term drifts of sensors and modules, malfunction of sensors and malfunction of the water level sensors and data loggers.<br>d. Dissemination of the validated data with concise description of data quality. | • One day classroom and two day operational training using field data.<br>• On-the-job training during implementation. | • Hydrologists and hydrological data QA/QC supervisor |

| Training Modules | Training Elements | Training Method | Targeted Trainees |
|---|---|---|---|
| 8. Database Management<br>(Priority 1) | a. Database and Data Management Principles<br>b. Time series data processing<br>c. GIS vector data processing<br>d. GIS raster data processing | • One week classroom and demonstration workshop<br>• One week operational training<br>• On-the-job training during implementation | • Meteorological and hydrological data management officers |
| 9. Data Entry<br>(Priority 1) | a. Using data entry to provide data to database management systems<br>b. Update Database Management Systems with data from Data Entry<br>c. Distributing the Data Entry component | • 2 days formal classroom training<br>• On-the-job training during implementation | • Meteorological and hydrological data management officers |
| 10. Data analysis tools and applications<br>(Priority 2) | a. Flow frequency analysis<br>b. Flow duration analysis<br>c. Trend analysis<br>d. Low flow analyses<br>e. Inundation duration analyses<br>f. Correlation and data comparisons | • A series of one day training sessions for each analytical application with practical demonstrations<br>• On-the-job training during implementation | • Hydrologists |
| 11. Hydromet monitoring communication and outreach<br>(Priority 2) | a. Development of written, audio, and visual educational and awareness material about hydromet data and information products<br>b. Design and implementation of outreach programs to raise awareness about benefit of hydromet monitoring services among field technicians, decisions makers, and public and private data and information users.<br>c. How to explore opportunities for private sector funding to support development and sustainability of hydromet services. | • 2 days of formal classroom and operational training<br>• On-the-job training during implementation | • MEDIWR and SSMD Communication officers and other relevant staff |
| 12. Institutional Development for sustainable hydromet systems<br>(Priority 1) | a. Factors of sustainability of hydromet services<br>b. Principle of lead and supporting institutions<br>c. Defining functions, roles and responsibilities of hydromet services<br>d. Creating policy and legal environment for sustainable hydromet services | • 2 days of formal classroom and operational training<br>• On-the-job training during implementation | • Institutional and Policy Representatives of MEDIWR, SSMD, and other relevant institutions |

| Training Modules | Training Elements | Training Method | Targeted Trainees |
|---|---|---|---|
| 13. Web operations and support<br>(Priority 1) | a. Web Design and Applications<br>b. Web Data and Information Applications<br>c. Web Data and Information – Software<br>d. Editing data<br>e. Web services | • One week formal classroom training<br>• One week operational training<br>• On-the-job training during implementation | • Meteorological and hydrological data management officers |
| 14. Earth Observation Products<br>(Priority 1) | a. Introduction to Sensor capabilities and availability.<br>b. Physical principles of precipitation, soil moisture, evapotranspiration, and land cover retrieval<br>c. Processing precipitation, soil moisture, evapotranspiration, and land cover from satellite measurements. | • One week classroom and demonstration workshop<br>• One week operational training | • Climatologists and hydrologists |
| 15. WQ Sampling<br>(Priority 1) | a. Sampling goals: water quality assessment, permitting studies, waste load allocation studies, habitat studies.<br>b. Types of samples: grap, composite, time composite, integrated.<br>c. Method of sampling: manual, automatic, from bridges, from boats, depth, stream sampling.<br>d. Sampling containers: container materials, container caps, container structures, disposable containers, container washing, container wrapping.<br>e. Container preparation for analysis of: metals, nutrients, non organics, organics, microbiology.<br>f. Sampling volume and holding time<br>g. Sampling timing and frequency.<br>h. Sample preservation: preservation guidelines, addition of chemicals, pH control, freezing, refrigeration, alternative methods.<br>i. Chain of custody procedures: sample labels, sample seal, log book, records analysis request sheet, sample delivery form, sample received form, sample test assignment form, etc. | • 3 day formal training and practical demonstration | • Field technicians and field supervisor, WQ laboratory specialists |

| Training Modules | Training Elements | Training Method | Targeted Trainees |
|---|---|---|---|
| 16. Field observations and use of WQ testing kits and automatic WQ monitoring technology<br>(Priority 1) | a. Preparation for the field trip.<br>b. Field quality assurance.<br>c. Field quality control.<br>d. Prevention of sample contamination and losses.<br>e. Calibration and maintenance of field instruments.<br>f. Use of automatic samplers.<br>g. Measurement of field parameters such as temperature, pH, electrical conductivity, dissolved oxygen, turbidity via portable kits and on site sondes. | • 2-3 day practical demonstration. | • Field technicians and field supervisor, WQ laboratory specialists |
| 17. General Laboratory Water Quality Testing and Analysis<br>(Priority 1) | a. Water quality testing parameters: physical, organics, inorganic anions, inorganic cations, gases, microbiology.<br>b. Instrumental methods for water quality analysis: atomic absorption spectrometry, inductively coupled and direct current plasma, flame photometry, ion chromatograph, gas-liquid chromatography, high pressure liquid chromatography, potentiometry with ion selective electrodes, spectrophotometry, FTIR, Conductometry, turbidimetry.<br>c. Techniques used for water quality analysis: biological oxygen demand (BOD), Chemical oxygen demand (COD), total oxygen demand (TOD), total organic carbon (TOC), Kjeldahl total nitrogen (TKN), microbiological investigation using most probable number and membrane filter methods, solvent and solid phase extraction of organic compounds, clean-up of organic extractants for chromatographic measurements, sample digestion, Titrimetry.<br>d. Instrumentation and equipment maintenance: troubleshooting, handling, and simple repair of instrumentation and equipment such as balances, flame photometers, sondes, AAS, HPLC, UV-VIS. | • One week formal classroom and practical demonstration | • WQ laboratory staff |

| Training Modules | Training Elements | Training Method | Targeted Trainees |
|---|---|---|---|
| 18. Quality Control and Quality Assurance<br>(Priority 1) | a. Laboratory quality policy<br>b. Equipments calibration: methods and schedules.<br>c. Control charts.<br>d. Types of internal quality control samples.<br>e. Daily interpretation of control charts.<br>f. Long term use of control chart data.<br>g. Results uncertainty.<br>h. Standard addition.<br>i. Analysis of blind samples.<br>j. Analysis of split samples.<br>k. Repeated (or duplicate) analysis.<br>l. Blank assessment.<br>m. Use of certified reference materials. | • 3 day practical training and demonstrations | • WQ laboratory staff |
| 19. Safety in water quality laboratories<br>(Priority 1) | a. Chemical inventory, storage and handling.<br>b. Material safety data sheets (MSDS).<br>c. Chemical spills and spill cleanup.<br>d. Hazardous waste disposal.<br>e. Fire types, safety and distinguishing.<br>f. Safety of electricity, water and gas lines and connections.<br>g. Proper handling and storage of compressed gas cylinders.<br>h. Emergency procedures.<br>i. First aid kit.<br>j. Handling of laboratory accidents.<br>k. Chemical hygiene responsibilities.<br>l. Safety showers and eye wash station.<br>m. Personal protective equipments. | • One day formal training and demonstrations | • WQ laboratory staff |
| 20. Laboratory Information Management System (LIMS)<br>(Priority 1) | a. Introduction to LIMS concept<br>b. Logging samples<br>c. Interface of laboratory instruments with LIMS.<br>d. Entering WQ results into LIMS or exported results directly from the laboratory instruments into the system.<br>e. QA/QC and approval of WQ results<br>f. Reporting of WQ results and interface of LIMS with WQ database. | • 3 day formal training and demonstrations | • WQ laboratory staff |

Given the current status of the hydromet services in South Sudan, significant increased benefits could be derived by complementing formal training with two years of mentoring. Hands-on training and learning will assist current and new staff in progressively acquiring the required skills for the operation and maintenance of the hydromet systems. It is proposed that South Sudan be provided with on-the-job training by two experts, one meteorologist and one hydrologist during the first two years of the hydromet program implementation to support and speed up capacity building in various aspects of hydromet services. These could be international or regional experts. WMO guidelines on the implementation of education and training standards of personnel for both meteorological (WMO-No. 1083, 2012) and hydrological (WMO-No. 258, 2003) services have been provided as supplemental resources with summaries of each given in Appendix H.

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# Appendix A: Country Consultation and Field Visit Reports

## Appendix A.1: National Consultation and Field Visit Report for Burundi

### 1. Introduction and Background

In May 2014, the Nile Basin Initiative (NBI) contracted with Riverside Technology to develop design specifications and an implementation plan for the Nile Basin Regional Hydro-meteorological Monitoring System (this Assignment). The assignment aims to enhance Nile River basin monitoring. It will address coverage, equipment, techniques, data acquisition and dissemination, sampling and testing, standard procedures, capacity development, cost estimates, and implementation planning.

As part of this assignment, field visits and national consultations have been organized in each project country, with the aim to appreciate the potential value, benefits, and need for the regional water resource monitoring system, acquire a deeper appreciation of the current state of the monitoring technologies and practices, and to understand the institutional context within which the designed system will be operated. The consultations will also identify needs for technical support, capacity building, and institutional strengthening. The defined objectives include the following:

- Confirm understanding of current network and practices based on country assessment report and metadata from associated countries and past studies. Supplement information and metadata based on discussions.
- Identify country protocols for data communication, storage, formatting, dissemination, sharing, and use. Identify and discuss what data could be used in a regional network and how it could be delivered.
- Confirm the important socio-economic drivers for data collection and elaborate specific needs for data to inform decisions and development.
- With each country/ministry representatives discuss perceived needs both with regards to data collection and institutional capacity development and how these can relate to the regional monitoring network.
- Conduct field visits at key monitoring locations that adequately represent the current technologies and practices within use. This will include visits to any water quality labs to further assess data sampling, testing, management, and dissemination.

### 2. Main Water Resources Issues in Burundi

The Nile basin area in Burundi is blessed with considerable water resources. In discussions with IGEBU management and interviews with sector stakeholders in Burundi, the below key water resources issues were identified:

- Bacterial contamination of surface water and shallow groundwater because of poor sanitation; in fact, the overall majority of the rural population has no access to proper sanitation facilities, and only Bujumbura has a sewage water treatment plant;
- No effective source water protection from overuse and contamination;
- Extensive land degradation and severe soil erosion across the country because of high population density, hilly terrain, poor agricultural practices, and soil characteristics;
- The overall majority of seasonal wetlands outside the national parks has been transferred into small-scale irrigated gardens; these lands typically flood during the rainy season; wetland irrigation has a very high irrigation efficiency; it should be noted that irrigation water use in converted wetlands – in excess to original wetland evapotranspiration – is low; hence, seasonal wetland irrigation does not lead to significantly higher water use;

- There is currently no management of water levels in the seasonal irrigation areas; this would concern a highly complex undertaking that needs to balance drainage, irrigation, and in-stream flow requirements in the dry season;
- Outside the wetlands, no major irrigation activities are foreseen in the short and medium-term future; irrigated agriculture is currently not sufficiently profitable to afford the associated investment or pumping costs;
- The country has considerable potential for small and micro-scale Run-of-River hydropower production; it requires hydrometric information on minimum and maximum flows, as well as flow-duration curves;
- So far, low flows have mostly been sufficient to meet irrigation water demand; however, water demand for seasonal irrigation continues to rise and may conflict in the future with other low-flow water demands (such as in-stream flow requirements and RoR hydropower – see above); low flow management, therefore, is critical and probably more important than flood management (which is absorbed by the large wetland areas);
- In case of conflicting water demands, irrigation will in most cases be prioritized at the expense of RoR electricity production; nevertheless, it represents a conflict between rural areas (farmers) and urban dwellers (electricity consumers) that needs to be managed;
- Information on groundwater potential and sustainable yields is only available for three regions in the country; groundwater over-abstraction is increasing and needs to be looked into;
- High levels of iron and some uranium traces are found in groundwater in the alluvial aquifers in the western rift valley, but not in other parts of the country;
- There are a number of potential dam locations, including Burasira (multi-purpose dam – studied by NELSAP) and Saburenda (Ruhigi province – with 45 MW power potential);
- Reforestation and sustainable land management is critical to reduce overland flow, capture rainfall for productive use, and promote groundwater infiltration; while there are many ongoing reforestation and watershed protection projects, the scope of this task is enormous;
- Periodic droughts increase pest problems and adversely affect agricultural production; drought forecasting would assist pest control; it would require a higher density of climate monitoring stations with (near) real-time data communication.

At first glance, the implications of the above issues with regard to hydro-meteorological monitoring include:

- Focus on water quality monitoring (in particular regarding bacterial contamination and sediments);
- Emphasize low flow monitoring;
- Expand the use of Earth-Observation products to design, plan, and monitor watershed protection projects;
- Better assessment of groundwater potential and sustainable yields.

The transboundary dimension of the above water resources concerns is quite limited. As an upstream nation, Burundi's main concern is not to exceed reasonable Nile water use and ensure that flows crossing its border to the downstream riparians are of adequate quality.

## 3. Hydromet Network in Burundi

### *3.1 Status of the Hydromet Network*

The status of water resources monitoring in Burundi has been reported in detail in the recent report "Assessment of the Current Status of the Hydrological Monitoring System in Burundi" prepared by IGEBU. The report presents station tables with station coordinates and monitoring parameters. The mission confirmed the information presented in the assessment report and the reader is referred to this document for up-to-date information.

The network in the Nile basin area comprises some 30 hydrologic stations. The extent and coverage of the network is adequate but the system requires modernization. Water levels are measured with staff gauges through manual observations. Only recently have a few stations been equipped with automatic instruments (see below). A field measurement campaign is organized on a quarterly basis. River flow is measured with a propeller-type current meter operated from a bridge. Low flows are measured using a small current meter on a wading rod. Measurement of flood-flows takes place only occasionally and the upper ranges of the rating curves are therefore subject to considerable uncertainties. There is no systematic measurement of WQ or sediment.
The operation of the hydromet network in Burundi is constrained by a recent government policy that is restricting use of government vehicles. As a result, only a single 4WD at IGEBU is available for all field work. The road network in Burundi is excellent and most stations have good accessibility.

### *3.2 Ongoing and Planned Expansion of the Network*

It is important to note that IGEBU is implementing a number of concurrent projects to enhance the hydro-meteorological monitoring capacity in the country. Coordination is essential to make best use of the available resources. This paragraph lists the various ongoing initiatives.

### *3.3 IGAD HYCOS*

IGAD and WMO are jointly implementing a project to provide adequate infrastructure for hydrological observations and regional cooperation in information exchange. The project will install a total of 100 hydrometric stations accompanied by a comprehensive training program. Seven project countries are involved: Burundi, Ethiopia, Kenya, Rwanda, Sudan, Tanzania, and Uganda. IGAD HYCOS is being implemented in two phases: 1) preparatory phase (with 1 year duration) and 2) implementation phase (with a duration of 33 months). The first phase has been completed and the project has started the procurement process of hardware and the data management system.

IGAD HYCOS has proposed to upgrade the following 3 hydrometric stations in the Nile basin area in Burundi (an additional 4 stations have been selected outside the Nile Basin):

| STATION ID | RIVER | LOCATION | TYPE |
|---|---|---|---|
| 11031 | Ruvubu | Muyinga | River flow |
| 11038 | Ruvubu | Gitega | River flow |
| 11040 | Ruvyironza | Muyange | River flow |

The stations will be equipped with staff gauges (Ott) and a pressure transducer connected to a datalogger and telemetry facilities using GSM/GPRS data communication (from SEBA). IGAD HYCOS also provides an ADCP (make SEBA – specifications unknown to the reporter).
It is important to note that IGAD HYCOS support is limited to instruments, software, and training. The project does not support (minor) civil works to improve discharge measurement, such as simple cableway facilities (support posts with pulley). The field visit (see Annex 1) visited all IGAD HYCOS stations and noted that simple cableway facilities are needed in particular at Muyinga (Ruvubu) and Gitega (Ruvubu) to conduct a proper discharge measurement. At other sites, the ADCP can be operated with a rope from both river banks because of the relatively narrow rivers and presence of a bridge near the gauging site.

### *3.4 World Bank*

Under a World Bank project, 22 stations have been earmarked for upgrading. However, all are located outside the Nile basin area in Burundi. The reporter has no information on equipment and database specifications, or a possible training program.

### 3.4.1 NELSAP Kagera Project

The NELSAP Kagera project has recently upgraded the below stations:

| STATION ID | RIVER | STATION | LAT | LON | TYPE |
|---|---|---|---|---|---|
| 11039 | Ndurumu | Shombo | -3.2097 | 30.0458 | River flow |
| 11042 | Ruvyironza | Kibaya | -3.3172 | 29.9166 | River flow |
| 11044 | Nyabaha | Mubuga | -3.3905 | 30.0513 | River flow |
| 11047 | Kayongozi | Nyankanda | -3.2811 | 30.3013 | River flow |

The above stations have been equipped with an OTT Thalimedes float operated shaft encoder, without telemetry facilities.

In addition, NELSAP Kagera has also provided 5 Automatic Weather Stations (AWS) – make Sutron - with sensors for rainfall (tipping bucket), incoming solar radiation (short and long wave), relative humidity, T, and wind-speed and direction at 2 m. The Sutron datalogger includes a data display and uses standard memory cards for data transfer. The setup is easy to use and functions well.

AWS stations are in Gitega (3850), Karuzi (4450), Muyinga (8200), Ruyingi (9750), and Cankuzo(2950). It is noted that Karuzi (station ID 4450) has been vandalized.

Further, the NELSAP project has provided an OTT ADCP to IGEBU (specificiation unknow to the reporter). However, this instrument is not suitable for the river conditions in Burundi and cannot be used.

### 3.4.2 GIRET

The GIRET project – which is implemented under NELSAP – has recently installed automatic water level recorders (OTT Thalimedes) at the lakes Kanzigi, Cohoh, and Rweru in the Nile Basin area in Burundi. No telemetry facilities have been installed.

### 3.4.3 LVEMP-2

LVEMP 2 is initiating a consultancy to develop hydro-meteorological and agro-meteorological monitoring capacity in Burundi. The Terms of Reference for this consultancy are attached as Annex 2. There is considerable overlap with the ongoing NBI project and the other initiatives listed in this paragraph.

### 3.4.4 Coordination is Required to Avoid a Patchwork Approach

Coordination is required to make best use of the available resources and harmonize equipment, software, and communication systems. In the absence of a general master-plan or coordinated approach, the respective projects provide a diverse range of instruments that may or may not be suitable for the specific environment in Burundi, and prove difficult to operate and maintain by the limited human resources available. In short, coordination is required to avoid a patchwork approach.
It is noted that the key stations for Nile water resources monitoring in Burundi (i.e. Ruvubu at Muyinga, Ruvubu at Gitega, and Ruvyironza at Muyange) have been earmarked for upgrading by IGAD HYCOS. It is also noted, however, that IGAD HYCOS will only provide instruments and will not improve discharge measurement facilities at these sites.

### *3.5 Possible Gaps*

In discussions with IGEBU management, the following data gaps have been identified:

- Upgrade the remaining 16 principal climate stations in the Nile basin area with Automatic Weather Stations (AWS);

- Install Automatic Weather Stations (AWS) at the provincial agricultural offices (9 in the Nile basin) to support agricultural practices; include associated training;
- Provide simple cableway facilities Ruvubu at Muyinga and Ruvubu at Gitega, which are key stations for Nile water resources monitoring;
- Provide two ADCPs, in order to facilitate two concurrent teams in the field for the quarterly measurement campaign; the current OTT ADCP is not functional, while there are doubts about the functionality of the SEBA ADCP that will be provided by IGAD HYCOS (this has to be checked);
- Upgrade stations 11032, 11034, 11036, 11037, 11043, 11046, and 11051 (Lake Station); it is noted, however, that these stations measure small rivers with little importance for Nile water resources monitoring.

### *3.6 Data Management*

#### 3.6.1 Existing Setup

Hydrometric and meteorological data are stored in a central MS Access database at IGEBU in Gitega. Front-end forms have been developed for collecting data input and quality control, while back-end procedures have been added for standard queries and analysis. The database is stored on a protected server with proper backup while adequate admin procedures are in place.

The current database setup works well and a large pool of well-trained staff can operate the system. Nevertheless, the MS Access system will meet its limit in the near to mid-term future, in particular for meteorological data and when automatic stations are introduced that will greatly increase the volume of data. Also, the current system is unable to incorporate real-time information from stations equipped with telemetry facilities.

Furthermore, information from recently installed Automatic Weather Stations (SUTRON) is not entered into the central database and is currently archived in a parallel system.
In view of the ongoing initiatives to modernize the hydromet system, it is clear that the database setup needs to be modernized and reconsidered.

A separate well-organized groundwater SQL database has been established. The system – called Geo Hydro Database v3.14 - includes information on:

- Location;
- WQ info;
- Water levels (for boreholes);
- Yields (for springs);
- Drilling logs.

The groundwater database will in time be linked to the central hydromet database at IGEBU.

#### 3.6.2 Ongoing Database Modernization Activities

At least three projects have been identified that plan to introduce new data management systems in Burundi:

1. WMO: this organization has asked IGEBU to adopt CLIMSOFT; this software is based on MS Access with interfaces developed in Visual Basic; the software is free;
2. IGAD HYCOS: in an informal discussion with an IGAD HYCOS engineer, the reporter was informed that this projects intends to introduce HYDSTRA, which is a time-series data management system specifically developed for water resources by Kisters – a German company;

3. Lake Victoria Information System: this system has been developed by LVEMP2 and includes a custom-made data management system; the system is in an advanced state of completion.

Introducing a new data management system in an organization is a huge undertaking that carries substantial risks and needs to be carefully considered. Selection and procurement of the software is obviously just the first step in this process. New software needs to be accompanied by a comprehensive training program and well-establish external support – on the ground – for a prolonged period of time. Furthermore, all peripheral systems (such as data entry forms and backup procedures) need to be simultaneously upgraded and re-engineered in order to guarantee at least the same level of functionality.

It is obvious that coordination is required among the various initiatives that aim to introduce new data management systems in Burundi.

### *3.7 Water Quality Laboratory*

IGEBU maintains a small WQ laboratory, mainly used for groundwater testing. Parameters include: pH, conductivity, BOD, temperature, Fe, Fluor, dissolved oxygen, arsenic, and various types of bacterial contamination. The lab has limited capacity and only basic facilities and equipment. Four IGEBU staff members have received WQ analysis training and seem competent. For more advanced analysis, samples are sent to a certified laboratory in Hannover – Germany.

The national WQ laboratory - Laboratoire d'Analyse et de Recherche en Eau (LARE) – is located in Bujumbura and run by the Institute National Pour l'Environnement et la Conservation de la Nature (INECN), which is part of the Directorate General for Natural Protection.

The lab is housed in a newly renovated building and is well equipped with a wide range of new instruments from Germany and China. Most WQ parameters can be analyzed with the exception of heavy metals and complex organic and biological compounds. The lab is not yet accredited and many instruments have not yet been used. Consumables (for instance for the Spectometer) and spare parts are limited. Some 7 trained analysts work at the lab.

There is no regular groundwater or surface water monitoring program and measurements are taken on an ad-hoc basis, with the exception of a few boreholes and industrial effluent points.

## 4. Institutional Setting

### *4.1 Institutional Framework for Water Resources Monitoring*

IGEBU (l'Institut Geographique du Burundi) is responsible for monitoring of surface and groundwater, and climatic parameters. IGEBU is part of the Ministry of Water, Environment, Land Management, and Urbanization (MEEATU).
MEEATU consists of:

- IGEBU (all monitoring and cartography)
- DG Natural Protection
- DG Environment et Forest
- DG Water
- DG Urbanization

This is a new structure and effective collaboration arrangements between the various entities have yet to be established.

A number of government entities were visited during the mission. It is noted that the effective capacity of most entities is quite limited (skeleton staff, no vehicles for field program, limited activities on the ground).

### *4.2 Data Exchange Policies*

To obtain hydrometric and climatic information, a letter is required explaining the intended purpose of the data and addressed to the Director General IGEBU. Consultants pay per station year while students and development projects have free access to the data.

IGEBU is willing to share data with the co-riparians in the Nile Basin under condition that data are not transferred to third-parties.

### *4.3 Institutional Questionnaire*

The results of the institutional questionnaire have been presented in a separate document.

### *4.4 Capacity Building Requirements*

In discussions with IGEBU management, the below training requirements were identified:

- Hydrometric Methods and Instruments: installation, operation, and maintenance of modern hydrometric stations equipped with electronic datalogger and sensors; (5 persons)
- Hydro-acoustic discharge measurement techniques; (5 persons)
- Database management using CLIMSOFT; (approximately 5 persons)
- Formal (1-year) training of meteorological technicians (30 persons)

## 5. Field Visits

Field visits were organized to a number of stations:

- Synoptic Station at Gitega Aerodrome (19 Aug 2014);
- Ruvubu at Gitega (19 Aug 2014);
- Ruvyironza at Muyange (20 Aug 2014);
- Waga at Muyange (20 Aug 2014);
- Ruvyironza at Nyabiraba (20 Aug 2014);
- Ruvubu at Muyinga (21 Aug 2014);
- Synoptic Station at Muriza (21 Aug 2014);
- Synoptic Station at Cankuzo (21 Aug 2014).

The findings of the field visits are presented in Annex A1-1.

## 6. Conclusion and Recommendations

The main findings of the consultation visit and field trip are presented below:

- Most water resources issues in Burundi are local in scope; the transboundary dimension of water resources management in the country is limited;
- Coordination is required among the various initiatives currently upgrading hydro-meteorological monitoring capacity in the country; coordination is presently inadequate;
- The current hydromet data management system at IGEBU functions well; while the system requires upgrading (in time), this process needs to be carefully considered; new software needs to be accompanied by a comprehensive training program and well-establish external support – on the ground – for a prolonged period of time;
- Coordination is required among the various initiatives that are planning to upgrade the data management system at IGEBU; it should be avoided to introduce multiple concurrent systems;
- The key stations for Nile water resources monitoring in Burundi (Ruvubu at Muyinga, Ruvubu at Gitega, and Ruvyironza at Muyange) have been earmarked for upgrading by IGAD HYCOS;

however, this project will not establish adequate discharge measurement capacity at these stations (both in terms of cableway facilities or appropriate ADCP).

**ANNEXES**
**Annex A.1-1: Field Visits**
**Annex A.1-2: Terms of Reference of LVEMP 2**

**Annex A.1-1: Field Visits**

## 1. Synoptic Station at Gitega Aerodrome (date of visit 19 Aug 2014)

General Station Information

| | |
|---|---|
| Station Code | 3850 |
| Purpose of Station | Monitoring of climatic parameters; synoptic climate station |
| Latitude | 29.9167 |
| Longitude | -3.4167 |
| Period of Record | |
| Equipped with | Typical instrumentation for a classic synoptic weather station complemented with an Automatic Weather Station (AWS) with sensors for T, RH, rainfall, incoming solar radiation, wind speed & direction at 2 m |
| Observer present | Yes |
| Status | Operational |
| Distance to IGEBU Office | <5 km |

Site Description

The climate station is located at the compound of Gitega aerodrome. The station is in good condition with adequate security. The classic meteorological equipment is in reasonable condition and functions well. Data are transferred to IGEBU by mobile telephone on a daily basis, while the complete paper record sheet is filed on a weekly basis. Manual recordings are digitized at IGEBU and stored in the general database (in MS Access).

Recently, a Sutron AWS has been added with sensors for incoming solar radiation (short and long wave), wind speed and direction at 2 m, relative humidity, temperature, and a tipping bucket rain-gage. The Sutron datalogger includes a data display and uses standard memory cards for data transfer. The setup is easy to use and functions well.

Station Photos

AWS at Gitega aerodrome

Sutron datalogger and power unit

Status Report and Comments

The AWS functions well. It can be considered to equip the station with telemetry facilities for (near) real-time data communication. The classic instrumentation is in need of general maintenance.

## 2. Ruvubu at Gitega (date of visit 19 Aug 2014)

General Station Information

| | |
|---|---|
| Station Code | 11038 |
| Purpose of Station | Water level and discharge monitoring; key station for monitoring the Nile / Lake Victoria system in Burundi |
| Latitude | 29.980 |
| Longitude | -3.351 |
| Period of Record | 1973 – 2014 |
| Equipped with | Staff gauges; cableway support posts & winch (without cables) |
| Observer present | Yes |
| Status | Operational; no recent discharge measurements |
| Distance to IGEBU Office | ~10 km |

Site: General Map


Ruvubu – Gitega hydro station is situated downstream of the Ruvyironza – Ruvubu confluence. A weir in the Ruvyironza directs a large percentage of flow to a Run-of-River hydropower facility, with a head of 17 m and a capacity of 750 KW. The outflow of the hydro facility enters Ruvubu upstream of the hydromet station. A new bridge has been constructed some 1 km upstream of the station (see image above) and could be used for discharge measurement during peak flows, when the Ruvubu flood plain is inundated.

Site Description


The control section is stable without visible signs of scour or deposition. Flow is restricted to a single wide channel and streamlines are straight both up- and downstream of the control section. There is no high turbulence and the rating curve is fairly stable. The wide floodplain will inundate during periodic flood events, making it impossible to conduct flow measurements during peak flows, and introducing considerable uncertainty in the higher range of the rating curve.
Station accessibility is adequate and the site can be reached on foot from the nearby main road (with the exception of a flood event – see above). The GoB owns the land on which the station is located. Mobile phone coverage (LEO provider) is available. There is no access to the public power network.

Station Photos

**Ruvubu at Gitega hydro station – control section**

**Ruvubu at Gitega hydro station – downstream of control section**

Winch for cableway system (no longer used, but in good condition)

Ruvubu at Gitega hydro station – upstream of the control section

Existing Instruments and Equipment

Ruvubu – Gitega hydro station is equipped with staff gauges. Facilities for a cableway (constructed by HYDROMET) are present on both river banks, but the cable(s) are absent. Discharge measurements have not been conducted for an extended period.

Status Report and Comments

Ruvubu – Gitega is a key station that has been earmarked by IGAD HYCOS for upgrading. The station will be equipped with a pressure transducer connected to a datalogger and GSM/GPRS telemetry facilities for (near) real-time data communication.

It is noted that IGAD HYCOS will not repair the cableway facilities and that conducting flow measurements at the site remains a challenge.

It is recommended that the project will 1) put in place a simple tag line with a pulley using the existing cableway support posts, 2) investigate how to use the upstream bridge for flood flow measurements, and 3) consider introducing satellite data communication to reduce possible communication down-time and improve the reliability of real-time data transfer.

### 3. Ruvyironza at Muyange (date of visit 20 Aug 2014)

General Station Information

| | |
|---|---|
| Station Code | 11040 |
| Purpose of Station | Water level and discharge monitoring |
| Latitude | 29.8483 |
| Longitude | -3.5125 |
| Period of Record | 1985 - 2014 |
| Equipped with | Staff gauges |
| Observer present | Yes |
| Status | Operational |
| Distance to IGEBU Office | ~25 km |

Site: General Map

Google Earth image is not available for this specific location because of cloud cover.

Site Description

The station is located at the road-bridge just downstream of the Waga-Ruvyironza confluence. While streamlines are straight both up- and downstream of the control section, the remnants of an old steel bridge obstruct flow at the control section. Discharge measurement at this site is therefore not accurate, and the rating curve will be unstable.

An alternative is to construct a cableway just upstream of the bridge. Flow is restricted to a single channel but both riverbanks will inundate during peak flows.

Station accessibility is adequate and the site can be reached with a normal car. The GoB owns the land on which the station is located. Mobile phone coverage (LEO provider) is available. There is no access to the public power network. However, security in the area is poor and vandalism is a real concern with regard to solar panels and batteries. Consequently IGEBU staff advised against installing a solar panel or other visible electronic equipment.

Station Photos

**Staff gauges at Ruvyironza - Muyanga**

**Remnants of the old steel bridge obstructing river flow at the control section**

**Ruvyironza downstream of control section**

**Ruvyironza upstream of the control section**

Existing Instruments and Equipment

Ruvyironza at Muyange is equipped with staff gauges. Flow measurements have been conducted with a propeller-type current meter from the bridge but the rating curve at this section is not stable because of the remnants of the old steel bride (see picture above). IGAD HYCOS has earmarked this station for upgrading. The station will be equipped with a pressure transducer connected to a datalogger and GCM/GPRS telemetry facilities for (near) real-time data communication.

Status Report and Comments

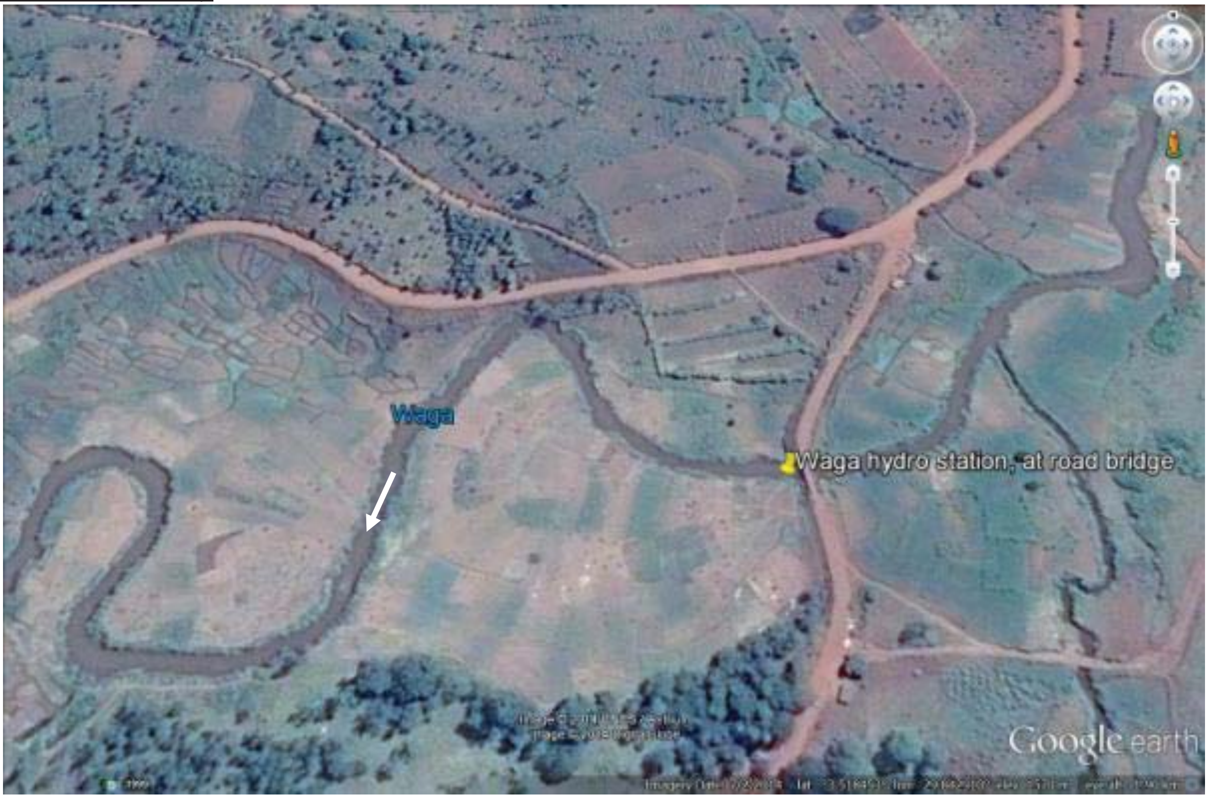
The rating curve is not stable because flow is obstructed at the control section. However, with the introduction of the ADCP, it is easy to move the control section either up- or downstream to a stable location. The river is narrow, and the ADCP can be operated from both river banks using ropes. It is noted that security is an issue at this site.

**4. Waga at Muyange road bridge (date of visit 20 Aug 2014)**

General Station Information

| | |
|---|---|
| Station Code | 11041 |
| Purpose of Station | Water level and discharge monitoring |
| Latitude | 29.8414 |
| Longitude | -3.520 |
| Period of Record | |
| Equipped with | Staff gauges |
| Observer present | Yes |
| Status | Operational |
| Distance to Head Office | ~25 km |

Site: General Map




Site Description
Waga at Muyange road bridge is a small tributary of the Ruvyironza. Flow at the control section at the bridge is obstructed by the remnants of the former bridge. Peak flow inundates the flood plain but will not submerge Waga road bridge. Streamlines are straight both up- and downstream of the bridge. There are no signs of erosion or sediment deposition.

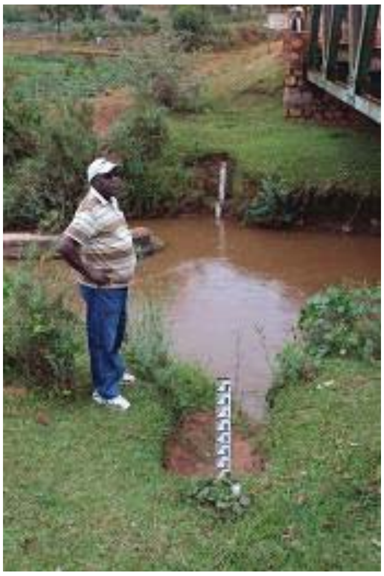
Security is a real concern and IGEBU staff advised against installing electronic equipment (such as a solar panel) at this site.

Station Photos


**Downstream river**


**Upstream river**


**Waga: maximum flood level**


**Staff gauges at Waga road bridge**

Existing Instruments and Equipment
Waga hydro-station is equipped with staff gauges. There are no cableway facilities. Flow is measured with a propeller-type current meter from the bridge. However, because of obstacles (former bridge pylon) in the upstream river reach, turbulent flow will occur during floods and the rating curve is consequently not stable.

Status Report and Comments
Waga is a relatively small tributary of the Ruvyironza. The rating curve at the control section is not stable because river flow is obstructed by the old bridge head. However, with the introduction of the ADCP, it is easy to move the control section either up- or downstream to a stable location. The river is narrow, and the ADCP can be operated from both river banks using ropes. It is noted that security is an issue at this site.

### 5. Ruvyironza at Nyabiraba (date of visit 20 Aug 2014)

General Station Information

| | |
|---|---|
| Station Code | 11043 |
| Purpose of Station | Water level and discharge monitoring |

| | |
|---|---|
| Latitude | 29.9106 |
| Longitude | -3.5244 |
| Period of Record | 1988 – 2014 |
| Equipped with | Staff gauges |
| Observer present | Yes |
| Status | Operational |
| Distance to IGEBU Office | ~25 km |

Site: General Map


Site Description

Nyabiraba station is located a few meters upstream of the new bridge crossing Ruvyironza river. Streamlines are straight both up- and downstream of the control section but the site is used for sand mining (see picture below) and the rating curve at this section is therefore not stable.

Station Photos

**Control section**

**Sand mining at old bridge: no stable rating curve**

**Upstream river**

**Downstream river**

Existing Instruments and Equipment

Nyabiraba station is equipped with staff gauges. Discharge is measured from the new bridge with a propeller-type current meter.

Status Report and Comments

Because the rating curve is not stable at the control section (because of sand mining), it is advised to move the control section either up- or downstream. The river is narrow, and the ADCP can be operated from both river banks using ropes. It is noted that security is an issue at this site.

Since security is adequate, the station can be equipped with automatic level measuring equipment (such as a radar sensor on the bridge) connected to GSM/GPRS telemetry facilities for (near) real time data transmission.

### 6. Ruvubu at Muyinga (date of visit 21 Aug 2014)

General Station Information

| | |
|---|---|
| Station Code | 11031 |
| Purpose of Station | Water level and discharge monitoring; key station for Nile water accounting (since it measures the total outflow of the Nile Basin in Burundi) |
| Latitude | 30.4729 |
| Longitude | -2.9844 |
| Period of Record | 1974 – 2014 |
| Equipped with | Staff gauges; the supports of a former cableway are present and in good condition (cables and winch are absent) |

| | |
|---|---|
| Observer present | Yes |
| Status | Operational |
| Distance to IGEBU Office | ~150 km (estimate) |

Site: General Map


Site Description

The control section is stable without visible signs of scour or deposition. The river is surrounded by wetlands on both riverbanks. Flow is restricted to a single wide channel and streamlines are straight both up- and downstream of the control section. There is no high turbulence. Overbank flow will not occur during flood events although a wide wetland area downstream of the road bridge will inundate (see image above). The rating curve is fairly stable.

Station Photos

**Ruvubu – upstream Muyinga road bridge**

**Ruvubu – downstream Muyinga road bridge**

**Muyinga road bridge: narrow, and no railing to support flow measurement**

**Support post of former cableway installation**

<u>Existing Instruments and Equipment</u>

Ruvubu at Muyinga station is equipped with staff gauges. Flow is measured with a propeller-type current meter from the road bridge. However, this setup is unsafe and unpractical because of the absence of a railing on the bridge (see picture above). Furthermore, the bridge is narrow and the safety of the operators is compromised during the measurement. This applies equally to ADCP measurement from the bridge.

However, the support posts (HE profile) of the former cableway installation – installed by HYDROMET – are still present and in good condition on both river banks. It could be considered to reinstall the cable way (simple tag line with pulley) at this site, in combination with a low berm to provide easy access to the installation.

IGAD HYCOS has earmarked Ruvubu at Muyinga for upgrading. This project will provide automatic water level monitoring equipment and an ADCP. However, it will not improve the facilities for flow measurement.

Given the importance of the station for transboundary monitoring, it could be considered introducing satellite data communication to reduce possible communication down-time and improve the reliability of real-time data transfer.

Status Report and Comments

Ruvubu at Muyinga Road Bridge is a key hydrometric station in Burundi. IGAD HYCOS has undertaken to provide modern hydrometric equipment for this station, but will not improve infrastructure (e.g. cableway) for discharge measurement.

### 7. Synoptic Station at Muriza (date of visit 21 Aug 2014)

General Station Information

| | |
|---|---|
| Station Code | 7500 |
| Purpose of Station | Monitoring of climatic parameters; synoptic climate station |
| Latitude | 30.083 |
| Longitude | -3.533 |
| Period of Record | |
| Equipped with | Typical instrumentation for a classic synoptic weather station |
| Observer present | Yes |
| Status | Operational |
| Distance to IGEBU Office | ~100 km (estimate) |

Site Description

The climate station is located near the government offices at Muriza in the center of town. The station is in good condition with adequate security. The classic meteorological equipment is in reasonable condition and functions well. Data are transferred to IGEBU by mobile telephone, while the complete paper record sheet is filed on a monthly basis. Manual recordings are digitized at IGEBU and stored in the general database (in MS Access).

Station Photos

**Muriza Met Station**

**Unipod: Muriza Station Office**

Status Report and Comments

The classic instrumentation is in need of general maintenance. It can be considered to equip the station with an AWS and telemetry facilities for (near) real-time data communication.

### 8. Synoptic Station at Cankuzo (date of visit 21 Aug 2014)

General Station Information

| | |
|---|---|
| Station Code | 2950 |
| Purpose of Station | Monitoring of climatic parameters; synoptic climate station |
| Latitude | 30.383 |

| | |
|---|---|
| Longitude | -3.283 |
| Period of Record | |
| Equipped with | Typical instrumentation for a classic synoptic weather station complemented with an Automatic Weather Station (AWS) with sensors for T, RH, rainfall, incoming solar radiation, wind speed & direction at 2 m |
| Observer present | Yes |
| Status | Operational |
| Distance to IGEBU Office | ~125 km (estimate) |

Site Description

The climate station is in good condition with adequate security. The classic meteorological equipment is in reasonable condition and functions well. Data are transferred to IGEBU by mobile telephone, while the complete paper record sheet is filed on a monthly basis. Manual recordings are digitized at IGEBU and stored in the general database (in MS Access).

Recently, a Sutron AWS has been added with sensors for incoming solar radiation (short and long wave), wind speed and direction at 2 m, relative humidity, temperature, and a tipping bucket rain-gage. The Sutron datalogger includes a data display and uses standard memory cards for data transfer. The setup is easy to use and functions well.

Station Photos

**Cankuzo Met Station**

**Classic Sunshine Recorder**

Status Report and Comments

The AWS functions well. It can be considered to equip the station with telemetry facilities for (near) real-time data communication. The classic instrumentation is in need of general maintenance.

**Annex A.1-2: Terms of Reference for Consultancy for Developing Hydro-meteorological Capacity etc.**

REPUBLIC OF BURUNDI
MINISTRY OF WATER, THE ENVIRONMENT, SPATIAL PLANNING AND URBANISM (MEEATU)
PROJECT OF ENVIRONMENTAL MANAGEMENT OF THE BASIN OF THE LAKE VICTORIA, PHASE 2 (LVEMP II)
PROJECT No : P 118316
GIFT AID No.: H 710-BI

**TERMS OF REFERENCE FOR THE RECRUITMENT OF A CONSULTANT RESPONSIBLE FOR DEVELOP A PAPER CAPACITY IN HYDRO-METEOROLOGICAL AND AGRO-METEOROLOGY INSTITUTE GEOGRAPHIC OF BURUNDI (IGEBU)**

**1. Context of the LVEMP II Project and the Study**

The Government of the Republic of Burundi has received a donation of the International Association for development (AID) for the implementation of the second phase of the project's environmental management of Lake Victoria (LVEMP II). The Government of the Republic of Burundi intends to use a portion of this donation to retain an individual consultant for the preparation of a plan to improve the national hydromet and agromet networks.

This second phase of the environmental management project of Lake Victoria will develop the vision of the African community's (CAE) for the development of the Lake Victoria Basin (LVB) having "*prosperous people living in a managed environment healthy and sustainable manner offering opportunities and equitable benefits*". The overall project objectives are to contribute to: (i) improving the collaborative management of national and regional water resources, and; (ii) reduce environmental stress in the places most affected by water pollution and degraded watersheds and to substantially improve the standard of living of the communities that depend on natural basin of Lake Victoria resources.
The contribution of the LVEMP II to the above-mentioned objectives will be accomplished, through (i) the development of institutional capacities and the harmonization of policies, legislation and the regulatory frameworks; (ii) the control and prevention of pollution sources; (iii) the management of watersheds and; (iv) coordination and management of the project. The project will be implemented in 4 provinces namely: MWARO, GITEGA, KARUZI, KIRUNDO, over a 6 year period divided into 3 phases of two years.

The project will be implemented through a 3 tier structure. At the regional level, policy guidelines will be provided by the Regional Steering Committee. At the national level, the implementation of the project will be guided by the National Steering Committee, the technical National Advisory Committee, the Focal Point Ministry and the National Coordination of project team. At the local level, execution will be overseen by the municipal coordination teams in the municipalities involved in the project. The implementation of the various activities of the project at the local level will involve a group of agencies and partners, including local government entities, NGOs, community-based organizations (OCB), universities, research institutions and private sector agencies. Memoranda of understanding or other contractual arrangements will be made between the Focal Point Ministry, through the national team of Project Coordination and implementation institutions/partners.

Lake Victoria, covering a surface of about 68,800 $km^2$, is the second largest fresh water resources in the world. The Lake Victoria Drainage Basin (BLV), with an area of 194,000 $km^2$, is shared by five countries: Burundi (7%), Kenya (22%), Rwanda (11%), Tanzania (44%), and Uganda (16%). Lake Victoria is a transboundary water resource shared by the Kenya, Tanzania and Uganda, while Rwanda and

Burundi share the headwaters of the watershed that feeds Lake Victoria via River Kagera. The Lake is also part of the system of the Nile basin shared by eleven countries: Burundi, the Democratic Republic of the Congo, Egypt, Ethiopia, Eritrea, the Kenya, Rwanda, Sudan, South Sudan, Tanzania and Uganda. The population of the BLV is approximately 35 million people and represents about 30% of the total population of the Member States of the African community's (EAC). EAC countries are Burundi, Rwanda, Tanzania, Uganda, and Kenya.

In Burundi, the national hydrological and meteorological observation networks are managed by the IGEBU through the Department of Hydrometeorology and the Agro-meteorology.

**2. Study Area**

The area of interest for this study coincides with the LVEMPII project area consisting of the Provinces of Mwaro, Gitega, Karuzi and Kirundo.

**3. Goal and Objectives**

The goal of the consultancy is to develop a plan for advancing national hydromet and agromet services through the development of infrastructure and institutional capacity. In particular, the rehabilitation and well-planned expansion of observation systems to better serve the people of Burundi coupled with development of institutional capacity to manage and utilize such systems is of prime importance.

**4. Duties of Consultant**

The Consultant will perform the following activities and document the results of these activities in inception, interim, and final reports.

***Task 1: Hydromet Stakeholder Analysis***

Acquire, document, and evaluate the requirements of users and stakeholders of hydromet and agromet information including the data and value added products required (consumer side analysis). Facilitate stakeholder workshop to document opinions.

Recommend additional data and products (e.g. related to forecasting of weather, hydrologic or floods/droughts) required by the users and stakeholders of hydromet and agromet systems.

***Task 2: Hydromet Monitoring Network Analysis***

Acquire, document, and evaluate the inventory of all hydromet and agromet stations/manual monitoring locations indicating operational readiness and problems that need to be addressed on a station-by-station basis.

Recommend hydromet and agromet stations for rehabilitation or expansion (incl. real-time telemetry). This recommendation will include precise latitude and longitude of each station as agreed to with Department personnel.

Propose a plan of rehabilitation, modernization and expansion of the hydromet and agromet network for the country considering both in-situ and remote observations systems. This plan will include station locations, costs, and implementation schedule. Also propose ways of upgrading manual monitoring to make it more real-time through use of cellphone networks.

***Task 3: IGEBU Institutional Support***

Acquire organizational setup (organogram) of the Department of Hydrometeorology and Agro-meteorology of the IGEBU.

Evaluate the organizational setup of the Department of Hydrometeorology and Agrometeorology noting gaps and a recommendation for strengthening the institution.

Facilitate brainstorming workshop in IGEBU and perform interviews of staff in place in order to determine opportunities for training and/or capacity strengthening.

Facilitate consideration of improved partnerships with regional and global climate data providers (including regional climate centers, earth observation data providers, etc.) as well as internal partnerships (e.g. with the National Geospatial Center) for the future.

Propose augmentation of the skill-base and technical capacity of IGEBU and outline TORs for key staff/consultants needed. This is expected to include a Consulting Firm to help undertake detailed designs of an enhanced hydromet system for Burundi.

Propose a training plan of the technical and professional staff of the Department of Hydrometeorology and Agrometeorology based on the evaluation of gaps determined earlier in the study.
Conceptualize the creation of an Operational Control Room for accessing real-time (e.g. satellite) hydromet data.

This is expected to help meet the needs of users of the products of the Department of Hydrometeorology and Agrometeorology.

**5. Deliverables**
The following reports will be provided by the Consultant:

- An inception report 15 calendar days after the signing of the contract containing a detailed work plan and clarifying the methodology to be used and listing available documentation that the Consultant has acquired. List immediate support or facilitation required for improving the facilitation of the Consultancy from IGEBU or the LVEMP team. The report will be presented to the national project coordinating team (ENCP) and the team of experts for exchanges, comments and approval.

- An interim report will be provided 45 calendar days after the signing of the contract. The interim report will be presented to the ENCP and a team of experts for discussion and comment.

- The final report will be due 60 calendar days after the signing of the contract. This will consist of, but not be limited to the following:
  - The State of the network in hydrological, meteorological and agrometeorological stations
  - The hydro-meteorological and agrometeorological stations equipment needs,
  - To rehabilitate existing stations and or to modernize,
  - New stations to be installed to meet the standards of the international best practices and the WMO,
  - Software and modern tools for processing and presentation of meteorological and agrometeorological information,
  - An assessment of the capabilities of the Department staff
  - A plan of training of the staff of the Department
  - An evaluation and a proposal of the system of collection, analysis and dissemination of information,

- The design of equipment and related infrastructure to put in place (new and rehabilitate).
- Stakeholder interaction documentation

**6. Qualifications of Consultant**

The Consultant shall meet or exceed the following qualifications:

- Have at least a Masters university degree in meteorology, hydrology, water resources or other related field,
- Have at least 10 years of work experience in the field of meteorology or hydrology,
- Have worked on at least two similar activities with proof/ certificates or other documents evidencing good performance,
- Have some relevant experience working with regional climate institutions in Africa,
- Have knowledge of the principles and procedures of WMO would be an advantage,
- Speak and write fluently French essential. Ability to also speak in English would be an added advantage.

**7. Reporting**

The consultant will report to the Coordinator National of LVEMP II project who will be responsible for the approval of the results.

**8. Duration**

The duration of the consultancy is 60 calendar days spread over a 4 month period.

## Appendix A.2: National Consultation and Field Visit Report for DR Congo

**The Core Team**

The mission has been organized and conducted by the Water Resources Management Department of the NILE SEC, NBI. Nationally, principal resource persons of the Directorate of Water Resources facilitated, coordinated, administered, and participated in all the meetings and field visits.

- Eng. MULWA GASUGA Bienvenu (Directorate of Water Resources, Kinshasa, DRC)
- Mr. MANTEKE KABAY Jean (Directorate of Water Resources, Kinshasa, DRC)
- Mr. BOPE BOPE Jean Marie (Directorate of Water Resources, Kinshasa, DRC)
- Dr. Mohsen Alarabawy (Nile Secretariat, Entebbe, Uganda)

**Background and Introduction**

As part of national consultations led by the Nile Basin Secretariat (NILESEC) in all riparian countries to finalize the Nile-Hydromet system conceptual design, a mission in Democratic Republic of Congo (DRC) was carried out from 13 to 16 October 2014. The visit enabled NBI to work closely and hence finalize the hydromet gap analysis and needs assessment with the country team at the Water Resources Department of the Ministry of Environment, Nature Conservation and Tourism (MECNT).

The main objective of the mission was to consult relevant stakeholders and DRC institutions dealing with the issues influencing or related to the Nile Basin Regional Hydromet design. Exploring viable options and possible means to adopt an approach in order to harmonize the technologies, mode of transmission and data processing, identify the needs for capacity building and strategically align the national hydromet services to be integrated within the regional context; this would certainly contribute to a better hydro meteorological monitoring of the Nile River part within the DR Congo.

**Consultation Meetings and Site Visits**

Visits were made to the key players involved in the DRC hydrological and meteorological services, all offices are mainly based in Kinshasa, as described by the following table:

| Person interested | Institution | Title | Summary of discussions |
|---|---|---|---|
| National Team | Water Resources Directorate | Water Resources Engineers | Agreement on the scope and desirable outcomes and planning for representative site visits as well as appointments with the institutions and focal personnel to meet. |
| Mrs. MARIE-ROSE MUKONKOLE MAYELE | Head of Control and Surveillance Division, Water Resources Directorate | TAC MEMBER DRC, NILE BASIN INITIATIVE | Orientation, information exchange, and explanation of the mission methodology and primary objectives. Agreement on the overall process and outputs. |
| Mr. KASULU SEYA Vincent | Secretariat for the Environment, Ministry of Environment (MECNT) | Permanant Secretary (PS) | Presentation of the Nile-Hydromet assignment and the purpose of the visit. Awareness and appreciation of the program by the PS, and team orientation to the Sustainable Development Directorate where a similar project on hydrological monitoring to be implemented with funding from the World Bank (WB). |

| Person interested | Institution | Title | Summary of discussions |
|---|---|---|---|
| Mr. TOHIRAMBE Benjamin | Sustainable Development Department (SDD), MECNT | Director | Satisfaction of associating the SDD in the Nile-Hydromet process from the conceptual phase.<br>This merger will integrate all aspects of biodiversity, climate change and resilience of species in the process.<br>Exchange of all working documents between WRD and SDD was agreed. |
| Mr. MOKANGO | Waterways Authority (RVF) | Technical Director | RVF is mainly focused in the navigable reaches of the Congo River and has no stations in the Congolese side of the Nile. The measurements are levied by water depths for navigation purposes, but also began to integrate the flow measurements at selected locations. |
| Mr. NYEMBO Jean Paul | Water Resources Department, MECNT | Director | Initial and final meetings were held for informing and securing support of the decision maker to essentially achieve the mission primary goals. |
| Mrs. MALANDA Marie Pascale | Ministry of Environment, Nature Conservation and Tourism (MECNT) | Advisor of the Minister in charge of water and renewable energy | Presentation of the Nile-Hydromet SYSTEM and its contribution in the WRMD and socio-economic growth. Being particularly interested in the hydromet equipment, the top official took part in the field trips. |
| Mr. WAKU John | National Agency for Meteorology and Remote Sensing by Satellite (METTELSAT) | Technical Director (ADT) | The METTELSAT deals mainly with meteorological observations; although also mandated to undertake hydrological monitoring. The latter does not occur due to lack of financial and technical resources.<br>With SADC HYCOS, the METTALSAT acquired 09 automated telemetry stations for the Congo Basin but not installed since acquisition (2010) due to lack of funds and resources. |
| Hydro-meteorological stations Visit | Users Association of *River Lukaya sub basin* | Experts, Users, Academics, officials, and | The IWRM-Lukaya is a pilot project in DRC coordinated by UNEP. The project installs and operates both hydrological and meteorological |

| Person interested | Institution | Title | Summary of discussions |
|---|---|---|---|
| | | decision makers | stations. Linkages and correlation have been mutually discussed. |
| Eng. Bienvenu MULWA<br>Mr. Jean MANTEKE and Mr. BOPE Jean Marie | Water Resources Department, MECNT | National Thematic Experts | Discussions and consolidation of findings and agreement on the proposed hydromet locations with sufficient justification. Mission reporting and documentation. |

**History and Situation Analysis**

- History and background of the Ministry of the Environment
- Specifications of representative equipments and sites visited

<u>History of the Ministry of Environment, Nature Conservation and Tourism</u>

The Ministry of Environment, Nature Conservation and Tourism was established in July 1975 by Presidential Order No. 75-231 and its powers strengthened by Presidential Order No. 07/018 of 16 May 2007, in which the tasks and powers of the Ministry are specified, namely:

- Water Resources Management
- Forest management
- Nature conservation and Tourism Promotion
- Environment protection (by applying environmental impact assessment)

At this stage, with the public administration reform, the Department is composed of a General Secretariat and twelve Directorates, including the *Directorate of Water Resources*.

**The Water Resources Directorate**

This department has full responsibility for the management of water resources, mainly through:

- Knowledge on the quality and quantity of water
- Management of the marine and aquatic biodiversity
- Data storage (DB) and statistics

This department contains four divisions which are:

1. Division of Conservation and Protection of Aquatics Ecosystems

This division undertakes:

- Inventory and protection of water resources
- Control and understanding of aquatic ecosystems

2. Division of Transboundary Management

This division is responsible for:

- Monitoring of cooperation and international agreements
- Studies of the common measures of performance
- Management and protection of transboundary aquatic ecosystems

3. Division of Regulation, Control and Monitoring of Aquatic Ecosystems

This division is responsible for:

- Control of aquatic ecosystems
- Control and Pollution Prevention
- Monitoring of aquatic ecosystems

4. Division of Implementation of Water Resources Management Unities for Basins and Sub-basins

This division is responsible for:

- Data management and statistics
- Project planning, monitoring and implementation of hydro-meteorological Basins projects
- Management of the International Hydrological Programme (IHP)
- Mycological Education

Moreover, this division is also responsible for all hydrology and hydrological studies.

All these divisions are composed of different offices and affiliates that are managed by office managers, experts and implementers. The director supervises and coordinates activities and tasks.

Characteristics of Equipments (representative technology)

1. *Meteorological Service (METTELSAT)*

During the last decade, the quality of equipment of meteorological observation stations that cover the DRC's network has suffered a dramatic decline; furthermore, the number of functional stations significantly reduced from 342 in 1960 to 25 at the present time.

Currently in the Congolese side of the Nile Basin, the weather service does not have any observation stations. In Kinshasa, at the METTELSAT Headquarters, a combination of technologies is found with a range from *classical* to *automatic* stations (SIMEL Electronics).

Technology Used

The service receives data via satellite through a satellite dish EMESAT 0.8 which transmits recordings to Data Storage, Treatment and Analysis Center equipped with computers for different areas of interest; e.g. environment, agriculture, land use, etc.

The data are received by the Centre via two prime systems:

- A satellite system by antenna and website EMESAT CDM
- Manual cable connected directly to the equipment system

The software used for data processing and management is CLIMSOFT and EXCEL. METTELSAT Headquarters has received 09_hydrological stations through the SADC HYCOS Project which were originally planned to be installed on the Congo River basin since 2010. The stations have not yet been installed because of funds' limitations and shortage of basic pre-requisites.

2. *IWRM Project Lukaya / UNEP*

A Pilot Project for Integrated Water Resources Management implementation establishes by the United Nations Environmental Program (UNEP) has installed stations in the sub-basins of *Lukaya River*. During the field trip, the sites included the automatic weather station, river gauging station installed in the downstream reach - near Kinshasa - inside the Water Supply Plant of drinking water (REGIDESO). Established since April 2014, SEBA brand equipment is working properly. Involving users in collecting observations and interpreting records and developing trends and knowledge is practiced since the beginning of the project. Local associations are trained to run the hydromet stations.

3. *Waterways Authority ( RVF )*

In the past the RVF service had several gauging stations, but currently there are only *two monitoring stations in the Congolese side of the Nile Basin*. Both stations are installed at the entrance and exit of

Lake Edward. These units are used for measurement of water levels (stages). RVF deals primarily with waterways. The equipment found on site during the visit is outdated and not fully functional.

The functioning – one unit - ADCP is used jointly by the DRC and Congo-Brazzaville for discharge measurements of the Congo River, mostly on the Malebo pool.

The water level recorder that works lacks graph paper and provides no information, accordingly.
RVF expected funding from the World Bank and the European Union for the installation of 42 gauge stations on the waterways of the *Congo Basin* under the WB funded HYDROMET project.

Main Findings and Conclusions
The part of Nile Basin in DRC covers about 88000 $km^2$ from upstream (Rutshuru River) to downstream (Lake Albert). Lake Albert is connected to Lake Edward by Semuliki River for a distance of 250 km along the East African Rift valley; very few information are available on the hydrology of the Semuliki River. The Semuliki river basin covers about 26632 $km^2$ and contained several falls or rapids along its flows; with many tributaries such as Bumama, Bunyanwe, Molowe and Munda. Munda is the most important tributary where minimum and maximum discharges of 90 $m^3/s$ and 147 $m^3/s$ were recorded.

Nile Basin within DRC:
No hydromet stations exist, IGAD HYCOS program focuses only on the Congo Basin. Information on the Nile Regime within DRC is therefore scarce. The present NBI system design will lay down the basis for the River Nile monitoring within DRC.

*Additional Stations:*
Based on transboundary significance, information needs and complementarity with relevant programmes, DRC requests the following stations to be taken into account for the regional Nile Basin "HYDROMET" Monitoring system design:

A. Hydrometric:
1. Ishango (Both); for potential hydropower production downstream of Lake Edward
2. Vitshumbi (Both)
3. Kasenyi (Both)
4. Mahagi port (Both; existing station needs rehabilitation)
5. Burasi

B. Meteorological:
1. Rutshuru (existing, to be rehabilitated)
2. Rumangabo
3. Bogoro (on the mountain near Lake Albert)
4. Ugongo
5. Vitshumbi (Semliki River between – linking - Lakes Edward and Albert)

("Both" means the proposed location is for both hydrological and meteorological observations.)

**Water Quality:**
Water quality monitoring within the entire DRC is lacking. No competencies could be identified. Major attention is therefore required for the water quality assessment. The needs expressed are:

a. Water quality laboratory; with capacity building and standard operational procedures
b. Proposed locations for water quality sampling:
    a. Ishango (along Lake Edward, at outlet)
    b. Mahagi port (along Lake Albert, at inlet)
    c. Kasenyi (along Lake Albert)

**Civil Society Engagement:**
Under the on-going UNEP Flood Protection Project, both hydrometric and meteorologic stations are installed in areas where flood warning and flood preparedness are paramount. Awareness and outreach activities are carried out and training of local Associations on operating and maintaining the installed stations takes place. The operational stations are handed over for the associations to run and collect data. Information is shared with pertinent authorities and trouble shooting in case of malfunctioning is provided by the supplier firms (instrument vendors).

This model can be considered when the institutional setup for the HYDROMET system within DRC is being developed. Supervised, assisted, and backed by the public agencies (Ministry of Environment and other relevant entities), Civil Society Associations can take significant part in operation and maintenance of the proposed network of hydromet stations in the Nile catchment within DRC.

In conclusion, the part of the Nile River within Congo is severely under-gauged and therefore little is known on hydrology and climatology. This calls for due emphasis on the locations of transboundary significance during the design of the Nile Basin Regional Hydromet System. DRC expects some solid recommendations for the national hydromet system, especially with respect to consistent technologies and compatible systems, including data management and reporting.

# Appendix A.3: National Consultation and Field Visit Report for Ethiopia

## 1. Introduction and Background

In May 2014, the Nile Basin Initiative (NBI) contracted with Riverside Technology to develop design specifications and an implementation plan for the Nile Basin Regional Hydro-meteorological Monitoring System (this Assignment). The assignment aims to enhance Nile River basin monitoring. It will address coverage, equipment, techniques, data acquisition and dissemination, sampling and testing, standard procedures, capacity development, cost estimates, and implementation planning.

As part of this assignment, field visits and national consultations have been organized in each project country, with the aim to appreciate the potential value, benefits, and need for the regional water resource monitoring system, acquire a deeper appreciation of the current state of the monitoring technologies and practices, and to understand the institutional context within which the designed system will be operated. The consultations will also identify needs for technical support, capacity building, and institutional strengthening. The defined objectives include the following:

- Confirm understanding of current network and practices based on the country assessment report and metadata, as well as past studies. Supplement information and metadata based on discussions.
- Identify country protocols for data communication, storage, formatting, dissemination, sharing, and use. Identify and discuss what data could be used in a regional network and how it could be delivered.
- Confirm the important socio-economic drivers for data collection and elaborate specific needs for data to inform decisions and development.
- Discuss perceived needs both with regards to data collection and institutional capacity development and how these can relate to the regional monitoring network.
- Conduct field visits at key monitoring locations that adequately represent the current technologies and practices within use. This will include visits to any water quality labs to further assess data sampling, testing, management, and dissemination.

This report acknowledges the country assessment documents prepared previously by staff from the Ethiopian Ministry of Water, Irrigation and Energy and which have been summarized in the inception report for the current study. The following material supplements the country assessment documents.

## 2. Institutional Setting

*Overview of responsible ministries*

- The Hydrology and Water Quality Directorate under the Ministry of Water, Irrigation and Energy (Hydrology) is the Directorate responsible for surface water, groundwater, and water quality monitoring and data processing. Additional activities include flood forecasting and early warning systems, reservoir monitoring and management, and workshop and laboratory activities. Under the Hydrology and Water Quality Directorate nine regional hydrology offices exist. River basin authorities responsible to the ministry are beginning to be established, and will be responsible for hydrological monitoring operations within their areas.
- The National Meteorology Agency (NMA) is the agency responsible for precipitation and meteorological monitoring within Ethiopia. There are a total of 11 NMA Branch Offices located throughout the country.

*Consultations*

Visits were made both to NMA and Hydrology to review operating procedures and gather input on monitoring network needs. An institutional questionnaire was presented and discussed with officials at both Hydrology and NMA, and initial responses were prepared, with subsequent follow up and completion of the questionnaire in consultation with a broader cross-section of stakeholders within the Ministry. The following additional questions were posed regarding modernization of monitoring networks:

1. What is the experience with the likelihood of vandalism at manned conventional stations vs. automatic stations? Is vandalism less at manned conventional stations where there is an observer to offer some degree of security?
2. Would it be worth some additional expense to maintain manned staff at newly installed automatic station to provide the benefits of additional security?
3. How does the initial and ongoing infrastructure/equipment cost differ between conventional stations and automatic stations?
4. How does the initial and ongoing labor cost differ between conventional stations and automatic stations?

The consultant noted that for the regional water resources monitoring network, timeliness and reliability are critical, and that the density of Ethiopia's combined automatic and manual precipitation networks is more than sufficient. Development and investment would need to focus on automating existing manual stations and strengthening or upgrading existing automatic stations.

The 11 NMA offices are independent from (not co-located with) MOWIE hydrology offices, but sometimes NMA hosts hydrology staff at its facilities.

NMA staff explained that if the MOWIE hydrology department will be the single organization that provides data from Ethiopia to NBI, a special policy agreement would be required both for explicit sharing of data between NMA and Hydrology, and for Hydrology to transmit the data to NBI. It would be technically feasible for Hydrology to have a CLIDATA client system to receive data from NMA and then to transmit a subset of that data to the NBI regional center, together with other hydromet data collected by Hydrology.

Although there is a general interest and willingness to collaborate with NBI on data, specific decisions on the commitment that both agencies are in a position to make will depend on the final design and implementation plan, including what support NBI or a future River Basin Commission will be able to provide to facilitate data collection and sharing efforts. For example, will it only include designs like this study and support for tendering and standards? Will it also include a template for a data management system (DMS)? Financial support for equipment, installation, spare parts, training, and operation and maintenance?

Ethiopia's response and commitment to providing data would depend on both policy development and constraints as well as logistical, organizational, and financial constraints that would need to be balanced with support from the region and benefits to national data collection and management needs.

*Hydrology*

Hydrology staff reported that shaft encoders have not been preferred in Ethiopia because the connection tubes regularly become clogged with sediment and are difficult to maintain. The current preference is for radar sensors and pressure sensors to measure water level.

The current data management software in use by Hydrology is the HYDATA software (a 2001 version, perhaps, from the Institute of Hydrology in Wallingford, UK). The system stores daily and monthly data in an MS Access database, but only conventional hydrologic data (water level, and flow) are stored and there is no GIS integration. Updates and upgrades for the software have not been provided and a need exits for software that can handle more volume and different types of data and integrate with a GIS.

For its basin information system the Tana-Beles region is using QUASHI, a free data management system from the U.S. that also stores data in MS Access.

MODFLOW is used for regional groundwater modeling, in connection with manual observation sites, mostly in the Rift Valley. The hydrology department took over the gauges as primary monitoring sites after the groundwater directorate completed an assessment with them. Several of the of the sites, however, were not maintained and the boreholes have been clogged with debris and are not functional.

Training – hydrometric technicians are retiring and there are not qualified people to replace them. Ethiopia is considering a program to train and then hire a large group of new people. There are also discussions about establishing ongoing training programs (train the trainers) in collaboration with Universities.

Discussions with field staff during site visits confirmed limited resources for network operation. The hydrologic technician for the Debre Markos branch office, for example, has one assistant and is responsible for operation and maintenance of 39 river gauging stations. The stream gauging equipment is kept at the branch office, and the technician makes a round to the gauges approximately once every quarter. It takes 15 days to simply make the rounds and collect the log books. If maintenance and discharge measurements are required, it may take 30 days. He reported that a major obstacle in fulfilling his job is the lack of skilled manpower, especially on automation and telemetry systems.

The national central Water Laboratory at Addis Ababa reports having only some basic equipment and lacks vital equipment such UV-Vis, AAS and GLC.  This compromises the ability of the laboratory to meet its national and regional data management needs. It is also noted, however, that in addition to the central laboratory in Addis Ababa, there are five regional laboratories, which can undertake limited analysis. These are at Gambella, Tigray, Benshangul-Gumuz, and Amhara. The laboratories are able to undertake basic physico-chemical and microbiological analysis, and they collaborate with the central laboratory in Addis Ababa. MOWIE plans to standardize lab procedures to be harmonized and coordinated. The Ethiopian Standards Agency is also in process of adopting ISO standards.

Regional Water Quality Bureaus are supported by water quality services offered by Water Works Enterprise, which serves private customers. The associated water quality laboratory was originally established by MOWIE.

Microsoft Excel is used as a database for both sediment and water quality data.

MOWIE reports that there are unique water quality monitoring sites that do not coincide with Hydromet sites. Samples are taken by the regional WQ staff, in collaboration with national WQ staff.

*NMA*

While NMA is beginning to operate a number of automated stations throughout the country, most data are captured at branch offices in MS Excel spreadsheets, which are then sent by e-mail or through a network to NMA headquarters offices. These are loaded by the database administrator into the CLIDATA information management system. Branch offices do not currently run CLIDATA.

Data are not disseminated freely on-line, but can be provided to "users" by request, based on policy guidelines. There is a minor cost recovery charge associated with receiving the data. NMA does not currently have any real-time data sharing agreements, but arrangements could be made.

NMA provides licenses for anyone who operates a MET station in Ethiopia. Copies of the data are to be sent to NMA. The agricultural research institution operates monitoring stations, receives training from NMA, and sends data to NMA every month. These data are also entered into CLIDATA

In its conventional meteorological network, first class stations are maintained by a full-time attendant. Other stations have observers who are responsible to take periodic readings. The challenges noted in operating its network of conventional stations include the following:

- Poor observer reliability (observers are not always consistent in taking measurements, and occasionally fabricate observations
- Insufficient vehicles to travel to stations to provide maintenance
- Insufficient number of observers
- Insufficient spare parts

For several years Ethiopia has been gaining momentum in the implementation of automatic weather stations with GSM/GPRS telemetry. These have been cost effective, but there is a limit to what can be maintained with current resources and technology. The immediate plan is to increase the number from 100 to 200, and this may be increased to an upper limit of 400. The biggest cost is the replacement of parts that wear out quickly, and the biggest operating challenge is the communications. Specific issues have included the following:

- Equipment malfunctions have exceeded the inventory of spare parts for replacement
- The GPRS network service is unreliable;
- Vandalism;
- The batteries do not last long
- Relative humidity and temperature sensors of AWS do not last long.

The World Food Program (WFP) has provided monitoring sensors in the past, and NMA has an agreement with WFP to share data from the sensors provided by WFP.

Training is needed in sensor calibration, maintenance, and inspection. There is a calibration center in Addis, but it has the capacity to calibrate only certain sensors. Some type of mobile calibration lab is appealing, and was, in fact, in a prior proposal made by NMA. These would be especially good for inspection.

*Priorities*

The following list of priorities was determined for the 14 water management issues identified for the water resources monitoring study, based on the consultations and results of the institutional questionnaire:

1. Improved Water Resource Planning and Management
2. Hydropower
3. Watershed Management
4. Soil Erosion and Sediment Transport
5. Flood Management
6. Climate Change
7. Drought Management
8. Rain-fed Agricultural Management
9. Irrigated Agricultural Management
10. Wetlands Management
11. Navigation

12. Fisheries
13. Surface Water Quality
14. Groundwater Management

Field Visits

Site visits were made to the following locations:

- Abbay at Kesse Bridge (30 July 2014);
- Mojo R. At Mojo (31 July 2014);

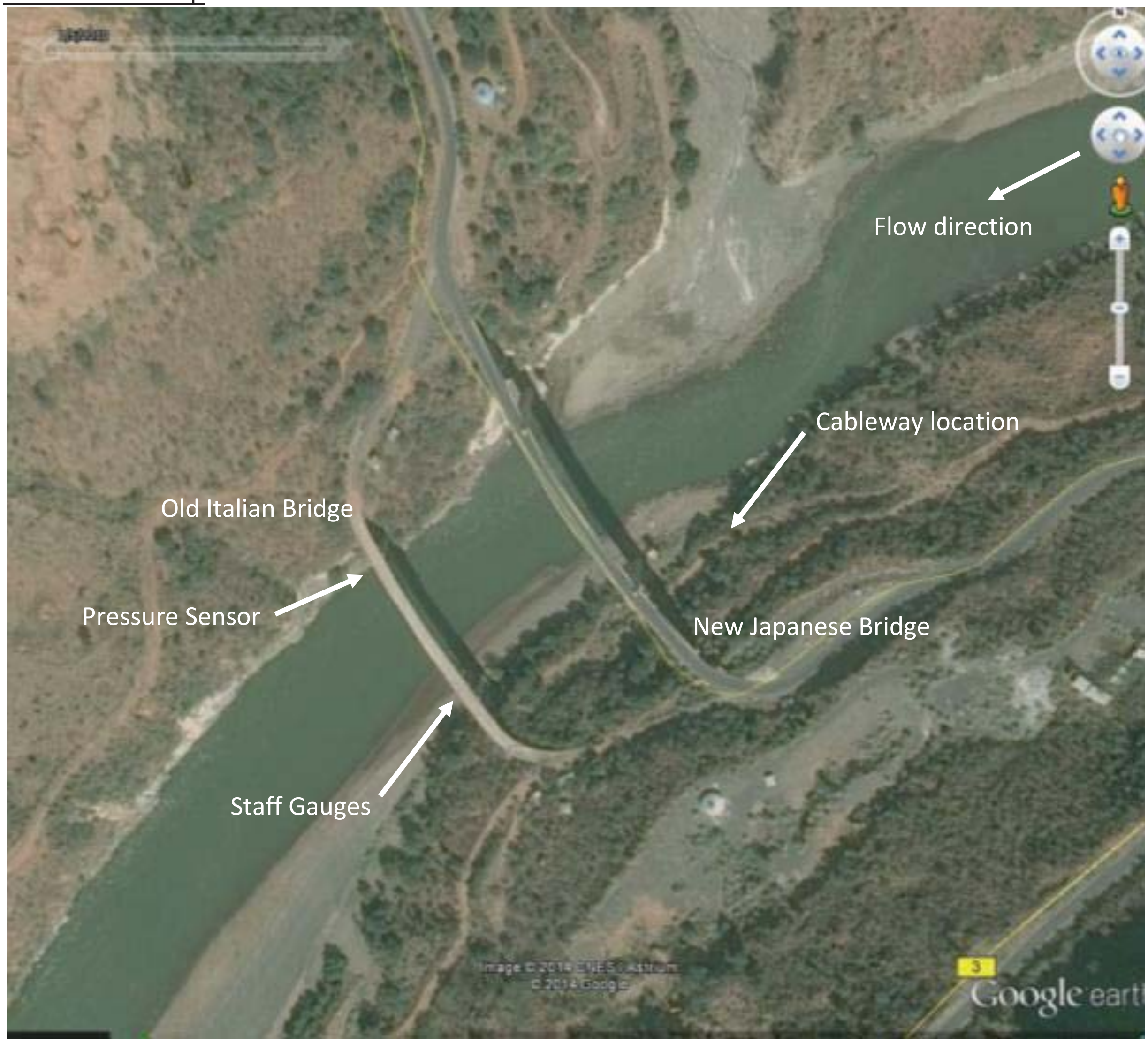
These are described below:

### a. Abbay at Kesse (date of visit 30 July 2014)

General Station Information

| | |
|---|---|
| Station Name | Abbay at Kesse |
| Purpose of Station | Stream monitoring |
| Latitude | |
| Longitude | |
| Period of Record | From USBR, 1960's |
| Equipped with | Staff Gauge, pressure sensor |
| Observer present | Lives in village; visits site 1/day |
| Status | Operational |
| Water Management Zone | Debre-Markos; Oromia/Amhara region |
| Distance to Head Office | 205 Km (4 hours) from Addis; 90 Km (2 hours) to branch office in Debre Markos, Nearest Town is Dejen; paved highway and bridge provides year-round accessibility |

Site: General Map




Site Description

Kesse is the name of the region from long ago, even before the bridge was constructed.

Equipment includes staff gauge and pressure sensor. Staff gauge has an eleven meter range.

Flow measurement is taken at the old (Italian) bridge.

The old bridge was constructed in January 1939 (Ethiopian Calendar).

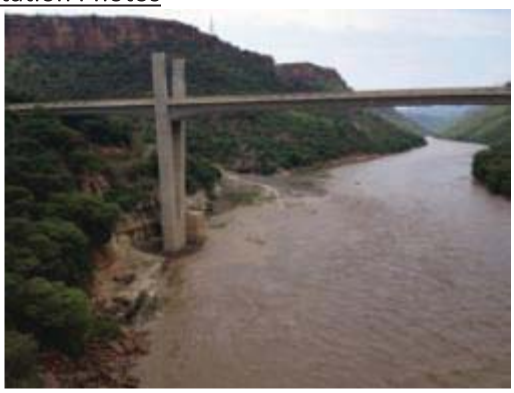
Staff gauge was made on the left side of the bridge, together with a stilling well for a shaft encoder. The stilling well has long since filled with silt. The rock banks near the right bridge abutment provided a place to install the first and second meter section and a pressure transducer whose cable is embedded in concrete and emerges part-way up the bank under the bridge.

A cableway was also installed upstream of the bridge. During the construction of the new (Japanese) bridge, there was damage to the foundation of the cableway that makes it unsafe and requires rehabilitation. Subsequently all discharge measurements have been taken from the old bridge. It is easier to gauge from the cableway – better view of the upstream condition and debris, no obstructions to flow, and the cableway is much closer to the water. It is now very difficult to measure discharge at high flows due to velocity and depth. They have used weights from 75lb to 200lb weight, with the maximum now being a 150 Kg weight for high flow measurements. The current meter and counterweight are attached to a crane which rolls along the bridge to take measurements.

If the observer is not careful, the cable assembly can be entangled in debris, whereupon the bolt that attaches the cable to the hangar will break and all the equipment will be lost.

The river forms the boundary between Oromia (on the left bank) and Amhara (on the right bank).

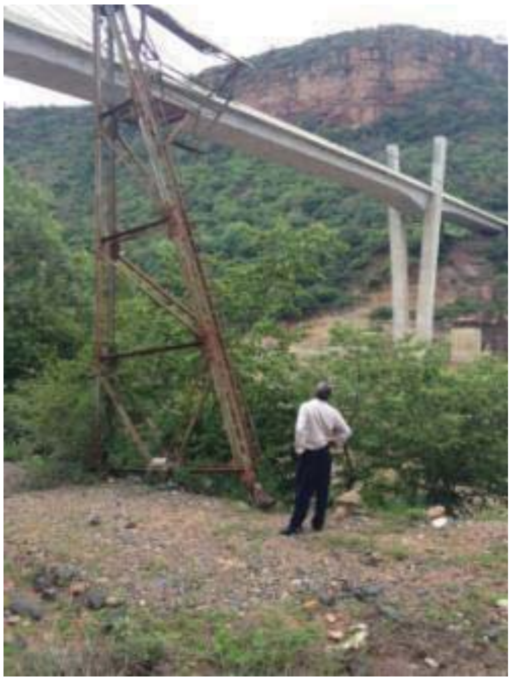
Station Photos



**Upstream view from old bridge**

**Downstream view from old bridge**

**Staff gauges on left bank**



**Damaged cable-way**

<u>Existing Instruments and Equipment</u>
The station is equipped with staff gauges and a pressure transducer with data-logger (the technician did not have a key – A hydrologist comes periodically from Addis to download data from the data-logger, but otherwise there is no display for monitoring of the readings from the pressure transducer at the site by the observer or the technician.

There is a damaged cableway, as noted above.

The old bridge is currently being use for discharge measurements but it is very high above the water surface and measurements are difficult. At high flows they often skip the 0.8d velocity measurment because it is too difficult to manage with the current meter assembly submerged that deep. And depth is determined during the dry season, so is not determined by sounding at the time of measurement.

It would be beneficial to have a bank operated cableway for highflow measurement.

Visibility exists for satellite transmission. The GSM signal at the site (MTN – Ethiopian Telecom) is weak to non-existent. There is no power at the site, and the nearest power lines are approximately 10 Km away. GPRS with radio relay would be possible at the site.

**b. Mojo River at Mojo (date of visit 31 July 2014)**

General Station Information

| | |
|---|---|
| Station Name | Mojo R. at Mojo |
| Purpose of Station | Stream monitoring |
| Latitude | |
| Longitude | |
| Period of Record | 1971 to present |
| Equipped with | Staff Gauge, radar sensor |
| Observer present | Lives in village; 1 km from site |
| Status | Operational |
| Water Management Zone | Awash basin |
| Distance to Head Office | *205 Km (4 hours) from Addis; 90 Km (2 hours) to branch office in Debre Markos,* Nearest Town is Dejen; *paved highway and bridge provides year-round accessibility* |

Site: General Map


Site Description

The water level monitoring site is located about 50 meters upstream of a bridge for the main road into the town of Mojo. There was once a bridge at the site, and much of the current equipment is mounted to the right abutment of the former bridge. There was once a cableway and the foundation of the cableway is still present.

There is a site about 100 meters upstream of the water level monitoring location where gauging measurements can be taken by wading during low flows. For high flows discharge measurement is taken by crane from the new bridge. A rating curve is updated based on these discharge measurements.

It was reported that readings are taken twice daily, but it seemed clear that no reading had been taken on the day of the visit because debris completely obscured the gauge. The observer initially stated that the water level was 1 meter, but when the debris was cleared the reading was 0.77m

Access to the radar sensor and upper staff gauges is through an industrial park entrance. Gauging area is at the end of a dirt road

Station Photos

Stilling well used as mounting for radar sensor; former support for cableway in background top center; staff gauge left center

**Staff gauge**

**Downstream view from new bridge**

**Gauging section**

<u>Existing Instruments and Equipment</u>

There is an old stilling well and shaft encoder that is no longer functioning. It has been replaced by a radar sensor mounted on a bracket hanging over the water. Both are mounted to an old bridge abutment (the old bridge is gone) There is also a staff gauge consisting of a trio of brackets located at various locations for measuring water level within a distinct range for each bracket. However, above two meters the gauge on the left bank is overtopped, ant the gauge on the right bank is covered in silt to 2.3 meters. So water level readings above 2.3 meters are possible but between 2.0 and 2.3 meters one would need to dig out the silt to observe the stage.

A class 3 meteorological station is located within 50 meters of the left bank of the water level monitoring site. Daily precipitation and max-min temperature are recorded at the site. A class 1 meteorological station is located in the nearby town of Adama.

**Class 3 met station at Mojo**

**Class 1 met station in nearby Adama**

# Appendix A.4: National Consultation and Field Visit Report for Kenya

**Introduction and Background**

National consultations and field visits have been organized in nine (9) Nile Basin countries, with the aim to appreciate the potential value, benefits, and need for the regional water resource monitoring system; acquire a deeper appreciation of the current state of the monitoring technologies and practices, and to understand the institutional context within which the designed system will be operated. The consultations will also identify needs for technical support, capacity building, and institutional strengthening. The defined objectives include the following:

- Confirm the important socio-economic/water resources management issues related to the development, management and protection of the shared Nile Water Resources.
- Identify lead and supporting institutions for the confirmed socio-economic/water resources management issues.
- Identify geographic priority areas for each socio-economic issue.
- Confirm data needs for each socio-economic issue to inform decisions and development, and show how these can relate to the regional monitoring network.
- Identify capacity building needs, and explore ideas for improved sustainability of hydromet services.
- Conduct field visits at key monitoring locations that adequately represent the current technologies and practices within use. This will include visits to any water quality labs to further assess data sampling, testing, management, and dissemination.
- Confirm understanding of current network and practices based on country assessment report and metadata from associated countries and past studies. Supplement information and metadata based on discussions.
- Identify country protocols for data communication, storage, formatting, dissemination, sharing, and use. Identify and discuss what data could be used in a regional network and how it could be delivered.

This report presents the consultation meetings and field visits conducted in Kenya for five working days during the 7-13 August period.

## 1. Consultation Meetings

Consultation meetings in Kenya were organized at the Ministry of Environment Water and Natural Resources (MEWNR), the Water Resources Management Authority (WRMA) headquarters in Nairobi and its regional Offices in the Lake Victoria Basin, Kenya Meteorological Services, and the National Irrigation Board at the Ministry of Agriculture Livestock and Fisheries.

*1.1 Ministry of Water Environment and Natural Resources*

Ms. Gladys Wekesa, Head Transboundary Waters Division, Water Resources Department at MWENR organized a meeting on Thursday 06 August 2014 at the Ministry premises with participation of the Chief Economist, and senior representatives from the surface water, groundwater, and water quality divisions, and the national liaison officers of the NELSAP Mara Basin project NELSAP Malaba Malakisi River project, and Riverside consultants[15]. A presentation about the background and objectives of the Nile Basin Hydromet project was given by Mohamed Chebaane, Riverside Consultant, followed by a participatory session to discuss and complete the water management/socio-economic section of the questionnaire related to the identification of lead and supporting institutions for each issue, prioritization of the issues based on a list of regional and national benefits relevant to each issue,

[15] Mohamed Chebaane and John Omwenga

confirmation of the data requirement and identification of the geographical areas relevant to each issue. This meeting also highlighted specific capacity building needs for data analysis and modeling tools and discussed the institutional, management, technical, financial and behavioral change factors related to the sustainability of hydromet systems.

*1.2 Ministry of Agriculture Livestock and Fisheries*

A meeting was held at the National Irrigation Board on Friday 07 August 2014 to identify lead and supporting institutions for the rainfed agriculture and irrigated agriculture, confirm hydromet data needs for specific geographical areas within Nile Basin in Kenya for these two sectors, and identify capacity building needs to improve data analysis and modeling for enhanced rainfed and irrigated agriculture.

*1.3 Kenya Meteorological Service*

Riverside consultants met on Friday 07 August 2014 with a six member team of the Kenya Meteorological Services (KMS) including Mr. Andrew Njogu, Principal meteorologist and Meteorological monitoring representative of the project. The meeting covered the identification of the lead and supporting institutions for the rainfall and evaporation monitoring, collaboration between these institutions, standardization and decentralization of data collection, processing, checking and validation, storage and dissemination. It also discussed the technical, management, financial and behavioral factors affecting sustainability of meteorological services and identified needs for capacity building.

During the visit Mr. Njogu gave Riverside consultants a brief about the Early Flood Warning Project in lower Nzoia River in Budalangi area, near the border with Uganda. In this project KMS is operating a surface water monitoring station in collaboration with WRMA, and automatic meteorological stations.

*1.4 Water Resources Management Authority*

Riverside consultants met on Thursday 06 August 2014 with the Mr. Joseph Kinywa, Technical Coordination Manager at WRMA head-office in Nairobi. We discussed with Mr. Kinywa the project objectives and the institutional questionnaire. Mr. Enock Sabuni Wanyonyi, Deputy Technical Coordination Manager and Hydrological monitoring representative of the project was instrumental in coordinating our meetings at WRMA head office and at the regional offices in Kisumu and Kakamega.

*1.5 Regional Offices*

Riverside Consultant[16] traveled to Kisumu and Kakamega to meet during 11-13 Aug 2014 with the staff and technicians of the WRMA regional offices in these two locations and visit key hydromet stations in the Kenyan part of Lake Victoria Basin (LVB). WRMA has two regional offices in the Nile Basin: The Lake Victoria South Regional Office (RO) in Kisumu which covers the southern side of LVB extending from Northern Kisumu to the Border with Tanzania, and Lake Victoria North Regional Office in Kakamega which covers the Northern side of LVB extending from Yala catchment to the Sio Malaba Malakisi catchment. Each regional office has three sub-regional offices responsible of data collection. The sub-regional offices are located in Kisii, Kisumu and Kericho for Kisumu RO; and in Kitale, Eldoret and Siaya for Kakamega RO. Data processing, checking and validation, storage and dissemination are managed by the regional offices. Meetings at each regional office covered the identification of the lead and supporting institutions in the rainfall and evaporation monitoring, collaboration between these institutions, standardization and decentralization of data collection,

[16] Mohamed Chebaane

processing, checking and validation, storage and dissemination. The meetings also discussed the technical, management, financial and behavioral factors affecting sustainability of meteorological services, and identified national and transboundary priority areas related to water resources planning and management, groundwater management, and water quality hot spots.

## 2. Field Visits

### *2.1 Lake Victoria South Region*

The field visits took place in the South Regional Office during the afternoon of 11 August 2014 and the morning of 12 August 2014. They covered the following sites:

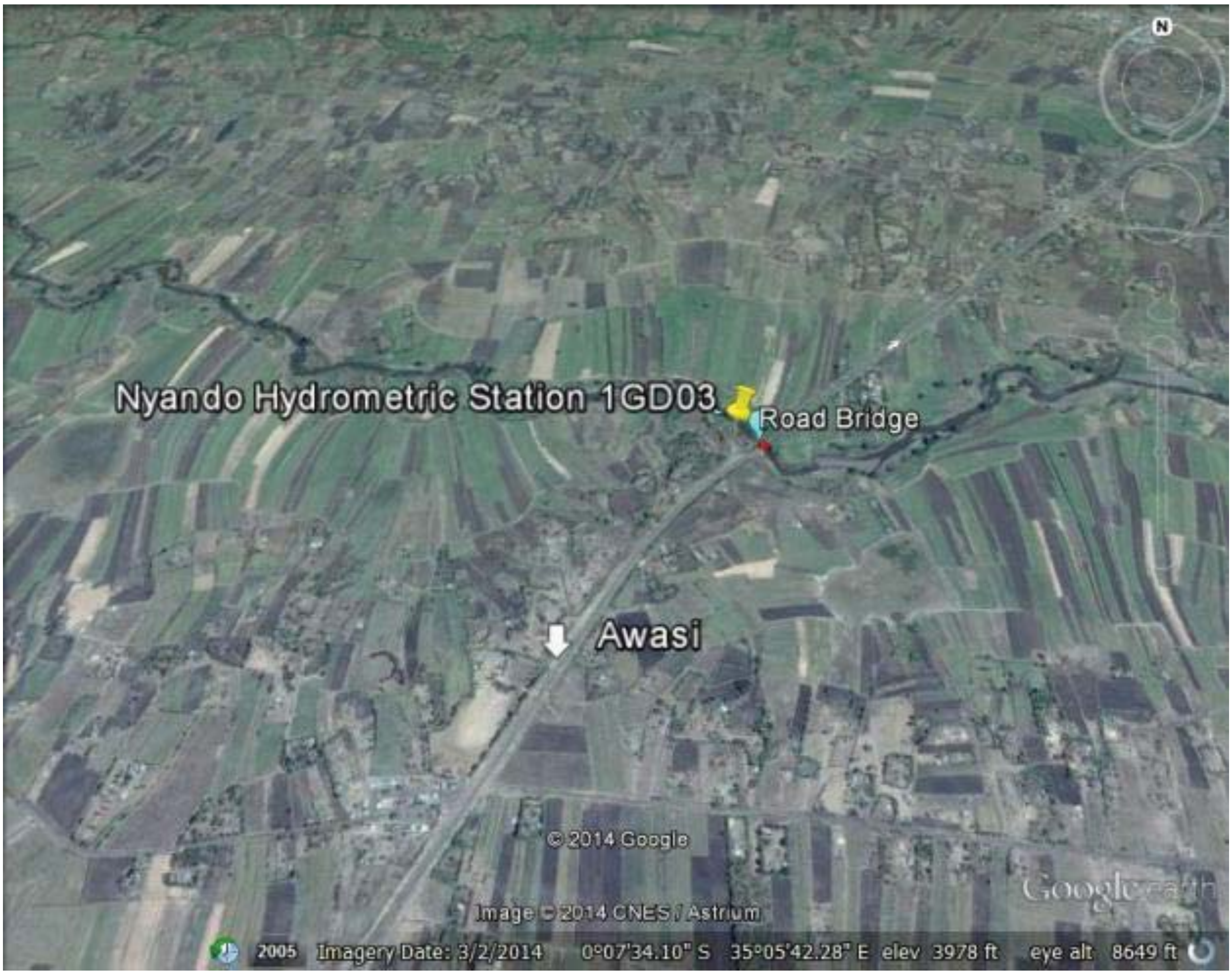
- Nyando Hydrometric Automatic Station
- Lake Victoria Manual Water Level Station
- Ahero Automatic Agro-meteorological Station
- Kisumu Port Compound- Groundwater Level station

#### *2.1.1 Nyando Hydrometric Station*

Station Information

| | |
|---|---|
| Station Name | Nyando River Near Awasi |
| Station Code | ID: 1GD03 |
| Catchment | Nyando |
| Purpose of Station | Water level and discharge monitoring; key station on the main Nyando River |
| Latitude | -0.125 |
| Longitude | 34.960 |
| Period of Operation | 1967-2014 |
| Equipment | Staff gauges; Automatic water level recorder (float recorder), Datalogger, Recorder house |
| Time interval | Hourly |
| Observer | Yes |
| Status | Automatic station is operational; staff gauges for upper cross section are missing. |

Site Map




Nyando hydrometric station is located near Awasi Town, few meters downstream of the Awasi-Chemelil/Murram road bridge. The station can be accessed on foot from the bridge, and is adjacent to agriculture land with silt and clay soil. This can make access to the station difficult during the wet season.

Site Description


The control section is fairly stable. The flow is restricted to a single straight stream channel upstream and downstream of the control section. There is a potential change of river bed due to scouring or sediment deposit during floods. Thus, it is highly recommended to conduct routine flow measurements at low, medium, and high flows (during significant flood events) and update the rating curve. Flow measurements can be made at the crossing section via boat or at the bridge site.

Station Photos

**Nyando River-Near Awasi (1GD03), Upstream**

**Nyando River-Near Awasi (1GD03), Downstream**

**Nyando River near Awasi (1GD03) Automatic WL Shelter, and Automatic WL Recorder and datalogger**

**Nyando River near Awasi (GD03), Staff**

Existing Equipment

Nyando River near Awasi (1GD03) has a float type- Automatic Water Level Recorder (AWLR) and a Thalimedes Data Logger. Both were operational during the visit. Kisumu office hydrologists are very satisfied with the equipment, and have the capacity to operate and maintain this type of automatic stations. They prefer float type AWLRs to the pressure transducers recorders[17]. The station has staff gauges that are not properly installed and are missing at the upper level of the cross section.

Recommendations

[17] Pressure transducers AWLRs are also called divers by Kisumu Office hydrologists

- Establish an adequate path from the bridge to the station to facilitate access to the site during the wet season
- Properly position the lower manual staff gauges and install additional staff gauge elements to cover the upper part of the cross section.
- Resume manual staff gauges reading as a back-up for the AWLR until the technology of AWLRs is fully validated and sustained.

### *2.1.2 Lake Victoria Manual Water Level Station*

Station Information

| | |
|---|---|
| Station Name | Lake Victoria at Kisumu |
| Station Code | ID: 1HB04 |
| Catchment | Lake Victoria |
| Purpose of Station | Water level –Manual Station |
| Latitude | -0.088 |
| Longitude | 34.74 |
| Period of Operation | 1961-2012 |
| Equipment | Staff gauges |
| Time interval | Daily |
| Observer | Yes |
| Status | Manual station is operational, but data collection is inactive due to non-payment of observer for the last two years |

Site Map


**Lake Victoria Water Level Monitoring station is located at Kisumu port in Lake Victoria**

<u>Station Photos</u>

Lake Victoria Water Level Monitoring Station

Staff gauge covered with algaes


Staff gauge after cleaning algae

<u>Existing Equipment</u>

Lake Victoria Water Level Monitoring Station (1HB04) has a staff gauge attached to a concrete wall as shown in the picture. During the visit the staff gauge was covered with algaes. The observer has not been paid for two years, thus he has ceased reading the water level and maintaining the station. The station was cleaned during the visit, but water level reading may not resume before paying the observer. Note that this is the only water level monitoring station of Lake Victoria in Kenya.

Recommendations

Observers are paid a small stipend which is insignificant compared to the socio-economic value of the water level records. Thus, it is recommended to ensure payment of the observers to resume collection of the hydrologic records at the manual stations that are currently inactive. It is also recommended to upgrade Lake Victoria Water Level Monitoring Station (1HB04) to an automatic station equipped with automatic float recorder and a data logger given the importance of the lake water level records in the understanding of the hydrology of Lake Victoria.

#### *2.1.2 Ahero Agro-meteorological Station*

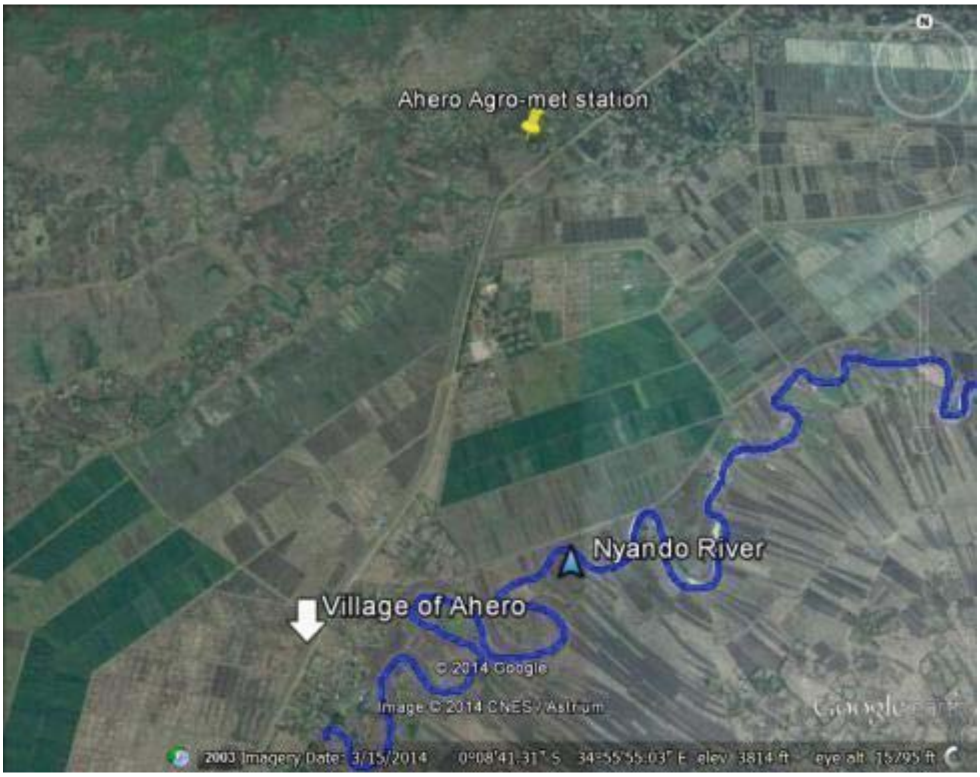
Station Information

| | |
|---|---|
| Station Name | Ahero Irrigation |
| Station Code | 9034086 |
| Purpose of Station | Monitoring of climate and agro-climate parameters |
| Latitude | 34.9333 |
| Longitude | -0.1333 |
| Altitude | 1312 m |
| Period of Record | 1970 to present |
| Equipped with | Manual equipment and Automatic equipment added in 2013 |
| Observer present | Yes |
| Status | Operational |

Site Description

The Automatic station is not installed according to WMO Standards of site location. It is very close to a water tank as per photo shown hereafter. This would affect particularly rainfall, wind direction and wind speed data.

Site Map




The climate station is located at the National Irrigation Board (NIB) Irrigation Research Center near Ahero town.

Station Photos

**Ahero Agromet-Station, Nyando River Basin, Manual Equipment**


Ahero Agromet Automatic weather Station adjacent to water tank

<u>Existing Equipment</u>
The station is jointly operated by NIB and WRMA. WRMA has the manual rain gauge and a Class A evaporation pan. NIB has both the manual and automatic climate monitoring equipment. The manual equipment includes the evaporation Piche instrument and a solar radiometer. The automatic station was in installed in 2013, it is equipped with a tipping bucket rain gauge, solar panel and sensors for temperature, relative humidity, wind speed, wind direction, and dew point.

<u>Recommendations</u>
Compliance with WMO standards for installation of weather monitoring stations is essential for the reliability of the climate data. Thus, it is recommended to move the automatic weather station to a new location at the proximity of the evaporation pan and the manual solar radiometer where there is an open space as shown in the manual equipment photo.

#### *2.1.3 Groundwater Level Monitoring Station- Kisumu Port Compound*

Groundwater monitoring in both the North and South Victoria Regional Offices areas is limited to measurement of water level at production wells which does not represent a standard and reliable monitoring of groundwater aquifers. Groundwater aquifers are not fully delineated. Below is a photo of a monitoring site at the production well of Kisumu Port Complex visited on 12 August 2014

**Groundwater Level Monitoring Station at a Production well at Kisumu Port Compound**

Recommendation

Once the groundwater aquifers are mapped out, a proper groundwater level monitoring needs to be carried out at observation wells designed for this purpose.

### *2.2 Lake Victoria North Region*

The field visits were conducted in the North Regional Office on 13 August 2014. They covered the following site:

- Nzoia River Hydrometric Station
- Lusumu Hydrometric Station
- Isiukhu River Hydrometric Station
- Uholo Meteorological Station

#### *2.2.1 Nzoia River Hydrometric Station*

Station Information

| | |
|---|---|
| Station Name | River Nzoia |
| Station Code | ID: 1DD01 |
| Catchment | Nzoia |
| Purpose of Station | Manual water level and discharge monitoring |
| Latitude | 00.36914 |
| Longitude | 034.48766 |
| Period of Operation | 01/01/1962-31/8/2009 |
| Equipment | No equipment, Station vandalized, nothing left in the site |
| Time interval | Daily data when it was operating |
| Observer | No |
| Status | Recommended for restoration |

Site Map


Before it was vandalized, Nzoia hydrometric station was located near Mumias town, about 100m upstream of the Mumias/Mayoni road bridge, and downstream of Mumias Sugar Factory. The station can be accessed on foot from the bridge. The station is adjacent to a sugar plantation. This can make access to the monitoring site difficult during the growing season.

Site Description

The control section is fairly stable. The flow is restricted to a single straight stream channel upstream and downstream of the control section. There is a potential change of river bed due to scouring or sediment deposit during floods. Thus, it is highly recommended to conduct routine flow measurements at low, medium, and high flows (during significant flood events) and update the rating curve. Flow measurements can be made at the crossing section via boat or at the bridge site.

Station Photos

Nzoia River Bridge downstream of Station

Nzoia River Downstream of the Bridge

River Nzoia Hydrometric Station Site Vandalized

Nzoia River Upstream and Downstream of Hydrometric Station

Recommendations

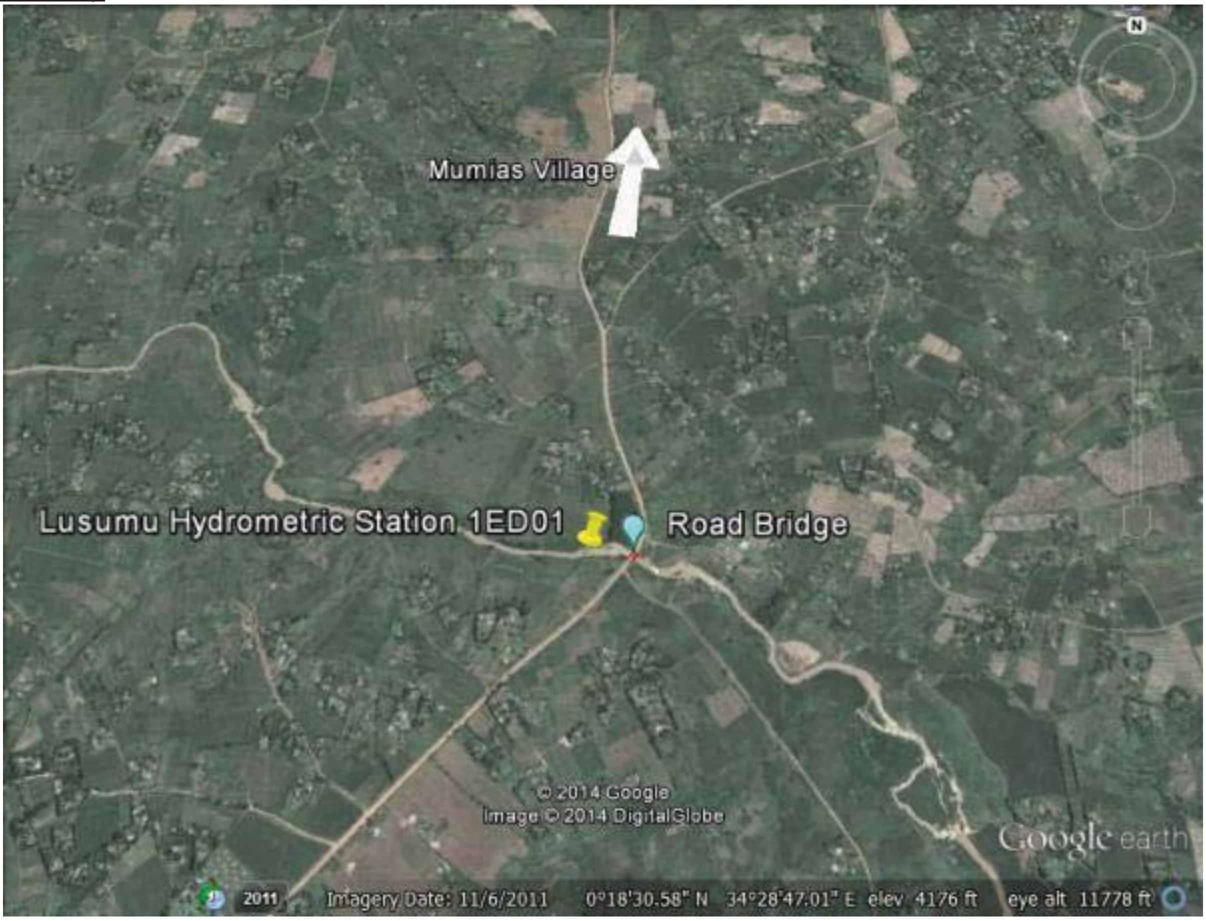
It is recommended to re-establish the Nzoia River-1DD01 station with installation of an Automatic Float Recorder for Water level. Discharge measurement can be taken via Acoustic Doppler Current Profiler (ADCP) at the station crossing section or at the bridge cross section. Water quality monitoring is also recommended at this site given that the station is located downstream of one of the largest sugar factory in Kenya. An adequate path from the bridge to the station needs to be established to facilitate access to the site.

### 2.2.2 River Lusumu Hydrometric Station

Station Information

| | |
|---|---|
| Station Name | River Lusumu |
| Station Code | ID: 1ED01 |
| Catchment | Lusumu, Nzoia Sub-Catchment |
| Purpose of Station | Manual water level and discharge monitoring |
| Latitude | 00.30622 |
| Longitude | 34.4793 |
| Period of Operation | 20/01/1951-Present |
| Equipment | Staff gauges |
| Time interval | Daily |
| Observer | Yes |
| Status | Operating, staff gauge plates should be replaced with new plates |

Site Map




Lusumu hydrometric station is located downstream of the road bridge at Lusumu River near Mumias town, one of the main reaches of Nzoia River.

Site Description


The control section is not appropriate for water level measurement. The channel at the control section is not straight and it is unstable.

Station Photos

**Lusumu River upstream and downstream of road bridge and Hydrometric Station**

**Water Level recorder at Lusumu River**

Existing Equipment
Lusumu River Hydrometric station (1ED01) has staff gauges with two elements, one with faded plate and one with partially corroded plate as shown in the above picture.

Recommendations
It is recommended to move the gauge around 10-15 meters upstream of the current location to a new stable site where the flow is restricted to a single straight stream channel upstream and downstream of the control section. It is also recommended to replace the plates of the staff gauges with new plates.

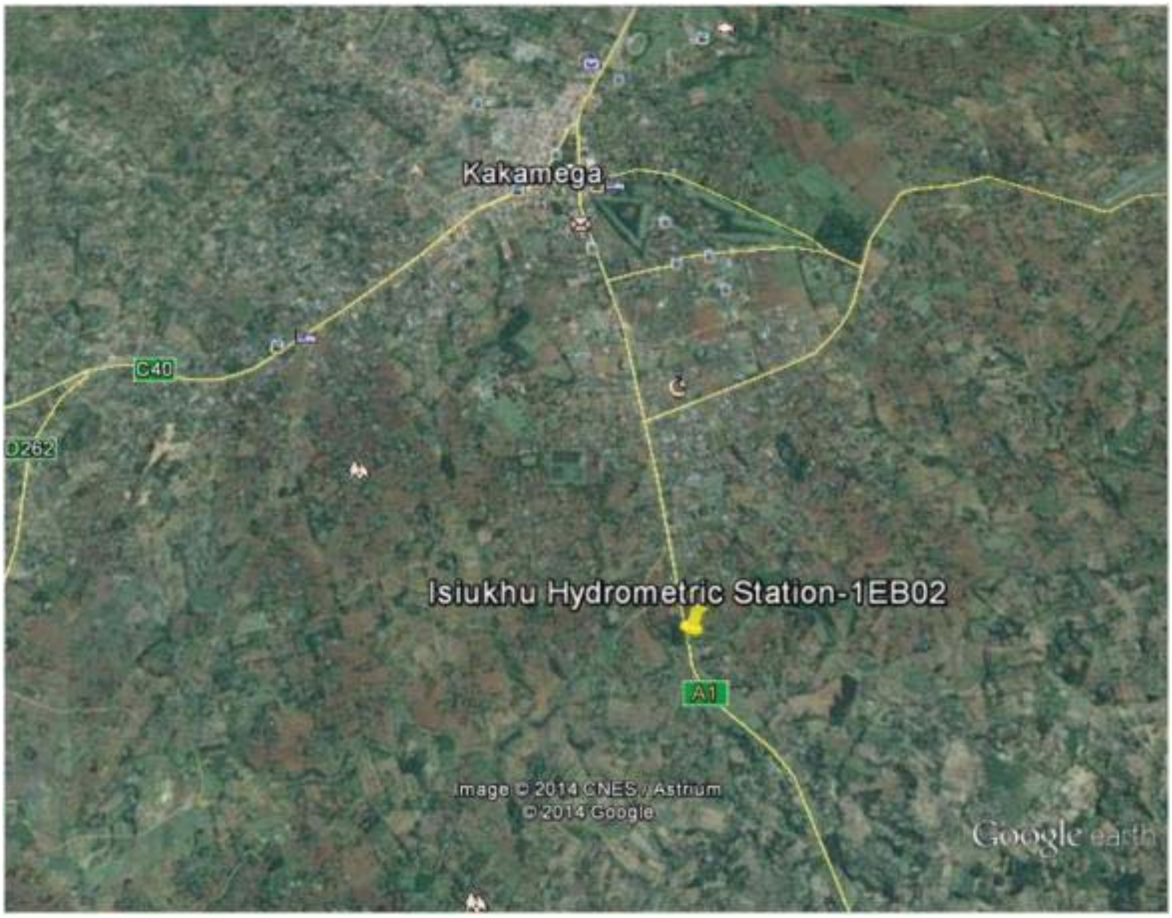
### *2.2.3 Isiukhu Hydrometric Station*

Station Information

| | |
|---|---|
| Station Name | River Isiukhu |
| Station Code | ID: 1EB02 |
| Catchment | Isiukhu, Nzoia Sub-Catchment |
| Purpose of Station | Manual water level and discharge monitoring |
| Latitude | 00.25455 |
| Longitude | 34.4750 |
| Period of Operation | 19/03/1963- 28/09/2013 |

| | |
|---|---|
| Equipment | Staff gauges |
| Time interval | Daily |
| Observer | Yes |
| Status | Operational, but records are not available at Kakamega regional office since 28/09/2013 due to non-payment of observer. |

Site Map




Isiukhu hydrometric station is located near Kakamega town upstream of the Kisumu-Kakamega road bridge.


The control section is fairly stable. Flow is restricted to a single straight stream channel upstream and downstream of the control section.

**River Isiukhu upstream from bridge**

**River Isiukhu downstream from bridge**

Isiukhu River Hydrometric Station

Existing Equipment

Isiukhu Hydrometric Station (1EB02) has a staff gauge as shown in the picture above. The staff gauge is properly installed, and it is in good condition.

Recommendations

It is recommended to ensure payment of the observer to resume collection of the hydrologic records at this station.

#### *2.2.4 Uholo Meteorological Station*

General Station Information

| | |
|---|---|
| Station Name | Uholo Chief's Office |
| Station Code | |
| Purpose of Station | Monitoring of meteological parameters |
| Latitude | 0.2020 |
| Longitude | 34.3652 |
| Altitude | 1313 m |
| Period of Record | 1940 to present |
| Equipped with | Automatic Station (see description of equipment) |
| Observer present | Yes |
| Status | Operational, installed and operated by Kenya Meteorological Service |

Site Description
The station is located at the premises of the Chief's Office at Uholo in a fenced area (see photo below).

Site Map

Station Photos

Existing Equipment
Uholo meteorological is equipped with a tipping bucket rain gauge, solar panel and sensors for temperature, relative humidity, wind speed, wind direction, radiation, and dew point.

Recommendation
The station is in good condition. There is no specific recommendation.

## 3. Institutional Questionnaire Key Findings

### *3.1. Institutional Aspect of the Water Resources Management Issues*

Results of the questionnaire regarding the lead and support institutions for each of the fourteen (14) water resources management/socioeconomic issues and the priority of each of issue are indicated below.

| Water Management/ Socio-economic-issues | Lead Institution | Support Institutions | Priority |
|---|---|---|---|
| WRPM | MEWNR | County Governments, Ministry of Agriculture Livestock and Fisheries, Ministry of Health, Ministry of Energy and Petrolium, Ministry of Devolution and Planning, WESCORD (NGOs and civil society), Water Resources Users Associations (WRUAs). | 1 |
| Flood Management | MEWNR | County Government, Ministry of Devolution and Planning (Directorate of Special Programs) | 1 |
| Rainfed Agriculture | Ministry of Agriculture Livestock and Fisheries | MEWNR-(WRMA and Kenya Meteorological Service) | 1 |
| Irrigated Agriculture | Ministry of Agriculture Livestock and Fisheries | MEWNR-(WRMA and Kenya Meteorological Service) | 1 |
| Groundwater Management | MEWNR | County Governments | 2 |
| Water Quality and Pollution | MEWNR | Ministry of Health, Kenya Bureau of Standards, County Governments, Regional Organizations, NGOs, and Civil Society | 1 |
| Erosion/Sediment | MEWNR | Ministry of Agriculture Livestock and Fisheries | 1 |
| Energy | Ministry of Energy and Petroleum | MEWNR | 1 |
| Watershed Management | MEWNR | Ministry of Agriculture Livestock and Fisheries, County Government, Ministry of Devolution and Planning, WRUAs | 1 |
| Wetland Management | MEWNR | Ministry of Culture and National Heritage | 1 |
| Drought | Ministry of Devolution and Planning | MEWNR (Kenya Met Service), Ministry of Agriculture Livestock and Fisheries, Kenya Red Cross, other NGOs | 3 |
| Climate Change | MEWNR | Ministry of Devolution and Planning, Ministry of Agriculture Livestock and Fisheries, County Government, Ministry of Energy and Petroleum | 1 |
| Fisheries | Ministry of Agriculture Livestock and Fisheries | MEWNR | 1 |
| Navigation | Ministry of Transport and Infrastructure | MEWNR (WRMA-monitoring Lake Victoria Level), LVBC | 4 |

The table above shows that the MEWNR leads eight (8) of the socio-economic issues and has a support role for the other six (6) issues. The lead by MEWNR of a significant majority of the issues would help in the regional collaboration towards maximizing the benefit of Hydromet systems and allows for leveraging resources in the operation and management of these systems. On the other hand, there is a considerable number of supporting institutions composed of national Ministries representing sectors such as agriculture, health, infrastructure, energy[18], fisheries, navigation, environment, interior, and research as well as other entities representing state[19] level government services, NGOs, and local organizations and associations. The number of the supporting government institutions (Ministries and specialized agencies) for all the fourteen (14) water resources

[18] The energy sector, specifically hydropower, is in most countries led by institutions that are separate from the Ministries of Water Affairs.
[19] State can be regional Ministries at the Governorate level.

management/socioeconomic issues is more than twelve (12). This is a challenge for the effective operation and delivery of the hydromet services, if the roles and responsibilities of the lead and supporting institutions are not clearly defined.

It should be noted that Kenya has adopted a decentralized system that links the Transboundary Water Directorate to the national office of the Water Resources Management Authority (WRMA) which is responsible of two Regional Offices covering respectively the Northern and Southern Basins of the Kenyan Lake Victoria Basin. Each the regional offices has three sub-regional offices. This institutional model is well suited for regional (transboundary), national, and catchment water resources management needs.

Eleven (11) socio-economic issues have been ranked as first priority. Only groundwater, drought, and navigation have been given respectively 2nd, 3rd, and 4th priority. Among the eleven (11) first priority issues the following seven (7) have been given highest priority:

- Water Resources Planning and Management
- Irrigated Agriculture
- Water Quality
- Energy
- Watershed Management
- Climate Change
- Fisheries

An examination of the Nile Basin Transboundary Issues presented in the Interim Report of the Conceptual design shows the following regional issues relevant to Kenya:

| Cooperative issue | Socio-economic benefits | Key system and data requirements |
|---|---|---|
| Monitor transboundary water quality and quantity flows between Kenya and Tanzania in the Mara basin.<br><br>Notable concerns include soil erosion and sediment loads; deforestation of the watershed; degradation of water quality due to poor agricultural, sanitation, and mining practices. | • Basin has significant environmental and biodiversity conservation interests. This includes eco-tourism benefits for both countries result from the world famous Masai Mara-Serengeti ecosystem.<br>• Improve agricultural, mining, and watershed management practices to sustain the long term environmental health and production of the basin | • Data sharing policies between Kenya and Tanzania;<br>• Data transmission facilities;<br>• river discharge, sediment loads, and water quality at key locations along the Mara river;<br>• Data processing, storage, and dissemination facilities |
| Monitor transboundary water quality and quantity flows between Kenya and Uganda in the Malaba basin<br><br>Notable concerns of watershed degradation leading to increased levels of suspended sediment as well as | • Maintain water quality standards for existing and potential irrigation along the Malaba River.<br>• maintain water quality standards of flows entering the wetlands of Lake Kyoga<br>• improve upstream watershed management | • Data sharing policies between Kenya and Uganda<br>• River discharge, sediment loads, and water quality at key locations along the Malaba River<br>• Data processing, storage, and dissemination facilities |

| | | |
|---|---|---|
| potential water quality issues. This affects downstream irrigation and wetlands eco-systems. | practices to sustain the long term environmental health and production of the basin | |

The above transboundary issues reinforce the selection of water quality and watershed management as top issues at the national and regional levels.

### *3.2. Institutional responsibilities of hydromet parameters*

Rainfall and Evaporation Parameters

Kenya Meteorological Service (KMS) is the lead institution responsible for rainfall and evaporation data in Kenya. WRMA and the Ministry of Agriculture, Livestock, and Fisheries (Research Stations) are the two main other institutions that collect rainfall and evaporation data. Both KMS and WRMA are under the MEWNR. Even though KMS and WRMA share data, it is recommended that WRMA rainfall and evaporation network be transferred to KMS. Similarly, all rainfall and evaporation station under the Ministry of Agriculture, Livestock, and Fisheries need to be transferred to KMS given that KMS has an agro-meteorological unit specialized in monitoring agro-climate data. This will help in streamlining of the network, improve data quality, and leverage funds for capacity building and for acquiring effective monitoring technologies.

#### 3.2.1 Water discharge/Level

WRMA is the only institution in charge of Water discharge/level monitoring in Kenya. WRMA has decentralized data collection, processing, validation, and dissemination to regional offices. As stated in sections 2.5 and 4.1 WRMA has two regional offices in Lake Victoria area one in Kisumu and one in Kakamega. Each office has three sub-regional offices. The sub-regional offices are in charge of data collection and processing. Data checking, validation, and dissemination are done at the regional offices.

#### 3.2.2 Water Quality and sediment

WRMA is the lead surface water and groundwater quality monitoring and sediment monitoring institution. The Ministry of Health also collects water quality at drinking water distribution points. WRMA water quality monitoring and sediment monitoring services are decentralized to regional offices in the same way as the water level/discharge monitoring services. Sediment monitoring is fairly limited. More details about Water Quality monitoring are WQ lab are in the inception report and interim conceptual design report.

#### 3.2.3 Groundwater monitoring

Groundwater monitoring is mainly carried out by WRMA at production wells. NGOs such as VIRED (research based NGO) conduct groundwater monitoring at specific production wells. As mentioned in section 3, groundwater monitoring needs to be conducted at observation wells specifically designed for this purpose.

#### 3.2.4 Water Quality Laboratories

Both Regional WRMA Offices in Kisumu and Kakamega have small water quality laboratories. The capacity of the Labs in Kisumu and Kakamega to meet minimum regional and national data needs is average. The new Lab at Nyalenda Kisumu should be commissioned and handed over to WRMA. More details are presented in the inception report and conceptual design report.

### 3.2.5 Surface water and groundwater use

WRMA is responsible for providing bulk surface and groundwater to water users. According to the questionnaire's response water users are the lead entities in charge of monitoring their water consumption. As a bulk provider, WRMA needs to lead monitoring of both surface water and groundwater use. The National Irrigation Board (NIB) would be a suitable entity for monitoring surface water and groundwater irrigation water use.

### 3.2.6 Earth Observations Products

Kenya Meteorological Service uses rainfall satellite data for rainfall forecast. It is recommended to strengthen the Earth Observation Products institutional and technical capacity to take advantage of the advance of this promising sector, particularly for earth products related to precipitation, soil moisture, and evaporation.

Key Institutional Recommendations

The key steps for the institutionalization of the hydromet systems to meet the data and information needs of decision makers, professionals and relevant stakeholders in Kenya to address the regional transboundary issues related to water quality and watershed management in collaboration with Tanzania and Uganda will follow the institutional conceptual design presented in the interim and final reports of the Nile Basin Hydromet Systems Conceptual Design.

The following are the key steps for the institutionalization of the national hydromet systems in kENYA:

4. Confirm the priority water resources management/socio-economic issues identified in the institutional questionnaire (i.e. WRPM, irrigation, water quality, watershed management, energy, climate change, fisheries).
5. Confirm the lead and supporting institutions for each of the water resources management issue identified in the institutional questionnaire.
6. Define the functions (activities) related to each water resources management issue.
7. Identify the roles and responsibilities of the lead institution and supporting institutions for implementation of each defined function.
8. Develop policies, action plans, and procedures to support the implementation of the functions based on the roles and responsibilities of each lead and supporting institution.
9. Validate the list of data requirements (Demand) for each water resources management factor.
10. Identify the data requirements for the lead institution and supporting institutions based on the above validated list (Demand) and the functions and responsibilities of each institution.
11. Confirm the monitoring network for each Hydromet parameter.
12. Identify the lead and support institutions responsible for providing hydromet services for the required data with clear functions and roles of each institution.
13. Develop national policies, action plans, and procedures to support the roles and responsibilities of each lead and supporting institutions providing hydromet services.

## *3.3 Hydromet Services- Technical Aspects*

According to the questionnaire around 90% of rainfall, evaporation, and surface water level monitoring stations in Kenya are manual. The lack of maintenance is the main reason for malfunction of the hydrometeorological equipment. Two out of the four visited hydrometric stations had staff gauge plates covered with algaes, corroded or faded due to lack of maintenance. The automatic climate station at Ahero agro-meteorological sites was not properly located. This may be the case for other weather stations that are not operated by KMS[20]. Lusumu water level staff gauge is not installed at an adequate cross section (see section 3.2.2). Other hydrometric stations may also not be properly sited.

Tipping rain gauges, automatic float recorders, and wireless data transmission are among the favorable technologies in Kenya. The idea of mobile calibration labs has been welcomed given that mobile labs can be used for both calibration and maintenance of equipment.

Recommendations

- Check all the rainfall and evaporation stations that are not operated by KMS and ensure that they are installed according to WMO standards.
- Check hydrometric stations, and relocate the ones that are not properly installed. As mentioned in section 3.2.2, the hydrometric station needs to be located at a stable site where the flow is restricted to a single straight stream channel upstream and downstream of the control section.

### *3.4 Hydromet Services- Management Aspects*

The meteorological data collection, processing, validation and storage are standardized within KMS; however, standard procedures are not often adopted by other institutions such as WRMA and the Ministry of Agriculture, Livestock and Fisheries. The meteorological database of KMS is centralized. The hydrological data collection, processing, validation and storage are not fully standardized within WRMA. The Hydrological database is decentralized. Data is collected and processed by the sub-regional offices, then sent to the regional offices for validation, and storage. A copy of the data is sent to WRMA headquarter in Nairobi. There is no specific standard database used by the sub-regional, and regional office. The regional office at Kakamega is short of staff. In addition to the Regional Manager, Kakamega RO has a technical staff composed of a surface water officer, a database officer, a community development officer, and a water quality laboratory specialist. The surface water specialist is in charge of coordination of Hydrometeorological and water quality data collection with the sub-regional offices. He may not have time for data processing and validation. Kisumu regional office has in addition to the regional manager a technical staff that includes a senior surface water officer, groundwater officer, and a senior water quality laboratory officer. Given the large number of hydrometric stations and WRMA climate/rainfall stations, the senior surface water officer needs at least two assistants to properly oversee the data collection and processing, and validate the data. Staff at both Kisumu at Kakamega offices expressed the need of training and capacity building in data collection, processing, validation, and management. There are difficulties in hiring and retaining qualified staff due mainly to low wages.

Recommendations

- Move all rainfall and weather stations that are currently operated by WRMA, Ministry of Agriculture, Livestock, and Fisheries to KMS.
- Establish and enforce standard procedures for data collection, processing, validation, storage, and dissemination.
- Adopt a standard database system that can serve local, national, and transboundary data management and data sharing needs.
- Hire staff for data processing, validation, and management. A minimum of two additional surface water hydrologists are needed for each Regional Office.

[20] Technical standards for installation of climate stations are more readily available and adopted by meteorological services due to technical support from WMO, but these standards are often not adopted by other national institutions that support monitoring of rainfall and evaporation parameters.

- Provide formal and hands on training on data processing, validation, and management.
- Recommendations for water quality monitoring and water quality lab are presented in details in the interim conceptual design report.

### *3.5 Hydromet Services- Financial Aspects*

According to the questionnaire both KMS and WRMA do not have sufficient funding to effectively operate their monitoring services. The questionnaire results also indicate that the main reasons for lack of adequate funding are the low priority given to the sector, lack of awareness about the economic value of the hydrological data, and lack of studies to demonstrate the socio-economic benefits of the hydrological data.

Recommendations

- Conduct a study to show the socio-economic value of hydromet services[21].
- Develop and conduct an awareness and outreach program based on the results of this study targeted to decision makers and users in the various sectors benefiting from the hydromet services.
- Explore opportunities of funding from Water utilities, Electricity companies, Sugar Factories, Mining Companies and other relevant private sector that benefit directly or indirectly from Hydromet data and information.
- Move progressively to automated hydromet system which is more accurate and efficient, and has been proven to be at the long run more cost effective than the manual system.

### *3.6 Hydromet Services- Behavioral Aspects*

WRMA relies on local field observers to read and report data from manual staff gauges. Despite the low stipends for these services, manual observers are often not compensated on time. WRMA has not paid their field observers for the past two years. This has significantly affected data collection given that 90% of WRMA hydrometric network is composed of manual stations. The Metadata received shows that the majority of the hydrometric stations, particularly those of the Kakamega Regional Office are either closed or inactive. The questionnaire results confirm the need of communication and awareness program to change the attitude about compensation of the field observers, raise awareness of field observer about the benefits of the data, and convince decision makers about the added socio-economic national and local benefits.

Recommendations

- Expedite payment of the observers given that this issue is currently crippling a major part of the hydromet operation.
- Develop communication capacity at KMS and WRMA to develop and conduct awareness and communication programs targeted to decisions makers, public and private sectors data users, and observers.

### *3.7 Training and Capacity Building*

Based on the questionnaire, below are the areas where training and capacity building is needed:

Improved Water Resources Planning and Management

a. Water resources assessment , specifically groundwater
b. Modeling of surface water and groundwater
c. Remote sensing for water resources planning and management

[21] This study can be conducted at the regional level.

Flood Management
a. Flood forecasting, warning, risk analysis, and preparedness

Rainfed Agriculture
c. Weather forecasting
d. Rainwater Harvesting

Irrigated Agriculture
a. Crop Water Requirement
b. Improved crop production
c. Irrigation Management

Groundwater Management
a. Mapping of groundwater resources
b. Groundwater modeling

Water Quality Management
a. Water quality data analysis and interpretation
a. Sediment sampling
b. Sediment analysis and modeling

Watershed Management
a. Principles of IWRM
b. Remote sensing
c. Watershed modeling

Hydromet Monitoring Technologies
a. Automatic Rainfall and evaporation data collection and maintenance technologies, and Evaporation estimation methods
b. Automatic water level and water discharge data collection and maintenance technologies
c. Automatic water quality monitoring technologies
d. Modern sediment load monitoring technologies
e. Automatic groundwater level and water quality monitoring technologies

Water quality laboratory technologies
a. Data management
b. Training on AAS, Chromatographs and NMR

Management of Meteorological and Hydrological Services
a. Data processing
b. Data Validation (Q/A)
c. Data storage
d. Data dissemination

<u>Recommendations</u>
The above areas will be considered, streamlined at the regional level, discussed with NBI and packaged in a series of formal and hands on training programs.

# Appendix A.5: National Consultation and Field Visit Report for Rwanda

### 1.0 Introduction

Rwanda is 26,338 square kilometres in size and approximately 8.0 percent of the area is water. Rwanda is located in Central Eastern Africa and is bordered by the Democratic Republic of the Congo to the west, Uganda to the north, Tanzania to the east, and Burundi to the south. Rwanda lies a few degrees south of the equator and is landlocked. The capital, Kigali, is located near the centre of Rwanda.


The population of Rwanda is 10,600,000 (2012). The population is young with an estimated 42.7 percent under the age of 15, and 97.5 percent under 65. Most of the population is rural with some 90 percent earning their living from agriculture.

### 2.0 Geography and Climate

Mountains dominate central and western Rwanda, running from north to south along Rwanda's western border. The centre of the country is predominantly rolling hills, while the eastern border region consists of savanna, plains, and swamps. Much of the country is at an altitude between 1500 to 2500 metres with the higher altitudes being in the western region.

Highland tropical forests are found at moderate altitudes in the mountain ranges. The natural vegetation in the lower regions is mostly composed of savanna and woody savanna types, often appearing as a mosaic in combination with farmlands. Lands predominantly covered by woody savanna and shrub vegetation are present in the eastern and central south parts of the country.

The two principle drainage basins are the Congo and Nile, with around 67 percent of the country's area draining into the Nile and 33 percent into the Congo via the Rusizi River and Lake Tanganyika.

The country's longest river in the Nile drainage basin is the Nyabarongo. The Nyabarongo rises in the southwest as the Mwogo River, flows north, then east to Kigali. The Akanyaru River along the southern border with Burundi joins the Nyabarongo south of Kigali, after which it becomes the Akagera River and forms the border with Tanzania in the southeast and east. In the southeast the Ruvubu River from Tanzania merges with the Akagera to form the Kagera. The Kagera then flows due north along the eastern border with Tanzania. The Nyabarongo-Kagera eventually drains into Lake Victoria.

Rwanda has many sizable lakes in the Nile drainage basin which include Burera, Ruhondo, Muhazi, Rweru, and Ihema, the last being the largest of a string of lakes in the eastern plains of Akagera National Park.

Rwanda has a temperate tropical highland climate, however temperatures are lower than those typical for equatorial countries because of its high elevation. Kigali, in the centre of the country, has a typical daily temperature range between 12 and 27 °C, with little variation through the year. The mountainous west and north are generally cooler than the lower lying east.

There are two rainy seasons in the year. The first runs from February to June and the second from September to December. The rainy seasons are separated by two dry seasons, with the major one from June to September, during which there is often no rain, and a shorter and less severe one from December to February. Rainfall varies geographically, with the west and northwest of the country receiving more precipitation annually (2000 mm) than the east and southeast (800 mm).

**Climate Data**
**Kigali, Rwanda**

| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average high °C | 26.9 | 27.4 | 26.9 | 26.2 | 25.9 | 26.4 | 27.1 | 28.0 | 28.2 | 27.2 | 26.1 | 26.4 | 26.89 |
| Average low °C | 15.6 | 15.8 | 15.7 | 16.1 | 16.2 | 15.3 | 15.0 | 16.0 | 16.0 | 15.9 | 15.5 | 15.6) | 15.73 |
| Precipitation mm | 76.9 | 91.0 | 114.2 | 154.2 | 88.1 | 18.6 | 11.4 | 31.1 | 69.6 | 105.7 | 112.7 | 77.4 | 950.9 |
| Avg. Precipitation Days (≥ 0.1 mm) | 11 | 11 | 15 | 18 | 13 | 2 | 1 | 4 | 10 | 17 | 17 | 14 | 133 |

Source: World Meteorological Organization

According to a report by the Strategic Foresight Group, climate change has caused a change in the pattern of the rainy seasons. There are times when there is a late onset of rainfall or an early cessation. At times, the total number of annual rainy days is reduced with short periods of more intense rainfall. Other times, frequent torrential rainfall on a daily basis exceeds the total monthly quantity.

## 3.0 Institutional Setting

The Ministry of Natural Resources (MINIRENA) has the legal mandate for land, water resources, environment, forests, and geology and mines. According to the Water Law (GOR, 2009), MINIRENA's responsibilities include the assessment, management, and governance of water resources, and the Ministry is responsible for leading the formulation of national water resources policy and the national water resources master plan. MINIRENA also represents the State in water-related international organization and promotes international cooperation.

MINIRENA is a coordinating institution for the National Water Consultative Commission as established by the Prime Minister's Order of May 2013. The commission is composed of Ministries and Authorities who have responsibilities or activities related to water resources.

Agencies and departments residing under MINIRENA are:

- REMA, the Rwanda Environment Management Authority is an inter-sector agency overseeing environmental integrity and regulations including strategies for climate change mitigation and adaptation.
- RNRA, the Rwanda Natural Resources Authority is responsible for land, water resources, geology and mines, and forestry sectors.
- IWRM, the Department of Integrated Water Resources Management under RNRA is responsible for managing water resources, and hydrological data collection and information provision.
- DLM, the Department of Lands and Mapping under RNRA is responsible for land management and administration including surveying, mapping, and GIS.
- OGMR, the (former) Rwanda Geology and Mines Authority now under RNRA is responsible for the geology and mining sector including geological mapping and exploration.
- DFNC, the Department of Forest and Nature Conservation, is responsible for management and conservation of forests, and for agro-forestry development.

The Ministry of Infrastructure (MININFRA) is responsible for the transport, energy, habitat and urbanism, water supply and sanitation, and meteorology sectors. The Rwanda Meteorological Agency, responsible for meteorology including meteorological and climate data and information, resides under MININFRA.

The Ministry of Agriculture and Animal Resources (MINAGRI) is responsible for agriculture and fisheries, including irrigation development. The Rwanda Agricultural Board under the Ministry is responsible for increased agricultural production through innovative technologies. The Board is in charge of conducting research activities related to water resources management.

The Ministry of Disaster Management and Refugee Affairs (MIDIMAR) is a newly established Ministry in charge of managing disaster including floods, droughts, and hazard-preparedness.

The Ministry of East African Community (MINEAC) is responsible for coordination of the implementation of EAC water resources management programs and activities in Rwanda.

The Rwanda Bureau of Standards (RBS) is responsible for establishing standards for water quantity and quality monitoring.

The following educational institutions offer programs with curricula relevant to water resources:

- The University of Rwanda through its college of Sciences and Technology offers a master program in Water Resources and Environmental Management (WREM). The University also conducts an undergraduate civil engineering specialization in water and environmental engineering. Furthermore, the University of Rwanda has a research centre in Geographical Information Systems and is planning to start the Centre of Water Resources and Environmental Management offering a MSc in Water Resources, a MSc in Hydraulics, and a

MSc in Water Supply and Sanitation. The Centre will have a reference water laboratory as well as offer short courses in water related issues. The Netherlands Government is financing the Centre under the NICHE/RWA/099 Project (2013).

- The Integrated Polytechnic Regional Center offers an Advanced Diploma in Civil Engineering and water related programs.
- Saint Joseph Integrated Technical College offers an Advanced Diploma program in Civil Engineering with curricula on water management.

MINIRENA has a cooperative agreement with the University of Rwanda for water quality monitoring support and for the conduct of water resources studies.

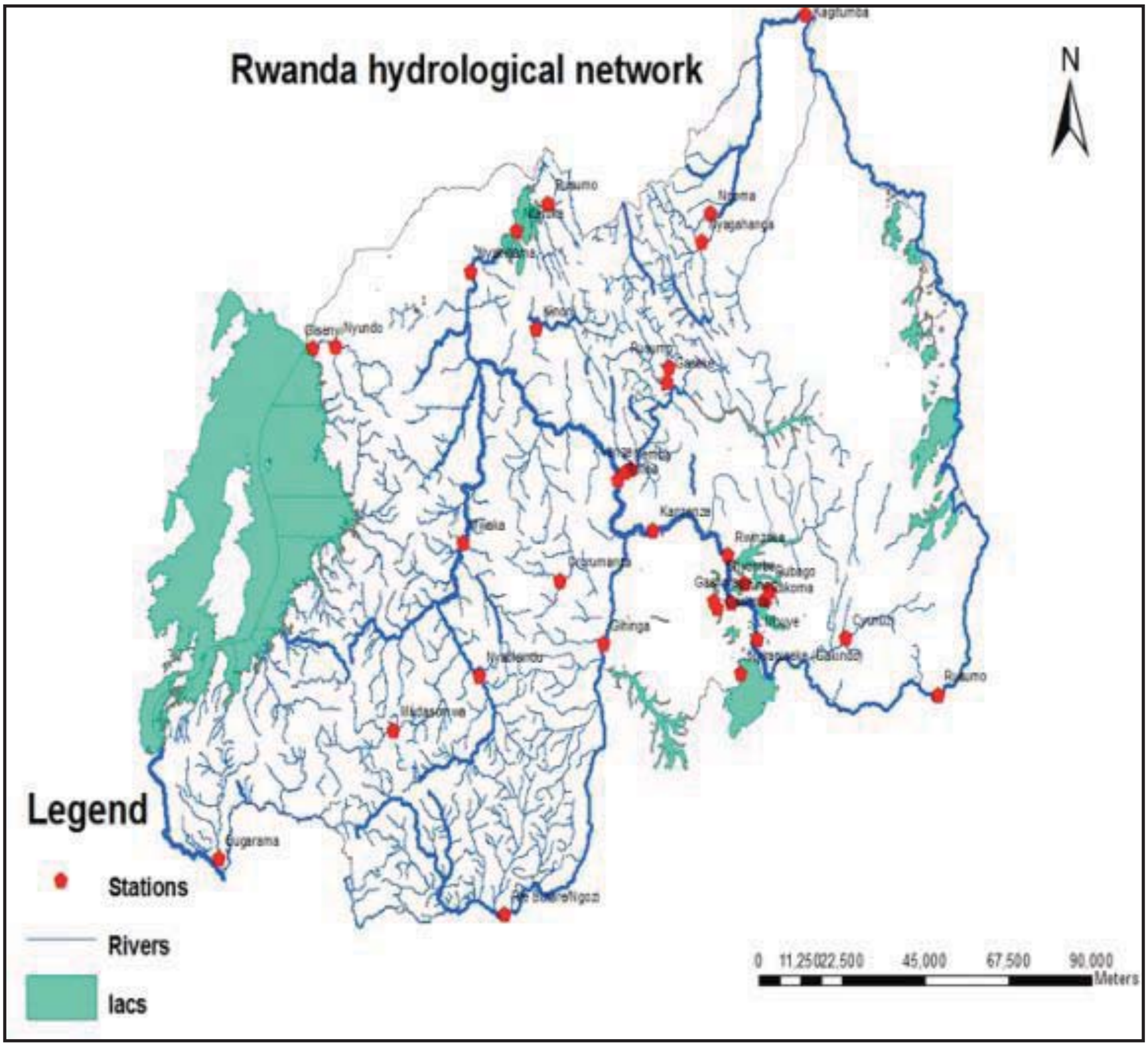
**4.0 Hydrologic Network**

The Rwanda Natural Resources Authority maintains an operational network of 41 hydrometric stations, 10 of which measure lake levels. Before 1990 there were some 68 hydrological stations in the country.

The network provides manual water level observations three times per day at 08:00, 12:00, and 17:00 local time. The manual observations are transmitted daily through telephone text messages. The observers submit hard copies of their observations to the district office in which the station is located. For the automatic stations data are collected once per month or once every two months as required.

The Rwanda Natural Resources Authority is expanding the observing network by 12 new stations and upgrading the observing network infrastructure with the installation of automatic water level instruments and data loggers. The instrumentation is supplied by OTT and consists of shaft encoders placed in a stilling well.

Vandalism is a major challenge.




**5.0 Data and Information Management**

The Rwanda Natural Resources Authority (RNRA) uses a web based system support by the Telecom service provider to archive and manage the daily SMS messages received from the field observers. These data are downloaded from the web service twice per month or more frequently as required. The data are manually reformatted and processed using Excel prior to entry in the database.

Data from the data loggers are checked for errors by comparing the logged data with manual staff gauge readings. These data are also processed in Excel prior to entry in the database.

RNRA uses an Aqualium database system for the storage of observational data. Aqualium is a simple hydrological data storage system based on MS-Access. The database is on a single desktop computer located in the open office environment. Provisions for metadata management are minimal. Backups of the database are not done due to the lack of available hardware. However, all SMS observations are archived in their original format on the Telecom's web site.

Data processing involves manual format conversion, data entry, and the computation of discharges. The computation of discharge is done using rating curves, however the rating curves require review and updating.

The data management system has very limited functionality with respect to its ability to support data analysis and interpretation. Hydrological analysis of the data requires exporting the data to other software applications such as HEC-DSSVue to analyze data and to prepare reports. A HYDRACCESS database system is being evaluated by RNRA/IWRM.

Beginning in June 2012, quarterly hydrological bulletins were produced and posted on RNRA's website as well as sent by email to key stakeholders in the water resources sector. However due to limited capability to conduct the analysis, the production of the hydrological bulletin has been stopped.

Hydrological data are available to users free of charge. Users may complete a data request form available on RNRA's website and the typical response time is three days.

### 6.0 Rwanda Environmental Management Authority

The Rwanda Environmental Management Authority (REMA) has constructed seven automatic hydrometeorological stations to support their environmental management activities as well as to support climate change studies with respect to water resources. Data communications is via GSM/GPRS.

The data collected include meteorological parameters, water level, and water temperature. REMA shares these data with others stakeholders through their web portal.

The following table provides information on the seven REMA stations.

| Station | Water Body | Province | District |
|---|---|---|---|
| Ntaruka | Ntaruka | North | Musanze |
| Sebeya | Sebeya | West | Rubavu |
| Gihinga | Akanyaru | South | Kamonyi |
| Muhembe | Muhembe | West | Ngororero |
| Bakokwe | Bakokwe | South | Muhanga |
| Iwawa | Lac Kivu | West | Rubavu |
| Mukunguri | Akanyaru | South | Kamonyi |

### 7.0 Proposed NBI Regional Hydrologic Network

As a result of the country consultation and considering the work done under the Lake Victoria Basin study for the Lake Victoria Basin Commission, a number of hydrological sites have been identified to form NBI's Regional Monitoring network for Rwanda.

The proposed NBI Regional Network consists of eight hydrologic stations in Rwanda of which seven are existing sites.

Proposed Hydrologic Stations - Rwanda
NBI Regional Network

| ID | Name | Country | Lat | Long | Elevation (m) | Basin | Status | Parameters |
|---|---|---|---|---|---|---|---|---|
| 294701 | Rusumo_Rugezi | Rwanda | -1.554 | 29.643 | 1645 | Mukungwa | Manual - Active | Water Level, Discharge, Water Quality |
| 295501 | Mwaka | Rwanda | -2.086 | 29.624 | 1511 | Nyabarongo Upper | Manual - Active | Water Level, Discharge, Water Quality |
| 270001 | Ruliba | Rwanda | -1.963 | 29.998 | 1356 | Nyabarongo Lower | Automatic - Active | Water Level, Discharge, Water Quality |
| 265701 | Gihinga | Rwanda | -2.285 | 29.966 | 1350 | Akanyaru | Automatic - Active | Water Level, Discharge, Water Quality |
| 255001 | Mfune | Rwanda | -2.206 | 30.265 | 1330 | Akagera Upper | Automatic - Active | Water Level, Discharge, Water Quality |
| 239001 | Rusumo Falls | Rwanda | -2.385 | 30.781 | 1324 | Akagera Lower | Manual - Active | Water Level, Discharge, Water Quality |
| New | | Rwanda | | | | Muvumba | new | Water Level, Discharge, Water Quality |
| 221001 | Kagitumba | Rwanda | -1.052 | 30.458 | 1291 | Muvumba | Manual - Active | Water Level, Discharge, Water Quality |
| New | | Uganda | | | | Middle Kagera | new | Water Level, Discharge, Water Quality |

RNRA noted that they are receiving some support to upgrade the hydrologic network from UNECA under the IGAD-HYCOS project. Further discussions are required with IGAD to clarify IGAD's level of support and the status of the IGAD–HYCOS project.

As well, station 265701 has a REMA auto station at the same location as RNRA hydrologic station. Further discussions to clarify access to the data and planned cooperation is required.

### 8.0 Meteorological Network

The Rwanda Meteorological Agency's mandate is to observe, record, and analyze weather and climate data and to generate forecasts and information on weather and climate conditions for Rwanda .

The conduct of surface observations follows WMO requirements and methods. The maximum and minimum temperatures as well as rainfall are observed at climate stations. For synoptic and agro stations, the data observations include rainfall, maximum and minimum temperatures, wet bulb and dry bulb temperatures, humidity, evaporation, atmospheric pressure, hours of sunshine, radiation, soil temperatures, wind speed and direction, and cloud information. There are a number of sites were only rainfall is observed.

The observational network consists of 41 automatic stations with GPRS, 5 automatic stations without telemetry, and a 100 plus auto-rainfall observing stations with GPRS. There are plans to increase the rainfall network by an additional 60 sites.

The Rwanda Meteorological Agency has real-time access to the stations installed by REMA via REMA's web portal.

The database management system currently in use is WMO's Climsoft. Climsoft is also used to encode and transmit meteorological data to WMO's Global Telecommunication System (WIS) via the Regional Telecommunication Centre.

Data is provided free of charge, however the law establishing the Rwanda Meteorological Agency allows for cost recovery in some instances.

### 9.0 Proposed NBI Regional Meteorological Network

The meteorological stations proposed for the NBI Regional Monitoring network considers the work done under the Lake Victoria Basin study for the Lake Victoria Basin Commission.

The proposed NBI Regional Network consists of twelve meteorological stations in Rwanda.

Proposed Meteorological Stations - Rwanda
NBI Regional Network

| ID | Name | Country | Lat | Long | Elevation (m) | Basin | Status | Parameters |
|---|---|---|---|---|---|---|---|---|
| 1001 | | Rwanda | -1.910 | 30.133 | 1492 | Nyabarongo | Automatic with Telemetry | Wind, Temp, Humidity, Barometric Pressure, Solar Radiation, Precipitation |
| 2002 | Kawangire | Rwanda | -1.824 | 30.448 | 1525 | Middle Kagera | Automatic with Telemetry | Wind, Temp, Humidity, Barometric Pressure, Solar Radiation, Precipitation |
| 2004 | Nyagatare | Rwanda | -1.295 | 30.331 | 1380 | Middle Kagera | Automatic with Telemetry | Wind, Temp, Humidity, Barometric Pressure, Solar Radiation, Precipitation |
| 3003 | Karama-ISAR | Rwanda | -2.260 | 30.280 | 1335 | Nyabarongo | Automatic with Telemetry | Wind, Temp, Humidity, Barometric Pressure, Solar Radiation, Precipitation |
| 3005 | | Rwanda | -1.620 | 30.200 | 2012 | Middle Kagera | Automatic with Telemetry | Wind, Temp, Humidity, Barometric Pressure, Solar Radiation, Precipitation |
| 3010 | | Rwanda | -1.480 | 29.750 | 1777 | Nyabarongo | Automatic with Telemetry | Wind, Temp, Humidity, Barometric Pressure, Solar Radiation, Precipitation |
| 3013 | Muramba | Rwanda | -1.765 | 29.613 | 1835 | Nyabarongo | Automatic with Telemetry | Wind, Temp, Humidity, Barometric Pressure, Solar Radiation, Precipitation |
| 7014 | | Rwanda | -2.260 | 30.650 | 1598 | Middle Kagera | Automatic with Telemetry | Wind, Temp, Humidity, Barometric Pressure, Solar Radiation, Precipitation |
| 7045 | Byimana | Rwanda | -2.160 | 29.740 | 1772 | Nyabarongo | Automatic with Telemetry | Wind, Temp, Humidity, Barometric Pressure, Solar Radiation, Precipitation |
| 7049 | Cyanika | Rwanda | -1.380 | 29.740 | 2011 | Nyabarongo | Automatic with Telemetry | Wind, Temp, Humidity, Barometric Pressure, Solar Radiation, Precipitation |
| 7050 | Rwerere | Rwanda | -1.490 | 29.860 | 2210 | Nyabarongo | Automatic with Telemetry | Wind, Temp, Humidity, Barometric Pressure, Solar Radiation, Precipitation |
| 7061 | Murambi | Rwanda | -2.180 | 29.580 | 1647 | Nyabarongo | Automatic with Telemetry | Wind, Temp, Humidity, Barometric Pressure, Solar Radiation, Precipitation |

Further review and feedback from the Rwanda Meteorological Agency is required to confirm the suitability of the proposed sites.

### 10.0 Water Quality Monitoring

The Rwanda Natural Resources Authority with assistance from the University of Rwanda conducts water quality monitoring at 46 sites three times per year. The core program is at existing hydrologic sites and at locations where water quality is of concern. The non-hydrologic sites are near water treatment plants, critical industrial areas, and flood prone zones.

Field sampling is conducted using field water quality test kits and portable water quality meters. Some field samples are collected and analyzed at the University of Rwanda's water quality laboratory.

Water quality data are stored as excel files.

Water quality data are compiled as an annual status report and these reports are made available free of charge to researchers and stakeholders.

Two water quality stations are proposed under the NBI Regional Network. The monitoring points are at hydrological stations 270001 near Kigali and 239001 near Rusumo Falls.

### 11.0 Groundwater Monitoring

Groundwater extraction is a common source of water supply for urban areas and is being expanded as a urban water supply. However, a groundwater monitoring program does not exist in Rwanda.

### 12.0 Sediment Monitoring

There is no sediment monitoring program being conducted in Rwanda

**Annex A.5-1: Field Visits**

On August 11, 2014 field visits were conducted to the following hydrologic sites.

**1. Site 270001 - Nyabarongo River at Ruliba**

The hydrometric gauging station is situated west of Kigali within a 30-minute drive of the city centre. Access is by an all-weather road.

The gauging station is located on the left back some 100 metres below the highway bridge and consists of a recently constructed (2011) series of staff gauges and a small shelter on a stilling well with a shaft encoder and data logger. The site has one benchmark.

The range in stage is 6 to 7 metres. The lower staff gauge is unusable due to siltation and it is unclear whether the intake to the stilling well is functional due to siltation. The upper staff gauges are in excellent condition.

The shaft encoder and data logger are housed in a look-in type shelter.

The stage-discharge rating requires review and updating. The rating curve is affected by shifting sediment deposits at lower flows while the medium to upper flows are affected by changes in the channel control. However the channel control appears to very stable, as shown in the following photo looking downstream.

**2. Site 265701 - Akanyaru River at Gihinga**
The hydrometric gauging station is situated south of Kigali within a two-hour plus drive of the city centre. Access is by a 20 km gravel road branching off of the main all-weather highway near the border with Burundi.

The gauging station is a concrete well with staff gauges situated on the right bank upstream of the road bridge. All flows past under the bridge even for high flow situations. The range in stage is only 0 to 4 metres giving the significant flood plan upstream of the bridge.

The Rwanda Environmental Management Authority operates a automatic weather station at the same site and has an transducer installed in RNRA's stilling well. The data from the REMA station are reported via GPRS. However RNRA uses an observer to take readings three times per day and send the readings daily via sms.

There are no benchmarks at the site.

The stage-discharge rating requires review and updating. The rating is affected by shifting sediment deposits at lower flows while the medium to upper flows are controlled via the bridge. The following photo is looking downstream from the bridge.

# Appendix A.6.1: National Consultation and Field Visit Report for South Sudan (September 22-26, 2014)

## 1. Introduction and Background

In May, 2014 the Nile Basin Initiative (NBI) contracted with Riverside Technology to develop design specifications and an implementation plan for the Nile Basin Regional hydro-meteorological monitoring system (this assignment), including a national water resources monitoring system for South Sudan. The assignment aims to enhance Nile River basin monitoring. Enhancing the basin-wide monitoring typically addresses coverage, equipment, techniques, data acquisition and dissemination, sampling and testing, standard procedures, capacity development, cost estimates, and implementation planning.
As part of this assignment, field visits and national consultations have been organized in South Sudan during the period from September 22 to 26. The purpose of the visits is to build off the previous consultations conducted by Riverside with South Sudan representatives Simon Otoung Awikjak of the Ministry of Electricity, Dams, Irrigation and Water Resources (MEDIWR), and Edward Andrew Ashiek of the Civil Aviation Authority – Department of Meteorology. These consultations were conducted August 6-7th 2014, following the NBI Inception workshop for a regional hydro-meteorological network design. Main topics covered during the consultations included mapping of socio-economic concerns for South Sudan, an institutional questionnaire, preliminary hydrometric station network design for both the national and regional level, and a visit to the national water quality laboratory of Uganda.

The primary objective of the field visits and consultations are to gain a deeper appreciation of the current hydro-meteorological practices currently being conducted to further identify the needs of South Sudan. This involves assessing the existing technologies in use for hydrological and meteorological monitoring; and data acquisition, processing, management, and dissemination.

The sites to be visited were selected based on following factors similar to other countries for the regional design:

- *Type of station and parameters measured* - All countries have hydrometric and meteorological stations but there can be sub-categories within each based on parameters measured, recording, and transmission types. The goal is to visit a wide range of station types to gain an appreciation of the technologies in use from the most advanced to the least.
- *Likely to be part of Network* - Hydrometric stations on main river segments, of historical significance, or at key locations. All proposed hydrometric sites were identified in the initial consultations as part of the preliminary national or regional network design.
- *Ease of Access* – GIS and Google Earth were used to plot stations and identify locations nearest major roads or cities to maximize the use of time.

## 2. Hydromet Network in South Sudan

### *2.1 Status of the Hydromet Network*

The status of hydro-meteorological network situation in the Republic of South Sudan has been presented in the report on Current Status of National Hydrological Systems which was prepared by the Directorate of Hydrology and Survey of the MEDIWR for the project. Account of current monitoring network, technologies in use, method of measurements, availability of data and sources, data gaps, condition of water quality lab, data management condition and ground water is presented in this report. The mission confirmed that the report provides necessary information on the hydro-meteorological conditions. The mission also finds the five year strategic plan (2015-2019) for the development of South Sudan Meteorological Department (SSMD) provides good information on the current and future development of meteorological network.

*2.2 Ongoing and Planned Expansion of the Network*

Currently, there are initiatives running parallel that aim at improving the hydro-meteorological monitoring systems in the South Sudan. Identified initiatives include IGAD-HYCOS, Egyptian Technical Cooperation, and World Meteorological Organization (WMO). Some of the activities of these initiatives do overlap, which calls for coordination among these activities to effectively utilize available resources.

2.2.1 IGAD-HYCOS

Through the support of EU, IGAD and WMO are jointly implementing a project to provide adequate infrastructure for hydrological observations and regional cooperation in information exchange. Currently, 8 project countries are involved: Burundi, Djibouti, Ethiopia, Kenya, Rwanda, South Sudan, Sudan, and Uganda. South Sudan was admitted to IGAD in 2011.

IGAD-HYCOS is being implemented in two phases: 1) preparatory phase (with 1 year duration) and 2) implementation phase (with a duration of 33 months). The first phase has been completed and the project has started the procurement process of hardware and the data management system.

IGAD-HYCOS has proposed to upgrade 15 hydrometric stations in South Sudan for the purpose of water resources assessment, water quality monitory and to support flood forecasting (see Annex 1).

2.2.2 WMO

WMO has been assisting in drafting 5 year strategic plan for the development of SSMD. The plan outlined the future development in terms of institutional setup, human resource capacity building, weather forecast, research on climate change, and hydromet network system including data acquisition, management and dissemination. The draft plan has been finalized and submitted to WMO for approval.

2.2.3 Egyptian Technical Cooperation

In addition to the support provided for the rehabilitation of Malakal, Wau, Juba, Mongalla, and Bor, there is a plan to strengthen water quality assessment and monitoring capability of South Sudan. According to the information from the ministry, delegates from Egypt are expected to arrive in few weeks time.

2.2.4 MEDIWR

MEDIWR through its own means has procured 5 automatic hydro-meteorological equipments but have never been installed due to budget limitations for installation and to bring in qualified expert.

*2.3 Data Management*

2.3.1 Hydrometric Data

Currently, there are 5 manual hydrometric stations operational in South Sudan that are managed by the Directorate of Hydrology and Survey of MEDIWR. The stations are Juba, Mongalla, Wau, Sobat, and Malakal. According to the ministry, the Dam Implementation Unit (DIU) of Sudan installed automatic water level recorders with data logger at Nimule and Mongalla on the left back of the Bahr El Gebel (White Nile). After independence, DIU did not handover these stations and never left behind any document and data records. The status of these stations and the kind of technology used are not known. The mission team could not also verify the condition of these stations due to accessibility problem.

Gauge height reading is done twice daily at every station at 6:00 and 18:00. Previously, daily records at Wau, Malakal and Sobat were carried out by Egyptian Irrigation Mission in South Sudan. The records were then shared with the Department of Water Resources in the State. However, recently, the Government of South Sudan has made a decision for the stations to be managed by national staff.

River discharge measurements used to be done twice a week. Measurements done at Wau and Malakal stations were supported by Egyptians. But, after the conflict, the measurements have been discontinued. Juba discharge measurement stopped in 2012 due to Lack of operating cost to cover boat rental, staff transport facility, budget limitation to replace failed ADCP battery, failure of laptop and software for ADCP. At this point in time, discharge measurements are not made at any of the operational stations in the South Sudan.

Daily measured gauge heights are recorded on log book and maintained by the gauge reader. The log books are then physically sent to the Hydrology and Survey Directorate when required. There is no, as such regular set time for the collection of the log books from the observers. Most of the data available, since 2006, are in hard copy except limited records digitized and maintained in MS Excel Spreadsheets.

### 2.3.2 Meteorological Data

There are 5 synoptic meteorological stations that are operational in South Sudan managed by the Meteorological Department. These are Juba, Malakal, Wau, Raga and Renk. Two stations, namely, Bentiu and Rumbek are closed due to war in the area in 1983. The recent conflict also impacted Malakal station. Though the station is in good condition, field measurement readings are not yet started.

According to FAO annual report of 2009 on Food Security Information for Action (SIFSIA), in collaboration with Sudan Meteorological Authority, nine Automatic Weather Stations (AWS) were installed in state capitals and Yei Crop Training Center. The tenth one was planned to be installed in Nasir, Upper Nile State in 2010. During this mission, except stations at Juba Airport and Torit, the rest are not functional either due to discontinued GPRS service of Telecommunication Company or due to maintenance problem and lack of spare parts.

At all the synoptic stations, instrument measurement readings are made every 3 hours starting from 06:00 through 18:00 except Juba station which is made at every half an hour interval for aviation purposes. Observer at all stations record readings on monthly record log books. Three hourly weather records are used mainly for general weather, whereas the half hourly records are for aviation meteorology.

For the synoptic stations, field measurement records are communicated to SSMD in Juba using personal cell phones every three hours which is then recorded to manual log book. The field log books are sent from different stations at the end of every month.

At SSMD, meteorological data are stored both on hard copy and soft copy in Excel spreadsheet format. An effort was made to encode data into WMO-ClimSoft but couldn't continue using the application due to software failure. There are still data in hard copy format to be digitized.

The AWSs at Juba and Torit send data every hour. AWSs use GPRS to send data on hourly basis to http://www.fieldclimate.com/ server where data are stored and accessed. User need to register the serial number and key for a station to access data sent to the server. All data the sensor records and send can be accessed from desktop using Internet. For non-SSMD users, access to the data can be possible for online registered users at the server and need to have station serial number and key.

Meteorologists at SSMD do carry out some rudimentary trend analysis of rainfall and temperature data on decadal and monthly basis. Data from ground stations are also used for seasonal forecast which is done every three months.

*2.4 Supports to MEDIWR and SSMD*

Recently, MEDIWR and SSMD have been supported by different institutions in the area of human resources capacity building, rehabilitation of river gauging stations and procurement of meteorological equipment. Some of these supports include:

- Finish Meteorological Institute provided aviation training to SSMD staff, paid for data that was retrieved from Sudan Meteorological Authority, bought thermometer for minimum temperature measurement and barograph for the currently operational synoptic Stations.
- IGAD-ICPAC provided training to SSMD staff on seasonal forecast.
- African Center for Meteorological Application and Development (ACMAD) trained three staff from SSMD: one on Numerical Weather Prediction for 4 months, one on climate and environment for 6 months, and one on IT for 6 months.
- Through Egyptian Technical Cooperation Malakal, Wau, Juba, Mongalla, and Bor river gauging stations have been rehabilitated.

*2.5 Water Quality Laboratory*

At this time, there is no station for assessing and monitoring water quality in the south Sudan. But MEDIWR has water quality lab facility which is used for testing the quality of drinking water. The lab does own some portable field kits and other equipment for testing some of the physical, chemical and microbiological parameters. But the mission team couldn't confirm the kind of facility in the lab. The person in charge of the lab was not able to come to the lab on the date of appointment due to personal problem.

Each state also has water quality lab.

## 3. Institutional Setting

*3.1 Institutional Framework for Water Resources Monitoring*

The major institutional players in the water resources monitoring are MEDIWR, SSMD and Ministry of Environment.

The directorate of Hydrology and Survey (DHS) of MEDIWR is responsible for collection, compilation, management and dissemination of both surface and ground water data. Directorate of Water Resources Management (DWRM) is responsible for water quality monitoring.

The wetland management and development responsibility lies in the Directorate of Wetland and Biodiversity (DWBD) under the Ministry of Environment. But hydrological monitoring of the wetlands is the responsibility of DHS.

At a state level, Department of Water Resources resides in the State Ministry of infrastructure, Directorate of Water and Sanitation. The Department of Water Resources can be structured under different state ministry depending on a state institutional arrangement.

SSMD is a department under Civil Aviation Authority of South Sudan, which in turn is accountable to Ministry of Transport and Roads. If the 5 year strategic plan is approved, SSMD will be replaced by South Sudan Meteorological Service/Agency (SSMS/A).

*3.2 Data Sharing and Data Exchange Policies*

There is no as such, formal hydromet data sharing mechanism in place both at the ministry and meteorological department, but users can make written requests to get available digital data and hard copy. Users are not charged on any data receipt.

Water Information Management System (WIMS) portal were used to share data on the location of water points (boreholes, springs, hand dug wells, etc.) but the web portal is currently off line due to Internet connection problem. Service agreement between the ministry and telecommunication company expired and has never been renewed due to lack of budget.

The SSMD is, however, working on the formulation of data sharing policy and planning to charge data users.

Seasonal forecast and severe weather warnings are communicated to government institutions like Ministry of Agriculture, Forestry, Cooperative and Rural Development; Ministry of Gender, Child, Social Welfare and Disaster Management; Ministry of Environment; NGOs and UN Agencies like FAO, UNDP, etc. by email. To also broadcast weather forecast and actual ground weather records, SSMD is discussing with South Sudan radio and TV.

Rainfall and temperature data are sent to Climate Prediction and Applications Center (ICPAC) of IGAD for climate watch bulletin in Nairobi and weather forecasts are sent to Singapore Met center for transmission to the global network.

## 4. Field Visits

On the first day of the mission to South Sudan, the team consulted with the acting undersecretary for the Directorate of Water Resources and Irrigation and relevant staff members of the ministry, and representative from the meteorological Department. The proposed itinerary for the consultation and field visit was presented to the ministry and discussed upon. Concerns were raised from the ministry on the field visit as all the selected sites are only from one sub-basin, while the other three will not be covered. In response to this concern, the following points were discussed and agreed upon:

- The team explained that the ministry can suggest other sites of interest which can be covered with in the duration of the mission. Moreover, it was further reiterated that the purposes of visiting representative sites are to understand the current hydro-meteorological technologies in use, how discharge measurements are made, how data are acquired, processed, managed and disseminated within South Sudan. At this point, it was agreed that the mission team and representatives from the ministry and meteorological department can continue with the proposed itinerary.
- For areas in the other sub-basins, which need further consideration, Nile-SEC representative suggested to look into options of planning another mission for longer period of time to address the request of the ministry.

As planned and agreed upon schedule, the team could able to conduct field visits to Mongalla, Nimule and Juba hydromet stations. Visit to Kennite at Torit or Yei was cancelled due to rough road condition. Travelling to these areas requires two days. To gain more understanding about the data management and institutional issues, the team decided to do more consultation at the ministry than spending two days out in the field. Aswa station was not also visited due to time constraint. It was already late to go to the far site downstream of the bridge on the Juba-Nimule highway. The site is not accessible by car and travelling to the site on foot requires more than an hour walk (nearly 7 Km – round trip).

The following list provides the name of sites and date of visits:

- Juba Airport Manual Synoptic Station and AWS (22 September 2014);
- Bahr El Gebel (White Nile) at Juba water treatment station (22 September 2014);
- Bahr El Gebel (White Nile) at Mongalla (23 September 2014);
- Bahr El Gebel (White Nile) at Nimule (24 September 2014);

The findings of the field visits are presented in Annex 2.

## 5. Gaps and Challenges

<u>Hydrometric</u>

- Intermittent data records at Malakal, Wau and Sobat due to conflict.
- Rehabilitation of historically existing stations and implementation of new stations could not be possible due to financial constraint. Budget and transportation facility are also not available for the staff of the ministry to do the rehabilitation within their technical capacity.
- In addition to budget constraints, the geographic distribution of the gauging stations in the country and the prevailing poor road conditions, pose serious challenges to assess the status of the stations.
- The need of training in the use and maintenance of high-tech instruments like ADCP.
- Lack of data management system that handles hydrological time-series data.
- Lack of ground water monitoring stations.
- No station for water quality and sediment monitoring.
- In spite of the vast amount of wetland, there is no single monitoring site in the country. There is also no clear institutional arrangement among the different parties responsible for the management of wetlands (Ministry of Environment, Ministry of Wild Life conservation and Tourism, MEDIWR, and other users like Ministry of Animal Resources and Fisheries).
- The status of automatic water level recorders installed by the DIU is not known. The mission team couldn't also visit the instruments as it required crossing River Nile by boat which was not available during the visit.

<u>Meteorological</u>

- Office space is not sufficient to accommodate all the staff. All the staff members: observes, forecasters, meteorologists, administrator, including the director and deputy director are accommodated in a small room.
- Their challenges are immense in terms of shortage of trained manpower (for instance for all 10 AWSs implemented in the country, there is only one person who can maintain the system), vehicles for field visits, computers, office equipment, etc).
- No sufficient budget to purchase equipment to rehabilitate non-operational stations and establish new station.
- Low awareness level in the country on the use of meteorological data.
- Lack of metrological data in quality and quantity.
- Facilities for real time data collection processing and dissemination systems are lacking.

**Annex A.6.1-1: Proposed IGAD-HYCOS Hydrometric Stations in South Sudan**

| No. | Station Name | Longitude | Latitude | Station Purpose |
|---|---|---|---|---|
| 1 | Nimule | 31.98270 | 3.62020 | WRA, WQ |
| 2 | Mongalla | 31.74810 | 5.19270 | WRA, WQ |
| 3 | Wau | 27.99400 | 7.69080 | WRA, FF |
| 4 | Malakal | 31.67700 | 9.55380 | WQ, WRA |
| 5 | Doleib Hill | 31.62910 | 9.29560 | WRA, FF |
| 6 | Renk | 32.68740 | 11.51880 | WRA,FF |
| 7 | Jikou | 33.81890 | 8.42660 | WQ, WRA |
| 8 | Bor | 31.49970 | 6.21400 | FF, WRA |
| 9 | Bentiu | 30.32650 | 9.19520 | WQ, FF |
| 10 | Juba | 31.51350 | 4.61300 | FF, WRA |
| 11 | Pibor | 33.81569 | 6.36944 | WRA, FF, WQ |
| 12 | Pagarau | 30.40759 | 6.73869 | WRA, WQ |
| 13 | Raga | 25.68064 | 8.45990 | WRA, WQ |
| 14 | Phom El- Zeraf | 31.15368 | 9.40966 | WRA, WQ, FF |
| 15 | Shambe | 30.77707 | 7.10409 | WRA, WQ, FF |

WRA – Water Resources Assessment
WQ – Water Quality
FF – Flood Forecasting

**Annex A.6.1-2: South Sudan Field Visit Report**

**1. Juba Airport Manual Synoptic and AWS Stations (22 September 2014)**

General Station Information

| | | | |
|---|---|---|---|
| Station Code | | AWS: 00000968 | Synoptic: |
| Purpose of Station | | For monitoring climatic parameters and aviation meteorology | |
| Latitude | | AWS: 4°52'11.39"N | Synoptic: 4°52'1.92"N |
| Longitude | | AWS: 31°36'7.06"E | Synoptic: 31°36'1.12"E |
| Elevation | | 460 m | |
| Start year | | AWS: 2009 | Synoptic: 1925 |
| Equipped with | Synoptic | ✓ Wind vane – operational<br>✓ Manual rain gauge – operational<br>✓ Automatic rain gauge – non-operational due to maintenance problem. Abandoned long time ago.<br>✓ Thermometers for<br>• Minimum and maximum temperature<br>• Soil temperature at three depths<br>• Wet and Dry Bulb<br>✓ Campbell sunshine hours duration recorder | |
| | AWS sensors | ✓ Solar radiation<br>✓ Wind direction<br>✓ Precipitation<br>✓ Wind speed<br>✓ Leaf Wetness<br>✓ HC air temperature<br>✓ HC Relative humidity<br>✓ Dew Point<br>✓ Air Pressure | |
| Observer present | | Yes | |
| Status | | Operational | |
| Distance to Head Office | | At the head office | |

Site Description

The synoptic weather station is located just very close to the flight monitoring tower where SSMD office is. The site is located in a place that can be easily flooded during rainy season. See the photo on the right that shows soil thermometers flooded during the visit. The AWS is installed very close to the runway in an open grass land (see Google map below).

General Site Map


Station Photos

**Juba Airport synoptic station**

**Juba Airport AWS**

Status Report and Comments

The synoptic station is poorly maintained. It is not protected by fence (look photo above). In the south-east side, the site is not visible due to bushy tree and tall grasses which can easily obstruct the incoming wind in that direction. This can easily give faulty wind speed readings. The station ground has marshy behavior during the rainy season. At the time of visit, the ground around the soil temperature measuring thermometers was flooded which may also give faulty reading.

The AWS is operational and is in good condition. The equipment is supplied by METO Pessl Instruments under FAO project called Food Security Information for Action. It is equipped with GSM/GPRS telemetry facility which transmits data to the server located outside of South Sudan and can be accessible via Internet at http://www.fieldclimate.com.

The location of both synoptic and AWS stations are inappropriate. Both of them need to be relocated.

**2. Bahr El Gebel (White Nile) at Juba water treatment plant (22 September 2014)**

General Station Information

| | |
|---|---|
| Station Code | |
| Purpose of Station | Water level and discharge monitoring |
| Latitude | 4°50'54.57"N |
| Longitude | 31°37'14.64"E |
| Elevation | 460 m |
| Period of Record | 2007 – 2012 for discharge measurement<br>Started on June 1924 |
| Equipped with | Staff Gauges |
| Observer present | Yes |
| Status | Operational |
| Distance to Head Office | Located in Juba few kilometers from MEDIWR |

General Site Map


Gauging Stations at Juba Water Treatment Plant

Site Description

Juba discharge measurement site is located just downstream of the bridge. The site is well accessible but measurement discontinued since 2012.

The Juba water level gauging stations are located at the Juba water treatment plant, which is well secured and easily accessible. The gauging stations are located on the left bank of a branch from the Bahr El Gebel (White Nile). The station at the pumping site was installed by the Dam Implementation Unit of Sudan before independence. This station is not currently in use.

The other station upstream of the pumping site is currently operational. The right bank is characterized by the presence of large trees, while the left bank is full of tall water weeds. The passage way to the gauging staff is cleared off water weeds.

Station Photos

Staff gauges

Downstream Benchmark

Silted up staff gauge

**Gauging Station Implemented by DIU**

Existing Instruments and Equipment

The DIU implemented staff gauges are metallic while the staff gauges of station upstream of the pumping site are made of marble. Measurement graduations are inscribed on the marble plates. The marble plates are supported by brick wall.

Status Report and Comments

The Juba water level gauging stations at the water treatment plan are located in a secure and ideal place. The station upstream of the pumping station requires rehabilitation. Silt deposits around some of the stages of staff gauge should be cleared.

There were three reference benchmarks (upstream, middle and downstream) for the station upstream of the pumping site. The upstream and middle benchmarks were removed while the downstream benchmark still exists.

### 3. Bahr El Gebel (White Nile) at Mongalla (23 September 2014)

General Station Information

| | |
|---|---|
| Station Code | 162 |
| Purpose of Station | Water level monitoring |
| Latitude | 5°11'56.44"N |
| Longitude | 31°46'2.70"E |
| Elevation | 435 m |
| Period of Record | Started in 1905 |
| Equipped with | Staff Gauges and *"Automatic Water Level Recorder"* |
| Observer present | Yes |
| Status | Operational |
| Distance to Head Office | 75 km - 3 hours and 30 minutes drive |

General Site Map



**Gauging Station at Mongalla**

Site Description

Mongalla station is located on the right bank of Bahr El Gebel (White Nile). The surrounding of the station is covered by short water weeds. The left bank is covered by few trees and tall grasses. The station can be easily accessible and the access is also used by the local people to cross the river to the other side using locally made wooden boats. Little area of the left bank at the gauging station is exposed to scouring.

The road from Juba to Mongolia is heavily damaged and driving to this site takes nearly 3 hours and 30 minutes. The distance from Juba to Mongalla station is 75 km.

Station Photos

Observer reading staff gauge during visit

Benchmark

Staff gauge

Downstream view of the station

Access to the station

Existing Instruments and Equipment

According to the staff of the ministry and the gauge reader at Mongalla, the DIU installed automatic water level recorder with data logger on the left bank of the river. At the time of field visit, it was not possible to verify. The team couldn't get safe boat to cross the river.

The staff gauges installed at the station are made of marble. The inscription on the marble plates and the way they are fixed on brick wall are quite the same as Juba station and other stations too.

Status Report and Comments

The status of automatic water level recorder mentioned above is not known. The ministry has not yet assessed the station. The manual station requires rehabilitation.

**4. Bahr El Gebel (White Nile) at Nimule (24 September 2014)**

General Station Information

| | |
|---|---|
| Station Code | 163 |
| Purpose of Station | Water level and discharge monitoring |
| Latitude | 3°36'26.71"N |
| Longitude | 32° 1'28.23"E |
| Elevation | 605 m |
| Period of Record | Started in 1905 |
| Equipped with | Staff Gauges and "*Automatic Water Level Recorder*" |
| Observer present | Yes |
| Status | Non-operational |
| Distance to Head Office | 195 km |

General Site Map


**Gauging Station at Nimule located in the Nimule National Park**

Site Description

Nimule station is located on the right bank of Bahr El Gebel (White Nile). The station area is totally covered by water weeds and grasses. The cable way structure on the right bank is covered by bush (see photo below). The left bank is also covered completely and any structure on that side is hardly noticed. Automatic water level was installed on the left bank by DIU and no one knows the status of this instrument.

The station can be accessible by car from Juba-Nimule high way junction to 2/3 way to the station and then by foot.

Station Photos

**Location of discharge measurement and staff gauge**

**Staff gauge**

**Cable way structure covered by bush** **Another Cable way pulley covered by tall weeds**

Existing Instruments and Equipment

According to the staff of the ministry, the DIU installed automatic water level recorder with data logger on the left bank of the river. At the time of field visit, it was not possible to verify due to accessibility problem.

The staff gauges installed at the station are made of marble. The inscription on the marble plates and the way they are fixed on brick wall are quite the same as Juba station and Mongalla stations.

Status Report and Comments

The status of automatic water level recorder mentioned above is not known. The ministry has not yet assessed the station. The station is not operational.

# Appendix A.6.2: Field Visit Report for South Sudan (November 18-28, 2014)

## 1. Introduction and background

In May, 2014 the Nile Basin Initiative (NBI) contracted Riverside Technology Inc., to Develop Design Specifications, Phased Implementation Plan, and Tender Documents for Enhancing Nile River Basin Monitoring System and National Water Resources Monitoring System for South Sudan under World Bank Grant #NBTF13767. The undertaking aims to enhance Nile River basin monitoring. Enhancing basin-wide monitoring typically addresses improved coverage, formulation of proposals for appropriate equipment and techniques, data acquisition and dissemination, sampling and testing, standard procedures, capacity development, cost estimates, and implementation planning.

As part of this assignment, field visits and national consultations had previously been organized in South Sudan from 22nd to 26th September 2014. These were conducted by Mr Tadesse Mulugeta. A second set of field activities was scheduled with a view to increase countrywide coverage of surveyed stations from 18th to 28th November 2008. These have been conducted jointly by the representative of Riverside, and officials from NBI and South Sudan. In a planning meeting held between the South Sudan officials from the Directorate of Water Resources and Irrigation in the Ministry of Electricity, Dams, Irrigation and Water Resources (MEDIWR), a tentative program of field visits consultations was agreed upon. The actual implementation of the scheduled visits changed due to circumstances dictated by availability of domestic flights and limitations imposed by logistical arrangements. The itinerary of field trips and consultations is tabulated below (Table 1):

Table 1: Activity schedule

| Itinerary or consultation activity | Duty station or site visited | Dates implemented | Resource persons involved |
|---|---|---|---|
| Travel from Entebbe to Juba. Planning meeting and briefing from Dr. Mohsen on planned schedule of visits. | - | Afternoon of Tuesday 18th November 2014 | Dr. Mohsen Alarabawy<br>Mr S. Kizzy<br>Eng. Benon Zaake |
| Travel from Juba to Mongalla by boat to check automatic transmission hydrometric station | Mongalla hydrometric station along the Bahr el Jebel | Morning of Wednesday 19th November 2014 | Eng. Deng Santino<br>Dr. Mohsen Alarabawy<br>Mr S. Kizzy<br>Eng. Benon Zaake |
| Planning meeting | MEDIWR Irrigation Master Plan Development Office in Juba | Afternoon of Wednesday 19th November 2014 | Eng Simon Otoung<br>Eng. Deng Santino<br>Eng. Robert Zakayo<br>Eng. Gai Simon<br>Dr. Mohsen Alarabawy<br>Mr S. Kizzy<br>Eng. Benon Zaake |
| Logistical preparations and planning meeting for travel to Wau | MEDIWR Irrigation Master Plan Development Office in Juba | Thursday 20th November 2014 | Under Secretary<br>Eng Simon Otoung<br>Eng. Deng Santino<br>Eng. Robert Zakayo<br>Eng. Gai Simon<br>Dr. Mohsen Alarabawy<br>Mr S. Kizzy<br>Eng. Benon Zaake |

| Itinerary or consultation activity | Duty station or site visited | Dates implemented | Resource persons involved |
|---|---|---|---|
| Travel from Juba to Nimule by road | Kit 1 | Friday 21st November 2014 | Eng Simon Otoung<br>Eng. Robert Zakayo<br>Eng. Gai Simon<br>Dr. Mohsen Alarabawy<br>Eng. Benon Zaake |
| | Aswa before confluence with Nile | | |
| Travel from Nimule to National Park | Nimule hydrometric station along the Bahr el Jebel | Saturday 22nd November 2014 | Eng Simon Otoung<br>Eng. Robert Zakayo<br>Eng. Gai Simon<br>Dr. Mohsen Alarabawy<br>Eng. Benon Zaake |
| Travel from Nimule to Torit | Kennite at Torit | | |
| Travel from Torit to Juba | - | Sunday 23rd November 2014 | Eng Simon Otoung<br>Eng. Robert Zakayo<br>Eng. Gai Simon<br>Dr. Mohsen Alarabawy<br>Eng. Benon Zaake |
| Report writing | - | Monday 24th November 2014 | Eng. Benon Zaake |
| Report writing | - | Tuesday 25th November 2014 | Eng. Benon Zaake |
| Travel from Juba to Wau | Nango Halima station – Bussary river in Western Bahr el Gharzal State | Wednesday 26th November 2014 | Eng Deng Santino<br>Eng. Robert Zakayo<br>Eng. Gai Simon<br>Dr. Mohsen Alarabawy<br>Eng. Benon Zaake |
| | Sue river | | |
| Travel from Wau to Tonj and back to Wau | Tonj bridge – River Tonj in Warrap State | Thursday 27th November 2014 | Eng Deng Santino<br>Eng. Robert Zakayo<br>Eng. Gai Simon<br>Dr. Mohsen Alarabawy<br>Eng. Benon Zaake |
| | Wau bridge - River Wau in Western Bahr el Gharzal State | | |
| Travel within Wau town | Wau meteorological station | Friday 28th November 2014 | Eng Deng Santino<br>Eng. Robert Zakayo<br>Eng. Gai Simon<br>Dr. Mohsen Alarabawy<br>Eng. Benon Zaake |
| Travel from Wau to Juba | Wrap up | | Eng Deng Santino<br>Eng. Robert Zakayo<br>Eng. Gai Simon<br>Dr. Mohsen Alarabawy<br>Eng. Benon Zaake |
| Travel from Juba to Entebbe | End of Mission | Saturday 29th November 2014 | Dr. Mohsen Alarabawy<br>Mr S. Kizzy<br>Eng. Benon Zaake |

According to the TOR, the Consultant was required to participate as Riverside's representative in conducting field visits in South Sudan to assess institutional and infrastructure status of hydrometric monitoring and meteorological monitoring. The Consultant was required to document the field visits, including the following:

1. Dates and sites visited, with latitude and longitude coordinates of station locations;
2. Photographs of the site, including infrastructure, measurement equipment, sensors, site layout, upstream and downstream river reaches at hydrometric sites, etc.;

3. Description of site, including historical information and site characteristics that might be provided by a local observer or by national staff;
4. Assessment of the suitability of the site for meteorological measurements or for hydrometric measurements, including both water level and discharge (by wading or from a cableway) and assessment of security situation at the site and vandalism risks;
5. Assessment of rehabilitation requirements at the site;
6. Other observations pertinent to the study

This report constitutes the consultation report for the second round of field surveys undertaken in accordance to the itinerary previously outlined. The report is organized as follows:

Chapter 1 presents the background as indicated. Chapter 2 is a brief discussion of the institutional issues that have a bearing on the current status of hydrometric and meteorological monitoring infrastructure in South Sudan. Chapter 3 describes in detail the actual observations and documentation made during the field visits in line with Tasks 1 – 6 of the TOR.

## 2. Institutional issues

The Republic of South Sudan is administered in accordance to 10 administrative states corresponding to the three historical regions of South Sudan: Bahr el Ghazal, Equatoria, and Great Upper Nile. The regions and states, respectively, are Eastern Equatoria, Central Equatoria, Western Equatoria, Lakes - Bahr el Ghazal, Western Bahr el Ghazal, Northern Bahr el Ghazal, Warrap, Jonglei, Unity and Upper Nile. The 10 states are further subdivided into 86 counties, and the counties are further subdivided into payams (subcounties) and bomas (villages).

The Ministry of Electricity, Dams, Irrigation and Water Resources (MEDIWR) in South Sudan is the focal point agency for hydrometric monitoring and water resources management at national level. Within the Ministry, the Directorate of Hydrology and Survey is responsible for hydrological surveys while the Directorate of Water Resources Management (WRM) is mandated to undertake water quality monitoring.

Four administrative states were visited during this round of consultations. These are Central Equatoria, Eastern Equatoria, Eastern Bahr el Ghazal and Warrap state. In each of these states, it was found that the Department for Water Irrigation and Resources is under the jurisdiction of the State Ministry of infrastructure in the Directorate of Water and Sanitation.

The report on current status of hydrological monitoring in South Sudan, issued by the Directorate of Hydrology and Survey, indicates that levels of water in rivers in South Sudan are mainly measured by staff gauges. The gauges consist of a scale usually of marble, on which the level of water is detected. The standard type of concrete or brickworks, stones works of the river gauge consists of a series of steps to each of which a section of the scale of marble is fixed. These steps are built into the river bank and the scale is protected by using walls to reduce the effect of the waves and so make it easier to observe. As a rule gauge height reading is done twice or thrice daily at every station by river technicians or gauge readers and recorded in a gauge form (Figure 1). The log books are then physically sent to the Hydrology and Survey Directorate when required. There is no, as such regular set time for the collection of the log books from the observers.

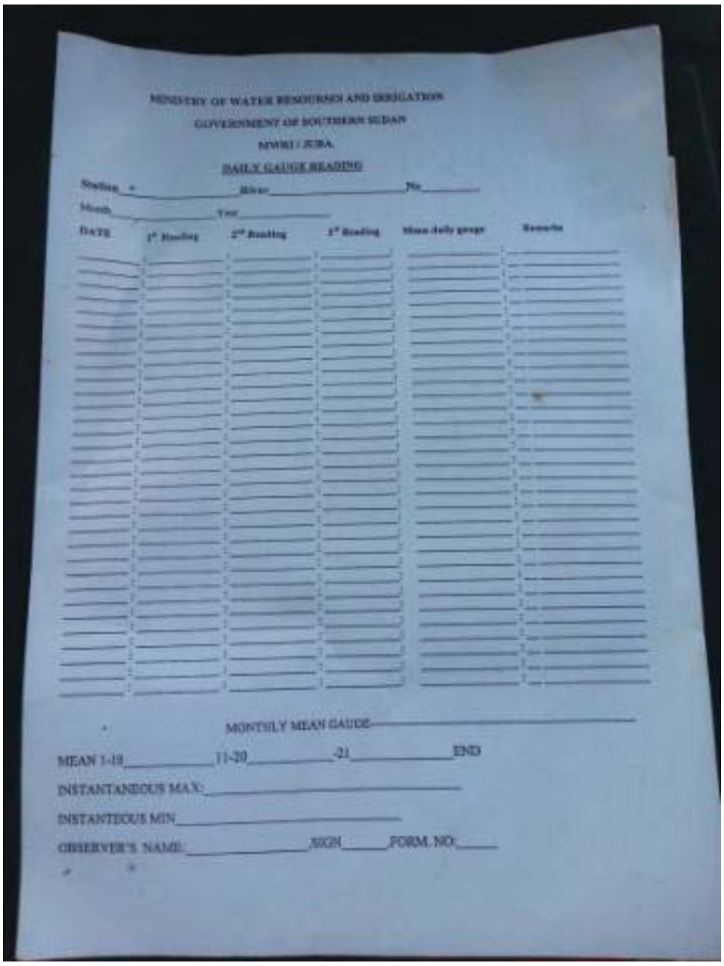



Figure 1: Gauge recording form utilized by MEDIWR

Measurements done at Wau are currently supported by the Egyptian Irrigation Mission.

## 3. Field observations and consultation findings

Field observations and details regarding the consultation visits are presented serially in accordance to stations visited below.

### 3.1 Mongalla hydrometric station along the Bahr el Jebel

Mongalla is a key reference station that has been utilized in the past to quantify outflow below the Equatorial Lakes and inflow into the Sudd. Measurements at this key station were initially made by the Physical Department of Egypt during the period 1904 to 1957. Discharge measurements were established with the aid of cableways, and rating curves were derived to convert records of river gaugings to discharges. The data was published in successive volumes and supplements of the Nile Basin (Sutcliffe and Parks, 1999). Due to political instability in Southern Sudan in 1983, flow measurements at Mongalla were suspended. Measurements were resumed after the conflict by the Dam Implementation Unit of Sudan. An "Orpheus" Pressure Transducer Automatic Water Level Recorder (AWLR) was installed at this station to supplement the Nilometers under support from the FAO Nile Basin Water Resources Project (Figure 2).

The FAO Nile Basin Water Resources Project piloted the use of electronic sensors connected to a datalogger as it considered that the technology facilitates automating data processing, which often forms the main obstacle in database development. Another major benefit is the possibility to acquire a continuous set of sub-daily data values.


Figure 2: Location of OTT automatic water level recorder at Mongalla – left bank of the Bahr el Jebel

Orpheus measures changes in water levels using an electronic sensor, and then stores this data in the logger's non-volatile memory. The records are retrieved using: (a) a laptop PC, or (b) the OTT VOTA data retrieval unit. Orpheus is used as a stand-alone device for recording water levels. The components of the Orpheus are:

**Pressure Transducer Integrated with Datalogger**: Orpheus consists of a pressure transducer sensor integrated with datalogger (with 128kb storage capacity of upto 52000 measuring values) via a pressure probe cable. The pressure transducer is installed in a stilling well with the datalogger installed on a secure place away from the water (Figures 3 and 4).

**Standard Logistics Unit:** This unit enables communication between the datalogger and the VOTA and/or PC, and provides the power supply of the Orpheus. The standard logistics unit is a plastic housing, which consists of a 6 volts power supply unit, terminal strip for pressure probe cable, an optical interface for data readout, pressure probe cable, cable suspension clamp and a reusable silica-gel cartridge for moisture absorption. The power supply unit needs commonly available 4 x 1.5V type-C batteries.

**Data Retrieval Unit:** Data is retrieved using either a laptop PC or an OTT VOTA. The VOTA is a ruggedized data programming/retrieval unit for use in the field. Its design is based on PC technology, and its software is pre-installed. Primary data processing can be done in HYDRAS 3: a proprietary software package specifically developed by OTT for this purpose. The process includes converting raw data files into ASCII text files. Secondary data processing involves importing the ASCII data files into an MS Access database.

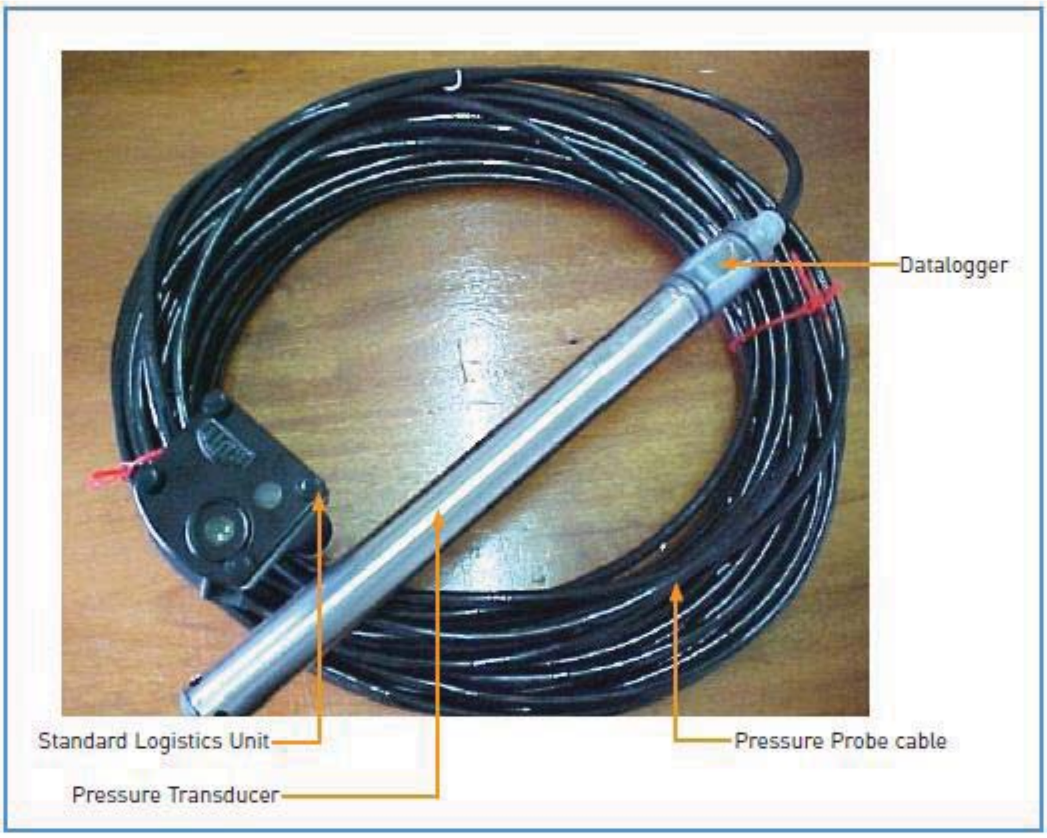



Figure 3: Data logger housing

Figure 4: Orpheus with integrated data logger and standard logistics unit

Figure 5: Upstream view of gauging section Figure 6: ADCP discharge measurement location seen from left bank

Table 2 below summarises the record of observations, assessment of site suitability and rehabilitation requirements for Mongalla.

Table 2: Mongalla

| **General station details** | |
|---|---|
| Station code/name | Mongalla |
| Purpose of station | National and Regional water level and discharge monitoring |
| Latitude | N 5°11'59.2'' |
| Longitude | E 31°45'53.9'' |
| Elevation | 435 m |
| Period of record | 1905 – 1983, sporadically between 2000 – 2011. Current method of observation is by manual recording of gauge levels on gauge forms |
| Measurement equipment and sensors | 3 Gauge pillars (Nilometers) namely; 13, 14 and 15.<br>River Ray ADCP – (in disuse).<br><br>OTT – Orpheus AWLR (In disuse). Battery is down. Data has not been downloaded since2011. Lack of Laptop, VOTA unit and HYDRAS 3 software to download data. Housing unit not accessible due to lack of key) |
| Staffing | Mustafa is the resident gauge reader |
| **Site description** | |
| The AWLR is located on the left bank while the Egyptian constructed gauge pillars (Nilometers) are located on the right bank. Figures 5 & 6 illustrate the site conditions. The easiest way to access the site is by a 2 hour round trip motorised boat drive. The river reach is a long, relatively straight, uniform, well-defined approach channel. | |
| **Assessment of suitability of site** | |
| Flow is well confined within the banks at high or low stages. Flood plain is free of swamp or marsh. Control is through straight section of river with well defined surface water slope. Downstream control is stable and the rating curves are likely to be stable. The hydraulic suitability of the site for flow measurements is very good. There are no high turbulence zones near the ADCP discharge measuring location. There are no existing structures or confluences to cause backwater effects. Although the banks would have preferably been steep, there are stable. Sediment loads are visibly low.<br><br>Discharge measurements were by ADCP e.g. twice a month but this equipment is not functional. The River ray software needs to be re-installed. Currently it is easier to access the site by boat from Juba. GSM communication is available. Gauge reader resides at station. If site is fenced vandalism risk can be minimal. | |
| **Rehabilitation requirements** | |
| Repairs to Nilometer gauge pillars required (Refer to picture inset).<br><br>Fence off entire AWLR unit. Construct secure concrete AWLR housing. Stilling well will be re-constructed to improve accessibility for maintenance and checking activities. AWLR Instrument needs to be serviced and checked to replace parts such as batteries, VOTA, software, access key. Telemetric transmission of data can be considered. | |

Standard Logistics Unit containing optical interface, humidity absorber, terminal strip, power supply, pressure probe cable must be checked to ensure it is in good working condition, at secure dry area above the maximum flood level. Servicing will also be necessary to desilt sensor unit, check sensor cable. The batteries require periodic replacement. it is recommended to check the battery status at each visit to the station to be sure of proper functioning of the Orpheus. Changing the battery at a later stage has no effect on the stored data.

Procure battery for ADCP. Download software and procure appropriate tough book and boat to facilitate regular discharge measurements. Routine maintenance of gauge pillars.
Existing benchmarks need to be levelled so as to re-establish the datums since MEDWIR has no access to previous station file history.

### 3.2 Kit1

Kit 1 is a new proposed station within the national network. Staff from MEDIWR indicated that the river was gauged in the past but did not have information regarding its past location. It is one of a few stations that can also be used to quantify torrent flows i.e. the presently un-gauged flow contribution in the area between Mongalla and the outlet of Lake Albert. The proposed location is at the bridge at Juba – Nimule road (Figure 7).


Figure 7: Kit1 bridge at Juba-Nimule Road.

Figure 8 below illustrates section downstream of the bridge. Gauging can be taken upstream of the bridge abutment.

Figure 8: Kit1 - Section downstream of the bridge.

Table 3 below summarises the record of observations, assessment of site suitability and determination of operational needs for Kit 1.

Table 3: Kit1

| | |
|---|---|
| **General station details** | |
| Station code/name | Kit1 |
| Purpose of station | National and water level and discharge monitoring |
| Latitude | N 4°12.684' |
| Longitude | E 31°59.769' |
| Elevation | 675 m |
| Period of record | Previous period of record not indicated from MEDIWR |
| Measurement equipment and sensors | Proposal is to install 3 gauge pillars and fit with AWLR. Data can be periodically downloaded on PC or VOTA unit and transferred to national or state database. |
| Staffing | A resident gauge reader is required |
| **Site description** | |
| The river reach upstream of the bridge is a long, well-defined approach channel. However, it curves further downstream. The banks are steep and stable. Flow is ephemeral. Access to the bridge is easy from Juba or Nimule by road. GSM network is readily available. Figures 7 & 8 illustrate the site conditions. | |
| **Assessment of suitability of site** | |
| Flow is well confined within the banks at high or low stages. Downstream control is stable and the rating curves are likely to reliable. The hydraulic suitability of the site for flow measurements is acceptable. The gauging station should be located further upstream to avoid high turbulence zones likely to be caused by the bridge abutment at high flow. | |

| |
|---|
| Discharge measurements can be conducted by current meter or RIVER RAY ADCP towed by rope from one side of the river bank. Discharges can be more frequently measured during the wet season (e.g. Monthly plus at least one high flow event a year) considering the ephemeral nature of flow. |
| **Station requirements** |
| Install 3 gauge pillars and fit with AWLR. The recorder will require to be housed in a secure structure fitted with a bridge platform for safety and ease of access. Benchmarks need to constructed and levelled to reference datum. |

A suitable and secure structure fitted with a bridge platform for the gauging station is illustrated under Figure 9 below. The structure should be deep enough for its bottom to be at least a foot below the minimum stage anticipated and its top above the level of the 2-percent annual-exceedance probability (50-year) flood [0.5-percent annual-exceedance probability (200-year) flood. The inside of the structure should be big enough to permit free operation of all the equipment to be installed.

Figure 9: Recommended reinforced concrete stilling well and shelter.

### 3.3 Aswa

The proposed station at Aswa is close to its confluence with the Bahr el Jebel. It has been proposed as both a national and regional station for monitoring of flows between Uganda and South Sudan. It is another of a set of a few stations that can also be used to quantify torrent flows i.e. the presently un-gauged flow contribution in the area between Mongalla and the outlet of Lake Albert. The proposed location is at the bridge along Juba – Nimule road (Figure 10).


Figure 10: Aswa mouth – upstream of bridge at Juba – Nimule road.

Figure 11 below illustrates the rock/riffle control section upstream of the bridge where a suitable gauge can be located.

Figure 10: Control section upstream of Aswa bridge.

Table 4 below summarises the record of observations, assessment of site suitability and determination of operational needs for Aswa.

Table 4: Aswa

| General station details | |
|---|---|
| Station code/name | Aswa |
| Purpose of station | National and regional water level and discharge monitoring |
| Latitude | N 3°43.380’ |
| Longitude | E 31°58.337’ |
| Elevation | 602 m |
| Period of record | 1923 – 1965 |
| Measurement equipment and sensors | Proposal is to install 5 gauge pillars and fit with AWLR. Data can be periodically downloaded on PC or VOTA unit and transferred to national or state database. |
| Staffing | A resident gauge reader is required |
| **Site description** | |
| The river reach upstream of the bridge is a long, well-defined approach channel. The banks are steep, rocky and stable. The downstream section is also straight and wide with no obstructions downstream. Hence there are potentially no backwater flow effects to interfere with potential rating. Access to the station is easy from Juba or Nimule by road. GSM network is readily available. Figures 9 & 10 illustrate the site conditions. | |
| **Assessment of suitability of site** | |
| Flow is well confined within the banks at high or low stages. Downstream control is stable and the rating curves are likely to reliable. The hydraulic suitability of the site for flow measurements is good. The gauging station should be located upstream at the control rock/riffle. The section is sufficiently far away from high turbulence zones likely to be caused by the bridge abutment at high flow.<br><br>Discharge measurements can be conducted by RIVER RAY ADCP towed by rope from one side of the river bank to the other. Discharges can be more frequently measured during the wet season (e.g. Monthly plus at least one high flow event a year) considering the nature of torrent flows. | |
| **Station requirements** | |
| Install 5 gauge pillars and fit with AWLR. The recorder will require to be housed in a secure structure fitted with a bridge platform for safety and ease of access (Figure 9). Benchmarks need to constructed and levelled to reference datum. | |

### 3.4 Bahr el Jebel at Nimule

The historical station is situated on the left bank of the Nile in Nimule national park. Currently no discharge measurements or water level readings are being taken. There is also no gauge reader. Section control is narrow and confined at the location (Figure 12). Water levels were in the past measured by the General Inspectorate of the Egyptian Irrigation Mission in the Sudan. This is evident from the dilapidated Nilometers on the right bank (Figure 13). The rusty ruins of what appears to be a cable-way are also visible in a dense enclosure of tree tops and bush on the right bank (Figure 14). Flow velocity is high at the control section and large masses of floating papyrus reeds can be seen floating past (Figure 15). The left bank can only be currently accessed by hiring a boat belonging to South Sudan Wild Life Services. The OTT Orpheus AWLR that was installed on the left bank has recently been stolen (Figure 16).


Figure 12: Nimule gauge pillar – right bank of the Bahr el Jebel in Nimule National park.

Figure 13: Nilometers on right bank

Figure 14: Remains of cable way

Figure 14: Floating debris of papyrus reeds

Figure 15: Empty recorder housing

Table 5 below summarises the record of observations, assessment of site suitability and determination of operational needs for Nimule.

Table 5: Bahr el Jebel at Nimule

| **General station details** | |
|---|---|
| Station code/name | Nimule |
| Purpose of station | National water level and discharge monitoring |
| Latitude | N 3°36.480' |
| Longitude | E 32°1.481' |
| Elevation | 616 m |
| Period of record | 1913 – 1937 |
| Measurement equipment and sensors | Proposal is to re-install 4 gauge pillars and fit with AWLR. Data can be periodically downloaded on PC or VOTA unit and transferred to national or state database. |
| Staffing | A resident gauge reader is required |
| **Site description** | |
| The river reach upstream of the bridge is a well-defined narrow approach channel. The banks are flat, giving rise to marshy conditions at high flow. The downstream section is straight with no obstructions downstream. Hence there are potentially no backwater flow effects to interfere with potential rating. Access to the station is easy from Juba or Nimule by road. GSM network is readily available. Figures 12 – 15 illustrate the site conditions. | |
| **Assessment of suitability of site** | |
| Flow is not well confined within the banks at high stage. However, the rating curves are likely to be reliable. The hydraulic suitability of the site for flow measurements is acceptable.<br><br>Discharge measurements can be conducted by an ADCP mounted to a boat. Discharges can be more measured monthly as they are likely to vary slowly along the main Nile. | |
| **Station requirements** | |
| Install 4 gauge pillars and fit with AWLR. The recorder will require to be housed in a secure structure fitted with a bridge platform for safety and ease of access (Figure 9). Benchmarks need to constructed and levelled to reference datum. An automatic weather station should be placed within the compound of Nimule National Park Wild office premises. | |

### 3.5 Kennite at Torit

This is a new station that has been proposed within the national monitoring framework. Three candidate sites were reviewed prior to making a final decision about the final location of the gauging station. These were:

(i) The bridge along Juba – Torit road (N 4°25.065’; E 32°32.158) – Figure 16.

(ii) A bridge within Torit town (N 4°24.343’; E 32°33.974) – Figure 17.

(iii) A bridge adjacent to the premises of the Ministry of Physical Infrastructure (N 4°24.062’; E 33°34.348) – Figure 18

(iv) Intake point for water supply scheme for Torit town (N 4°24.068’; E 32°34.331) – Figure 19

Figure 16: Upstream section of bridge; Juba-Torit road.

Figure 17: Bridge within Torit town.

The locations illustrated in Figures 16 & 17 were not favoured due to concerns about vandalism due to lack of proximity from the offices of the Ministry of Infrastructure. Concerns about locating these gauge station in the vicinity of a bridges likely to be demolished in the event of anticipated upgrading of road works was also a major consideration that was taken into account in ruling out the two locations. In both cases, river flow is not fully confined within the banks at high stages. It was also noted that the rating curve would most likely be poorly defined at high stage at these two candidate locations.

Figures 18 and 19 illustrate the preferred location of the gauging station. The two are in close proximity to the offices of the Ministry of Infrastructure.

Figure 18: Bridge adjacent to the premises of the Ministry of Physical Infrastructure.

Figure 19: Location of gauging station for Kennite at Torit – water intake works.

The location of the pump house (Figure 19) was favoured as the ideal location of the proposed gauging station as hydraulic conditions here are free of turbulence and backwater effects (Figure 20).


Figure 20: Pump house – intake water supply system for Torit town.

Table 6 below summarises the record of observations, assessment of site suitability and determination of operational needs for Nimule.

Table 6: Kennite at Torit

| **General station details** | |
|---|---|
| Station code/name | Kennite at Torit |
| Purpose of station | National water level and discharge monitoring |
| Latitude | N 4°24.068’ |
| Longitude | E 32°34.331’ |
| Elevation | 605 m |
| Period of record | 1923 – 1965 |
| Measurement equipment and sensors | Proposal is to install 4 gauge pillars and fit with AWLR. Data can be periodically downloaded on PC or VOTA unit and transferred to national or state database. |
| Staffing | A resident gauge reader is available |
| **Site description** | |
| The river reach at the pump house is a well-defined narrow approach channel. The banks are steep and stable (Figure 20). The downstream section is straight with no obstructions downstream. Hence there are potentially no backwater flow effects to interfere with potential rating. Access to the station is easy from Torit town. GSM network is readily available. | |
| **Assessment of suitability of site** | |
| Rating curves are likely to be well defined at high and low stages. The hydraulic suitability of the site for flow measurements is good.<br><br>Discharge measurements can be conducted by current meter or RIVER RAY ADCP towed by rope from one side of the river bank to the other. Discharges can be more frequently measured during the wet season (e.g. Monthly plus at least one high flow event a year) considering the nature of torrent flows from the mountain ranges. Sediment loads are potentially high. | |
| **Station requirements** | |
| Install 4 gauge pillars and fit with AWLR. The recorder will require to be housed in a secure structure fitted with a bridge platform for safety and ease of access (Figure 9). Benchmarks need to constructed and levelled to reference datum. | |

### 3.6 Busseri at Nago Halima

The station was omitted from either the regional or national network design. Officials from MEDIWR however attach a high priority to this station. The historical station is situated on the left bank of the river. Currently no discharge measurements or water level readings are being taken. However, the gauge reader attended the site inspection. Section control is good and well defined at the location (Figure 21).

Water levels were in the past measured by the General Inspectorate of the Egyptian Irrigation Mission in the Sudan. This is evident from a series of 5 gauge pillar Nilometers (Figure 22). Access to this site is particularly difficult as it is located in a remote area with no proper access road and no GSM network.


Figure 21: Existing gauges at Busseri River.

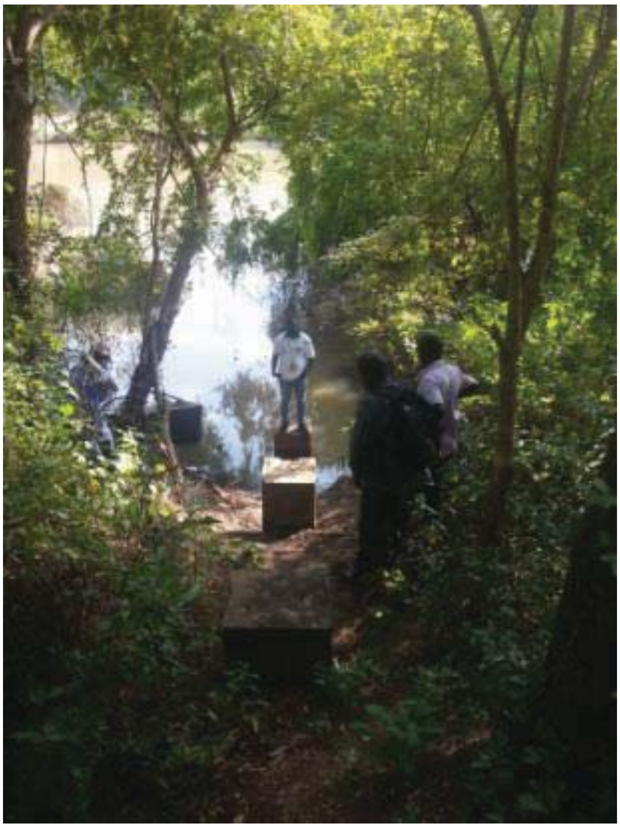


Figure 22: Gauge pillars, gauging station and existing benchmark at Nago Halima station on Busseri River.

Table 7 below summarises the record of observations, assessment of site suitability and determination of operational needs for Nago Halima station.

Table 7: Nago Halima on River Busseri

| | |
|---|---|
| **General station details** | |
| Station code/name | Nago Halima on River Busseri |
| Purpose of station | National water level and discharge monitoring |
| Latitude | N 7°31.235' |
| Longitude | E 27°55.247' |
| Elevation | |
| Period of record | 1953 – 1974 |
| Measurement equipment and sensors | Proposal is to complement existing gauges by fitting with AWLR. Data can be periodically downloaded on PC or VOTA unit and transferred to national or state database. |
| Staffing | A resident gauge reader is available |
| **Site description** | |
| The river reach is well-defined. The banks are steep and stable (Figure 20). The downstream has no obstructions downstream. Hence there are potentially no backwater flow effects to interfere with potential rating. Access to the station is difficult and there is no GSM network is readily available. Installation may be vulnerable to vandalism if not well protected. | |
| **Assessment of suitability of site** | |
| Rating curves are likely to be well defined at high and low stages. The hydraulic suitability of the site for flow measurements is good. | |

| |
|---|
| Discharge measurements can be conducted by RIVER RAY ADCP towed by rope from one side of the river bank to the other. Discharges can be more frequently measured during the wet season (e.g. Monthly plus at least one high flow event a year). Sediment loads are high. |
| **Station requirements** |
| The recorder will require to be housed in a secure structure fitted with a bridge platform for safety and ease of access (Figure 9). The gauge reader needs to be provided with a motor bike and small boat to facilitate his work. |

### 3.7 KhorNyinakok (at Nyinakok mouth with Jur)

This station was also omitted from either the regional or national network design. Officials from MEDIWR however attach a high priority to this station. The historical station was operational during the period 1953 – 1962. Currently no discharge measurements or water level readings are being taken. Assessment of current status and suitability of this site and for gauging and rehabilitation needs is not available as the site could not be reached.

### 3.8 River Sue

The historical station is situated on the right bank of the river. Currently no discharge measurements or water level readings are being taken. Section control is good and well defined at low flow but likely to be poorly defined at high stage. This is due to the fact that the left bank is a low lying flood plain with extensive reed vegetation. The approach section of the river to the gauge station meanders (Figure 23).

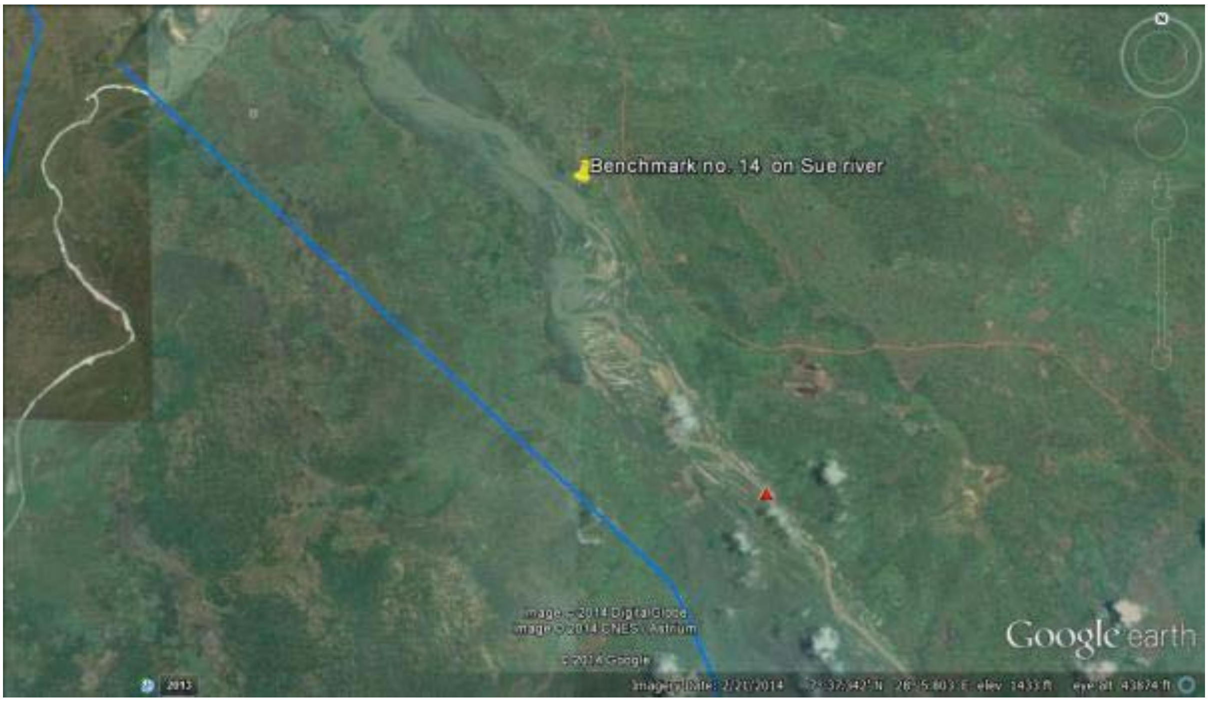



Figure 23: Sue river location of gauge pillar no. 14

Water levels were in the past measured by the General Inspectorate of the Egyptian Irrigation Mission in the Sudan. This is evident from a series of 3 gauge pillar Nilometers (Figure 24). Access to this site is relatively easy from the road to Wau, with proper access road and GSM network.

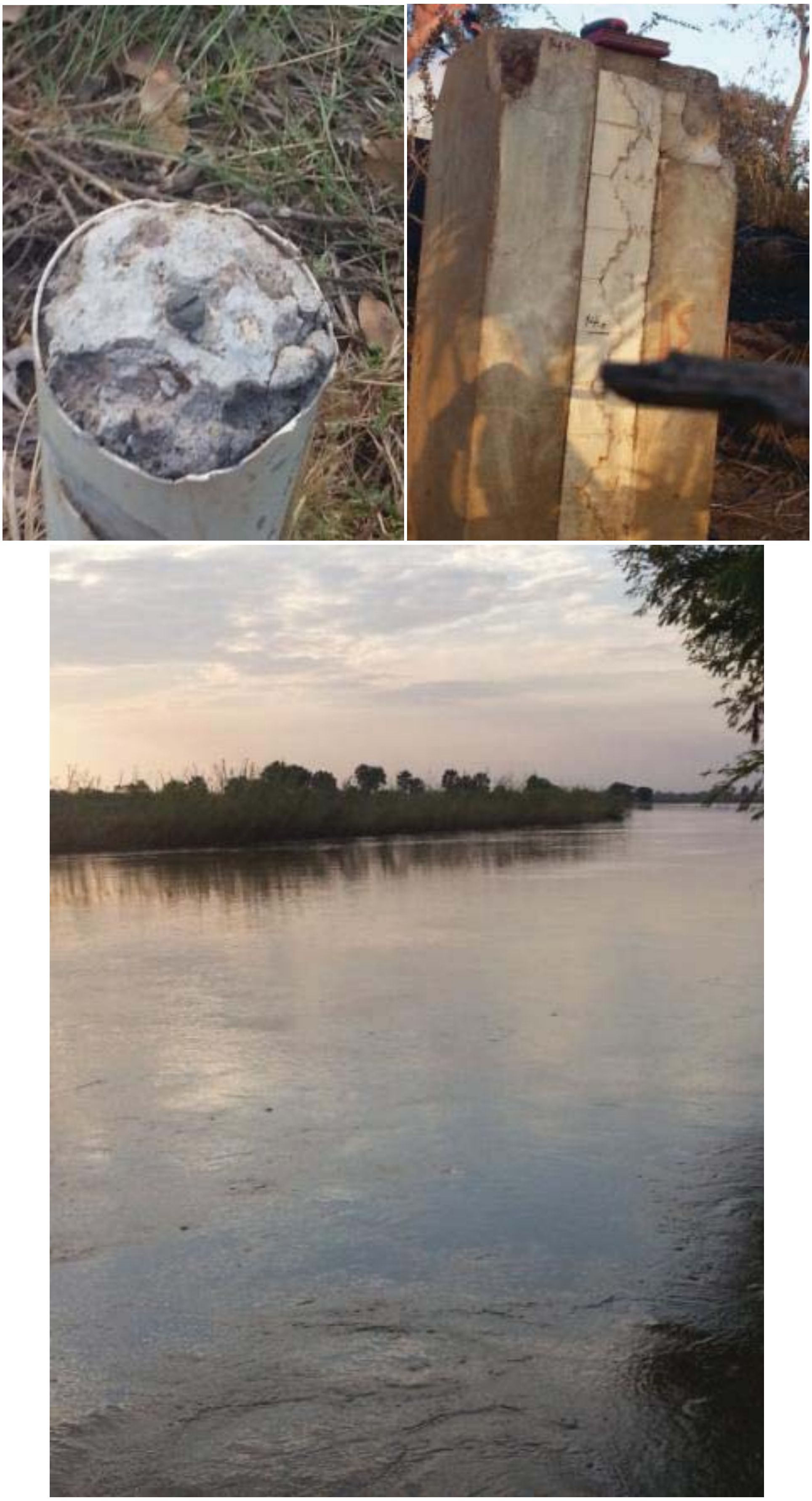


Figure 24: Benchmark, gauge pillar no. 14, and downstream view of gauging station at Sue River.

Table 8 below summarises the record of observations, assessment of site suitability and determination of operational needs for River Sue.

Table 8: Sue River

| **General station details** | |
|---|---|
| Station code/name | Sue River |
| Purpose of station | National water level and discharge monitoring |
| Latitude | N 7°38.516' |
| Longitude | E 28°05.594' |
| Elevation | |
| Period of record | 1953 – 1963 |
| Measurement equipment and sensors | Proposal is compliment existing gauges by fitting with AWLR. Data can be periodically downloaded on PC or VOTA unit and transferred to national or state database. |
| Staffing | A gauge reader is required |
| **Site description** | |
| The upstream river reach is not straight. The left bank is steep and stable but the right bank is likely to be transformed into a marshy flood plain at high stage. The section downstream of the gauge station has no obstructions. Hence there are potentially no backwater flow effects to interfere with potential rating. Access to the station is good and GSM network is readily available. Installation may be vulnerable to vandalism if not well protected. | |
| **Assessment of suitability of site** | |
| Rating curves are likely to be well defined at low stage but difficult to establish at high stage. The hydraulic suitability of the site is however, acceptable.<br><br>Discharge measurements can be conducted by RIVER RAY ADCP towed by rope from one side of the river bank to the other. Discharges can be more frequently measured during the wet season (e.g. Monthly plus at least one high flow event a year). | |
| **Station requirements** | |
| The recorder will require to be housed in a secure structure fitted with a bridge platform for safety and ease of access (Figure 9). The gauge reader needs to be provided with a motor bike and small boat to facilitate his work. Minor repairs to the gauge pillars are necessary. | |

### 3.9 River Tonj

The historical station is situated on the left bank of the river. Currently no discharge measurements or water level readings are being taken. Section control is good and well defined at the existing old bridge openings, at low flow, but evidently poorly defined at high stage. This is due to the fact that the right bank is an extensive low lying papyrus swamp. The approach and downstream sections of the river are poorly defined with several meanders (Figure 25). At the time of visit, all gauges were submerged (Figure 26).


Figure 25: Tonj river at old bridge

Figure 26: Left bank view of Tonj flood plain

Figure 27: Partial view of downstream section below bridge

Table 9 below summarises the record of observations and assessment of site suitability for River Sue. The site conditions are not conducive to realisation of good quality flow data at this site and it is not recommended to rehabilitate this station. A more suitable location should be determined. Water levels can however be routinely monitored.

Table 9: Tonj River

| **General station details** | |
|---|---|
| Station code/name | Tonj River |
| Purpose of station | water level |
| Latitude | N 7$^{o}$ 16 18 |
| Longitude | E 28 41 15 |
| Elevation | |
| Period of record | 1941 – 1963 |
| Measurement equipment and sensors | Water level gauges can be re-instated |
| Staffing | A gauge reader is required |
| **Site description** | |
| The approach and downstream sections of the river are poorly defined with several meanders. Section control is good and well defined at the existing old bridge openings (Figure 27), at low flow, but evidently poorly defined at high stage. This is due to the fact that the right bank is an extensive low lying papyrus swamp. Access to the station is good and GSM network is readily available. | |
| **Assessment of suitability of site** | |

| |
|---|
| Rating curves are likely to be poorly defined. It is possible to maintain a god record of water levels downstream of the bridge. |
| **Station requirements** |
| The gauge pillars can be reinstated. |

### 3.10 River Jur at Wau bridge

The station is operational and has been rehabilitated with support from the Egyptian Cooperation projects. It is equipped with 7 Nilometer gauges with marble scales. The upstream and downstream approach sections in the vicinity of the gauge station are straight and well defined (Figure 28).

Figure 28: Wau gauge station upstream of the bridge

Figure 29: Wau gauge location upstream of the bridge

Figure 30: Catamaran used for ADCP discharge measuring downstream of the bridge.

Table 10 below summarises the record of observations and assessment of site suitability, and upgrade requirements for River Jur at Wau bridge.

Table 10: River Jur at Wau bridge

| **General station details** | |
|---|---|
| Station code/name | River Jur at Wau Bridge |
| Purpose of station | National and Regional water level and discharge monitoring |
| Latitude | N 7°41.829 |
| Longitude | E 28°0.487' |
| Elevation | 434 m |
| Period of record | 1930 – 2012. Current method of observation is by manual recording of gauge levels on gauge forms |
| Measurement equipment and sensors | 7 Gauge pillars (Nilometers) namely; 15, 14, 13, 12, 11, 10 and 9.<br><br>ADCP and motorised boat<br>Catamaran<br>1 Current meter |
| Staffing | Silvano Amet is the technician responsible for gauging from state Department of Water Resources and Irrigation.<br><br>Two Egyptian Engineers from the Egyptian Irrigation Office |
| **Site description** | |
| The Egyptian constructed gauge pillars (Nilometers) are located on the left bank.<br>Figures 28 – 30 illustrate the site conditions. The river reach is a long, relatively straight, uniform, well-defined approach channel. | |
| **Assessment of suitability of site** | |
| Flow is well confined within the banks at high or low stages. Flood plain is free of swamp or marsh. Control is through straight section of river with well defined surface water slope. Downstream control is stable and the rating curves are likely to be stable. The hydraulic suitability of the site for flow measurements is very good. There are no high turbulence zones near the ADCP discharge measuring location. There are no existing structures or confluences to cause backwater effects. Although the banks are steep and stable.<br><br>Discharge measurements are taken by ADCP but not in a structured regular manner. Measurements are often taken to the discretion of the Egyptian team. These exercises should be conducted jointly. Access to this site is excellent. GSM communication is available. | |
| **Rehabilitation requirements** | |
| Equip with an AWLR and fence off entire AWLR unit. Construct secure concrete AWLR housing and stilling (Figure 9). Telemetric transmission of data can be considered.<br><br>Procure ADCP, motorized boat and tough book for Eastern Bahr el Gharzhal state Water Resources and Irrigation Department . Provide a mortor bike for the technician. | |

### 3.11 Wau met station

Wau (Figure 31) is one of 5 synoptic meteorological stations that are operational in South Sudan managed by the Meteorological Department. Its location was noted to be as follows: (N 7$^0$41.880' E 27$^0$59.983 El. 441 m). According to the previous consultation visit record undertaken in September 2014, all the synoptic stations, instrument measurement readings are made every 3 hours starting from 06:00 through 18:00. Observers at all stations record readings on monthly record log books.

Three hourly weather records are used mainly for general weather, whereas the half hourly records are for aviation meteorology.

For the synoptic stations, field measurement records are communicated to SSMD in Juba using personal cell phones every three hours which is then recorded to manual log book. The field log books are sent from different stations at the end of every month.


Figure 31: Location of Wau synoptic meteorological station

The existing synoptic station is not fully constituted. (Figure 32). The fence is crumbling and the station is not properly maintained. It lacks an evaporation pan, wind vane, and radiometer pan. It could not be determined whether the Stevenson's screen is fully equipped with all thermometers and hygrometers.

Figurer 32: Current state of Wau synoptic meteorological station

Whereas the wind speed anemometer, ordinary rain gauge, and sunshine recorder appeared to be functional, the Stevensons screen housing is falling apart.

## Appendix A.7: National Consultation and Field Visit Report for Sudan

### 1. Introduction and Background

National consultations and field visits have been organized in nine (9) Nile Basin countries, with the aim to appreciate the potential value, benefits, and need for the regional water resource monitoring system; acquire a deeper appreciation of the current state of the monitoring technologies and practices, and to understand the institutional context within which the designed system will be operated. The consultations will also identify needs for technical support, capacity building, and institutional strengthening. The defined objectives include the following:

- Confirm the important socio-economic/water resources management issues related to the development, management and protection of the shared Nile Water Resources.
- Identify lead and supporting institutions for the confirmed socio-economic/water resources management issues.
- Identify geographic priority areas for each socio-economic issue.
- Confirm data needs for each socio-economic issue to inform decisions and development, and show how these can relate to the regional monitoring network.
- Identify capacity building needs, and explore ideas for improved sustainability of hydromet services.
- Conduct field visits at key monitoring locations that adequately represent the current technologies and practices within use. This will include visits to any water quality labs to further assess data sampling, testing, management, and dissemination.
- Confirm understanding of current network and practices based on country assessment report and metadata from associated countries and past studies. Supplement information and metadata based on discussions.
- Identify country protocols for data communication, storage, formatting, dissemination, sharing, and use. Identify and discuss what data could be used in a regional network and how it could be delivered.

This report presents the consultation meetings and field visits conducted in Sudan for five working days during the 17-21 August period.

### 2. Consultation Meetings

Consultation meetings in Sudan were organized at the Ministry of Water Resources and Electricity (MWRE), the Nile Water Directorate (MWRE), Sudan Meteorological Authority (SMA), the General Directorate of Groundwater and Wadis (MWRE), the Hydraulics Research Station-Wad Medani (MWRE), and the Remote Sensing Authority located at the Faculty of Engineering at the University of Khartoum.

*2.1 Ministry of Water Resources and Electricity*

Mr. Ahmed Eltayeb Ahmed, Director of the Nile Water Directorate, organized a meeting on Sunday 17 August 2014 at the Ministry premises with participation of twenty one (21) ministry staff[22] including senior representatives and advisors from various MWRE departments including the Nile Water Directorate, Water Resources Technical Organ, Dam Implementation Unit, and the Hydraulics Research Station-Wad Medani. Dr. Abdulkarim Seid, Head of the Water Resources Management at the Nile-Sec, presented the background and objectives of the Nile Basin Hydromet project. Mohamed Chebaane, Riverside Consultant, followed with a participatory session to discuss and complete the

[22] List of participants is in Annex 1.

water management/socio-economic institutional factor section of the institutional questionnaire related to the identification of lead and supporting institutions for each issue, prioritization of the issues based on a list of regional and national benefits relevant to each issue, confirmation of the data requirement and identification of the geographical areas relevant to each issue. This meeting also highlighted specific capacity building needs for data analysis and modeling tools and discussed the institutional, management, technical, financial and behavioral change factors related to the sustainability of hydromet systems.

*2.2 Sudan Meteorological Authority*

Dr. Abdulkarim Seid (Nile-Sec), Mr. Ahmed Eltayeb Ahmed (MWRE), Dr. Iqbal Salah (MWRE), and Mohamed Chebaane (Riverside Consultant) visited Sudan Meteorological Authority (SMA) on Monday 18 August 2014 and met with Dr. Noureldin Ahmed Abdalla (Director General of SMA) and three SMA staff[23]. The meeting covered the identification of the lead and supporting institutions for the rainfall and evaporation monitoring, collaboration between these institutions, standardization and decentralization of data collection, processing, checking, validation, storage and dissemination. It also discussed the technical, management, financial and behavioral factors affecting sustainability of meteorological services and identified needs for capacity building.

*2.3 Directorate General of Groundwater and Wadis*

Dr. Abdulkarim Seid (Nile-Sec), Mr. Ahmed Eltayeb Ahmed (MWRE), Dr. Iqbal Salah (WREM), and Mohamed Chebaane (Riverside Consultant) visited the Directorate General of Groundwater and Wadis (DGGWW) on Monday 18 August 2014. The visit included a meeting with the Directors and staff[24] of the groundwater and Wadi monitoring and the water Quality Laboratory and a tour of the water quality laboratory and environmental isotopes laboratory. The meeting focused on the institutional questionnaire related to the identification of the lead and supporting institutions for groundwater monitoring, monitoring of surface flows in wadis[25] that are within the Nile Basin, water quality monitoring, and water quality laboratory. Details about the questionnaire analysis and the visits to the laboratories are presented in the institutional questionnaire key findings section.

*2.4 Hydraulics Research Station*

Dr. Abdulkarim Seid (Nile-Sec) and Mohamed Chebaane (Riverside) visited the Hydraulics Research Station (HRS) at Wad Medani on Tuesday 19 August 2014. They met with HRS scientists and technical staff[26] who presented HRS activities including sediment testing and sediment data analysis and modeling. Mohamed Chebaane discussed and interviewed HRS's staff on the sediment and erosion control sections of the institutional questionnaire. The main objectives of HRS[27] , which was established in 1976, include field investigation of hydraulic structures and sedimentation of canals, calibration of head regulators, irrigation water management including on farm water management, rehabilitation and modernization aspects of the Gezira Scheme, pilot farm studies and research jointly with other institutes such as Gezira University, Sudan Gezira Board, and the Agricultural Research Center.

*2.5 Remote Sensing Authority*

[23] List of participants is in Annex 2.
[24] List of participants is in Annex 3.
[25] Wadis are natural channels that flow only during rainy periods that generate runoff that reach these channels. Some of the wadis in arid areas flow only once every few years.
[26] List of participants in Annex 4.
[27] Development of The Hydraulic Research Station - Wad Medani - Phase II, United Nations Educational, Scientific and Cultural Organization (UNESCO) and the United Nations Development Programme (UNDP),1987.

Riverside Consultant[28] and Dr. Iqbal Salah (MWRE) visited the Remote Sensing Authority (RSA), which is under the National Center for Research, Ministry of Science and Communication. RSA main objectives include proposing main policies of the space sciences and technologies, conducting scientific research in the field of geoinformatics, coordinating the efforts and activities related to space technology , training in space science and technology, establishing links between Sudan and regional and international centers and organizations specialized in space science and technology, and providing technical services and consultations.

We met with Dr. Yahya Hasan Al-Tayeb, Director of RSA, and Khalid Elhag, remote sensing specialist. They indicated that RSA worked on the National Land Cover program (1999-2011) supported by FAO, and have been involved in flood mapping interventions for flood management.

## 3. Field Visits

*3.1 Wad Medani Area*

The field visits took place on Tuesday 19 August 2014 and covered the following sites:

- Wad Medani Hydrometric Station
- Wad Medani Meteorological Station
- Sennar Dam[29]

3.1.1 Wad Medani Hydrometric Station

Station Information

| | |
|---|---|
| Station Name | Wad Medani |
| Station Code | |
| Catchment | Blue Nile |
| Purpose of Station | Water level , discharge, and sediment monitoring |
| Latitude | 14.406 |
| Longitude | 33.523 |
| Period of Operation | 1906-2014 |
| Equipment | Manual Staff gauges |
| Time interval | Daily |
| Observer | Yes |
| Status | Monitoring has been temporarily discontinued. |

[28] Mohamed Chebaane

[29] Short visit was made to Sennar dam

Site Map


Wad Medani station is located at Medani Town. The station can be accessed on foot from a paved street.

Site Description


The control section is stable. The flow is restricted to a single straight stream channel upstream and downstream of the control section. Flow measurements can be made at the crossing section via boat.

Station Photos

Wed Medani Hydrometric Station, Upstream

Wed Medani Hydrometric Station, Downstream

Wed Medani Manual Water Level Staff Gauge

Existing Equipment

Wad Medani Hydrometric Station has a manual water level staff gauge with ceramic elements built in a masonry wall as shown in the station picture.

Recommendations

- Resume water level reading, discharge measurement, and sediment load monitoring given the hydrological importance of this station, its water resources importance for Gesira irrigation scheme, and its proximity to the Hydraulics Research Station.
- Upgrade this station to automatic hydrometric station.

3.1.2 Wad Medani Meteorological Station

Station Information

| | |
|---|---|
| Station Name | Wad Medani |
| Station Code | ID: WMD |
| Catchment | Blue Nile |
| Purpose of Station | Meteorological Station |
| Latitude | 14.24 |
| Longitude | 33.29 |
| Altitude | 408 m |
| Period of Operation | 1901 to present |
| Equipment | Manual equipment to measure Temperature, Rainfall, Evaporation, Relative Humidity, Wind Direction and Speed, Pressure, Sunshine, and Radiation. |
| Time interval | Data recorded and transmitted daily via phone at 9:00 am, 12:00 pm, 3:00 pm, 6:00 pm, and 9:00 pm. |
| Observer | Yes, Station has 3 employees on duty including the head of the station. |
| Status | Manual station is operational, to be upgraded to automatic station |

Site Map


Wad Medani meteorological station is located near the Agricultural Research and Technology Corporation.

Station Photos

Wad Medani Meteorological Station

Site Description
The station is located in a large open space. The equipment is installed according to WMO Standards.

Existing Equipment
The station includes two Stevenson screens, anemometer, wind vane, sunshine recorder, and rain gauge.

Recommendations

- Upgrade station to automatic meteorological station.

*3.2 Shendi Visit*
The field visits took place on Wednesday 20 August 2014 and covered the following sites:

- Shendi Hydrometric Station
- Shendi Meteorological Station

3.2.1 Shendi Hydrometric Station

Station Information

| | |
|---|---|
| Station Name | Shendi |
| Station Code | |
| Catchment | Main Nile |
| Purpose of Station | Manual water level monitoring |

| | |
|---|---|
| Latitude | 16.70 |
| Longitude | 33.43 |
| Period of Operation | 1908 to present |
| Equipment | Manual staff gauge |
| Time interval | Daily |
| Observer | Yes |
| Status | Operational |

Site Map


Shendi hydrometric station is located near Shendi Town downstream of Shendi Bridge. The station can be accessed on foot.

Site Description


The control section is fairly stable. The flow is restricted to a single straight stream channel upstream and downstream of the control section.

Station Photos


Shendi of Hydrometric Station, Upstream


Shendi of Hydrometric Station, Downstream

**Shendi Hydrometric Station-Staff Gauge (Silt Deposit)**

**Shendi Hydrometric Station-Water Intake**

**Shendi Bridge, Upstream Side**

**Shendi Bridge, Downstream Side**


Main Nile reach, Upstream of the bridge


Main Nile reach, Downstream of the bridge

Recommendations

- Remove silt deposited near staff gauge to allow water from the intake to reach the staff gauge.
- Transfer the station to a new location at the Shendi bridge (see picture) and upgrade it to Automatic Hydrometric gauge with automatic water level recorder. The radar type water level recorder would be suitable at this location, preferably at the upstream side of the bridge.

3.2.2 Shendi Meteorological Station

Station Information

| | |
|---|---|
| Station Name | Shendi |
| Station Code | ID: SHN |
| Catchment | Main Nile |
| Purpose of Station | Meteorological Station |
| Latitude | 16.42 |
| Longitude | 33.26 |
| Altitude | 380 m |
| Period of Operation | 1941 to present |
| Equipment | Manual equipment (see description hereafter) to measure Temperature, Rainfall, Evaporation, Relative Humidity, Wind Direction and Speed, Pressure, Sunshine, and Radiation. |
| Time interval | Data recorded and transmitted daily via phone at 9:00 am, 12:00 pm, 3:00 pm, 6:00 pm, and 9:00 pm. |
| Observer | Yes, Station has 3 employees on duty including the head of the station. |
| Status | Manual station is operational, to be upgraded to automatic station |

Site Map


Shendi meteorological is located in Shendi town, near the police office.

Station Photos

Site Description

The station is located in a fairly open space in front of the station office. Most of the equipment is installed according to WMO Standards.

Existing Equipment
The station includes a Stevenson screen, anemometer, wind vane, sunshine recorder, and rain gauge.

Recommendations

- Upgrade station to automatic meteorological station, and consider relocation of the site to a more open and spacious space.

### 3. Institutional Questionnaire Key Findings

*4.1 Institutional Aspect of the Water Resources Management Issues*

Results of the questionnaire regarding the lead and support institutions for each of the fourteen (14) water resources management/socioeconomic issues and the priority of each of issue are indicated below.

| Water Management/ Socio-economic-issues | Lead Institution | Support Institutions | Priority |
|---|---|---|---|
| **WRPM** | **MWRE** | Sudan Meteorology Authority, Ministry of Agriculture and Irrigation, Ministry Environment Forestry and Physical Development, National Water Corporation (MWRE), Ministry of Foreign Affairs (Water Department). | 1 |
| **Flood Management** | **MWRE** | Ministry of Interior (Civil Defense Dep.), Ministry of Planning and Infrastructure, Localities, Sudan Red Crescent, NGOs and Civil Association, Sudan Meteorology Authority, Humanitarian Aid Commission (HAC). | 1 |
| **Rainfed Agriculture** | **State Ministries of Agriculture** | Ministry of Water Resources and Electricity, Sudan Meteorology Authority, Ministry of Agriculture and Irrigation. | 1 |
| **Irrigated Agriculture** | **MWRE** | Sudan Meteorology Authority, Ministry of Agriculture and Irrigation | 1 |
| **Groundwater Management** | **MWRE** | Ministry of Agriculture and Irrigation (Groundwater units at state level), NGOs. | 1 |
| **Water Quality and Pollution** | **MWRE** | Ministry of Health, Ministry of Agriculture and Irrigation, States Drinking Water Corporations, UNICEF. | 1 |
| **Erosion/Sediment** | **MWRE** | Dam Implementation Unit (DIU at MWRE), Min. of Agriculture and Irrigation, State Ministries of Physical Development, State Ministries of Agriculture, Ministry of Environment, Forestry and Physical Development | 1 |
| **Energy** | **MWRE** | Ministry of Petroleum, Electricity Companies (MWRE). | 1 |
| **Watershed Management** | **MWRE** | Ministry of Finance and National Economy, Ministry of Agriculture and Irrigation, Ministry of Tourism and Wildlife, Ministry of Interior (General Administration for National Parks and Wildlife), Higher Council for Environment and Natural Resources, Forest National Cooperation, Chamber for Federal Governance, State Ministries of Agriculture. | 1 |
| **Wetland Management** | **MWRE** | Ministry of Finance and National Economy, Ministry of Agriculture and Irrigation, Ministry of Tourism and Wildlife, Ministry of Interior (General Administration for National Parks and Wildlife), Higher Council for Environment and Natural Resources, Forest National Cooperation, Chamber for Federal Governance, State Ministries of Agriculture. | 1 |
| **Drought** | **MWRE** | Ministry of Environment Forestry and Physical Planning, Ministry of Agriculture and Irrigation, Sudan Meteorology Authority, Humanitarian Aid Commission (HAC). | 1 |
| **Climate Change** | **Ministry Environment Forestry and Physical Development** | MWRE, Ministry of Agriculture and Irrigation, Sudan Meteorology Authority, Humanitarian Aid Commission (HAC). | 1 |
| **Fisheries** | **Ministry of Animal Resources and Fisheries** | Ministry of Water Resources and Electricity, Ministry Environment Forestry and Physical Development, Ministry of Agriculture and Irrigation. | 1 |
| **Navigation** | **Ministry of Transport** | Ministry of Water Resources and Electricity | 1 |

The table above shows that MWRE leads ten (10) of the socio-economic issues and has a support role for the other four (4) issues. The lead by MWRE of a significant majority of the issues would help in the regional collaboration towards maximizing the benefit of Hydromet systems and allows for leveraging resources in the operation and management of these systems. On the other hand, there is a considerable number of supporting institutions composed of national Ministries representing sectors such as agriculture, health, infrastructure, fisheries, navigation, environment, interior, and research as well as other entities representing state[30] level government services, NGOs, and local organizations and associations. The number of the supporting government institutions (Ministries and specialized agencies) for all the fourteen (14) water resources management/socioeconomic issues is more than twenty (20). This is a challenge for the effective operation and delivery of the hydromet services, if the roles and responsibilities of the lead and supporting institutions are not clearly defined.

The table above shows that all the fourteen (14) socio-economic issues have been ranked as first priority. Among the fourteen first priority issues the following seven (7) have been given highest priority by MWRE:

- Improved water resources planning and management
- Flood management
- Irrigated agriculture
- Groundwater management
- Water quality management and pollution control
- Energy planning, development and management
- Climate change resilience

An examination of the Nile Basin Transboundary Issues presented in the Interim Report of the Conceptual design shows the following regional issues relevant to Sudan.

| Cooperative issue | Socio-economic benefits | Key system and data requirements |
|---|---|---|
| Ethiopia and Sudan need to coordinate the release policies of the Tekezze dam and the downstream facilities on the Atbara.<br><br>The Tekezze (or Setit as the river is called in Sudan) is a highly seasonal river. The bulk of runoff occurs between July and September while dry season flows are very low.<br><br>Coordinated operation of the dams on the Tekezze/Atbara (Tekezze, Upper Atbara Complex, Kashm el Girba) can increase dry season flows and attenuate the flood-wave. | • optimizing hydropower production on the Atbara / Tekezze (ETH, SUD);<br>• flood & drought management along the rivers, but also of parts of the main Nile in Sudan upstream of Merowe (ETH, SUD);<br>• irrigation scheduling of New Halfa scheme and planned intensification (SUD);<br>• management of spate irrigation along the lower Atbara reaches in Sudan (SUD);<br>• minimizing evaporation losses at Kashm el Girba and | • Data sharing policies between Ethiopia and Sudan;<br>• data transmission facilities;<br>• River discharge at key locations along the Atbara/Tekezze;<br>• water levels at key locations along the Atbara/Tekezze and Main Nile;<br>• reservoir levels of Tekezze, Upper Atbara Complex, and Kashm el Girba;<br>• H-V relations for the above reservoirs;<br>• open-water evaporation of the above reservoirs;<br>• sediment load at key locations upstream and |

[30] State can be regional Ministries at the Governorate level.

| | | |
|---|---|---|
| | Upper Atbara Complex reservoirs (SUD);<br>• minimizing siltation of all reservoirs including Merowe and Lake Nubia (EGY, ETH, SUD);<br>• minimizing siltation of New Halfa irrigation scheme (and planned extension) (SUD);<br>• maintaining in-stream flow requirements and WQ standards (SUD);<br>• Improved watershed management and reduction of erosion. | downstream along the Atbara/Tekezze;<br>• data processing, storage, and dissemination software.<br>• Catchment (field) soil erosion monitoring. |
| Ethiopia and Sudan need to coordinate the release policies of the future Grand Ethiopian Renaissance Dam (GERD) on the Blue Nile, which is under construction.<br><br>The Blue Nile provides the greater part (around 60%) of the flow of the Main Nile. The river has a pronounced seasonal flow distribution with very high sediment loads in the flood season. The flood potential of the Blue Nile is high, while flows in the period between January to May are reduced to a trickle. The river serves as the primary water source for a group of irrigation schemes in Sudan, the largest of which is the Gezira.<br><br>GERD can potentially mitigate flood risks, increase hydropower production, and provide water for irrigation during the dry season in Sudan. | • optimizing hydropower production on the Blue Nile (GERD, Roseires, Sennar) and the Main Nile (Merowe and future dams) (ETH, SUD);<br>• irrigation scheduling and intensification in the Gezira irrigation scheme in Sudan, and other schemes along the Blue and Main Nile (SUD);<br>• flood & drought management along the Blue Nile, at the Blue-White Nile confluence, and the Main Nile (ETH, SUD);<br>• flood management of the Rahad and Dinder (which are affected by Blue Nile levels) (SUD);<br>• minimizing siltation of all reservoirs, including Merowe and Lake Nubia (EGY, ETH, SUD);<br>• minimizing siltation of Gezira scheme and other gravity schemes in Sudan (including Rahad extension) (SUD);<br>• maintaining in-stream flow requirements and WQ quality standards at the urban centers along the Blue and Main Nile (Sennar, | • Data sharing policies between Ethiopia and Sudan, and possibly Egypt;<br>• data transmission facilities;<br>• River discharge at key locations along the Blue Nile and Main Nile;<br>• Reservoir level of GERD, Roseires, Sennar, and Merowe;<br>• H-V relations of all reservoirs;<br>• open-water evaporation of the above reservoirs;<br>• sediment load at key locations along the Blue Nile;<br>• detailed river profile of the downstream reaches of the Blue Nile to assess flood extent and associated return periods;<br>• water quality parameters around the urban centers in Sudan (Sennar, Wad Medani, Khartoum, Atbara)<br>• data processing, storage, and dissemination software.<br>• Catchment (field) soil erosion monitoring. |

| | | |
|---|---|---|
| | Wad Medani, Khartoum, Atbara) (SUD);<br>• minimizing reservoir evaporation losses (Roseires, Sennar, Merowe, planned facilities, but also of Lake Nasser/Nubia) (SUD, EGY);<br>• Improved navigation on the Main Nile, Blue Nile, and on the Abbay between planned reservoirs. | |
| Ethiopia and South Sudan need to coordinate the release policies of the potential dams on the Baro river.<br><br>The Baro is a highly seasonal river that originates almost entirely in Ethiopia, and is the principle tributary of the Sobat river.<br><br>Overbank spills of the Baro and Sobat during the flood season contribute to the extensive seasonal wetlands in the area (including the Machar marshes), which represent important ecological value and sustain the pastoralist economy. The Baro, Gilo and lower reaches of the Sobat are navigable during part of the year.<br><br>Coordinated management of the future Baro dams can attenuate the Baro-Sobat regime and modify the flooding and low-season flow patterns. | • optimize hydropower production on the Baro reservoirs (ETH);<br>• manage flood-flows to reduce overbank spills on the Baro-Sobat in order to protect the pastoralist economy and decrease wetland evaporation losses (SOUTH SUD – SUD);<br>• preserving important environmental value in wetlands such as the Machar marshes by managing the extent and fluctuation of the seasonal and permanent wetlands (ETH, SOUTH SUD);<br>• support the pastoralist economy by managing the extent and seasonal fluctuation of the seasonal and permanent wetlands (SOUTH SUD);<br>• maintain minimum water levels for navigation on the Baro (up to Gambella) , Gilo and the Sobat, and for drought management and maintaining minimum flows (ETH, SOUTH SUD, SUD).<br>• future irrigation along the Baro and downstream rivers (ETH, SOUTH SUD)<br>• maintain minimum discharge and water levels for navigation, minimum flows, and irrigation (pumping) on the White | • data sharing policies between Ethiopia, South Sudan, and Sudan;<br>• data transmission facilities;<br>• river discharge at key locations along the Baro, Sobat, Pibor, and Akabo;<br>• levels and H-V curves for the future Baro reservoirs;<br>• wetland area topography in order to assess (seasonal) wetland dynamics;<br>• wetland evapotranspiration and rainfall;<br>• detailed river profile of the lower reach of the Sobat up to Gambeila (to asses water depths for navigation purposes);<br>• data processing, storage, and dissemination facilities |

| | | |
|---|---|---|
| | Nile, and limiting releases for flood control on the White Nile. (SUD, SOUTH SUD). | |
| Sudan and South Sudan need to coordinate the release policies of Jebl Aulia reservoir for irrigation, navigation, flood control, fisheries, and tourism | • maintain water levels in order to facilitate use of (fixed) pump installations for the irrigation schemes along Jebl Aulia reservoir and White Nile, and minimize pumping head; (SOUTH SUD, SUD);<br>• flood management at the Blue-White Nile confluence (i.e. Khartoum) and Main Nile (SUD);<br>• maintaining navigation and in-stream flow requirements and WQ quality standards for fisheries, tourism and hyacinth control along the White and Main Nile and for the urban centers (Khartoum, Atbara) (SUD);<br>• minimize reservoir evaporation losses of Merowe reservoir (and other future R-o-R hydro-facilities along the Main Nile in Sudan) (SUD) | • data sharing policies between South Sudan and Sudan;<br>• data transmission facilities;<br>• White Nile flows at Malakal;<br>• Sobat flows at outlet;<br>• Jebel Aulia levels (at various points along the lake in order to assess wind setup at the dam);<br>• data processing, storage, and dissemination facilities. |
| Egypt and Sudan need to exchange information on water quality and sand encroachment of the Main Nile; maintaining water quality standards of the Main Nile is a joint undertaking of the two riparians. | • maintain WQ standards along the main Nile and in the respective reservoirs (including Lake Nasser/Nubia) (SUD, EGY);<br>• reduce contamination by hazardous chemicals from industries and agriculture;<br>• reduce water treatment costs and protect drinking water facilities along the Main Nile<br>• Maintain positive or improved environment for fisheries at Lake Nasser / Nubia<br>• Manage impacts of sand encroachment along the | • data sharing policies between Egypt and Sudan;<br>• data transmission facilities;<br>• water quality monitoring at key locations along the Main Nile and near the urban centers (such as Khartoum, Atbara, Aswan, etc.);<br>• data processing, storage, and dissemination facilities. |

| | | |
|---|---|---|
| | Main Nile and in the reservoirs. | |

The above transboundary issues reinforce the selection of improved water resources planning and management, flood management, irrigation, energy planning, development and management, and water quality management and pollution control as top issues at the national and regional levels.

*4.2 Institutional responsibilities of hydromet parameters*

4.2.1 Rainfall and Evaporation Parameters

Sudan Meteorological Authority (SMA) is the lead institution responsible for rainfall and evaporation data in Sudan. MWRE, Ministry of Agriculture and Irrigation, and Farmers Union (voluntary) are the main other institutions and entities that collect rainfall and evaporation data. Even though these parties share data with SMA, it is recommended that their entire rainfall and evaporation network be transferred to SMA. This will help in streamlining of the network, improve data quality, and leverage funds for capacity building and for acquiring effective monitoring technologies.

4.2.2 Water discharge/Level

MWRE is the only institution in charge of Water discharge/level monitoring in Sudan where the Nile Water Directorate (NWD) is responsible for monitoring rivers and the General Directorate of Groundwater and Wadis (GDGWW) for monitoring wadis. Water discharge/level data collection is decentralized. Data checking, validation, and dissemination are centralized at NWD and GDGWW.

4.2.3 Water Quality

The GDGWW is the lead surface water and groundwater quality monitoring institution. The Dam Implementation Unit (MWRE) conducts water quality monitoring in dam sites like Merowe. The Ministry of Health, Sates Drinking Water Corporations, and UNICEF also collect water quality for drinking water. More details about water quality monitoring are in the inception report and interim conceptual design report. According to the institutional questionnaire interview, technical standards for water quality monitoring are not harmonized among these institutions.

4.2.4 Sediment Load

Except of the monitoring of the silt concentration made by the HRS at key locations in the Blue Nile, and the Gezira scheme, there is no well established sediment monitoring in Sudan[31]. A recommended list of sediment stations for the Nile hydromet regional network is presented at the final design report. The hydraulics Research Station (HRS) at Wad Medani is the lead institution for sediment monitoring. The Dam Implementation Unit (DIU) carries out sediment monitoring to support of the design and operation of news dams.

In addition to sediment monitoring HRS conduct sediment data analysis and modeling. The sediment laboratory of HRS at Wad Medani is one of the pioneer labs in the region in this field. According to the institutional questionnaire, HRS ensures that technical standards for sediment load monitoring are harmonized among all other institutions that monitor sediment load. It is also noted that most of

[31] Sediment & Water Quality Monitoring for the EN Basin - (Phase I) Sudan, Eastern Nile Technical Regional Office (ENTRO) Eastern Nile Watershed project , Project ID: TF 094531, Yasir A. Mohamed, June 2010.

current automated technologies are not fit for high sediment concentration, which is the case of the Blue Nile and Atbara Rivers.

HRS has extensive experience in sediment monitoring, laboratory testing, and modeling with highly qualified staff and capacity to train and mentor other countries in the region.

4.2.5 Water Quality Laboratory

The water quality laboratory at the DGGWW is the official national Nile Basin focal laboratory. The laboratory is testing water samples for the MWRE and for other national and private entities and NGOS with focus on drinking water testing. DGGWW has also an Environmental Isotopes laboratory. The States Drinking Water Corporations and the Drinking Water and Sanitation Corporation have their own water quality laboratories. According to the interview with the laboratory staff, there is collaboration between the DGGWW lab and the latter two labs. More details are presented in the inception report and conceptual design report.

4.2.6 Groundwater Monitoring

The GDGWW is the lead groundwater monitoring institution. The Ministry of Health, Ministry of Agriculture and Irrigation, States Drinking Water Corporations, and UNICEF are the main other institutions that conduct groundwater monitoring. The GDGWW has financial difficulties; as a result their groundwater quality monitoring operation has been idle for the past few years. Groundwater monitoring is only performed by the Directorate at project level, it often ceases when project ends. It is recommended to resume groundwater monitoring by the GDGWW given the importance of managing and protecting groundwater resources from depletion and pollution, particularly in the arid and semi-arid areas that are far from surface water resources.

4.2.7 Surface Water and Groundwater Use

The Ministry of Water Resources and Electricity is the lead institution of surface water and groundwater use. The Ministry of Agriculture and Irrigation is a supporting institution for monitoring irrigation water use and the National Water Corporations and State Water Corporations are supporting institutions for monitor domestic and municipal water supply. According to the questionnaire there are no data sharing agreements between these supporting institutions and MWRE.

4.2.8 Earth Observations Products

The Remote Sensing Authority (National Research Center), Hosted at the Faculty of Engineering of the University of Khartoum, is the lead institution for earth observation products. Sudan National Survey Authority and Sudan Meteorology Authority are the two main supporting institutions. The Remote Sensing Authority activities are limited to land cover and flood mapping studies as presented in section 2.5. It is recommended to strengthen the Earth Observation Products institutional and technical capacity to take advantage of the advance of this promising techonology, particularly for earth products related to precipitation, soil moisture, and evaporation.

Key Institutional Recommendations

The key steps for the institutionalization of the hydromet systems to meet the data and information needs of decision makers, professionals and relevant stakeholders in Sudan to address the regional transboundary issues shown in Table 2 will follow the institutional conceptual design presented in the interim and final reports of the Nile Basin Hydromet Systems Conceptual Design.

The following are the key steps for the institutionalization of the national hydromet systems in Sudan:

- Confirm the priority water resources management/socio-economic issues identified in the institutional questionnaire (i.e. WRPM, irrigation, water quality, watershed management, energy, climate change, fisheries).
- Confirm the lead and supporting institutions for each of the water resources management issue identified in the institutional questionnaire.
- Define the functions (activities) related to each water resources management issue.
- Identify the roles and responsibilities of the lead institution and supporting institutions for implementation of each defined function.
- Develop policies, action plans, and procedures to support the implementation of the functions based on the roles and responsibilities of each lead and supporting institution.
- Validate the list of data requirements (Demand) for each water resources management factor.
- Identify the data requirements for the lead institution and supporting institutions based on the above validated list (Demand) and the functions and responsibilities of each institution.
- Confirm the monitoring network for each Hydromet parameter.
- Identify the lead and support institutions responsible for providing hydromet services for the required data with clear functions and roles of each institution.
- Develop national policies, action plans, and procedures to support the roles and responsibilities of each lead and supporting institutions providing hydromet services.

*4.3 Hydromet Services- Technical Aspects*

According to the questionnaire around 75% of rain gauges and 90% of surface water level monitoring stations in Sudan are manual. The lack of spare parts and vandalism are respectively the main reasons for malfunction of the rain gauges/evaporation stations and hydrometric stations. Tipping rain gauges, bubbler water level recorders[32], and wireless data transmission are among the favorable technologies in Sudan. The idea of mobile calibration labs has been welcomed given that mobile labs can be used for both calibration and maintenance of equipment.

Recommendations

- Check all the rainfall and evaporation stations that are not operated by SMA and make sure that they are installed according to WMO standards.
- Progressively replace manual meteorological stations and manual hydrometric stations by automatic stations.

*4.4 Hydromet Services- Management Aspects*

The meteorological data collection, processing, validation and storage are standardized within SMA; however, standard procedures may not be fully adopted by other institutions such as the Ministry of Agriculture and Irrigation. The meteorological database of SMA is centralized.

Updating of rating curves is less regular, in-particular at dynamic river cross sections subject to seasonal changes of sedimentation and scouring, e.g., Kubor and Wad El Hilew on Atbara River, Khartoum on Blue Nile, and Dongola on Main Nile[33]. The hydrological data processing, validation and storage experience real constraints in terms of staff and facilities. There is no annual hydrological

[32] Bubbler water level recorders are suitable to rivers that have high sediment load.

[33] Sediment & Water Quality Monitoring for the EN Basin - (Phase I) Sudan, Eastern Nile Technical Regional Office (ENTRO) Eastern Nile Watershed project , Project ID: TF 094531, Yasir A. Mohamed, June 2010.

data books published, at least in a regular manner[34]. The Hydrological database is centralized. According to the questionnaire, there is a need for training and capacity building in data collection, processing, validation, and management. There are difficulties in hiring and retaining qualified staff for hydrological data collection due mainly to low wages, difficulty of the task, lack of awareness, and lack of training.

Recommendations

- Establish and enforce standard procedures for collection, processing, validation, storage, and dissemination of meteorological and hydrological data.
- Adopt a standard hydromet database system that can serve local, national, and transboundary data management and data sharing needs.
- Hire staff for hydrometric data processing, validation, and management.
- Provide formal and hands on training on data processing, validation, and management.
- Recommendations for water quality monitoring and water quality lab are presented in details in the interim conceptual design report.

*4.5 Hydromet Services- Financial Aspects*

According to the institutional questionnaire both SMA and MWRE do not have sufficient funding to effectively operate their monitoring services. The questionnaire results also indicate that the main reasons for lack of adequate funding are the lack of awareness about the economic value of the meteorological and hydrological data, and lack of studies to demonstrate the socio-economic benefits of these data.

Recommendations

- Conduct a study to show the socio-economic value of hydromet services[35].
- Develop and conduct an awareness and outreach program based on the results of this study targeted to decision makers and users in the various sectors benefiting from the hydromet services.
- Explore opportunities of funding from Water utilities, Electricity companies, Oil companies and other relevant private sector that benefit directly or indirectly from Hydromet data and information.
- Move progressively to automated hydromet system which is more accurate and efficient, and has been proven to be at the long run more cost effective than the manual system.

*4.6 Hydromet Services- Behavioral Aspects*

The questionnaire results confirm the need of communication and awareness program to change the attitude about compensation of the field observers, raise awareness of field observer about the benefits of the data, and convince decision makers about the added socio-economic national and local benefits.

Recommendations

- Develop communication capacity at SMA and MWRE to develop and conduct awareness and communication programs targeted to decisions makers, public and private sectors data users, and observers.

*4.7 Training and Capacity Building*

Based on the questionnaire, here are below the areas where training and capacity building is needed:

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[34] Sediment & Water Quality Monitoring for the EN Basin - (Phase I) Sudan, Eastern Nile Technical Regional Office (ENTRO) Eastern Nile Watershed project , Project ID: TF 094531, Yasir A. Mohamed, June 2010.

[35] This study can be conducted at the regional level.

Improved Water Resources Planning and Management
- Integrated water resources management
- Water resources management analysis and modeling
- Database management
- Integrated flood management
- Water quality monitoring & management
- Sediment monitoring & management

Flood Management
- Hydrological modeling & Arc-GIS application
- Flood risk mapping
- Hydrological forecasting & time series analysis
- Website portal

Rainfed Agriculture
- Rainfed crop water requirement modeling
- Rainfall and ET trend analysis

Irrigated Agriculture
- Crop Water Requirement Modeling
- ET analysis

Groundwater Management
- Groundwater Modeling
- Pumping test data interpretation
- Hydrochemistry
- GIS Tools

Water Quality Management
- Water Quality data interpretation and analysis
- Water quality modeling Water Quality data interpretation and analysis
- Water quality modeling

Erosion and Sediment Control
- Sediment data collection and analysis
- Geomorphological changes of river basins
- Erosion at basin level
- Reservoir siltation management
- Irrigation canals and infrastructure siltation

Energy Planning, Development, and Management
- Hydrological and Hydraulic modeling
- Hydropower development and optimization
- Bathymetric survey

Wetland Management
- GIS and Remote Sensing
- Environmental Impact Assessment (EIA)

Watershed Management

- Integrated watershed management
- GIS and Remote Sensing
- Watershed modeling
- Environmental Impact Assessment (EIA)
- Biophysical and socio-economic survey study and tools such as Participatory Rapid Appraisal (PRA) and Participatory Learning and Action (PLA)
- Mike 11 modeling

Drought Management
- Drought monitoring and forecasting
- Drought mitigation measures and techniques

Climate Change Resilience
- Climate and weather prediction modeling
- Climate adaptation
- GIS and Remote Sensing

Navigation
- Control aquatic weeds
- Bathymetric Survey

Hydromet Monitoring Technologies
- Automatic Rainfall and evaporation data collection and maintenance, and transmission technologies
- Automatic water level and water discharge data collection and maintenance technologies
- Automatic water quality data collection and maintenance technologies
- Modern sediment load monitoring and testing technologies and data analysis
- Automatic groundwater level and water quality monitoring technologies

Water quality laboratory technologies
- LIMS

Management of Meteorological and Hydrological Services
- Data processing
- Data Validation (Q/A)
- Data storage
- Data dissemination
- Data Analysis and Interpretation

<u>Recommendations</u>
The above areas will be considered, streamlined at the regional level, discussed with NBI and packaged in a series of formal and hands on training programs.

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# Appendix A.8: National Consultation and Field Visit Report for Tanzania

## 3. Introduction and Background

In May 2014, the Nile Basin Initiative (NBI) contracted with Riverside Technology to develop design specifications and an implementation plan for the Nile Basin Regional Hydro-meteorological Monitoring System (this Assignment). The assignment aims to enhance Nile River basin monitoring. It will address coverage, equipment, techniques, data acquisition and dissemination, sampling and testing, standard procedures, capacity development, cost estimates, and implementation planning.

As part of this assignment, field visits and national consultations have been organized in each project country, with the aim to appreciate the potential value, benefits, and need for the regional water resource monitoring system, acquire a deeper appreciation of the current state of the monitoring technologies and practices, and to understand the institutional context within which the designed system will be operated. The consultations will also identify needs for technical support, capacity building, and institutional strengthening. The defined objectives include the following:

- Confirm understanding of current network and practices based on the country assessment report and metadata, as well as past studies. Supplement information and metadata based on discussions.
- Identify country protocols for data communication, storage, formatting, dissemination, sharing, and use. Identify and discuss what data could be used in a regional network and how it could be delivered.
- Confirm the important socio-economic drivers for data collection and elaborate specific needs for data to inform decisions and development.
- Discuss perceived needs both with regards to data collection and institutional capacity development and how these can relate to the regional monitoring network.
- Conduct field visits at key monitoring locations that adequately represent the current technologies and practices within use. This will include visits to any water quality labs to further assess data sampling, testing, management, and dissemination.

## 4. Ministry of Water Headquarters, Dar es Salaam

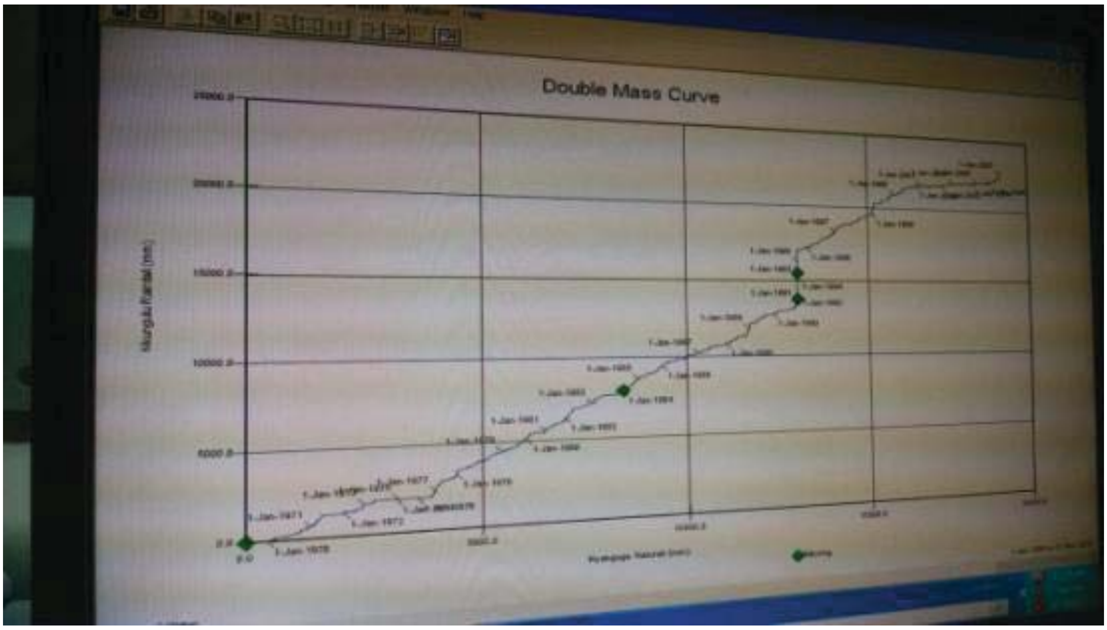
The Ministry of Water is the lead institution for hydrologic monitoring including surface and groundwater quantity and quality. Consultations were conducted at the headquarters in Dar es Salaam August 11-12, 2014. The visit included a brief presentation of the NBI project overview followed by discussions with the Ministry of Water employees regarding data processing and management. In addition, applicable topics from the institutional questionnaire were discussed.

*HYDATA System*

Currently the UK based HYDATA system is the primary database utilized by the Ministry of Water but the agency is migrating to the Nile Basin DSS. The data flow involves the ministry headquarters receiving spreadsheets once a month via email from the local basin offices. The data collection and processing is carried out by the local basin offices. The spreadsheets are converted to CSV format for import to the HYDATA DB with column headers of Time, Date, and Data. Parameters entered include Water Level, Discharge, rainfall, and some meteorological parameters (temperature, wind, RH, Solar Radiation).

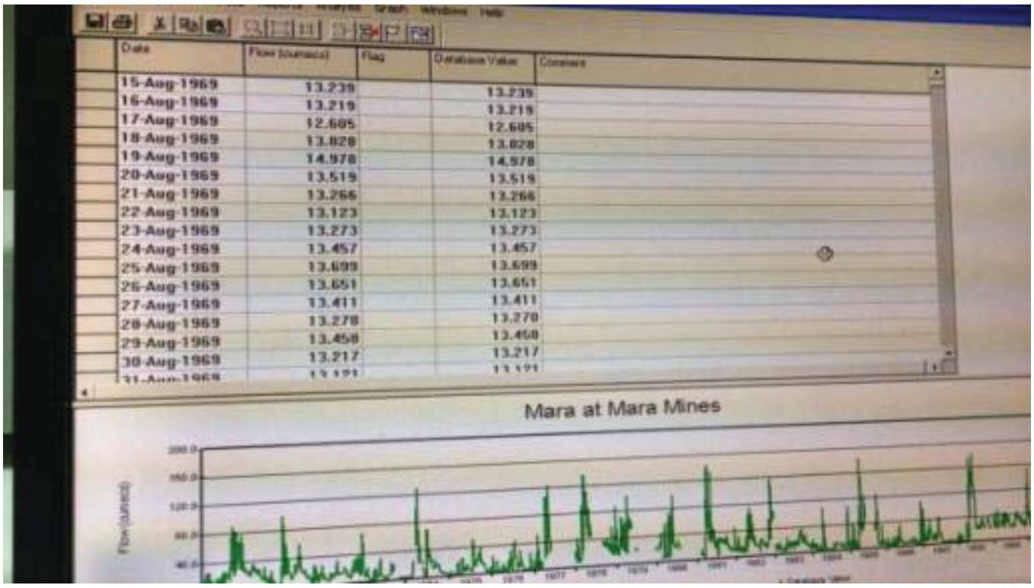
HYDATA has the capability of flagging missing and questionable values that can then be addressed by the user. The questionable values are based on thresholds defined by the user for min, max, min change and max change at each location.

The primary analysis tools consist of flow duration curves used for assessing water supply, yearbook tables for reporting, and double mass analysis plots for quality control of long term precipitation data (see figure below).




**Double Mass Analysis Curve for precipitation analysis in HYDATA system**

Currently the data stored in HYDATA is used for development of rating curves. However, the most recent rating curve data stored for several sites was 1994 with the majority of measurements from the 1980's. The most recent hydrological data shown was from 2010. The following figure below displays the flow for the Mara Mines in the HYDATA system.




**Mara Mines station flow data in HYDATA system**

*Rating Curve Concerns*

Rating curve development was identified by Ministry of Water consultant Mr. Sylvand Kamugisha as one of the key challenges in the development of a national hydro-meteorological monitoring program. There was reportedly about a 10 year period within Tanzania where flows were not measured at key locations. Historical measurements that have been taken were often done arbitrarily without accounting for the need to capture a range of flow levels.

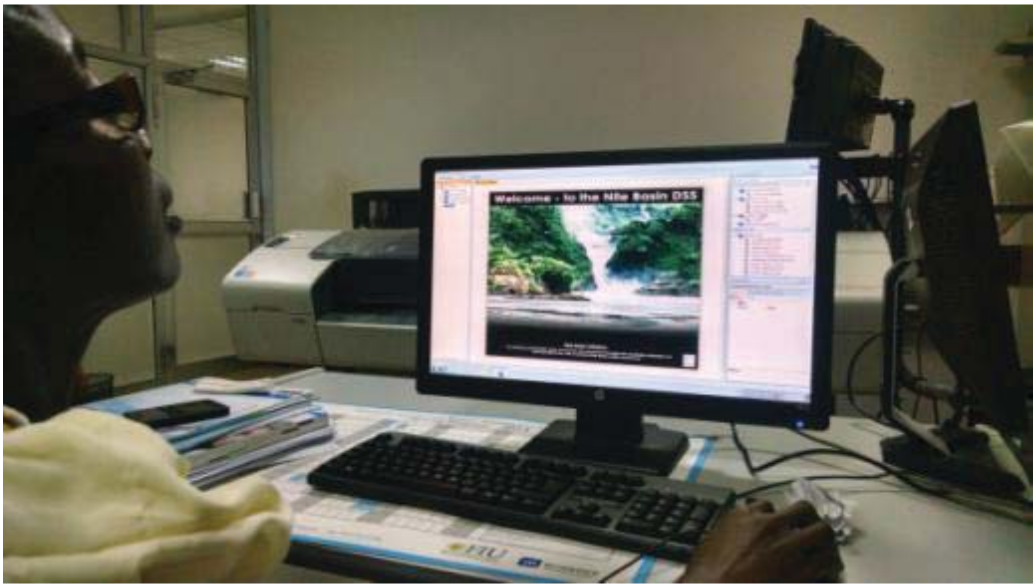
It was noted that there needs to be capacity development with regards to measuring flows and developing rating curves. In addition, the current practice of importing flow data to the NB DSS involves only importing discharge derived by each respective basin office. Importing the water level would allow calculated discharges to be updated based on new flow measurements and rating curve adjustments. In addition, it was noted that the NBDSS should include a tool for developing rating curves if it is to be used as the primary data management system at the national level.

*Nile Basin Decision Support System (NBDSS)*
The Ministry of Water is looking to migrate their data management and processing from the HYDATA software to the NBDSS. During the consultation visit at the Ministry, an example of the NBDSS was demonstrated to show basic operations but the actual system/database utilized by the Ministry was not available due to issues with the computer and license problems with the DHI dongle. It was noted that the NBDSS is a user friendly tool when it is functional but one of the biggest challenges is simply getting the system up and running with limited licenses available.

Data import to the NBDSS involves setting up the spreadsheet of the time series to have header columns of date-time and the location name. Upon import a menu will request for other metadata related to the time series such as parameter and units of measurement. It was noted that one frustrating and time consuming aspect of utilizing the NBDSS is setting up the format of the time series data for import to the system. Often times the data will not be read in properly and debugging features to inform the user of a malfunction are lacking.

The NBDSS is utilized at both the Ministry and the Basin Water Boards but the majority of expertise is currently more established at the local basin offices. The local and headquarter systems are reported to be importing the same data but the systems are currently not integrated. As noted previously, there are concerns with the direct import of discharge data without also importing stage for potential flow adjustments based on rating curve development. There is also a desire to have a tool incorporated in the NBDSS for ease of rating curve development. At the time of the consultation, there had only been a few trainings conducted within Tanzania on the NBDSS and the Ministry recognizes the transition and capacity development are still in the beginning stages.

Features of the NBDSS demonstrated at the Ministry of Water included importing time series data, adding shapefiles, and displaying plots for potential reporting applications.




**Nile Basin DSS in use at Ministry of Water headquarters**

*Additional Notes from Ministry of Water Headquarters*

- Water quality and sediment sampling are conducted for some Basin Water Boards but there is no central database where this data is stored. Data is currently saved in multiple spreadsheets.
- Metadata station IDs include a number for primary basin (i.e. "5" for Lake Victoria Basin) and letter for sub basins (i.e. "A" for Kagera)
- It was reported that TMA and the Ministry of Water share data on a monthly basis but a formal request for historical data is generally necessary. A new memorandum of understanding is in the process of being finalized to improve the data sharing process.
- It was noted that there is one Ministry of Water station in the Mbeya region that is utilizing Meteosat for telemetry and receiving the data through the internet.
- The Ministry of Water is open to the concept of sharing data on a regional basis with the contingent that there is full participation from the other countries to also provide their data.

### 5. Tanzania Meteorological Agency (TMA)

The Tanzania Meteorological Agency (TMA) is the lead institution responsible for meteorological monitoring. Consultations were carried out from August 11-14, 2014 through discussions with Mr. Gideon Mwanyilu of the headquarters office in Dar es Salaam and Mr. Michael Likunama Zonal Manager at the Mwanza office. Similar to the Ministry of Water, the primary focus of discussion revolved around current operational and data management practices at TMA. Applicable topics from the institutional questionnaire were also discussed. Lastly, a field visit to the Mwanza meteorological station was conducted and is presented in Annex 1.

There are a limited number of manual synoptic stations run by TMA but each includes a full staff to make observations every 30 minutes to 1 hour. Within the Mwanza TMA office there is a total of 27 staff of which 15 are observers. This allows for manual data collection to be conducted 24 hours a day with a high degree of quality assurance protocols in place. One of the primary concerns for TMA using meteorological data from other Tanzania agencies is the uncertainty and potential inconsistencies with how the data is collected and reported which may not meet the level of TMA standards.

The trade off of having a full staff to operate a meteorological station to ensure timely and accurate recordings is a limited number of stations operated by TMA. Within the Lake Victoria sub-basin there are only three TMA stations in Mwanza, Musoma, and Bukoba, along with another station just outside the sub-basin boundary in Shinyanga. These are reported to all have the same equipment and collection/reporting practices as the site visited in Mwanza. At each TMA station recordings are conducted manually every 30 minutes to half hour. The values are recorded in a spreadsheet and then sent to the headquarters in Dar es Salaam via email or phone. The data are then processed and utilized for forecasting in a WRF model with 15 km resolution. Forecasts products from Dar es Salaam are then sent back to the local offices. TMA is currently in the process of installing a radar station from EEC near Mwanza. This was reported to become operational within the coming months.

**6. Lake Victoria Basin Water Board, Mwanza**

Consultations and field visits were conducted at the Lake Victoria Basin Water Board in Mwanza from August 13-15, 2014. Discussions were primarily focused on filling gaps of the institutional questionnaire, water resource issues mapping, and station metadata details with local feedback from the regional office. In addition, current technologies and data retrieval practices were discussed during field visits to monitoring stations. A visit to the Ministry water quality lab in Mwanza was also conducted to understand their capabilities and discuss capacity needs. Lastly, field visits were conducted for a few key locations and are presented in Annex 1.

*Hydrology Department*

Discussions and activities conducted with the local hydrology staff were highly informative. The department is responsible for data collection, processing, validation, storing and dissemination of both hydrologic and meteorological data collected from local Ministry of Water stations.

All hydrometric sites contain staff gauges and a benchmark. Stage is recorded two times a day (once in the morning and then again in the evening) by a local observer and recorded in a log book. The log is submitted once a month to the nearest office. For the Lake Victoria basin there is an office at each of the main cities of Mwanza, Bukoba, and Musoma. The data from the Sub-Basin office is recorded into a spreadsheet and sent to the main Lake Victoria Basin office in Mwanza via email.

At the Mwanza office the discharge measurements are calculated from the stage to be entered into the NBDSS and sent to headquarters in Dar es Salaam. Again, it is worth noting that the databases in Mwanza and Dar es Salaam are not integrated but rather two separate systems. In addition to entry to the NBDSS, data is also updated in the Lake Victoria Basin Commission (LVBC) Water Resource Information System (WRIS). The LVBC WRIS is an integrated system where data uploaded is sent to a regional data management system in Kisumu, Kenya. During the visit it was noted by hydrologist Mangasa Ogoma that there have been issues with uploading data to the LVBC WRIS and follow-up training and capacity development in utilizing the software is needed by local staff.

As noted previously there has been a lack of protocols and procedures for how and when to conduct discharge measurements in establishing rating curves for the past several years within Tanzania. The ministry is taking measures to revamp the flow monitoring program which included training for the LVBWB in July of 2014. The LVBWB does have an OTT Qliner which is currently being utilized as well as an ADCP as a backup tool for conducting flow measurements.

**OTT Qliner being used during discharge measurement training; Qliner sensor under boat; backup ADCP**

The majority of automatic hydrometric stations currently installed utilize the OTT Orpheus Mini integrated pressure sensor and data logger for measuring water level. A PDA is used to download the data by a field technician when the site is visited for discharge measurements. This data can then be used to cross-check or supplement manual recordings taken by the observer. The pressure sensor operates off 3 AA batteries that do require replacement for uninterrupted recordings. It was noted that there have been issues with obtaining operation and maintenance budget for visiting the sites to retrieve data and ensuring batteries are replaced before they die. It was possible to observe some uninstalled sensors at the LVBWB office which included an iridium antenna to be coupled with the Orpheus Mini sensor for telemetry.

**New OTT Orpheus Mini pressure sensor and integrated data logger; downloading data from sensor with PDA; iridium antenna**

Additional equipment at the LVBWB office included a shaft encoder (float) with data logger (top and bottom left), water level radar (top right), Vaisala tipping bucket gauge (bottom middle left), Vaisala data logger for an AWS (bottom middle right), and a bed load sampler (bottom right) as shown in the images below. The equipment has been procured with plans for installation when funds become available.

**Additional hydrometric equipment at LVBWB office**

One of the primary benefits of meeting with representatives of the LVBWB was the opportunity to get clarification on existing station equipment and capabilities as well as clarify station locations and parameters measured. An example was identifying the type of automatic weather sensors and status for those stations operated by the LVBWB. Updates to the meta-database were made based on these consultations to inform decisions on the regional network design. In addition, metadata for proposed groundwater monitoring borehole sites was provided in Annex 2.

*Mwanza Zonal Water Quality Laboratory*

A visit to the Mwanza water quality laboratory under the Ministry of Water was conducted to assess existing capabilities, address applicable topics outlined in the institutional questionnaire, and discuss development needs identified by the staff. Environment and water quality expert Mteki Heri Chisute was responsible for answering questions and providing a tour of the laboratory facilities.

The Mwanza lab currently provides ongoing monitoring for several sites within the Lake Victoria Basin. A table of all water quality sites, parameters, frequency, estimated annual cost, and selection criteria for the Mwanza lab are provided in Annex 3. In addition to these sites the lab also provides water quality monitoring for specific areas of interest for potential contamination of mining operations. The lab has the capability to perform all basic water quality tests and only lacks the ability/equipment to monitor pesticides and heavy metals which are contracted out to a private company. The laboratory is hopeful to gain accredited status in the coming months.

**Photos from Mwanza Water Quality Lab**

When conducting monitoring with the hydrology department, a staff member of the water quality lab accompanies the crew taking discharge measurements to conduct water quality sampling at the same time.

One of the biggest needs identified by the Mwanza water quality staff was an ability to analyze data collected. There is currently no Laboratory Information Management System (LIMS) or other type of data management system in use for analyzing and quality controlling data. The Mwanza lab has been conducting monitoring for the LVEMP project for approximately 5 years. The data collected is analyzed by a team of experts associated with the LVEMP project but the Basin Water Board currently does not have the capacity or associated tools to perform analysis on the monitoring of these LVEMP sites or others.

An additional concern by the Mwanza lab is a lack of staff retention. The lab often provides opportunities to new graduates but these same employees eventually leave for higher paying jobs at private laboratories. As a result, the more senior staff constantly needs to retrain incoming employees rather than focus efforts on research, development, and administrative duties.

## 7. Conclusions

Through consultations with lead institutions, conclusions regarding the priority water resource management issues and recommendations/capacity development needs could be determined.

*Priority Water Resource Management Issues*

Through both the mapping exercise and institutional questionnaire the primary water resource management issues for the Lake Victoria basin in Tanzania include the following:

1. **Improved Water Resource Planning and Management (IWRPM**) – Significant interest in improving access to safe water and sanitation along with supply management for food security, health, and nutrition.
2. **Rainfed Agriculture** – Majority of region utilizes rainfed agriculture for food production. Limited instances of drought but there are concerns with climate change affecting the timing of dry and wet seasons for planting and harvesting.
3. **Groundwater Management** – The region consists of several major mining sites and the understanding of how these operations impact groundwater quality is limited. There is also an interest in simply understanding the extent of aquifers in the region. Plans are being established for defining groundwater monitoring sites.
4. **Water Quality Management** – Significant interest in water quality impacts from mining and agricultural operations (sugar factories and slaughter houses) along the Lake Victoria coastline and riparian systems.
5. **Hydropower** – The Kagera River is one of the few places within Tanzania with significant hydropower potential. There is interest in both local hydropower production and impacts on the Kagera from potential upstream hydropower projects in other countries
6. **Fisheries** – An important part of local subsistence for the Lake Victoria coastline, seasonal high flows in major rivers, and small lakes in the Kagera basin.
7. **Wetland Management –** Both the Kagera and Mara wetlands are significant ecosystems that support a range of biodiversity and need to be monitored for potential impacts from mining and other developments.

*Recommendations and Capacity Development Needs*

The following is a list of the primary recommendations and capacity development needs identified and discussed between the consultant and staff at representative institutions. This list is not comprehensive for the entire country of Tanzania but is rather focused on the institutions within the Lake Victoria/Nile basin.

- **Data Software Integration Tools** – During the visit to the local LVBWB office in Mwanza there was a need to extract data from the PDA's for both the water level stations and Qliner to a laptop for data entry. Because no formal training had been offered by the vendor initially, all the data was being typed in manually by hand rather than using software to automatically download the data. A training program and protocols for downloading data from PDA's and then transferring data to a database needs to be established. If automated telemetry and data retrieval are implemented for the Nile Basin regional network there needs to an initial and follow-up training sessions to ensure staff can adequately manage processes and troubleshoot potential problems.
- **Data Management System** –At the time of the consultation, there had only been a few trainings conducted within Tanzania on the NBDSS and the Ministry recognizes the transition and capacity development are still in the beginning stages. However, if the NBDSS or similar system is utilized for the data management system a thorough training program will need to be developed. In addition, it was proposed that whatever data management system is utilized it should incorporate rating curve updates for determining flow from stage based on the most recent discharge measurements taken in the field. The NBDSS currently lacks this capability. Furthermore, there was a strong request for water quality data analysis tools that would allow the Mwanza lab to assess the status
- **Discharge and Rating Curve Development** – As has been noted there has been a lack of proper discharge measurements and rating curve updates within Tanzania for the past several years. The ministry is currently working to rectify this problem with training sessions throughout the country to establish standard protocols and procedures. After the initial round of training is conducted follow-up visits and assessments can be conducted to assess improvements or

identify areas that still require work. Procedures should also be established at the local offices to assess and update rating curves based on new measurements.

- **Budget and Protocols for Station Operation and Maintenance –** During the field visit to Mara Mines it was discovered that although an automated pressure sensor had been installed at the location no data was available for retrieval. This was the result of a battery needing replacement in the sensor that had not been recording for almost a year. In order to achieve the benefits associated with automatic monitoring, protocols for operation and maintenance need to be established to ensure the continuous flow of data. This includes a budget to provide consumables such as fuel costs and new batteries to keep stations up and running. In addition, standard training should be provided for basic ongoing operation and maintenance.
- **Data Sharing Between Ministry of Water and TMA** – During the consultations it was noted that a Memorandum of Understanding was being established between the Ministry of Water and TMA. The intention is for data to be exchanged freely between institutions but this may still require a formal request. It is recommended that the institutions make recent and historical data freely available through a webportal or similar system. This would benefit both institutions by allowing the Ministry of Water to use meteorological data for potential future hydrologic models and allow TMA to benefit from a greater range of meteorological monitoring stations operated by the Ministry.

**Annex A.8-1: Tanzania Field Visits**

**1. Meteorological Synoptic Station at Mwanza Airport (August 13, 2014)**

| | |
|---|---|
| Station Code | TMA: 63756; WMO Index: 9232009 |
| Purpose of Station | Monitoring of meteorological parameters; synoptic climate station |
| Latitude | -2.442 |
| Longitude | 32.9247 |
| Period of Record | ~1950 to present |
| Equipment | Typical instrumentation for a classic synoptic weather station including automatic rainfall sensor (analog), anemometer, wet bulb, dry bulb, max and min temperature gauge, Piché evaporimeter, classic sunshine recorder, and evaporation pan. An inactive AWS was also at the site but has been inactive for about 10 years. |
| Observer present | Yes |
| Status | Operational |
| Distance to TMA Office | At local TMA office (Mwanza Airport) |

General Site Map:


Site Description:
The current location of the Mwanza airport synoptic station is very close to the runway as can be seen in the map. TMA is aware this could have impacts on measurements and is planning to have the site moved to a hill roughly 0.5 km from the airport. The current site is properly fenced and requires passing through security to access given its location near the runway.

Station Photos:

**Synoptic station layout**

**Automatic analog rainfall gauge**

**Wet and Dry bulb**

**Anemometer outside of fenced area**

**Inactive AWS**

<u>Station Notes:</u>
Manual recordings at the Mwanza Airport synoptic station are taken every hour and data is forwarded to the TMA headquarters in Dar es Salaam. The station is important for aviation purposes so an ongoing operational environment is maintained with multiple staff taking readings throughout the 24 hour day. On the return drive the Radar to be operated by TMA was spotted from the roadside. This is located on a hillside south of the Airport as shown in the following map.

**Radar as seen from road on drive back to Mwanza from Airport**


**Map of Radar south of Mwanza Airport**

**2. Mara Mine Hydrometric Station (August 14, 2014)**

| | |
|---|---|
| Station Code | 107072 |
| Purpose of Station | Water level and discharge monitoring; periodic water quality |
| Latitude | -1.54847 |

| | |
|---|---|
| Longitude | 34.5542 |
| Period of Record | ~1960 to present |
| Equipment | Pressure Sensor (OTT Orpheus Mini); staff gauges |
| Observer present | Yes – Marwamita Manwengwena (20 year observer) |
| Status | Operational |
| Distance to LVBWB Office | ~320 km (4-5 hours) |

General Site Map:


Site Description:

The site is about a 4-5 hour trip from Mwanza (2.5 hours from Musoma) and the road conditions are difficult during the rainy season. The control section is stable without visible signs of scour or deposition. Flow is restricted to a single channel with straight streamlines up and downstream of control section. There are some large boulders and braiding upstream about 300 meters but should not affect flow measurements at site. It was noted by observer Marwamita Manwengwena that flood stage has never overtopped the banks in 20 years.

Station Photos:

**Observer standing next to staff gauges; piping protecting pressure sensor cable; housing for pressure sensor data logger**

**Upstream of Mara Mine station**

**Downstream of Mara Mine Station**

**Vehicle and Mara Mines station sign**

**Benchmark with Vehicle in the background at station location**

Station Notes:

Staff gauge readings are taken by observer Marwamita Manwengwena twice a day at 9:00 and 17:00 hour. A log book gets sent once a month from the site to the Musoma office where it is entered into a spreadsheet and emailed to the Mwanza office for entry into either HYDATA or NBDSS and then forwarded again to headquarters in Dar es Salaam. Discharge measurements are taken about twice per year with the OTT Qliner depending on site accessibility. The site was recently used in July of the 2014 for staff training on proper procedures and protocols for taking discharge measurements. Water quality parameters are measured at the same time as discharge and samples are analyzed at the Musoma lab. The current site is actually upstream of the existing mining operations but is noted as the last stable location on the Mara River for conducting discharge measurements before entering the wetlands. A new OTT Orpheus Mini pressure sensor was installed in May of 2012. However, at the time of visit it was believed that the battery had been dead for about 1 year and was not replaced. Cell signal on the Vodacom network was noted as weak which may hinder using GPRS for telemetry. Any power requirements for automation and telemetry would have to be off the grid using solar panels with batteries.

**3. Bunda/Bitaraguru Automatic Weather Station (August 14, 2014)**

| | |
|---|---|
| Station Code | NA |
| Purpose of Station | Meteorological/climate monitoring |
| Latitude | -1.94739 |
| Longitude | 33.848222 |
| Period of Record | 2013 |
| Equipment | Vaisala Station; Full Meteorological parameters associated with AWS including tipping bucket rain gauge, relative humidity sensor, temperature, dew point, solar radiation, wind speed and direction, digital read out, service cable, SD card for data storage, GPRS capable but not implemented, solar panel. Manual rain gauge also at site. |
| Observer present | Yes (but not during visit) |
| Status | Operational |
| Distance to LVBWB Office | ~150 km (2 hours) |

General Site Map:


Site Description:
Site is well fenced and equipment looks newly installed. Easily accessible right off of major highway.

Station Photos:

**AWS at Bunda/Bitaraguru** **School children and fenced in AWS and manual rain gauge**

Station Notes:
The observer who is a teacher was not available to allow us to inspect the equipment but similar hardware for the Vaisala station was inspected for installed stations at the LVBWB office the following day. The manual rain gauge is checked once per day and values are crosschecked with recordings form the AWS when data is downloaded. The AWS is noted to operate well with the exception of missing data being occasionally recorded at the end of the month (unclear as why this consistently occurs).

**4. Grumeti Hydrometric Station (August 14, 2014)**

| | |
|---|---|
| Station Code | 110012 |
| Purpose of Station | Water level and discharge monitoring; periodic water quality |
| Latitude | -2.098444 |
| Longitude | 33.868833 |
| Period of Record | ~1960 to present |
| Equipment | Staff gauges |
| Observer present | Yes (but not during visit) |
| Status | Operational |
| Distance to LVBWB Office | ~150 km (2 hours) |

General Site Map:



Site Description:

A new bridge has been recently constructed which resulted in the previous staff gauges being destroyed. New staff gauges have been placed but they are currently not aligned at a single cross-section with the lowest gauge (1) on the upstream side of the old bridge, the second gauge at the downstream end of the new bridge (2), and the gauges 3 through 5 aligned in a row but further downstream. Ideally these staff gauges should be constructed at a single cross section in order to establish a consistent stage to discharge relationship as the water level could rise or fall upstream and downstream of the bridge constriction. The site is very accessible along the main highway but this also makes it more prone to potential vandalism and theft (previous pressure sensor stolen). Flood stage may exceed the highest staff gauge level and surrounding bank area appears to be susceptible to erosion which may be a result of the bridge construction.

Station Photos:


View looking upstream under new and old bridge

Upstream of Grumeti with showing first staff gauge


Downstream of Grumeti from bridge showing staff gauges 3-5

Staff gauges 3-5

Old Grumeti housing for pressure sensor damaged by flood waters

Station Notes:

Observer was not present during the visit but water level measurements are reported to be recorded twice per day. The site previously had a pressure sensor similar to the Mara Mines station but it was stolen. The existing housing for the sensor needs repair after flood waters breached it's sides. It may be more advantageous to utilize a radar for automated water level recording given that the bridge height above the river does not exceed 10 meters. Discharge measurements are taken by carrying a line across the bridge and then running the OTT Qliner across. Like most hydrometric stations this is currently done once or twice a year and coincides with water quality measurements. The rating curves were noted to be old and are not updated regularly. Despite being along a major road cell coverage was limited (Vodacom) for potential GPRS telemetry. Power lines ran along the road but it is unclear how accessible this would be for any station equipment.

**Annex A.8-2: LVBWB Proposed Groundwater Monitoring Boreholes**

| DISTRICT | VILLAGE | Latitude | Longitude |
|---|---|---|---|
| **SERENGETI** | ROBANDA | -2.158988 | 34.68951055 |
| **RORYA** | RYAGORO* | -1.2935 | 34.18868553 |
| **BUTIAMA** | KAMGEGE* | -1.740272 | 33.80556398 |
| **KWIMBA** | MILYUNGU* | -3.195718 | 33.19830194 |
| **MASWA** | NGULIGULI | -3.137496 | 33.93253614 |
| **KAHAMA** | ZONGOMERA* | -3.851835 | 32.55819508 |
| **GEITA** | SAMINA* | -2.891221 | 32.15801284 |
| **GEITA** | BUGARAMA | -2.66973 | 32.24975381 |
| **SENGEREMA** | SIMA | -2.704727 | 32.54230661 |
| **NYAMAGANA** | IGOMA | -2.552738 | 32.98876448 |
| **KARAGWE** | KISHAO | -1.58182 | 31.14779597 |
| **NGARA** | KABANGA | -2.622429 | 30.46824265 |
| **BARIADI** | IKINABUSHU | -2.458998 | 34.05570727 |
| **MAGU** | NG'HAYA | -2.637337 | 33.56657222 |
| **ITILIMA** | MWASWALE | -2.817415 | 34.36527585 |

**Mining Operations monitoring*

**Annex A.8-3: LVBWB Water Quality Monitoring Sites**

| *Location* | W/Sources | Coordinate | Measurable parameters | Frequency | Estimated cost annually (TSH) | Selection criteria |
|---|---|---|---|---|---|---|
| *Tarime* | Tighite river upstream (SWT01) North Mara | E 034º34.170' S 01º25.377' | Physical chemical parameters (Temperature, pH, EC, Turbidity,Alkalinity,Hardness) and heavy metals (As,Pb,Fe,Cu,Mn,Ni,Cd,Ag,Hg) | Monthly | 15,000,000 | To explore the status of water prior to the mining site/area<br>Artisanal miners around the mining areas (where by mercury is used for extraction purposes) |
| | Tighite river (SWT04) North Mara | E 034º33.057' S 01º26.428' | Physical chemical parameters (Temperature, pH, EC, Turbidity,hardness,alkalinity) and heavy metals (As,Pb,Fe,Cu,Mn,Ni,Cd,Ag,Hg) | Monthly | | The station is proximity to the famous leachate ponds/gokona pit<br>Livestock keeping<br>Artisanal miners around the mining areas (where by mercury is used for extraction purposes) |
| | Tighite river (SWT05) North Mara | E 034º31.996' S 01º26.928' | Physical chemical parameters (Temperature, pH, EC, Turbidity,Alkalinity,Hardness) and heavy metals (As,Pb,Fe,Cu,Mn,Ni,Cd,Ag,Hg) | Monthly | | The station is very close to the mining road, the effect of dust caused by mining vehicles can easily be traced from this station<br>Livestock keeping<br>Artisanal miners around the mining areas (where by mercury is used for extraction purposes) |
| | Tighite river downstream (SWT06) North Mara | E 034º28.409' S 01º27.505' | Physical chemical parameters(Temperature, pH, EC, Turbidity,Alkalinity,Hardness) and heavy metals (As,Cu,Mn,Ni,Cd,Ag,Hg, TCN) | Monthly | | This station is at the downstream to the mining processing plant<br>Livestock keeping.<br>Artisanal miners around the mining areas (where by mercury is used for extraction purposes) |

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|---|---|---|---|---|---|---|
| | North Mara gold MBN- 23 | N 9836598 E 666297.1 | Physical chemical parameters (Temperature, pH, EC, Turbidity) and heavy metals (As,Cu,Mn,Ni,Cd,Ag,Hg,,TCN) | Monthly | | Observation borehole for seepage monitoring at TSF (Groundwater monitoring) |
| | North Mara gold MBN- 24D | N 9836619.558 E 665968.9 | Physical chemical parameters (Temperature, pH, EC, Turbidity) and heavy metals (As,Cu,Mn,Ni,Cd,Ag,Hg,,TCN) | Monthly | | Observation borehole for seepage monitoring at TSF(Groundwater monitoring) |
| | North Mara gold MBN- 25S | N 9836785.224 E 665840.9 | Physical chemical parameters (Temperature, pH, EC, Turbidity,Alkalinity,Hardness) and heavy metals (As,Cu,Mn,Ni,Cd,Ag,Hg,,TCN) | Monthly | | Observation borehole for seepage monitoring at TSF(Groundwater monitoring) |
| ***Geita*** | SW-12 (GGM) | E 032º09.840' S 02º50.141' | Physical chemical parameters (Temperature, pH, EC, Turbidity,hardness,alkalinity) and heavy metals(As,Pb,Fe,Cu,Mn,Ni,Cd,Ag,Hg) | Quarterly | 8,000,000 | Effect of mining operation<br>Artisanal miners around the mining areas<br>(where by mercury is used for extraction purposes) |
| | SW-14 (GGM) | E 032º10.335' S 02º51.815' | Physical chemical parameters(Temperature, pH, EC, Turbidity,Alkalinity,Hardness) and heavy metals (As,Pb,Fe,Cu,Mn,Ni,Cd,Ag,Hg) | Quarterly | | Effect of mining operation<br>Artisanal miners around the mining areas<br>(where by mercury is used for extraction purposes) |
| | SW-37 (GGM) | E 032º09.288' S 02º50.243' | Physical chemical parameters(Temperature, pH, EC, Turbidity,Alkalinity,Hardness) and heavy metals (As,Pb,Fe,Cu,Mn,Ni,Cd,Ag,Hg) | Quarterly | | The station is at waste rock dump area and normally there is seepage (already reported)<br>Artisanal miners around the mining areas<br>(where by mercury is used for extraction purposes) |
| | SW-23 (GGM) | E032º09.228' S 02º51.662 | Physical chemical parameters(Temperature, pH, EC, Turbidity,hardness,alkalinity) and heavy metals (As,Cu,Mn,Ni,Cd,Ag,Hg, FCN,TCN) | Quarterly | | The station is at the downstream and closely to the Tailing dam storage facility(TSF)<br>Artisanal miners around the mining areas<br>(where by mercury is used for extraction purposes) |
| | Mgusu River mouth | E032º01.320' S 02º46.684' | Physical chemical parameters(Temperature, pH, EC, Turbidity,Alkalinity,Hardness) and heavy metals (As,Pb,Fe,Cu,Mn,Ni,Cd,Ag,Hg) | Quarterly | | Ongoing artisan mining at Mgusu village<br>(The impact of small mining activities to the stream)<br>Ongoing mining at Mgusu by GGM(investors) |
| | Mtakuja River mouth | E032º01.508' S 02º46.600' | Physical chemical parameters(Temperature, pH, EC, Turbidity,hardness,alkalinity) and heavy metals (As,Pb,Fe,Cu,Mn,Ni,Cd,Ag,Hg) | Quarterly | | Mtakuja river passes across mining area prior entering lake Victoria at Nungwe bay<br>Artisanal miners around the mining areas<br>(where by mercury is used for extraction purposes) |
| | GW-51 GGM | E 032º09.846' S 02º50.137' | Physical chemical parameters(Temperature, pH, EC, Turbidity,Alkalinity,Hardness) and heavy metals (As,Cu,Mn,Ni,Cd,Ag,Hg,,TCN) | Quarterly | | Observation borehole for seepage monitoring at TSF (Groundwater monitoring) |

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| | GW-27 GGM | E 032º10.518' S 02º50.381' | Physical chemical parameters(Temperature, pH, EC, Turbidity,Alkalinity,Hardness) and heavy metals (As,Cu,Mn,Ni,Cd,Ag,Hg,,TCN) | Quarterly | | Observation borehole for seepage monitoring at TSF(Groundwater monitoring) |
| | GW-04 GGM | E 032º11.600' S 02º52.095' | Physical chemical parameters(Temperature, pH, EC, Turbidity,Alkalinity,Hardness) and heavy metals (As,Cu,Mn,Ni,Cd,Ag,Hg,,TCN) | Quarterly | | Mining operation |
| *Kahama* | TMB 02-Bulyanhulu | E 032º28.791' S 03º13.190' | Physical chemical parameters(Temperature, pH, EC, Turbidity,Alkalinity,Hardness) and heavy metals (As,Cu,Mn,Ni,Cd,Ag,Hg,,TCN) | Quarterly | | Observation borehole for seepage monitoring at TSF(Groundwater monitoring) |
| | PMB 07-Bulyanhulu | E 032º28.837' S 03º13.045' | Physical chemical parameters(Temperature, pH, EC, Turbidity,Alkalinity,Hardness) and heavy metals (As,Cu,Mn,Ni,Cd,Ag,Hg,,TCN) | Quarterly | | Observation well for plant-processing monitoring ( the impact of processing plant to the groundwater ) |
| | PMB 03-Bulyanhulu | E 032º28.733' S 03º13.265' | Physical chemical parameters(Temperature, pH, EC, Turbidity,Alkalinity,Hardness) and heavy metals (As,Cu,Mn,Ni,Cd,Ag,Hg,,TCN) | Quarterly | | Observation well for plant-processing monitoring ( the impact of processing plant to the groundwater ) |
| | TMB 09-Bulyanhulu | E 032º29.784' S 03º13.877' | Physical chemical parameters(Temperature, pH, EC, Turbidity,Alkalinity,Hardness) and heavy metals (As,Cu,Mn,Ni,Cd,Ag,Hg,,TCN) | Quarterly | | Observation borehole for seepage monitoring at TSF (Groundwater monitoring) |
| | SW-08 Buzwagi | E 032º39.081' S 03º50.521' | Physical chemical parameters(Temperature, pH, EC, Turbidity,Alkalinity,Hardness) and heavy metals (As,Pb,Fe,Cu,Mn,Ni,Cd,Ag,Hg) | Quarterly | | Surface water ponds close to the mining operation |
| | TSF-1b-Buzwagi | E 032º40.484' S 03º51.120' | Physical chemical parameters(Temperature, pH, EC, Turbidity,Alkalinity,Hardness) and heavy metals (As,Cu,Mn,Ni,Cd,Ag,Hg,,TCN) | Quarterly | | Borehole for TSF seepage monitoring (Groundwater monitoring) |
| | TSF05-Buzwagi | E 032º41.067' S 03º51.332' | Physical chemical parameters (Temperature, pH, EC, Turbidity,Alkalinity,Hardness) and heavy metals (As,Cu,Mn,Ni,Cd,Ag,Hg,,TCN) | | | Borehole for TSF seepage monitoring (Groundwater monitoring) |
| | GW-08 Buzwagi | E 032º38.513' S 03º50.151' | Physical chemical parameters (Temperature, pH, EC, Turbidity,Alkalinity,Hardness) and heavy metals (As,Pb,Fe,Cu,Mn,Ni,Cd,Ag,Hg,) | Quarterly | | Shallow well used by public for domestic purposes, its is far from mining area because it is not covered it could also be affected/polluted by mining dusts |

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| ***Ilemela*** | Nile perch | E 032º57.681'<br>S 02º32.298' | Faecal coliform,<br>Total coliform,<br>Physical chemical parameters<br>(Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, SO4,Fe)<br>,nutrients ( PO4,TP,TN,TDN,NO3,NO2 NH3 DRSI )<br>,BOD,COD,DO | Quarterly | 1,400,000 | Discharge effluent environment |
| | Serengeti breweries | E 032º58.174'<br>S 02º32.399' | Faecal coliform,<br>Total coliform,<br>Physical chemical parameters<br>(Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, $SO_4$,Fe), nutrients<br>( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) BOD,COD,DO | Quarterly | | Discharge effluent to environment |
| | Mwanza fish mills | E 032º54.214'<br>S 02º32.514' | Faecal coliform,<br>Total coliform,<br>Physical chemical parameters<br>(Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, $SO_4$,Fe), nutrients<br>( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) BOD,COD,DO | Quarterly | | Discharge effluent to environment |
| | Mwatex | E 032º57.799'<br>S 02º28.242' | Faecal coliform,<br>Total coliform,<br>Physical chemical parameters<br>(Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, $SO_4$,Fe), nutrients<br>( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) BOD,COD,DO | Quarterly | | Discharge effluent to environment |
| | TBL | E 032º54.214'<br>S 02º28.039' | Faecal coliform,<br>Total coliform,<br>Physical chemical parameters<br>(Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, $SO_4$,Fe), nutrients<br>( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) BOD,COD,DO<br>(Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, $SO_4$,Fe), nutrients<br>( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) BOD,COD,DO | Quarterly | | Discharge effluent to lake Victoria |

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| | Butuja WSPs | E 032º54.619'<br>S 02º28.022' | Faecal coliform,<br>Total coliform,<br>Physical chemical parameters<br>(Temperature, pH, EC, Turbidity, Alkalinity,<br>Hardness,colour,TSS,TDS, $SO_4$,Fe), nutrients<br>( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) BOD,COD,DO | Quarterly | | Discharge effluent to lake victoria |
| | Tan perch | E 032º54.569'<br>S 02º27.498' | Faecal coliform,<br>Total coliform,<br>Physical chemical parameters<br>(Temperature, pH, EC, Turbidity, Alkalinity,<br>Hardness,colour,TSS,TDS, $SO_4$, Fe ), nutrients<br>( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) BOD,COD,DO | Quarterly | | Discharge effluent to environment |
| | Mwanza fishing ltd, | E 032º54.580'<br>S 02º27.433' | Faecal coliform,<br>Total coliform,<br>Physical chemical parameters<br>(Temperature, pH, EC, Turbidity, Alkalinity,<br>Hardness,colour,TSS,TDS, $SO_4$,Fe), nutrients<br>( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) BOD,COD,DO | Quarterly | | Discharge effluent to lake Victoria |
| | TFDC | E 032º54.464'<br>S 02º27.281' | Faecal coliform,<br>Total coliform,<br>Physical chemical parameters<br>(Temperature, pH, EC, Turbidity, Alkalinity,<br>Hardness,colour,TSS,TDS, $SO_4$,Fe), nutrients<br>( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) BOD,COD,DO | Quarterly | | Discharge effluent to lake victoria |
| | Omega fish ltd | E 032º54.167'<br>S 02º27.079' | Faecal coliform,<br>Total coliform,<br>Physical chemical parameters<br>(Temperature, pH, EC, Turbidity, Alkalinity,<br>Hardness,colour,TSS,TDS, $SO_4$, Fe), nutrients<br>( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) BOD,COD,DO | Quarterly | | Discharge effluent to lake Victoria |
| | SBC-Pepsi | E 032º58.001'<br>S 02º32.289' | Faecal coliform,<br>Total coliform,<br>Physical chemical parameters<br>(Temperature, pH, EC, Turbidity, Alkalinity,<br>Hardness,colour,TSS,TDS, $SO_4$, Fe ), nutrients<br>( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) BOD,COD,DO | Quarterly | | Discharge effluent to environment |
| | TFP ltd | E 032º54.182'<br>S 02º32.496' | Faecal coliform,<br>Total coliform,<br>Physical chemical parameters | Quarterly | | Discharge effluent to environment |

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| | | | (Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, SO4, Fe), nutrients ( PO4,TP,TN,TDN,NO3,NO2 NH3 DRSI ) BOD,COD,DO | | | |
| ***Nyamagana*** | Vic fish ltd | E 032º54.154' S 02º32.465' | Faecal coliform, Total coliform, Physical chemical parameters (Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, $SO_4$,Fe), nutrients ( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) BOD,COD,DO | Quarterly | | Discharge effluent to lake Victoria |
| | Vic fish Co Ltd | E 031º49.425' S 01º19.533' | Faecal coliform, Total coliform, Physical chemical parameters (Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, $SO_4$,Fe), nutrients ( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) BOD,COD,DO | Quarterly | | Discharge effluent to lake Victoria |
| | Nyanza bottling limited | E 033º58.309' S 02º32.239' | Faecal coliform, Total coliform, Physical chemical parameters (Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, $SO_4$, Fe ), nutrients ( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) BOD,COD,DO | Quarterly | | Discharge effluent to lake Victoria |
| ***Kagera*** | Kagera fish Co Ltd | E 031º44.47' S 01º28.16' | Faecal coliform, Total coliform, Physical chemical parameters (Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, $SO_4$,Fe), nutrients ( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) BOD,COD,DO | Quarterly | | Discharge effluent to lake Victoria |
| | Kagera Sugar Ltd | E 031º33.337' S 01º24.519' | Faecal coliform, Total coliform, Physical chemical parameters (Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, $SO_4$, Fe ), nutrients ( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) BOD,COD,DO | Quarterly | 22,500,000 | Discharge effluent to lake Victoria |
| | TANICA Ltd | E 031º81.168' S 01º32.385' | Faecal coliform, Total coliform, Physical chemical parameters (Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, $SO_4$, Fe ), nutrients ( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) BOD,COD,DO | | | Discharge effluent to lake Victoria |

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| | Kitoboka BH | S 01⁰03.401'<br>E 030⁰98.121' | Faecal coliform,<br>Total coliform,<br>Physical chemical parameters<br>(Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, $SO_4$, Fe), nutrients<br>( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) | Quarterly | | |
| | Igayaza BH | S 01º13.001'<br>E 031º39.454' | Faecal coliform,<br>Total coliform,<br>Physical chemical parameters<br>(Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, $SO_4$, Fe), nutrients<br>( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) | Quarterly | | Discharge effluent to environment |
| | Kilimilile BH | S 01º30.688'<br>E 031º42.574' | Faecal coliform,<br>Total coliform,<br>Physical chemical parameters<br>(Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, $SO_4$, Fe), nutrients<br>( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) | Quarterly | | Discharge effluent to environment |
| | Kashaba market BH | S 01º27.523'<br>E 031º45.886' | Faecal coliform,<br>Total coliform,<br>Physical chemical parameters<br>(Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, $SO_4$, Fe), nutrients<br>( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) | Quarterly | | Discharge effluent to environment |
| | Mushasha-Borehole | S 01º22.695'<br>E 031º50.315' | Faecal coliform,<br>Total coliform,<br>Physical chemical parameters<br>(Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, $SO_4$, Fe), nutrients<br>( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) | Quarterly | | Discharge effluent to environment |
| | Water intake BUWASA | S 01º34.631'<br>E 031º81.591' | Faecal coliform,<br>Total coliform,<br>Physical chemical parameters<br>(Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, $SO_4$, Fe), nutrients<br>( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) | Quarterly | | Discharge effluent to environment |

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| | Bukoba pier | S 01º34.804'<br>E 031º81.663' | Faecal coliform,<br>Total coliform,<br>Physical chemical parameters<br>(Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, $SO_4$, Fe), nutrients<br>( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) | Biannually | | Discharge effluent to environment |
| | Kemondo/Kagera fish | S 01º38.002'<br>E 031º59.551' | Faecal coliform,<br>Total coliform,<br>Physical chemical parameters<br>(Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, $SO_4$, Fe), nutrients<br>( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) | Quarterly | | Discharge effluent to environment |
| | Nkenge bridge | S 01º23.944'<br>E 031º59.604' | Faecal coliform,<br>Total coliform,<br>Physical chemical parameters<br>(Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, $SO_4$, Fe), nutrients<br>( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) | Biannually | | Discharge effluent to environment |
| | Kyaka ferry | S 01º25.067'<br>E 031º41.842' | Faecal coliform,<br>Total coliform,<br>Physical chemical parameters<br>(Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, $SO_4$, Fe), nutrients<br>( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) | Biannually | | Discharge effluent to environment |
| | Nyakanyasi met station | S 01º19.304'<br>E 031º20.522' | Faecal coliform,<br>Total coliform,<br>Physical chemical parameters<br>(Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, $SO_4$, Fe), nutrients<br>( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) | Biannually | | Discharge effluent to environment |
| | Kyakakera bridge | S 01º35.200'<br>E 031º46.175' | Faecal coliform,<br>Total coliform,<br>Physical chemical parameters<br>(Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, $SO_4$, Fe), nutrients<br>( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) | Biannually | | Discharge effluent to environment |
| | Kalebe bridge | S 01º47.275'<br>E 031º67.518' | Faecal coliform,<br>Total coliform,<br>Physical chemical parameters | Biannually | | Discharge effluent to environment |

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| | | | (Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, $SO_4$, Fe), nutrients ( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) | | | |
| | Kyabakoba bridge | S 01º58.970' E 031º67.344 | Faecal coliform, Total coliform, Physical chemical parameters (Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, $SO_4$, Fe), nutrients ( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) | Biannually | | Discharge effluent to environment |
| | Rubale bridge | S 01º37.150' E 031º47.200' | Faecal coliform, Total coliform, Physical chemical parameters (Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, $SO_4$, Fe), nutrients ( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) | Biannually | | Discharge effluent to environment |
| | Kamishango bridge | S 01º84.068' E 031º61.847' | Faecal coliform, Total coliform, Physical chemical parameters (Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, $SO_4$, Fe), nutrients ( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) | Biannually | | Discharge effluent to environment |
| | Bujara-Ruhasa spring | S 01º81.004' E 031º13.567' | Faecal coliform, Total coliform, Physical chemical parameters (Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, $SO_4$, Fe), nutrients ( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) | Biannually | | Discharge effluent to environment |
| | Nyarwele spring | S 01º44.460' E 031º15.274' | Faecal coliform, Total coliform, Physical chemical parameters (Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, $SO_4$, Fe), nutrients ( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) | Biannually | | Discharge effluent to environment |
| | Nyaruhanga spring | S 01º24.567' E 030º69.623' | Faecal coliform, Total coliform, | Biannually | | Discharge effluent to environment |

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| | | | Physical chemical parameters<br>(Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, $SO_4$, Fe), nutrients<br>( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) | | | |
| *Mara* | Musoma Textile | | Faecal coliform,<br>Total coliform,<br>Physical chemical parameters<br>(Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, $SO_4$,Fe), nutrients<br>( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) BOD,COD,DO | Quarterly | 6,000,000 | Discharge effluent to environment |
| | Mara Diary Ltd | | Faecal coliform,<br>Total coliform,<br>Physical chemical parameters<br>(Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, $SO_4$,Fe), nutrients<br>( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) BOD,COD,DO | Quarterly | | Discharge effluent to environment |
| | Bunda Oil Ltd | | Faecal coliform,<br>Total coliform,<br>Physical chemical parameters<br>(Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, $SO_4$,Fe), nutrients<br>( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) BOD,COD,DO | Quarterly | | Discharge effluent to environment |
| | Musoma Fish Processor | | Faecal coliform,<br>Total coliform,<br>Physical chemical parameters<br>(Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, $SO_4$,Fe), nutrients<br>( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) BOD,COD,DO | Quarterly | | Discharge effluent to environment |
| | Prime Catch Ltd | | Faecal coliform,<br>Total coliform,<br>Physical chemical parameters<br>(Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, $SO_4$,Fe), nutrients<br>( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) BOD,COD,DO | Quarterly | | Discharge effluent to environment |

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| *Magu* | Busulwa intake | E 033º22.724'<br>S 02º31.753' | Faecal coliform,<br>Total coliform,<br>Physical chemical parameters<br>(Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, $SO_4$, Fe), nutrients<br>( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) | Biannually | 7,000,000 | Discharge effluent to environment |
| | Ihale | E 033º27.672<br>S 02º34.501' | Faecal coliform,<br>Total coliform<br>Physical chemical parameters<br>(Temperature, pH, EC, Turbidity, Alkalinity, Hardness,colour,TSS,TDS, $SO_4$, Fe), nutrients<br>( $PO_4$,TP,TN,TDN,$NO_3$,$NO_2$ $NH_3$ DRSI ) | Biannually | | Discharge effluent to environment |
| | Simiyu river | E 033º28.315'<br>S 02º26.989' | Nutrients<br>(Nitrogen and their species and Phosphorus and its species) both on sediments and water column | Biannually | | Discharge effluent to environment |
| *Misungwi* | Nyahiti intake | E 032º57.600'<br>S 02º49.382' | Faecal coliform,<br>Total coliform,<br>Physical-chemical parameters | Biannually | | Discharge effluent to environment |
| *Ukerewe* | Namasabo | S 02º06.494'<br>E 033º02.057' | Faecal coliform,<br>Total coliform,<br>Physical-chemical parameters | Biannually | | Discharge effluent to environment |
| | Kakukuru | S 01º55.184'<br>E 032º53.325' | Faecal coliform,<br>Total coliform,<br>Physical-chemical parameters | Biannually | | Discharge effluent to environment |

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|---|---|---|---|---|---|---|
| *Bunda* | Lugezi ferry | S 02º07.545'<br>E 033º10.548' | Faecal coliform,<br>Total coliform,<br>Dissolved oxygen, COD and BOD5,Oil and physical parameters | Biannually | | Discharge effluent to environment |
| | Gurumeti river | E 033º52.182'<br>S 02º05.912' | Nutrients<br>(Nitrogen and their species and Phosphorus and its species) both on sediments and water column | Biannually | | Discharge effluent to environment |

# Appendix A.9: National Consultation and Field Visit Report for Uganda

## 1. Introduction and Background

In May 2014, the Nile Basin Initiative (NBI) contracted with Riverside Technology to develop design specifications and an implementation plan for the Nile Basin Regional Hydro-meteorological Monitoring System (this Assignment). The assignment aims to enhance Nile River basin monitoring. It will address coverage, equipment, techniques, data acquisition and dissemination, sampling and testing, standard procedures, capacity development, cost estimates, and implementation planning.

As part of this assignment, field visits and national consultations have been organized in each project country, with the aim to appreciate the potential value, benefits, and need for the regional water resource monitoring system, acquire a deeper appreciation of the current state of the monitoring technologies and practices, and to understand the institutional context within which the designed system will be operated. The consultations will also identify needs for technical support, capacity building, and institutional strengthening. The defined objectives include the following:

- Confirm understanding of current network and practices based on the country assessment report and metadata, as well as past studies. Supplement information and metadata based on discussions.
- Identify country protocols for data communication, storage, formatting, dissemination, sharing, and use. Identify and discuss what data could be used in a regional network and how it could be delivered.
- Confirm the important socio-economic drivers for data collection and elaborate specific needs for data to inform decisions and development.
- Discuss perceived needs both with regards to data collection and institutional capacity development and how these can relate to the regional monitoring network.
- Conduct field visits at key monitoring locations that adequately represent the current technologies and practices within use. This will include visits to any water quality labs to further assess data sampling, testing, management, and dissemination.

## 2. Hydromet Network in Uganda

*Status of the Hydromet Network*

The status of surface and ground water monitoring in Uganda has been reported in detail in the recent Hydrological Assessment Report for Uganda prepared for the project. This document also reports on water quality and sediment monitoring. The report presents station tables with station coordinates and monitoring parameters. The mission confirmed the information presented in the assessment report and the reader is referred to this document for up-to-date information.

Climate and rainfall monitoring is the mandate of the Uganda Meteorological Authority (UMA). The operational status of the 635 historic rainfall stations in Uganda could not be established during the mission and is still being investigated.

*Ongoing and Planned Expansion of the Network*

It is important to note that DWRM is implementing a number of concurrent projects to enhance the hydro-meteorological monitoring capacity in the country. Coordination is essential to make best use of the available resources. This paragraph lists the various ongoing initiatives.

*IGAD HYCOS*

IGAD and WMO are jointly implementing a project to provide adequate infrastructure for hydrological observations and regional cooperation in information exchange. The project will install a total of 100 hydrometric stations accompanied by a comprehensive training program. Seven project countries are involved: Burundi, Ethiopia, Kenya, Rwanda, Sudan, Tanzania, and Uganda. IGAD HYCOS is being implemented in two phases: 1) preparatory phase (with 1 year duration) and 2) implementation phase (with a duration of 33 months). The first phase has been completed and the project has started the procurement process of hardware and the data management system.

IGAD HYCOS has proposed to upgrade 11 hydrometric stations in Uganda (Annex 1-A). Instruments will be procured from Ott (staff gauges and boat) and SEBA (the remainder, including the telemetry system and ADCP). GSM/GPRS data communication is proposed for areas with mobile phone coverage. Satellite telemetry will only be used for stations without adequate mobile phone connection.

The proposed database setup includes three levels: regional, national, and IGAD (international). While the data management system has not yet been selected, an IGAD HYCOS engineer interviewed during the mission indicated that the likely choice is HYDSTRA (from Germany) in view of the procurement rules of the European Union – the donor. The proposed HYDSTRA version includes more analysis tools than the standard Aquarius version but is significantly more expensive.

The stations proposed for upgrading by IGAD HYCOS, as well as contact details of key project staff, are presented in the Annex.

It is noted that IGAD HYCOS support is limited to equipment, software, and training. The project does not provide infrastructure for discharge measurement (such as cableway facilities) or improve the control section through small civil work such as berms.

*GIZ*

GIZ is upgrading 14 hydrometric stations in Uganda (Annex 1-B). The equipment has been selected (SEBA float operated shaft encoders with GSM/GPRS telemetry using the MTN network) and instrument shelters at the respective sites have already been constructed. It is noted that there is overlap with the network proposed by IGAD HYCOS (Jinja Pier, Mbulamuti, Masindi Port).

*World Bank*

World Bank is sponsoring a project to upgrade the hydrometric information system in Uganda. The project will upgrade 16 hydrometric stations, 17 groundwater stations, 4 automated full climate stations, and 4 automatic rain gauges (Annex 1-C).

The project will also upgrade the data center (in Entebbe) and procure a hydrologic information system that integrates various data sources and allows automated data import and validation (the tender specifications are provided in Annex 2). The system will connect real-time to the four zonal offices (Mbale – Kyoga WMZ; Mbarara – Victoria WMZ; Lira – Upper Nile WMZ; Fort Portal – Albert WMZ).

Further, the project will include a comprehensive training program.

The procurement of the hydrometric information system is in progress. The bid documents prepared by DWRM have been accepted by World Bank and the tender process is expected to be completed by early 2015.

*Other Initiatives*

Other initiatives in Uganda that are involved in hydrometric monitoring include the Lake Victoria Environmental Management Program (LVEMP – phase 2). The monitoring activities of this program will focus on sediment monitoring and upgrading monitoring station in the Lake Victoria watershed.

Lastly, the reporter was informed that also UNDP is assisting DWRM in enhancing hydromet monitoring capacity. The focus and extent of this initiative could not be established.

*Possible Gaps*
While the ongoing initiatives to expand the hydromet network in Uganda are extensive, a number of potential gaps have been identified in discussions with senior DWRM staff:

- No monitoring of lake evaporation, which is a key component of the water balance of the Nile system in Uganda;
- No stabilizing (through minor civil works) of river profiles/controls sections at monitoring sites in rivers surrounded by extensive wetlands (such as Kapiri at Awoja, which monitors the inflow from the vast Karamoja area into Lake Kyoga, or Kafu at the Gulu-Kampala road bridge); stabilizing control sections would greatly improve flood monitoring;
- No sediment monitoring (apart from possibly LVEMP) on the Aswa – where two multi-purpose dams are planned – or Semliki.

*Data Management*
Hydrometric data are transferred from the stations to the central office in Entebbe or the Water Management Zones (WMZ) through: 1) monthly or three-monthly transfer of paper record sheets, 2) use of storage modules such as the Ott Vota or laptop that download accumulated station data during periodic field visits, and 3) near real-time data transfer using the mobile phone network (GSM/GPRS). The latter is currently taking place on an experimental basis using SEBA DEMASdb software and is performing well.

The frequency of data transfer is a function of the method used and varies between three-months and near real-time.

Upon arrival in the office, manual recordings and strip charts are digitized and subjected to a manual quality check. Electronic data (from VOTA, other type of storage modules, or laptop) are first downloaded into MS Excel. No standard procedures or automated routines exist for data quality control. After manual quality control, all files are transferred to text files and exported to HYDATA, which is a hydrological database and analysis software developed by the Centre for Ecology & Hydrology in Wallingford, UK.

HYDATA stores the types of data most commonly required in water resources studies, including river levels and flows, and rainfall and other meteorological data. The software includes tools for developing rating curves. Output is provided in the form of "yearbook" style tabulations and graphs, while data can be exported to analysis software such as MS Excel. HYDATA is not connected to a GIS.

For a number of stations – including the Automatic Weather Stations (AWS) – data are also stored in a parallel MS Access database.

The National Groundwater Database is stored in a separate system developed in PostgreSQL. It is not connected to HYDATA or a GIS.

Backups are made on a regular basis and located in a separate building.

*Water Quality Laboratory*

The national water quality laboratory is located at the DWRM compound in Entebbe, while satellite laboratories are (or will be) established in each of the 4 Water Management Zones (in Mbale, Mbarara, Lira, and Fort Portal respectively). Currently only Mbale is operational.

Test kits are available at district level for early detection of water quality and associated health risks.

The laboratory in Entebbe is equipped with instrumentation for all standard water quality analysis (pH, turbidity, BOD, COD, DO, etc). Further, the laboratory has sophisticated equipment for:

- Detection of heavy metals and trace organic compounds;
- Isotope detection – to assess groundwater origin;
- Sediment analysis – including organic matter;
- Spectrography –to identify the molecular elements (in water) such as NO3, NH4, PO4, etc.

The national laboratory aims to achieve ISO certification in the near future. Its mandate is to:

1. Perform analysis for which specialist equipment and skills are required;
2. Check and maintain the quality of the zonal laboratories;
3. Capacity building of staff of the zonal laboratories;

## 3. Institutional Setting

*Institutional Framework for Water Resources Monitoring*
This paragraph lists the key organizations in the country involved in hydromet data acquisition.

DWRM
The Directorate of Water Resources Management (DWRM) – which is part of the Ministry of Water and Environment (MWE) - is responsible for monitoring, assessing, allocating and regulating water resources through the issuance of water abstraction and wastewater discharge permits.

DWRM comprises three departments: Department of Water Resources Monitoring and Assessments, Department of Water Quality Management, and Department of Water Resources Regulation. The latter contains the Transboundary Water Resources Management Division, which is responsible for Nile Basin affairs.
Some of the water resources management functions of DWRM have been de-concentrated to Water Management Zones (WMZ) as a way of moving closer to the stakeholders. The country has been divided into four WMZs (Victoria, Albert, Kyoga and Upper Nile) based on hydrological basins.

Uganda Meteorological Authority
The Uganda Meteorological Authority (UMA) plays an important role in providing meteorological information for water resources management, and flood and drought predictions and monitoring, and early warning.

NEMA
The National Environment Management Authority (NEMA) is a parastatal under MWE responsible for management of the environment. NEMA has delegated it functions for waste discharge (and associated WQ monitoring) to DWRM.

*Data Exchange Policies*
To obtain hydrometric information, a letter is required explaining the intended purpose of the data and addressed to the Director DWRM. Consultants pay 30,000 UGX per station year while students pay 10,000 UGX. Many exceptions are made, however, and data requests are in fact being reviewed on a case-by-case basis.

DWRM intends to start publishing hydrometric yearbooks shortly, which will effectively transfer the hydrometric information into the public domain. However, data related to the Nile system and hydropower generation will not be published.

The East African Community (EAC) is developing a comprehensive Information and Data Sharing Protocol. Under this protocol, guidelines for sharing hydrometric information have been developed by LVEMP2. The comprehensive protocol, however, has not yet been approved by the Council of Ministers and is therefore not yet operational. It is not expected that the protocol will be signed in the near future.

A Memory of Understanding (MoU) has been signed between DWRM and the Uganda Meteorological Authority. This MoU, however, is not operational and in practice no data are shared between the two organizations. This situation adversely affects hydrologic studies including drought monitoring and flood assessments.

*Institutional Questionnaire*
The results of the institutional questionnaire have been presented in a separate report.

## 4. Field Visits

Field visits were organized to a number of stations:

- Victoria Nile at Mbulamuti (11 Aug 2014);
- Lake Victoria at Jinja Pier (11 Aug 2014);
- Kyoga Nile at Kamdini (13 Aug 2014);
- Albert Nile at Panyango (13 Aug 2014);
- Lake Albert at Butiaba (14 Aug 2014);
- Kyoga Nile at Masindi Port (14 Aug 2014);
- River Kafu at Gulu-Kampala road bridge (14 Aug 2014);
- Nakasongola AWS (14 Aug 2014);
- Nakasongola groundwater station (14 Aug 2014).

The findings of the field visits are presented in Annex 3. It is noted that IGAD HYCOS or GIZ are upgrading all the above hydrologic stations.

## 5. Main Findings and Recommendations

The main findings of the consultation visit and field trip are presented below:

- There are various concurrent initiatives to upgrade the hydro-meteorological monitoring network in Uganda; a number of stations have been earmarked for upgrading by more than one initiative (e.g. Jinja Pier, Mbulamuti, Masindi Port); coordination is required to make best use of the available resources and harmonize equipment, communication, and software systems; coordination among the various initiatives is presently inadequate;
- GIZ, IGAD HYCOS, and World Bank are upgrading all main stations of the Nile transboundary monitoring system in Uganda;

- It is important to avoid introducing more than one data management system; the World Bank project is replacing the current HYDATA system with a new national hydrometric information system; it is advised that all initiatives use/link into this national system;
- Despite the various projects, a number of gaps have been identified: 1) no measurement of lake evaporation, 2) no sediment monitoring (apart from possibly LVEMP2 – this is not clear yet), and 3) no arrangements to improve the control section of rivers surrounded by large wetland (to improve flood monitoring);
- Satellite data communication would reduce possible communication down-time and improve the reliability of real-time data transfer; it is noted that both IGAD HYCOS and GIS are installing GSM/GPRS data communication;
- The Campbell Scientific AWS' installed by FAO have been operational for about 10 years and are functioning well; out of 11 stations, only one (Moroto) is no longer operational, as a result of vandalism;
- Improved coordination is required between UMA and DWRM; it could not be established during the field visit how rainfall/climate data are currently stored by UMA;
- No formal mechanisms exist for data exchange among Nile riparians;
- The setup and instrumentation of the national water quality laboratory is adequate.

**ANNEXES**

Annex A.9-1A: IGAD HYCOS stations and contact details
Annex A.9-1B: GIZ stations
Annex A.9-1C: World Bank stations and specifications of the hydro information system
Annex A.9-2: Tender Specifications for Hydromet Data Centre in Uganda
Annex A.9-3: Field Visits

**ANNEXES**

**Annex A.9-1A: IGAD HYCOS stations and contact details**

| No. | Station Name | Latitude (1) | Longitude (2) | Purpose (3) | Type (4) | Sensors/Equipment/ Remarks (5) |
|---|---|---|---|---|---|---|
| 1 | Lake Victoria at Jinja | 0:25: 0 N | 33:13: 0 E | (WRA) (WQ) | GSM | (WL), (TSS), (PH), (conductivity) etc |
| 2 | River Nile at Mbulamuti | 0:52: 0 N | 33: 0: 0 E | (WRA) (FF) | GSM | (WL) |
| 3 | River Nile at Laropi | 3:33: 0 N | 31:49: 0 E | (WRA) | GSM | (WL) |
| 4 | Masindi Port | 1:42: 0 N | 32: 6: 0 E | (WRA) (FF) | GSM | (WL) |
| 5 | River Kagera at kasensero | 1:14: 0 S | 31:26: 0 E | (WRA) (WQ) | GSM | (WL), (TSS), (PH), (conductivity) etc |
| 6 | River Nile at Kamdini | 2:16: 0 N | 32:16: 0 E | (WRA) | GSM | (WL) |
| 7 | River Nile at Panyango | 2:34: 0 N | 31:26: 0 E | (WRA) | GSM | (WL) |
| 8 | Lake Albert at Butiaba | 1:50: 0 N | 31:19: 0 E | (WRA) | GSM | (WL) |
| 9 | River Semiliki | 0:57: 0 N | 30:11: 0 E | (WRA) (WQ) (FF), | GSM | (WL) ,(TSS), (PH), (conductivity) etc |
| 10 | Lake Edward at Katwe | O: 09: 0 S | 29: 54: 0 E | (WRA) (WQ)] | GSM | (WL) , (TSS), (PH), (conductivity) etc |
| 11 | River Nile at Paraa | 2:17: 0 N | 32:34: 0 E | (WRA) | GSM | (WL) |
| 12 | Kapiri at Awoja | 1:40: 0 N | 33:46: 0 E | (WRA) (FF), | GSM | (WL) |

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**ANNEX A.9-1B: Hydrometric Stations that GIZ is upgrading**

| S/No | Station No. | Station Name | LONGITUDE | LADITUDE |
|---|---|---|---|---|
| 1 | 83213 | River Kafu | N $01^0$ 32.571' | E $32^0$ 02.552' |
| 2 | 82203 | Kyoga Nile at Masindi Port | N $01^0$ 41.685' | E $32^0$ 05.561' |
| 3 | 81202 | Lake Victoria Jinja Pier | 0:25: 0 N | 33:13: 0 E |
| 4 | 82203 | Victoria Nile at Mbulamuti | 0:52: 0 N | 33: 0: 0 E |
| 5 | 82218 | River Malaba | 0:35: 0 N | 34: 3: 0 E |
| 6 | 82212 | River Manafwa | 0:56: 0 N | 34:10: 0 E |
| 7 | 82231 | River Kelim | 1:36: 0 N | 34:33: 0 E |
| 8 | 82240 | River Sironko | 1:14: 0 N | 34:15: 0 E |
| 9 | 82217 | River Mpologoma | 0.83333 | 33.78333 |
| 10 | 82227 | River Kapiri at Awoja | 1:40: 0 N | 33:46: 0 E |
| 11 | 82201 | Lake Kyoga at Bugondo Pier | 1:38: 0 N | 33:17: 0 E |
| 12 | 82213 | River Namatala | 0: 6:45 N | 34: 0:20 E |
| 13 | 82243 | River Sipi | 1:23: 0 N | 34:19: 0 E |
| 14 | 82241 | River Simu | 1:18: 0 N | 34:17: 0 E |

## ANNEX A.9-1C: Hydrometric Stations that will be upgraded under the World Bank Project

**Category I – Digital Water Level Recording Stations (DWLR)**

| Station No. | Station Name | Location | Latitude | Longitude |
|---|---|---|---|---|
| 81250 | Kiruruma South | Kabale | -1.283 | 30.000 |
| 86201 | Aswa 1 | Puranga | 2.583 | 32.933 |
| 86202 | Aswa 11 | Gulu / Kitgum | 2.950 | 32.583 |
| 86212 | Pager | Kitgum | 3.250 | 33.883 |
| 86213 | Agago | Kitgum / Lira | 2.250 | 32.967 |
| 87207 | Ayugi | Atiak / Laropi | 3.350 | 32.050 |
| 86203 | Aswa 111 | Gulu/ Kitgum | 3.495 | 32.091 |
| 87210 | River Nile at Pakwach | At Pakwach | 2.450 | 31.500 |
| 85212 | River Nkussi | At Kyenjojo - Hoima Road | 1.130 | 30.995 |
| 84207 | Lake George | At Kasenyi / Kasese | -0.025 | 30.149 |
| 83212 | River Tochi II | At Kamdin -Lira Road | 2.227 | 32.342 |
| 84215 | River Mpanga | At Fort Portal - Ibanda Road | 0.101 | 30.462 |
| 84228 | River Nyamugasani | At Katwe - Zaire Road | -0.123 | 29.843 |
| 84267 | River Mitano | At Kanungu - Rwensama Road | -0.683 | 29.800 |
| 85201 | Lake Albert at Butiaba | At Butiaba | 1.836 | 31.328 |
| 85211 | River Muzizi | At Kyenjojo - Hoima Road | 0.871 | 30.730 |

**Category II – Ground Water Level Recording Stations (GWLR)**

| Station No. | Station Name | Location | Latitude | Longitude |
|---|---|---|---|---|
| 001 | Gulu Town | Gulu town | 2.790 | 32.290 |
| 002 | Pakwach Town | Packwach town | 2.487 | 31.452 |
| 003 | Hoima | Hoima | 1.380 | 31.070 |
| 004 | Aswa shear-zone border with Sudan | Along Gulu-Nimule road | 3.587 | 32.224 |
| 005 | Pader | Pader Municipality | 2.900 | 33.280 |
| 006 | Katabok | Katabok Municipality | 2.540 | 33.760 |
| 007 | Kitgum Town | Kitgum town | 3.290 | 32.870 |
| 008 | Kotido at Kabong Hospital | At Kabong Hospital | 3.007 | 34.109 |
| 009 | Kapchorwa | Kapchorwa town | 1.400 | 34.450 |
| 010 | Abim | Abim | 2.500 | 34.000 |
| 011 | Iganga (gneiss I) | Iganga town | 0.620 | 33.469 |
| 012 | Iki-Iki - Budaka | Iki-Iki town | 1.119 | 34.016 |
| 013 | Kaberamaido | Kaberamaido | 1.780 | 33.160 |
| 014 | Katakwi | Katakwi | 1.900 | 33.950 |
| 015 | Kasese (KCCL) | At Kasese Cobalt Company | 0.270 | 29.940 |
| 016 | Ibanda | Ibanda town | -0.140 | 30.470 |
| 017 | Kabale Municipality | Kabale | -1.251 | 29.982 |

**Category III –Automated Full Climate Stations (AFC)**

| Station No. | Station Name | Location | Latitude | Longitude | Elevation (m MSL) |
|---|---|---|---|---|---|
| **Lake Albert Basin** | | | | | |
| 001 | Bushenyi district Headquarters | Bushenyi district Headquarters | -0.81 | 29.92 | 1615 |
| 002 | Bundibugyo district Headquarters | Bundibugyo district Headquarters | 0.71 | 30.065 | 936 |
| **Aswa Basin** | | | | | |
| 003 | Gulu district Headquarters | Gulu district Headquarters | 2.78 | 32.28 | 1082 |
| 004 | Lira district Headquarters | Lira district Headquarters | 2.25 | 32.89 | 1095 |

**Category IV – Automated Rain Gauge Stations (ARG)**

| Station No | Station | Location | Latitude | Longitude | Elevation (m MSL) |
|---|---|---|---|---|---|
| **Victoria Basin** | | | | | |
| 005 | Ruizi | At the new NWSC station | -0.619 | 30.645 | 1386 |
| 006 | Entebbe Office | Entebbe Municipality | 0.05 | 32.4667 | 1180 |
| **Kyoga Basin** | | | | | |
| 007 | Kafu | Masindi | 1.543 | 32.042 | 1040 |
| 008 | Enget | Lira | 2.000 | 33.183 | 1076 |

**ANNEX A.9-2: Tender Specifications for Hydromet Data Centre in Uganda**

**Computer Server and Software for Network Data Reception, Data Processing and Data Storage**

The primary purposes of the data processing center are:

a) real-time reception and processing of data from the hydro-meteorological network
b) processing and analysis of hydro-meteorological data for station monitoring and maintenance (Data Management)

| Item | Technical specifications |
|---|---|
| **Site conditions** | ambient temperature: -30 to +60 degrees C<br>relative humidity: 5% to 100% with condensation<br>altitude: < 1000m |
| **System characteristics** | Flexible number of remote station data collection with the capability to collect all GoU stations and co-operator stations in or near the GoU watershed.<br>overall telemetry system performance better than 99.9% of error free data<br>backup power supply for up to 72hrs |
| **Hardware** | PC processing with the capability to process 600 stations through the Mobile Network. |
| **PC Specifications** | CPU and Memory - core i7 or better 3.0 GHz minimum or greater if required by ERS Software<br>Form Factor: Rackmount (To include computer cabinet and rails)<br>– 8 GB RAM<br>Hard disk size capable of storing 10 years' worth of data in addition to all software components<br>A minimum of three computer screens that can be used to display screens from data collection and data processing processes. These screens will be a minimum of 21 inches and shall incorporate Flat Screen technology. Computer hardware will have the proper interface to use a minimum of four screens.<br>The keyboard and mouse shall be wireless<br>CD/DVD RW+<br>Network – Giga Ethernet 10/100/1000Mbps (RJ45)<br>Interfaces - Serial, parallel, USB, 5V PCI Slot<br>Electrical - Supply Voltage: 230V, 450W<br>Computer Form Factor - Rack mounting to house computer(s), data receivers, network devices as required by the DCS. The rack space available shall be twice that which is actually required for the equipment that is being offered.<br>Operating systems - Windows Server 2010 or newer |
| **Power Supply** | 230 V AC power supply<br>including line conditioner (voltage stabilization)<br>UPS equipment sufficient for automatic data backup procedure<br>including backup generator as required for full operation |
| **Software** | software for data processing, communications handling as well as control and customization of ground station operations<br>Decoding and routing of data from the Data Center<br>Complete data collection diagnostics, including signal strength from each station, time of message reception, frequency as well as other indicators |

| Item | Technical specifications |
|---|---|
| | deemed necessary for data receive operation and remote data station data communication<br>Graphical and Tabular Data viewing facility<br>Real-time as well as Historical Trending<br>Statistics (Minimum, Maximum, Average, Standard Deviation, etc)<br>Equation and Rating table lookup capability<br>Graphs and Data exporting features<br>RDBMS PostGreSQL, ACCESS, or compatible for Data Storage<br>Data Exporting capabilities either in real-time, or in bulk<br>Automatic and Scheduled Reporting features<br>Diagnostic Reports |
| **Accessories** | including all necessary cables and connectors<br>including air conditioning equipment |
| **Documentation** | operators hand book and maintenance instructions for all parts of the system in English (3 copies)<br>full documentation (in English, 3 copies), including system block diagram and circuit wiring diagram |

**Data Collection Software for the collection of data over GSM/GPRS**
Software will be provided for reception of incoming data, which will also be subjected to quality control procedures through a quality control software package provided by the bidder. The quality control software will be used to screen incoming data for artifacts and flag data based on the following criteria:

1. Minimum threshold
2. Maximum threshold
3. Change in data value over time

These thresholds will be changeable through a simple interface.

**Computer for Database, data processing, and data visualization**

| Item | Technical specifications |
|---|---|
| **Site conditions** | ambient temperature: -30 to +60 degrees C<br>relative humidity: 5% to 100% with condensation<br>altitude: < 1,000m |
| **PC Specifications** | CPU and Memory - Core i7 or better or the equivalent GHz minimum or greater if required by Data Management Software<br>Memory –8 GB or greater. The<br>Hard disk size capable of storing 10 years' worth of data in addition to all software components or 1 TB, whichever is greater.<br>Monitor - A minimum of three computer screens that can be used to display screens from data collection and data processing processes. These screens will be a minimum of 21 inches and shall incorporate Flat Screen technology. Computer hardware will have the proper interface to use a minimum of four screens.<br>Keyboard and Mouse – The keyboard and mouse shall be wireless<br>Other Devices - CD/DVD RW+<br>Network – Giga Ethernet 10/100/1000Mbps (RJ45)<br>Interfaces - Serial, parallel, USB, 5V PCI Slot |

| | |
|---|---|
| | Electrical - Supply Voltage: 230V, 450W<br>Computer Form Factor - Rack mount. Please include computer rack with offer to house computer(s) data receivers, network devices as required by the DCS. The rack space available shall be twice that which is actually required for the equipment that is being offered.<br>Operating systems - Windows Server 2010 or newer |
| **Power Supply** | 220 - 230V AC power supply<br>UPS equipment |

**Database Software for the Storage of raw and processed hydro-meteorological data**

Software will be provided for the development of discharge rating curves, and the real time computation of discharges from the real time water levels, such that both real time water levels and corresponding discharges are made available to other subsystems as required for all discharge measurement stations.

| | |
|---|---|
| **Data Processing** | automatic storage in the server database<br>conversion of raw data (e.g. voltages) to engineering units<br>data validation (e.g. data out of range, discharge less than zero)<br>database management for measurement data, maintenance data, configuration data, event logger<br>upload of data retrieved by portable computer / mobile unit into database<br>manual data input / editing<br>SQL tools for generation of queries<br>basic statistical capabilities<br>graphical visualization and presentation of data (e.g. hydrographs) for control purposes, with adjustable scales<br>printing of graphic and tabular output<br>pre-defined reporting capabilities<br>real-time data conversion (water level to discharge)<br>management of rating curves<br>data aggregation (e.g. hourly to daily data), determination of totals, maxima and minima |

**Time Series Software for the processing of hydro-meteorological data**

| | |
|---|---|
| **Software Time Series** | Hydrologic Time Series Data Base, including rating table workup<br>Software package must not require annual maintenance contract or any other agreement that would prevent the software from operating indefinitely. Software types include Aquatic Informatics - Aquarius, Seveno - Data Sight, or comparable.<br>Software for data processing, communications handling as well as control and customization of ground station operations<br>Graphical and Tabular Data viewing facility<br>Real-time as well as Historical Trending<br>Statistics (Minimum , Maximum, Average, Standard Deviation, etc)<br>Equation and Rating table lookup capability<br>Graphs and Data exporting features<br>RDBMS PostGreSQL, ACCESS, or compatible<br>Data Exporting capabilities either in real-time, or in bulk<br>Automatic and Scheduled Reporting features<br>Diagnostic Reports |

| | |
|---|---|
| | The Data Management Computer will possess similar Data Management and related Software modules to the ERS<br>Alarms – Email, SMS Text, Fax user definable triggers to evaluate the following conditions<br>- Missing Station<br>- Low Battery<br>- Solar Power Failure<br>- Data out of limits<br>- Bad transmissions |

**Web based data visualization software for the display and dissemination of hydro-meteorological data**

| | |
|---|---|
| **Software: Data Visualization** | Web Server Software Apache (Open Source)<br>Connectivity programs to allow complete access to the database<br>Web application software that produces tabular data of any time selectable by the user<br>Web application to provide a download of data in EXCEL (xls) and CSV formats, selectable by the user<br>Web application to provide graphical presentation of the data. Graphical presentation will allow the user to plot up to four variable on a graph using a time scale selectable by the user<br>Web application to provide map presentation using GOOGLE maps or similar. Map presentation to allow for various presentations of data including stage data, rainfall data, ground water level and conductivity. Presentation tool to allow for pan and zoom function.<br>Map presentation will also allow for presentation of alert and alarm information such as rapidly rising water and exceptional rainfall events<br>Software must be easily configurable by the user such as the remote station alarm thresholds<br>Software must work seamlessly with the database to provide information quickly and simultaneously to multiple users.<br>Software must be COTS (Commercially Off-The-Shelf), and be a mature product being at least two years old. |
| **Export Interfaces** | export function for data transfer to other software packages (e.g. ASCII format, Excel)<br>open, well-documented Application Programming Interface<br>sufficient database documentation and user rights to allow for integration of the software provided with a tailor-made hydrological software package to be developed for analysis, modelling and forecasting purposes |
| **Accessories** | all necessary cables and connectors compatible with the computer<br>air conditioning<br>battery backup provided by the online UPS shall be 1hr at full load |
| **Documentation** | database structure must be well documented, including entity-relationship diagrams<br>operators hand book and maintenance instructions for all parts of the system in English (3 copies)<br>full documentation (in English, 3 copies), including system block diagram and circuit wiring diagram |

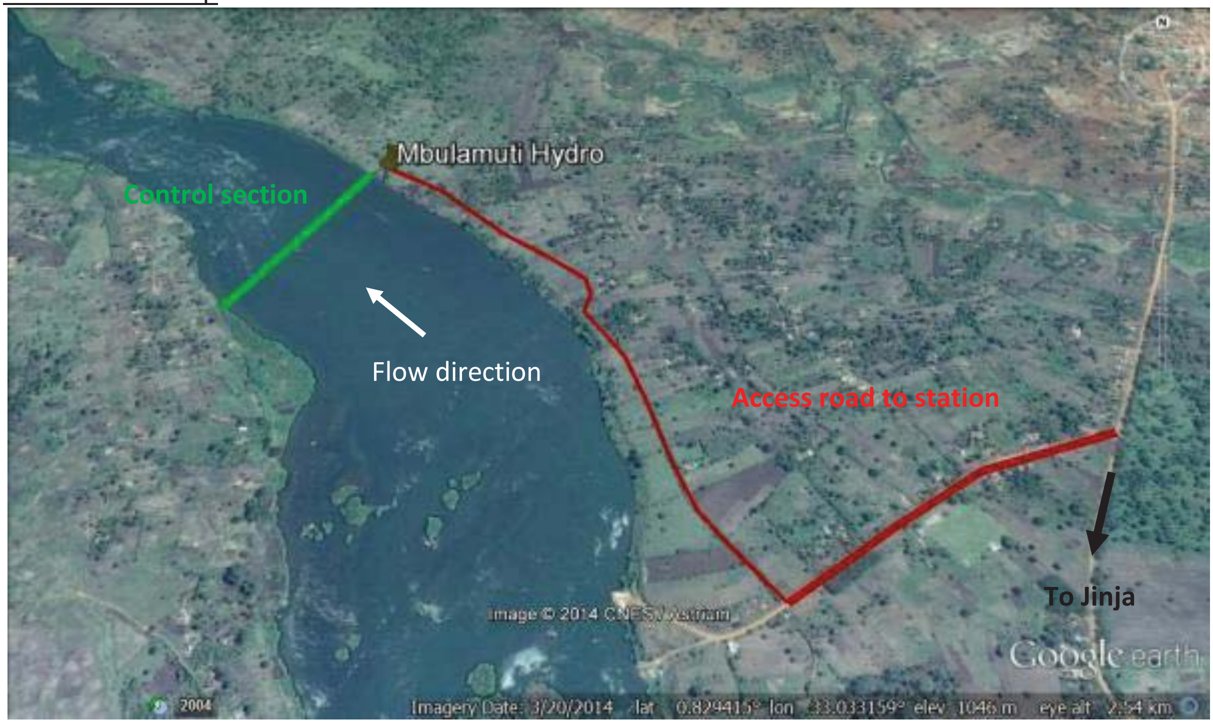
**ANNEX A.9-3: Uganda Field Visit Report**

1. **Mbulamuti on the Victoria Nile (date of visit 11 August 2014)**

General Station Information

| | |
|---|---|
| Station Code | 82203 |
| Purpose of Station | water level and discharge monitoring; measurement of Lake Victoria outflow and Lake Kyoga inflow |
| Latitude | 0.83540 |
| Longitude | 33.02790 |
| Period of Record | 1956 – 2014 |
| Equipped with | AWLR and staff gauges; ADCP flow measurement |
| Observer present | Yes |
| Status | Operational |
| Water Management Zone | Kyoga – Mbale Office |
| Distance to Head Office | ~150 km |

Site: General Map




The flow of the Victoria Nile is controlled by the Kiira and Nalubaale Hydropower facilities at the outlet of Lake Victoria in Jinja. No main tributaries enter the river system between the lake-outlet and Mbulamuti. River flow is slightly modified by the upstream Bujagali Run-of-River facility. The Isimba Run-of-River facility is under construction and located a few kilometers upstream of the control section.

Site Description

The control section is stable without visible signs of scour or deposition. Water weeds and large vegetation are mostly absent on both riverbanks. Flow is restricted to a single wide channel and streamlines are straight both up- and downstream of the control section. There is no high turbulence. Overbank flow will not occur during flood events. A boat can be launched on site for ADCP flow measurement. Maximum flow velocities during a flood event will not exceed 2 m/s – most likely less. Victoria Nile flow at Mbulamuti is not affected by backwater effect from Lake Kyoga. The rating curve is stable. Maximum level fluctuation does not exceed 1.5 m.

Station accessibility is adequate and the site can be reached by 4WD. The GoU owns the land on which the station is located. Mobile phone coverage (MTN provider) is available. There is no access to the public power network.

<u>Station Photos</u>

**Newly constructed equipment shelter**

**Control-section**

**Upstream of the control-section**

**Downstream of the control-section**

<u>Existing Instruments and Equipment</u>

The station is equipped with staff gauges and a stilling well. While automatic water level recording instruments are presently absent, the station will shortly be equipped with a SEBA float operated shaft encoder connected to a GSM/GPRS modem for near-real time data transmission. The station shelter has already been constructed while the equipment has arrived at the DWRM offices in Entebbe. The equipment has been provided by GIZ.

Discharge measurements are conducted with a RDI-Teledyne ADCP Workhorse Rio Grande (600 Khz or 1200 Khz) on a three-monthly (quarterly) basis. A boat can be launched on-site.

<u>Status Report and Comments</u>

Mbulamuti is an excellent site for discharge measurement of the Victoria Nile. Accessibility is adequate and hydrometric recording practices are well established. The station is currently being upgraded with support from GIZ. An automatic station with near real-time data transmission should be operational within the coming 6 weeks.

Mbulamuti hydromet station does not require further investments apart from possible satellite data communication to reduce possible communication down-time and improve the reliability of real-time data transfer.

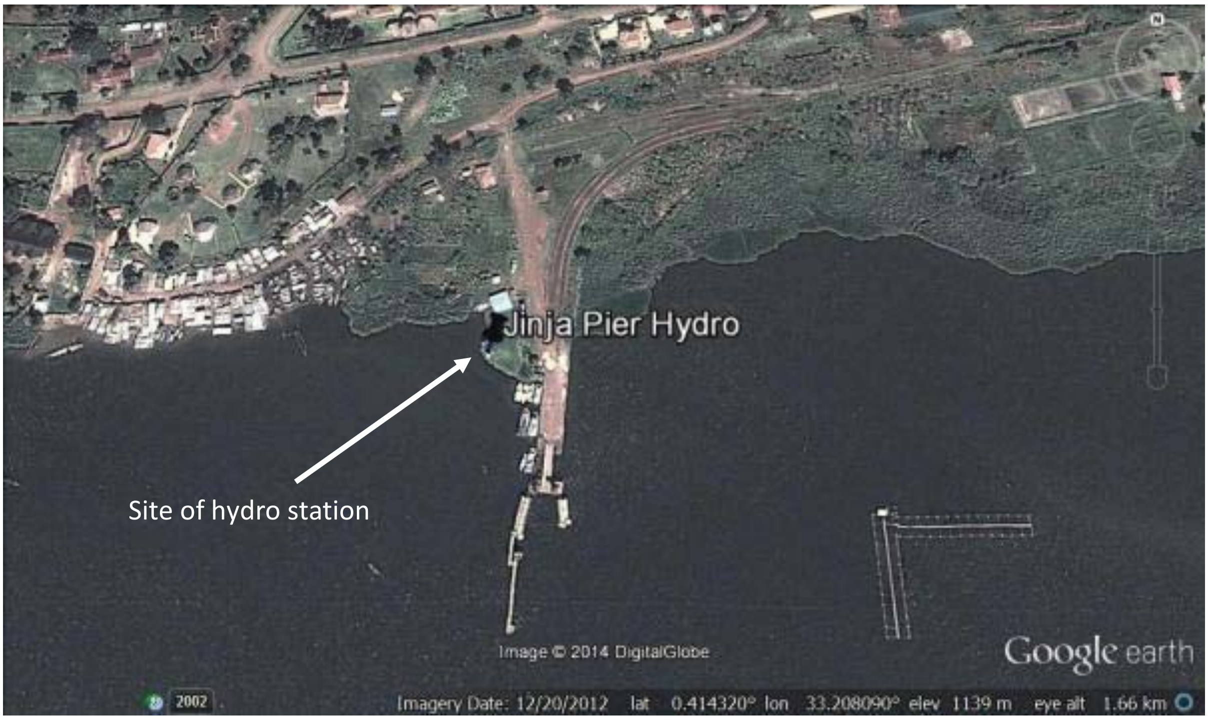
**2. Jinja Pier on Lake Victoria (date of visit 11 Aug 2014)**

General Station Information

| | |
|---|---|
| Station Code | 81202 |
| Purpose of Station | water level recording |
| Latitude | 0.40850 |
| Longitude | 33.20450 |
| Period of Record | 1948 – 2014 |
| Equipped with | AWLR and staff gauges |
| Observer present | Yes |
| Status | Operational |
| Water Management Zone | Victoria – Mbarara Office |
| Distance to Head Office | ~350 km |

Site: General Map


Site: Location Map




The Jinja Pier hydro station measures the water level of Lake Victoria close to the outlet of the Victoria Nile. The station is located on the gated compound of the Jinja Pier, which provides excellent accessibility and security of the equipment.

The outflow of Lake Victoria is controlled by the parallel Kiira and Nalubaale hydropower plants. The setup of the intake pipes of these facilities constrains lake level fluctuation to a range of 3 meters.

Station Photos

**Newly constructed equipment shelter**

**Staff gauges**

Existing Instruments and Equipment

Jinja hydro is equipped with a classic strip chart recorder and a series of staff gauges. GIZ is currently upgrading the station with a float operated shaft encoder (SEBA) connected to a GSM/GPRS modem for near real-time data transmission. The new equipment shelter and stilling well have already been constructed. The station has access to the public power network.

No further investments are required on this site.

Status Report and Comments

Jinja Pier hydro station is an excellent and secure site for measurement of Lake Victoria water levels. The station is currently being upgraded with support from GIZ. An automatic station with near real-time data transmission should be operational within the coming 6 weeks.

### 3. Kamdini on the Kyoga Nile (date of visit 13 August 2014)

General Station Information

| | |
|---|---|
| Station Code | 83206 |
| Purpose of Station | Water level and discharge monitoring |
| Latitude | 2.26667 |
| Longitude | 32.26667 |
| Period of Record | 1950 – 2012 |
| Equipped with | AWLR and staff gauges |
| Observer present | Yes |
| Status | Operational |
| Water Management Zone | Upper Nile – Lira Office |
| Distance to Head Office | ~50 km |

Site: General Map


Kamdini Hydro station measures the flow of the Kyoga Nile. The station is located just downstream of the Tochi confluence and thus includes the contribution from this (mid-size) tributary. Kamdini station is upstream of the series of rapids near Karuma bridge (see figure above) – which is the site of a new 600 MW hydro power station that is under construction and is scheduled for completion by 2018. Backwater effects from Karuma dam could affect water levels and flows at Kamdini. This needs to be investigated before further investments are made at Kamdini station.

Site Description


The control section is stable without visible signs of scour or deposition. A wide band of very dense water weeds is present on both sides of the river (see figure above). Flow is restricted to a single wide channel and streamlines are fairly straight, both up- and downstream of the control section. There are no signs of turbulence. Overbank flow will not occur during flood events. Possible flow through the thick water weeds will be minor and can effectively be ignored. The rating curve is stable and the maximum level fluctuation does not exceed 1.5 m.

Because of the water weeds, there is no access to the river at the control section. ADCP flow measurements are being conducted but the boat is launched at upstream Masindi Port. The GoU owns the land on which the station is located. Mobile phone coverage (MTN provider) is available but subject to frequent downtime. There is no access to the public power network.

Station Photos


**Control section at Kamdini**


**Thick water weeds on both river banks**


**Staff gauges**


**AWLR shelter, with a strip chart recorder**

Existing Instruments and Equipment
The station is located in dense water weeds (see photos above) and equipped with a float operated strip chart recorder in a stilling well and a series of staff gauges. Access to the site is difficult, and the last kilometer has to be made on foot.

Discharge measurements are conducted with a RDI-Teledyne ADCP Workhorse Rio Grande (600 Khz or 1200 Khz) on a three-monthly (quarterly) basis. It is noted that the boat cannot be launched on site and comes from upstream Masindi Port.

Status Report and Comments
Kamdini hydro station is operational but will require modernization. However, any decision to this end needs to be based on an analysis of possible backwater effect caused by Karuma dam. At the time of writing, the reporter had no access to the design specifications (height, operational water level range) of this facility. It is quite possible that Kamdini station will need to be abandoned upon completion of Karuma dam, which is scheduled for 2018.

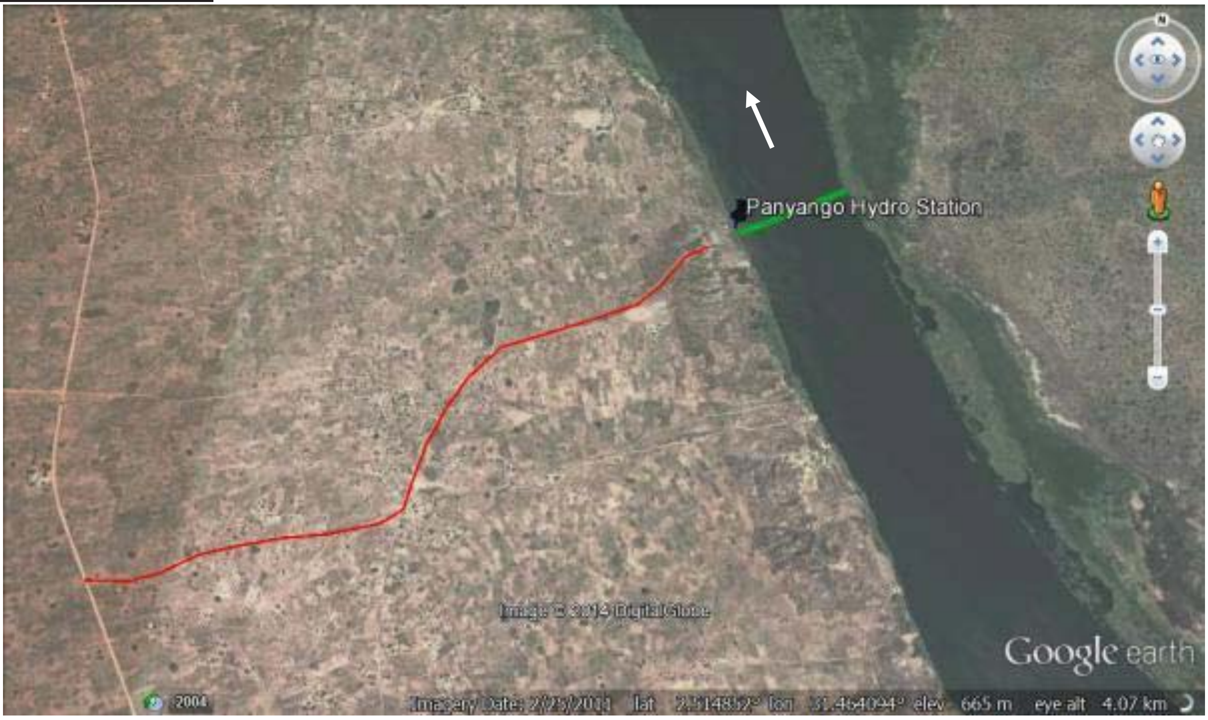
While the site is not ideal for discharge measurement, it is acceptable and good quality flow recordings can be obtained by a skilled hydrometric technician.

**4. Panyango on the Albert Nile (date of visit 13 August 2014)**

General Station Information

| | |
|---|---|
| Station Code | 87222 |
| Purpose of Station | Water level and discharge monitoring |
| Latitude | 2.47000 |
| Longitude | 31.50000 |
| Period of Record | 1969 – 2014 |
| Equipped with | AWLR and staff gauges |
| Observer present | Yes |
| Status | Operational |
| Water Management Zone | Upper Nile – Lira Office |
| Distance to Head Office | ~100 km |

Site: General Map




Panyango hydromet station measures the Albert Nile after it has left Lake Albert. It is a key site in determining the water balance of this lake, which is still subject to considerable uncertainties and important for Nile water accounting and for determining the contributions from the Congo to the Nile system.

Site Description

The control section is stable without visible signs of scour or deposition. A narrow band of thick water weeds is present on the east bank (see picture above) but does not constitute a real impediment to discharge monitoring. Flow is restricted to a single wide channel and streamlines are straight both up- and downstream of the control section. There are no signs of turbulence. Overbank flow will not occur during flood events. There is no proper boat landing site, but a boat can be launched at a nearby upstream location for ADCP flow measurement. Maximum flow velocities during a flood event will not exceed 2 m/s – most likely less. The rating curve is stable. Maximum level fluctuation does not exceed 1.5 m.

Access to the site is acceptable. The last kilometer has to be made on foot but represents a pleasant walk. The GoU owns the land on which the station is located. Mobile phone coverage (MTN provider) is available. There is no access to the public power network.

Station Photos

**Panyango – Albert Nile at control section**

**Panyango – downstream river**

**Panyango – upstream river**

**Panyango hydro station**

Existing Instruments and Equipment

The station is equipped with staff gauges and a float operated shaft encoder in a stilling well, all in good condition. The equipment shelter is in excellent condition. There are no facilities for (near) real-time data transmission.

Reading the staff gauges at low water levels can be a bit difficult because of the existence of a small wetland area (see photo). It could be considered to construct a small berm – about 10 m long and 1 m high– to facilitate better access to low water levels and make it easier to read the staff gauge.

Discharge measurements are conducted with a RDI-Teledyne ADCP Workhorse Rio Grande (600 Khz or 1200 Khz) on a three-monthly (quarterly) basis.

Status Report and Comments

Panyango station is an important element of the Nile hydrometric network. Panyango is an excellent site for discharge measurement of the Albert Nile. Accessibility is adequate and hydrometric recording practices are well established.

The station is operational but installation of telemetry equipment for (near) real-time data transmission is required. Panyango is not part of the GIZ program but IGAD HYCOS has proposed to provide GSM/GPRS data communication. To improve the reliability of real-time data transfer, it could be considered to install satellite data communication to reduce possible communication down-time.

### 5. Butiaba on Lake Albert (date of visit 14 August 2014)

General Station Information

| | |
|---|---|
| Station Code | 85201 |
| Purpose of Station | Water level monitoring |
| Latitude | 1.81971 |
| Longitude | 31.32748 |
| Period of Record | 1969 – 2014 |
| Equipped with | AWLR and staff gauges |
| Observer present | Yes |
| Status | Operational |
| Water Management Zone | Albert WMZ – Fort Portal Office |
| Distance to Head Office | ~150 km |

Site: General Map


Butiaba Hydromet measures the level of Lake Albert. Butiaba pier used to be a key element in the navigation network on Lake Albert and the Albert Nile, but this system is no longer operational. The navigation facilities around Butiaba pier have mostly collapsed and the water front is now occupied by fishermen.

Site Description

Butiaba station is located near a fish landing site/fishermen village. The area is polluted and security is poor. The equipment shelter and staff gauges are situated in a wetland and are difficult to access (see photos). It is recommended to reconsider the station location and move Butiaba Hydromet to the nearby UPDF compound, which is about a kilometer up the Masindi road.

The UPDF compound also houses the weather station (with instruments for rainfall, RH, temperature, and wind speed) and provides good security. The small UPDF pier presents an excellent (and secure) location for establishing a stilling well and instrument shelter.

Station Photos

**Staff gauges in a wetland: difficult access**

**Fishermen village: security is poor**

Existing Instruments and Equipment
While a stilling well and instrument shelter are present, Butiaba station is currently not equipped with automatic instruments. Staff gauges are used for manual observations. There is no (near) real-time data transmission.

Status Report and Comments
Because of poor security and sanitation considerations, it is recommended to abandon the current station and move Butiaba Hydromet to the nearby UPDF compound. It is noted that the UPDF base also houses a comprehensive (although dilapidated) meteorological station.

In case this new site can be secured, Butiaba station needs to be upgraded with automatic water level recording equipment and telemetry facilities.

If the old site cannot be abandoned, poor security will prevent installation of a solar panel and use of electronic equipment (including telemetry facilities and electronic monitoring instruments). It is noted that Butiaba has been earmarked for upgrading by the World Bank project.

### 6. Masindi Port on the Kyoga Nile (date of visit 14 August 2014)

General Station Information

| | |
|---|---|
| Station Code | 83203 |
| Purpose of Station | Water level and discharge monitoring |
| Latitude | 1.69473 |
| Longitude | 32.09270 |
| Period of Record | 1947 – 2014 |
| Equipped with | AWLR and staff gauges |
| Observer present | Yes |
| Status | Operational |
| Water Management Zone | Kyoga – Mbale Office |
| Distance to Head Office | ~200 km |

Site: General Map


Masindi Port Hydromet measures the outflow of Lake Kyoga. Because of its location just downstream of the River Kafu confluence, the flow at Masindi Port also includes the (small) contribution of this Kyoga Nile tributary.

A ferry crosses the Kyoga Nile at Masindi Port and the site has excellent accessibility and good security. Masindi Port is used as the boat landing site for ADCP measurement of the downstream Kamdini station.

While wide bands of very dense water weeds are present on both sides of the river (see figure above), a long pier to Masindi Port ferry prevents river flow through the wetlands and provides good access. Masindi Port is the most appropriate site on this stretch of the Kyoga Nile for river flow measurements. There is – in effect – no alternative.

Site Description

The control section is stable without visible signs of scour or deposition. Masindi Port pier prevents flow through the wide band of water weeds. Flow is restricted to a single wide channel and streamlines are straight both up- and downstream of the control section. There is no high turbulence. Overbank flow will not occur during flood events. A boat can be launched on site for ADCP flow measurement. Maximum flow velocities during a flood event will not exceed 2 m/s – most likely less. The rating curve is stable. Maximum level fluctuation does not exceed 2 m.

Station Photos

**Access road to Masindi Port (pier through wetlands, blocking flow)**

**Control section – Kyoga Nile**

**Kyoga Nile downstream of Masindi Port**

**Newly constructed equipment shelter**

Existing Instruments and Equipment

The station is equipped with staff gauges and an instrument house with a stilling well, all in good condition. Automatic water level recording instruments (float operated shaft encoder, SEBA) will shortly be provided by GIZ. The equipment will be connected to a GSM/GPRS modem for near-real time data transmission. The equipment has arrived at the DWRM offices in Entebbe.

Discharge measurements are conducted with a RDI-Teledyne ADCP Workhorse Rio Grande (600 Khz or 1200 Khz) on a three-monthly (quarterly) basis. A boat can be launched on-site.

Status Report and Comments

Masindi Port is an adequate site for discharge measurement of the Kyoga Nile. Accessibility is good and hydrometric recording practices are well established. The station is currently being upgraded with support from GIZ. An automatic station with near real-time data transmission should be operational within the coming 6 weeks.

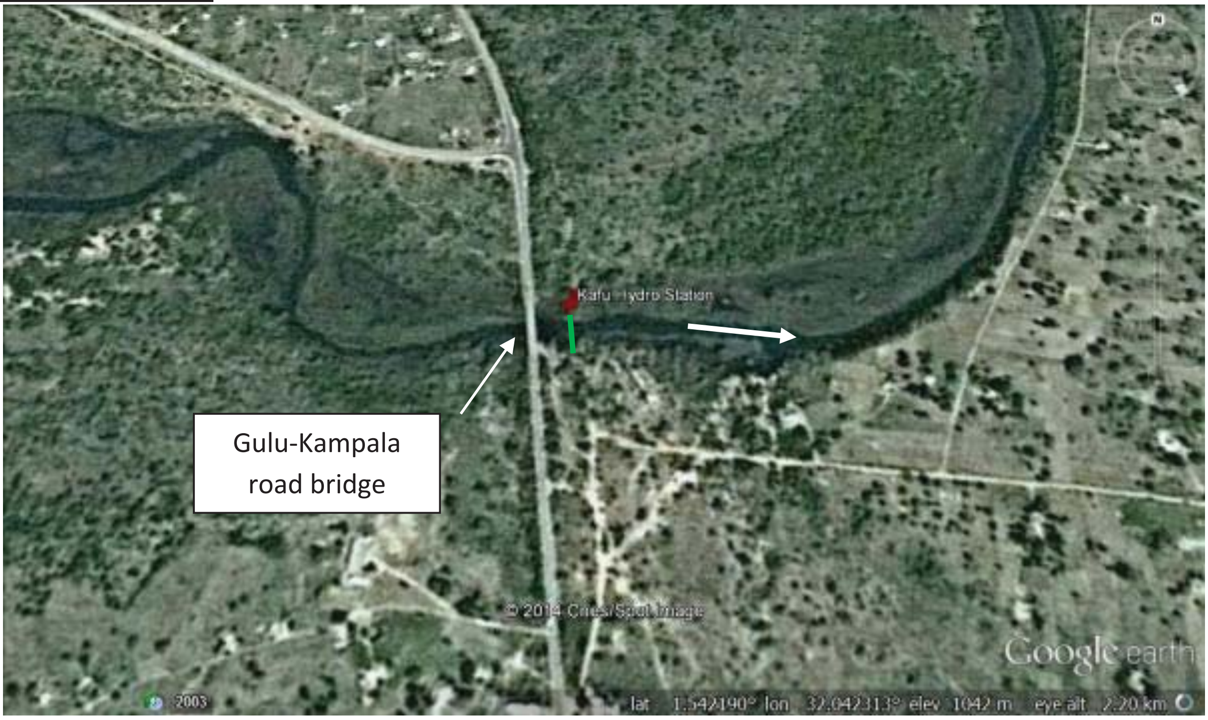
Masindi Port Hydromet station does not require further investments apart from possible satellite data communication to reduce possible communication down-time and improve the reliability of real-time data transfer.

## 7. River Kafu at Kampala-Gulu Road (14 August 2014)

General Station Information

| | |
|---|---|
| Station Code | 83213 |
| Purpose of Station | Water level and discharge monitoring |
| Latitude | 1.54300 |
| Longitude | 32.04235 |
| Period of Record | 1952 – 2014 |
| Equipped with | AWLR and staff gauges |
| Observer present | Yes |
| Status | Operational |
| Water Management Zone | Kyoga – Mbale Office |
| Distance to Head Office | ~200 km |

Site: General Map




River Kafu drains a large basin in Uganda. However, because of the flat terrain and large wetland areas, the specific runoff is just 30 mm/year and the runoff coefficient is around 2% (NWRA 2012). Kafu's contribution to the Kyoga Nile, therefore, is small. Nevertheless, anecdotal evidence and the profile of the cross section suggest considerable flood flows on River Kafu.

River Kafu joins the Kyoga Nile just upstream of the Masindi Port Hydromet station. Knowledge of Kafu flows, therefore, is important in order to establish accurate Lake Kyoga outflows.

Site Description

Kafu Hydromet is located just downstream of the bridge on the Kampala-Gulu road. Low flows are constricted to a well established channel bordered by a wide band of wetlands on both river banks (see image above). Flood flows will occupy the wide river valley and overflow the entire wetland area with its dense vegetation. Flood measurement, therefore, is a very difficult undertaking, even if observers are present on site during peak flow, which is rarely the case.

Station Photos

**River Kafu downstream of the Gulu-Kampala road bridge**

**Gulu-Kampala Road Bridge at River Kafu**

**River Kafu - equipment shelter (no equipment)**

**River Kafu – staff gauges**

Existing Instruments and Equipment
The station is equipped with staff gauges and a stilling well in a shelter house in good condition. There is currently no automatic monitoring equipment.

The Kampala-Gulu road bridge presents an excellent opportunity for installing a radar sensor, as well as for discharge measurement during flood flows using an ADCP on a tethered float. It is recommended to construct a low levee/berm across the wetlands to restrict low flows to the main channel and provide a control for flood measurement. The design of this levee/berm needs to be carefully considered.

Status Report and Comments
River Kafu at the Gulu-Kampala road bridge is an acceptable site for flow measurement, in particular for low flows. However, because of the wide wetland areas that are flooded during high flows, measurement of flood flows is very difficult. It is recommended to construct a small berm/levee to provide a good control section for flood measurement. A radar sensor can be installed on the bridge. Currently, no automatic equipment is present. It is noted that Kafu hydro station is included on the GIZ list.

**8. Nakasongola (AWS and Groundwater – date of visit 14 August 2014)**

General Station Information

| | |
|---|---|
| Station Code | 88320020 |
| Purpose of Station | Monitoring of climatic parameters |
| Latitude | 32.467 |
| Longitude | 1.317 |
| Period of Record | 1933 – 1980; 2005 – 2014 |
| Equipped with | T, RH, rainfall, incoming solar radiation, wind speed & direction at 2 m |
| Observer present | Yes |
| Status | Operational |
| Water Management Zone | Kyoga – Mbale Office |
| Distance to Head Office | ~150 km |

Site Description

The weather station and groundwater monitoring site are located at the compound of the District Head Quarters in Nakasongola. It provides a secure environment with excellent accessibility, and connection to the national power grid.

Station Photos

**Nakasongola automatic weather station**

**Nakasongola groundwater station**

Existing Instruments and Equipment (AWS)

The Automatic Weather Station (AWS) is equipped with a data logger powered by a solar panel and electronic sensors for rainfall (tipping bucket), wind-speed and direction at 2 m, relative humidity (RH), temperature, and incoming solar radiation (both long and short wave). The data logger and power unit are housed in an equipment shelter. The equipment has been supplied by Campbell Scientific, USA, under a project implemented by FAO.

The station is in good condition and the station site is enclosed by a fence (see photo). Data are transferred to the WMZ office in Mbale using a hand-held storage device on a quarterly basis. The observer works at the compound of the District Office and visits the station on a daily basis.

The AWS has been operational for over 10 years and has provided a high quality data set without data gaps. It is part of a network of over 10 AWS' installed throughout the country, including two on Bukasa and Lolui islands in Lake Victoria.

Existing Instruments and Equipment (groundwater monitoring site)

The groundwater station consists of a well that is measured with a dip meter on a daily basis. The observer works in close proximity of the site. The station is in good condition and operational.

Status Report and Comments

The AWS and groundwater station are both operational and in good condition. It could be considered to equip the AWS with GSM/GPRS telemetric facilities.

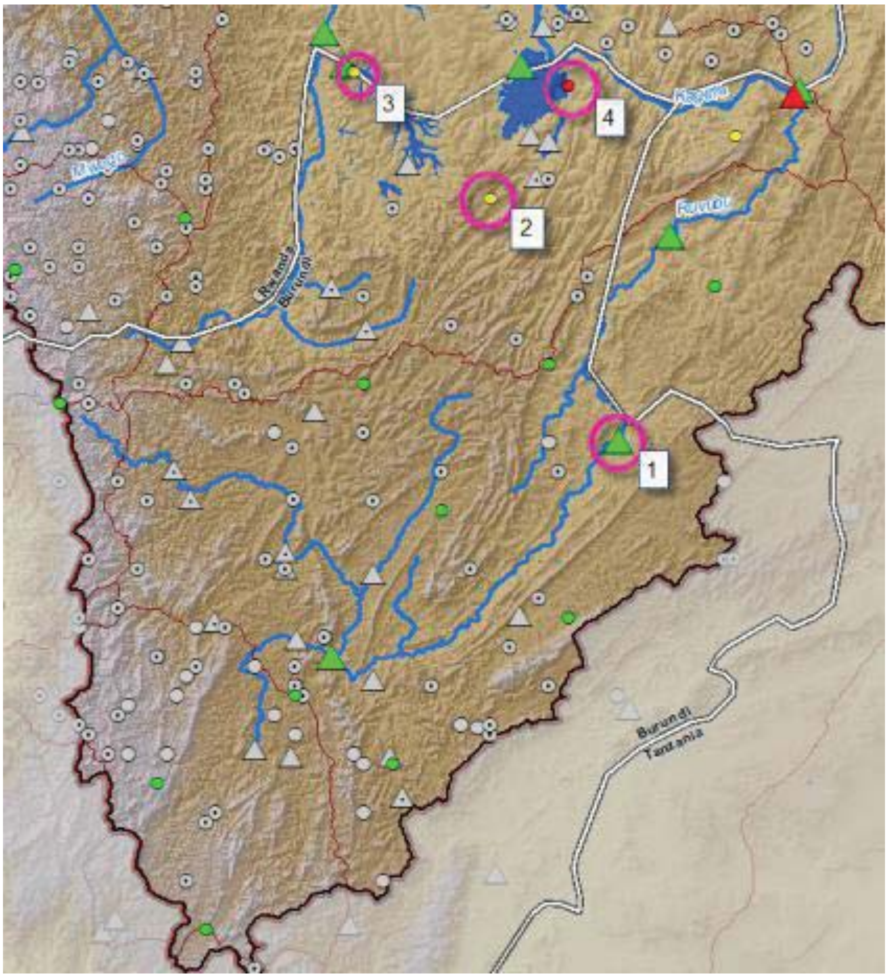
# Appendix B: Station Location and Parameter Updates from Workshop Feedback

During the Conceptual Design Workshop, Final Design Workshop, and Implementation Plan Workshop the Nile Basin country representatives were given the opportunity to review the network design and make recommendations for changes during breakout sessions. Riverside has noted proposed changes and addressed concerns for each country as follows.

For presented maps discussion of specific stations are circled and numbered ([#]) for reference in the write up. Updates are presented by country in alphabetical order.

## Burundi

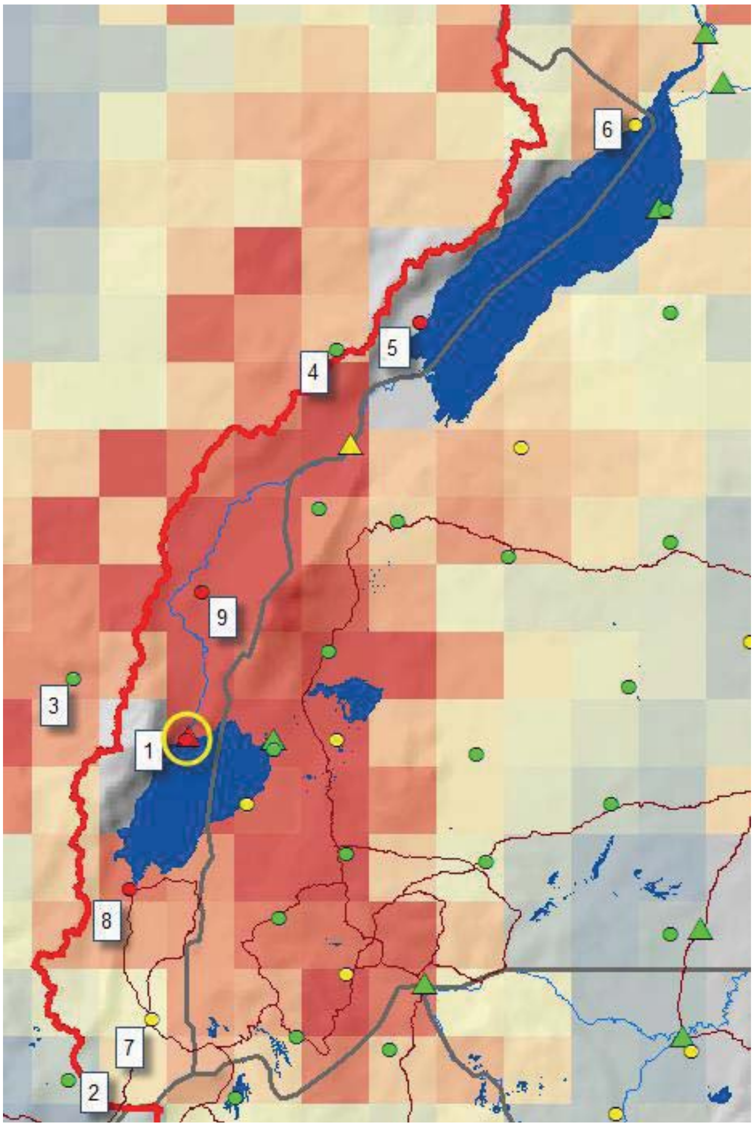
Burundi representatives noted that the overall design and process was good. However, they did recommend the inclusion of the hydrometric station "RUVUBU (MUYINGA)" [1] for transboundary monitoring between Burundi and Tanzania and the meteorological station "MULEHE" [2] for additional rainfall monitoring in the northern region of the country. These have been updated in the design. In addition, monitoring of the transboundary lakes Cyohoha and Rweru with Rwanda includes the need to assess evaporation from the lakes. As a result the inactive "RUHUHA" [3] meteorological gauge is proposed to be rehabilitated to monitor Lake Cyohoha and a new meteorological station [4] is proposed to monitor Lake Rweru. The hydrometric stations for monitoring water level and quality for the transboundary lakes are being proposed at two existing sites in Rwanda.



# DRC

The DRC provided Riverside with proposed monitoring locations within the Lake Edward/Albert watershed prior to the initial design as well as during consultations October 13-16, 2014. However, several of the proposed hydrometric sites did not provide regional monitoring benefits based on identified regional issues. The one hydrometric site that did provide significant regional benefits was the outflow from Lake Edward at the "Ishango" site [1] (circled in yellow). It is proposed that this station will also provide water quality monitoring for Lake Edward's outflow.

Additional proposed hydrometric sites from the DRC included water level at Vitshumbi for Lake Edward, water level at Kasenyi and Mahagi port for Lake Albert, and water level and discharge for the Semliki River at Burasi. These stations could be incorporated for national monitoring purposes but are not being proposed for the regional network since lake level and water quality for both Edward and Albert is already being achieved at existing and active hydrometric sites Katwe and Butiaba in Uganda. In addition, the inflow to Lake Albert on the Semliki River is proposed to be monitored at the "R. Semliki at Bweramule" site operated by Uganda which is already planned to be upgraded through the IGAD HYCOS project.




The DRC proposed 5 stand along meteorological stations and an additional 4 to be located at coinciding hyrometric station at lake sites. Of these 8 it was believed that 6 new or rehabilitated stations could be justified to add to the 3 existing active station (GOMA [2], BUTEMBO [3], and BUNIA

[4]) located just outside the Nile Basin boundary. Meteorological stations recommended by the DRC and included in the regional design include: Ishango [1], Kasenyi [5], Mahagi Port [6], and Rutshuru [7], with the first three of these capturing evaporation around the lakes. In addition to these sites, stations at Bwera [8] (evaporation around Lake Edward) and Tumbula [9] (high rainfall variability in region as displayed by red grids) were also proposed to provide good spatial distribution. The stations recommended by the DRC but not included in the regional design because of close spatial proximity to other stations includes Vitshumbi (close proximity to proposed Bwera site); Rumangabo (close proximity to Rutshuru and GOMA sites); Bogoro (close proximity to Bunia and Kasenyi sites); Ugongo (close proximity and better location at Mahagi Port). As was noted with the hydrometric network, all of these proposed DRC sites could be incorporated in a national network but the regional design is looking to optimize the network to capture spatial rainfall variability and evaporation at regional lakes to justify the number of proposed stations in the region.

## Ethiopia

### Design Workshop Updates

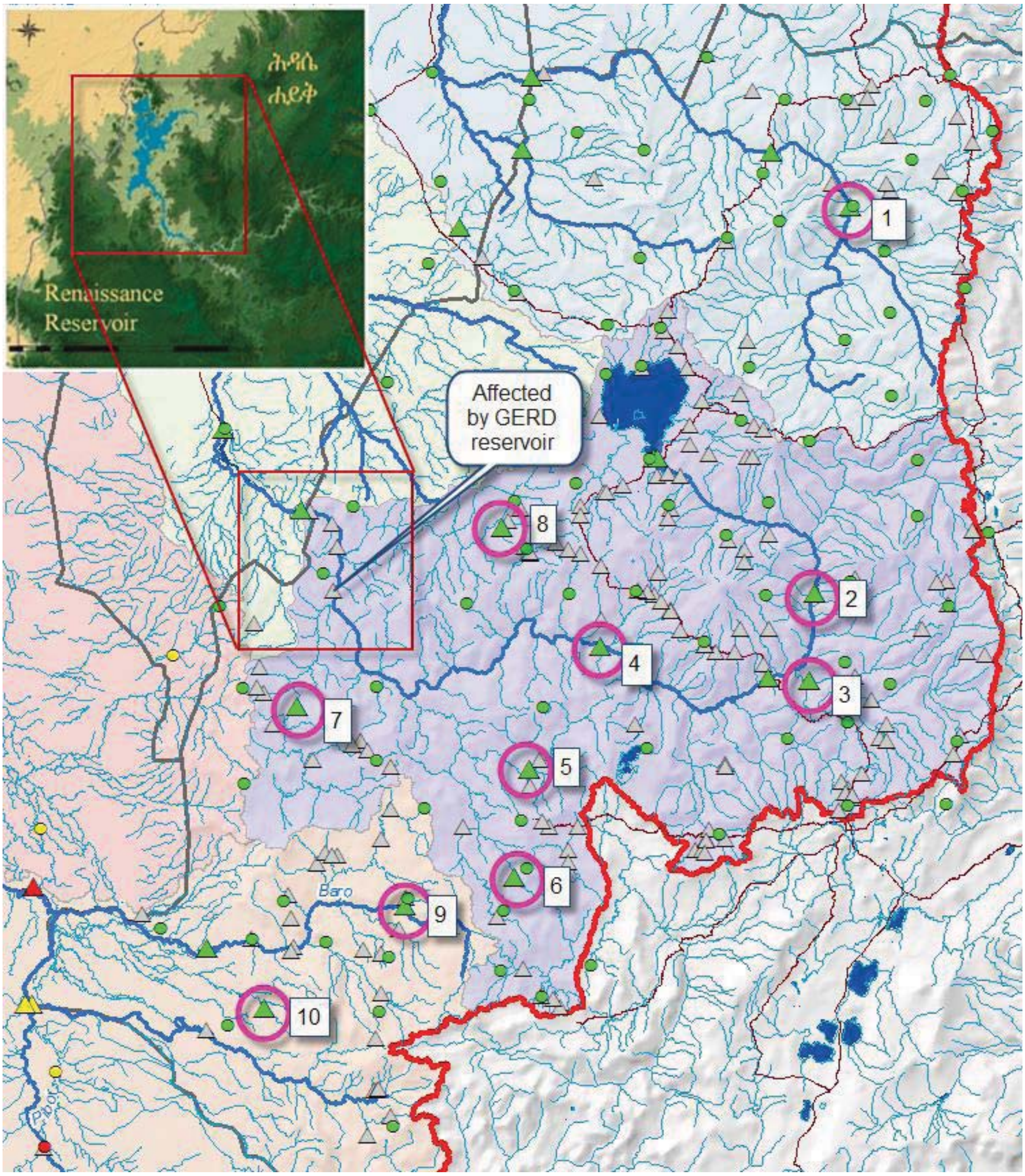
More hydrometric stations for sediment monitoring and erosion assessment on the main tributaries of the Blue Nile, Tekeze, and Baro Rivers were proposed and were updated in the design. Several of these stations originally had incorrect coordinates and updates to locations were informed by Ethiopian representatives and confirmed (at bridge crossings) using Google Earth. As labeled in the following map this includes:

1. "Tekeze Nr. Yechila" to monitor the direct outflow and sediment load of the Tekeze Dam.
    a. An update following the final design workshop included removing this station as it was confirmed to be inundated. Limited accessibility exists directly downstream of the dam.
2. "Abbay at Mekane Selam-Gundewein Br." to assess flows and sediment load from upstream contributing sub-basins.
3. "Jemma at Abbay Confluence" to assess flows and sediment load from Jemma river and large contributing upstream basin.
4. "Abbay Nr. Bure" to assess flows and sediment load from upstream basins up to Kessi Bridge.
5. "Angar Nr. Nekemte" to assess upstream flows and sediment loads of Abbay tributary.
6. "Didessa Nr. Arjo" to assess upstream flows and sediment loads of Abbay tributary.
7. "Dabus Nr. Asosa" to assess the upstream flows and sediment loads of Abbay tributary.
8. "Main Bele at Bridge DS of Bagusta" to assess the upstream flows and sediment loads of Abbay tributary.
9. "Geba Nr. Suppi" to assess the upstream flows and sediment load of the Baro River.
10. "Awero at Dam/Dumbong Village" to assess releases and sediment load downstream of dam.

In addition, to the above proposed and updated locations, Ethiopia recommended the site "Abbay at Shergole Cableway RGS". Based on a map displaying the projected Grand Ethiopian Renaissance Reservoir, the site will clearly be inundated and is therefore not being proposed. The map image embedded in the following figure can be found at:

http://en.wikipedia.org/wiki/Grand_Ethiopian_Renaissance_Dam#mediaviewer/File:Renaissance_Reservoir.jpg

Additional amendments were also made to the meteorological network to include 33 of the 36 AWS station sites that were provided at the Conceptual Design workshop. This involved reassessing the previous stations and distribution to maximize the number of AWS sites to propose in the regional network design.




## Implementation Planning Workshop

Feedback regarding the number of meteorological stations and selection of hydrometric stations for implementation was provided by Ethiopia representatives during the Implementation Plan Workshop held in Entebbe, Uganda April 24-25.

***Meteorological Stations:***

Although the design calls for 84 meteorological stations to capture the high rainfall depth (Figure 6-6) and variability (Figure 6-7) resulting in the Ethiopian highlands, Ethiopian representatives conveyed that only 40 total meteorological stations could be included in the regional network for logistical reasons. It was proposed that 20 stations be implemented in the Upper Blue Nile with 10 in the

Tekeze-Atbara and 10 in the Baro-Akobo-Sobat basin. In addition, 30 of the stations would be AWS and 10 would be ARG.

Riverside reviewed the exisiting design and conducted a re-analysis with the additional contraints to provide optimal network coverage for the Ethiopian Nile Basin region. Based on the delineated sub-basins this resulted in 19 stations for the Upper Blue Nile, 1 for the Lower Blue Nile, 7 for the Baro-Akob0-Sobat, 3 for the White Nile, and 10 for the Atbara-Tekeze. This resulted in 31 AWS and only 9 ARG stations since the original design only included 9 ARG stations in Ethiopia to begin with. Details of the 40 stations included in the implementation plan are provided in the following table.

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| ETH_008_Met | Sanja | 12.998 | 37.289 | Active | Full Met | AWS | Sat |
| ETH_012_Met | Bullen | 10.596 | 36.082 | Active | Full Met | AWS | Sat |
| ETH_016_Met | Finoteselam | 10.682 | 37.263 | Active | Full Met | AWS | Sat |
| ETH_019_Met | Pawe | 11.312 | 36.41 | Active | Full Met | AWS | Sat |
| ETH_023_Met | Fugnido | 7.65 | 34.417 | Active | Full Met | AWS | GPRS |
| ETH_025_Met | Jikawo (Lare) | 8.33 | 33.95 | Active | Full Met | AWS | Sat |
| ETH_027_Met | Aman | 6.95 | 35.567 | Active | Full Met | AWS | GPRS |
| ETH_028_Met | Jeba | 6.25 | 35.218 | Active | Full Met | AWS | Sat |
| ETH_030_Met | Ambo Agriculture | 8.985 | 37.84 | Active | Full Met | AWS | GPRS |
| ETH_031_Met | Debre Berhan | 9.633 | 39.5 | Active | Full Met | AWS | Sat |
| ETH_040_Met | Assosa | 10 | 34.517 | Active | Full Met | AWS | GPRS |
| ETH_041_Met | Begi | 9.333 | 34.533 | Active | Full Met | AWS | GPRS |
| ETH_042_Met | Dembidolo | 8.517 | 34.8 | Active | Full Met | AWS | Sat |
| ETH_043_Met | Gidayana | 9.867 | 36.617 | Active | Full Met | AWS | GPRS |
| ETH_044_Met | Gimbi | 9.167 | 35.783 | Active | Full Met | AWS | Sat |
| ETH_046_Met | Kurmuk | 10.577 | 34.354 | Active | Full Met | AWS | Sat |
| ETH_051_Met | Mekane Selam | 10.743 | 38.757 | Active | Full Met | AWS | Sat |
| ETH_052_Met | Wegel Tena | 11.59 | 39.221 | Active | Full Met | AWS | Sat |
| ETH_054_Met | Gondar A.P. | 12.521 | 37.432 | Active | Full Met | AWS | Sat |
| ETH_055_Met | Bahir Dar New | 11.6 | 37.36 | Active | Full Met | AWS | GPRS |
| ETH_056_Met | Debre Markos | 10.326 | 37.739 | Active | Full Met | AWS | Sat |
| ETH_057_Met | Gore | 8.133 | 35.533 | Active | Full Met | AWS | GPRS |
| ETH_058_Met | Axum Air Port | 14.11 | 38.73 | Active | Full Met | AWS | Sat |
| ETH_059_Met | Mekele Air Port | 13.471 | 39.531 | Active | Full Met | AWS | GPRS |
| ETH_060_Met | Nekemte | 9.083 | 36.463 | Active | Full Met | AWS | GPRS |
| ETH_061_Met | Baeker | 13.88 | 36.85 | Active | Rainfall | ARG | Sat |
| ETH_062_Met | Chenek | 13.262 | 38.259 | Active | Rainfall | ARG | Sat |
| ETH_064_Met | Guhala | 12.24 | 38.05 | Active | Rainfall | ARG | Sat |
| ETH_065_Met | Kunzila | 12.167 | 36.167 | Active | Rainfall | ARG | Sat |
| ETH_067_Met | Siadebr | 9.65 | 38.317 | Active | Rainfall | ARG | Sat |
| ETH_068_Met | Sululta | 9.183 | 38.733 | Active | Rainfall | ARG | Sat |
| ETH_069_Met | Adiremets | 13.75 | 37.321 | Active | Rainfall | ARG | Sat |
| ETH_070_Met | Guroro | 13.69 | 39.18 | Active | Rainfall | ARG | Sat |
| ETH_071_Met | Mendi | 9.783 | 35.1 | Active | Rainfall | ARG | Sat |
| ETH_072_Met | Sherekole | 10.8 | 35.083 | Active | Full Met | AWS | GPRS |

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| ETH_073_Met | Sekota | 12.626 | 39.031 | Active | Full Met | AWS | GPRS |
| ETH_074_Met | Delgi | 12.193 | 37.055 | Active | Full Met | AWS | Sat |
| ETH_075_Met | Setema | 8.033 | 36.317 | Active | Full Met | AWS | GPRS |
| ETH_078_Met | Combolcha | 11.086 | 39.72 | Active | Full Met | AWS | Sat |
| ETH_079_Met | Adigrat | 14.28 | 39.45 | Active | Full Met | AWS | Sat |

As has been noted in both the design and Implementation Plan, the proposed telemetery can be changed from satellite to GPRS based on country evaluations following the initial demonstration sites. Additionally, where national policy imposes constraints on allowable telecommunications technologies, an exception may be required to this design to permit GPRS to be used also for the demonstration stations.

***Hydrometric Stations:***

Feedback was received during the Implementation Plan Workshop that five of the proposed hydrometric stations are adequately equipped by Ethiopian standards and there planned resources will instead by applied to other locations per request of Ethiopian representatives. The five stations assessed as adequately equipped include the following:

- ETH_003_Hyd – Lake Tana @ Bahir Dar
- ETH_009_Hyd – Abay Nr Bure
- ETH_010_Hyd – Abbay Nr. Pedagogi
- ETH_013_Hyd – Abay at Kessi Bridge
- ETH_015_Hyd – Main Bele at Bridge DS of Bagusta

It was agreed at the workshop that these locations have significant importance for regional monitoring, particulary those along the Blue Nile (Abay) and are therefore still considered part of the regional design. However, the planned resources for these stations will be applied to the following five new locations that and will also be part of the regional network:

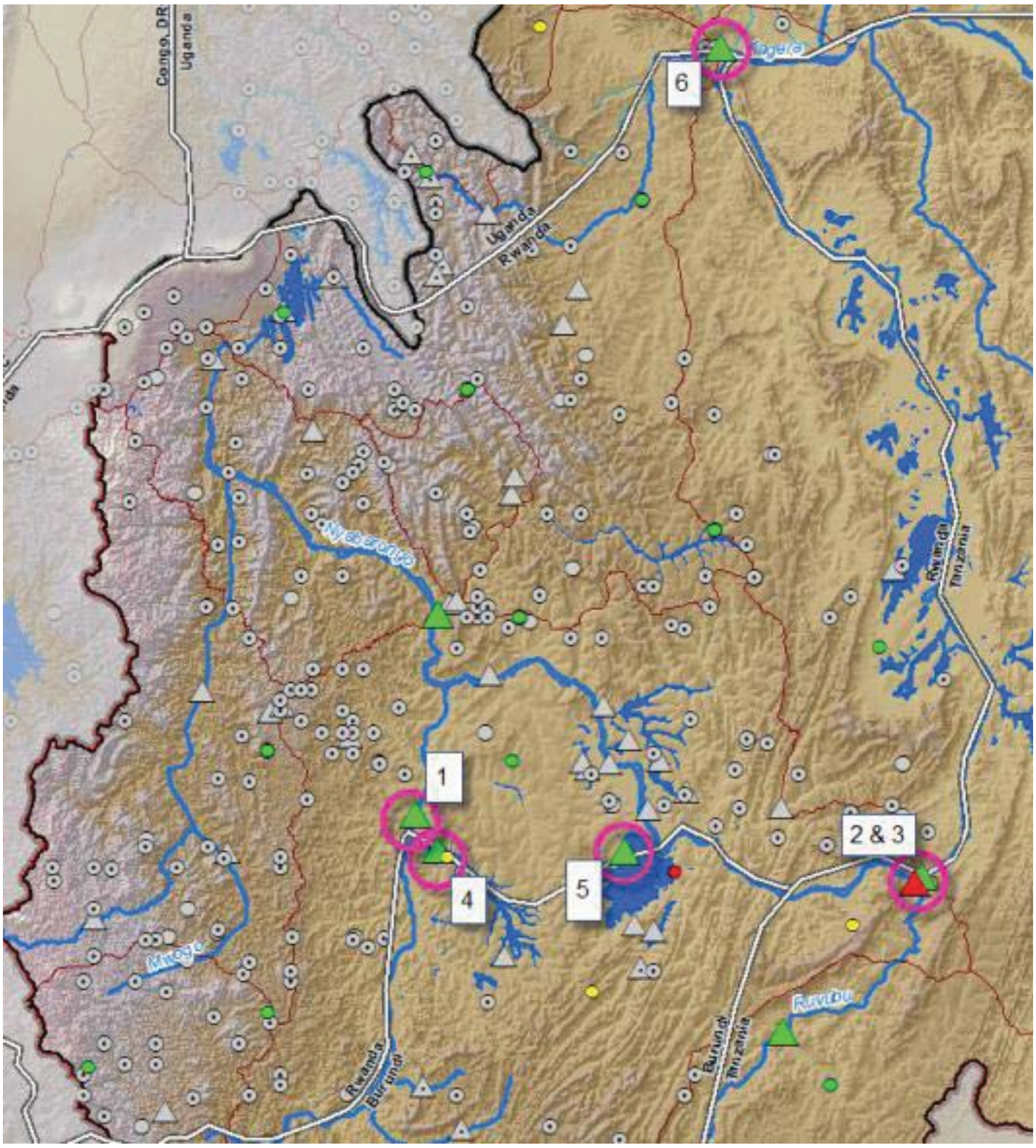
- ETH_016_Hyd – Gumero Nr. Gore
- ETH_017_Hyd – Gheba Nr. Mekele
- ETH_018_Hyd – Sulluh Nr. Hawsien
- ETH_019_Hyd – Illala Nr. Mekele
- ETH_020_Hyd – Bonga Nr. Bonga

## Kenya

Kenya representatives noted that the overall design process was good. However, they did recommend that more emphasis should be given to monitoring evaporation in and around major lakes. As a result, Riverside has reviewed and updated the meteorological network design to provide more stations near major lakes for monitoring evaporation.

## Rwanda

Rwanda representatives requested water quality and sediment monitoring at key sites. All proposed hydrometric stations within Rwanda were proposed to include sediment monitoring. The design has been updated to include water quality monitoring at “Gihinga (Akanyaru)” [1] for transboundary purposes with Burundi as well as at the two downstream locations, the “New proposed station for inflows to Rusumo” and “Rusumo (Akagera)” [2 & 3].




In addition, Rwanda had concerns for the water quality of the transboundary lakes Cyohoha and Rweru. Active hydrometric sites “SHELL (Lac Cyohoha S)” [4] and “Gakindo (Lac Rwero)” [5] within Rwanda have been included in the regional network design. Furthermore, Rwanda representatives requested that downstream flows from the Muvumba River be monitored due to the significant flow contribution and transboundary watershed between Rwanda and Uganda. The active station “Kagitumba (Muvumba)” [6] has been added to the design to monitor both water quality and sediment.

Following the Final Design workshop Rwanda representatives inquired about the the ability of the system to support flood early warning. The current regional network design proposes real-time monitoring on a 10 minute interval with telemetry reporting on a 1 hour basis. However, the proposed equipment and telemetry can be configured to report at a higher frequency for high threshold recordings, such as those related to a flood event. These reported thresholds can then be integrated in the data management system to provide real-time alerts when flood conditions arise. Any additional stations needed to complement the regional network in support of a flood warning system (such as rainfall in urban areas) will be the responsibility of the country. A flood early warning system can thus be established on the foundation of the proposed regional network and national data management system, as noted in the design report.

Rwanda also indicated interest in an additional station on the Akanyaru River to monitor the marshland for planned power generation from peat. Currently there is one proposed regional hydrometric station on the Akanyaru River at Gihinga. This is consistent with the standard design for the regional network to capture the main tributaries of the Nyabarongo and Ruvubu Rivers upstream of Rusumo for both flow quantity and quality. The current regional design emphasizes the Kagera Basin with 12 proposed stations (7 of which are in Rwanda), reflecting the transboundary significance for the countries of Rwanda, Burundi, Tanzania, and Uganda. We believe the current proposed network will help establish monitoring to meet the most essential current regional needs and will be a foundation on which the countries can build to expand their national networks to meet future needs.

## South Sudan

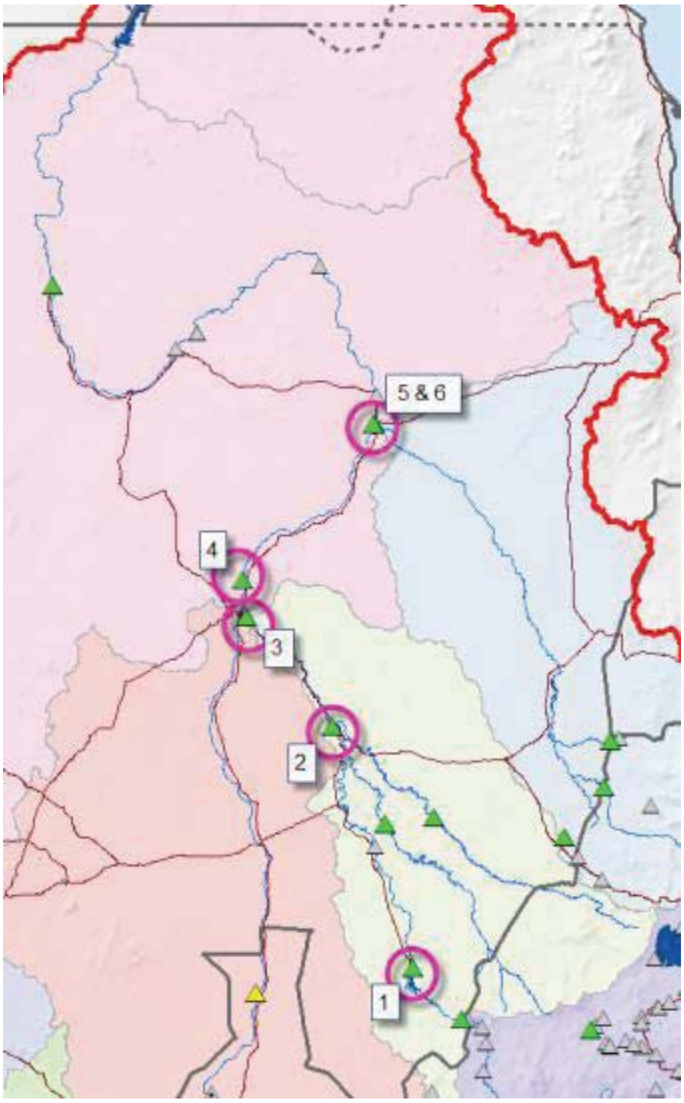
Three recommendations were provided by South Sudan representatives regarding the regional network design. The first two included adding water quality and sediment monitoring at both "Nasir" on the Sobat River and and the "Akobo Mouth" for monitoring transboundary effluents from Ethiopia. This change was updated in the design. The last recommendation was to include the "Nimule" site that measured the Bahr el-Jebel (White Nile) from Uganda in the regional network. However, it was agreed that the currently active Uganda station "R. Albert Nile at Laropi" just upstream of Nimule would currently be more suitable given its operational status. It was agreed for Nimule to be included in the South Sudan national network (including transboundary water quality monitoring) and may be considered in the regional network once rehabilitated.

## Sudan

Based on the initial network design presented at the Conceptual Design workshop, Sudan provided a list of stations it considered to be regional versus national. It was first made clear that all regional stations would also be part of the national network but Sudan still felt that six proposed locations for the regional network should not be included as listed below. This recommendation is noted but Riverside still feels these stations have a significant role in the regional network with reasons noted.

1. "Roseires" – This station is located downstream of Roseires Dam and provides information on both the quantity and sediment load of releases which ultimately effects available flows (both timing and quantity) to the Nile River for downstream use in Egypt.
2. "Madani" – This station is located downstream of the Sennar Dam and provides information on both quantity and sediment load of releases along the Blue Nile before the confluence with the Dinder and Rahad. This information has regional significance for the effects on available flows (both timing and quantity to the Nile River for downstream use in Egypt.
3. "Khartoum" – This station provides the last downstream monitoring of the Blue Nile before the confluence with White. This has regional significance for accounting the total flow quantity and quality of the Blue Nile within the Nile Basin. This has widespread hydrologic significance and regional importance for downstream user Egypt.
4. "Tamanyat" – This station is proposed to monitor both the quantity and quality of flow of the Nile River downstream of the confluence of both the White and Blue. Total flow quantity and quality of White Nile flows and releases from Jebel el-Aulia can be assessed with the complimentary data from Blue Nile gauge at "Khartoum". This has widespread hydrologic significance and regional importance for downstream user Egypt.
5. "Hassanab" – This station is proposed to monitor both the quantity and quality of flow of the Main Nile River before the confluence with the Atbara tributary. This is important to assess the change in flow from "Tamanyat" from both a hydrologic accounting and regional monitoring perspective for downstream Egypt.
6. "Atbara Kilo 3" – This station provides the total flow quantity and quality of the Atbara tributary before the confluence with the Main Nile. This is important for assessing the effects

of upstream regulation at Khashm el-Girba Dam and its impacts on flows (timing, quantity and quality) to the Nile River for hydrologic accounting and downstream use in Egypt.




An update to the Sudan regional design following the Final Design Workshop included proposing rehabilitation of an inactive hydrometric site ("Jabalawlia") just upstream of Jebel Aulia dam and an additional met station ("Jebelein") along the the Jebel Aulia reservoir between Renk and Kosti. These additions were accepted and incorporated in the final design to provide additional regional benefits.

## Tanzania

Tanzania did not provide representation at the Conceptual Design workshop but detailed information on the existing station network was gathered during the consultations and field visits which aided in the proposed design. Station locations and methodology were confirmed at the Final Design workshop.

## Uganda

Uganda recognized the need for several proposed stations within the country which carried significant regional importance. Uganda representatives did propose the need to monitor discharge, sediment, and water quality on the Malaba River near the border with Kenya to assess the upstream catchment impacts. The station "R. Malaba at Jinja-Tororo Road" has been added to the design for this transboundary regional purpose.

During implementation planning it was discovered that a redundant meteorological station in Kampala was included in the design. The original regional station "UGA_056_MET" with station name "Kampala Met.Station" was removed due to the existing AWS station "UGA_021_MET" with station name "Kampala Sewerage Works" already included in the design.

# Appendix C: Table of Proposed Hydrometric Stations

Note the addition of Ethiopia stations 016 through 020 not included in the Design of Section 6.4. See Appendix B for further explanation.

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| **BUR_001_Hyd** | RUVUBU (MUYINGA) | -2.980 | 30.470 | Active | WL, D, WQ, S | Rad | Sat |
| **BUR_002_Hyd** | RUVUBU (GITEGA) | -3.350 | 29.980 | Active | WL, D, S | PS | Sat |
| **DRC_001_Hyd** | Ishango | -0.137 | 29.584 | New | WL, D, WQ | PS | Sat |
| **ETH_001_Hyd** | Geba Nr. Suppi | 8.483 | 35.650 | Active | WL, D, S | Rad | Sat |
| **ETH_002_Hyd** | Baro @ Itang | 8.190 | 34.267 | Active | WL, D, WQ, S | PS | Sat |
| **ETH_003_Hyd** | Lake Tana @ Bahir Dar | 11.600 | 37.383 | Active | WL, WQ | PS | Sat |
| **ETH_004_Hyd** | Didessa Nr. Arjo | 8.683 | 36.417 | Active | WL, D, S | Rad | Sat |
| **ETH_005_Hyd** | Angar Nr. Nekemte | 9.433 | 36.517 | Active | WL, D, S | Rad | Sat |
| **ETH_006_Hyd** | Dabus Nr. Asosa | 9.867 | 34.900 | Active | WL, D, S | Rad | Sat |
| **ETH_007_Hyd** | Tekeze Nr. Embamadre | 13.733 | 38.200 | Active | WL, D, S | Rad | Sat |
| **ETH_008_Hyd** | Angareb Nr. Abdi Rafi | 13.750 | 36.467 | Active | WL, D, WQ, S | Rad | Sat |
| **ETH_009_Hyd** | Abay Nr. Bure | 10.292 | 37.013 | Active | WL, D, WQ, S | Rad | Sat |
| **ETH_010_Hyd** | Abbay Nr. Pedagogi | 11.600 | 37.417 | Active | WL, D, S | PS | Sat |
| **ETH_011_Hyd** | Awero at Dam/Dumbong Village | 7.770 | 34.670 | Active | WL, D, S | PS | Sat |
| **ETH_012_Hyd** | Jemma at Abay Confluence | 10.056 | 38.466 | Active | WL, D, S | Rad | Sat |
| **ETH_013_Hyd** | Abay at Kessi Bridge | 10.070 | 38.180 | Active | WL, D, S | Rad | Sat |
| **ETH_014_Hyd** | Abay at Mekane Selam-Gundewein Br. | 10.664 | 38.503 | Active | WL, D, S | Rad | Sat |
| **ETH_015_Hyd** | Main Bele at Bridge DS of Bagusta | 11.120 | 36.326 | Active | WL, D, S | Rad | Sat |
| **ETH_016_Hyd** | Gumero N. Gore | 8.150 | 35.483 | Active | WL, D, S | Rad | Sat |
| **ETH_017_Hyd** | Gheba Nr. Mekele | 13.600 | 39.383 | Active | WL, D, S | Rad | Sat |
| **ETH_018_Hyd** | Sulluh Nr. Hawsien | 13.983 | 39.500 | Active | WL, D, S | Rad | Sat |
| **ETH_019_Hyd** | Illala Nr. Mekele | 13.517 | 39.000 | Active | WL, D, S | Rad | Sat |
| **ETH_020_Hyd** | Bonga Nr. Bonga | 8.167 | 34.850 | Active | WL, D, S | Rad | Sat |
| **KEN_001_Hyd** | Nzoia Ruambwa | 0.124 | 34.090 | Active | WL, D, WQ | Rad | Sat |
| **KEN_002_Hyd** | Yala Kadenge | 0.002 | 34.140 | Active | WL, D, WQ | Rad | Sat |
| **KEN_003_Hyd** | NYANDO (Ahero Bridge) | -0.164 | 34.919 | Active | WL, D, WQ | Rad | Sat |
| **KEN_004_Hyd** | MIRIU SONDU | -0.336 | 34.802 | Active | WL, D, WQ | Rad | Sat |
| **KEN_005_Hyd** | GUCHA MIGORI | -0.947 | 34.207 | Active | WL, D, WQ | PS | Sat |
| **KEN_006_Hyd** | MARA | -1.233 | 35.036 | Active | WL, D, WQ, S | PS | Sat |
| **RWA_001_Hyd** | Gakindo (Lac Rweru) | -2.341 | 30.302 | Active | WL, WQ | PS | Sat |
| **RWA_002_Hyd** | Gihinga (Akanyaru) | -2.283 | 29.967 | Active | WL, D, WQ, S | PS | Sat |
| **RWA_003_Hyd** | Kagitumba (Muvumba) | -1.049 | 30.458 | Active | WL, D, WQ, S | Rad | Sat |
| **RWA_004_Hyd** | Ruliba (Nyabarongo) | -1.960 | 30.003 | Active | WL, D, S | PS | Sat |
| **RWA_005_Hyd** | Rusumo (Akagera) | -2.382 | 30.780 | Active | WL, D, WQ, S | PS | Sat |
| **RWA_006_Hyd** | SHELL (Lac Cyohoha S) | -2.339 | 30.002 | Active | WL, WQ | PS | Sat |
| **RWA_007_Hyd** | New Proposed Station for inflows to Rusumo | -2.391 | 30.769 | New | WL, D, WQ, S | PS | Sat |
| **SSD_001_Hyd** | Akobo at mouth | 7.795 | 33.057 | Inactive | WL, D, WQ, S | PS | Sat |

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| **SSD_002_Hyd** | Akobo Town | 7.794 | 33.009 | Inactive | WL, D | PS | Sat |
| **SSD_003_Hyd** | Doleib Hill | 9.300 | 31.630 | Active | WL, D | PS | Sat |
| **SSD_004_Hyd** | Malakal | 9.536 | 31.644 | Active | WL, D | PS | Sat |
| **SSD_005_Hyd** | Mongalla | 5.202 | 31.768 | Active | WL, D | PS | Sat |
| **SSD_006_Hyd** | Nasir | 8.615 | 33.067 | New | WL, D, WQ, S | PS | Sat |
| **SSD_007_Hyd** | Nyamlell | 9.139 | 26.978 | Inactive | WL, D | PS | Sat |
| **SSD_008_Hyd** | Renk | 11.520 | 32.690 | Inactive | WL, WQ | PS | Sat |
| **SSD_009_Hyd** | River Assua at mouth | 3.723 | 31.972 | Inactive | WL, D, WQ | Rad | Sat |
| **SSD_010_Hyd** | Wau | 7.694 | 28.014 | Active | WL, D | Rad | Sat |
| **SSD_011_Hyd** | Tonj | 7.272 | 28.687 | Inactive | WL, D | Rad | Sat |
| **SSD_012_Hyd** | Bentiu | 9.292 | 29.804 | New | WL, D, WQ | PS | Sat |
| **SUD_001_Hyd** | Eldeim | 11.238 | 34.928 | Active | WL, D, WQ, S | PS | Sat |
| **SUD_002_Hyd** | Roseries | 11.800 | 34.389 | Active | WL, D, S | Rad | Sat |
| **SUD_003_Hyd** | Madani | 14.406 | 33.523 | Active | WL, D, S | Rad | Sat |
| **SUD_004_Hyd** | Khartoum | 15.599 | 32.588 | Active | WL, D, WQ, S | Rad | Sat |
| **SUD_005_Hyd** | Gewesi | 13.357 | 34.099 | Active | WL, D, S | PS | Sat |
| **SUD_006_Hyd** | Hawata | 13.416 | 34.623 | Active | WL, D, S | PS | Sat |
| **SUD_007_Hyd** | Atbara Kilo 3 | 17.679 | 33.974 | Active | WL, D, WQ, S | Rad | Sat |
| **SUD_008_Hyd** | Tamanyat | 15.985 | 32.559 | Active | WL, D, WQ, S | PS | Sat |
| **SUD_009_Hyd** | Hassanab | 17.676 | 33.973 | Active | WL, D, WQ, S | Rad | Sat |
| **SUD_010_Hyd** | Dongola | 19.181 | 30.494 | Active | WL, D, WQ, S | Rad | Sat |
| **SUD_011_Hyd** | Al Asira | 13.213 | 36.034 | Active | WL, D, WQ, S | PS | Sat |
| **SUD_012_Hyd** | Hamdait | 14.254 | 36.537 | Active | WL, D, WQ, S | PS | Sat |
| **SUD_013_Hyd** | Jabalawlia | 15.233 | 32.490 | Inactive | WL, WQ | PS | Sat |
| **TAN_001_Hyd** | Mara river at Mara Mine | -1.549 | 34.554 | Active | WL, D, WQ, S | PS | Sat |
| **TAN_002_Hyd** | Grumeti river at M/Bridge | -2.098 | 33.869 | Active | WL, D, WQ, S | PS | Sat |
| **TAN_003_Hyd** | mbalageti | -2.196 | 33.868 | Active | WL, D, WQ | PS | Sat |
| **TAN_004_Hyd** | Duma River at Sayaka | -2.572 | 33.533 | Active | WL, D, WQ, S | SE | Sat |
| **TAN_005_Hyd** | Kagera/Kyaka Ferry | -1.250 | 31.419 | Active | WL, D, WQ | PS | Sat |
| **TAN_006_Hyd** | Ruvuvu/Mumwendo Ferry | -2.631 | 30.558 | Active | WL, D, WQ, S | SE | Sat |
| **TAN_007_Hyd** | Simiyu River at Lumeji | -2.647 | 33.546 | Active | WL, D, WQ, S | PS | Sat |
| **TAN_008_Hyd** | Kogatende Ranger Post | -1.563 | 34.887 | Active | WL, D, WQ, S | PS | Sat |
| **UGA_001_Hyd** | L. Victoria at Jinja Pier | 0.409 | 33.205 | Active | WL, WQ | SE | Sat |
| **UGA_002_Hyd** | R. Kagera at Masangano | -0.940 | 31.750 | Active | WL, D, WQ | SE | Sat |
| **UGA_003_Hyd** | R. Katonga at Kampala - Masaka | -0.034 | 32.004 | Active | WL, D, WQ | Rad | Sat |
| **UGA_004_Hyd** | R. Sio at Luhalali near Bunadet | 0.240 | 34.000 | Active | WL, D, WQ | SE | Sat |
| **UGA_005_Hyd** | R. Bukora at Mutukula - Kyotera | -0.850 | 31.483 | Active | WL, D, WQ | Rad | Sat |
| **UGA_006_Hyd** | L. Kyoga at Bugondo Pier | 1.620 | 33.274 | Active | WL, WQ | SE | Sat |
| **UGA_007_Hyd** | R. Victoria Nile at Mbulamuti | 0.835 | 33.028 | Active | WL, D | SE | Sat |
| **UGA_008_Hyd** | R. Malaba at Jinja - Tororo Road | 0.585 | 34.052 | Active | WL, D, WQ, S | Rad | Sat |
| **UGA_009_Hyd** | R. Kyoga Nile at Masindi Port | 1.695 | 32.093 | Active | WL, D | SE | Sat |
| **UGA_010_Hyd** | R. Kyoga Nile at Paraa | 2.283 | 31.564 | Active | WL, D | PS | Sat |
| **UGA_011_Hyd** | L. Edward at Katwe | -0.150 | 29.900 | Active | WL, WQ | PS | Sat |

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| **UGA_012_Hyd** | L. Albert at Butiaba | 1.820 | 31.327 | Active | WL, WQ | SE | Sat |
| **UGA_013_Hyd** | R. Semliki at Bweramule | 0.950 | 30.183 | Inactive | WL, D, WQ | PS | Sat |
| **UGA_014_Hyd** | R. Albert Nile at Laropi | 3.552 | 31.813 | Active | WL, D, WQ | PS | Sat |
| **UGA_015_Hyd** | R. Albert Nile at Panyango. | 2.470 | 31.500 | Active | WL, D, WQ | SE | Sat |

# Appendix D: Table of Proposed Meteorological Stations

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| **BUR_001_Met** | CANKUZO (Projet) | -3.283 | 30.383 | Active | Full Met | AWS | Sat |
| **BUR_002_Met** | MUYINGA | -2.850 | 30.350 | Active | Full Met | AWS | Sat |
| **BUR_003_Met** | KARUZI | -3.100 | 30.167 | Active | Full Met | AWS | Sat |
| **BUR_004_Met** | GITEGA (Aero) | -3.417 | 29.917 | Active | Full Met | AWS | Sat |
| **BUR_005_Met** | GISOZI | -3.567 | 29.683 | Active | Full Met | AWS | Sat |
| **BUR_006_Met** | MURIZA | -3.533 | 30.083 | Active | Full Met | AWS | Sat |
| **BUR_007_Met** | RUVYIRONZA | -3.817 | 29.767 | Active | Full Met | AWS | Sat |
| **BUR_008_Met** | RWEGURA | -2.917 | 29.517 | Active | Full Met | AWS | Sat |
| **BUR_009_Met** | NYAMUSWAGA | -2.883 | 30.033 | Active | Full Met | AWS | Sat |
| **BUR_010_Met** | MULEHE | -2.567 | 30.250 | Inactive | Rainfall | ARG | Sat |
| **BUR_011_Met** | Lake Rweru | -2.375 | 30.384 | New | Full Met | AWS | Sat |
| **DRC_001_Met** | BUNIA | 1.300 | 30.130 | Active | Full Met | AWS | Sat |
| **DRC_002_Met** | BUTEMBO | 0.080 | 29.160 | Active | Full Met | AWS | Sat |
| **DRC_003_Met** | GOMA | -1.410 | 29.140 | Active | Full Met | AWS | Sat |
| **DRC_004_Met** | Tumbula | 0.402 | 29.634 | New | Rainfall | ARG | Sat |
| **DRC_005_Met** | Bwera | -0.702 | 29.362 | New | Full Met | AWS | Sat |
| **DRC_006_Met** | Kasenyi | 1.397 | 30.443 | New | Full Met | AWS | Sat |
| **DRC_007_Met** | Mahagi Port | 2.131 | 31.240 | Inactive | Full Met | AWS | Sat |
| **DRC_008_Met** | Lake Edward Outlet | -0.150 | 29.576 | New | Full Met | AWS | Sat |
| **DRC_009_Met** | Rutshuru | -1.182 | 29.451 | Inactive | Rainfall | ARG | Sat |
| **ETH_001_Met** | Aykel | 12.540 | 37.059 | Active | Full Met | AWS | Sat |
| **ETH_002_Met** | Debark | 13.142 | 37.898 | Active | Full Met | AWS | GPRS |
| **ETH_003_Met** | Debre Tabor | 11.867 | 37.995 | Active | Full Met | AWS | Sat |
| **ETH_004_Met** | Humera | 14.104 | 36.522 | Inactive | Full Met | AWS | GPRS |
| **ETH_005_Met** | Metema | 12.775 | 36.414 | Active | Full Met | AWS | GPRS |
| **ETH_006_Met** | Nefas Mewcha | 11.730 | 38.468 | Active | Full Met | AWS | GPRS |
| **ETH_007_Met** | Quara | 12.137 | 35.532 | Active | Full Met | AWS | Sat |
| **ETH_008_Met** | Sanja | 12.998 | 37.289 | Active | Full Met | AWS | Sat |
| **ETH_009_Met** | Shahura | 11.929 | 36.874 | Active | Full Met | AWS | GPRS |
| **ETH_010_Met** | Adet | 11.274 | 37.493 | Active | Full Met | AWS | Sat |
| **ETH_011_Met** | Ayehu | 10.661 | 36.793 | Active | Full Met | AWS | Sat |
| **ETH_012_Met** | Bullen | 10.596 | 36.082 | Active | Full Met | AWS | Sat |
| **ETH_013_Met** | Chagni | 10.974 | 36.499 | Active | Full Met | AWS | Sat |
| **ETH_014_Met** | Dangila | 11.434 | 36.846 | Active | Full Met | AWS | Sat |
| **ETH_015_Met** | Debre Work | 10.651 | 38.162 | Active | Full Met | AWS | Sat |
| **ETH_016_Met** | Finoteselam | 10.682 | 37.263 | Active | Full Met | AWS | Sat |
| **ETH_017_Met** | Mankush | 11.273 | 35.291 | Active | Full Met | AWS | GPRS |
| **ETH_018_Met** | Motta | 11.074 | 37.890 | Active | Full Met | AWS | Sat |
| **ETH_019_Met** | Pawe | 11.312 | 36.410 | Active | Full Met | AWS | Sat |

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| ETH_020_Met | Alge | 8.533 | 35.667 | Active | Full Met | AWS | GPRS |
| ETH_021_Met | Bedele | 8.450 | 36.333 | Active | Full Met | AWS | Sat |
| ETH_022_Met | Bure | 8.233 | 35.100 | Active | Full Met | AWS | GPRS |
| ETH_023_Met | Fugnido | 7.650 | 34.417 | Active | Full Met | AWS | GPRS |
| ETH_024_Met | Gambela | 8.250 | 34.583 | Active | Full Met | AWS | GPRS |
| ETH_025_Met | Jikawo (Lare) | 8.330 | 33.950 | Active | Full Met | AWS | Sat |
| ETH_026_Met | Masha | 7.750 | 35.467 | Active | Full Met | AWS | Sat |
| ETH_027_Met | Aman | 6.950 | 35.567 | Active | Full Met | AWS | GPRS |
| ETH_028_Met | Jeba | 6.250 | 35.218 | Active | Full Met | AWS | Sat |
| ETH_029_Met | Alem Ketema | 10.033 | 39.033 | Active | Full Met | AWS | GPRS |
| ETH_030_Met | Ambo Agriculture | 8.985 | 37.840 | Active | Full Met | AWS | GPRS |
| ETH_031_Met | Debre Berhan | 9.633 | 39.500 | Active | Full Met | AWS | Sat |
| ETH_032_Met | Fiche | 9.767 | 38.733 | Active | Full Met | AWS | GPRS |
| ETH_033_Met | Gunde Meskel | 10.183 | 38.717 | Active | Full Met | AWS | Sat |
| ETH_035_Met | Atsebi | 13.883 | 39.741 | Active | Full Met | AWS | Sat |
| ETH_036_Met | May Tsebri | 13.589 | 38.145 | Active | Full Met | AWS | Sat |
| ETH_037_Met | Nebelet | 14.100 | 39.280 | Active | Full Met | AWS | Sat |
| ETH_038_Met | Shire Endasilasse | 14.102 | 38.294 | Active | Full Met | AWS | GPRS |
| ETH_039_Met | Arjo | 8.750 | 36.500 | Active | Full Met | AWS | GPRS |
| ETH_040_Met | Assosa | 10.000 | 34.517 | Active | Full Met | AWS | GPRS |
| ETH_041_Met | Begi | 9.333 | 34.533 | Active | Full Met | AWS | GPRS |
| ETH_042_Met | Dembidolo | 8.517 | 34.800 | Active | Full Met | AWS | Sat |
| ETH_043_Met | Gidayana | 9.867 | 36.617 | Active | Full Met | AWS | GPRS |
| ETH_044_Met | Gimbi | 9.167 | 35.783 | Active | Full Met | AWS | Sat |
| ETH_045_Met | Kamashe | 10.017 | 35.450 | Active | Full Met | AWS | GPRS |
| ETH_046_Met | Kurmuk | 10.577 | 34.354 | Active | Full Met | AWS | Sat |
| ETH_047_Met | Nedjo | 9.500 | 35.450 | Active | Full Met | AWS | Sat |
| ETH_048_Met | Amba Mariam | 11.203 | 39.217 | Active | Full Met | AWS | GPRS |
| ETH_049_Met | Amde Work | 12.428 | 38.714 | Active | Full Met | AWS | Sat |
| ETH_050_Met | Lalibela | 12.039 | 39.040 | Active | Full Met | AWS | GPRS |
| ETH_051_Met | Mekane Selam | 10.743 | 38.757 | Active | Full Met | AWS | Sat |
| ETH_052_Met | Wegel Tena | 11.590 | 39.221 | Active | Full Met | AWS | Sat |
| ETH_053_Met | Wereilu | 10.579 | 39.437 | Active | Full Met | AWS | Sat |
| ETH_054_Met | Gondar A.P. | 12.521 | 37.432 | Active | Full Met | AWS | Sat |
| ETH_055_Met | Bahir Dar New | 11.600 | 37.360 | Active | Full Met | AWS | GPRS |
| ETH_056_Met | Debre Markos | 10.326 | 37.739 | Active | Full Met | AWS | Sat |
| ETH_057_Met | Gore | 8.133 | 35.533 | Active | Full Met | AWS | GPRS |
| ETH_058_Met | Axum Air Port | 14.110 | 38.730 | Active | Full Met | AWS | Sat |
| ETH_059_Met | Mekele Air Port | 13.471 | 39.531 | Active | Full Met | AWS | GPRS |
| ETH_060_Met | Nekemte | 9.083 | 36.463 | Active | Full Met | AWS | GPRS |
| ETH_061_Met | Baeker | 13.880 | 36.850 | Active | Rainfall | ARG | Sat |
| ETH_062_Met | Chenek | 13.262 | 38.259 | Active | Rainfall | ARG | Sat |

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| **ETH_063_Met** | Gorgora | 12.250 | 37.300 | Active | Full Met | AWS | Sat |
| **ETH_064_Met** | Guhala | 12.240 | 38.050 | Active | Rainfall | ARG | Sat |
| **ETH_065_Met** | Kunzila | 12.167 | 36.167 | Active | Rainfall | ARG | Sat |
| **ETH_066_Met** | Agaro | 7.850 | 36.600 | Active | Full Met | AWS | GPRS |
| **ETH_067_Met** | Siadebr | 9.650 | 38.317 | Active | Rainfall | ARG | Sat |
| **ETH_068_Met** | Sululta | 9.183 | 38.733 | Active | Rainfall | ARG | Sat |
| **ETH_069_Met** | Adiremets | 13.750 | 37.321 | Active | Rainfall | ARG | Sat |
| **ETH_070_Met** | Guroro | 13.690 | 39.180 | Active | Rainfall | ARG | Sat |
| **ETH_071_Met** | Mendi | 9.783 | 35.100 | Active | Rainfall | ARG | Sat |
| **ETH_072_Met** | Sherekole | 10.800 | 35.083 | Active | Full Met | AWS | GPRS |
| **ETH_073_Met** | Sekota | 12.626 | 39.031 | Active | Full Met | AWS | GPRS |
| **ETH_074_Met** | Delgi | 12.193 | 37.055 | Active | Full Met | AWS | Sat |
| **ETH_075_Met** | Setema | 8.033 | 36.317 | Active | Full Met | AWS | GPRS |
| **ETH_076_Met** | Shola Gebeya | 9.191 | 39.416 | Active | Full Met | AWS | Sat |
| **ETH_077_Met** | Simada | 11.300 | 38.180 | Active | Full Met | AWS | Sat |
| **ETH_078_Met** | Combolcha | 11.086 | 39.720 | Active | Full Met | AWS | Sat |
| **ETH_079_Met** | Adigrat | 14.280 | 39.450 | Active | Full Met | AWS | Sat |
| **ETH_080_Met** | Maichew | 12.790 | 39.550 | Active | Full Met | AWS | Sat |
| **ETH_081_Met** | Shiraro | 14.401 | 37.760 | Active | Full Met | AWS | Sat |
| **ETH_082_Met** | Tekeze Hydro power | 13.360 | 38.770 | Active | Full Met | AWS | GPRS |
| **ETH_083_Met** | Limu Genet | 8.070 | 36.950 | Active | Full Met | AWS | GPRS |
| **ETH_084_Met** | Niruaq | 13.050 | 38.990 | Active | Full Met | AWS | GPRS |
| **KEN_001_Met** | Siaya ATC | 0.058 | 34.283 | Active | Full Met | AWS | Sat |
| **KEN_002_Met** | Alupe KARI | 0.500 | 34.124 | Active | Full Met | AWS | Sat |
| **KEN_003_Met** | Chwele | 0.734 | 34.610 | Active | Full Met | AWS | Sat |
| **KEN_004_Met** | Bomet | -0.712 | 35.391 | Active | Full Met | AWS | Sat |
| **KEN_005_Met** | Kisumu Airport Met | -0.100 | 34.750 | Active | Full Met | AWS | Sat |
| **KEN_006_Met** | Eldoret Airport | 0.400 | 35.230 | Active | Full Met | AWS | Sat |
| **KEN_007_Met** | Eldoret Kapsoya Met | 0.533 | 35.283 | Active | Full Met | AWS | Sat |
| **KEN_008_Met** | Suba Met, RUSINGA ISLAND KASWANGA HDR. STN | -0.417 | 34.133 | Active | Full Met | AWS | Sat |
| **KEN_009_Met** | Nganyi Community RANET | 0.064 | 34.578 | Active | Full Met | AWS | Sat |
| **KEN_010_Met** | Kakamega Airport | 0.274 | 34.785 | Active | Full Met | AWS | Sat |
| **KEN_011_Met** | Mumias Sugar Factory | 0.370 | 34.500 | Active | Full Met | AWS | Sat |
| **KEN_012_Met** | Kaimosi Farmers Training Centre | 0.220 | 34.950 | Active | Full Met | AWS | Sat |
| **KEN_013_Met** | Lugari Forest Station | 0.670 | 34.900 | Active | Full Met | AWS | Sat |
| **KEN_014_Met** | Kapsara Tea Factory | 1.088 | 35.159 | Active | Full Met | AWS | Sat |
| **KEN_015_Met** | CHORLIM ADC | 1.033 | 34.800 | Active | Full Met | AWS | Sat |
| **KEN_016_Met** | CHEPTONGEI CHIEF's Office | 0.855 | 35.501 | Active | Full Met | AWS | Sat |
| **KEN_017_Met** | KIPKABUS FOREST STATION | 0.284 | 35.546 | Active | Full Met | AWS | Sat |
| **KEN_018_Met** | NABKOI FOREST STATION | 0.136 | 35.469 | Active | Full Met | AWS | Sat |
| **KEN_019_Met** | Bunyala RANET FM | 0.130 | 34.027 | Active | Full Met | AWS | Sat |

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| **KEN_020_Met** | ANGORAI CHIEF'S CENTRE | 0.717 | 34.350 | Active | Rainfall | ARG | Sat |
| **KEN_021_Met** | OYUGIS AGRICULTURAL STATION | -0.517 | 34.733 | Active | Rainfall | ARG | Sat |
| **KEN_022_Met** | HOMABAY FARMERS TRAINING CENTRE | -0.533 | 34.467 | Active | Full Met | AWS | Sat |
| **KEN_023_Met** | KEBABE PRIMARY SCHOOL | -0.533 | 34.983 | Active | Rainfall | ARG | Sat |
| **KEN_024_Met** | SOUTH NYANZA SUGAR FACTORY | -0.900 | 34.533 | Active | Rainfall | ARG | Sat |
| **KEN_025_Met** | LONDIANI MAKUTANO FOREST STATION | -0.050 | 35.617 | Active | Rainfall | ARG | Sat |
| **KEN_026_Met** | NDOINET FOREST STATION | -0.450 | 35.483 | Active | Rainfall | ARG | Sat |
| **KEN_027_Met** | KORU, COFFEE BOARD SUB-STATION | -0.133 | 35.283 | Active | Rainfall | ARG | Sat |
| **KEN_028_Met** | KILGORIS DIVISSIONAL AGR.OFFICE | -1.000 | 34.883 | Active | Rainfall | ARG | Sat |
| **KEN_029_Met** | GOD BURA SCHOOL,S.D.A. | -0.717 | 34.083 | | Full Met | AWS | Sat |
| **KEN_030_Met** | ELBURGON, BARAGET FOREST STATION | -0.417 | 35.733 | | Rainfall | ARG | Sat |
| **KEN_031_Met** | SOTIK, AITONG VET. HOUSE | -1.183 | 35.250 | | Rainfall | ARG | Sat |
| **KEN_032_Met** | NAROK,KEEKOROK GAME LODGE | -1.583 | 35.233 | | Rainfall | ARG | Sat |
| **KEN_033_Met** | NAIKARA AFRICA GOSPEL CHURCH | -1.550 | 35.633 | | Rainfall | ARG | Sat |
| **RWA_001_Met** | BYIMANA | -2.180 | 29.730 | Active | Full Met | AWS | Sat |
| **RWA_002_Met** | KAWANGIRE | -1.824 | 30.448 | Active | Full Met | AWS | Sat |
| **RWA_003_Met** | KIGALI AERO | -1.965 | 30.133 | Active | Full Met | AWS | Sat |
| **RWA_004_Met** | Ntaruka | -1.476 | 29.756 | Active | Full Met | AWS | Sat |
| **RWA_005_Met** | NYAGATARE | -1.295 | 30.331 | Active | Full Met | AWS | Sat |
| **RWA_006_Met** | BUTARE AERO | -2.600 | 29.730 | Active | Full Met | AWS | Sat |
| **RWA_007_Met** | BYUMBA MET | -1.600 | 30.050 | Active | Full Met | AWS | Sat |
| **RWA_008_Met** | Mayange | -2.196 | 30.122 | Active | Full Met | AWS | Sat |
| **RWA_009_Met** | Ndego | -2.014 | 30.711 | Active | Full Met | AWS | Sat |
| **RWA_010_Met** | Nyabimata | -2.689 | 29.440 | Active | Full Met | AWS | Sat |
| **RWA_011_Met** | RUHUHA | -2.350 | 30.017 | | Full Met | AWS | Sat |
| **SSD_001_Met** | Malakal | 9.550 | 31.650 | Active | Full Met | AWS | Sat |
| **SSD_002_Met** | Juba | 4.867 | 31.600 | Active | Full Met | AWS | Sat |
| **SSD_003_Met** | Wau | 7.700 | 28.017 | Active | Full Met | AWS | Sat |
| **SSD_004_Met** | Renk | 11.750 | 32.783 | Active | Full Met | AWS | Sat |
| **SSD_005_Met** | Raga | 8.467 | 25.667 | Active | Full Met | AWS | Sat |
| **SSD_006_Met** | BENTIU | 9.233 | 29.833 | Inactive | Full Met | AWS | Sat |
| **SSD_007_Met** | RUMBEK | 6.800 | 29.700 | Inactive | Full Met | AWS | Sat |
| **SSD_008_Met** | TORIT | 4.417 | 32.550 | Inactive | Full Met | AWS | Sat |
| **SSD_009_Met** | YAMBIO | 4.567 | 28.400 | Inactive | Full Met | AWS | Sat |
| **SSD_010_Met** | YEI | 4.083 | 30.667 | Inactive | Full Met | AWS | Sat |
| **SSD_011_Met** | BOR | 6.217 | 31.550 | Inactive | Full Met | AWS | Sat |
| **SSD_012_Met** | AWEIL | 8.767 | 27.383 | Inactive | Full Met | AWS | Sat |
| **SSD_013_Met** | KODOK | 10.470 | 32.190 | Inactive | Rainfall | ARG | Sat |
| **SSD_014_Met** | NASIR | 9.020 | 33.110 | Inactive | Rainfall | ARG | Sat |
| **SSD_015_Met** | PIBOR | 7.330 | 33.220 | Inactive | Rainfall | ARG | Sat |
| **SSD_016_Met** | TONGA | 9.770 | 31.080 | Inactive | Rainfall | ARG | Sat |
| **SSD_017_Met** | GOGREIAL | 8.880 | 28.190 | Inactive | Rainfall | ARG | Sat |

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| SSD_018_Met | MESHRAERREQ | 8.690 | 29.440 | Inactive | Rainfall | ARG | Sat |
| SSD_019_Met | SHAMBE | 7.190 | 31.270 | Inactive | Rainfall | ARG | Sat |
| SSD_020_Met | TONJ | 7.470 | 29.250 | Inactive | Rainfall | ARG | Sat |
| SSD_021_Met | KAPOETA | 5.300 | 33.970 | Inactive | Full Met | AWS | Sat |
| SSD_022_Met | LUI | 5.550 | 30.750 | Inactive | Rainfall | ARG | Sat |
| SSD_023_Met | MONGALLA | 5.410 | 32.380 | Inactive | Rainfall | ARG | Sat |
| SSD_024_Met | MARIDI | 5.520 | 29.770 | Inactive | Full Met | AWS | Sat |
| SSD_025_Met | NA'ANDI | 5.610 | 28.500 | Inactive | Rainfall | ARG | Sat |
| SSD_026_Met | NAGI SHOT | 4.440 | 33.940 | Inactive | Rainfall | ARG | Sat |
| SSD_027_Met | TUMBURA | 6.000 | 27.770 | Inactive | Full Met | AWS | Sat |
| SSD_028_Met | Fakwak | 8.355 | 30.724 | New | Full Met | AWS | Sat |
| SSD_029_Met | Pibor Post | 6.804 | 33.140 | New | Full Met | AWS | Sat |
| SSD_030_Met | Boma | 6.281 | 34.415 | New | Rainfall | ARG | Sat |
| SSD_031_Met | Faddoi | 8.133 | 32.298 | New | Full Met | AWS | Sat |
| SSD_032_Met | Pachua | 10.080 | 29.947 | New | Rainfall | ARG | Sat |
| SUD_001_Met | Abu Naama | 12.733 | 34.133 | Active | Full Met | AWS | Sat |
| SUD_002_Met | Sennar | 13.550 | 33.617 | Active | Full Met | AWS | Sat |
| SUD_003_Met | Wad Medani | 14.383 | 33.483 | Active | Full Met | AWS | Sat |
| SUD_004_Met | Abu Hammad | 19.533 | 33.333 | Active | Full Met | AWS | Sat |
| SUD_005_Met | Atbara | 17.667 | 33.967 | Active | Full Met | AWS | Sat |
| SUD_006_Met | Ed Damazine | 11.817 | 34.400 | Active | Full Met | AWS | Sat |
| SUD_007_Met | Dongola | 19.167 | 30.483 | Active | Full Met | AWS | Sat |
| SUD_008_Met | Ed Dueim | 13.983 | 32.333 | Active | Full Met | AWS | Sat |
| SUD_009_Met | El Fasher | 13.617 | 25.333 | Active | Full Met | AWS | Sat |
| SUD_010_Met | Khartoum | 15.600 | 32.550 | Active | Full Met | AWS | Sat |
| SUD_011_Met | Karima | 18.550 | 31.850 | Active | Full Met | AWS | Sat |
| SUD_012_Met | Kosti | 13.167 | 32.667 | Active | Full Met | AWS | Sat |
| SUD_013_Met | Shendi | 16.700 | 33.433 | Active | Full Met | AWS | Sat |
| SUD_014_Met | Wadi Halfa | 22.000 | 31.250 | Active | Full Met | AWS | Sat |
| SUD_015_Met | El Gadaref | 14.033 | 35.400 | Active | Full Met | AWS | Sat |
| SUD_016_Met | Kadugli | 11.000 | 29.717 | Active | Full Met | AWS | Sat |
| SUD_017_Met | Babanusa | 11.333 | 27.817 | Active | Full Met | AWS | Sat |
| SUD_018_Met | En Nahud | 12.700 | 28.433 | Active | Full Met | AWS | Sat |
| SUD_019_Met | Kassala | 15.467 | 36.400 | Active | Full Met | AWS | Sat |
| SUD_020_Met | New Halfa | 15.317 | 35.600 | Active | Full Met | AWS | Sat |
| SUD_021_Met | Rashad | 11.867 | 31.050 | Active | Full Met | AWS | Sat |
| SUD_022_Met | Nyala | 12.050 | 24.883 | Active | Full Met | AWS | Sat |
| SUD_023_Met | Khashm Elgirba | 14.961 | 35.903 | Active | Full Met | AWS | Sat |
| SUD_024_Met | Elobeid | 13.150 | 30.230 | Active | Full Met | AWS | Sat |
| SUD_025_Met | Elshwak | 14.294 | 35.846 | Active | Full Met | AWS | Sat |
| SUD_026_Met | Aldali | 10.233 | 34.033 | Inactive | Rainfall | ARG | Sat |
| SUD_027_Met | Hamsh Koreab | 17.117 | 36.733 | Active | Rainfall | ARG | Sat |

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| **SUD_028_Met** | Goz Ragab | 16.067 | 35.567 | Inactive | Rainfall | ARG | Sat |
| **SUD_029_Met** | Sidon | 17.317 | 34.433 | Inactive | Rainfall | ARG | Sat |
| **SUD_030_Met** | Togan | 16.083 | 36.783 | Inactive | Rainfall | ARG | Sat |
| **SUD_031_Met** | Barbar | 18.033 | 35.983 | Inactive | Full Met | AWS | Sat |
| **SUD_032_Met** | Station no.6 | 20.750 | 32.633 | Inactive | Rainfall | ARG | Sat |
| **SUD_033_Met** | DANKOG | 12.083 | 23.983 | Inactive | Rainfall | ARG | Sat |
| **SUD_034_Met** | EL-TEWAISHA | 12.283 | 26.717 | Inactive | Full Met | AWS | Sat |
| **SUD_035_Met** | Gazala gawazat | 11.467 | 26.283 | Inactive | Rainfall | ARG | Sat |
| **SUD_036_Met** | RADOM | 9.867 | 24.833 | Inactive | Full Met | AWS | Sat |
| **SUD_037_Met** | TORA TONGA | 12.933 | 24.300 | Inactive | Rainfall | ARG | Sat |
| **SUD_038_Met** | tulus | 11.050 | 24.550 | Inactive | Rainfall | ARG | Sat |
| **SUD_039_Met** | EL NEIMA | 14.533 | 32.817 | Inactive | Rainfall | ARG | Sat |
| **SUD_040_Met** | Fatisa | 14.550 | 32.217 | Inactive | Rainfall | ARG | Sat |
| **SUD_041_Met** | J Megeneis | 11.850 | 32.100 | Inactive | Rainfall | ARG | Sat |
| **SUD_042_Met** | Wd alkali | 14.983 | 33.300 | Inactive | Rainfall | ARG | Sat |
| **SUD_043_Met** | kogmer | 14.400 | 30.483 | Active | Rainfall | ARG | Sat |
| **SUD_044_Met** | Shirkela Um aush | 12.817 | 31.467 | Active | Rainfall | ARG | Sat |
| **SUD_045_Met** | Sodari | 14.417 | 29.083 | Active | Rainfall | ARG | Sat |
| **SUD_046_Met** | Um bader | 14.233 | 27.950 | Active | Rainfall | ARG | Sat |
| **SUD_047_Met** | Basunda | 12.967 | 35.817 | Active | Rainfall | ARG | Sat |
| **SUD_048_Met** | Doka | 13.533 | 35.900 | Inactive | Rainfall | ARG | Sat |
| **SUD_049_Met** | ElFaw | 14.433 | 34.533 | Active | Rainfall | ARG | Sat |
| **SUD_050_Met** | ElHawata | 13.417 | 34.633 | Active | Rainfall | ARG | Sat |
| **SUD_051_Met** | Jebelein | 12.583 | 32.800 | Inactive | Full Met | AWS | Sat |
| **TAN_001_Met** | Bunda/ Bitaraguru Met. Station | -1.947 | 33.848 | Active | Full Met | AWS | Sat |
| **TAN_002_Met** | Kidinda Met. Station | -2.797 | 33.967 | Active | Full Met | AWS | Sat |
| **TAN_003_Met** | Magu Met. Station | -2.592 | 33.454 | Active | Full Met | AWS | Sat |
| **TAN_004_Met** | Maswa Met. Station | -3.182 | 33.791 | Active | Full Met | AWS | Sat |
| **TAN_005_Met** | Randa Met. Station | -1.295 | 34.112 | Active | Full Met | AWS | Sat |
| **TAN_006_Met** | Ukerewe Met. Station | -1.933 | 32.917 | Active | Full Met | AWS | Sat |
| **TAN_007_Met** | Kahunda Met. Station | -2.417 | 32.533 | Active | Full Met | AWS | Sat |
| **TAN_008_Met** | Buhemba met. Station | -1.759 | 34.064 | Active | Full Met | AWS | Sat |
| **TAN_009_Met** | Kuruya met. Station | -1.489 | 33.986 | Active | Full Met | AWS | Sat |
| **TAN_010_Met** | Mugumu met. Station | -1.846 | 34.681 | Active | Full Met | AWS | Sat |
| **TAN_011_Met** | Nyabusara met. Station | -1.527 | 34.583 | Active | Full Met | AWS | Sat |
| **TAN_012_Met** | Rulenge Met. Station | -2.717 | 30.633 | Active | Full Met | AWS | Sat |
| **TAN_013_Met** | Ngudu Met. Station | -2.946 | 33.354 | Active | Full Met | AWS | Sat |
| **TAN_014_Met** | Bukoba | -1.333 | 31.817 | Active | Full Met | AWS | Sat |
| **TAN_015_Met** | Musoma | -1.500 | 33.800 | Active | Full Met | AWS | Sat |
| **TAN_016_Met** | Mwanza | -2.442 | 32.925 | Active | Full Met | AWS | Sat |
| **TAN_017_Met** | Shinyanga | -3.650 | 33.417 | Active | Full Met | AWS | Sat |
| **TAN_018_Met** | Biharamulo | -2.633 | 31.317 | Inactive | Full Met | AWS | Sat |

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| **TAN_019_Met** | Kayanga Met. Station | -1.533 | 31.167 | Inactive | Full Met | AWS | Sat |
| **TAN_020_Met** | Kishanda met. Station | -1.733 | 31.583 | Inactive | Full Met | AWS | Sat |
| **TAN_021_Met** | Kyakakera Met. Station | -1.300 | 31.450 | Inactive | Full Met | AWS | Sat |
| **TAN_022_Met** | Ngara | -2.460 | 30.670 | Inactive | Full Met | AWS | Sat |
| **TAN_023_Met** | Busweta P/School | -1.267 | 34.633 | Active | Rainfall | ARG | Sat |
| **TAN_024_Met** | Bwai P/school | -2.367 | 33.917 | Active | Rainfall | ARG | Sat |
| **TAN_025_Met** | Kikubiji P/School | -3.350 | 33.083 | Active | Rainfall | ARG | Sat |
| **TAN_026_Met** | Mugumu P/School | -2.450 | 35.200 | Active | Rainfall | ARG | Sat |
| **TAN_027_Met** | Kharumwa P/School | -3.383 | 32.633 | Inactive | Rainfall | ARG | Sat |
| **UGA_001_Met** | Mbale | 1.083 | 34.183 | Active | Full Met | AWS | Sat |
| **UGA_002_Met** | Gulu Met Station | 2.783 | 32.283 | Active | Full Met | AWS | Sat |
| **UGA_003_Met** | Lira | 2.250 | 32.900 | Active | Full Met | AWS | Sat |
| **UGA_004_Met** | Moyo | 3.617 | 31.733 | Active | Full Met | AWS | Sat |
| **UGA_005_Met** | Nakasongola | 1.378 | 32.456 | Active | Full Met | AWS | Sat |
| **UGA_006_Met** | Kasese | 0.660 | 30.360 | Active | Full Met | AWS | Sat |
| **UGA_007_Met** | Mbarara | -0.200 | 30.650 | Active | Full Met | AWS | Sat |
| **UGA_008_Met** | Masaka | -0.330 | 31.750 | Active | Full Met | AWS | Sat |
| **UGA_009_Met** | Bukasa | -0.411 | 32.526 | Active | Full Met | AWS | Sat |
| **UGA_010_Met** | Lolui | -0.129 | 33.669 | Active | Full Met | AWS | Sat |
| **UGA_011_Met** | Kome | -0.080 | 32.733 | Active | Full Met | AWS | Sat |
| **UGA_012_Met** | Bushenyi District Headquarters | -0.810 | 29.920 | Active | Full Met | AWS | Sat |
| **UGA_013_Met** | Bundibugyo Headquarters | 0.710 | 30.065 | Active | Full Met | AWS | Sat |
| **UGA_014_Met** | Bugiri Hospital | 0.573 | 33.743 | Active | Rainfall | ARG | Sat |
| **UGA_015_Met** | Namayingo Health Centre | 0.343 | 33.876 | Active | Rainfall | ARG | Sat |
| **UGA_016_Met** | Kafu (Masindi) | 1.543 | 32.042 | Active | Rainfall | ARG | Sat |
| **UGA_017_Met** | Moroto | 2.550 | 34.483 | | Full Met | AWS | Sat |
| **UGA_018_Met** | Kasese Met Station | 0.183 | 30.100 | Active | Full Met | AWS | Sat |
| **UGA_019_Met** | Mbarara Met Station | -0.600 | 30.683 | Active | Full Met | AWS | Sat |
| **UGA_020_Met** | Mubende 2nd Order Station | 0.583 | 31.367 | Active | Full Met | AWS | Sat |
| **UGA_021_Met** | Kampala Sewerage Works | 0.317 | 32.617 | Active | Full Met | AWS | Sat |
| **UGA_022_Met** | Mpanga Forest statio | 0.217 | 32.300 | Active | Full Met | AWS | Sat |
| **UGA_023_Met** | Namulonge Res Station | 0.533 | 32.617 | Active | Full Met | AWS | Sat |
| **UGA_024_Met** | Entebbe Intl Airport | 0.050 | 32.450 | Active | Full Met | AWS | Sat |
| **UGA_025_Met** | Jinja Met. Station | 0.450 | 33.183 | Active | Full Met | AWS | Sat |
| **UGA_026_Met** | Tororo Met.Station | 0.683 | 34.167 | Active | Full Met | AWS | Sat |
| **UGA_027_Met** | Butiaba HM | 1.817 | 31.350 | Active | Full Met | AWS | Sat |
| **UGA_028_Met** | Hoima | 1.433 | 31.367 | Active | Full Met | AWS | Sat |
| **UGA_029_Met** | Masindi Met Station | 1.683 | 31.717 | Active | Full Met | AWS | Sat |
| **UGA_030_Met** | Soroti Met Station | 1.717 | 33.617 | Active | Full Met | AWS | Sat |
| **UGA_031_Met** | Kabale Met Station | -1.250 | 29.983 | Active | Full Met | AWS | Sat |
| **UGA_032_Met** | Arua Met Station | 3.050 | 30.917 | Active | Full Met | AWS | Sat |
| **UGA_033_Met** | Kitgum Centre VT | 3.300 | 32.883 | Active | Full Met | AWS | Sat |

| Regional ID | Name | Lat | Long | Status | Parameters | Eq | Tel |
|---|---|---|---|---|---|---|---|
| UGA_034_Met | Yumbe Hospital (Aringa) | 3.467 | 31.250 | | Rainfall | ARG | Sat |
| UGA_035_Met | Karenga | 3.483 | 33.717 | | Rainfall | ARG | Sat |
| UGA_036_Met | Kotido | 3.017 | 34.100 | Active | Rainfall | ARG | Sat |
| UGA_037_Met | Loyoro [County Dodoth] | 3.367 | 34.217 | | Rainfall | ARG | Sat |
| UGA_038_Met | Wangkwar Camp | 2.433 | 31.783 | | Rainfall | ARG | Sat |
| UGA_039_Met | Wadelai WDD | 2.733 | 31.400 | Active | Rainfall | ARG | Sat |
| UGA_040_Met | Jaber Verona Fathers | 2.200 | 32.350 | | Rainfall | ARG | Sat |
| UGA_041_Met | Morulem | 2.617 | 33.767 | Active | Rainfall | ARG | Sat |
| UGA_042_Met | Nakapiripirit | 2.233 | 34.650 | | Rainfall | ARG | Sat |
| UGA_043_Met | Kachung Port KUR | 1.900 | 32.967 | | Full Met | AWS | Sat |
| UGA_044_Met | Kakoge Gombolola | 1.067 | 32.467 | Active | Rainfall | ARG | Sat |
| UGA_045_Met | Ngoma | 1.183 | 32.017 | Active | Rainfall | ARG | Sat |
| UGA_046_Met | Kiige WDD | 1.183 | 33.033 | Active | Full Met | AWS | Sat |
| UGA_047_Met | Labori Irrigation | 1.467 | 33.267 | | Full Met | AWS | Sat |
| UGA_048_Met | Namalu W.D.D. | 1.817 | 34.617 | Active | Rainfall | ARG | Sat |
| UGA_049_Met | Greek River Police Post | 1.417 | 34.717 | | Rainfall | ARG | Sat |
| UGA_050_Met | Buginyanya Coffee Res | 1.283 | 34.367 | Active | Rainfall | ARG | Sat |
| UGA_051_Met | Nariam Tractor Hire Unit | 1.967 | 34.133 | | Rainfall | ARG | Sat |
| UGA_052_Met | Kagadi Gombololo | 0.933 | 30.817 | | Rainfall | ARG | Sat |
| UGA_053_Met | Matiri | 0.533 | 30.767 | Active | Rainfall | ARG | Sat |
| UGA_054_Met | Ntusi | 0.050 | 31.217 | Active | Rainfall | ARG | Sat |
| UGA_055_Met | Madu | 0.217 | 31.667 | | Rainfall | ARG | Sat |
| UGA_057_Met | Namukooge | 0.917 | 33.433 | Active | Rainfall | ARG | Sat |
| UGA_058_Met | Ikulwe Farm Institute | 0.433 | 33.483 | Active | Rainfall | ARG | Sat |
| UGA_059_Met | Rwenshama Police Post | -0.383 | 29.800 | | Full Met | AWS | Sat |
| UGA_060_Met | Uganda Institute of Ecology - Kasese | -0.183 | 29.900 | Active | Full Met | AWS | Sat |
| UGA_061_Met | Bushenyi Agromet Station | -0.567 | 30.167 | Active | Rainfall | ARG | Sat |
| UGA_062_Met | Lyantonde Dispensary | -0.383 | 31.150 | Active | Rainfall | ARG | Sat |
| UGA_063_Met | Kibanda WDD | -0.867 | 31.367 | Active | Rainfall | ARG | Sat |
| UGA_064_Met | Nkozi Exp Farm | -0.017 | 32.017 | | Rainfall | ARG | Sat |
| UGA_065_Met | Rubale | -1.017 | 30.167 | | Rainfall | ARG | Sat |
| UGA_066_Met | Rwomuhororo - Mbarara | -0.150 | 30.133 | | Rainfall | ARG | Sat |

# Appendix E: Water Quality Attributes for Proposed Regional Stations

**Burundi**

| Regional ID | Name/Location of Station | Parameters | Equipment | Sampling Frequency |
|---|---|---|---|---|
| BUR_001_Hyd | Ruvubu at Muyinga | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment (GLC) | Quarterly |

**DRC**

| Regional ID | Name/Location of Station | Parameters | Equipment | Sampling Frequency |
|---|---|---|---|---|
| DRC_001_Hyd | Semliki at Ishango | Basic Parameters+ Advancedl Parameters | Basic Equipment + Advanced Equipment ( AAS, GLC) | Quarterly |

**Ethiopia**

| Regional ID | Name/Location of Station | Parameters | Equipment | Sampling Frequency |
|---|---|---|---|---|
| ETH_002_Hyd | Baro at Ithang | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment (AAS & GLC) | Quarterly |
| ETH_003_Hyd | Lake Tana at Bahir Dar | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment (AAS &GLC) | Quarterly |
| ETH_008_Hyd | Angareb Nr. Abdi Rafi | Basic Parameters+Advanced Parameters | Basic Equipment + Advanced Equipment (AAS &GLC) | Quarterly |
| ETH_009_Hyd | Abay Nr. Bure | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment (AAS &GLC) | Quarterly |

**Kenya**

| Regional ID | Name/Location of Station | Parameters | Equipment | Sampling Frequency |
|---|---|---|---|---|
| KEN_001_Hyd | Nzoia at Ruambwa | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment (GLC) | Quarterly |
| KEN_002_Hyd | Yala at Kadenge | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment (GLC) | Quarterly |
| KEN_003_Hyd | NYANDO at Ahero Bridge | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment (GLC) | Quarterly |

| | | | | |
|---|---|---|---|---|
| KEN_004_Hyd | Sondu Miriu at Nyakwere | Basic Parameters+Advanced Parameters | Basic Equipment + Advanced Equipment (GLC) | Quarterly |
| KEN_005_Hyd | Gucha Migori at Wathonger | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment (GLC) | Quarterly |
| KEN_006_Hyd | Mara | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment (GLC) | Quarterly |

**Rwanda**

| **Regional ID** | **Name/Location of Station** | **Parameters** | **Equipment** | **Sampling Frequency** |
|---|---|---|---|---|
| RWA_001_Hyd | Gakindo (Lac Rweru) | Basic Parameters + Advanced Parameters | Basic Equipment + Advanced Equipment (GLC) | Quarterly |
| RWA_002_Hyd | Akanyaru at Gihinga | Basic Parameters + Advanced Parameters | Basic Equipment + Advanced Equipment (GLC) | Quarterly |
| RWA_003_Hyd | Kagitumba (Muvumba) | Basic Parameters + Advanced Parameters | Basic Equipment + Advanced Equipment (GLC) | Quarterly |
| RWA_005_Hyd | Akagera at Rusumo | Basic Parameters + Advanced Parameters | Basic Equipment + Advanced Equipment (GLC) | Quarterly |
| RWA_006_Hyd | SHELL (Lac Cyohoha S) | Basic Parameters + Advanced Parameters | Basic Equipment + Advanced Equipment (GLC) | Quarterly |
| RWA_007_Hyd | New Proposed Station for inflows to Rusumo | Basic Parameters + Advanced Parameters | Basic Equipment + Advanced Equipment (GLC) | Quarterly |

**South Sudan**

| **Regional ID** | **Name/Location of Station** | **Parameters** | **Equipment** | **Sampling Frequency** |
|---|---|---|---|---|
| SSD_001_Hyd | Akobo at mouth | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment (GLC+AAS) | Quarterly |
| SSD_006_Hyd | Nasir | Basic Parameters+ Advanced Parameters | Basic Equipment +Advanced Equipment(GLC+AAS) | Quarterly |
| SSD_008_Hyd | Renk | Basic Parameters+ Advanced Parameters | Basic Equipment +Advanced Equipment(GLC+AAS) | Quarterly |
| SSD_009_Hyd | River Asua at Mouth | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment (GLC+AAS) | Quarterly |

| | | | | |
|---|---|---|---|---|
| SSD_012_Hyd | Bentiu | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment(HPLC,GC-MS)+ | Monthly |

**Sudan**

| Regional ID | Name/Location of Station | Parameters | Equipment | Sampling Frequency |
|---|---|---|---|---|
| SUD_001_Hyd | Blue Nile at Eldeium | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment (AAS & GLC) | Quarterly |
| SUD_004_Hyd | Blue Nile at Khartoum | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment (AAS & GLC) | Quarterly |
| SUD_007_Hyd | Atbara at Kilo 3 before confluence with Blue Nile | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment (AAS & GLC) | Quarterly |
| SUD_008_Hyd | Main Nile at Tamanyat downstream of Confluence of Blue and White Nile | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment (AAS & GLC) | Quarterly |
| SUD_009_Hyd | Main Nile at Hassanab before confluence with Atbara | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment (AAS & GLC) | Quarterly |
| SUD_010_Hyd | Main Nile at Dongola before entering Egypt | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment (AAS & GLC) | Quarterly |
| SUD_011_Hyd | Al Asira | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment (AAS & GLC) | Quarterly |
| SUD_012_Hyd | Hamdait | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment (AAS & GLC) | Quarterly |

**Tanzania**

| Regional ID | Name/Location of Station | Parameters | Equipment | Sampling Frequency |
|---|---|---|---|---|
| TAN_001_Hyd | Mara river at Mara Mine | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment (AAS & GLC) | Quarterly |
| TAN_002_Hyd | Gurumeti river at M/Bridge | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment (GLC) | Quarterly |
| TAN_003_Hyd | Mbalageti | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment (GLC) | Quarterly |

| | | | | |
|---|---|---|---|---|
| TAN_004_Hyd | Duma river at Sayaka | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment (GLC) | Quarterly |
| TAN_005_Hyd | Kagera at Kyaka Ferry | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment (GLC) | Quarterly |
| TAN_006_Hyd | Ruvuvu River at Mumwendo | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment (GLC) | Quarterly |
| TAN_007_Hyd | Simiyu river @ Lumeji | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment (GLC) | Quarterly |
| TAN_008_Hyd | Kogatende Ranger Post | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment (GLC) | Quarterly |

**Uganda**

| Regional ID | Name/Location of Station | Parameters | Equipment | Sampling Frequency |
|---|---|---|---|---|
| UGA_001_Hyd | L. Victoria at Jinja Pier | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment (GLC) | Quarterly |
| UGA_002_Hyd | R. Kagera at Masangano | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment (GLC) | Quarterly |
| UGA_003_Hyd | R. Katonga at Kampala – Masaka | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment (AAS & GLC) | Quarterly |
| UGA_004_Hyd | R. Sio at Luhalali near Bunadet | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment (GLC) | Quarterly |
| UGA_005_Hyd | R. Bukora at Mutukula – Kyotera | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment (GLC) | Quarterly |
| UGA_006_Hyd | L. Kyoga at Bugondo Pier | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment (GLC) | Quarterly |
| UGA_008_Hyd | R. Malaba at Jinja - Tororo Road | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment (GLC) | Quarterly |
| UGA_011_Hyd | L. Edward at Katwe | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment (AAS & GLC) | Quarterly |
| UGA_012_Hyd | L. Albert at Butiaba | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment( (HPLC, GC-MS) | Monthly |

| | | | | |
|---|---|---|---|---|
| UGA_013_Hyd | R. Semliki at Bweramule | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment (AAS & GLC) | Quarterly |
| UGA_014_Hyd | R. Albert Nile at Laropi | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment(HPLC, GC-MS) | Monthly |
| UGA_015_Hyd | R. Albert Nile at Panyango | Basic Parameters+ Advanced Parameters | Basic Equipment + Advanced Equipment(HPLC, GC-MS) | Monthly |

# Appendix F: Water Quality Training Modules

| Training Theme | Training Elements | Training Method and Duration | Targeted Trainees |
|---|---|---|---|
| 1. WQ Sampling | a. Sampling goals: water quality assessment, permitting studies, waste load allocation studies, habitat studies.<br>b. Types of samples: grap, composite, time composite, integrated.<br>c. Method of sampling: manual, automatic, from bridges, from boats, depth, stream sampling.<br>d. Sampling containers: container materials, container caps, container structures, disposable containers, container washing, container wrapping.<br>e. Container preparation for analysis of: metals, nutrients, non organics, organics, microbiology.<br>f. Sampling volume and holding time<br>g. Sampling timing and frequency.<br>h. Sample preservation: preservation guidelines, addition of chemicals, pH control, freezing, refrigeration, alternative methods.<br>i. Chain of custody procedures: sample labels, sample seal, log book, records analysis request sheet, sample delivery form, sample received form, sample test assignment form, etc. | • 3 day formal training and practical demonstration | • Field technicians and field supervisor, WQ laboratory specialists |
| 2. Field observations and use of WQ testing kits and automatic WQ monitoring technology | a. Preparation for the field trip.<br>b. Field quality assurance.<br>c. Field quality control.<br>d. Prevention of sample contamination and losses.<br>e. Calibration and maintenance of field instruments.<br>f. Use of automatic samplers.<br>g. Measurement of field parameters such as temperature, pH, electrical conductivity, dissolved oxygen, turbidity via portable kits and on site sondes. | • 2-3 day practical demonstration. | • Field technicians and field supervisor, WQ laboratory specialists |
| **3.** General Laboratory Water Quality Testing and Analysis | a. Water quality testing parameters: physical, organics, inorganic anions, inorganic cations, gases, microbiology.<br>b. Instrumental methods for water quality analysis: atomic absorption spectrometry, inductively coupled and direct current plasma, flame photometry, ion chromatograph, gas-liquid chromatography, high pressure liquid chromatography, potentiometry with ion selective electrodes, spectrophotometry, FTIR, Conductometry, turbidimetry. | • 3 day formal classroom and practical demonstration | • WQ laboratory staff |

| Training Theme | Training Elements | Training Method and Duration | Targeted Trainees |
|---|---|---|---|
| | c. Techniques used for water quality analysis: biological oxygen demand (BOD), Chemical oxygen demand (COD), total oxygen demand (TOD), total organic carbon (TOC), Kjeldahl total nitrogen (TKN), microbiological investigation using most probable number and membrane filter methods, solvent and solid phase extraction of organic compounds, clean-up of organic extractants for chromatographic measurements, sample digestion, Titrimetry.<br>d. Instrumentation and equipment maintenance: troubleshooting, handling, and simple repair of instrumentation and equipment such as balances, flame photometers, sondes, AAS, HPLC, UV-VIS. | | |
| **4.** Quality Control and Quality Assurance | a. Laboratory quality policy<br>b. Equipments calibration: methods and schedules.<br>c. Control charts.<br>d. Types of internal quality control samples.<br>e. Daily interpretation of control charts.<br>f. Long term use of control chart data.<br>g. Results uncertainty.<br>h. Standard addition.<br>i. Analysis of blind samples.<br>j. Analysis of split samples.<br>k. Repeated (or duplicate) analysis.<br>l. Blank assessment.<br>m. Use of certified reference materials. | • 3 day practical training and demonstrations | • WQ laboratory staff |
| 5. Safety in water quality laboratories | a. Chemical inventory, storage and handling.<br>b. Material safety data sheets (MSDS).<br>c. Chemical spills and spill cleanup.<br>d. Hazardous waste disposal.<br>e. Fire types, safety and distinguishing.<br>f. Safety of electricity, water and gas lines and connections.<br>g. Proper handling and storage of compressed gas cylinders.<br>h. Emergency procedures.<br>i. First aid kit.<br>j. Handling of laboratory accidents.<br>k. Chemical hygiene responsibilities.<br>l. Safety showers and eye wash station.<br>m. Personal protective equipments. | • One day formal training and demonstrations | • WQ laboratory staff |
| 6. Laboratory Information Management System (LIMS) | a. Introduction to LIMS concept<br>b. Logging samples<br>c. Interface of laboratory instruments with LIMS.<br>d. Entering WQ results into LIMS or exported results directly from the laboratory instruments into the system. | • 3 day formal training and demonstrations | • WQ laboratory staff |

| Training Theme | Training Elements | Training Method and Duration | Targeted Trainees |
|---|---|---|---|
| | e. QA/QC and approval of WQ results<br>f. Reporting of WQ results and interface of LIMS with WQ database. | | |
| 7. Requirements for ISO -17025 Accreditation | a. Management requirements<br>• Laboratory organization and responsibilities.<br>• Quality system.<br>• Documents, records and reports control.<br>• Control of non-conforming testing and calibration.<br>• Corrective actions.<br>• Preventive actions.<br>• Internal audit.<br>• Management review.<br>b. Technical requirements<br>• Personnel training records.<br>• Standard operational procedures (SOP's).<br>• Method validation ( limit of detection - accuracy – trueness - precision – sensitivity – range – selectivity – linearity – ruggedness – speed – cost).<br>• Calibration and maintenance of equipments.<br>• Measurement traceability.<br>• Quality control/quality assurance plans.<br>• Participation in proficiency testing or intra laboratory comparison programs. | • One week workshop on theory and practical demonstration in an accredited Laboratory | • WQ laboratory staff |
| 8. Water Quality Modeling | a. Water quality modeling process<br>b. Model input parameters (Nutrients, DO, Sediment Loads, organics, other pollutants).<br>c. Model calibration<br>d. Model testing and validation | • 3 day formal training and demonstrations | • WQ specialists |

# Appendix G: Water Quality Laboratory Equipment Specifications

The following table provides the specifications of water quality laboratory equipment that could be procured for the national laboratories to support regional monitoring within the Nile Basin.

| Description of Goods | Technical Specification of Goods Required |
|---|---|
| **Ultraviolet Visible Spectroscopy (UV/VIS)** | **Must meet or exceed these specifications:** |

| **Specification** | |
|---|---|
| Wavelength range | 190-1100 nm |
| Spectral bandwidth | 1 nm |
| Wavelength display | 0.1 nm increments |
| Wavelength setting | 0.1 nm increments |
| Wavelength accuracy | 0.1 nm at peak 656.1 nm |
| Wavelength repeatability | 0.1 nm |
| Lamp interchange wavelength | Automatic interchange linked to wavelength |
| Photometric system | Double beam optics |
| Light source | 20-W halogen lamp and deuterium lamp built in light source, auto position adjustments |
| Detector | Silicon photodiode |
| Power requirements | AC 220,230, 240 V, 50/60 hz , |
| Environmental requirements | Temperature : 15- 35 degrees Celsius humidity:30%-80% |
| Output device | USB memory |
| PC compatibility | Provided with UV probe software. External control possible via USB. |

<table>
<tr><th>Description of Goods</th><th colspan="2">Technical Specification of Goods Required</th></tr>
<tr><td rowspan="11">Analytical Balance</td><td colspan="2">Must meet or exceed these specifications:</td></tr>
<tr><td>Specification</td><td></td></tr>
<tr><td>Weighing range. mg</td><td>0.1 mg- 220 g</td></tr>
<tr><td>Weighing plate. mm</td><td>80mm</td></tr>
<tr><td>Read- out[d]. mg</td><td>0.1 mg</td></tr>
<tr><td>Reproducibility. mg</td><td>0.1 mg</td></tr>
<tr><td>Linearity. mg</td><td>0.1 mg</td></tr>
<tr><td>Permissible temperature</td><td>5-35 degrees Celsius</td></tr>
<tr><td>Calibration</td><td>External calibration, included 200 g calibration weight</td></tr>
<tr><td>Display</td><td>Digital LCD with back light function</td></tr>
<tr><td>DC power and AC adapter</td><td>DC 9v, with AC 220v adapter, 60hz</td></tr>
<tr><td rowspan="12">Top-pan Balance</td><td colspan="2">Must meet or exceed these specifications:</td></tr>
<tr><td>Specification</td><td></td></tr>
<tr><td>Weighing range. mg</td><td>0.01-3200g</td></tr>
<tr><td>Weighing plate. mm</td><td>168x168 mm</td></tr>
<tr><td>Read- out[d]. mg</td><td>0.01 g</td></tr>
<tr><td>Reproducibility. mg</td><td>0.01g</td></tr>
<tr><td>Linearity. mg</td><td>0.01 g</td></tr>
<tr><td>Permissible temperature</td><td>5-35 degrees Celsius</td></tr>
<tr><td>Counting mode</td><td>Available counting and weighing mode</td></tr>
<tr><td>Calibration</td><td>External calibration included 2kg calibration weight</td></tr>
<tr><td>Display</td><td>Digital super size LCD with back light function</td></tr>
<tr><td>Power supply and cord plug</td><td>DC 12v, with AC 220v adapter, 60hz</td></tr>
<tr><td>Colorimeter</td><td colspan="2">Must meet or exceed these specifications:<br>A General purpose, color comparator for colorimetric WQ analysis complete with color discs for the following (aluminum, bromine, chlorine, chlorine dioxide, copper, hydrogen peroxide, iron, nitrate, nitrite, ozone, oxygen, ph value, ammonia, sodium hypochlorite and zinc). Also should have glass/plastic measuring cells, and reagents.</td></tr>
</table>

<table>
<tr><th>Description of Goods</th><th>Technical Specification of Goods Required</th></tr>
<tr><td>Dissolved Oxygen Meter</td><td>A hand held portable meter for measuring both dissolved oxygen and temperature. Measurements are fully temperature compensated over the range 0-40 deg c and expressed either as % or mg/l.<br>Must meet or exceed these specifications:
<table>
<tr><th>Specification</th><th></th></tr>
<tr><td>Range</td><td>0-200%<br>0-19mg/l</td></tr>
<tr><td>Resolution</td><td>1%</td></tr>
<tr><td>Accuracy</td><td>-2% or +2 %</td></tr>
<tr><td>Auto temperature compensation</td><td>0-40 deg c</td></tr>
<tr><td>Battery</td><td>1x 9v</td></tr>
<tr><td>displays</td><td>LCD 10.4mm</td></tr>
<tr><td></td><td></td></tr>
</table></td></tr>
<tr><td>Autoclave</td><td>Shall have following general features:
<ul>
<li>Easy to operate</li>
<li>Easy to move around</li>
<li>Easy to Load</li>
<li>Easy to Clean</li>
<li>Easy to service</li>
<li>Shall be supplied with accessories and Manuals</li>
</ul>
Must meet or exceed these specifications:
<table>
<tr><th>Specification</th><th></th></tr>
<tr><td>Temperature range</td><td>Ambient to 140 degrees Centigrade</td></tr>
<tr><td>Pressure range</td><td>2.25kg/square cm</td></tr>
<tr><td>Steam Supply pressure</td><td>For Steam Models, 2.8-4.6 kg/square cm</td></tr>
<tr><td>Electrical Power</td><td>230V/50-60 Hz</td></tr>
</table></td></tr>
<tr><td>Fluoride Meter</td><td>NB: No specifications for a Fluoride meter are necessary. Fluoride can be determined using the Ion analyzer below, if a Fluoride Ion Selective Electrode is procured.</td></tr>
</table>

<table>
<tr><th>Description of Goods</th><th>Technical Specification of Goods Required</th></tr>
<tr><td>Ion Analyzer</td><td>Can be used with the following Ion Selective electrodes: ammonia, barium, bromide, cadmium, calcium, chloride, copper, cyanide, fluoride, iodide, lead, nitrate, silver, sodium and many more.<br><br>Must meet or exceed these specifications:
<table>
<tr><th>Specification</th><th></th></tr>
<tr><td>pH range</td><td>0-14</td></tr>
<tr><td>Accuracy</td><td>+_0.1</td></tr>
<tr><td>Manual Calibration</td><td>Yes</td></tr>
<tr><td>MV Auto ranges</td><td>+_400mv or +_200mv</td></tr>
<tr><td>MV Resolution or Accuracy</td><td>0.1 mv or 1mv</td></tr>
<tr><td>Display</td><td>12mm LCD</td></tr>
<tr><td>Power</td><td>9v Battery or AC Adaptor</td></tr>
</table>
</td></tr>
<tr><td>Flame Photometer</td><td>To be used for the rapid and accurate determination of Sodium, Potassium, Lithium, Calcium and Barium in solution.<br>Must meet or exceed these specifications:
<table>
<tr><th>Specification</th><th></th></tr>
<tr><td>Readout</td><td>0-100</td></tr>
<tr><td>Linearity</td><td>Better than 2% of full scale deflection</td></tr>
<tr><td>Specificity</td><td>Less than 0.5% from concentration of interferences for Na, K, Li, Ba, and Ca</td></tr>
<tr><td>Sample size</td><td>2-6ml/min</td></tr>
<tr><td>Power</td><td>230/240; 50-60Hz</td></tr>
<tr><td>Fuel</td><td>Propane, Butane or natural gas</td></tr>
</table>
</td></tr>
</table>

| Description of Goods | Technical Specification of Goods Required |
|---|---|

**Titration Equipment (2 per Lab)**

**Shall comprise of :**

- One or more dispensing stations, single or double units
- Appropriate dispensing Pumps
- Program terminal
- Intake and discharge tubes
- Control unit (optional)

Can be operated electronically or manually

**Must meet or exceed these specifications:**

| **Specification** | |
|---|---|
| Display on dispensing Station | 5 digit alpha numeric display |
| Housing | Shall be of acid, alkali and solvent resistant steel plate |
| Volume range | Up to 300ml with one piston stroke |

**Oven**

**Must meet or exceed these specifications:**

| **Specification** | |
|---|---|
| Temperature range | 50-250 degrees Celsius |
| Temperature fluctuation at 160 degrees Celsius | +1 or -1 degrees Celsius |
| Temperature variation | 5 degrees Celsius |
| Heating up time to 160 degrees Celsius | 75 min |
| Recovery time after door has been opened for 1 min | 5 min |
| Ventilation rate, liters/hour | 3000 |
| No. of pairs of shelf runners | 3 |
| Heater rating, W | 1000 |

| Description of Goods | Technical Specification of Goods Required | |
|---|---|---|
| **Centrifuge** | **Must meet or exceed these specifications:** | |
| | **Specification** | |
| | **RPM & max. RCF** | Max. 5,500 rpm 1,775xg |
| | **Max capacity** | 6x0.5-/1.5-/2 ml tubes, 2x0.2ml PCR 8-tube strip or 16x 0.2ml PCR 8 tubes |
| | **Rotor** | 16 hole strip rotor for 0.2 ml PCR 8-tube strip or individual tubes |
| | **Adapter** | Included 6x 0.2-/0.5-ml tube adapter |
| | **Material** | PC-Lid, |
| | **Power consumption** | 8watts |
| | **Power supply and cord/plug** | 1 phase, AC 100-240v, 50/60 hz, with cord/plug |
| **Incubator** | **Must meet or exceed these specifications:** | |
| | **Specification** | |
| | No of shelves | 2 |
| | Capacity, liters | 107 |
| | Heater, W | 375 |
| | Voltage range, 50 to 60 hz | 200-250V |

| Description of Goods | Technical Specification of Goods Required | |
|---|---|---|
| **Gas Liquid Chromatograph<br><br>(GLC)** | **Must meet or exceed these specifications:** | |
| | **Column oven** | |
| | Temperature range | (ambient +10) – 400 degrees Celsius |
| | Oven capacity | 15.8L |
| | Temperature accuracy | Set value (k)+-1% |
| | Temperature deviation | 2 degrees Celsius max |
| | Linear heating range | 30/min up to 150 degrees Celsius |
| | Cooling rate | 300-50 degrees Celsius in 6 min max |
| | Columns accepted | Capillary columns: 2 |
| | Sample injection unit | |
| | Temperature range | Up to 400 degrees Celsius |
| | Heating settings | 1 degrees Celsius steps |
| | No. of units installed simultaneously | Up to 3 units |
| | **Carrier gas flow controller** | |
| | Flow rate setting range | 0-100ml/min |
| | Programmable steps | 7 |
| | Pressure setting range | 0-970kpa/min |
| | Flow rate setting range | 0-1200ml/min |
| | **Detectors** | |
| | Temperature range | 400 degrees Celsius max |
| | Temperature setting | 1 degrees Celsius steps |
| | No. of units installed simultaneously | Up to 4 units (restricted depending on detector type) |
| | Detector type | FID, TCD, ECD, FPD, FTD for capillary/packed |
| | Dimensions, weight, power, requirements (GC main unit) | |
| | Power requirements | AC100v/120v 230v |

| Description of Goods | Technical Specification of Goods Required |
|---|---|
| **Atomic Absorption Spectrophotometers (AAS)** | **Must meet or exceed these specifications:** |

| **Specification** | |
|---|---|
| **Optics** | |
| Wavelength range | 185.0 – 900.0 nm |
| Monochromator | Aberration corrected |
| Detector | Photomultiplier tube |
| Optics | Optical Double beam |
| Number of HC Lamps | 6 Lamp turret, 2 lamps simultaneously |
| **Data Processing** | |
| Measurement Mode | Flame continuous method |
| Repeat Analysis | Up to 20 repetitions, Mean value, SD and coefficient of variation displayed |
| Report generation | Summary report |
| Digital recording | Management by log in |
| **Flame** | |
| Type | Air cooled pre-mix type |
| Burner Head | Titanium type |
| Angle adjustment | 0 – 90 degrees |
| Type | Air- Acetylene; Nitrous oxide Acetylene |
| **Others** | |
| Power | 230/240, 50-60 hz |
| Safety measures | Automatic gas leak check, gas pressure monitor, drain tank level monitor, automatic flame extinction |
| Computer & Printer | Accessories that can be procured separately |
| Accessories | Auto sampler, Hollow Cathode Lamps, Atomizer systems (optional); Gas cylinders of air, acetylene and nitrous oxide and Operation Manuals |

<table>
<tr><th>Description of Goods</th><th>Technical Specification of Goods Required</th></tr>
<tr><td>Inductively Coupled Plasma-Mass Spectrometry (ICP-MS)</td><td>Inductively Coupled Plasma Mass Spectrometry or ICP-MS is an analytical technique used for elemental determinations. ICP-MS combines a high-temperature ICP (Inductively Coupled Plasma) source with a mass spectrometer. The ICP source converts the atoms of the elements in the sample to ions. These ions are then separated and detected by the mass spectrometer.<br>An ICP-MS must consist of the following components: It must meet or exceed these specifications:
<table>
<tr><th>Specification</th><th></th></tr>
<tr><td>Sample introduction system</td><td>consisting of the peristaltic pump, nebulizer, and spray chamber that introduces sample to the instrument,</td></tr>
<tr><td>ICP torch</td><td>generates the plasma which serves as the ion source of the ICP-MS, converting the atoms to be analyzed to ions,</td></tr>
<tr><td>Interface</td><td>the sample ions are extracted from the central plasma channel and separated from the bulk ions by cooled conical aperture plates in the vacuum interface</td></tr>
<tr><td>Vacuum system</td><td>provides high vacuum for ion optics, quadrupole and detector,</td></tr>
<tr><td>Quadrupole</td><td>the high frequency quadrupole acts as a mass filter to sort ions by their mass-to-charge ratio (m/e).</td></tr>
<tr><td>Detector</td><td>the ions are either detected through direct current measurements on the ion collector or the ions generate secondary electrons that are propagated in the multiplier.</td></tr>
<tr><td>Data handling and system controller</td><td>Shall have a Computer and Printer</td></tr>
<tr><td>Sensitivity/Detection Limit</td><td>Parts per Billion (ppb, ug/l)</td></tr>
<tr><td>Accessories-</td><td>Must also be supplied Complete with all accessories including and Operation Manuals. Argon Gas Cylinder(optional)</td></tr>
</table></td></tr>
<tr><td>Assorted Glassware and other items</td><td>The List of Assorted Glassware and other items is attached at the end of this Tender document as Appendix 1.<br>These items are a common feature in all operational laboratories. Many Laboratories within the Nile Basin countries already use these items; but this list would be useful for South Sudan as they establish their Laboratory facilities. These items are many and it would be impractical to have specifications for each of the items. The individual Laboratories can use their discretion on the items they need and their quantities as long as they don’t exceed the budgeted lump sum amount.</td></tr>
</table>

| Description of Goods | Technical Specification of Goods Required |
|---|---|
| **Assorted General Laboratory Chemicals** | The List for Assorted General Laboratory Chemicals is attached as **Appendix 2**<br>This is a list of common chemicals that may be needed for use in a Water Quality Testing Laboratory. The Reagents or chemicals may be purchased either as Analar Grade (AR) or General Purpose Reagent (GPR) depending on the intended use. The final list of chemicals to be procured will be decided by the individual Laboratory using this list as a guide. Many of the operational laboratories in the Nile Basin countries have most of these chemicals in stock, but South Sudan will find this list useful. The list however is not exhaustive. |

# Appendix H: Summary of WMO and Other Guideline Publications

The following publications provide standard guidelines and practices with regards to the development, training, management, and operation of hydro-meteorological networks, programs, and services. A brief summary of each publication follows along with an online link when available. These documents are also being provided as supplemental material to the Nile Basin regional hydro-meteorological network design.

## WMO Publications

**WMO-No. 8 – Guide to Meteorological Instruments and Methods of Observation**

This publication provides guidance on good practices for meteorological measurements and observations that may support a variety of purposes. Recommendations and standards with regards to quality assurance, management, and maintenance of instruments and measurements are covered in detail.

http://www.wmo.int/pages/prog/gcos/documents/gruanmanuals/CIMO/CIMO_Guide-7th_Edition-2008.pdf

**WMO-No. 49 – Technical Regulations**

*Volume I: General Meteorological Standards and Recommended Practices*

This volume contains the regulations of the World Weather Watch; climatology; meteorological services for marine activities, agriculture and environmental pollution; meteorological bibliography and publications; education and training; units and procedures used in international meteorological research programs and during special observational periods.

http://library.wmo.int/pmb_ged/wmo_49-v1-2012_en.pdf

*Volume III: Hydrology*

This volume contains definitions of technical terms, a classification of hydrological observing stations, and guidance on the establishment of networks of these stations, their identification, observing programs, equipment and methods of observation. It also contains a chapter on meteorological services for hydrology.

http://library.wmo.int/pmb_ged/wmo_49-v3-2006_en.pdf

**WMO-No. 134 – Guide to Agricultural Meteorological Practices**

This publication provides guidance for agricultural meteorology which is concerned with the meteorological, hydrological, pedological, and biological factors that affect agricultural production and its interaction with the environment.

http://www.wmo.int/pages/prog/wcp/agm/gamp/documents/WMO_No134_en.pdf

**WMO-No. 168 – Guide to Hydrological Practices**

*Volume I: Hydrology- From Measurement to Hydrological Information*

This volume provides guidance with regards to networks, instruments, methods of observation and primary data processing and storage. Specifics include chapters on instruments and methods of observation; rain gauge and remote sensing observations; evaporation, evapotranspiration, and soil moisture; surface water quantity and sediment measurement; groundwater; water quality; safety considerations in hydrometry; and data processing, quality control, storage, and dissemination.

http://www.hydrology.nl/images/docs/hwrp/WMO_Guide_168_Vol_I_en.pdf

*Volume II: Management of Water Resources and Application of Hydrological Practices*

This volume provides guidance with regards to the application of topics covered in Volume 1 to provide hydrologic forecasting and the planning, management, and design of various water projects.

http://www.hydrology.nl/images/docs/hwrp/WMO_Guide_168_Vol_II_en.pdf

**WMO-No. 258 – Guidelines for the Education and Training of Personnel in Meteorology and Operational Hydrology**

This completely revised edition consists of two separate Volumes - Volume I: Meteorology and Volume II: Hydrology. It covers two major items: the new classification of personnel and revised curricula for initial qualifications and early specialization in meteorology and hydrology.

*Volume I (Meteorology) replaced by WMO-No. 1083 on 1 December 2013*

*Volume II (Hydrology)*

**WMO-No. 1003 – Guidelines on the Role, Operation and Management of National Hydrological Services**

This publication provides guidance to senior managers of National Hydrological Services (NHS), on the key issues they may face. This includes an overview of the responsibilities and functions of a NHSs as well as aspects of management, such as strategic planning, human resources, financial management, marketing, asset management, process and quality management, and relationships with other institutions.

http://www.wmo.int/pages/prog/hwrp/documents/WMO%201003.pdf

**WMO-No. 1044 – Manual on Stream Gauging**

*Volume I: Fieldwork*

This volume focuses on the selection of gauging station sites, measurement of stage, and measurement of discharge.

http://www.wmo.int/pages/prog/hwrp/publications/stream_gauging/1044_Vol_I_en.pdf

*Volume II: Computation of Discharge*

This volume focuses on the computation of the stage-discharge relationship and computation of a daily mean discharge.

http://www.wmo.int/pages/prog/hwrp/publications/stream_gauging/1044_Vol_II_en.pdf

**WMO-No. 1083 – Manual on the Implementation of Education and Training Standards in Meteorology and Hydrology, Volume I – Meteorology**

*This document replaced WMO-NO.258 Volume-I on 1 December 2013.*

The present publication is intended to facilitate a common understanding of the basic qualifications being required of individuals who are to be recognized either as Meteorologists or as Meteorological

Technicians, as defined by World Meteorological Organization (WMO), while also assisting National Meteorological and Hydrological Services (NMHSs) in establishing their respective personnel classification systems and training programs to satisfactorily meet international standards.

http://www.wmo.int/pages/prog/dra/etrp/documents/1083_Manual_on_ETS_en_rev.pdf

**WMO-No. 1210 Guidelines on Climate Data Rescue**

Technical document intended to provide guidance in the form of best practices of data rescue that can be used by National Meteorological Services.

http://www.wmo.int/pages/prog/wcp/wcdmp/documents/WCDMP-55.pdf

**WMO-No. 1146 Guidelines for Hydrological Data Rescue**

Guidelines established by the WMO that aim to: highlight the importance of hydrological data resuce; provide an overview of hydorological data rescue issues; identify data rescue issues that are specific to hydrological data; provide sufficient information to allow data managers to decide how to go about data rescue.

http://www.wmo.int/pages/prog/hwrp/publications/guidelines_hydrological_DR/wmo_1146_en.pdf

**WMO Laboratory Intercomparison of Rainfall Intensity Guages**

The main objective ofhte intercomparison was to test the performance of catchment type rainfall intensity gauges of different measuring principles under documented conditions. Other objectivies were to define a standardized procedure for laboratory calibration of catchment type rain gauges, and to provide information relevant to improving the homogeneity of rainfall time series with special consideration given to high rainfall intensities. Finally, a comment on the need to proceed with a field intercomparison of catchment type of rainfall intensity gauges was required as well as to identify a recommend the most suitable method of equipment for reference purposes within the field intercomparison of catching and non-catching types of gauges.

http://www.wmo.int/pages/prog/www/IMOP/reports/2003-2007/RI-IC_Final_Report.pdf

## Other Publications

**Environment Canada – Measuring Discharge with Acoustic Doppler Current Profilers from a Moving Boat**

The purpose of this report is to present the procedures that should be followed when using an ADCP from a moving boat to make surface-water discharge measurements. The procedures for pre-deployment preparation, field data collection, and processing of collected data are discussed. A detailed description of how an ADCP measures velocity and computes discharge and additional details on selected topics are presented in appendices.

*USGS similar publication (http://pubs.usgs.gov/tm/3a22/pdf/tm3a22.pdf)*

**Aquatic Informatics – 5 Best Practices for Building Better Stage-Discharge Rating Curves (Whitepaper)**

Whitepaper discusses the 5 best practices in developing a rating curve. These are broken down as (1) developing a plan through an effective monitoring program; (2) understanding the science behind the hydraulics and statistical analysis; (3) systematic analysis of data; (4) management of variance related to changes in channel dynamics; and (5) qualifying the derived discharge results.

http://pages.aquaticinformatics.com/Whitepaper-Rating-Curves.html?source=Blog

**FAO – Installation, Operation and Maintenance of the Orpheus Automatic Water Level Recorders in the Nile Basin and Processing of Retrieved Data**

A manual of detailed instructions for the installation, operation, and maintenance of the "Orpheus" Pressure Transducer Automatic Water Level Recorder (AWLR) installed in the Nile Basin by the FAO Nile Basin Water Resources Project. Manufacturer of the Orpheus is OTT Hydrometrie, based in Germany, which has provided conventional and automatic hydrometric equipment in the basin for over 50 years.

http://www.fao.org/nr/water/faonile/products/Docs/Manuals/Installation_Operation_and_Maintenance_of_Orpheus_AWLR.pdf

**Canadian Council of Ministers of the Environment –**

1. **CCME Water Quality Index 1.0 User's Manual**

   User's manual that provides general introduction and explanation of data needed and the calculation of the CCME water quality index. This index can be used to reflect the overall ongoing condition of the water quality based on combination of three factors (scope, frequency, and amplitude).

   http://www.ccme.ca/files/Resources/calculators/WQI%20User%27s%20Manual%20%28en%29.pdf

2. **Application of CCME Procedures for Deriving Site-Specific Water Quality Guidelines for the CCME Water Quality Index**

   This paper presents the adaptation and implementation of an existing CCME-approved SS-WQGs derivation method called the background concentration (BC) procedure into a Site-Specific Water Quality Index (SS-WQI) calculator and tool. It discusses the application of the SS-WQI calculator to compute water quality indices for five pristine ambient water quality sites in Newfoundland and Labrador. The effects of using five different BC-based SS-WQGs (mean; median; mean ± one standard deviation; mean ± two standard deviations; 90th and $10^{th}$ percentile) are examined. The paper also discusses the challenges and benefits of using this methodology and provides recommendations for further testing.

   http://www.env.gov.nl.ca/env/waterres/quality/background/wqj_40_4_khan.pdf

# Appendix I: Data Rescue Status

As part of NBI's Nile Basin hydromet monitoring network design, additional information from riparian countries regarding data rescue efforts was requested. This information will facilitate planning efforts for establishing the regional database of historical records for existing stations in the regional network, which will complement the real-time monitoring data that will be generated by the network.

The following table provides a summary of responses to questions from respective countries. This is followed by the actual replies to questions as received by NBI.

| # | Question | Burundi | DRC | Kenya | South Sudan |
|---|---|---|---|---|---|
| 1 | Does a program exist for digitizing historical observations and records in a digital database ("data rescue")? | No | Yes | Yes | No |
| 2 | What procedures exist to assure and control the quality of the digitizing process? | None | Validation Process | Validation Process | None |
| 3 | Is there an on-going program to record current manual observations in a digital form? | Yes | No | Yes | Yes |
| 4 | What is the approximate percentage of all national meteorological data that are archived in a digital format? | 35-40% | < 30% | < 70% | 20-30% |
| 5 | What is the approximate percentage of all national hydrological data that are archived in a digital format? | 90% | 30% | 60% | 30% |
| 6 | Are these data regularly available in the respective ministries for query and retrieval in a database? | Yes | No | Yes | Yes |
| 7 | Please provide any additional detail regarding data digitization/rescue efforts that would be helpful in understanding current circumstances in your countries. | Support for hist. data digitizat-ion | conflict limiting data for past 20 years | limited manual readings; DB updates needed | Support needed |

## Burundi Responses:

1. Does a program exist for digitizing historical observations and records in a digital database ("data rescue")? No
2. What procedures exist to assure and control the quality of the digitizing process? No procedures
3. Is there an on-going program to record current manual observations in a digital form? Yes
4. What is the approximate percentage of all national meteorological data that are archived in a digital format? 35-40%
5. What is the approximate percentage of all national hydrological data that are archived in a digital format 90%
6. Are these data regularly available in the respective ministries for query and retrieval in a database? Yes

7. Please provide any additional detail regarding data digitization/rescue efforts that would be helpful in understanding current circumstances in your countries.
   We need a support for data rescue because there is a lot of historical data which is not yet entered in our database (it is only on paper).

## DRC Responses:

1. Does a program exist for digitizing historical observations and records in a digital database ("data rescue")? **YES**
2. What procedures exist to assure and control the quality of the digitizing process? **There is validation process within METTELSAT**
3. Is there an on-going program to record current manual observations in a digital form? **No program**
4. What is the approximate percentage of all national meteorological data that are archived in a digital format? **under 30%**
5. What is the approximate percentage of all national hydrological data that are archived in a digital format under 30%
6. Are these data regularly available in the respective ministries for query and retrieval in a database? **NO**
7. Please provide any additional detail regarding data digitization/rescue efforts that would be helpful in understanding current circumstances in your countries. **Our interested area was in conflict for longtime last 20 years.**

## Kenya Meteorological Service Responses:

1. Does a program exist for digitizing historical observations and records in a digital database ("data rescue")?**YES**
2. What procedures exist to assure and control the quality of the digitizing process? **USING THE CLIMSOFT SOFTWARE**
3. Is there an on-going program to record current manual observations in a digital form? **YES**
4. What is the approximate percentage of all national meteorological data that are archived in a digital format? **BELOW 70%**
5. What is the approximate percentage of all national hydrological data that are archived in a digital format **(????? WRMA TO PROVIDE)**
6. Are these data regularly available in the respective ministries for query and retrieval in a database? **YES**
7. Please provide any additional detail regarding data digitization/rescue efforts that would be helpful in understanding current circumstances in your countries. **CHALLEGES INCLUDE: LIMITED RESOURCES SUCH AS UNDER STAFFING, OUTDATED COMPUTER HARDWARE/EQUIPMENT, INEFFICIENT DATA ACQUISITION SYSTEM, NEED TO AUTOMATE DATABASE UPDATING, ETC**

## Kenya WRMA Responses:

1. Does a program exist for digitizing historical observations and records in a digital database ("data rescue")? – **YES:** Water Resources Management Authority (WRMA) is partnering with GiZ to digitize historical data at the sub basin offices. Also, WRMA has been routinely digitizing data from hard copy files
2. What procedures exist to assure and control the quality of the digitizing process? - Data is digitized at the sub regional offices, checked for errors and send to the regional office where the officer in charge of surface water the data is verified before entry into the regional database.

3. Is there an on-going program to record current manual observations in a digital form? – YES: data is collected by private gauge readers who send them to the sub regional offices on monthly basis where they are digitized before sending to the regional office
4. What is the approximate percentage of all national meteorological data that are archived in a digital format?
5. What is the approximate percentage of all national hydrological data that are archived in a digital format – 60%
6. Are these data regularly available in the respective ministries for query and retrieval in a database? – YES
7. Please provide any additional detail regarding data digitization/rescue efforts that would be helpful in understanding current circumstances in your countries. - Hydrological data in Kenya is currently managed by WRMA. Private gauge readers are engaged to take readings twice a day at the Regular Gauging Stations. The payment of Kshs. 1000 honoraria has not been regular; there is fear that the gauge readers may not be regularly taking the readings.

## South Sudan Responses:

1. Does a program exist for digitizing historical observations and records in a digital database ("data rescue")? No
2. What procedures exist to assure and control the quality of the digitizing process? No procedures
3. Is there an on-going program to record current manual observations in a digital form? Yes
4. What is the approximate percentage of all national meteorological data that are archived in a digital format? 20-30%
5. What is the approximate percentage of all national hydrological data that are archived in a digital format 30%
6. Are these data regularly available in the respective ministries for query and retrieval in a database? Yes
7. Please provide any additional detail regarding data digitization/rescue efforts that would be helpful in understanding current circumstances in your countries. -support for data rescue is needed; past activities have been associated with a single effort, but long term priority is needed for this topic.

# ONE RIVER
# ONE PEOPLE
# ONE VISION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ENTRO

NELSAP-CU

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