Final report

Consulting Services to Define Conceptual Frameworks for ESAWAS Interventions

Information system and database management and development for strengthened water and sanitation systems regulation

This report is carried out for the ESAWAS by: Ernest Uwayezu

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List of abbreviations

Abbreviations	Meaning
ADB	Asian Development Bank
AFDB	African Development Bank
API	Application Programming Interfaces
AREEN	Authority for Regulation of Water and Energy Sectors (AREEN) of Burundi
ASCII	American Standard Code for Information Interchange
BOD	Biological Oxygen Demand
CEDR	Conference of European Directors of Roads
cmd	Command
CMS	Content Management System
COD	Chemical Oxygen Demand
CPU	Central Processing Unit
CRS	Coordinate Reference System
CSV	Comma- Separated Values
CSW	Catalogue Service-Web
CU	Commercial Utility
DAWASA	Dar-es-salaam Water Supply and Sanitation
DBMS	Database Management System
DEM	Digital Elevation Model
DGPS	Differential Global Positioning System
E-COLI	Escherichia Coli
EDB	Ethylene Dibromide
ERDAS	Earth Resources Data Analysis System
ESAWAS	Eastern and Southern African Water and Sanitation
EWURA	Energy and Water Utilities Regulatory Authority
FAO	Food Agriculture Organization
FID	Feature Identifier
FSM	Faecal Sludge Management
GB	Gigabyte
GDAL	Geospatial Data Abstraction Library
GDB	Geodatabase
GGIS	Global Geographic Information and Services
GHZ	Gigahertz
GIS	Geographic Information Systems
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GML	Geography Mark-up Language
GPS	Global Positioning System
GSM	Global System for Mobile communication
GUI	Graphical User Interface
HDD	Hard Disk Drive

HDPE	High Density Polyethylene
HTTP	Hypertext Transfer Protocol
ICT	Information and Communication Technology
ID	Identification
IS	Information System
ISO	International Organization for Standardization
IT	Information Technology
JDK	Java Development Kit
JMP	Joint Monitoring Programme
JSON	JavaScript Object Notation
KML	Keyhole Markup Language
LEWA	Lesotho Electricity and Water Authority
LWSC	Lusaka Water Supply and Sanitation Company
M^3	Meter Cubic
M^3/S	Meter cubic per second
MB	Megabyte
MDGs	Millennium Development Goals
MIS	Management Information System
MN	Manganese
MWDS	Ministry of Water Development and Sanitation
NBS	National Bureau of Statistics
NIS	National information System
NWASCO	National Water Supply and Sanitation Council
ODK	Open Data Kit
OECD	Organization for Economic Cooperation and Development
OGC	Open Geospatial Consortium
OWS	Official Web Sites
PDF	Portable Document Format
PH	Potential of Hydrogen
PNG	Portable Network Graphic
POC	Proof of Concept
PPR	Polypropylene Random
PSQL	Postgre Structural Query Language
PVC	Polyvinyl Chloride
QGIS	Quantum Geographic Information System
QoSSS	Quality of Supply and Service Standards
RAM	Random Access Memory
RURA	Rwanda Utilities Regulator Authority
S/N	Serial Number
SATA	Serial Advanced Technology Attachment
SDGs	Sustainable Development Goals
SDI	Spatial Data Infrastructure
SLD	Style Layer Descriptor
SQL	Structural Query Language
SRS	Software Requirements Specification
SSL	Secure Sockets Layer

STP	Sewer treatment plant
SVG	Scalable Vector Graphics
TIFF	Tagged Image File Format
TMS	Transportation Management System
UN	United Nations
UNICEF	United Nations Children's Fund
UNW-DPAC	United Nations Water-Decade Programme on Advocacy and Communication
URL	Uniform Resource Locator
USAID	United States Agency for International Development
UTM	Universal Transverse Mercator
UWSS	Urban water supply and sanitation
WARIS	Water Regulation Information System
WASAMA	Water Services Association of Malawi
WASH	Water, Sanitation and Hygiene
WASREB	Water Services Regulatory Board
WCS	Web Coverage Service
WFS	Web Feature Service
WHO	World Health Organization
WMC	Web Map Context
WMS	Web Map Service
WMTS	Web Map Tile Service)
WPRA	Web Portal Reference Architecture
WPS	Web Processing Service
WS	Water reservoirs
WSBs	Water Service Boards
WSP	Water Service Provider
WSS	Water Supply and Sanitation
WSSAs	Water Supply and Sanitation Authorities
WSTF	Water Services Trust Fund
WTP	Water Treatment Plant
WURD	Water Utility Regulation Department
XML	Extensible Mark-up Language
ZIP	Zone Improvement Plan
ZURA	Zanzibar Utility Regulatory Authority

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Executive summary

This report is the compilation of the results on the study for setting up an GIS based as a decision support tool for performance monitoring, planning, and resource allocation, utilities management, with the aim to enhance WSS services delivery within the ESAWAS members' countries, especially in urban areas. The main key points covered by the study are summarized below:

1. Introduction

Equitable provision of potable water and sanitation is crucial for human health, wellbeing, and productive human capital, as recognized as a human right. However, sustainable drinking water supply for impoverished communities remains a global challenge, despite the Millennium Development Goals (MDGs) aiming to achieve sustainable water supply by 2015 and the Sustainable Development Goals (SDGs) continuing this goal by 2030. Challenges in achieving this goal include maintaining water availability, ensuring access to clean and reliable water, and managing the entire water supply system. Water pricing, tariff structures, and affordability are important factors in water management, necessitating sustainable governance, management systems, and accounting practices. The ongoing efforts are necessary to ensure the long-term sustainability of water supply systems, supported by several SDGs and targets. Achieving the Universal SDG targets requires disaggregated data on various sub-groups within the population, which can be facilitated through the use of National Management Information Systems (MIS) and web-based tools. The integration of MIS and Geographic Information System (GIS) enhances service delivery and decision-making, allowing service providers to make informed decisions and be more accountable to citizens for different development objectives. The collection and use of spatial data in water and sanitation services (WSS) supports monitoring of national and equitable access, investment prioritization, and promotion of access for marginalized and vulnerable communities. Comprehensive data, including location data, improves utilities' decision-making in maintaining, managing, and expanding networks. Robust data facilitates a common understanding of the sector's status, efficient resource allocation, mobilization of additional finance, and implementation of realistic sector plans. The efficient use of data at various levels influences national, regional, and global development agendas, while spatial data collection and processing track progress towards SDG goal 6, ensuring availability and sustainable management of water and sanitation for all, optimize service delivery monitoring, and raise awareness of water and sanitation issues. GIS and integrated databases enable the confrontation of data from different sources, allowing access and management by different organizational units, and harmonized indicators for comparisons between countries. Its establishment in ESAWAS region will help in producing the harmonized reports on WSS and track the progresses in achieving the related targets. The design of the framework for establishing such a GIS system was the main aim of this study.

2. The relevance of GIS-based information system in WSS

The use of Geographic Information System (GIS) in water and sanitation utilities allows for easy identification and access to the location of resources and water usage models, enabling users to query and analyze information based on its spatial relationship to other features. GIS helps monitor and manage challenges such as leaking pipes, long-term water supply, population growth, water loss, and water quality, by providing valuable data required for effective decision-making. GIS facilitates visualization and generates real business value for water utilities, enabling systematic and efficient water resource management. The MIS and GIS framework support mapping, management, and monitoring of water and sanitation systems in relation to geographic features, allowing stakeholders to assess performance, progress, and gaps in the sector. The framework is flexible, user-friendly, and expandable, storing baseline and updated data in a data warehouse. It can be revised and updated annually to ensure relevance and accommodate improved data collection and monitoring approaches, incorporating new indicators, additional data, and more extensive queries. Moreover, the MIS and GIS framework requires alignment with data needs for planning, monitoring performance indicators, and investment decision-making. Establishing a GIS-based information system helps utilities and regulators consolidate and present data graphically for decision-making, using tools like dashboards and web applications for filtering, graphical representation, and decision-making based on user-defined criteria. The WSS GIS-based MIS for utilities and regulators is as a web-based system collects, processes, analyzes, and visualizes water and sanitation data, following Joint Monitoring Programme (JMP) guidelines for tracking progress and monitoring SDG targets. The system supports decision-making in areas such as investment planning, operational monitoring, tariff setting, licensing, and consumer protection. In addition, it assists in monitoring standards and setting standards for effluent, water supply, and FSM. It is in this respect that a study aimed to design such as a system was requested by ESAWAS through the support of AfDB.

3. Methodology

This study approaches consisted of three main components: a literature review, data collection, and data analysis, leading to system development. The literature review encompasses gathering existing knowledge and understanding of GIS applications in water and sanitation management. Data collection involves collecting relevant spatial and non-spatial data related to water resources, sanitation infrastructure, population, and other relevant factors. Data collection involved using survey for gathering information necessary for accurately measuring and analyzing the current status of water and sanitation management systems. The survey was designed to collect the following information: the ICT infrastructure for data management and publication, the organization responsible for hosting data online, the content management system used for data hosted on the website, the organization's role in the existing information management system, the database management system being utilized, the staff knowledge and skills in GIS, the presence of a geospatial portal for information management and sharing, the capacity building requirements for developing a geospatial portal, the desired characteristics of the geospatial portal, the roles of utilities in geospatial portal administration, the data format produced by

the organization, the format and description of data acquired from other organizations, the software used for data manipulation, the GIS data collection and updating methods, and the compliance of data with ISO 55000:2014 standards. This comprehensive data collection process ensures a thorough understanding of the existing data infrastructure, systems, and capabilities, enabling informed decision-making for the development and implementation of an effective geospatial portal for water and sanitation management. In the process of developing a comprehensive WSS data management system, several key aspects were addressed. The roles and responsibilities of all actors involved in the data management process, including data collection, entry, and validation, were analyzed to ensure a clear understanding of the workflow. The examination of available data focused on water supply and sanitation systems, aiming to assess the existing information and management practices. The availability of the ICT infrastructure, including software and hardware, was assessed to determine the capability of the relevant agencies to set up the GIS based system (a Geoportal) for efficient WSS data management. Additionally, the individuals involved in water supply and sanitation, such as stakeholders, staff, and decision-makers, were identified to understand their roles and requirements in the data management system. Finally, data sharing methods were considered to establish effective mechanisms for sharing and disseminating information among relevant parties. Based on these aspects, a robust data management framework based on WSS Geoportal is proposed for enhanced collection, storage and management of data on water supply and sanitation.

4. The existing information systems in Kenya, Tanzania and Zambia

The study was informed by examining the current Management Information Systems (MIS) employed by three regulators, namely WASREB in Kenya, EWURA in Tanzania, and NWASCO in Zambia. These web-based systems are utilized by the regulators for performance monitoring and annual reporting. The study conducted an analysis of the functions and datasets collected and stored within these MIS. The primary objective was to assess the feasibility of migrating to Geographic Information System (GIS)-based information systems, considering the potential benefits and advantages they can offer.

4.1. WARIS and MajiData at the Water Services Regulatory Board (WASREB) in Kenya

The water and sanitation sector in Kenya has undergone significant reforms driven by the National Water Policy of 1999 and the Water Act of 2002 amended in 2016. As part of these reforms, the establishment of the Water Sector Regulatory Board (WASREB) has played a crucial role in improving water and sanitation service delivery in the country. The board utilizes Information and Communication Technology (ICT) tools such as WARIS and MajiData for data collection and analysis in regulating the water sector. WARIS is a monitoring and reporting system that facilitates data entry, aggregation, and evaluation of performance indicators for regulatory reporting. WARIS enhances regulatory reporting efficiency, reduces the compliance burden on WSPs, and improves data quality. It serves as a decision support tool and enables electronic submission of regulatory reports while calculating performance indicators. MajiData is an online database launched in 2011 that collects and manages socio-

economic data on the urban poor regions in Kenya, with a focus on unserved urban settlements. It includes utility performance data from WASREB, Water Services Trust Fund (WSTF) investments, and WSPs. MajiData serves as a performance assessment tool alongside WARIS, measuring the performance of WSPs, identifying areas for improvement, and providing recommendations. MajiData is a performance assessment tool used by WASREB in combination with WARIS to measure the performance of WSPs identify areas of improvement, and provide recommendations for improvement in the country. The related database can be accessed through its website. Its user interface only allows external users to view available data and no direct analysis can be made It comprises the function tabs that allow for exploring data on WSS indicators, infrastructure and general data. The MajiData comprises a dashboard displaying the spatial data for main WSS facilities. Yet, those data do not meet the basic GIS standards for a Geoportal design and easy generation of reports

4.2. Majis information system for the Energy and Water Utilities Regulatory Authority in Tanzania

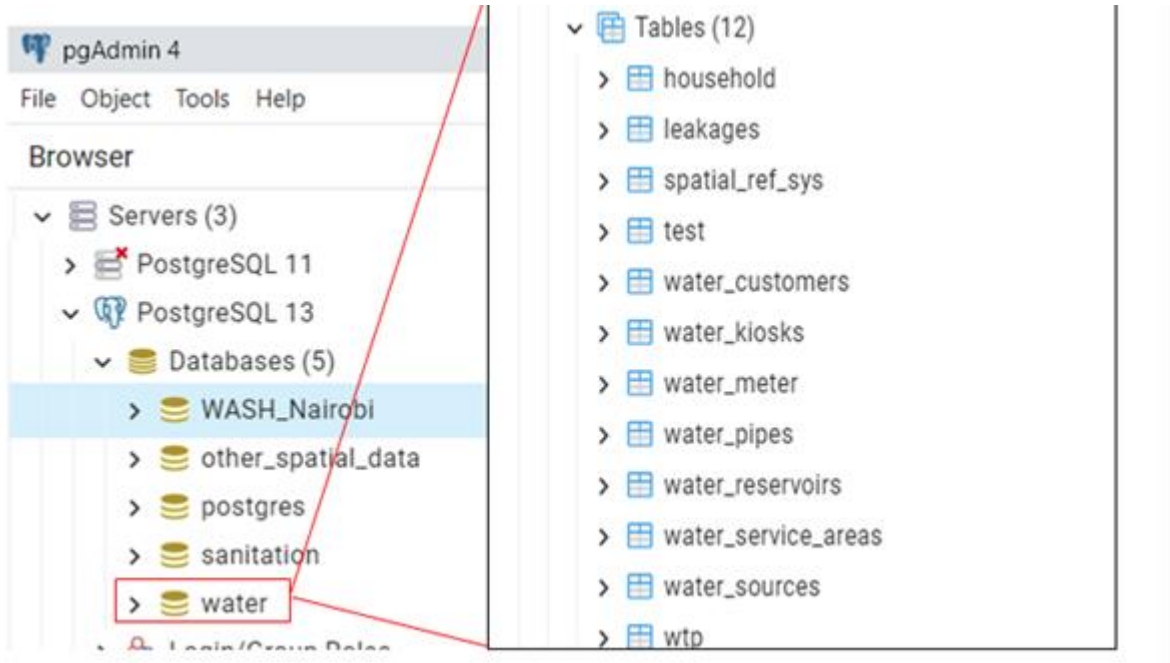
The water sector in Tanzania has experienced significant reforms in recent years, with the Water Supply and Sanitation Act (2019) playing a pivotal role in driving transformation. This Act establishes the legal framework and policies for water supply, sanitation, and hygiene service delivery and regulation across urban, peri-urban, and rural areas. The Energy and Water Utilities Regulatory Authority (EWURA) is responsible for implementing regulation in the water sector, ensuring the interests of stakeholders, sustainability, and availability of services. Water Supply and Sanitation Authorities (WSSAs) are entrusted with the responsibility of providing reliable, sustainable, and affordable water supply and sanitation services throughout Tanzania. To streamline data collection and management, EWURA has adopted the Maji Information System (Majis), a web-based system that facilitates the collection and management of data related to water connections, sewerage systems, and other operational aspects of WSSAs. Majis serves as a central database for monitoring the performance of water utilities and enables real-time data collection on water supply services. The system collects data on water production, distribution, consumption, customer complaints, and also conducts field inspections for infrastructure maintenance and compliance. EWURA prepares Annual Water Utilities Performance Reports based on the data obtained from Majis, providing a comparative analysis of WSSAs' performance across Tanzania. EWURA does not have any GIS system in place. The information which is relevant to the development of GIS is stored under the Technical module. If the GIS system is developed, some of data on water production (like the daily water production capacity, water production, etc.) can be attached to the layers of water treatment plants.

4.3. The National Information System (NIS) for the National Water Supply and Sanitation Council in Zambia

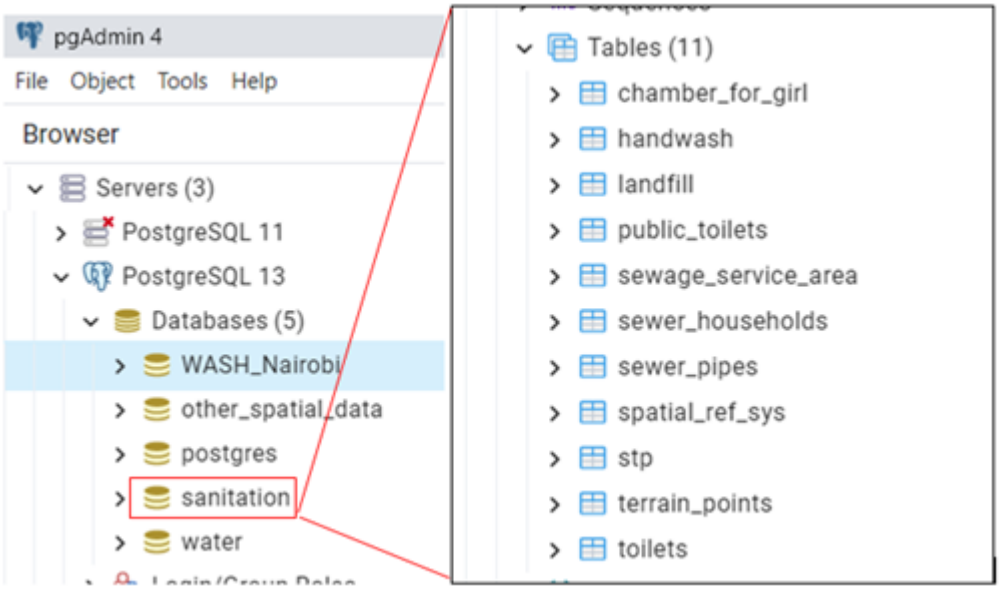
The National Water Supply and Sanitation Council (NWASCO) is an independent regulatory body in Zambia with the responsibility of regulating water supply and sanitation services. NWASCO has developed the National Information System (NIS) to enhance its regulatory functions and facilitate data-driven decision-making. NIS is a digital platform specifically designed for data collection, management, and analysis in the water supply and sanitation sector. It serves as a centralized and standardized system for collecting data on various performance indicators, including water quantity and quality, facility conditions, and financial performance. Through the NIS, NWASCO has achieved improved efficiency in data management, enabling timely access to reliable information for regulatory purposes. The system has not only enhanced NWASCO's internal operations but also facilitated coordination, monitoring, and assistance in the sector. Multiple stakeholders, including other government agencies, development partners, and civil society organizations, also utilize the NIS to ensure a coordinated approach to water supply and sanitation service provision. The NIS is used in parallel with the Zambia Water and Sanitation Digital Atlas under development which is a web-application, that allows user to query spatial data.

5. Analysis of the GIS based Information system

The information presented on existing GIS is based on empirical data collected through interviews, surveys, and discussions with regulators in Nairobi, Dar Es Salaam, and Zambia. The existing GIS datasets primarily focus on water networks in Nairobi and Dar Es Salaam, indicating that spatial data collection on WSS are already developed in these areas. In Zambia, notable advancements have been made by the Lusaka Water and Sewerage Company (LWSC) in gathering spatial data on water supply, sanitation, and hygiene facilities specifically in Lusaka city. However, the study revealed the need for improvements in data collection and management processes in the three cities, suggesting that data coverage and quality can be enhanced in order to ensure the development of very well structured and documented GIS databases. This is crucial, if one can make reference on some of the existing GIS layers: Water data (even for single layer) are not stored in a geodatabase or feature class. They are presented in different layers based on service areas, indicating a lack of a centralized and organized system for managing those data and potentially leading to fragmentation and difficulties in performing a comprehensive overview. The following figure show the model structure that should be adopted:



The suggested structure allows for recording the attribute data which are important for reporting on all aspect of water and sanitation service. This will allow for bridging the gap in the existing systems where those attributes are missing, indicating a gap in the dataset's completeness and relevance. To effectively utilize this data, upgrading is necessary to address the missing attributes and ensure the accuracy and integrity of the information. By implementing a geodatabase and incorporating the missing attributes, a more unified and robust system should be established for managing water pipeline data, enhancing accessibility, and supporting informed decision-making processes. Data on different types of sanitation is available, indicating that information regarding various latrine structures exists. However, the data is not stored in a well-structured database, implying a lack of a systematic and organized approach to managing this information. To address this issue and facilitate effective utilization, there is a need to re-organize the data into a Geodatabase. The figure below shows the model structure that should be adopted:



By adopting the suggested structure, the sanitation data can be organized in a way that supports their integration into a geoportal development. This reorganization will enhance data management practices, improve accessibility, and enable the utilization of those data in a spatial context for better planning, analysis, and decision-making related to sanitation and infrastructure development.

6. Recommendations for a GIS-based Water and Sanitation Geoportal

A GIS-based portal, commonly referred to as a geoportal, serves as a web framework for discovering and utilizing spatial data via the internet. In the context of the Water and Sanitation Management Information System, a GIS-based portal is developed to effectively manage water and sanitation resources, and optimize the benefits derived from water supply and sanitation services through supporting the well-informed decision making regarding service delivery, enabling them to formulate suitable policies. By targeting specific geographic areas, the system can be used in assessing the water and sanitation challenges and making decisions that are meant to ensure the provision of adequate drinking water and sanitation services.

6.1. GIS-based Water and Sanitation Data base Management system

The WSS Geoportal will be based on the database management system (DBMS) consisting of computerized system designed to store and manage data in an organized and accessible manner. With a DBMS, users can manipulate and analyze data, ensuring data-driven workflows and maintaining data security and integrity. Several options for DBMS are available, including Microsoft Access, MySQL, Oracle Database, MongoDB, and PostgreSQL/PostGIS. These systems offer varying features and capabilities to cater to different user requirements and in conjunction with desktop GIS software, they allow users to display, query, update, and analyze geographic data and its associated information. Core functionalities of desktop GIS software encompass tasks such as adding layers, styling layers, labeling features, creating selection sets and queries, as well as editing and managing data. Two popular desktop GIS software options are ArcGIS and QGIS. ArcGIS is a comprehensive solution offered by ESRI, while QGIS is a free and open-source software supported by an active community. Thus, considering the handling of geospatial data within the ESAWAS context, the assignment focused on evaluating and comparing free GIS software options to determine the most suitable one. This evaluation resulted in identifying the software that best meets the requirements and effectively manages the geospatial data pertinent to ESAWAS initiatives. The QGIS was therefore suggested.

6.2. Data accessibility via web services

Geospatial data can be stored either locally or in the cloud, allowing for remote access and collaboration. However, implementing a GIS-based MIS comes with challenges, including the dependence on internet connectivity and potential security risks. To address these challenges, open-source Geospatial Content Management Systems (CMS) offer platforms for effectively managing and publishing geospatial data. These CMS have core features such as

spatial data storage, data creation and editing capabilities, data publishing with integrated maps, and support for Open Geospatial Consortium (OGC) standards like WMS, WFS, WCS, SLD, and GML. Additionally, Geospatial CMS provide features like privilege handling, security measures, metadata collection, extensibility, and the development of interactive dashboards. The proposed Geoportal will be made of a Geospatial CMS comprising a spatially enabled object-relational database, a geospatial data server (e.g., Geoserver), a tile cache server, a web application for map composition and publishing, and a desktop application for working with WSS related geospatial data and maps.

6.3. User of the system

Geoportal resources can be classified as public or restricted, with public resources accessible to all users and restricted resources limited to specific user groups. The GIS-based Portal users will be divided in three categories based on their roles: Geoportal Manager, Publisher, and Viewer. The Geoportal Manager (the Regulators) will be responsible for managing accounts, administering the system, adding and disabling users or groups, creating user passwords, and managing datasets and published documents and maps. Publishers (comprising the utilities) will be responsible for publishing datasets using desktop GIS software or editing online datasets. Viewers will be any users who can search and visualize published information on the internet and may also have the ability to send requests or share their points of view through forms or blogs. The roles within the Geospatial CMS proposal for ESAWAS aim to provide system administration and access to publishers and viewers. Training will be provided to all involved parties to ensure their ownership of the GIS-based water and sanitation portal and the ability to update geospatial data using web services or desktop GIS with Geoserver for publishing edited data. Regulators will utilize the system and stored data for performance monitoring, planning follow-up, service delivery improvement, compliance checks, licensing decisions, and more. Utilities will utilize the system for infrastructure management, planning new extensions, financial matters and investments, establishing tariffs, and reporting on performance metrics related to water production, supply, non-revenue water, leakages, coverage in relation to consumer locations, and more.

6.4. Requirements for WSS Geoportal development

In the case of ESAWAS, the plan is to utilize open-source software for handling WSS-related spatial data. The identified software solutions that are easy to install and user-friendly include QGIS desktop and QField for desktop and mobile GIS functionality, respectively. PostgreSQL/PostGIS is chosen for spatial database management, Geoserver for GIS server capabilities, Mapstore2 for web mapping applications, and Apache Tomcat as the web server. To ensure smooth operation, specific hardware requirements must be met. For PostgreSQL, a 1 GHz processor, 2 GB of RAM, and 512 MB of HDD are recommended. Mapstore2 requires a minimum of 2 cores, 2 GB of memory (4 GB recommended), and Geoserver necessitates a Java 11 or Java 17 environment. QGIS desktop calls for a minimum processor of Core i3 2.7 GHz or Core i7 3.5 GHz, 2 GB or more of RAM, and a 500 GB SATA

HDD or 128 GB SSD. QField requires a mobile device with at least Android 9. Finally, Apache Tomcat 9.0.x requires Java 8 or later, 256 MB of RAM (512 MB recommended), and 100 MB of free storage space for installation. It is important to allocate additional disk space for data and supporting components to ensure smooth operation of the geoportal.

6.5. GIS Geoportal components

Open source applications provide the means to develop a GIS portal with multiple components. Desktop and smartphone GIS tools offer capabilities such as data collection, cleaning, visualization, analysis, map production, and spatial data publication. The spatial database management component relies on PostgreSQL/PostGIS, which is a suitable choice due to its spatial extension capabilities, supporting spatial data types, queries, and indexes, to securely store prepared spatial data. This data can be seamlessly connected to QGIS desktop and then published to Geoserver as web services. The web server component incorporates Geoserver for efficient administration and publishing of spatial data in various formats. Additionally, the map store component serves as a web mapping application, facilitating the creation of web maps, story maps, and dashboards.

6.6. Database management for WSS

A database management system (DBMS) that fits with the ESAWAS needs is the PostgreSQL with PostGIS. It is a suitable choice due to its spatial extension capabilities, supporting spatial data types, queries, and indexes. PostgreSQL with PostGIS provides benefits such as easy organization, multi-user support, security, data backups, spatial analysis, and seamless integration with QGIS. It will be sued in creating the GIS database containing the two categories of datasets: data on water supply system and data on sanitation.

Spatial Data on water supply system will comprise the following, with the respective attribute data that will be extracted from the existing systems or collected from the Field (for the attributes which are not stored in the existing data management systems) :

- **Water source:** discharge, PH, Fe, Eschelchia, Colorine, Water source upkeep.
- **Water treatment plant:** Design capacity, Production capacity, Distribution capacity, Energy, demand, Water loss per day, Income, Water source, Billing efficiency, PH, Turbidity standards, Percentage of Fe Percentage of Eschelchia coli, Percentage of Residual chlorine Bacteriology, Fluorides standards, water distribution expense, BOD 5 results, COD results, operating costs of water distributed, Operating costs of water distributed, Operating costs of water billed, Chemical expenses, Water losses per active connection, Average water tariff, Water loss per month, Results of residual chlorine, Results of E-Coli, Results of turbidity, Results of PH, Results of chlorides, Results of Fe, Results of Mn, Results of nitrates.
- **Water pipe:** Date of installation, Materials, Diameter, Pressure class, Length, Leakage frequency, Rehabilitation date, Replacement, Category of connection, Customer complaint, Leakage date, Leakage location, New features on water connection,
- **Water reservoir:** Date of installation, Meter number, Active connection, Replacement, Average monthly billing, Material, PH, Turbidity standards, Fe, Eschelchia coli, Residual chlorine, Bacteriology, Fluorides standards, Mn standards, Results of residual chlorine

tests, Results of E-coli tests, Results of turbidity tests, Results of PH test, Results of chlorides test, Results of fluorides test, Results of Fe test, Results of Mn test, Results of nitrates test.

- **Water meter:** Customer category, Active connection, Inactive connection, Operational, Replacement, Complaint, Average monthly billing, Billing reliability, Claim on billing.
- **Water Kiosk:** POC number, Date of installation, Service provider, Customers, Daily consumption, Water tariff, Service hours, Private connection, Billed water per month, Results of residual chlorine, Results of E-Coli, Results of turbidity, Results of PH, Results of chlorides, Results of Fe, Results of Mn, Results of nitrate.
- **Service area:** Region/Province, District, Sector, Total population, Number of households, Number of active customers, Number of connections, Population with access to kiosk, Service provider, Coverage, Demand, Land use, Interruptions frequencies, Collection efficiency, Billing efficiency, Billing reliability, Billing complaints, Days taken to resolve billing complaint, Daily water distribution, Collections based on billing, Service hours, Percentage of connections with 24 hours supply, Water losses per month.
- **Household:** Owner names, Connected Household, Main Source of water, Distance to fetch water, Time to fetch water, Size of the container, Average household monthly consumption, Average monthly payment for water, Service hours, Average consumption per day, Average consumption per month, Average monthly payment, Interruptions frequencies, Water storage, Water storage capacity, PH, Turbidity standard, Fe, Eschelchia coli, Residual chlorine, Bacteriology, Fluorides standards, Mn standards, Nitrates standards, Distribution service hours.
- **Water leakage:** Location name, Landmark, leakage cause, Leakage time, Leakage date, Leakage repair time, Leakage repair date, Leakage duration in hours, Leakage frequency (per month).
- **Water customer:** Average daily consumption, Status of tap sharing, Water tariff, User category, Service provider, Class, Connection status.

As for the sanitation, the main datasets will consist of the following:

- **Sewer treatment plant:** Year of construction, Capacity, Domestic connection, Sewerage coverage, Water reuse mechanisms, Treatment plant functionality, Volume of sewage treated, Volume of sewage imported, Volume of sewage exported, Volume of sewage discharged, Sewer flooding, Sewerage tariff, Sewerage disposal expenses, Maintenance and repair expenses, BOD 5 Results, COD Results, Energy consumption, Treated quantity, Number of effluent carried out, Reused faecal sludge, Received faecal sludge, Delivered faecal sludge, Results of sludge tests.
- **Toilet:** Users, Owner, Shape, Date of construction, Classes, Type, Landmark, Number of toilet rooms, Number of functional toilet rooms, Condition of toilet, Latrine accessible with limited mobility or vision, Maintenance undertaken for the household's toilet, Handwashing facility, Emptying tariff, Service provider, Emptying type, Average number of users, Services ladder category, Percentage of population with safely managed sanitation, Desludging frequencies, Connection to soak pit.
- **Sewer pipes:** Materials, Shape, Diameter, Minimum velocity, Maximum velocity, Sewerage system, Length, Inactive pipes, Sewer blockages, Sewer blockages per network, Sewer blockages per connection, Blockage results, Blockages time, Rehabilitation, Complaint, Number of connections, Operational sewer pipe.

- **Landfill:** Year of construction, Landfill name, Maximum height, Slope of the sides, Buffer zone, Landfill access roads, Landfill fenced, Inspection of the site after construction works, Type, Service area, Weight of the landfill waste, Depth of burial, Composition of waste, Capacity of landfill, Landfill height, Area, Waste generation volume, Weighing bridge, Service hours, Landfill facility management, Supervision institution, Employees, Sorting service, Type of truck, Waste deposited compaction, Burning of waste on the Site, Waste covering, Covering materials, Security guard.
- **Public toilet:** Year of construction, Classes, Type, Landmark, Number of toilet rooms, Condition of the toilet, Usable toilet, Maintenance needed, Handwashing facility, emptying tariff, Service provider, emptying type, Number of users, Services ladder category, emptying frequencies, Connection to soak pit.
- **Sewer household:** Owner, Population with safely managed sanitation, Population with basic sanitation, Population with limited sanitation, Population with unimproved sanitation, Population practising open defecation, Connection to sewer pipe, Experience with flooding, Connections interruptions, Number of blockages,
- **Sewer service area:** Total Population, Region/Province, District, Sector, Service area name, Average households, served households, Total number of connections, Service provider, Coverage, Land use, Collection efficiency, Septic tanks, Septage sucking machines, collected septage, Number of septic tanks, Connection to soak pit,
- **Hand wash:** Owner or hosting agency, Water and soap availability, Water availability only, Functionality status, Cleaning frequency, Number of sink, Average number of users, Services ladder category.
- **Chamber of girl:** School Name, Bed availability, Bin for Pad availability, Soap availability, Bathroom availability, Bathroom status, Water availability, Toilet paper availability, Taulo availability, Body cosmetic.

Those data will be compiled into a Geopackage that will serve as a centralized location for their storage and will facilitate the transfer of multiple layers within a single package, and streamlining the data integration process.

6.7. WSS data manipulation in desktop GIS

Using the QGIS, the WSS geodatabase can be seamlessly imported from a database management system and visualized and manipulated within the QGIS desktop environment. Any edits made in QGIS will be automatically synchronized with the PostgreSQL database, ensuring data consistency and integrity. QGIS desktop provides additional functionality for spatial analysis. It enables users to perform spatial queries based on spatial relationships between features, allowing for in-depth analysis and exploration of the data. Additionally, QGIS offers a variety of tools for performing different operations and tasks related to geospatial data. For detailed instructions on how to connect QGIS to a PostgreSQL database and leverage its capabilities, the training manual included in the report provides comprehensive guidance and step-by-step procedures. It ensures that users have the necessary knowledge and guidance to effectively utilize QGIS in conjunction with a PostgreSQL database.

6.8. WSS data updating in mobile GIS

There are numerous mobile applications, both open source and proprietary, specifically designed for collecting and updating WSS data. QGIS, a popular GIS software, offers the QField Sync plugin, which simplifies the process of packaging QGIS projects for use in the QField app allowing users to deploy existing projects to the field and collect new data efficiently. It provides a seamless integration with QGIS, ensuring smooth data synchronization between the desktop and mobile environments. With regard to its advantages and capabilities, the QField app is highly recommended for data collection and updating tasks in the WSSdomain. It offers robust features and functionality that surpass other available apps, providing users with a reliable and user-friendly platform for field data collection and updating.

6.9. WSS Geoportal

The WSS Geoportal comprises several key components that facilitate its functionality and data management processes. These components include a spatial database management system, specifically PostgreSQL with PostGIS, Apache Tomcat as the web server, Geoserver as the GIS server, and Map store. The GIS server, Geoserver, being an OGC-compliant GIS server, has the capability to handle large datasets and facilitates the publication of spatial data from sources such as PostgreSQL databases as web services. It plays a vital role in the WSS Geoportal by enabling mapping, analysis, and management of spatial data. It serves as a centralized platform for managing, publishing, and serving map layers and associated data online. Through Geoserver, publishers or geospatial administrators can publish web mapping services (WMS) that adhere to the Open Geospatial Consortium (OGC) standards. The browser acts as the client-side component, facilitating communication with the GIS server through HTTP requests. Geoserver a GIS server supports various OGC standards, enabling the publication of different types of web mapping services. These services include WMS for map and image viewing, WFS for feature layer manipulation, WCS for multidimensional raster data, and WPS for data processing and geospatial analysis. Map store enhances the user experience by providing intuitive tools for visualization and exploration of geospatial data.

Together, these components form a robust infrastructure that supports the functionality and usability of the WSS Geoportal, enabling efficient management and sharing of geospatial information in the WSS domain.

6.10. Managing data in a Geoportal

Alongside Geoserver, Map store serves as a platform where users with admin or publisher roles can configure interactive web maps. The configuration tools within Map store offer various capabilities, including the addition of remote services such as CSW, TMS, WMS, and WMTS, as well as the incorporation of layers, map or vector file imports, annotations, and table of contents management. The Background Selector feature empowers users to customize their map backgrounds by adding, managing, or removing providers like Google Maps, Open Street Map, Bing, or other OGC-compliant servers. Furthermore, Map store provides additional map exploration tools for enhanced user experience. Users can also create metadata for maps, set permissions, and provide detailed descriptions through the edit properties window, ensuring comprehensive and informative map representation.

6.11. Dashboard in the WSS Geoportal

Dashboards will combine maps with associated data, providing a simplified yet comprehensive view of key indicators. It will encompass various components such as charts, text, tables, counters, and maps, all working together to present a holistic picture of the data. The interactive nature of dashboards will allow the users to connect widgets, enabling simultaneous inspection and interaction with multiple data representations and they can extract meaningful information and make informed decisions based on the insights gained.

6.12. Resource sharing with WSS Geoportal

The Geoportal facilitates seamless sharing of resources such as maps and dashboards through multiple methods, ensuring effective dissemination of information. Users can easily share resources by utilizing the share button located in the toolbar of each resource. Additionally, the Geoportal includes a social section that enables sharing on popular networks like Facebook, Twitter, and LinkedIn, extending the reach of shared content to a wider audience. Moreover, the Geoportal provides options for embedding code or utilizing APIs, allowing users to share maps by integrating them into external websites or applications. These sharing capabilities empower users to distribute geospatial resources efficiently and engage a broader user base.

6.13. Implementation and Cost of WSS Geoportal

The implementation of the WSS geoportal will be carried out through a phased approach, ensuring a systematic and effective deployment. The initial phase involves designing a

prototype system tailored to the requirements of one country. This includes establishing a robust database management system, preparing data in a GIS format, and integrating the necessary portal components. In the subsequent phase, the system design will be replicated and adapted for each country, taking into account their specific needs and considerations. Once the system prototype is ready, it will be deployed in the web hosting domain of each country, and the geoportal link will be shared with the administrators. Additionally, it is recommended to establish a system maintenance plan, with the consultant providing technical assistance for a period of 6 months. This support period will ensure a smooth transition and enable the country administrators to assume full ownership and responsibility for the geoportal's operation.

7. Readiness for GIS adoption by the Regulators

An investigation was conducted to assess users' needs and interest in adopting and using a Geoportal in the field of Water and Sanitation. The investigation focused on several key areas, including determining the level of interest in adopting Geographic Information System (GIS) technology, evaluating existing GIS initiatives implemented by regulators and utilities, assessing the commitment of utilities to support GIS adoption, examining the availability of necessary ICT facilities, identifying preferred applications for Geoportal development, and identifying capacity building needs. The results of the investigation confirmed that all regulators, under the coordination of ESAWAS, are ready to accept and utilize GIS-based information systems for the collection, management and dissemination of WSS. Some regulators (like ZURA; EWURA; AURA, IP; RURA; AREEN; WASAMA; LEWA and WURD) which do not have in place the GIS system are very interested in the setting up the system and ready to establish the WSS Geoportal if there is any support provided by AfDB and ESAWAS in relation to the capacity which is needed. At WASREB, the GIS is operated by a private consultant who does even collect and update the system on a regular basis. For this reason, the regulator is much interested in taking the leading of the system if its staff is trained on all related operations.

8.Capacity building needs for running the Geoportal

To ensure the successful operation of the geoportal, capacity building initiatives will be undertaken, involving comprehensive training for the geoportal administrators. The training will cover various aspects such as software installation, geodatabase administration, web mapping, and resource sharing. Moreover, data collection on water and sanitation services will involve the consideration of the total population of the area of interest, the priority areas, the fund availability and the required costs.

Structure of the Report

The whole report is structured as follows:

- Introduction
- Methodology

- GIS-based Water and Sanitation Portal
- The existing information systems in Kenya, Tanzania and Zambia
- System design for WSS Geoportal
- The sustainability of WSS GIS based Information system
- Conclusion

1. Introduction

The equitable provision of potable water and sanitation services for all people has been among the priorities of socio-economic development at the international level as it constitutes the pre-requisite for human health and wellbeing and development of well productive human capital (UNW-DPAC, 2015). It is globally the core aspects of sustainable development. The UN General Assembly and the UN Human Rights Council recognized water and sanitation as a human right in 2010 (UNW-DPAC, 2015). Yet, the provision of sustainable drinking water supply for impoverished communities remains a global challenge that requires more efforts. The Millennium Development Goals (MDGs) had set a target to achieve this between 2000 and 2015, and the Sustainable Development Goals (SDG) 6 continue to prioritize the "availability and sustainable management of water and sanitation for all" by 2030. This goal presents challenges related to maintaining water availability, managing the entire water supply system, and ensuring that the community has access to clean and reliable water. These challenges encompass the mode of water distribution, the supply chain, and how they reach and interact with the user community. Water pricing and tariff structures, affordability, and economics of supply are also significant factors, including socio-economic influences. All of these elements need to be overseen by sustainable governance, management systems, and accounting practices. Historically, providing "free" water through standpipes to impoverished communities has faced challenges in ensuring the long-term sustainability of this approach. Achieving sustainable water quality, accessibility, reliability, and quantity still requires a holistic approach that considers all of these factors and involves ongoing efforts to ensure the long-term sustainability of the water supply system (Coulson et al., 2021). A number of the SDGs and several targets were defined to support the universal access to WSS. In the urban areas, the relevant targets have been summarised as follows (UNICEF, 2019):

- **Target 1.4 (No poverty):** By 2030, ensure that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources, as well as access to basic services, ownership and control over land and other forms of property, inheritance, natural resources, appropriate new technology and financial services, including microfinance.
- **Target 3.8 (WSS in health care facilities):** Achieve universal health coverage, including financial risk protection, access to quality essential health care services and access to safe, effective, quality and affordable essential medicines and vaccines for all.
- **Target 4.a (WSS in schools):** Build and upgrade education facilities that are child, disability and gender sensitive and provide safe, nonviolent, inclusive and effective learning environments for all.
- **Target 6.1 (Water):** By 2030, achieve universal and equitable access to safe and affordable drinking water for all.
- **Target 6.2 (Sanitation and hygiene):** By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations.

- ❖**Target 11.1:** By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums.

In terms of monitoring progress in achieving those goal, with a focus on drinking water, sanitation and hygiene, two targets 6.1 and 6.2 are very important. The Target 6.1 aims at achieving the universal and equitable access to safe and affordable drinking water for all" by 2030. One of the related indicators consisting of the "percentage of population using safely managed drinking water services" comprises four elements: (i) the basic drinking water source; (ii) the water source should be located on premises; (iii) The water has to be available when needed, and (iv)the compliance with faecal and priority chemical standards (UN-Water 2014). As for the sanitation, there is consensus among the international community on the need to go beyond access to a basic facility and address safe management of faecal waste along the sanitation chain. The target 6.2 aims at achieving the adequate and equitable sanitation and hygiene for all, with paying special attention to the needs of women and girls and other people in vulnerable situations". This target has been monitored through the following indicator: "*percentage of population using safely managed sanitation services*" by 2030 (Joint Monitoring Programme, 2017).

The Universal SDG targets can only be considered achieved when met for all sub-groups within the population. This implies progressive disaggregation of data by income, gender, age, race, ethnicity, migratory status, disability, geographic location and other characteristics relevant in national contexts. The 2030 Agenda calls on countries to set their own national targets guided by the global level of ambition, by taking into account national circumstances. In some countries where basic services are not yet universal, national targets may focus more on the lower rungs of the water, sanitation and hygiene ladders. Many countries have established the well-developed routine monitoring systems and regulatory frameworks that report on safe management of WSS services. However, sectoral monitoring systems are still weak or absent in many low- and middle-income settings. Inventories may track numbers of facilities but have little information regarding the functionality or use of such systems. In the Eastern and Southern Africa, many countries do not yet have the data to fully understand the gaps in WSS service provision and progress towards achieving the related SDGs (UNICEF, 2021). Good information remains at the heart of effective regulation, and performance monitoring is crucial for performance improvements.

The performance monitoring is not only as the basis for regulatory decision-making, but helps countries understand if they are achieving national targets and where investment is needed to address gaps in provision and ensure that no-one is left behind. Monitoring is required at the global, national, regional levels and at the service provision level (Ndaw and Mwangi, 2015). To ensure the appropriate performance monitoring, the setting of the national Management Information Systems (MIS) which is already in place in some countries provide reliable information about access to and use of services in water and sanitation sector (WHO and UNICEF, 2017). The MIS, in combination with web-based tools are at the forefront of supporting the making of well informed decisions for the improving performance and efficiency in service

delivery in that sector (WHO, 2008; UN-Water, 2020). Policy- and decision-makers also need credible water and sanitation sector data which are translated into actionable information in an accessible format in order to observe and scrutinise the whole picture and account for synergies and trade-offs between different social, economic, and environmental development objectives (https://www.unwater.org/about-un-water/what-we-do/monitor-and-report). All the key-players including various government agencies, regulators, service providers have had much interest in those tools as they facilitate data gathering, sharing, analysis and its use in performance assessment.

The MIS applications are also used to support most of the operations and business processes, including billing. The integration of MIS and GIS customer/infrastructure database can enable the public water utilities to deliver improved services to its customers. They make the collection and storage of data and information on water and sanitation in a standardised manner and easily accessible by stakeholders at all levels (local, national and regional) for efficient decision making (UN Water, 2020). For instance, spatial data on households and social facilities such as schools, markets, health centres, hospitals and their overlay with georefrenced data on water and sanitation serve to examine the status of access to water and sanitation services across any utility operating areas (Ntozini, et. al., 2015). The performance measurement undertaken using GIS also helps water and sanitation services providers make better informed decisions and enable them to be more accountable to citizens. GIS based information systems provide the funding agencies the indications of whether those service providers are responsive to the values of their customers (UNICEF, 2015). In addition, the MIS and GIS applications offer better data workflow and more inclusive service delivery, through a quick data review. The systems allow for good reporting tool for better monitoring and tracking of reported issues and preventing revenue loss through early reporting and provide a customer portal that allows for improving customer engagement and new service connections requests direct to the service providers (World Bank, 2022).

From the framework of equity in WSS service delivery, the collection and use of spatial data and their use help monitoring the national and equitable access and prioritizing making decisions on investments that promote access for the marginalized and vulnerable communities that are unserved or underserved (UN-Water,2020). In other words, the availability of comprehensive data (including earth observation data) on the location of customers, infrastructure, and assets at the utilities improves the ability of utilities to make informed and cost-effective decisions to maintain, manage, or make new investment through the expansion of their network and connection of additional communities and households. Moreover, the availability of robust data that support the well sound analyses can help the various stakeholders involved in water and sanitation service provision to achieve a common understanding of the status of the water and sanitation service sector and their possible evolution; make the allocation of scarce resources more efficient; identify ways of mobilizing additional finance; improve the implementation of sector plans by making them more realistic; and make the sector a more credible partner for various financing agencies, donors and investors (OECD, 2009).

When those data that include coverage parameters of accessibility, availability, quality and safe management, their efficient use by various actors or stakeholders at various all levels can influence national, regional and global development agendas (UN-Water,2020). For the regulators, it enables the access collected and managed by different organizational units. A GIS based on an integrated output database facilitates the horizontal confrontation of data from different sources and encourages the technical staff to go beyond the vertical data flows within individual organizational units. Thus, the collection and process of spatial data help to tracks overall progress towards SDG 6 at global, regional and national levels and identify the access disparities that may be masked by the non-spatial data, can optimize service delivery monitoring, and enable to raises awareness of water and sanitation issues to help catalyze action. The collection of all data related to WSS also allows for the development and implementation of a harmonized set of indicators which are needed to allow comparisons between countries and over time. The availability and accessibility of credible and timely water and sanitation data provide various benefits, including the following (https://www.unwater.org/our-work/integrated-monitoring-initiative-sdg-6):

- **Stronger accountability:** Data can communicate that work is being done and progress that is being achieved. They can enable greater transparency, which reduces inefficiency and corruption.
- **Attracting commitment and investments:** Data can quantify problems and make it easier to communicate the needs for political commitment and public and private investments.
- **Evidence-based decision-making:** Data can inform policy- and decision-makers of where to focus efforts and which solutions are most effective, to ensure the greatest possible gains with existing resources.
- **Leaving none behind:** Disaggregated data can help identify specific groups or areas with unmet needs and higher levels of risk, to which the interventions can be targeted.

The collection and management of all data good quality data requires some forms of various investments for covering the needed human and IT resources.

1.1. Management Information Systems (MIS) in WSS

The development of coherent water and sanitation management is fundamental to ensure sustainable socio-economic development. Experience shows that efficient water and sanitation management cannot exist without efficient access to and management of the necessary data and information. At local and national levels, easy access and efficient use of the necessary data and information, e.g. on the status and evolution of water and sanitation and uses, is one of the keys to successful water and sanitation policy implementation (Haener, 2018). In this framework, many utilities and regulators in WSS sector have been setting up the information systems like Water Sector Management Information System (MIS). The MIS is an integrated manual computer system that provides information to support the operations of managements and the decisions making functions of the utility. The importance of the IS includes (World Bank, 2017):

- Responding to the general lack of up-to-date information on the status of WSS services;
- Generating data and information that can inform strategic policies and investment decisions;
- Supporting the performance evaluation of service providers by assessing their level of organization and financial sustainability;
- Improving the effectiveness of technical assistance within the utilities.

The MIS is also a collection of people, procedures and devices organized to convert data from internal and external sources into information and communicate such information in an appropriate form to management at all levels. Some of the MIS consist of web based systems which have been developed to support the collection, processing, and reporting data on various issues concerning water and sanitation sectors. Within those agencies, the systems host data which come from the planning/budgeting, procurement, contracts and finance of water supply and sanitation projects and development of water resources. Those data are usefully used to support, monitor and evaluate water and sanitation project and utilities performances. They are also used in ensuring the effective and evidence-based planning, budgeting, service improvement, and accountability. Timely availability of reliable WSS data is essential to proper service Planning and decision-making; 'with accurate data on who has access to water and sanitation, and at what level of service, States can prioritise the provision of services to the people who need them the most' (de Albuquerque 2014). More generally, data on Water and Sanitation and related information management are particularly needed for different purposes (Haener, 2018), including the following:

- Sectorial Water and Sanitation Management such as quantification water demand to be put into water supply and distribution system, etc.
- Integrated water and sanitation sector planning such at city, local, regional, and national levels;
- Disaster reduction in the case of flooding, droughts and water supply shortage period;
- Reporting at various stages: Global, Regional and National reporting, performance evaluation and decision making for various purposes.

The effective sector-wide monitoring and information systems are therefore a critical element of any country's efforts to expand and improve water and sanitation services and enhance efficacy, efficiency and equity of sector investments. From the perspective of SDGs, monitoring data has played a key role in providing the evidence base for a range of various interventions and actions at different levels, global, regional, and national. At the national level, the monitoring has been serving for national policy making, planning and financing. Some of the indicators employed in monitoring the progress focus on the human right to Water, Sanitation and Hygiene include the accessibility, reliability, affordability, sustainability and equal access. The availability of an information management system facilitates the planning and appropriate allocation of resources in a bid to improve the accessibility water supply and sanitation services. Without the evidence of access levels and coverage in terms of water supply and sanitation, it is difficult for commercial utilities to provide adequate service to its customers (United Nations Conference on Trade and Development, 2022).

Monitoring the SDG targets for drinking water and sanitation will require a holistic approach and credible data to stimulate political commitment, inform decision-making, underpin sector advocacy and trigger well-placed investments toward sustainable access to water, sanitation and hygiene (WASH) initiatives. In addition, SDG monitoring systems will need to be robust enough to adapt to advances in technology and accommodate the capacity of stakeholders, especially national sector and regulatory authorities. The non-availability of spatially referenced data impends monitoring and performance evaluation water and sanitation services delivery. It is also a barrier to good planning and resources allocation in WSS sector (World Bank, 2017). Thus, the current trends in WSS is the development of the GIS based information system that allows for WSS utilities and regulators to ensure safe and secure water supply to protect public health and the environment, and support economic development and liveability; Effective sewerage services to protect public health and the environment, and to support economic development and liveability; Good service delivery that meet customer needs; and Expectations and preferences and financially sustainable water utilities with efficient and affordable pricing for services.

1.2. The GIS based information system

Within the water and sanitation utilities, when the relevant data are linked to a geographic location, some resources such as water sources, water reservoirs, pipes can easily be pinpointed. The use of Geographic Information System (GIS) also helps to identify and access the location and water usage models of the individuals. GIS allows users to query and analyse information based on its location and its spatial relationship to other features-often where no other relationship is available (Aning, 2021). Many of the challenges water utility face, like leaking pipes, long- term water supply, population growth in urban sectors, water loss, water quality etc., can be well monitored and well managed by developing a GIS to support the public and business needs. Functions are created in the GIS platform which makes it unchallenging to use visualization tools and allows the utilities to generate real business value across their operation areas (Aning, 2021). With the data received into the dashboard, it is possible to identify what is going on, where an activity is occurring and how best response are effective with the idea of seeing trends and better recognize what several clients or communities desire and how best they can be provided. GIS has stimulated more systematic and efficient water resource management methods, that identify and resolve specific and sophisticated water resource challenges, in order to ensure the stability of water supply sources and also to build an intelligent water management system (Aning, 2021).

The Management Information System (MIS) and Geographic Information System (GIS) framework has been developed to map, manage, and monitor water and sanitation systems with respect to other geographic features, including land base and in-plant features. The MIS and GIS frameworks supports systematic decisions making on geographic placement of water supply units such intakes, water treatment units, distribution reservoirs, distribution mains and service pipes, etc. and sanitation facilities such wastes disposal sites, public toilets, etc. (Russomanno & Yury Tritenko, 2010). This MIS and GIS Framework is the basis of the web-

based Water and Sanitation systems, allowing stakeholders to assess performance, progress and gaps in the sector of water and sanitation. The framework can be revised and updated annually to ensure relevance and to account for improved data collection and monitoring approaches in both systems. It is fully flexible, user friendly and expandable. Baseline and updated data is stored in a data warehouse, and can be presented/downloaded in geographical and tabular form for all geographical levels in any framework. The MIS and GIS framework for water sanitation systems can incorporate new indicators, additional data and more extensive queries.

Reports of indicators can be generated to get proper insight about the indicators so they can be used for decision making. In the design of this, seven basic sequential stages can be followed. These include: (1) identification of the information need, (2) collection of information, (3) classification of the information collected, (4) storage of information, (5) retrieval of data, (6) analysis of data and (7) use of data for decision-making. Such information helps aid the management in taking operational, tactical and strategic decisions. Some of the basic principles of MIS to be considered while designing MIS&GIS framework are indicated as under:

- Use of Log frame/result frame while designing MIS
- Periodical authentication and validation of data
- Periodicity of data reporting under MIS
- Data should be easily accessible to public/community
- Utilization of data
- User-friendly MIS website

The MIS and GIS framework associated to water and sanitation systems allow for a dynamic approach to assess sector performance in terms of functionality and sustainability. The system has been developed over time and it is expected that it will become demand driven and meet the changing needs of various users through accommodating new data and indicators. GIS integrate hardware, software, and data required to capture, manage, analyse, and display all forms of geographically referenced information. GIS allows the user to view, visualize, analyse, interpret, and understand spatial data in different circumstances and identify patterns, trends, and relationships and present the outputs in the form of reports, maps, and charts[1]. The GIS system includes a sequence of maps and applications structured on a common information model, which is designed to work across several disciplines and help water professionals to support daily utilities, in addition to a wide range of operations and workflows (Fathy, 2014).

A major requirement of the MIS and GIS framework for water and sanitation systems is that the sector becomes more aligned with the needs for provision of data that support the planning, monitoring performance indicators, investment decision making, etc. The dispersity of data in the various utilities' information systems, as well as the high number of performance metrics related to water supply systems, has motivated the utilities and regulators to establish a system

[1]https://ctb.ku.edu/en/table-of-contents/assessment/assessing-community-needs-and-resources/geographic-information-systems/main

of information which is GIS based which can help graphically present the utilities data in order to facilitate the decision-making process (Grueau, et al., 2019). For instance, the overlay analysis combing houses footprints or land use dataset, public facilities and data on WSS could highlight public facilities without access to water or sanitation. A GIS based information system include various tools like dashboard and web applications that facilitate the decision-making process, based on user-defined filtering and offers the options for graphical representations of a set of data in different forms such as charts and maps (Veenendaal, et al., 2017).

The GIS online helps track overall progress towards SDG related to water and sanitation at global, regional and national levels. It enables assessment and analysis of the state of access to water and sanitation services and linkages to other sectors. The use of GIS based information system helps improve SDG monitoring and reporting at all levels and catalyze actions for improvement of services delivery (Mondejar, et al. 2021). Through this assignment, the main aim is to develop a framework that will be used for by utilities and regulators in the Eastern and Southern Africa along with the fulfillment of their missions in water and sanitation sectors. The information system will address the challenges faced by the WSS sector and promotes the long-term sustainability of urban WSS services by responding to the general lack of up-to date information, generating important information, evaluating the performance of service providers, and improving the overall effectiveness of technical assistance.

1.3. Objectives

The general objective of this work is to strengthen Information systems and database management and development for strengthened water and sanitation sector utility regulation. The work will support development of a water and sanitation services knowledge base and regulation information management system to be implemented in selected utilities. Such a knowledge base would support the models for operations and planning and comprise a widely available information resource on performance of the utilities. The information system will be GIS-based, using freeware, and would be available on the web. Its relevance in WSS sector can be summarised as follows:

- **WSS GIS-based MIS for utilities and regulators**

This WSS GIS is a web-based system that uses GIS technologies to collect, process and analyse and visualise data on water and sanitation in the forms of maps on coverage, functionality, quality, quantity, source type, etc. Those data should be up to date, reliable, complete, accurate, relevant, customized and well-integrated with other relevant non-spatial, including those collected by other agencies like the municipalities, organisations in charge of population census, etc. They have to be collected based on the JMP which is designed to track progress towards a basic level of service, and used for global monitoring of SDG targets for WSS (UNICEF and WHO, 2022). The information derived from the analysis can be used in making decisions related to investment planning and operational monitoring, tariff setting, licensing, consumer protection; monitoring effluent, water supply and other standards; sets standards for effluent,

water supply and FSM. The table below shows some of spatial data which should be collected and included in the web-based system and the purposes for their use by both the utilities and regulators.

Table 1: Key spatial data for the web-based system

Required data	Use	Utilities	Regulators
WSS network coverage (all related spatial data, including Water supply systems with individual connections, standpipes and kiosk, etc. and Sewer systems or FSM with onsite sanitation: septic tanks, pit latrines, etc.)	Investment decision	√	
	Informing national policy and financing decisions		√
	Utilities accountability for implementing service delivery mandates	√	√
	Sets standards for effluent, water supply and FSM		√
	Monitoring water supply, effluent, and other standards	√	√
Utilities service areas	Investment decision	√	
	Utilities accountability for implementing service delivery mandates	√	√
Customers connected to water supply and sewerage systems	Investment decision	√	
	Informing national policy and financing decisions		√
	Utilities' service delivery performance	√	√
Installed capacity and water production (quantity)	Utilities' service delivery performance	√	√
	Tariff setting		√
Water Quality (area of sampling and test results)	Utilities' service delivery performance	√	√
	Consumer protection		√
Water supply service hours	Utilities' service delivery performance	√	√
	Utilities accountability for implementing service delivery mandates		√
Waste production (quantity) and installed sewerage treatment	Investment decision	√	√
	Informing national policy and financing decisions.		

Required data	Use	Utilities	Regulators
capacity, volume treated	Utilities' service delivery performance	√	√
	Tariff setting		√
Non-Revenue Water	Utilities' service delivery performance	√	√

The regulators are generally mandated to undertake both economic and technical regulation of WSS service provision to ensure a balance between the quality of the service, the interests of consumers and the financial sustainability of the providers (ESAWAS, 2018). They can help to improve the quality of urban WSS. Areas of engagement include the regulation of utilities providing sanitation and water supply services (that can allow for the utilities to improve the service delivery) and provision of guidance on setting the tariffs. Both regulators and utilities can collaborate and coordinate data collection and management. This includes data collection, resource mobilization, execution of data collection processes, capacity building and creation of integrated information management systems for evidence-based decision making. The purpose for collecting and maintaining data which are accurate and update was highlighted during the consultative meeting on regulatory information management systems, held in Nairobi from 23 to 26 January 2023 as shown on the extract from the presentation made by ESAWAS executive secretary as follows:

Figure 1: Purpose for data collection on WSS

The GIS-based information system can support the existing instruments and tools which are applied by the regulators to collect all data which are relevant for the purposes indicated on the above figure.

❖**Spatial data plays a crucial role in assessing the national performance**

Through the analysis of the distribution and availability of water supply and sanitation services, regulators as well as utilities can identify areas where there are significant gaps in access to clean water and sanitation facilities. GIS and spatial data also are used to monitor the progress of water supply and sanitation projects and their impact on communities through measuring the spatial distribution of related facilities. The spatial statistics generated through GIS functions allow to determine the rate of access and spatial coverage of the infrastructure and the general picture about the performance of the WSS sector. GIS can also help in tracking changes in access to water and sanitation services, by combining data on WSS, population and other customers. For example, mapping the locations of water supply and sanitation facilities help identify areas with limited coverage and where additional investments or interventions are required. GIS can also help in tracking changes in access to water and sanitation services, by combining the related population and other customers' data. Information about access to water and sanitation can help in decision making and ensuring that resources are allocated efficiently and effectively, taking into account the needs of the customers.

❖**Spatial data plays a critical role in prioritisation**

The use of GIS allows for analysing the accessibility and distribution patterns of water and sanitation services by the regulators as well as the government agencies. They can identify areas where there is a need for improvement and make decisions about the allocation of required resources. In the case a particular region experiences a high incidence of waterborne diseases, regulators and policymakers can use GIS and water and sanitation data to identify the relationship between the area of contamination and the level of water and sanitation service coverage. If GIS analysis results reveal a low level or lack of water and sanitation services, some measures consisting of increasing the access to clean water and waste collection services will be taken. In addition, GIS analysis functions help to identify areas with the greatest need for infrastructure improvements, such as expanding water treatment plants or upgrading the aging water distribution pipes. Those analyses inform decision making on prioritization of the investment and the target areas for new interventions, and therefore maximizing the use of limited resources as well as improving their outcomes for communities.

❖**Spatial data plays a crucial role in planning and defining the sector requirements**

GIS technology enables the visualization and analysis of spatial data, which is essential for identifying suitable locations for water supply and sanitation facilities. It allows for undertaking an in-depth analysis of valuable information on topography, land use, and population density

and distribution, which are all critical factors in the planning and designing of water infrastructure. Through GIS applications, the utilities and regulators can identify areas with high water demand, such as densely populated urban areas, and design appropriate water treatment and distribution systems to meet the WSS needs. Similarly, GIS help identify suitable sites for sewer network and sewage treatment plants based on factors such as proximity to population and other categories of users, topography, and land use, soil types, etc.

❖**Spatial data is used to inform investment and financing decisions**

The availability of reliable and accurate spatial data and use of the GIS analysis functions enable the utilities and regulators to make informed decisions about investments in water supply and sanitation infrastructure. This includes determining what kind of infrastructure is required, and the expected impact of the investment on access to water and sanitation services and the calculation of the investment which is needed. For example, spatial data are used to identify areas where there is a high demand for water and sanitation services or low access and to determine the amount of investment which is targeted to those areas. Data can also be used to identify areas where there is a high risk of water contamination, enabling investment in water treatment infrastructure or water resources protection. Spatial data on WSS are also used to track progress and assess the impact of investment in water supply and sanitation. This includes monitoring changes in access to water and sanitation services over time and assessing the impact of investment on health outcomes and economic development. GIS is used to identify pro-poor areas that require investment in water and sanitation infrastructure. For example, based on socio-economic data, in combination with spatial location of households, it is possible to identify areas with high poverty rates and low access to water and sanitation services, allowing financing commitments to be directed towards these areas.

❖**Data for informed decision making: forecasting for the future**

The climate conditions can have impacts on water supply and sanitation services delivery. Some water sources like the groundwater and surface waters systems are often vulnerable to the extended dry periods. Piped distribution networks can be vulnerable to contamination and at the increased risk where more frequent flooding occurs. In drying environments, piped water supplies can be intermittent unless some resource management measures like the conservation of the water sources are undertaken. With increased rainfall, household-managed sanitation may contribute to the local groundwater contamination. In some areas, the lack of sewage treatment can have significant adverse impacts on health and environment and this can be aggravated by climate change if this increases flooding of sewers and overloading of treatment facilities. The collection of spatial data on WSS and their analysis, in combination with various thematic data can inform decision about water source management decision, regaling the protection, the prevention of risks induced by climate change, etc.

2.Methodological approach

The applied methodology for developing a conceptual framework for a GIS-based water and sanitation management system that will strengthen the water and sanitation regulation system in the ESAWAS operating region is described in this chapter. The methodology comprises three (3) main components, namely: Literature review, data collection, data analysis and development of a GIS-based water and sanitation management system.

2.1. Literature review

This step consisted of reviewing the existing publications related to water and sanitation management system, especially literature related to the following in the selected countries (Kenya, Tanzania and Zambia):

- Institutions involved in the water and sanitation,
- Institutions in charge of water and sanitation management: Organizational framework,
- Assess the existing online WSS management system: according to the client, the assessment was based on the systems which are in use in Kenya, Tanzania and Zambia in order to provide recommendations on ways of enhancing the data management system,
- Responsibilities of actors engaged in the information management system.

2.2. Data collection and analysis

Data collection consisted of gathering required information that will enable measuring and analysing accurate status of existing information related to water and sanitation management systems.

- Survey design: a number of questions were defined to collect information related to water and sanitation management systems:
  - ICT infrastructure for data management and publication
  - Organization hosting data published online
  - Content management system for data hosted on website
  - Organization role existing IMS
  - Database management system in use
  - Staff knowledge and skills on GIS
  - Presence of Geospatial portal for information management and sharing
  - Capacity building needed for developing a Geospatial portal

- Characteristics of the desired Geospatial portal
- Roles of utilities in Geospatial portal administration
- Data format (produced at the organization)
- Format of data (acquired from other organization) and description
- Data manipulation software
- GIS data collection and updating
- Data compliance with the ISO 55000:2014 standards

As for the spatial data related to WSS and which are held by the regulators, and the utilities, they were explored on the computers through visualization and check of the attribute tables, in the respective offices, and were not collected (the custodians could not share in their digital format with regard to the existing restrictions) for their use in the framework design. In order to conceptualize and design the GIS based information framework that can be proposed for ESAWAS and the regulators, defaults representing fort instance the water network were created and used for the system design.

Some of the questions relating to different data which are collected on water and sanitation, the system of data management. Questions related to the system functionalities and its administration were asked to the participants to the interviews, while others were asked through a google form questionnaire sherd with the respondents. The questionnaire covered the following topics: system of data management, data publication, the ICT facilities, the needs for establishing they GIS system, etc. During the field survey, three regulators (WASREB in Kenya, EWURA in Tanzania and NWASCO in Zambia) were the main targets for the survey as they were selected for representing other regulators. Their selection was informed by the existence of the web-based MIS which helps in undertaking the performance monitoring and annual reporting that has informed the design of the GIS based information system that will be suggested to all regulators. The information about the functionalities of those MIS and the types of managed datasets were collected and analysed to ascertain the possibilities to migrate to the GIS-based information systems.

The work was carried out with consideration of the following steps:

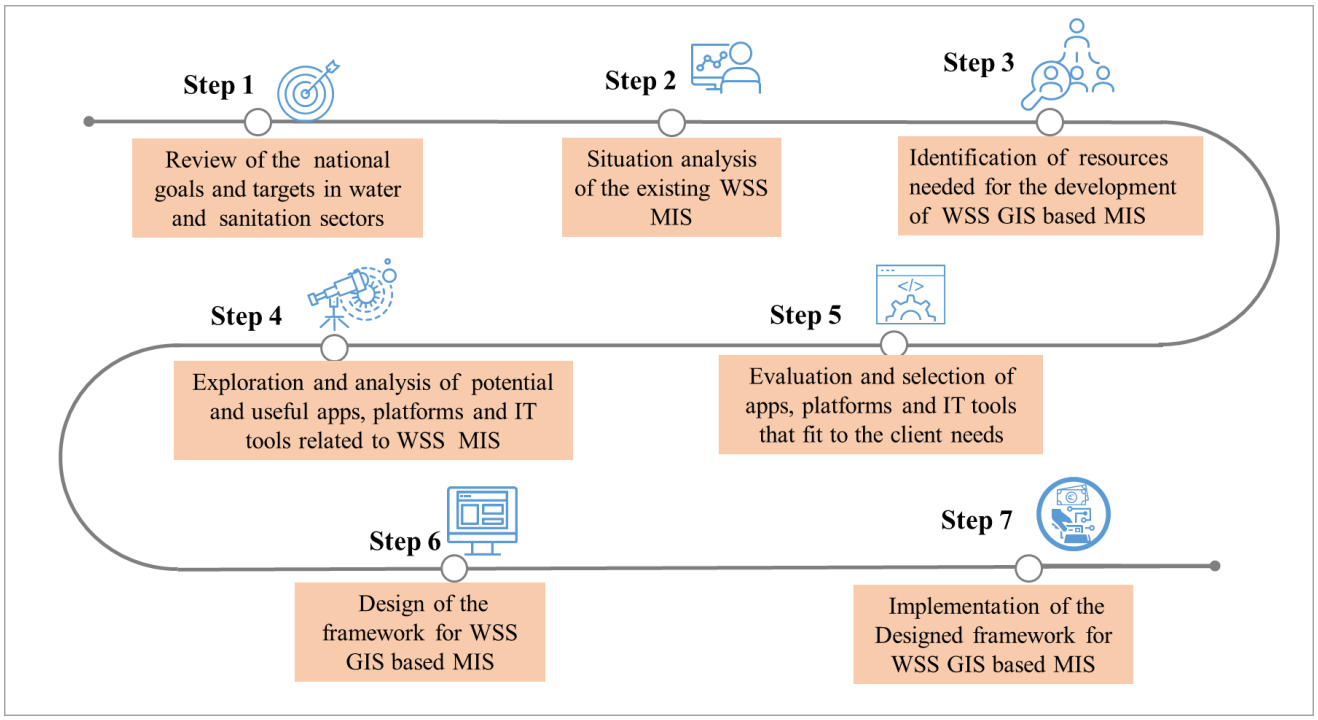


Figure 2: Steps guiding the assignment

Step 1: Review of the national goals and targets in water and sanitation sectors

The collection of reliable and updated data is required as they allow for monitoring progresses or country achievement in water and sanitation sector. The collected data are used by the agencies responsible for provision in water supply and sanitation services, and maintenance of the related systems. The regulatory framework for water supply and sanitation in the country relies also on those data. A review of the national goals and targets in water and sanitation sectors is therefore relevant as it allows to identify the key types of data required for developing the related IS which is required for monitoring WSS performance, making decision about relevant investments, etc.

Step 2: Situation analysis of the existing WSS MIS

- Review of the existing information systems for managing data on water and sanitation, their components, functionalities and operations in terms of data collection, storage, updating, etc.
- Identification of the existing data and information on water and sanitation services and critical analysis on their format, quality and the resources used to produce them;
- Identification of all producers and users of data and information on water and sanitation services;

The situation analysis was done during the visit of the agencies in charge of water and sanitation regulation and management. The visited agencies are presented in the table below:

Table 2: Visited agencies during the field survey

Country	**Target institution**	**Location**
Kenya	WASREB, and Trust Fund	Nairobi
Tanzania	EWURA, Dar es Salaam Water and Sewerage Authority (DAWASA) and the ministry of water	Dar Es Salaam
Zambia	NWASCO, Lusaka Water Supply and Sanitation Company (LWSC) and the Ministry of Water Development and Sanitation (MWDS)	Lusaka

Step 3: Identification of resources needed for the development of WSS GIS based MIS

- Identification of IT resources, human capacity, data
- Analysis of the migration of information systems for managing data on water and sanitation services to GIS based systems
- Diagnosis of the situation in the collection, processing, reporting and sharing data.

Step 4: Exploration and analysis of potential and useful apps, platforms and IT tools related to WSS MIS

- The existing applications, tools and systems which are widely used in developing and management of WSS MIS will be explored.

Step 5: Evaluation and selection of apps, platforms and IT tools that fit to the client needs

This step consisted of identification of applications, platforms and IT tools that fit to the client needs. Consideration will be paid to the open sources software and tools and missions of the regulators and targets of the utilities. The proposed apps, platforms and IT tools should facilitate the migration of the existing data to the integrated GIS database with a validation procedure to ensure integrity and the correction of the data.

Step 6: Design of the framework for WSS GIS based MIS

On the basis of the results from steps 1 to step 5, a framework for a GIS-based web portal development has been proposed and the hosting institution. The proposal of the hosting institution is based on the existing framework of the existing MIS administration and the national and inter-institutional regulations of data management and sharing.

Step 7: Implementation of the WSS GIS based MIS

The study identified the requirements (human capacity and other required resources) for the implementation of the proposed GIS-based web portal. The related costs estimated include the

IT tools at the regulator levels, the setting up of the system, and the training of the users. A crucial component of the implementation process is the integration of the Geoportal with the existing system of the information management, focusing on effective incorporation of data into policy design and decision-making processes, promotion of the GIS as the data and information management tool.

2.3. System design: ISO 55000 :2014 consideration

To successfully establish a multi-functional information geoportal, the integration of diverse data sources and systems, development of data sharing policies, and implementation of security measures are crucial. The geoportal should adhere to standards guaranteeing data discovery, accessibility, and interoperability. The ISO 55000:2014 standard offers guidance on aligning the data management strategy with the geoportal's objectives, focusing on frameworks for collecting, storing, and sharing geospatial data while ensuring quality and consistency, defining roles and responsibilities, implementing data protection measures, and ensuring data accuracy through quality protocols.

The table 3 below outlines how the different sections of ISO 55000:2014 can be applied to spatial data collection and sharing, and how they can inform the specifications for the establishment of a multi-functional information geoportal.

Table 3: Adaptation of ISO 55000:2014 for a multi-functional information geoportal

ISO 55000:2014 Guidance	**Application to Spatial Data Collection and Sharing**	**Implications for Multi-functional Information Geoportal**
Understanding the context of the organization	Identifying the needs and expectations of stakeholders, including those related to spatial data. Ensuring that spatial data collection and sharing align with stakeholder needs and expectations	Incorporating stakeholder feedback into the design and operation of the geoportal
Leadership	Establishing a clear asset management policy and strategy regarding data collection, management, and sharing	Developing a policy and strategy for data collection, management and sharing through the geoportal
Planning	Establishing objectives and plans for spatial data collection and sharing	Developing a plan for the collection, management, and sharing of spatial data that aligns with the overall asset

ISO 55000:2014 Guidance	Application to Spatial Data Collection and Sharing	Implications for Multi-functional Information Geoportal
		management plan for better data discovery and accessibility
Support	Providing the necessary resources, including personnel and technology, to support spatial data collection and sharing	Ensuring that the necessary resources are available to support the collection, management, and sharing of spatial data through the geoportal
Operation	Implementing the plans and procedures for spatial data collection and sharing	Operating the geoportal to collect, manage, and share spatial data in accordance with established plans and procedures
Performance evaluation	Monitoring and evaluating the effectiveness of spatial data collection and sharing	Assessing the effectiveness of the geoportal in collecting, managing, and sharing spatial data, and making improvements as necessary
Improvement	Continually improving the performance of the organization, including its spatial data collection and sharing practices. Openness toward new technologies for spatial data collection and sharing	Continually improving the performance of the geoportal in collecting, managing, and sharing spatial data, and ensuring that it remains aligned with stakeholder needs and expectations and the overall asset management strategy and policy. Embrace new technologies for efficient and effective data management and sharing through geoportal

The concept map in Figure 3 below visually represents the tasks and subtasks needed to establish a Multi-Functional Information Geoportal. It shows the connections among four essential tasks - Data Integration, Security, Data Management, and Data Sharing - and highlights specific subtasks and considerations involved. These tasks and subtasks should adhere to the ISO 55000:2014 guidelines, providing guidance on developing a comprehensive data management strategy aligned with the geoportal's objectives. Generally, any geoportal design considers this map to ensure a comprehensive approach to data collection, sharing, management, integration, and security in alignment with ISO standards.

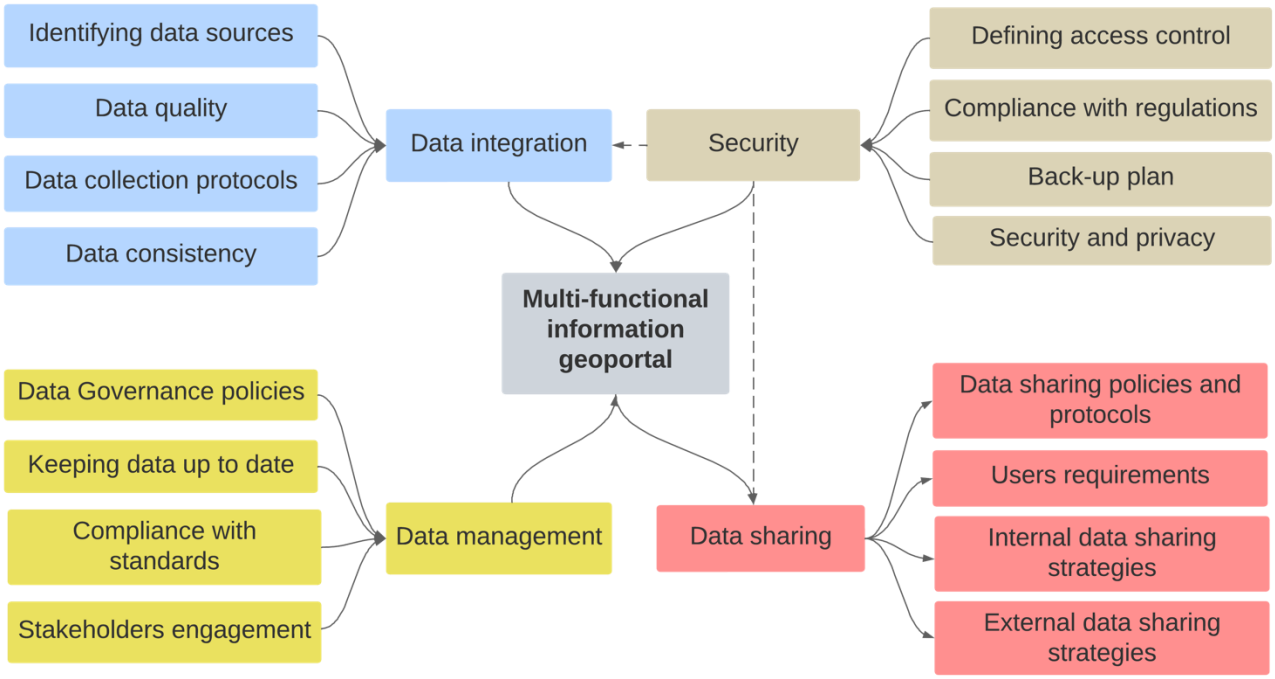
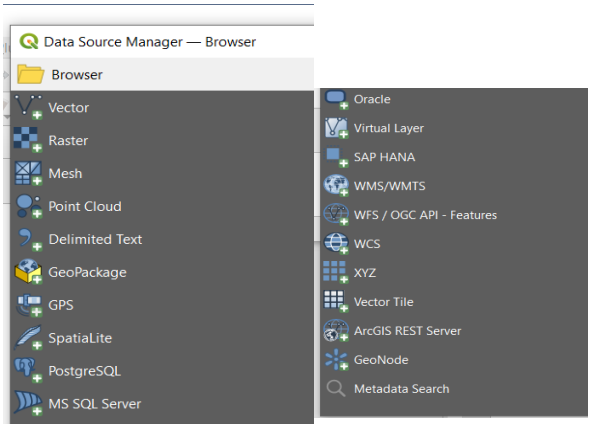


Figure 3: Concept map for creating a Multi-Functional Information Geoportal

For the GIS based information system (Geoportal and dashboards for water supply and sanitation), the following functional and non-functional requirements are also taken into account and complement the above concept map while taking into consideration the ISO 55000:2014 standard:

Functional requirements include the following:

- **Data Integration:** the system should enable data integration from various sources, including water meters, customers, customers' complaints, maintenance, water and sewerage distribution networks, and supply capacity. In the proposed system it is possible to do data integration by combining spatial data from different sources and formats into single datasets. In QGIS desktop, this functionality is implemented in the "Data source Manager" as follows:



The system should also have the ability to update and synchronize data in real-time to ensure that stakeholders such as regulation authorities, utilities and other relevant government bodies have access to the updated information. Data update and synchronization can be done either directly in the database by authorized user or in the QGIS desktop and QField application.

- **Spatial Analysis:** the system should offer spatial analysis capabilities, allowing the overlaying and comparison of data from different sources. For example, it can overlay water quality testing results with a service area map to identify areas with poor water quality, helping prioritize maintenance and repair work. Additionally, the system can generate maps and visualizations to enhance stakeholders' understanding. In the proposed system, this functionality is also available. Examples of spatial analysis presented in the user manual.
-
- **Data Visualization:** user-friendly interfaces in the system should facilitate data visualization in various formats, like maps, charts, and tables. For instance, stakeholders can create maps depicting water supply and sanitation infrastructure, aiding them in visualizing the distribution of facilities in the service area. Real-time reports and visualizations allow for keeping the stakeholders informed. In the proposed WSS, system data can be visualized in QGIS desktop, and in the geoportal as maps, online maps and dashboards.
- **User Management:** the system has to incorporate user management features, allowing the administration of user access and permissions. It ensures that only authorized users can access and edit data, with the ability to set up different user accounts based on varying levels of access. User activity tracking prevents unauthorized changes to data. In the proposed system, this functionality is implemented in the component where different roles have been defined.
- **Data Search and Retrieval:** data search function should be provided to retrieve relevant information from different modules. For example, stakeholders can search for customer

complaints related to water quality issues in specific areas to identify patterns and trends. The system also includes filtering and sorting capabilities for easy data access. This functionality is available in different component of the system. Data search and retrieval can be done in the database management system (select * from the_table_name where Exression_name), in the QGIS desktop and in the geoportal.

- **Reporting:** the system should allow the generation of reports in PDF, Excel, and CSV formats. Stakeholders can generate reports on specific metrics, such as the number of customer complaints related to water quality issues, to identify areas requiring improvements. Reports can be customized to cater to the needs of different stakeholders. This functionality is in GIS desktop and geoportal where information can be exported in different formats such as Excel, pdf, CSV and maps.
- **Data quality**: this has to be the priority for the system, offering validation, cleaning, and maintenance features. Validation rules can be set up to ensure correct data entry, such as adherence to acceptable water quality testing limits. Data quality is monitored over time to ensure accuracy and currency. This functionality is available in the proposed system where different roles for data entry, data quality check and data validation are well defined.

Non-functional requirements include the following:

- **Security:** The system must implement measures to prevent unauthorized access, modification, or data loss. These measures may include data encryption to protect sensitive information, access controls, firewalls, and intrusion detection systems. Additionally, data backups and recovery plans should be established to minimize data loss in case of system failures. This requirement was developed in the “System security management”.
- **Performance:** The system should efficiently handle large data volumes and user requests in real-time. For example, it should promptly display water supply and sanitation data to identify issues like leaks or blockages. In the database management system, PostgreSQL, can handle very large database. To reduce its load in the CPU, the PostgreSQL is used as a data storage, while sophisticated operations are performed in the GIS Desktop and in the Geoportal for published data.
- **Scalability:** The system needs to be scalable to accommodate future data and user demands. As the service area expands, the system should handle additional water supply and sanitation infrastructure data. It should also accommodate more users and data sources, such as new IT devices or mobile apps. This requirement is implemented in the database management system. The PostgreSQL doesn't just store information about tables and columns. It lets the user define data types. For example, in a given

field, user may define what type of data that must be captured. This helps to avoid typos in editing data.

- **Usability:** The system should be user-friendly and easy to navigate, catering to users with varying technical expertise. It must have a dashboard with intuitive data visualizations, allowing users to quickly understand the water supply and sanitation system's status. Usability requirements should include user training, manuals, and online help. The user manual for the system was developed (see appendix) and cover various steps from the system installation to the spatial analysis and data publication.
- **Interoperability:** The system should integrate seamlessly with existing systems and technologies. Interoperability requirements include using standard data formats and Application Programming Interfaces (APIs) for smooth data exchange. For instance, the system should be able to share data with billing or financial management systems.
- **Availability:** The system must remain functional at all times, ensuring continuous access to data and information. Regular monitoring is necessary to address any issues promptly. Redundant servers and data backups should be in place to minimize downtime during system failures. It is a best practice to regularly make a copy of the main spatial database. This backup can be automated using python script which will run Windows Task Scheduler. The backup storage should be different from the copied main database.

The next chapter provides an overview of the GIS based Water and Sanitation Portal components and considerations.

3. GIS-based Water and Sanitation Portal

GIS-base Portal, or Geoportal is a web framework enabling discovery and use of spatial data over internet (Mehdi, et al. 2014). Water and Sanitation Management Information System is the process of developing a GIS-based water and sanitation portal in a bid to manage water and sanitation resources, both terms of quantity and quality across all water and sanitation uses. In this way it is aiming at optimizing the benefits of water and sanitation by ensuring decision makers are well informed about the service delivery (for example there is enough drinking water, adequate sanitation services), and hence they can well develop appropriate policies aiming at addressing issues related to water and sanitation in any given geographic area. This section outlines how a GIS-based water and sanitation management information system will be structured as shown in the figure below.

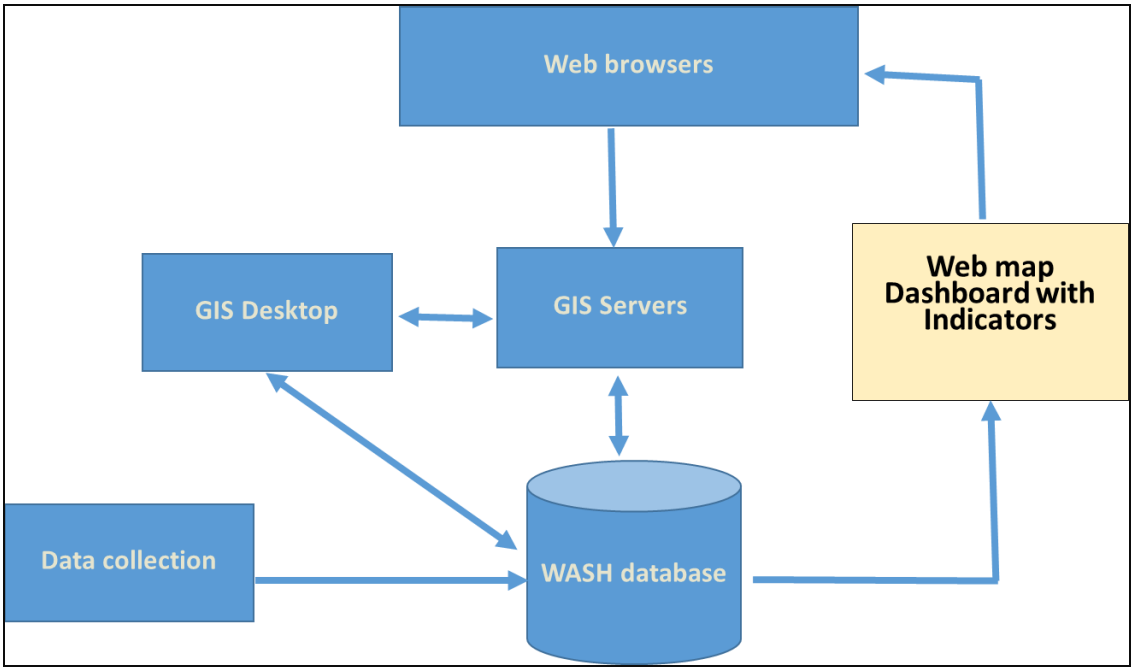


Figure 4: Structure of GIS-based water and sanitation management information system

The Information System is expected to provide reliable information enabling a comprehensive management approach to urban WSS with a strong focus on the service delivery. It will allow to generate the information that define sustainable and efficient provision of WSS services in four ways:

- **Access to water and sanitation services** which reflect the services in relation to the users or the public;
- **Quality of service** relating to the functionality of **water and sanitation systems** and physical condition of the infrastructure serving the users or the public;

- **Performance of service provider** as a function of their level of organization, commitment to operation and maintenance, and financial sustainability;
- **Effectiveness of technical assistance,** reflected in the use of Information System for efficient management of WSS facilities, and support of decision-making for any related interventions.

The system will allow for data analysis and generation of performance indicators that are aggregated at several levels and automatically used to produce the rankings and summary reports detailing the variables that factor into the performance of utilities or service providers, and technical assistance. Some of the indicators that can be used to measure the performance of the WSS services are presented in the table below:

Table 4: Performance aspects of water supply

Performance aspect	**Description**
Water producers and providers	Water and sanitation service providers
Water source	Water sources include piped water, boreholes, protected dug wells, etc.
Water production	Quantity (m^3) of produced water by source and treatment plants
	Water production cost
Water demand	Quantity (m^3) of water needed in relation to the number of consumers/users
Water service level and coverage	% of covered population by improved water pipes
	% of households with drinking water from an improved water source that is accessible on premises
	Number of public taps per population
	Public and private agencies with water connection
	Distance to water kiosks/potable sources
	% of households collecting water from an improved source, 30 minutes round trip collection time including queuing
	% of households collecting water from an improved source, within more than 30 minutes for a roundtrip including queuing
	% of households using water from an unprotected dug well or unprotected spring
	% of households using water directly from a river, dam, lake, pond, stream, canal or irrigation canal
Water quality	Level of pathogens and toxic chemicals
	% of acceptable bacteriological quality
Tariff	Different tariffs according to user type: residential,

Performance aspect	Description
	commercial, industrial, public.
	Water tariff by users' categories
Water supply performance	% of functional water pipes and kiosks compared to their total lengths and number
	Water produced
	Water supplied to consumers
	Quantity of Non-revenue water
	Water supply service time

Data source: Giné-Garriga, 2018; UNICEF, 2019 &2021; and UNW-DPAC, 2015.

Some of performance aspects of sanitation services that GIS based information system can help in tracking including the following.

Table 5: Performance aspects of sanitation services

Performance aspect	Description
Service providers	Sanitation service providers
Service types	Waste collection, treatment, etc.
Waste production	Quantity (m^3) of produced waste by users
Waste collected demand	Quantity (m^3) of waste collected in relation to the quantity of waste produced by customers
Sanitation service level and coverage	% of covered population by sanitation services within any location
	Public facilities with functional improved sanitation facilities
	Community coverage of improved/safely managed sanitation
	% of households with access to improved facilities that are accessible on premises and not shared with other households and where excreta are safely disposed of in situ or removed and treated offsite
	% of households with access to improved facilities which are not shared with other households
	% of households with access to improved facilities which are shared between two or more households
	% of households with access to improved facilities which are shared between two or more households
	% of households using the pit latrines without a slab or platform, hanging latrines or bucket latrines
	% of households disposing human faeces in fields, forests, bushes, open bodies of water, beaches and other open spaces or with solid waste.
Latrine sanitary	% of public latrines that are maintained in adequate sanitary

Performance aspect	Description
conditions	conditions.
	% of households having the handwashing facility with soap and water in the premises
	% of households having the handwashing facility without soap or water
	% of organizations whose latrines have the handwashing facilities without soap or water
Handwashing	% of public latrines that are equipped with handwashing facilities and soap
	% of public latrines that are not equipped with handwashing facilities
	% of organizations whose latrines are not equipped with handwashing facilities
Tariff	Different tariffs according to user type: residential, commercial, industrial, public.
Sanitation services performance	% of collected waste compared to their total quantity produced by customers
	Waste collection service time

Data source: Giné-Garriga, 2018; UNICEF, 2019 &2021; and UNW-DPAC, 2015.

3.1. GIS-based Water and Sanitation Database Management system

A database management system (DBMS) is a computerized solution that helps store information in a way that is easy to read, edit, delete, and scale. The primary objective of a database management system is to enable users to establish the relations among stored data, powering analysis of the data, and supporting data-driven workflows (Li, et al., 2020). The database management system links together the databases and the end users or application programs by making sure that the data is always organized and easy to find or search. Data managed by the DBMS is accessible, locked, and modifiable by the database engine, and has a logical structure defined by the database schema. Another feature of a DBMS is to provide concurrent execution operations, but also data security and integrity. It offers a centralized view of the data that may be accessed by several users from numerous places. It can restrict both what data and how the end user can view the data by managing all requests, so that end users and software programs do not know where the data is physically housed or what kind of storage medium it lives in. It means that it can protect data from being altered without the permission of the administrator. The data in the database is kept as a two-dimensional table composed of rows (also called tuples) and columns (also called Attributes or fields). The way in which two or more tables or datasets are linked is called “relationship, and the relationship between tables can be defined as follows:

- One-to-one relationship
- One-to-many relationship and

- Many-to-many relationship

The key benefits of defining relationship between datasets include the following:

- Data easily retrieved/queried/filtered in a categorized relational database
- Collaboration: Users may for example be updating one table, and edited data is visible to different user
- Security: Security of data is well managed.

There are different DBMS such as Microsoft Access, MySQL, Oracle Database, MongoDB, PostgreSQL/PostGIS, amongst others. Through this assignment, those DBMS will be analysed in order to select the most fulfilling the ESAWA needs and compatible with the Open GIS desktop software described in the next chapter.

3.2. GIS Desktop software (Open sources)

Desktop GIS software are programs that are installed onto and run on a personal computer and allows users to display, query, update, and analyze data about geographic locations and the information linked to those locations. These locations may be represented in form of point, line or polygon. All desktop GIS programs have the same core functionalities which are the following:

- Adding Layers: multiple layers are stacked up on top of each other to make a map.
- Styling or symbolizing layers: Each layer is symbolized to control its appearance in a map.
- Labels: Information linked to the geometry (Lines, points and polygons) can all be labeled in a GIS. The label can be made up of one or more attributes from the feature that's being labeled.
- Creating Selection Sets and queries: A selection set is a subset of features within a layer. Selection sets are used to visualize a particular group of features or to perform spatial operations such as aggregating, editing or deleting. Selection can be processed using a query on attributes or a query based on spatial relationship between different spatial data or features.
- Editing and Managing Data: A GIS software allows user to add, edit and delete features. The same operations are applied to the attributes or data linked to the features.
- There are various GIS software but, as required by ESAWAS, the attention will be paid to free GIS software that can:
  - ✓Perform hundreds of advanced GIS processing tasks.
  - ✓Generate stunning cartography and mapping products.
  - ✓Manage ESAWAS's geospatial assets and non-spatial data efficiently.

It is worth mentioning the two most used desktop GIS programs by far are ArcGIS and QGIS. Both offer similar functionalities but there are some major differences in terms of how they are distributed and their surrounding ecosystems. QGIS is free and popular, with a very large number of very active supporting community. It can be downloaded and installed for free without restriction, whereas ArcGIS for Desktop works only on windows, not free and

supported by the commercial company. In this assignment, it will be necessary to check most popular free GIS software, compare their functionalities and propose the most fulfilling requirements for handling ESAWAS geospatial data.

3.3. GIS Servers

GIS Server play a fundamental role in spatial data mapping, analysing and management for n organization. GIS server is used to publish services and host layers to either connected or disconnected deployments (Peggion, et al., 2008). GIS Server is a back-end component part of a Database Management System and allows anyone to centrally manage, publish and serve map layers and associated data online. The browser on the other hand is the client-side (front-end component) that is used to call the web services from GIS Server. This communication between the server and client happens through HTTP requests from the client to server.

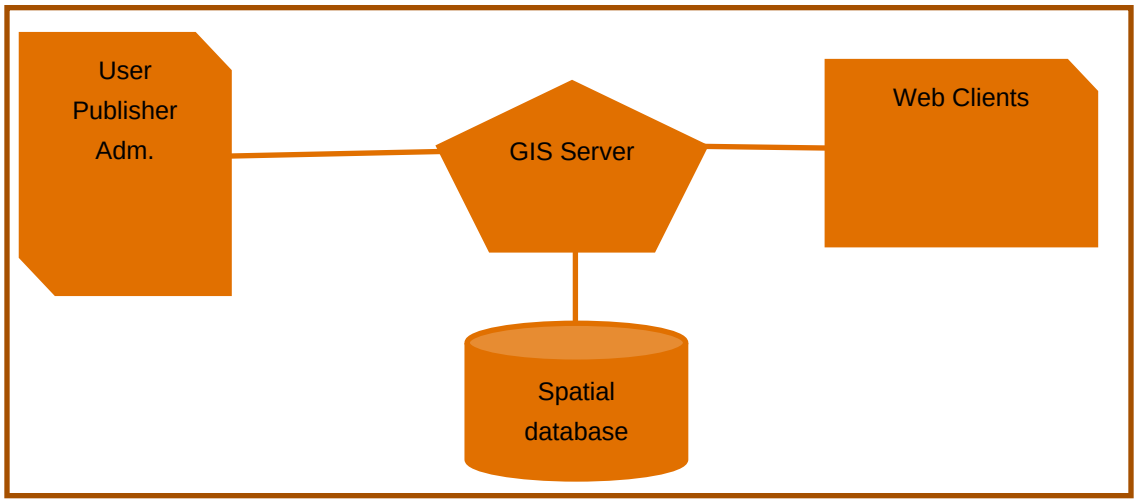


Figure 5:GIS Server and related components

It's through GIS server that the publisher and/or the geospatial administrator publish web mapping services. By definition, Web Mapping services (WMS) are the geospatial data hosted through the internet and complying with standards as set by the Open Geospatial Consortium (OGC)[2,3].

Web Mapping Services are of different types such as the following:

- Web Map Service (WMS): It enables the exchange of spatial information and viewing over the web in the form of a map or image to the web browser.
- Web Feature Service (WFS): It enables the capability of creating, manipulating, deleting, attributes editing and querying feature layers to retrieve their respective information.

[2] https://www.ogc.org/standards/wms

[3] https://docs.qgis.org/3.22/en/docs/user_manual/working_with_ogc/ogc_client_support.html

- Web Coverage Service (WCS): It enables performing requests on multidimensional raster data.

The report of this assignment will include clear details on how these different Web Mapping Services will be implemented in the GIS-based ESAWAS spatial database Management Information system.

3.4. Data accessibility via web services

Geospatial data can be stored on a local device or hard drive. But to be accessed by remote users, it needs to be saved on the cloud which makes the data to be accessed from anywhere and anytime (Yang, et al., 2017). In fact, cloud allows teams and organization to work on a common project across locations by giving them access to the same datasets. But the big challenges that need to be addressed during the implementation of a GIS-based Management Information system are the following:

- Dependency on internet connection: A user may not be able to access the data on cloud without a good internet connection.
- Security risks: With hackers increasingly targeting cloud storage to gain access to sensitive business data, this might be an even greater concern, for which the appropriate measures need to be taken.

There exist some platforms for the management and publication of geospatial data. These platforms are called “Open source Geospatial Content Management System (CMS)”. They bring together data and open-source software projects under a consistent and easy-to-use interface allowing users to share data and create interactive maps. The Geospatial CMS have core features which are the following:

- Spatial data storage with true geometry data types
- Creation of data types from within the Drupal Graphical User Interface (GUI)
- Integrated online editing of geospatial data
- Data publishing with integrated maps
- Configuration of map layouts and behaviours
- Symbol styling
- Data publishing through OGC standards-compliant web services (OWS) like WMS and WFS
- High performance map output through GeoWebCache
- Transparent privilege handling and security for all spatial data
- Content publication workflow and revision moderation
- Basic metadata collection through access to GeoServer-GUI
- Full extensibility through other modules or individual programming languages for visual customization
- Interactive Dashboard development: A dashboard is a web page that provides summary of published datasets.

- The dashboard is built with widgets available in the Geospatial CMS. Data on the dashboard are interactively linked to the database. Once data in the database is modified, indicators on the dashboard are changed as well. That is why the dashboard is graphic, easy-to-read form, of key information relating to progress and performance. This will be a good tool that the decision makers will use to monitor performance in water and sanitation sector.

All the above specified core features of a Geospatial CMS are implemented through the OGC standards: Web Map Service (WMS), Web Feature Service (WFS), Web Coverage Service (WCS) and Style Layer Descriptor (SLD), Geography Markup Language (GML).

To be a complete Geospatial CMS, it must be a geospatial software stack containing:

- A spatially enabled object-relational database (a PostGIS for example).
- A software server for loading and sharing geospatial data (a Geoserver). The Geoserver is used also to authenticate and authorize data sharing and data access in the organization
- A tile cache server that accelerates the serving of maps (built into GeoServer).
- A web application for composing, styling, and publishing maps.
- A complete desktop application for working with geospatial data and maps.

3.5. People

People involved in the GIS-based Portal are of three categories:

- ***Geoportal Manager:*** The manager's role is to manage accounts. He is administrator of the system. He can add and disable user or groups, create user password and manage datasets and other published documents and maps.
- ***Publisher:*** The role of publisher is to publish datasets using desktop GIS software or edited online datasets
- ***Viewer:*** A viewer is any user that can search and visualize the published information on the internet. Viewer can also be granted forms through which he can send requests or his/her points of views such as blogs.

This assignment will result in a proposal for a Geospatial CMS that fits the need of ESAWAS, how it will be managed by a system administrator, and accessed by the ESAWAS service providers (publishers) and water and sanitation regulators (viewers). The study will propose how all this involved people will be trained to own the developed GIS-based water and sanitation portal and to update geospatial data maintained in the geospatial database using either web services with enabled editing capabilities using created forms or using desktop GIS and publishing edited data through Geoserver.

The regulators will use the system and stored data through various analyses for performance monitoring, follow up of planning, advice on the service delivery improvement, areas for new investment. They will also use those data in standard compliance check (for example: water quality at different consumption points), and licensing (for example: in which area should the new operator invest), etc. The utilities will use the system for the management of the infrastructure, the planning for new extensions (finance matters and investment), the establishment of tariff, reporting on the performance (like water produced and water supplied, Non-revenue water, water leakages, water coverage in relation to consumers' locations, etc.).

3.6. Overview of spatial data format requirements for the development of Geoportal

Different data formats are recommended for the development of Geoportal for WSS, using Open sources. These acceptable formats are listed below for consideration during the Geoportal development.

3.5.1. Geodatabase

The Geodatabase should be developed in the latest compatible version of an QGIS file geodatabase (preferred) or personal geodatabase. The geodatabase is currently the common data storage and management framework for GGIS. It will combine spatial data with a data repository to create an intelligent structure for spatial data storage and management. In addition, the geodatabase format allows the user to define and apply a wide set of integrity rules and constraints to insure that data are created and delivered with correct topology. Topology allows data users to answer questions about adjacency, connectivity, proximity and coincidence. Both file and personal geodatabases are acceptable, with the file geodatabase preferable where large data sets are being submitted. Any geodatabases will adhere to at least the following standards:

- All feature classes included in the geodatabase will exist in one or more feature data sets,
- The XYZ coordinate system for all feature datasets and feature classes will be based on the national or local geodetic network,
- Topologies will be created for all feature datasets and feature classes and all data should not be subject to topologic errors,
- For topologies that involve more than one layer, the most accurate layer will be given the highest rank,
- The minimum topological rules are the following:

    - Features will not be duplicated
    - Coincident boundaries will be corrected within a feature dataset (features that share boundaries with features in other feature classes in the dataset)

- Linear features will not overlap; i.e., all line intersections will require a node, expect for those lines which are not connected to each)
- Polygons must be closed
- Polygons will have no overshoots or dangles
- Polygons from the same layer or layer will not overlap
- Polygons sharing edges will not have gaps
- Polygons will have one and only one label point

3.5.2. Coverages

Coverages are vector datasets depicting points, lines, polygons, regions, or routes. As with geodatabases, coverages allow topologic rules to be defined and enforced so that data sets can be created without topologic errors. In addition, data tolerances can be set during data creation that insure that data created meet minimum standards.

- All coverages must contain a projection (prj.adf), and projections will be defined based on the local or country geodetic network
- Correct arc directionality must be maintained on streets and any dataset with flow directions
- Polygons must close without overshoots or undershoots
- Lines, polygons, points and annotation must not be duplicated
- Streets and facility data do not break at overpasses and underpasses
- Polygons must edge match without slivers
- Polygons must not overlap
- Polygons will have one and only one label point, except for the background polygon, which will have none

3.5.3. Shapefiles

The shapefiles are vector data format that store non-topological geometry and attribute information for each of the features in a data set. The features can be points, lines or polygons. Shapefiles are actually a set of separate files that define the vector features and attributes.

- All shapefile data sets must include at a minimum the following files:
  - .shp (the file that stores the geometry)
  - .shx (the file that stores the feature geometry index)
  - .dbf (the file that stores the feature attribute information)
  - .prj (the file that stores the coordinate information)

- Shapefiles must be created so that the following basic topologic rules are not violated:
  - Features will not be duplicated
  - Linear features will not overlap; i.e., all line intersections will require a node

- Linear features will maintain correct arc directionality for any data set with flow directions
- Linear features will not have pseudo-nodes unless they are required to maintain a change in arc attribution
- Polygons must close
- Polygons will have no overshoots or dangles
- Polygons will not overlap or self-intersect
- Polygons sharing edges will not have gaps
- Polygons will have one and only one label point

3.5.4. Geodatabase XML

The QGIS Geodatabase XML is a mechanism for interchanging geospatial information to and from a geodatabase. While geodatabases can be simply copied and loaded into a new directory or folder, the geodatabase XML workspace export preserves the schema developed for the geodatabase and includes all simple and custom features data, participation in networks and topologies, network connectivity and topology rules, simple and composite relationships, and any other information associated with the geodatabase datasets. Therefore, any and all behaviors created within the original geodatabase will be recreated when the XML document is imported into the receiving system. For an XML extract, both the data and the schema should be exported.

3.5.5. Raster data sets

Raster data can be described as a spatial data model that defines space as an array of equally sized cells arranged in rows and columns, and composed of single or multiple bands. Each cell contains an attribute value and location coordinates. Unlike a vector structure, which stores coordinates explicitly, raster coordinates are contained in the ordering of the matrix. Groups of cells that share the same value represent the same type of geographic feature. Raster data sets that encompass imagery or elevation data are less likely to be used in the management of WSS data and their use in planning for new assets development. The following raster data formats will be used:

- Digital Elevation Model (DEM)
- Triangular Irregular Networks (TINs)
- MrSid (version 2, 3 or 4) with world file
- TIFF or GeoTIFF (.tif, .tfw) image with world reference file
- JPEG image with world reference file (.jpg, .jpw
- ERDAS Imagine
- ASCII

3.5.6. Tabular Data

The tabular data can be stored in the following formats:

- Microsoft Excel (.xlsx)
- Tab or comma-delimited text files (.txt, .csv)
- Database files (.accdb)
- Extensible Markup Language (.xml)

3.5.7. Naming conventions

GIS data may follow some naming conventions. To avoid possible data import/export problems, the following dataset and attribute naming conventions are applicable for data collected by WSS for internal use and for distribution:

❖**Dataset naming conventions**

- Dataset names will contain only alphanumeric characters (i.e. letters, numbers),
- Dataset names will start with a letter,
- Dataset names will be entirely in lowercase,
- No spaces, dashes, or special characters other than an underscore will be used,
- Dataset names will be 10 characters or less: Common abbreviations should be used where applicable.

❖**Attribute field naming**

- Attribute field names will contain only alphanumeric characters (letters and numbers) and underscores,
- Attribute field must start with a letter (it can be capital),
- No spaces, dashes or special characters other than an underscore will be used,
- Attribute field names will be 10 characters or less to avoid data conversion issues with truncation.

3.5.7. Metadata standards

Metadata is literally "data about data". It is a description of the content, quality, lineage, contact, condition, and other characteristics of data. Pertaining to spatial data, metadata can help provide answers to such questions as:

- Who created the data?
- When was the data created?

- Why was the data created?
- How often is the data updated?
- What kind of data is it?
- How accurate is the data?

The term “metadata” is defined as data about data. The term is often used to refer to information that allows either: (1) discovery of data, (2) understanding the provenance and quality of the data, or/and (3) analysis of the data via a set of machine readable instructions that describe the data and its relationship. The main elements of GIS metadata that can be considered for building a WSS information system include the following.

❖**Identification information**

- Title: the name of the dataset or the title of the map
- Abstract: a brief description of the dataset or map
- Date of Publication
- Purpose: the reason for creating the dataset or map
- Tags: Keywords or phrases that describe the dataset or map
- Citation: the citation information for the dataset or map
- Contact: the name and contact information of the organization or individual responsible for the dataset or map

❖**Data quality information**

- Lineage: a description of the sources of data used to create the dataset or map
- Completeness: a statement about the completeness of the dataset or map
- Accuracy: a statement about the accuracy of the dataset or map
- Logical consistency: a statement about the logical consistency of the dataset or map
- Completeness report: a report describing the completeness of the dataset or map
- Accuracy report: a report describing the accuracy of the dataset or map

❖**Spatial data organization information**

- Spatial reference: the coordinate system and projection used for the dataset or map
- Spatial resolution: the spatial resolution of the dataset or map
- Topology: the topology of the dataset or map

❖**Spatial data content information**

- Feature type: the types of features included in the dataset or map
- Attribute information: a description of the attributes associated with each feature
- Attribute accuracy: a statement about the attribute accuracy of the dataset or map

❖ **Distribution information**

- Distributor: the organization responsible for distributing the dataset or map
- Distribution format: the format in which the dataset or map is distributed
- Transfer option: the methods available for transferring the dataset or map

❖**Metadata reference information**

- Metadata date: the date the metadata was created or last updated
- Metadata contact: the name and contact information of the person responsible for the metadata

3.5.8. QGIS web service standards

The study assessed the capability of QGIS as an open-source GIS software to provide alternatives for WSS data management. Several components which are available within the ArcGIS platform are provided by QGIS developers so that actors in WSS sector can developed a Geoportal based on this platform. The QGIS components required for developing a Geoportal include the following:

1. QGIS Server is an open-source software that allows organizations to create, manage, and distribute GIS services over the web. It provides support for a variety of web service standards such as OGC standards, and proprietary QGIS services.
2. QGIS Desktop is a desktop GIS software application that allows users to create, edit, analyze, and visualize geospatial data. It includes tools for data management, analysis, and cartography.
3. QGIS Web Client is a web-based mapping application that allows users to create and share interactive maps. It provides access to a variety of base maps, data layers, and tools for visualization and analysis.
4. QGIS Cloud is a cloud-based mapping platform that allows users to create and share interactive maps over the web. It provides support for web service standards such as WMS, WMTS, and WFS.
5. QGIS2Web is a plugin for QGIS that allows users to easily create web maps from QGIS projects. It provides support for various web mapping frameworks such as Leaflet, OpenLayers, and Mapbox.
6. QGIS API for Python is a Python library that allows developers to build custom GIS applications using Python. It provides access to a variety of mapping tools, data layers, and services.
7. QField for QGIS is a mobile application that allows users to access and share geospatial data and maps on their mobile devices.

Table 6: Compatibility between QGIS Web Services and geospatial standards

Web services	Open geospatial data standards					
	KML	WCS	WFS	WMS	WMTS	WPS
QGIS Server	X	X	X	X	X	X
QGIS Desktop	X	X	X	X	X	X
QGIS Web Client	X	X	X	X	X	X
QGIS Cloud	X	X	X	X	X	X
QGIS2Web	X	X	X	X	X	X
QGIS API for Python	X	X	X	X	X	X
QGIS Explorer	X	X	X	X	X	X

3.5.8. Projections

All digital geospatial data, required for developing a WSS geoportal, whether vector or raster, must have a projection defined and embedded in, or associated with, the data file. Those data must contain spatial reference information describing the projection, datum, and units of measure.

▪ **Vector data** has to be in the UTM, geographic coordinate system, decimal degree units, and WGS84 datum. Other projections may be used if they are related to web-based applications or as requested for a project.

▪ **Raster data**, such as aerial photographs should be in the appropriate projection/coordinate system for the area depicted.

4. The existing information systems in Kenya, Tanzania and Zambia

The study was conducted using the existing Management Information Systems (MIS) which are available at three regulators: WASREB in Kenya, EWURA in Tanzania, and NWASCO in Zambia. These web-based MIS assist the regulators in performance monitoring and annual reporting. The study involved exploring and analysing the functions and datasets of these MIS to determine the feasibility of migrating to GIS-based information systems.

4.1. WARIS and Majidata at the Water Services Regulatory Board (WASREB) in Kenya

Kenya has undertaken significant reforms in the water and sanitation sector, guided by the 1999 National Water Policy and the 2002 and 2016 Water Act. Responsibility for water supply and sanitation services and water catchment area management lies with county governments, while the national government oversees water resource ownership, regulation, and national public works. To ensure effective regulation and management, the Water Act of 2016 established the autonomous Water Services Regulatory Board (WASREB), which plays a crucial role in providing recommendations for water services, particularly in marginalized regions. WASREB monitors Water Service Providers (WSPs), licensing utilities based on viability and efficiency, using digitalized maps for assessment (Republic of Kenya, 2010). Through the increased consideration of the role of ICT in Kenya's socio-economic growth (GSM Association, 2022), digital solutions like WARIS and MajiData have been adopted to improve performance and efficiency of water sector (WASREB, 2018).

The effort to adopt the ICT was vital for achieving universal access to safe water and sanitation, promoting socio-economic development, public health, and environmental sustainability in Kenya (Ndaw & Nduati Mwangi, 2015; Republic of Kenya, 2010). Water Regulation and Information System (WARIS) is an information management system that is web-based and available offline. It was established to facilitate data entry, aggregation and evaluation of data for Water Service Providers (WSPs) and Water Service Boards (WSBs). It allows an electronic submission of regulatory reports by WSPs, which are basis for calculation of their performance indicators by WASREB (WASREB, 2021; Peter, 2019). The system helps WSPs fulfill reporting obligations to WSBs and WASREB and provides them with progress reports and yearly comparisons. The compiled data from these reports enables WASREB to compare performance across different WSPs and Water Service Boards (WSBs) at regional and national levels (WASREB, 2019). Overall, ICT has significantly contributed to improving water sector management and service delivery in Kenya. The image below illustrates the entry point to the

WARIS website (https://waris.wasreb.go.ke). Note that only allowed person can enter and access the WARIS system.

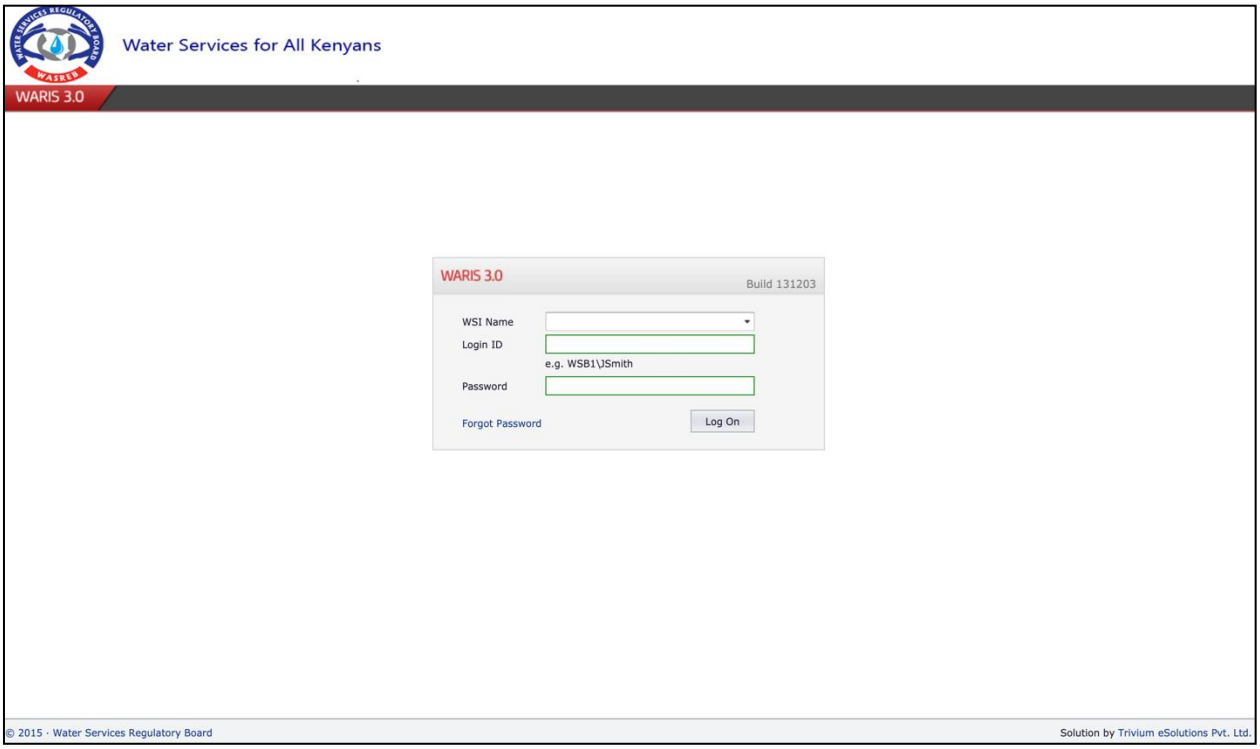


Figure 6 : Entry point to the WARIS website

MajiData, established in 2011, is an online database in Kenya focused on collecting and managing socio-economic data concerning the urban poor. It complements the WARIS system and integrates data from WASREB and the Water Services Trust Fund (WSTF) related to utility performance in urban areas (USAID, 2021b; WASREB, 2018). Accessible to the public, MajiData serves as a performance assessment tool for Water Service Providers (WSPs), evaluating indicators like water accessibility, quality, customer service, and financial performance. It originated in 2008 through GIZ to address the need for accurate pro-poor planning data identified during the 2007 water sector review performance (WASREB, 2018). While initially envisioned as a national platform, MajiData offers limited user rights for external users, who can manually export data for independent analysis and planning purposes from the website (USAID, 2021). To access MajiData, users can visit its website (http://dashboard.majidata.go.ke/Home/Dashboard). The user interface displays performance indicators and provides function tabs for indicators, infrastructure, and general data.

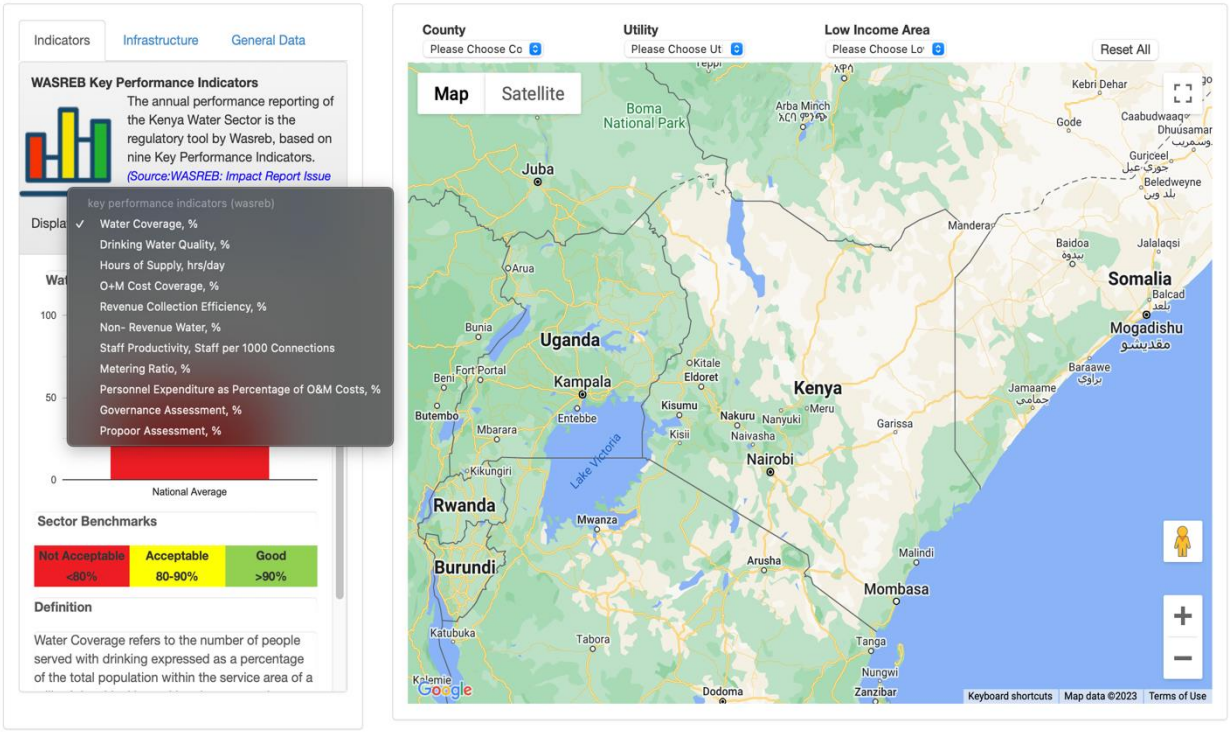


Figure 7: Entry point to the Majidata dashboard

The next two images illustrate the information displayed when the user clicks on the infrastructure tab and display a given type of infrastructure. In this case Water Kiosk and pipelines are displayed. The MajiData dashboard displays the spatial location points of water kiosk as infrastructure on the map.

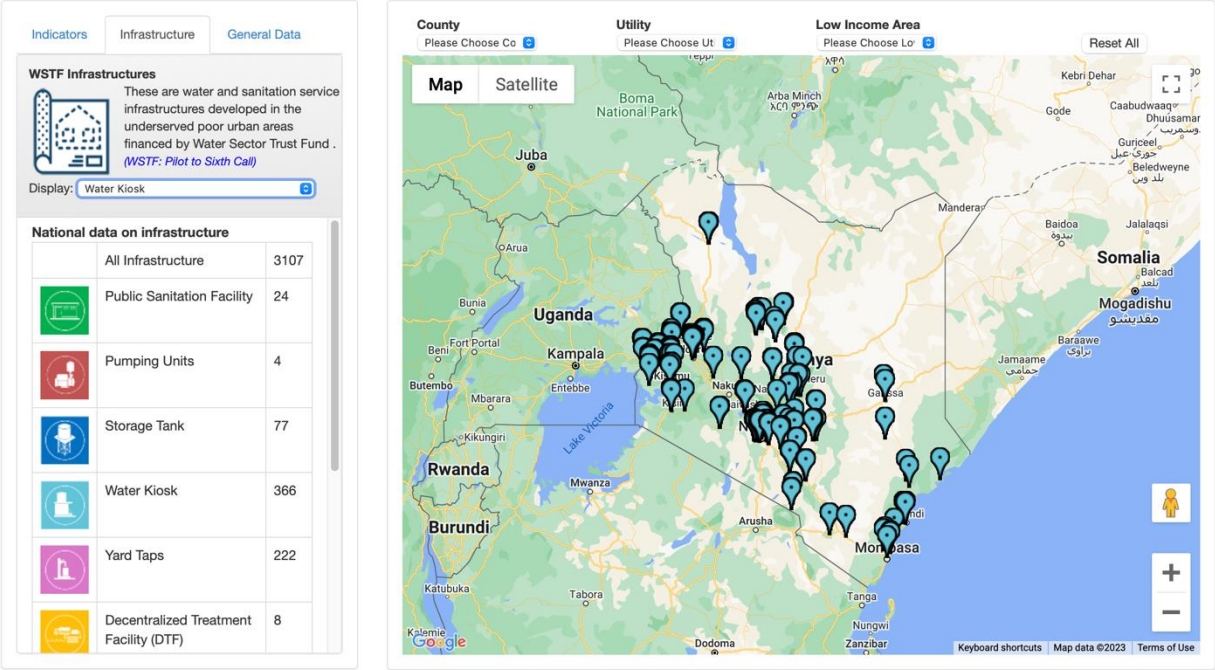


Figure 8: Visualization of WSS on MajiData dashboard

The MajiData dashboard presents the spatial location points of pipe extension as infrastructure, an unconventional method in spatial data representation and geo-visualization (next image). According to the fundamental aspect of spatial data modeling, points indicate features described geographically by a single coordinate pair denoting longitude and latitude. In contrast, lines are utilized to represent linear features represented as a series of connected points, with each point acting as a vertex of the line. Considering this context, using lines to represent pipe extensions would enhance understanding and interpretation.

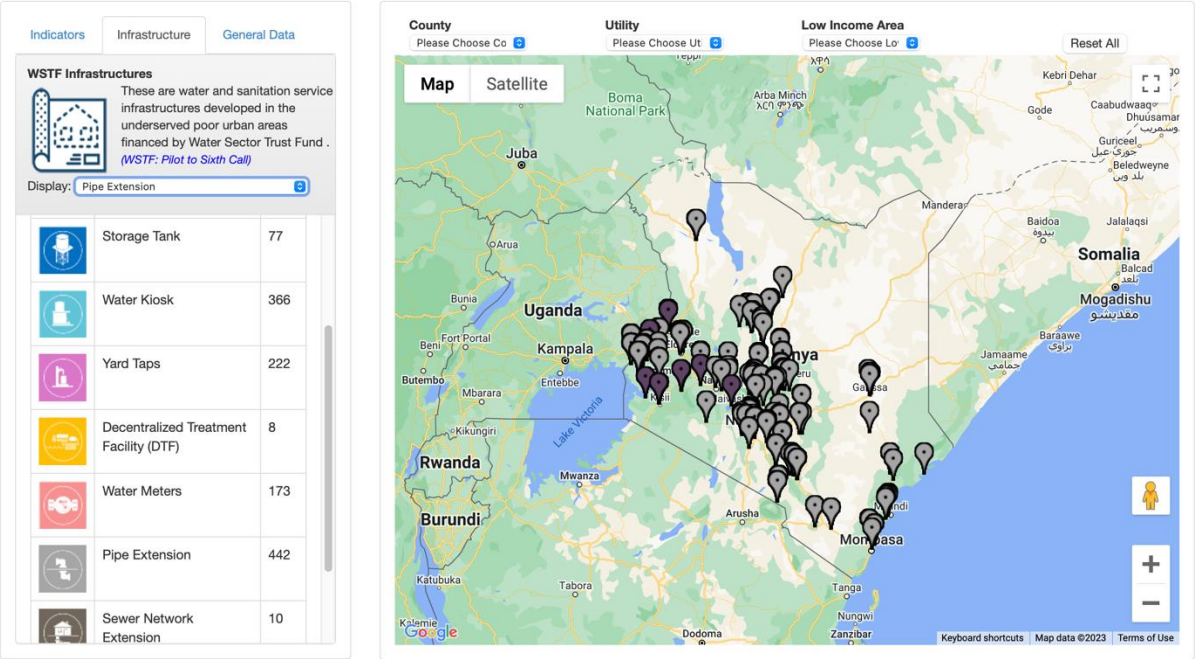


Figure 9: Visualization of pipeline on MajiData dashboard

By clicking on the point in the map, the user can display attribute information about the pipe extension as infrastructure such as the name of utility company operating the infrastructure, the year of implementation, location coordinates and status showing whether the infrastructure is operational or not. The image below shows the details.

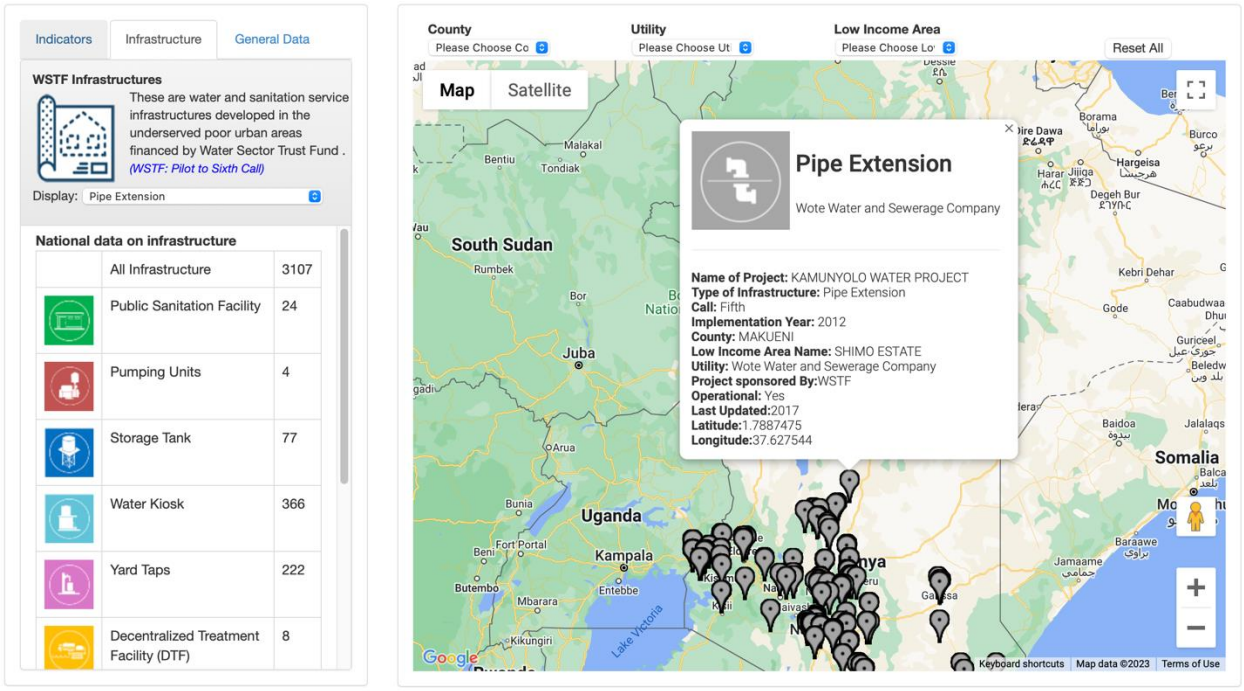


Figure 10: Attribute data for pipeline on MajiData dashboard

The image below also displays the attribute information on the Water Meters as infrastructure

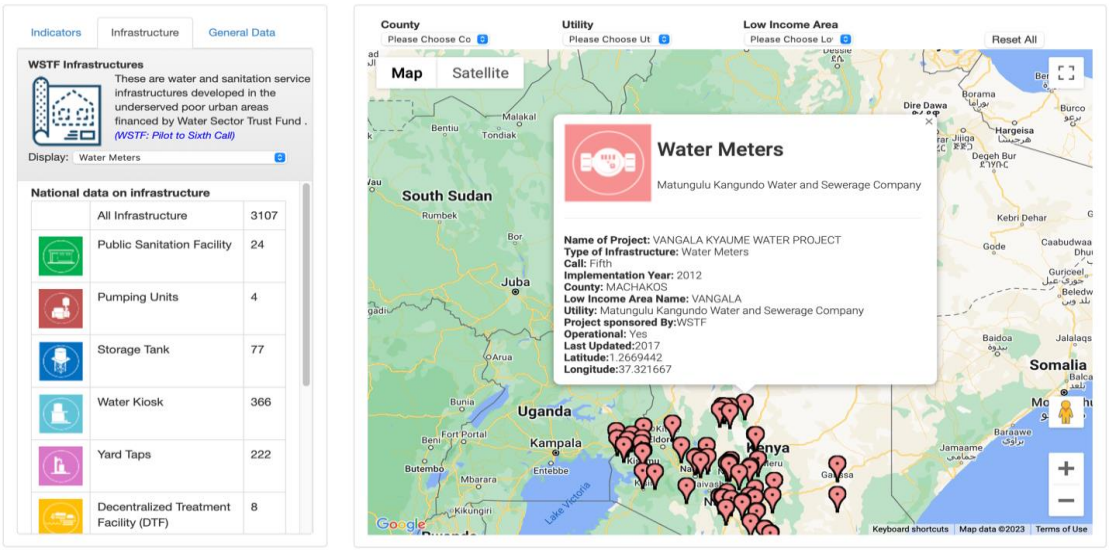


Figure 11: Attribute data for water meter on MajiData dashboard

The next image illustrates the information displayed when the user clicks on the General Data on MajiData dashboard.

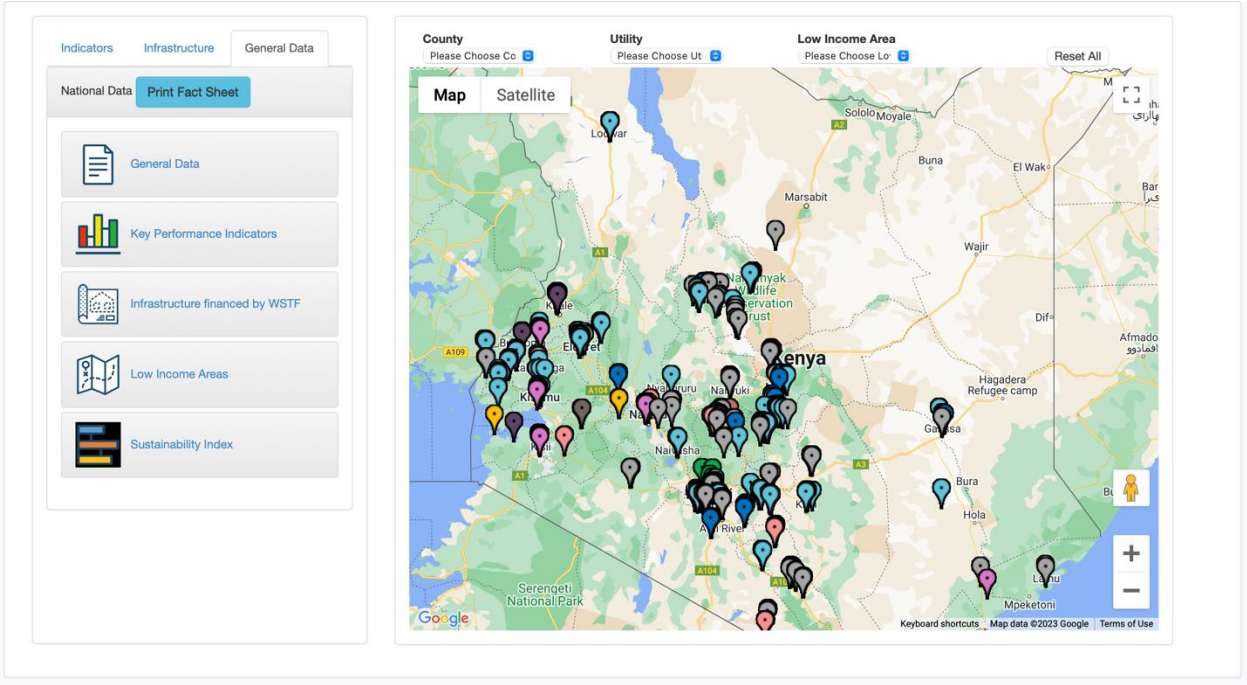


Figure 12: Details General data on MajiData dashboard

On the right of the display interface, there are tabs illustrating County, utility and low-income area tabs. The next 2 images illustrate the information on the performance indicators in two different Counties. On the image below, one can notice that only performance indicators are graphically displayed on the left and not displayed on the map.

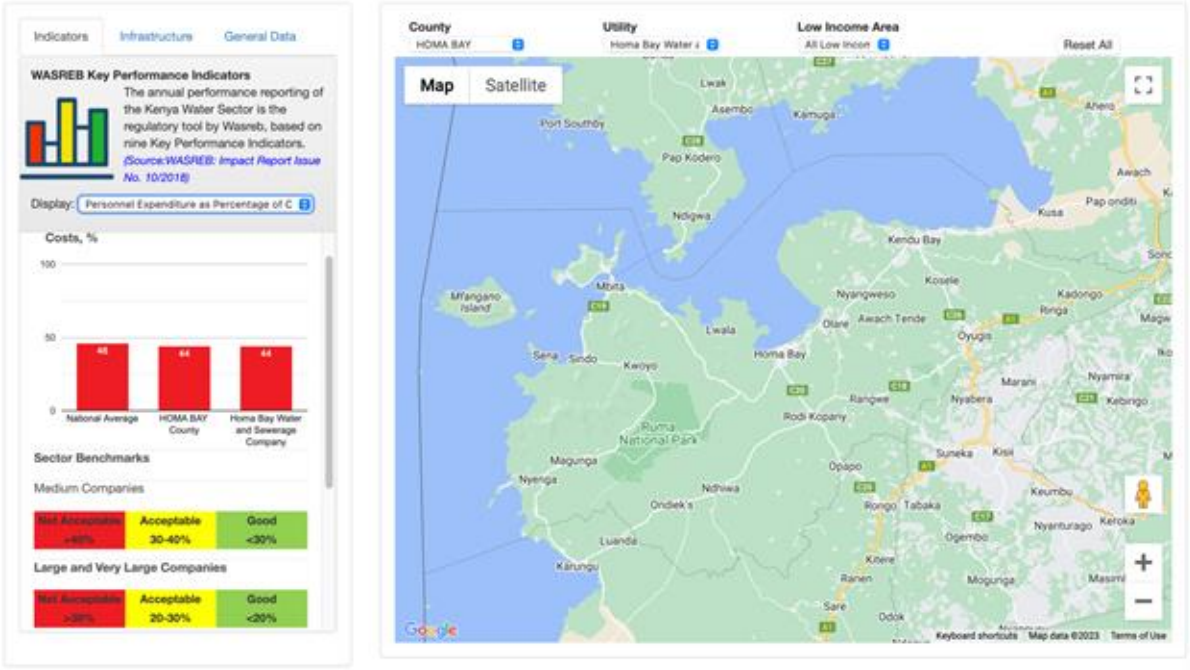


Figure 13: Display of performance indicators on MajiData dashboard

By using utility tab, it is possible to explore the infrastructure from each utility company in a certain county. However, boundary of the county is not visualized on the map for better understanding of the map visualization. The next 2 images display the infrastructure of a certain utilities under the Utility tab.

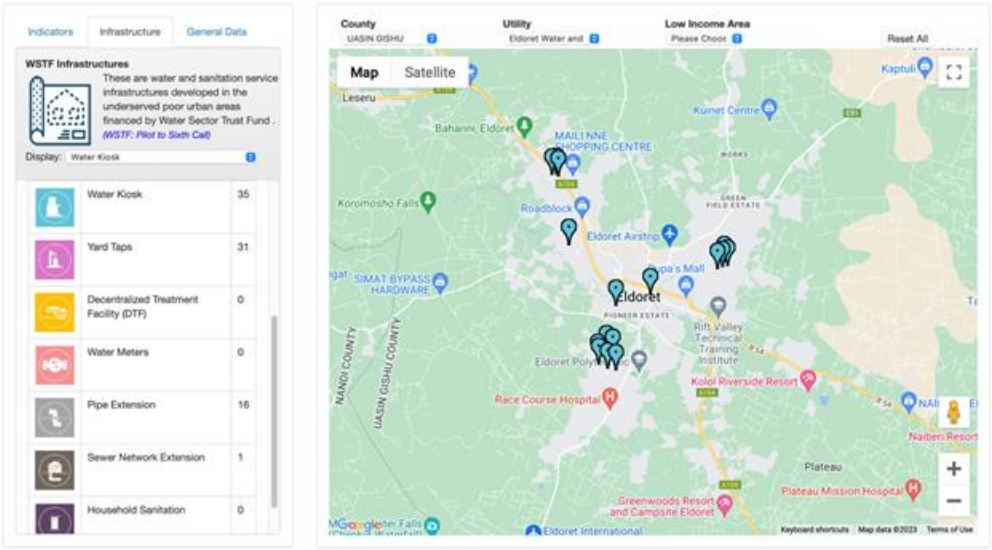


Figure 14: WSS infrastructure of a certain utilities under the Utility tab

4.2. MajIs information system for the Energy and Water Utilities Regulatory Authority, in Tanzania

Over the last two decades, Tanzania has undergone significant water sector reforms, including the enactment of the Water Supply and Sanitation Act of 2019, which serves as the legal framework for water, sanitation, and hygiene services. Several policies and acts, such as the Water Resources Management Act (2009), National Water Policy of 2002, and others, guide the water and sanitation sectors. Recognizing the potential of Information and Communication Technology (ICT), Tanzania's National ICT policy of 2003 promotes its adoption in the water and sanitation sectors for improved service delivery and asset management. Regulating the sector falls under the Energy and Water Utilities Regulatory Authority (EWURA), responsible for technical and economic regulation, licensing, and ensuring quality and consumer protection. To ensure equitable services, the Water Supply and Sanitation Authorities (WSSAs) were established, following national laws and reporting regularly to EWURA (Ndaw & Welsien, 2015).

To enhance data collection and management for water supply operations, Tanzania's EWURA adopted the Maji Information System (MajIs), a web-based platform that centralizes information on water connections, sewerage systems, non-revenue water, and other aspects of water supply services. Developed to meet the need for comprehensive and reliable data on water utilities, MajIs plays a pivotal role in monitoring water supply services' performance, aligning with the country's vision of sustainable economic and social development (Ministry of Water, 2021; Ndaw & Welsien, 2015). Thus, the MajIs system was designed to provide accurate and timely data on the performance of water utilities in Tanzania, with consideration of the module shown on the Figure below:

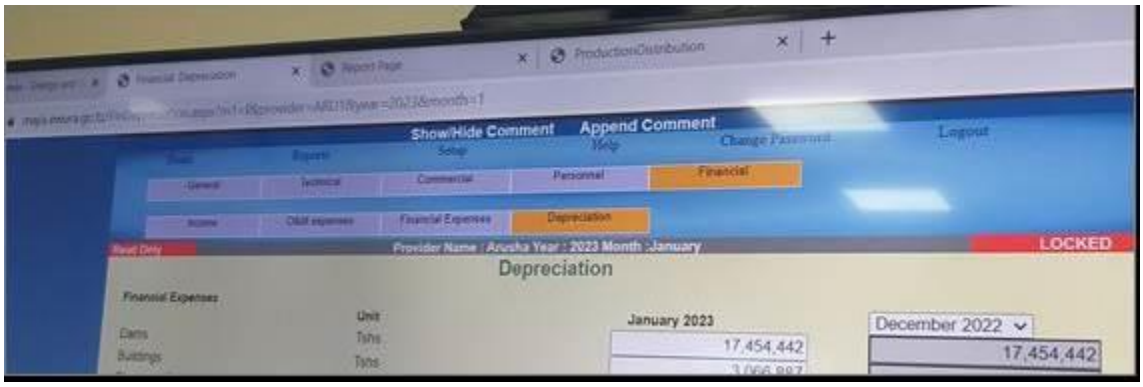


Figure 15: Interface structure of MajIs system

The information which is relevant to the development of GIS is stored under the technical module as shown below. If the GIS system is developed, some of data on water production (like

the daily water production capacity, water production, etc.) Can be attached to the layers of water treatment plants.

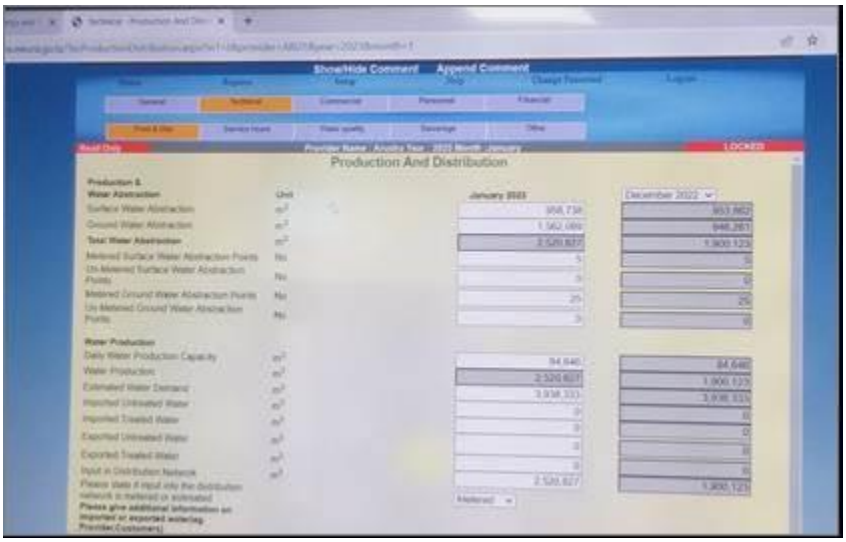


Figure 16: MajIs system Technical data relevant for a GIS based system

The MajIs system, developed collaboratively with stakeholders and government agencies, collects real-time data on water supply services from various sources like water meters and customer complaints (USAID, 2021a). This system provides customizable reports and dashboards, benefiting water utility providers in monitoring and enhancing services, and regulators in ensuring compliance and identifying areas for improvement. MajIs has resulted in improved service delivery, customer satisfaction, and transparency in the water sector. EWURA facilitates data submission by designing reporting formats for WSSAs and conducts field inspections to monitor water infrastructure (Ministry of Water, 2022). Additionally, EWURA generates Annual Water Utilities Performance Reports, ranking WSSAs based on indicators and benchmarks (Musonge et al., 2022). The Ministry of Water collaborates with NBS to align survey questionnaires with MajIs data to collect relevant information on safe drinking water access (Ministry of Water, 2021). The image below illustrates the entry point to the MajIs website (https://maji.gov.go.tz). Note that only allowed person can enter and access the MajIs system.

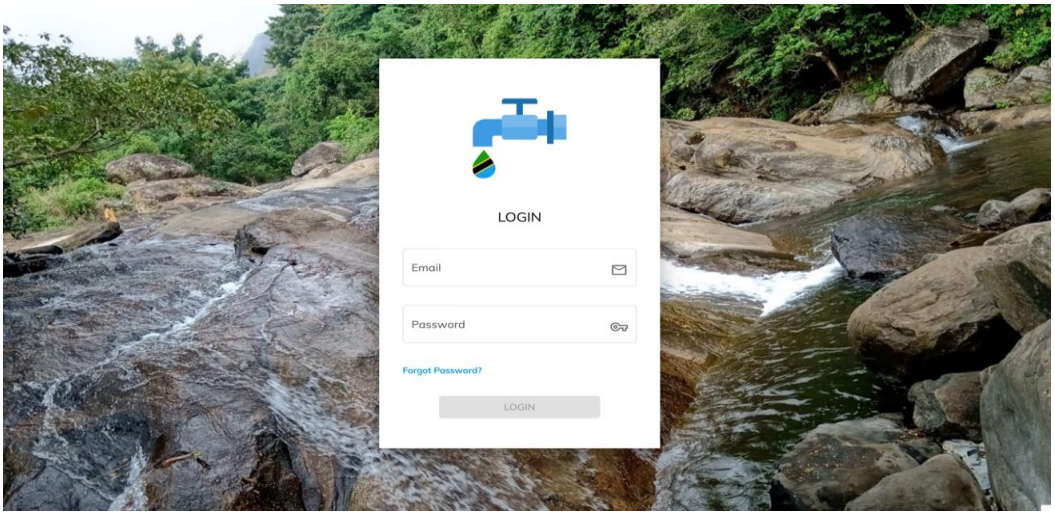


Figure 17: Entry point to the MajIs website

4.3. The National Information System (NIS) for the National Water Supply and Sanitation Council in Zambia

In Zambia, water supply and sanitation services are regulated by the National Water Supply and Sanitation Council (NWASCO), an independent organization established in 1997 and operational since 2000 under the Water Supply and Sanitation Act of 1997 (Government of the Republic of Zambia, 1997). NWASCO's main responsibilities include regulating and overseeing water supply and sanitation services in the country, conducting inspections to ensure compliance with regulations, and licensing both public and private service providers. Additionally, NWASCO sets standards for water and sanitation services, monitors adherence to these standards, and encourages community involvement in the planning and management of these services (Mbilima, n.d.). To carry out its regulatory functions effectively, NWASCO has focused on creating various tools, such as licensing requirements, performance guidelines, information gathering and analysis, subsidies, supervision of special services, benchmarking, and standard setting (Gerlach, 2019).

The key platform facilitating NWASCO's activities is the National Information System (NIS), developed in 2003 as an electronic version of the annual reports required from service providers under Statutory Instrument (SI) No. 63 of 2000 and the NWASCO Annual Reporting Guidelines. The NIS enables service providers to report electronically on their financial, commercial, technical, and personnel-related operations. It generates over 100 indicators in categories such as Operational, Financial, Cost Analysis, Quality of Service, and Personnel. These indicators are used to produce charts and tables for the annual urban and peri-urban

Water Supply and Sanitation (WSS) sector report, which assesses the performance of all service providers (NWASCO, 2018). The NIS was initially developed by a local company, Softel Ventures, using Visual Basic 6.0. Since its implementation in 2004, the system has undergone several modifications to accommodate changes in data requirements and incorporate various improvements over time (ESAWAS, 2019).

Before its creation, data were collected in diverse formats by various entities, making coordination and assistance identification challenging. The NIS, redesigned in 2017 to a user-friendly web-based format, collects performance indicators on water quality, quantity, facility conditions, and financial data. It supports NWASCO in monitoring service providers' performance and compliance, benefiting decision-makers, customers, and support agencies. By centralizing data, the NIS aids in understanding sector challenges and enhancing service delivery across Zambia (Gerlach, 2019). It encourages stakeholder engagement, including government agencies and civil society organizations, and promotes a coordinated approach to water supply and sanitation services in the country (ESAWAS, 2020).

4.3.1. System architecture of NIS

4.3.1.1. Technical environment

- The NWASCO Information System (NIS) version 5.0 is designed as a database driven web-based application.
- The web-application is designed as a client-server software application that will enable data entry on the client side without Internet (Offline-data entry) but data submission will he done via Internet.

4.3.1.2. Users

There are two main users of the system, these are NWASCO and the water supply and sanitation (WSS) providers.

- The Providers are classified in three categories: (i) Commercial Water Utilities (CUs), (ii) Other Service Providers and (iii) Rural WSS.
- The Providers enter data and submit it to NWASCO for verification and approval.
- Only the NWASCO Administrator can define the main users in the system, assign them to a category and assign permissions.
- The category of the provider, determines the data entry sheets accessible to them.

4.3.1.3. General user functions

The general functions available to Users, provided they have the required permissions, are as follows:

- Only NWASCO can define the reporting period.
- NWASCO can view data for all Providers.
- Providers can only view data for their respective institution.
- Each Provider has an Administrator to create / modify users and permissions.
- Data entry options are available for monthly, quarterly and annually.
- Only Providers can enter, modify or delete data.
- Only Providers can export/import data entry sheets into/from Excel for data entry purposes.
- All Users can enter comments against data fields.
- All Users can export the completed data fields into Excel.
- All Users can send and receive notifications.
- Once NWASCO approves a data submission, data entry by Providers is no longer possible.
- NWASCO has a special by-pass to reopen a data set for data entry after approval is given.
- All users can generate reports and export them into another format.

4.3. 2. Main features

4.3. 2.1. Main screen

➢ **The Login:**

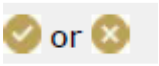
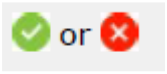
The current version of NIS (5.0) is accessed via a URL.

- The user selects the abbreviated name of the Institution (NWASCO or Provider) from a drop-down list.
- The user enters the login ID
- The login ID is generated as a combination of the Institution and ID entered e.g. NWASCO\pmutale
- If the user knows the complete login ID with abbreviated Institution name, they have the option to enter it directly.
- If the login credentials are incorrect, a message is displayed.
- The user has an option to reset the password if forgotten

➢ **Common Icons/Features**

The following table lists the icons and features that are common across the screens.

Table 7: Icons and features of NIS

Icon/Field	Description
	This icon appears if you try to save without entering values in a mandatory field or if you enter invalid values in a field. When you hover over the icon, a tooltip is displayed which indicates why the value is invalid.
	Click this icon to view the comments history for a field.
	When a data set is sent for review, the reviewer sees this icon beside all editable fields. This indicates that the item should be Accepted or Rejected.
	When any editable field in a data set is Accepted or Rejected, the icon changes correspondingly.
	A white field is an input field and editable
	A light grey field indicates that it is a non-editable field
	A dark grey field indicates that it is a summation field
	A light blue field indicates that it is a calculated Indicator
	A pink field indicates that the value entered is incorrect.
	Click this button to enter the screen-level comments in any of the data set screens. Enter the comments and click **Save** to save your entries or **Cancel** if you do not wish to enter any comments. Once saved, the comments are displayed in the comments box. You can Click to Edit or Delete comment

4.3. 2.2. Home Design

- The system uses breadcrumb navigation at the top of the screen.
- Main menu is on the left and sub-menus are expanded below the parent item
- Selection of a menu item opens as a tab in the centre screen.
- The name of the Institution and user name will be visible on the screen.

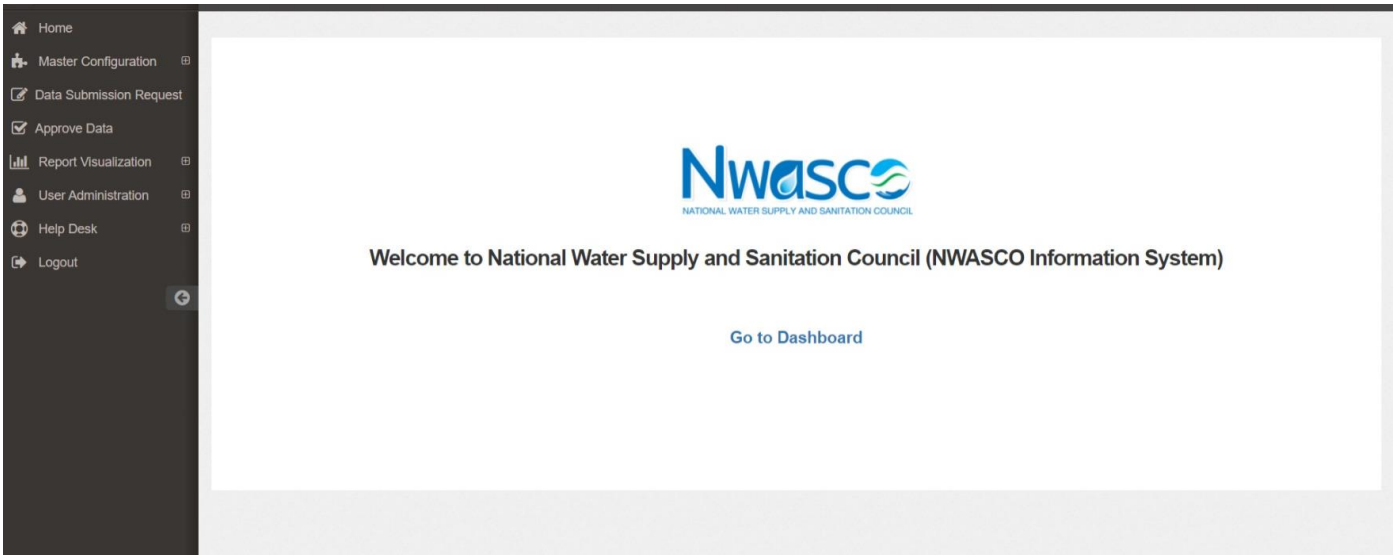


Figure 18:NWASCO NIS Home page

➢The system enables quarterly and annual data entry:

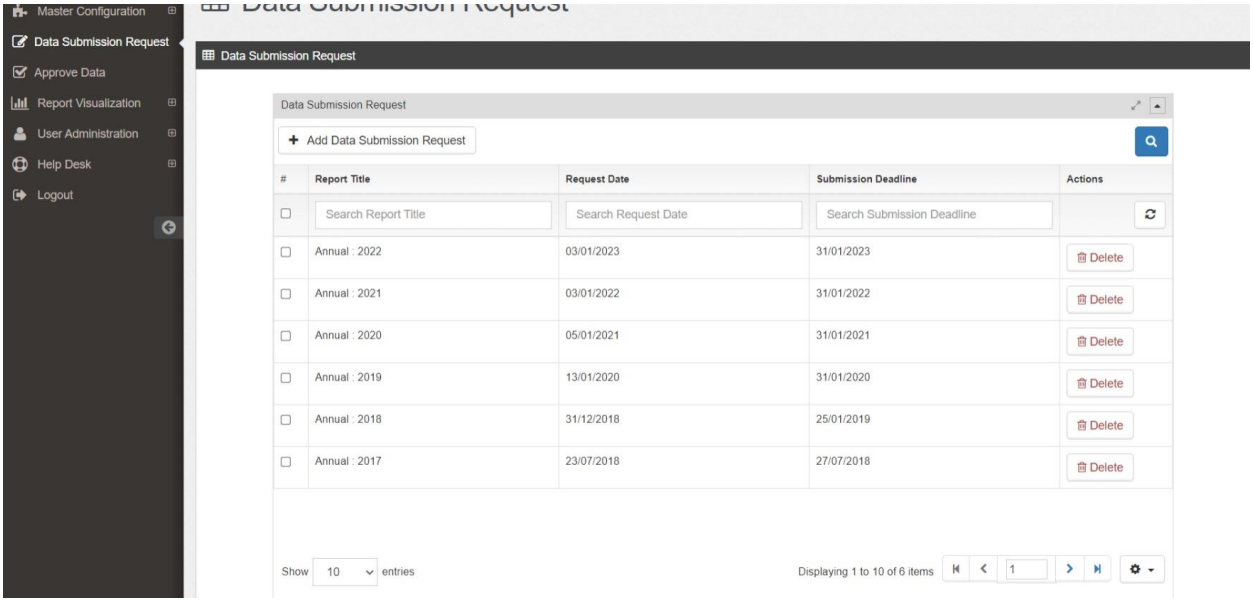


Figure 19: NIS home page for data entry for quarterly and annual report

4.4. NIS user functions

A NWASCO user can only perform functions within the NWASCO interface provided they have the permissions.

4.4.1. User management

View a list of all NWASCO users with their associated roles. Only the administrator has the permission to use this option to perform the following functions:

- Add New Users
- Edit User
- Delete User
- Change Password

The NWASCO Admin can define one Administrator role for the CU who can then create users and assign permissions to Modules for the respective CU. The user details include:

- Institution Type *(NWASCO, CU, Other Provider, Rural)*
- Institution Name
- First Name
- Surname
- Email Address
- Contact Number
- Login ID *(initial of firstname+surname)*
- Password
- Receive notification *(checkbox. When selected a notification email is sent to user)*
- Disable Account *(checkbox)*
- Role *(to determine permissions e.g. Admin, User, Guest etc)*

4.4.2. Permission management

Assigns permissions to specific Modules as follows:

- None: The user does not have any permission on the menu option; hence, it is not displayed in the navigation pane when the user logs in.
- Read: The user can only view the data, but cannot modify or save it.
- Write: The user can view, modify and save the data.
- Delete: The user can delete the data.

4.4.3. WSS providers management

View, add or edit a new WSS Provider. Data to be entered includes:

- Institution Type *(CU, Other Provider, Rural)*
- Full name of institution
- Abbreviation
- Logo *(image)*
- Address

- Phone Number
- Email Address
- Assign geographical area *(select Province from drop-down)*
- Assign Service Towns *(select Towns under the Province)*
- Assign Service Class *(select Urban or Rural)*
- Assign Service Areas *(select Areas under the Town according to Urban or Rural)*

4.4.4. General data

❖ View or edit General data about the Provider.

❖This option is only available for Annual reporting.

❖General information dataset is automatically transferred to the new reporting year for editing.

➢The options available are:

- Provider Information
- Committees
- Board Members
- Management
- Strategic Plan Objectives
- Service Areas

4.4.4.1. Service areas data

➢View or edit Service Areas Data about the Provider.

➢This option is available for Annual reporting only.

➢In a selected reporting year, the Service Areas dataset with updated population figures is automatically transferred to the new reporting year for editing.

➢A user will select the Town for which data is to be entered

➢The areas under the Town will appear as a drop-down list in the entry form

➢Flag all Total Population Served pink where the figure is higher than Population Entered. Do not accept higher Population served figure.

➢The options available are:

- Water Services
- Hours of Supply
- Sanitation Services
- Area Level Summary (option to view only)
- Town Level Summary (option to view only)

4.4.4.2. Commercial data

- View or edit Commercial Data about the Provider.
- This option is available for Quarterly and Annual reporting.
- The options available are:
  - Water Services
  - Sanitation Services
  - Billing Volumes
  - Billing Revenues
  - Collections
  - Metering
  - Complaints

4.4.4.3. Technical data

- View or edit Technical Data about the Provider.
- Only the Water Quality option is available for Quarterly reporting. The rest of the tabs are only available for Annual reporting.
- The options available are:
  - Water Production
  - Water Distribution Network
  - Water Quality
  - Sewer Network

4.4.4.4. Financial data

- View or edit Financial Data about the service providers.
- The options which are available include the following:
  - Expenses
  - Statement of Comprehensive Income
  - Statement of Financial Position
  - Statement of Cash flow
  - Investments

4.4.4.5. Personnel data

- View or edit the Personnel Data about the service providers.
- The options which are available include the following:
  - Staff Details
  - Education and Training
  - Salary Information and Absenteeism
  - Corporate Governance and Management
  -

4.4.4.6. Data entry sheets – Other service providers

View, enter or edit data for other Service Providers under Limited Regulation. The options available are:

- General
- Water and Sewer Coverage
- Hours of Supply
- Water Quality Compliance

4.4.4.7. Generated reports

All users can use this option to generate the indicators and required charts and tables in a selected format. The report required can be generated by specifying the Type of Report (Annual or Quarterly), Provider(s) and Years (1 year or multiple years).

- The report options are:
  - Operational Indicators
  - Service Level Indicators
  - Financial Indicators
  - Cost Analysis Indicators
  - Investments and Capital Expenditure
  - Staff Efficiency Indicators
  - Corporate Governance and Management Indicators
  - Other Service Providers

4.5. Zambia Water and Sanitation Digital Atlas (ZWSDA)

4.5.1. Technical environment

The Zambia Water and Sanitation Digital Atlas is a web-application, designed as a client-server software application that allows user to query spatial data.

4.5.2. Users

There are three main users of the system, including NWASCO, partners in the sector and consumers. The partners are segregated in three categories: (i) commercial water utilities (CUs), (ii) other service providers, (iii) regulators (iv) ministries and (v) cooperating partners.

Only the NWASCO Administrator can define the main users in the system, assign them to a category and assign permissions. The category of the data is determined by NWASCO.

4.5.3. General user functions

The general functions available to Users, provided they have the required permissions, are as follows:

- Map Navigation: Users can use the mouse to navigate and zoom in/out of the map to explore the water and sanitation data layers.
- Layer Selection: Users can select from a variety of data layers to display on the map, including water points, water quality, sanitation facilities, and more.
- Search Function: Users can search for specific water and sanitation data points or locations using the search function.
- Filtering: Users can filter the data shown on the map by specific attributes such as location, water source, water quality, sanitation facilities, etc.
- Legend: Users can view a legend of the data layers on the map and understand the meaning of the symbols and colors used.
- Measurements: Users can measure distances and areas on the map using the measurement tool.
- Printing and Exporting: Users can print or export the map and data in a variety of formats, including PDF, PNG, and CSV.
- Bookmarks: Users can save their favorite map views and easily return to them later using the bookmarks feature.
- Help and Support: Users can access the help and support center to learn more about the platform, its features, and how to use it.

- User Settings: Users can customize their user settings, such as language preference, map projection, and more

4.5.4. Main features

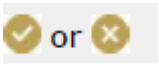
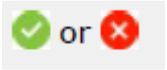
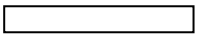
➢ **Dashboard:**

The ZWSDA 1.0 is accessed via a URL.

- The user can select the name of the document from a drop-down list to view.
- The user is able the view chart summary data on sanitation
- The dashboard does not require login details

➢ **Common Icons/Features**

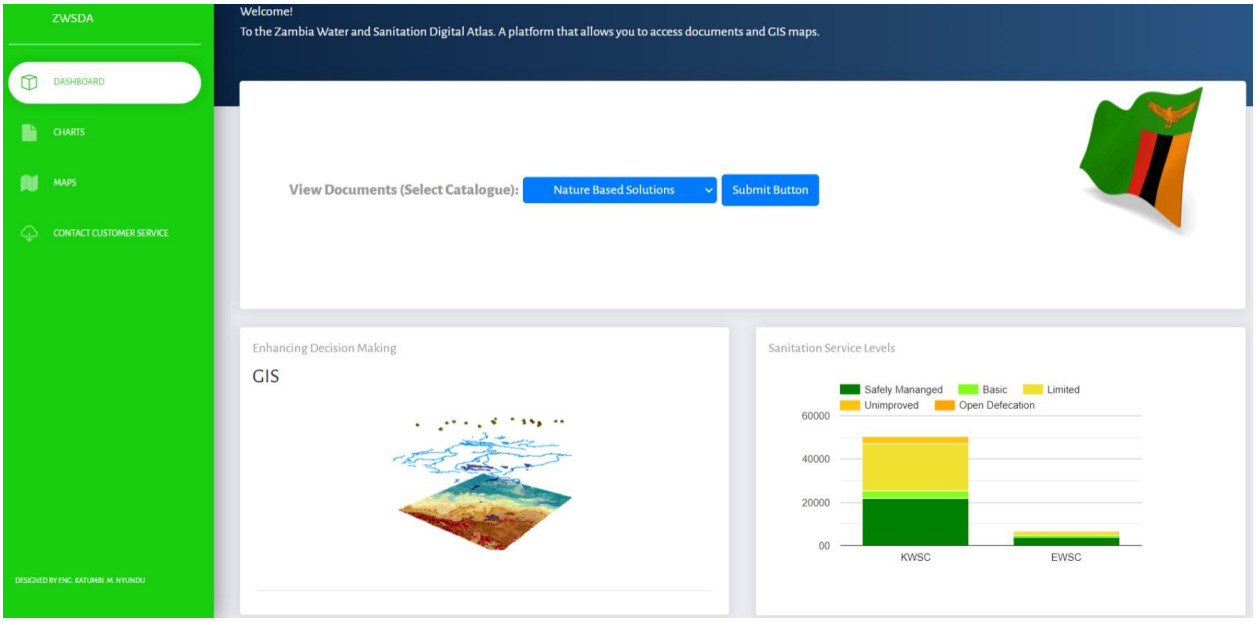
The following table lists the icons and features that are common across the screens:

Icon/Field	Description
	This icon appears if you try to save without entering values in a mandatory field or if you enter invalid values in a field. When you hover over the icon, a tooltip is displayed which indicates why the value is invalid.
	Click this icon to view the comments history for a field.
	When a data set is sent for review, the reviewer sees this icon beside all editable fields. This indicates that the item should be Accepted or Rejected.
	When any editable field in a data set is Accepted or Rejected, the icon changes correspondingly.
	A white field is an input field and editable
	A light grey field indicates that it is a non-editable field
	A dark grey field indicates that it is a summation field
	A light blue field indicates that it is a calculated Indicator
	A pink field indicates that the value entered is incorrect.
	Click this button to enter the screen-level comments in any of the data set screens. Enter the comments and click **Save** to save your entries or **Cancel** if you do not wish to enter any comments. Once saved, the comments are displayed in the comments box. You can Click to Edit or Delete comment

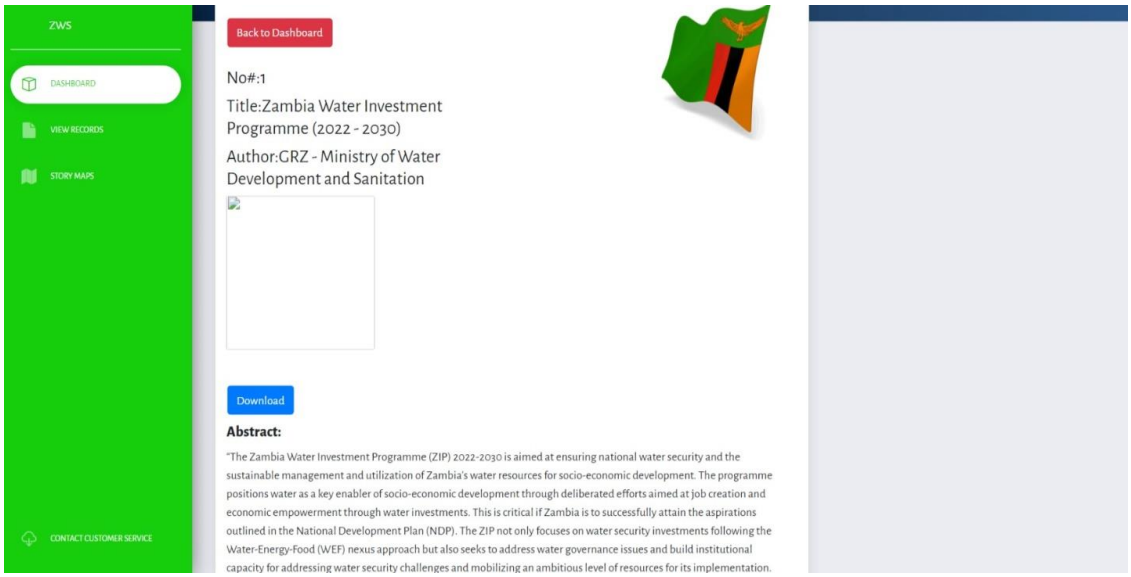
➢**Screen Design**

The system uses breadcrumb navigation at the top of the screen.

- Main menu is on the left and sub-menus are expanded below the parent item
- Selection of a menu item opens as a tab in the centre screen.
- The name of the platform and user name will be visible on the screen.



➢The system allows users to query documents as follows:



4.5.5. ZWSDA Functions

A NWASCO users can only perform functions within the NWASCO interface provided they have the permissions.

4.5.5.1. User management

Only the administrator has the permission to use this option to perform the following functions:

- Add New Users
- Edit User
- Delete User
- Change Password

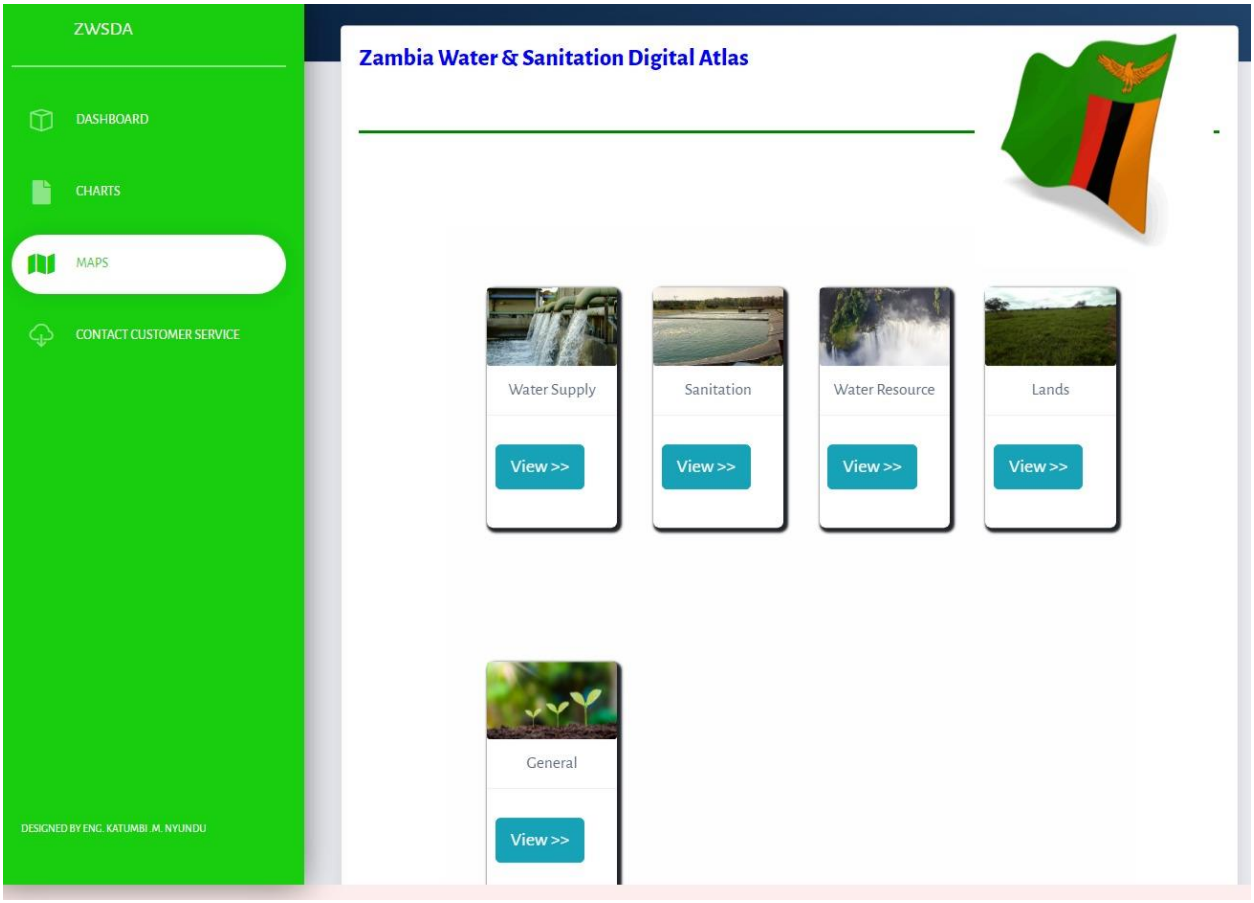
The NWASCO Admin defines administrator roles for the cooperating partners (CPs) who can then create users and assign permissions to view layers/maps respectively.

User details include:

- Institution Type *(NWASCO, CU, Other Provider, Rural)*
- Institution Name
- First Name
- Surname
- Email Address
- Contact Number
- Login ID *(initial of first name+surname)*
- Password
- Receive notification *(checkbox. When selected a notification email is sent to user)*
- Disable Account *(checkbox)*
- Role *(to determine permissions e.g. Admin, User, Guest etc)*

4.5.5.2. Master data

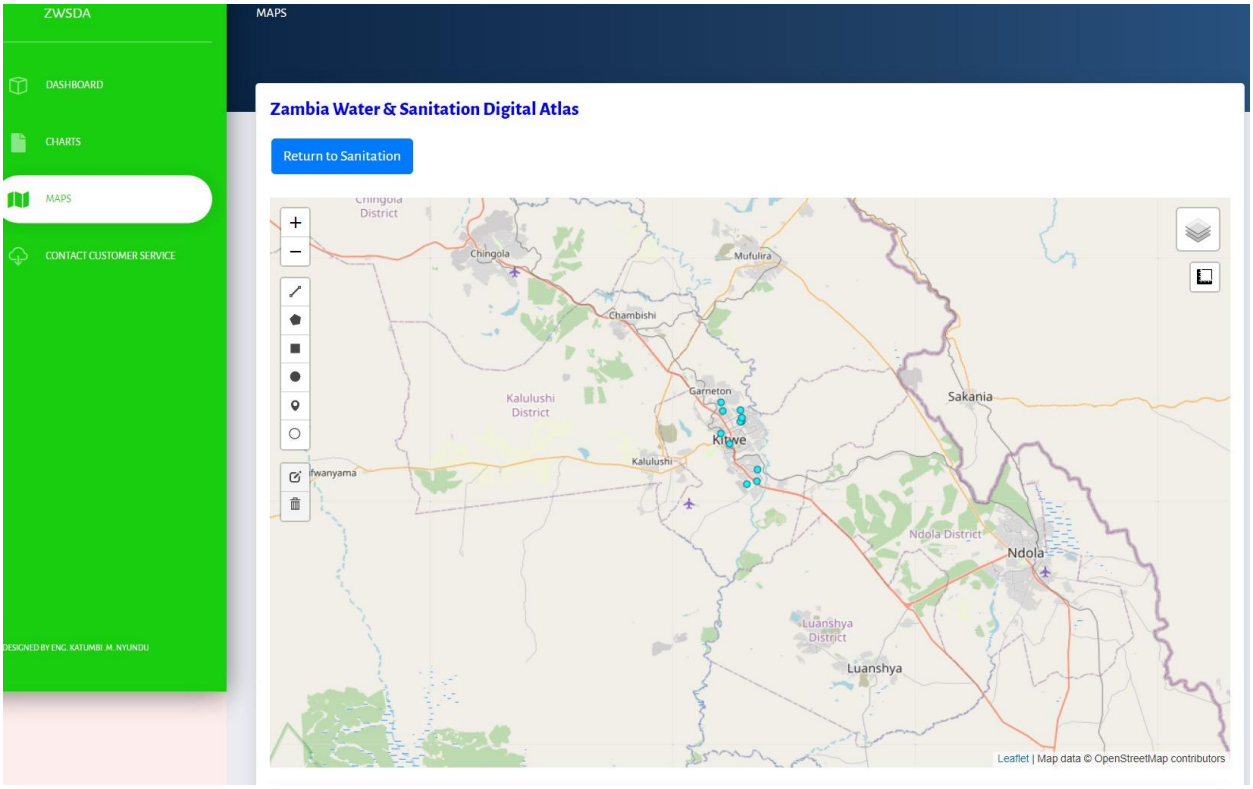
Master Data contains data common to all users of a particular Institution and centrally managed by NWASCO.



NWASCO defines, adds or edits all GIS information in terms of:

- Layer styling
- Data Attributes to be viewed
- Base maps
- Etc.

The information is drawn from the NWASCO GIS server which runs on QGIS and Postgres database. It allows to visualise data on dashboard, and in the form of maps and graphs as shown on the figure below.



4.6. Limitation of the existing IMS in data analysis and reporting

❖Zambia case

The growing data needs such as the inclusion of data and indicators for gender/HIV mainstreaming, maintenance management, Rural WSS, etc. The NIS in its state (version 5.0) is limited in terms of changes that could be made by the regulator which requires the intervention of the developer. Furthermore, the design of NIS has very restricted functionality that is not responsive to the needs of users, for example primary data entered by CUs cannot be exported out of the system in a readable format. It is impossible to query the NIS for specific information based on user criteria. Instead, the primary data must be extracted manually e.g. extracting information on specific areas, such as peri-urban, requires manual navigation through hundreds of entries and reorganising the data in Excel.

❖ EWURA case

Data are populated in the existing system by the utilities. The Regulator can make validation and use data for reporting. The system does not provide any option for the selection of some data based on specific criteria. Data on any thematic area can be downloaded, saved on the

computer in the excel format and processed based on the users' needs. Those processes are required for presentation of data in the format of table or graph. This has been time consuming so that a system that allows the storage of all data, their sorting and generation of a specific table or graph is needed.

4.7. Analysis of the GIS based Information system

Generally, the data used by all regulators are not tied to a geographic location. The Geographic Information System (GIS) technology is highly used by the utilities to indicate the location and some details about WSS facilities. The GIS allows those utilities to organize, manage, and distribute geographic information to administer infrastructure and planning of any extension. GIS is also used by utilities for mapping the coverages of their distribution systems and supporting the decision making for extension and budgeting. GIS also facilitates interdisciplinary analysis and provides the regulators like WASREB and NWASCO with the possibility of using data held by service providers for monitoring the development of water supply and sanitation activities in relation to the locations of various customers and natural environment. The overview of the existing GIS is presented in the table below. The content of the table was generated from data collected during the interviews held with the agencies visited in Nairobi, Dar Es Salaam, and Zambia, the survey questionnaire and the discussion on GIS held with the representatives of all regulators, during their MIS meeting in Nairobi, between 23-26 January 2023.

Table 8: Existing GIS and data management systems

Data aspects	Key aspects	Kenya		Tanzania			Zambia		
		WASREB	Trust Fund	EWURA	Ministry of Water	DAWASA	NWASCO	MWDS	LWSC
Data format (produced at the organization)	Hard copies (on paper)	✓	✓	✓	✓	✓	✓	✓	✓
	Soft data in table formats	✓	✓	✓	✓	✓	✓	✓	✓
	Soft data in the forms of reports	✓	✓	✓	✓	✓	✓	✓	✓
	GIS layers	-	✓	-	-	✓	✓	-	✓
Format of data (acquired from other organization) and description	Hard copies (on paper)	✓	-	✓	✓	✓	✓	✓	✓
	Soft data in table formats	✓	✓	✓	✓	✓	✓	✓	✓
	Soft data in the forms of reports	✓	✓	✓	✓	✓	✓	✓	✓
	GIS layers	✓	-	-	-	✓	✓	-	✓
	Metadata	-	-	-	-	-	-	-	-
Data manipulation software	Word	✓	✓	✓	✓	✓	✓	✓	✓
	Excel	✓	✓	✓	✓	✓	✓	✓	✓
	GIS software	-	✓	-	-	✓	✓	-	✓
GIS data collection	GPS	-	✓	-	-	✓	✓	-	✓
	Mobile phones and GIS data collector apps	-	-	-	-	✓	✓	-	-
	GIS data collection using modern tablets	-	✓	-	-	✓	✓	-	✓
	Surveying instruments	-	-	-	-	✓	-	-	✓
GIS software	Desktop ArcGIS	-	✓	-	-	✓	-	-	-
	ArcGIS on server	-	-	-	-	✓	-	-	✓
	Quantum GIS	✓	-	-	-	-	✓	-	-
GIS Data updating	Data editing in Desktop GIS	-	✓	-	-	✓	✓	-	
	Online Data editing	-	-	-	-	-	-	-	-
GIS data storage	Standalone shapefiles	✓	✓	-	-				✓
	Excel tables	✓	✓	-	-	✓	✓		✓
	Geodatabase comprising of feature classes and tables	-	✓	-	-	✓	-	-	✓

Data aspects	Key aspects	Kenya		Tanzania			Zambia		
		WASREB	Trust Fund	EWURA	Ministry of Water	DAWASA	NWASCO	MWDS	LWSC
Spatial data integrated with WSS data	Houses/buildings foot prints	-	-	-	-	✓	✓	-	✓
	Schools	-	-	-	-	✓	-	-	✓
	Health facilities (health centers, Hospitals, etc.)	-	-	-	-	✓	-	-	✓
	Markets	-	-	-	-	✓	-	-	✓
	Road networks	-	✓	-	-	✓	✓	-	✓
	Offices of public institutions and various services providers	-	-	-	-	✓	✓	-	✓
	Administrative boundaries (specify the level of administration)		✓	✓	✓	✓	✓	-	✓
	Urban residential blocks	-	✓	-	-	✓	✓	-	✓
	Cadastral data (land parcels)	-	-	-	-	✓	✓	-	✓
Staff knowledge and skills on GIS	Basic of GIS	-	✓	✓	-	✓	✓	✓	
	Basic of Remote sensing	-		-	-		✓	-	✓
	Cartography and maps production	-	✓	-	-	✓	✓	-	✓
	Geodatabase management for basic spatial analysis and maps production	-	✓	-	-	✓	✓	-	✓
	Geodatabase management for Geoportal design and management	-	✓	-	-	✓	✓	-	✓
	Web mapping and online map dissemination	-	✓	-	-		✓	-	✓
Database management system in use	Esri GDB system	-	✓	-	-	✓	-	-	
	PostgreSQL	-	-	-	-	-	-	-	-
	PostgreSQL and PostGIS	-	-	-	-	-	-	-	-
	Oracle Database	-	-	-	-	-	-	-	-
ICT infrastructure for data management	Server	✓	✓	✓	✓	✓	✓	✓	✓
	Desktop	✓	-	-	✓	✓	✓	✓	✓
	Laptop	✓	✓	✓	✓	✓	✓	✓	✓
	Switches	-	-	-	-	-	✓	-	-

Data aspects	Key aspects	Kenya		Tanzania			Zambia		
		WASREB	Trust Fund	EWURA	Ministry of Water	DAWASA	NWASCO	MWDS	LWSC
	Routers	-	-	✓	-	-	✓	-	✓
Online data publication	Yes/No	Yes	No	No	Yes	Yes	Yes	Yes	No
Organization hosting data published online	Internally hosted	✓	-	✓	✓	✓	✓	✓	✓
	Other specialized web hosting	-	-	-	-	-	-	-	-
Content management system for data hosted on website	Drupal	-	-	-	-	-	-	-	-
	Wordpress	-	-	✓	-	-	-	-	-
	Joomla	-	-	-	-	-	-	-	-
	Geonode	-	✓	-	-	-	-	-	-
	Django	-	-	-	-	-	-	-	-
	ArcGIS online	-	-	-	-	✓	-	-	-
	Link to Google earth	✓	-	-	-	-	-	-	-
	Water and Sanitation Digital atlas	-	-	-	-	-	✓	-	-
Organization role existing IMS	Administration role	✓	✓[4]	✓	-	-	✓	-	-
	Publishing role	✓	-	✓	-	-	✓	-	-
	Viewing role	-	✓[5]	-	✓	✓	-	✓	✓
	End use role	-	-	-	✓	✓	-	✓	✓
Presence of Geospatial portal for information management and sharing	Yes/No	No	No	No	No	No	Yes	No	No
Presence of Dashboard for information sharing	Yes/No	Yes	Yes	No	Yes	Yes	Yes	Yes	No
Characteristics of the existing Dashboard	Shared layers	✓	-	-	-	✓	✓	-	-
	Shared maps	✓	-	-	-	✓	✓	-	-
	Shared graphs	✓	-	-	✓	✓	✓	✓	-
Characteristics of the	Shared layers	✓	✓	✓	✓	✓	✓	✓	✓

[4] They have their own IMS

[5] They view Regulator IMS

Data aspects	Key aspects	Kenya		Tanzania			Zambia		
		WASREB	Trust Fund	EWURA	Ministry of Water	DAWASA	NWASCO	MWDS	LWSC
desired Geospatial portal	Shared maps	✓	✓	✓	✓	✓	✓	✓	✓
	Shared dashboards	✓	✓	✓	✓	✓	✓	✓	✓
	Shared reports	✓	✓	✓	✓	✓	✓	✓	✓
Capacity building needed for developing a Geospatial portal	Data collection using mobile apps	✓	✓	✓	✓	-	✓	✓	-
	Geodatabase management: data organization, cleaning, storage on Desktop and server	✓	✓	✓	✓	-	✓	✓	✓
	Map design and publication on web	✓	-	✓	✓	✓	✓	✓	✓
	Remote sensing	-	✓	✓	-	-	-	-	-
Roles of utilities in Geospatial portal administration	Administration role	-	-	-	-	-	✓	-	✓
	Publishing role	-	-	-	-	-	✓	-	✓
	Viewing role	✓	✓	✓	✓	✓	-	✓	✓
	End use role	✓	-	✓	✓	✓	-	✓	✓
	Data entry	✓	✓	✓	-	✓	-	-	✓

- ❖GIS is developed at the utility level. The Regulators like (NWASCO) which have GIS use data provided by the utilities.
- ❖At EWURA, they have a QGIS dashboard which is managed by a private consultant. The utility does not have the trained personnel to manage the system. The system is not regularly updated so the regulator needs to develop its personnel capacity that would allow for ensuring the management and administration of the system.
- ❖There is a need for training on GIS for most of staff at the regulator level, even for those where the GIS exists since it is operated by one technical staff (like at NWASCO) while others do not have knowledge and skills about GIS.
- ❖ The ICT hardware needed for GIS set up are available: laptop, desktop, server, etc.
- ❖The Open sources like QGIS is preferable for setting the IS based on GIS. The use of open source is highly supported in Tanzania, Kenya, and Zambia since it is cost effective and does not require many resources. In Tanzania, the government encourages its agencies to use local and open sources where possible in order to improve governance and service delivery through the use of information and communication technology (ICT) which can be at the reach of many users.

- ❖However, the Regulator in Rwanda suggests the use of the commercial GIS based Geoportal for the high level protection of data despite the costs required by the system.
- ❖The mobile apps for data collection are the most desired than the traditional devices (like Handheld GPS and DGPS) since those are expensive and require additional resources for maintenance.
- ❖In each country, there is an agency hosting the existing IMS. In Tanzania, the IMS is hosted in the data Center, within the Ministry of ICT. In Kenya, it is the Ministry of Water, while in Zambia, it is hosted by the Ministry of Water Development and Sanitation.

4.8. Data standards and alignment with the Geoportal development requirements

The research analyzed the quality of available data in term of standards required for developing the geoportal. Findings which are summarized in the table below show that the existing data are stored in the suitable formats so that they can be used for the development of Geoportal.

Table 9: GIS Data and standards

Data aspects	**Key aspects**	**Kenya**	**Tanzania**	**Zambia**
		WASREB	**DAWAS**	**LWSC**
Data model	Vector or raster	Both are used	Both are used	Both are used
Vector format	Shapefile with the following files: shp, .shx, .dbf and prj	Used	Used	Used
	Compliance to the topologic rules	Was not assessed	Not applied	Not applied
Raster format	Digital Elevation Model (DEM)	Was not assessed	Used	Used
	TIFF or GeoTIFF image with world reference file	Was not assessed	Used	Used
	PEG image with world reference file	Was not assessed	Used	Used
Tabular data	Microsoft Excel (.xlsx)	Used	Used	Used
	Tab or comma-delimited text files (.txt, .csv)	Used	Used	Used
Geodatabase	Topologies and topological rules	Was not assessed	Does not exist: they use shapefiles	Does not exist: they use shapefiles
Projections	UTM	Used	Used	Used
	Geographic coordinate system	Used	Used	Used
Metadata	Identification information	Was not assessed	Does not exist	Does not exist

Data aspects	Key aspects	Kenya	Tanzania	Zambia
		WASREB	**DAWAS**	**LWSC**
	Data quality information	Was not assessed	Does not exist	Does not exist
	Spatial data organization information	Was not assessed	Does not exist	Does not exist
	Spatial data content information	Was not assessed	Does not exist	Does not exist
	Distribution information	Was not assessed	Does not exist	Does not exist
	Metadata reference information	Was not assessed	Does not exist	Does not exist
Naming conventions	Dataset naming conventions	Was not assessed	They are not used	They are not used
	Attribute field naming conventions	Was not assessed	They are not used	They are not used
Geospatial standards for web	KML	Used	Used	Used
	WCS	It is not used	It is not used	It is not used
	WFS	It is not used	It is not used	It is not used
	WMS	It is not used	It is not used	It is not used
	WMTS	It is not used	It is not used	It is not used
	WPS	It is not used	It is not used	It is not used

4.9. General observations on data format and quality

The existing datasets cover mostly the water network in Nairobi, Dar Es salaam. In Zambia, there are good achievements as LWSC managed to collect data on almost all water supply, sanitation and hygiene facilities for Lusaka city. However, some improvements are needed in the collection and management of those data.

4.9.1. The Non-completeness of the data for reporting on various indicators

Data on water pipelines are not stored in a geodatabase. They are also presented in different layers, based on the services areas. Some attribute data that would allow for reporting on water pipe quality for instance are also missing. The use of those data will require updating activities.

Figure 20: Attribute data on water pipe in Lusaka

Data on sewerage network are also not well organised into a Geodatabase. This is shown on the figure below.

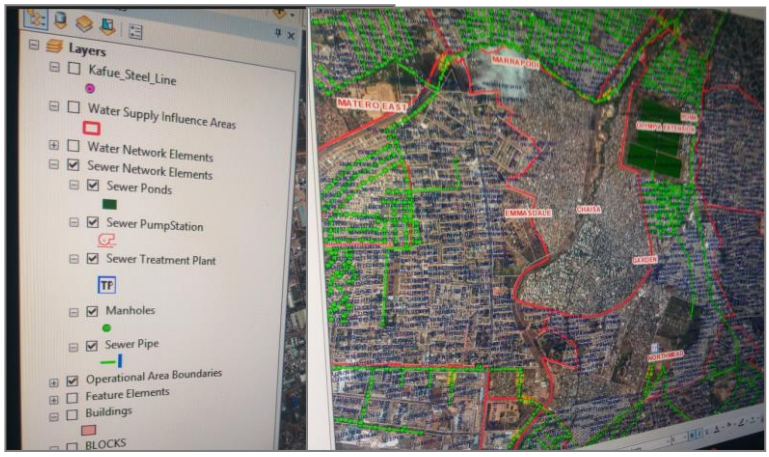


Figure 21:Distribution of sewerage network in Lusaka

4.9.2. Data organisation issue

Data on different types of latrines. Yet, those data are not stored in a well-structured database. Their use for geoportal development will require a re-organisation into a Geodatabase.

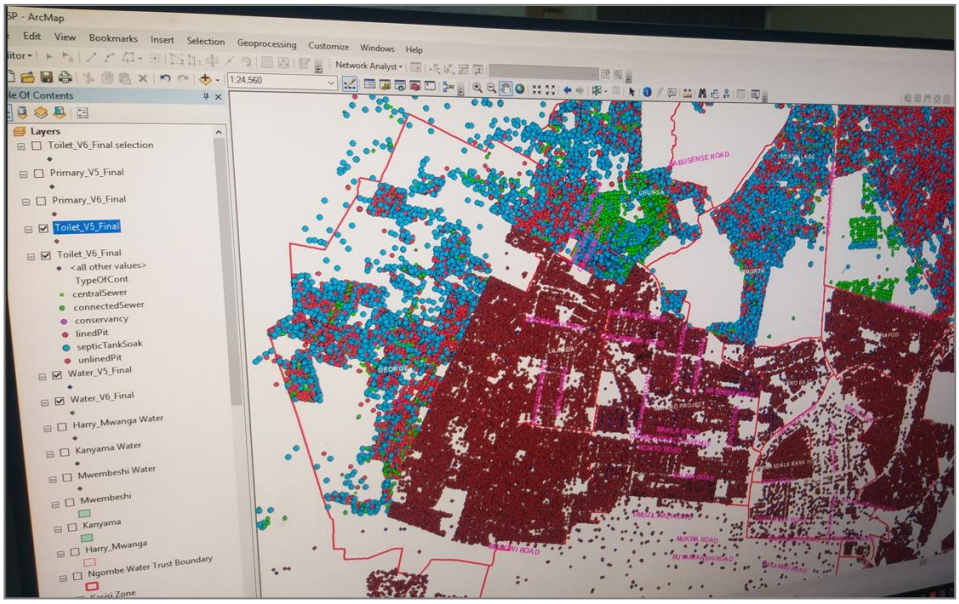


Figure 22 : Distribution of Sanitation facilities in Lusaka

4.10. Readiness for the Regulators for GIS adoption

Designing a framework for a Geoportal in Water and Sanitation requires the investigation on the users' needs and interest for its adoption and use. These aspects were investigated, focusing on the following issues: interest in GIS adoption, existence of GIS initiative at the regulator, existence of GIS initiative at the utilities, Commitment to support the adoption of GIS at the utility level, presence of the required the ICT facilities, the apps that should be used for Geoportal development and capacity building need. The results of the investigation are presented in the table below and confirm the readiness of all regulators under the coordination of ESAWAS to accept the use of GIS based Information system in collection and managing WSS data and generating the related reports.

Table 10:Status the Regulators for GIS adoption

Key aspect assessed	Comment	Regulator Name									
		WASREB	NWSACO	EWURA	AURA, IP	RURA	ZURA	AREEN	WASAMA	LEWA	WURD
Interest in GIS adoption	Interest and willingness to adopt GIS for supporting reporting and monitoring activities	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Existence of GIS initiative at the regulator	There is an operational GIS that would enable the development of Geoportal	No	Yes	No	No	No	No	No	No	No	No
Existence of GIS initiative at the utilities	There is an operational GIS that would enable the development of Geoportal	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Commitment to support the adoption of GIS at the utility level	Adoption of the GIS at the utility level will allow the collection and provision of data for development of Geoportal at the Regulator	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ICT facilities	Availability of ICT facilities (hardware , Internet, server) for setting up operational GIS and development of Geoportal	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Use Open Source apps for Geoportal	Use of open source software for the development of Geoportal	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Capacity building need	Need for capacity need building to use and maintain the Geoportal	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

The regulators like ZURA; EWURA; AURA, IP; RURA; AREEN; WASAMA; LEWA and WURD do not have a GIS which is linked with the existing IMS. They are very interested in setting up the system and ready to establish the WSS Geoportal if there is any support provided by AfDB and ESAWAS in relation to the capacity which is needed. At WASREB, the GIS is operated by a private consultant who collects and updates the system on a regular basis. For this reason, the regulator is much interested in taking the leading of the system if its staff is trained on all related operations. In the other regulators, like NWASCO, that have already the GIS and Water Atlas in place, the staff expressed little interest in setting any other system, unless it was designed in a way that would enable the upgrading of the one in use. Generally, the establishment of the GIS base information system and Geoportal should start with the regulators which do not have any GIS in place, after the assessment of the possibilities for collection of the required data where those data do not exist. Yet, as shown in the above table, the required basic datasets are available in many utilities as they have been mapping their WSS facilities.

5. Recommended System design for WSS Geoportal

This chapter present an overview of the GIS based information for the regulators and utilities that would allow for the recordation, maintain, and update various data which are required for reporting on the progress and performance in WSS sector.

5.1. Overview and requirements

GIS-base Portal, or Geoportal is a web framework enabling discovery and use of spatial data over internet (Mehdi, et al. 2014). Water and Sanitation Management Information System is the process of developing a GIS-based water and sanitation portal in a bid to manage water and sanitation resources, both in terms of quantity and quality across all water and sanitation uses. In this way, it is aiming at optimizing the benefits of water and sanitation by ensuring decision makers are well informed about the service delivery (for example there is enough drinking water, adequate sanitation services), and hence they can well develop appropriate policies aiming at addressing issues related to water and sanitation in any given geographic area. This part of the report relates to how a GIS-based water and sanitation management information system is structured as shown in the figure below.

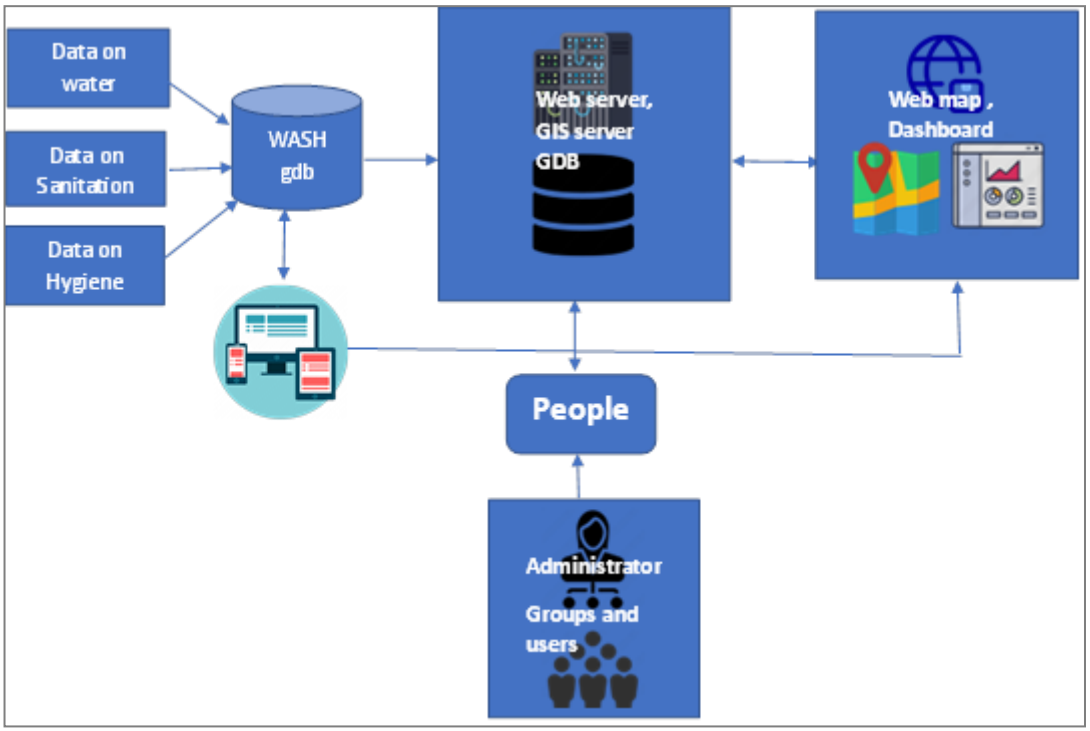


Figure 23:Simplified Model for WSS Geoportal

The details of each components of the system are developed below.

- Database: This database is hosted in PostgreSQL (it is described under the section of "WSS geodatabase management system" in the next sections)

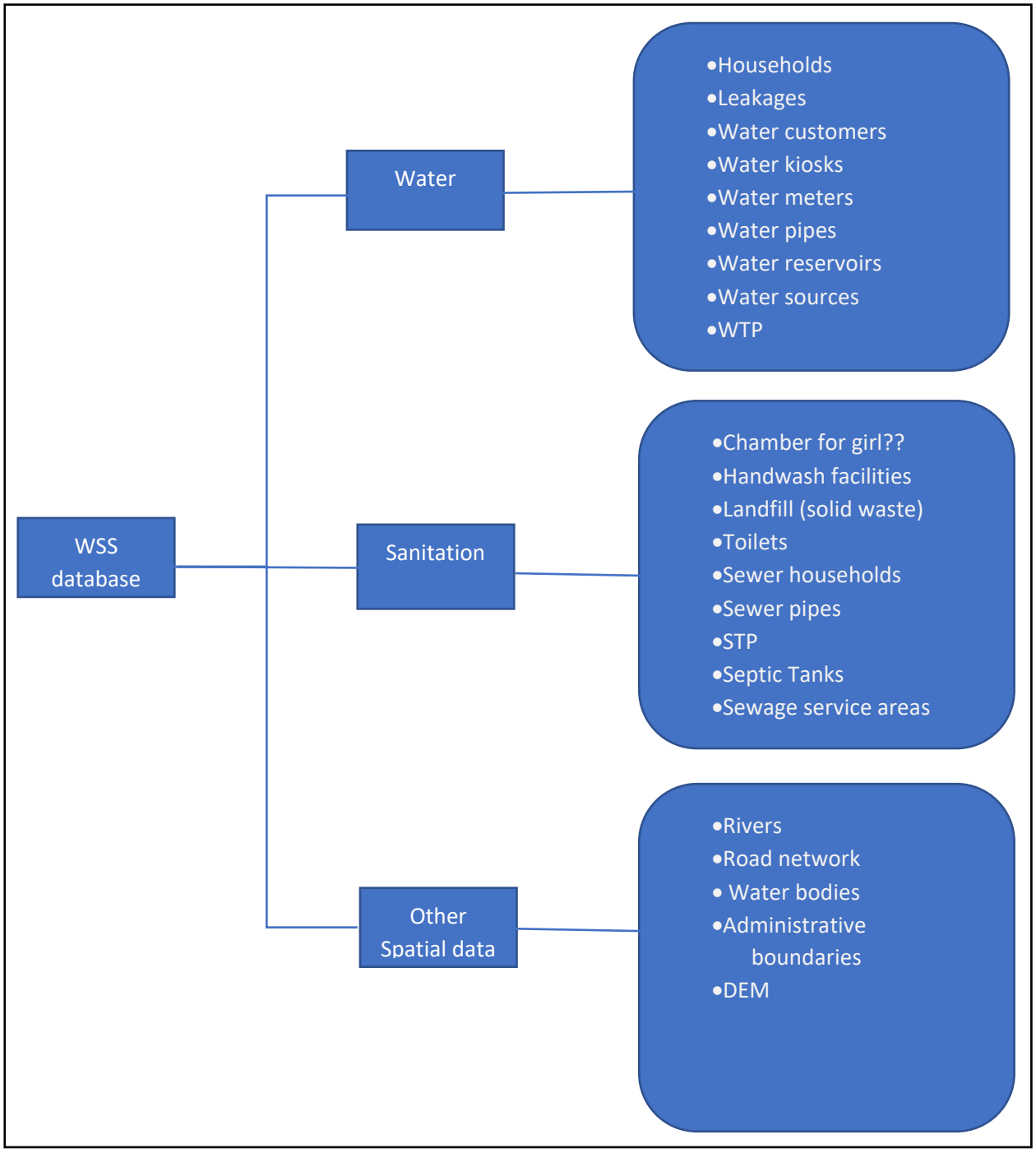


Figure 24: WSS database component

- Desktop and mobile application: This component is composed of GIS desktop and Mobile GIS applications. The GIS desktop plays a role of connecting to Postgresql databases, displaying data, analyzing data, preparing projects for offline editing/updating using mobile GIS Applications and synchronization with PostgreSQL database.

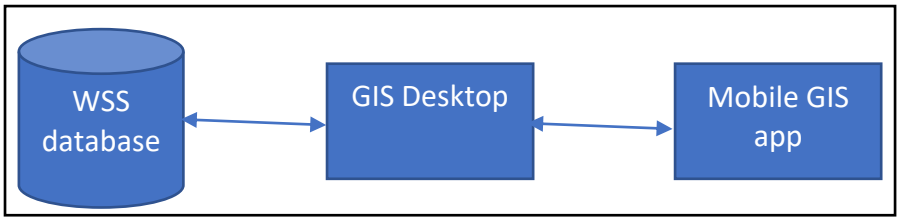


Figure 25: Database, GIS desktop and mobile apps

- GIS server component: This component is composed of the Geoserver connected to PostgreSQL database and have a role of publishing data to Mapstore which transforms the published web services as web maps and dashboards.

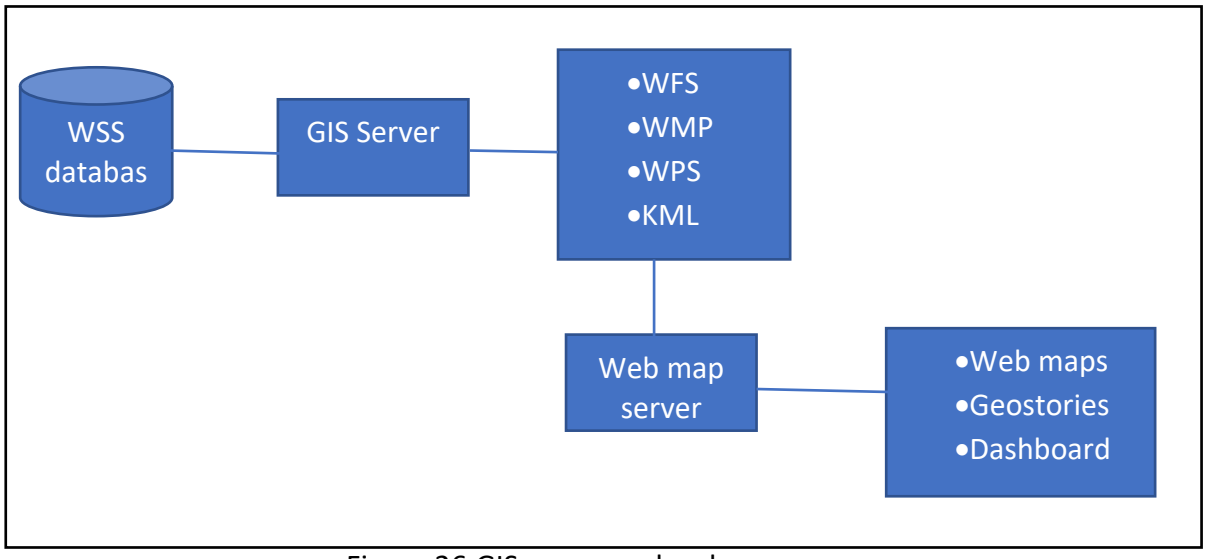


Figure 26:GIS server and webmap server

•System administration: This component is composed the system administrator and system users with different roles and responsibilities.

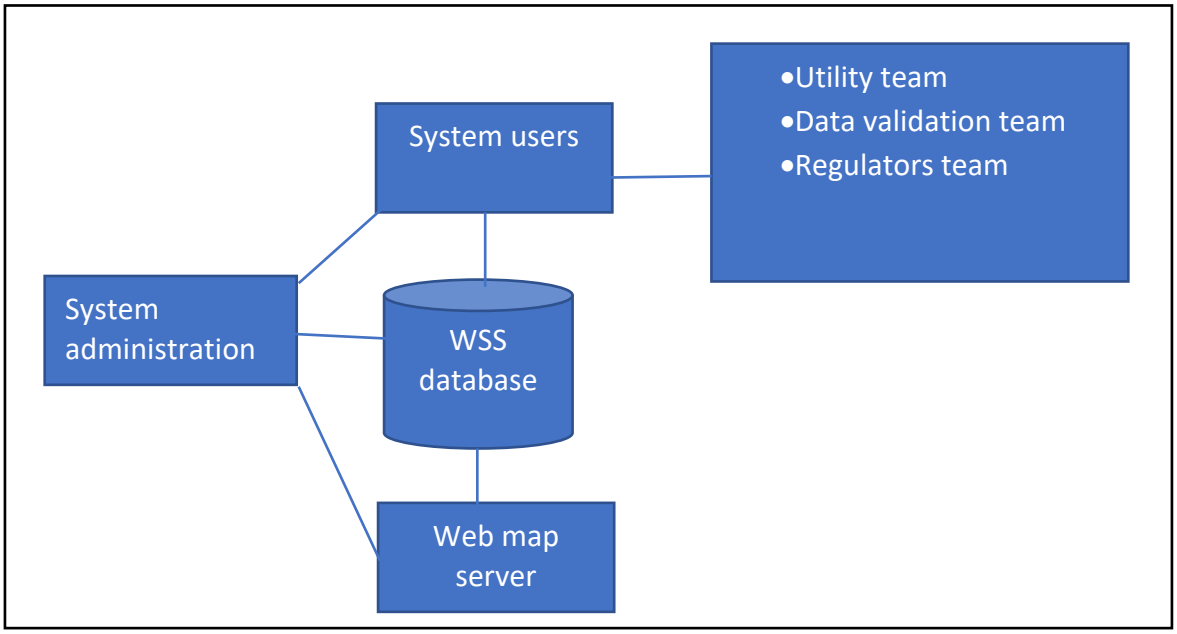


Figure 27:System administrators and system users

The Information System is expected to provide reliable information enabling a comprehensive management approach to urban and rural WSS with a strong focus on the service delivery. It will allow for data analysis and generation of performance indicators that are aggregated at several levels and automatically used to produce the rankings and summary reports detailing the variables that factor into the performance of utilities or service providers, and technical assistance.

5.2. Requirements for WSS Geoportal development

Before implementing a geoportal, it is necessary to assess the required assets (ICT hardware and software) that will be used to run efficiently depending on the organization needs and the data. ESAWAS would use the open-source software to handle all WSS-related spatial data. We identified the following easy-to-install and easy-to-use software:

- ✓QGIS desktop and its QField: QGIS is a free and open source Geographic Information System with which it is possible to create, edit, visualize and publish spatial data. At the time of this writing, the current release is QGIS 3.30 but the long-term stable release is QGIS 3.28.6. It can be installed on different platforms.
- ✓PostgreSQL/PostGIS: PostgreSQL is an open source object-relational database system. With its spatial extension, PostGIS, it supports spatial data as well non spatial data. The current version is PostgreSQL 15 while the current version of PostGIS is PostGIS 3.3.

- ✓Geoserver: Geoserver is an open source server for sharing and publishing geospatial data as Web Feature Service (WFS), Web Map Service (WMS), and Web Coverage Service (WCS), Web Processing Service (WPS), and Web Map Tile Service (WMTS). The current version is Geoserver 2.23.
- ✓Mapstore2: Mapsource is an open source framework for web mapping application using open mapping libraries such openlayers and leaflet.
- ✓Apache Tomcat: Apache Tomcat is a local java web container.

The usage of the above software is developed in next chapters. The following are the hardware requirements to make them run successfully:

- ➢The minimum hardware required to install and run PostgreSQL is:

- 1 GHz processor
- 2 GB of RAM
- 512 MB of HDD

- ➢Mapstore2 requires 2 core for processor and 2GB of memory, but 4GB is recommended
- ➢GeoServer requires a Java 11 or Java 17 environment (JRE) to be installed on your system.
- ➢QGIS desktop requires the following:

  - ✓Process-CPU. Core i3 2.7 Ghz. Core i7 3.5 Ghz
  - ✓Memory RAM 2GB or more
  - ✓Hard Disk 500Gb SATA, SSD de 128 Gb or more

QField minimum requirements: The mobile device with at least Android 9.

- ➢Apache Tomcat 9.0. x requires Java 8 or later, 256 MB of RAM (but 512 MB is recommended) and a storage space of 100mb free to install the product

Further to the above-mentioned requirements, additional disk space is required for data or supporting components.

5.3. GIS portal components

With the above listed open sources applications, it is possible to develop a GIS portal that will be composed of the following components:

- •Desktop and smartphone GIS for data preparation: Data collection, data cleaning, data visualization, spatial data analysis, map productions and spatial data publication.
- •Spatial database management component: Spatial data prepared in Desktop GIS are securely housed in the PostgreSQL/PostGIS database from which data can be connected to QGIS desktop on one hand and be published to Geoserver in different web services on the other.

•Web server component composed of both Geoserver and Mapserver: Geoserver plays a role of administering and publishing spatial data in different format, while Mapstore plays a role of web mapping application such as creating web maps, story maps and Dashboards.

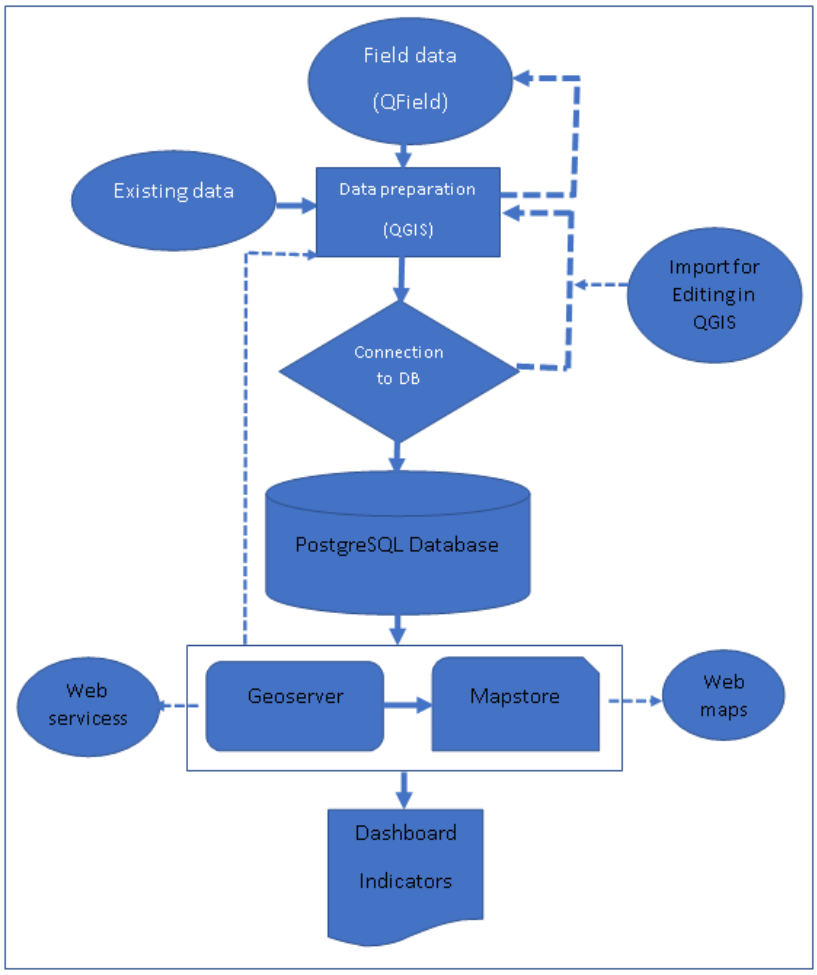


Figure 28:Framework of building WSS Geoportal

5.4. WSS geodatabase management system

There are different DBMS such as Microsoft Access, MySQL, Oracle Database, MongoDB, PostgreSQL, amongst others. PostgreSQL would be the DBMS fulfilling the ESAWAS needs as it supports the spatial extension, PostGIS. The PostGreSQL/PostGIS is characterised of the following three components:

- Spatial data types: It supports points, lines, and polygons.
- Spatial queries: A spatial query using SQL allows retrieving a specific subset of spatial data.

- Spatial indexes: spatial indexes are used to quickly locate spatial data or features in in a spatial dataset.

The benefits of using PostgreSQL\PostGIS are the following:

- Easy to organize and maintain
- Can be used with a variety of software
- Multi-user: Many users can concurrently update the same database
- Permission and security: Administrator of the database manages permissions to different connected user, and hence the database is well secured.
- Data back-ups
- Spatial analysis: such as proximity, buffering, …
- Integrates seamlessly with QGIS:

As far as WSS database is concerned, the following datasets can be managed within the PostgreSQL\PostGIS database:

- ✓The water supply systems or services such as provision of piped water on-site, public standpipes, boreholes, protected dug wells, protected springs or rainwater.
- ✓The sanitation system designed and used to separate human excreta from human contact at all steps of the sanitation service chain from safe toilets and containment (in some systems with treatment in-situ) through conveyance (in sewers or by emptying and transport), to treatment and final disposal or end use
- ✓Hygiene interventions include promoting handwashing with soap at critical times. A broader definition may include food hygiene measures (e.g. washing, covering, cooking and storage of food), environmental hygiene (e.g. cleaning of surfaces), menstrual hygiene, or hygiene interventions specific to prevention and control of particular diseases (e.g. face washing for trachoma, shoe wearing for soil-transmitted helminths, and animal management for zoonotic diseases).
- ✓Access to WSS services: Households, Health care facilities, Schools
- ✓Administrative data: branches, …

The database will be composed of different dataset or layers, whose attribute data are summarized in the following tables. Those datasets and their attributes were suggested based on the existing GIS data which are collected by the utilities, and all data which are collected by the regulators for reporting on the WSS indicators as indicated in the appendices 1, and 3. It is worth noting that the data which are related to all indicators that are taken into account for the reporting purposes cannot be collected and managed using GIS. The appendix 1 shows clearly the indicators that will be collected and stored using GIS, while other will be maintained in the existing MIS. This means that the GIS will be used in combination with the existing MIS. Yet, the non-spatial data information from the existing MIS can be linked with GIS layers (as attribute data as shown in the tables below) in order to produce the related tables and graphs automatically.

5.5. Data on water supply system

❖Data on water source

Identification	Attribute	Data type	Description
Water source	Source ID	Short text	The water source identification code
	Source Name	Short text	The name of source name or its location
	Type	Short text	The type of Water source(River, Spring, underground water, etc..)
	Latitude	Number	One of location indicators
	Longitude	Number	One of location indicators
	Elevation	Number	One of location indicators
	Date	Date	Year of extraction of water catchment
	Discharge	Number	Water quantity given by the Source(m3/s)
	pH	Number	Percentage of pH tested in raw water
	Fe	Number	Percentage of Fe tested in raw water
	Eschelchia chlorine	Number	Percentage of Eschelchia chlorine tested in raw water
	Water source upkeep	Short text	All infrastructure provided for water catchment security

❖Water treatment plant

Identification	Attribute		Description
Water treatment plant	Water treatment plant ID	Short text	The water treatment plant identification code
	Source ID	Short text	The water source identification code(foreign key in WTP)
	Reservoir ID	Short text	The Reservoir identification code(foreign key in WTP)
	Service area ID	Short text	The service area identification code(foreign key in WTP)
	Latitude	Number	One of location indicators
	Longitude	Number	One of location indicators
	Elevation	Number	One of location indicators
	Date	Date	Construction year
	Design capacity	Number	Quantity of water that can be stored at the water treatment plant
	Production capacity	Number	The quantity of water treated
	Distribution capacity	Number	The quantity of water distributed to the customers

Identification	Attribute		Description
	Energy	Number	Electrical energy used for daily or monthly water production
	Demand	Number	The daily water quantity demanded by the customers
	Operating costs of water treated	Number	The cost of the materials and manpower for one meter cube of billed water.
	Water loss per day	Number	The water quantity treated but not used per day
	Water source	Short text	The type of water source (River, Spring, underground water, etc..)
	pH	Number	Results of pH tests conducted
	Turbidity standards	Number	Results of Turbidity tests conducted
	Fe %	Number	Results of Fe tests conducted
	Echelchia coli %	Number	Results of Echelchia tests conducted
	Residual chlorine %	Number	Results of Residual tests conducted
	Bacteriology %	Number	Results of Bacteriology tests conducted
	Fluorides standards	Number	Results of Fluorides tests conducted
	Nitrates standards	Number	Results of Nitrates tests conducted
	Water production expense	Number	The money for production of one meter cube.
	Water distribution expense	Number	The water cost from WTP to customers
	BOD 5 Results	Short text	Quality of discharged effluent
	COD Results	Short text	Quality of discharged effluent
	Operating costs of water distributed	Number	The cost of the materials and manpower for one meter cube distribution.
	Chemical expenses	Number	The cost of chemical in water treatment process.

❖Water Pipe

Identification	Attribute	Data Type	Description
Water pipe	Water Pipe ID	Short text	The water pipe identification code
	Meter ID	Short text	The water meter identification code(Foreign key)
	Leakage ID	Short text	The Leakage identification code(Foreign Key)
	Date	Date	Year of pipe installation
	Materials	Long text	Pipe Materials(PVC,HDPE,DI, etc.)
	Diameter	Long text	Nominal diameter of pipe
	Pressure class	Long text	Nominal pressure of pipe
	Length	Long text	Length of the pipe

Identification	Attribute	Data Type	Description
	Category of connection	Short text	Pipeline categorized per its function,(Primary, Secondary and tertiary)
	Leakage date	Date	Date of the leakage
	Leakage frequency	Number	Leakages frequency on that pipe
	Leakage location	Short text	Village or centre name
	Rehabilitation	Date	Year of rehabilitation
	Replacement	Yes/No	Yes: there is a change/ No: there is no change
	Customer complaint	Short text	Number complaint of the clients
	New features on water connection	Short text	Functionality of the pipe

❖Water reservoir

Identification	Attribute	Data Type	Description
Water reservoir	Reservoir ID	Short text	The reservoir identification code
	Water pipe ID	Short text	The water pipe identification code(Foreign key)
	Water service area ID	Short text	The water service identification code(Foreign key)
	Kiosk ID	Short text	The kiosk identification code(Foreign key)
	Water customer ID	Short text	The water customer identification code(Foreign key)
	Latitude	Number	One of location indicators
	Longitude	Number	One of location indicators
	Elevation	Number	One of location indicators
	Date of installation	Date	Construction year
	Capacity		
	Meter number	Long text	S/N of meter
	Active connection	Yes/No	Yes: it is still connected/No: It is not connected
	Replacement	Date	Year of replacement or total rehabilitation
	Material	Long text	Construction material
	PH	Number	The tested PH at the inlet of reservoir
	Turbidity standards	Number	The tested turbidity standards at the inlet of reservoir
	Fe	Number	The tested Fe at the inlet of reservoir
	Echelchia coli	Number	The tested Echelchia coli at the inlet of reservoir
	Residual chlorine	Number	The tested residual chlorine at the

Identification	Attribute	Data Type	Description
			inlet of reservoir
	Bacteriology	Number	The tested bacteriology at the inlet of reservoir
	Fluorides standards	Number	The tested fluorides standards at the inlet of reservoir
	Mn standards	Number	The tested Mn standards at the inlet of reservoir
	Nitrates standards	Number	The tested Nitrates standards at the inlet of reservoir
	Results of residual chlorine tests conducted	Number	The tested chlorine at the outlet of Reservoir
	Results of E-Coli tests conducted	Number	The tested E-Coli at the outlet of reservoir
	Results of turbidity tests conducted	Number	The tested turbidity at the outlet of reservoir
	Results of pH tests conducted	Number	The tested PH at the outlet of reservoir
	Results of chlorides test conducted	Number	The tested chlorides at the outlet of reservoir
	Results of fluorides test conducted	Number	The tested fluorides at the outlet of reservoir
	Results of Fe test conducted	Number	The tested Fe at the outlet of Reservoir
	Results of Mn test conducted	Number	The tested Mn at the outlet of reservoir
	Results of nitrates test conducted	Number	The tested nitrates at the outlet of reservoir

❖Water meter

Identification	Attribute	Data Type	Description
Water meter	Meter ID	Short text	The meter identification code
	Latitude	Number	One of location indicators
	Longitude	Number	One of location indicators
	Elevation	Number	One of location indicators
	Meter Number	Long text	S/N of meter
	Meter type	Text	Electronic/Manual
	Customer ID	Number	The identification code of the customer
	Customer category	Short text	The category of Clients (Household, School, etc.)
	Active connection	Short text	The client who pays the monthly bill
	Inactive connection	Short text	The client who is disconnected
	Operating meter	Yes/No	Yes: it is working, No: it is not working

Identification	Attribute	Data Type	Description
	Replacement	Date	Year of replacement
	Complaint	Short text	Complaint about meter functionality
	Meter testing	Number	Number of testing per Year
	Average monthly billing	Large number	Average of monthly index used
	Claim on billing	Number	Number of billing complaints
	Water losses per active connection	Number	Non billed water for one customer per month
	Average water tariff	Number	Fixed cost per m3

❖Water kiosk

Identification	Attribute	Data Type	Description
Water kiosk	Kiosk ID	Short Text	The meter identification code
	Latitude	Number	One of location indicators
	Longitude	Number	One of location indicators
	Elevation	Number	One of location indicators
	POC number	Long text	Registration number of client
	Date	Date	Construction date
	Service provider	Long text	Name of kiosk user
	Customers	Large number	The number of population served by kiosk
	Daily consumption	Large number	Daily Index
	Water tariff	Large number	The Fixed cost per 20little
	Service hours	Large number	Service hours per day
	Private connection	Number	Number of Private connection around the Kiosk
	Billed water per month	Number	Monthly bill
	Results of residual chlorine	Number	The tested residual chlorine at kiosk tap
	Results of E-Coli	Number	The tested E-Coli at kiosk tap
	Results of turbidity	Number	The tested turbidity at kiosk tap
	Results of pH	Number	The tested PH at kiosk tap
	Results of chlorides	Number	The tested chlorides at kiosk tap
	Results of fluorides	Number	The tested fluorides at kiosk tap
	Results of Fe	Number	The tested Fe at kiosk tap
	Results of Mn	Number	The tested Mn at kiosk tap
	Results of nitrate	Number	The tested nitrates at kiosk tap

❖ Communal/public tap

Identification	Attribute	Data Type	Description
Communal/public tap	Communal/public tap ID	Short Text	The meter identification code
	Latitude	Number	One of location indicators
	Longitude	Number	One of location indicators
	Elevation	Number	One of location indicators
	POC number	Long text	Registration number of client
	Date	Date	Construction date
	Service provider	Long text	Name of Communal/public tap user
	Customers	Large number	The number of population served by Communal/public tap
	Daily consumption	Large number	Daily Index
	Water tariff	Large number	The Fixed cost per 20little
	Service hours	Large number	Service hours per day
	Private connection	Number	Number of Private connection around the Communal/public tap
	Billed water per month	Number	Monthly bill
	Results of residual chlorine	Number	The tested residual chlorine at Communal/public tap
	Results of E-Coli	Number	The tested E-Coli at Communal/public tap
	Results of turbidity	Number	The tested turbidity at Communal/public tap
	Results of pH	Number	The tested PH at kiosk tap
	Results of chlorides	Number	The tested chlorides at Communal/public tap
	Results of fluorides	Number	The tested fluorides at Communal/public tap
	Results of Fe	Number	The tested Fe at Communal/public tap
	Results of Mn	Number	The tested Mn at Communal/public tap
	Results of nitrate	Number	The tested nitrates at Communal/public tap

❖ Yard tap

Identification	Attribute	Data Type	Description
Yard tap	Communal/public tap ID	Short Text	The meter identification code
	Latitude	Number	One of location indicators
	Longitude	Number	One of location indicators
	Elevation	Number	One of location indicators
	POC number	Long text	Registration number of client
	Date	Date	Construction date
	Service provider	Long text	Name of Yard tap user
	Customers	Large number	The number of population served by Yard tap
	Daily consumption	Large number	Daily Index
	Water tariff	Large number	The Fixed cost per 20little
	Service hours	Large number	Service hours per day
	Private connection	Number	Number of Private connection around the Yard tap
	Billed water per month	Number	Monthly bill
	Results of residual chlorine	Number	The tested residual chlorine at Yard tap
	Results of E-Coli	Number	The tested E-Coli at Yard tap
	Results of turbidity	Number	The tested turbidity at Yard tap
	Results of pH	Number	The tested PH at Yard tap
	Results of chlorides	Number	The tested chlorides at Yard tap
	Results of fluorides	Number	The tested fluorides at Yard tap
	Results of Fe	Number	The tested Fe at Communal/public tap
	Results of Mn	Number	The tested Mn at Yard tap
	Results of nitrate	Number	The tested nitrates at Yard tap

❖Water Service area

Identification	Attribute	Data type	Description
Service area	Water service area ID	Short text	The service area identification code
	Name	Short text	Village or cell of service area
	Latitude	Number	One of location indicators
	Longitude	Number	One of location indicators
	Elevation	Number	One of location indicators
	Water Reservoir ID	Short text	The water reservoir identification code(Foreign Key)
	Water Pipe ID	Short text	The water pipe identification code(Foreign Key)
	Total population	Number	The number of populations in the service area
	Region/Province	Long text	Province of service area
	District	Long text	District of service area
	Sector	Long text	Sector of service area
	Number of households	Number	The number of households in the service area
	Number of active customers	Number	The number of clients who receive the monthly bill
	Number of connections	Number	The number of households with water connections in the area
	Population with access to kiosk	Number	The number of people who access water through Kiosk
	Population with access to Communal/public tap	Number	The number of people who access water through Communal/Public tap
	Population with access to Yard Tap	Number	The number of people who access water through Yard Tap
	Service provider	Number	The company that distributes water in the service area
	Coverage	Number	The percentage of people served in the area
	Demand	Number	The water quantity needed in the area
	Zoning	Long text	Category of zoning in the area
	Interruptions frequencies	Number	Number of interruption per week
	Collection efficiency	Number	Total collection from water sales
	Billing efficiency	Number	Total billed volume / Estimated billable water * 100
	Billing reliability	Number	(Total no. of bills dispatched) / (Total active connections) * 100
	Income	Number	The benefit from water

Identification	Attribute	Data type	Description
			distribution
	Billing efficiency	Short text	The quality of index collection
	Billing complaints	Number	Number of complaint of the client about the bills
	Average number of days taken to resolve billing complaints	Number	The time required to resolve the client's complaint.
	Daily water distribution	Number	Daily Water quantity in m3 used in the area
	Collections based on billing	Number	Total collection from water including billing of water sales meter rent and other operating income
	Service hours	Number	Service hour of water distribution in the Area (24hours/day,12hour/day…etc)
	Percentage of connections with 24 hours supply	Number	Percentage of households that can have water in 24hours without interruption.
	Water losses per month	Number	Difference between distributed water and billed water in the Area

❖Household

Identification	Attribute	Data type	Description
Household	Household ID	Short text	The household identification code
	Latitude	Number	One of location indicators
	Longitude	Number	One of location indicators
	Elevation	Number	One of location indicators
	Owner	Long text	Name of family representative
	Household size		Average number of persons in the house
	Connected Household	Yes/No	Yes: is connected/ No: is not connected
	Connection type		Household or Yard tap
	Main Source of water	Long text	The type of the source used for this water supply system
	Distance to fetch water	Large number	Distance required from to household to public tap or Source
	Time to fetch water	Large number	Time required to fetch water
	Size of the container	Large number	The size of container used to fetch water
	Average household monthly consumption	Large number	Water quantity used by household per month
	Tariff		
	Average monthly payment for water	Large number	The monthly money paid per a household
	Service hours	Large number	Service hours without interruption per day
	Average consumption per day	Large number	Water quantity used per day
	Average consumption per month	Large number	Water quantity used per month
	Average monthly payment	Large number	Money paid per month
	Interruptions frequencies	Number	Number of Interruptions per week
	Water storage	Yes/No	Yes: There is a water tank/No:There is not a water tank
	Water storage capacity	Number	Water tank capacity
	PH	Number	The tested pH at household tap

Identification	Attribute	Data type	Description
	Turbidity standard	Number	The tested turbidity standards at household tap
	Fe	Number	The tested Fe at household tap
	Echelchia coli	Number	The tested echelchia coli at household tap
	Residual chlorine	Number	The tested residual chlorine at household tap
	Bacteriology	Number	The tested bacteriology at household tap
	Fluorides standards	Number	The tested fluorides standards at household tap
	Mn standards	Number	The tested Mn standards at household tap
	Nitrates standards	Number	The tested nitrates standards at household tap
	Distribution service hours	Number	Distribution service hour per day

❖Water leakage

Identification	Attribute	Data type	Description
Leakage	Leakage ID	Short text	Leakage identification code
	Latitude	Number	One of location indicators
	Longitude	Number	One of location indicators
	Elevation	Number	One of location indicators
	Location name	Short text	Village or center Name
	Landmark	Short text	Reference
	Cause	Short text	Cause of leakage (accident, High pressure, ..etc.)
	Leakage time	Number	Starting time of leakage
	Leakage date	Date	Starting date of leakage
	Leakage repair time	Number	Starting time of leakage repairing
	Leakage repair date	Date	Starting date of leakage repairing
	Leakage duration in hours	Number	Difference between leakage stating time and repairing time
	Leakage frequencies	Number	The repetition of leakage at one point

❖Water customer

Identification	Attribute	Data Type	Description
Water customer	Water customer ID	Short text	The customer identification code
	Owner	Long text	Water client's Name
	POC number	Long text	Client's registration code
	Longitude	Number	One of location indicators
	Latitude	Number	One of location indicators
	Elevation	Number	One of location indicators
	Average daily consumption	Number	Water quantity used during the Day
	Sharing tap	Yes/No	Yes: it is shared/ No: it is not shared
	Water tariff	Number	Fixed price per number of people use the water kiosk
	User category	Long text	Client category (school, household…etc.)
	Service provider	Long text	Name of the company that distribute the water
	Class	Short text	Client class according to the consumption (big consumer or small consumer)
	Connection status	Short text	Active client or non-active client

5.6. Data on Sanitation

❖Pit Toilet

Identification	Attribute	Data type	Description
Pit Toilet	Pit Toilet ID	Short text	The Pit toilet identification code
	Latitude	Number	One of location indicators
	Longitude	Number	One of location indicators
	Elevation	Number	One of location indicators
	Shape	Short text	The shape of Pit
	Date	Date	Construction date
	Users	Short text	The type of users (School, Household….)
	Owner	Short text	Name of owner
	Classes	Short text	Public or private
	Landmark	Short text	Reference landmark
	Number of toilet rooms	Number	The number of all constructed rooms
	Number of functional rooms	Number	The number of used rooms out of total number
	Condition of toilet	Short text	The status of toilet
	Accessibility for users with limited mobility or vision	Number	The number of rooms accessible by users with limited mobility or vision
	Maintenance for the toilet	Long text	The needed maintenance for toilet
	Handwashing facility	Yes/No	Yes: it is available/ No: it is not available
	Emptying tariff	Number	The cost of septic tank emptying
	Service provider	Long text	The company name for emptying services
	Emptying type	Long text	The mode of emptying service (Manual, by Pump…)
	Average number of users	Number	The number of uses
	Desludging frequencies	Number	The number of emptying per years

❖Flush Toilet

Identification	Attribute	Data type	Description
Flush Toilet	Flash Toilet ID	Short text	The Flash toilet identification code
	Latitude	Number	One of location indicators
	Longitude	Number	One of location indicators
	Elevation	Number	One of location indicators

Identification	Attribute	Data type	Description
	Construction date	Date	Construction date
	Users	Short text	The type of users (School, Household….)
	Number of users	Number	The average number of uses
	Owner	Short text	Name of owner
	Location	Short text	Inside or outdoor
	Classes	Short text	Public or private
	Landmark	Short text	Reference
	Number of toilet rooms	Number	The number of all constructed rooms
	Number of functional rooms	Number	The number of used rooms out of total number
	Accessibility for users with limited mobility or vision	Number	The number of rooms accessible by users with limited mobility or vision
	The condition of toilet	Short text	The status of toilet
	Maintenance for the toilet	Long text	The needed maintenance for toilet
	Handwashing facility	Yes/No	Yes: it is available/ No:it is not available
	Connection to soak pit	Short Text	Availability of soak pit for effluent disposal

❖Septic Tank

Identification	Attribute	Data type	Description
Septic Tank	Septic Tank ID	Short text	The Septic tank identification code
	Sewer treatment plant ID	Short text	The water STP identification code
	Latitude	Number	One of location indicators
	Longitude	Number	One of location indicators
	Elevation	Number	One of location indicators
	Average number of users	Number	The number of users
	Connected Toilet	Number	The number of connected toilets
	Owner	Short text	Name of owner
	Shape	Short text	The shape of Pit
	Date	Date	Construction date
	Capacity	Number	The Capacity of Septic
	Landmark	Short text	Reference
	Maintenance for the septic	Long text	The needed maintenance for Septic
	Emptying tariff	Number	The cost of septic tank emptying
	Service provider	Long text	The company name for emptying

Identification	Attribute	Data type	Description
			services
	Emptying type	Long text	The mode of emptying service (Manual, by Pump…)
	Desludging frequencies	Number	The number of emptying per years

❖ Faecal Sludge Treatment Plant (FSTP)

Identification	Attribute	Data type	Description
Faecal Sludge Treatment Plant (FSTP))	FSTP ID	Short text	The water STP identification code
	FSTP Service area ID	Short text	The sewer service area identification code (foreign key)
	Latitude	Number	One of location indicators
	Longitude	Number	One of location indicators
	Elevation	Number	One of location indicators
	Year of construction	Date	Date of construction
	FSTP functionality	Yes/No	Yes: it is working/ No: it is not working
	Design capacity	Number	Total maximum design capacity of sewage treatment facilities per year
	Total volume of faecal sludge received	Number	Total of sludge received per year
	Volume of Volume of sludge treated	Number	Quantity of sludge treated per day
	Capacity	Number	Total maximum design capacity of Volume of sludge treated per year
	Sludge discharged without adequate treatment	Number	Volume of sludge discharged per year without adequate treatment
	Sludge treated in relation to design capacity	Number	Volume of sludge treated in relation to designed FSTP capacity

❖ Sewer treatment plant(STP)

Identification	Attribute	Data type	Description
Sewer treatment plant(STP)	Sewer treatment plant ID	Short text	The water STP identification code
	Sewer service area ID	Short text	The sewer service area identification code (foreign key)
	Sewer pipe ID	Short text	The sewer pipe identification code (foreign key)
	Latitude	Number	One of location indicators
	Longitude	Number	One of location indicators
	Elevation	Number	One of location indicators
	Year of construction	Date	Date of construction
	Treatment plant functionality	Yes/No	Yes: it is working/ No: it is not working
	Design capacity	Number	Total maximum design capacity of sewage treatment facilities per year
	Sludge received from decentralized sanitation systems	Number	Total maximum capacity of sewage from decentralized sanitation per year
	Total sewage to be treated	Number	Total maximum to be treated sewage per year
	Volume of sewage treated	Number	Total maximum treated sewage per year
	Domestic connection	Number	Number of connected clients
	Sewerage coverage	Number	Percentage of population connected to sewer network
	Water reuse mechanisms	Number	The quantity of water reused
	Volume of sewage treated	Number	Quantity of treated sewage per day
	Volume of sewage imported	Number	Faecal sludge that transported by trucks from household
	Volume of sewage exported	Number	Faecal sludge that transported from one treatment to another.
	Volume of sewage discharged	Number	Quantity of sewerage discharged
	Emptying tariff	Number	Fixed service charges for emptying the STP
	Sewerage disposal expenses	Number	Disposal charges
	Maintenance &	Number	Expenses of the sewer treatment

Identification	Attribute	Data type	Description
	repair expenses		plant maintenance
	BOD 5 Results	Number	Quality of discharged effluent
	COD Results	Number	Quality of discharged effluent
	Energy consumption	Number	Used Energy for one cubic meter
	Treated quantity	Number	Quantity of treated waste
	Number of effluent carried out	Number	Number of effluent tests meeting quality standards
	Reused faecal sludge	Number	The quantity of faecal sludge reused
	Received faecal sludge	Number	Quantity of received faecal sludge by pipe
	Delivered faecal sludge	Number	Quantity faecal sludge delivered by truck
	Results of sludge tests	Number	Total number of tested samples

❖Sewer Pipes

Identification	Attribute	Data Type	Description
Sewer Pipes	Sewer Pipe ID	Short text	The sewer pipe ID identification code
	Toilet ID	Short text	The toilet identification code (foreign Key)
	Latitude	Number	One of location indicators
	Longitude	Number	One of location indicators
	Elevation	Number	One of location indicators
	Materials	Short text	Material of Pipe (HDPE,PVC…etc)
	Shape	Short text	Shape of pipe (Circle….etc)
	Diameter	Short text	Nominal diameter
	Minimum velocity	Large number	Minimum velocity of liquid in pipe
	Maximum velocity	Large number	Maximum velocity of liquid in pipe
	Sewerage system	Short text	Name Sewerage system
	Length	Number	Length of the pipe of system
	Inactive Pipes	Number	Length of the that are not working
	Sewer blockages	Number	Number of sewer blockages
	Sewer blockages per network	Number	Number of blockages per 100km of network
	Sewer blockages per connection	Number	Number of blockages per 100 connections
	Blockage results	Number	Percentage of connections affected by sewer blockages
	Blockages time	Number	The time taken by blockages

Identification	Attribute	Data Type	Description
	Rehabilitation	Date	The date of the last rehabilitation
	Complaint	Number	Number of complaints of the connected client
	Number of connections	Number	Number of clients connected to a system
	Operational sewer pipe	Yes/No	Yes: it is working /No: it is not working
	Sewer flooding	Number	Percentage of connected properties that are affected by flooding from sewers during the assessment period

❖Landfill

Identification	Attribute	Data Type	Description
Landfill	Landfill ID	Short text	The landfill identification code
	Latitude	Number	One of location indicators
	Longitude	Number	One of location indicators
	Elevation	Number	One of location indicators
	Year of construction	Date	Construction date
	Landfill name	Long text	Landfill name
	Maximum height	Number	Height of the site from bottom
	Slope of the sides	Number	Average slope of the site
	Buffer zone	Number	Distance from households
	Landfill access roads	Yes/No	Yes: it is available/ No: it is not available
	Landfill fenced	Yes/No	Yes: it is available /No: it is not available
	Inspection of the site after construction works	Long text	Company or institution that do a checking
	Type	Short text	Type of landfill(Modern or classic)
	Service area	Short text	The service areas that bring the waste in the landfill
	Weight of the landfill waste	Number	The estimated tons that are in landfill
	Depth of burial	Number	Length from ground level to bottom
	Composition of waste	Short text	Main compositions of the received Waste
	Capacity of landfill	Number	Maximum quantity that can be in landfill
	Landfill height	Number	Current height of land fill
	Area	Number	Square meter of landfill
	Waste generation volume	Number	Quantity of waste received per day.
	Weighing bridge	Yes/No	Yes: it is available/ No: is not available
	Service hours/daily	Number	Opening time /Working day

Identification	Attribute	Data Type	Description
	operation		
	Landfill facility management	Short text	Availability of managing company
	Supervision institution	Short text	Name of managing company
	Employees	Number	Number of employees in landfill
	Sorting service	Yes/No	Yes: it is available/ No: it is not available
	Type of truck	Short text	Truck types that delivers waste to the landfill site(Truck manufactured for waste or normal track)
	Waste deposited compaction	Yes/No	Yes: There is compaction service/ No: there is n compaction service
	Burning of waste on the Site	Yes/No	Yes: There is a burning service; No: There is no burning service
	Waste covering	Yes/No	Yes: the cover is available/ No: the cover is not available
	Covering materials	Short text	Cover material (Soil or Plastic cover)
	Security guard	Yes/No	Yes: it is available/ No: it is not available

❖Public Toilet

Identification	Attribute	Data Type	Description
Public Toilet	Public toilet ID	Short text	The public toilet identification code
	Latitude	Number	One of location indicators
	Longitude	Number	One of location indicators
	Elevation	Number	One of location indicators
	Shape	Short text	The Shape of septic tank
	Year of construction	Short text	Date of construction
	Classes	Short text	Public or Private
	Type	Short text	The type of mode of using the toilet (Classic, Modern, Ecosan,)
	Landmark	Short text	Reference
	Number of toilet rooms	Number	The number of all constructed rooms
	Condition of the toilet	Short text	The status of toilet
	Usable toilet	Number	The number of used rooms
	Maintenance needed	Short text	The needed maintenance for toilet
	Handwashing facility	Yes/No	Yes: it is available/ No: it is not available
	Emptying tariff	Number	The cost of septic tank emptying
	Service provider	Short Text	The company name for emptying services
	Emptying type	Short Text	The mode of emptying service (Manual, by Pump…)
	Number of users	Number	Total number of users of public

Identification	Attribute	Data Type	Description
			toilets
	Services ladder category	Number	Percentage of service efficiency
	Emptying frequencies	Number	The number of emptying per years
	Connection to soak pit.	Yes/No	Yes: There is a connection/ No: There is no connection
		Number	

❖Sewer Household

Identification	Attribute	Data Type	Description
Sewer Household	Sewer Household	Short text	The landfill identification code
	Longitude	Number	One of location indicators
	Latitude	Number	One of location indicators
	Elevation	Number	One of location indicators
	Owner	Long text	Name of family representative
	Population with safely managed sanitation	Number	Number of population using improved facilities that are not shared with other households and where excreta are safely disposed of in situ or transported and treated off-site)"
	Population with basic sanitation	Number	Number of population using improved facilities that are not shared with other households
	Population with limited sanitation	Number	Number of population using improved facilities shared between two or more households
	Population with unimproved sanitation	Number	Number of population using pit latrines without a slab or platform, hanging latrines or bucket latrines
	Population practising open defecation	Number	Percentage of People who have not toilet
	Connection to sewer pipe	Yes/No	Yes: it is connected to Sewer Pipe/ No: it is not connected to Sewer Pipe
	Experience with flooding	Number	Number of flooding per year
	Connections interruptions	Number	Number of connection interruption per month
	Number of blockages	Number	the average number of blockages occurring per 100 km of sewers or 100 connections during the assessment period

❖Sewer Service area

Identification	Attribute	Data type	Description
Sewer Service area	Sewer service area ID	Short text	The service Area identification code
	Toilet ID	Short text	The toilet identification code(Foreign key)
	Public toilet ID	Short text	The public toilet identification code(Foreign key)
	Landfill ID	Short text	The landfill identification code(Foreign key)
	Latitude	Number	One of location indicators
	Longitude	Number	One of location indicators
	Elevation	Number	One of location indicators
	Total Population	Number	Number of people in the area
	Region/Province	Long text	Province of service area
	District	Long text	District of service area
	Sector	Long text	Sector of service area
	Service area name	Long text	Village or cell of service area
	Length of sewerage System	Number	Total length of sewer network in the area
	Operational sewerage system	Percentage	Length of Sewer network in service / Total Length of sewer network
	Average households	Number	Number of household in the area
	Served households	Number	Number of household connected to the sewer network
	Total number of connections	Number	Number of people living in the connected household
	Service provider	Short text	Name of sewer managing company
	Coverage	Number	Percentage of household connected to sewer network in the Area
	Institutional sewer connection	Number	Total number of Institutional sewer connections in the area
	School sewer connections	Number	Total number of school sewer connections in the area
	Commercial sewer connections	Number	Total number of all commercial sewer connections in the area
	Industrial sewer connections	Number	Total number of all industrial sewer connections in the area
	Bulk sewer connections	Number	Total number of bulk sewer in the area
	Population served through sanitation services	Number	Total population served through sewerage services + onsite sanitation
	Population served through individual flush or pour flush to septic tank systems	Number	Total population served through individual flush or pour flush toilets to septic tank systems

Identification	Attribute	Data type	Description
	Population served through shared flush or pour flush to septic tank systems	Number	Total population served through shared flush or pour flush toilets to septic tank systems
	Population served through individual flush or pour flush pit latrine systems	Number	Total population served through individual flush or pour flush toilets to pit latrine systems
	Population served through shared flush or pour flush to pit latrine systems	Number	Total population served through shared flush or pour flush toilets to pit latrine systems
	Population served through individual Ventilated Improved Pit Latrines (VIPs)	Number	Total population served through individual Ventilated Improved Pit Latrines (VIPs)
	Population served through shared Ventilated Improved Pit Latrines (VIPs)	Number	Total population served through shared Ventilated Improved Pit Latrines (VIPs)
	Population served through individual Pit Latrines with Slab	Number	Total population served through individual Pit Latrines with Slab
	Population served through shared Pit Latrines with Slab	Number	Total population served through shared Pit Latrines with Slab
	Population served through individual Composting Toilets	Number	Total population served through individual Composting Toilets
	Population served through shared Composting Toilets	Number	Total population served through shared Composting Toilets
	Sewer Flooding	Percentage	Total number of connections flooded from sewers / Total Connections
	Zoning	Long text	Zoning in the area
	Collection efficiency	Number	Percentage of emptying septic tank.
	Septic tanks	Number	Number of septic tank in the area
	Septage sucking machines	Number	Number of septic emptying machine in the area
	Collected septage	Number	Percentage of collected septic tank per year

❖ Handwash

Identification	Attribute	Data type	Description
Handwash	Handwash ID	Short text	Handwash identification code
	Type	Short text	Type of handwash (Tap; Reservoir; bucket)
	Latutide	Number	One of location indicators
	Longitude	Number	One of location indicators
	Elevation	Number	One of location indicators
	Owner or hosting agency	Long text	Name of owner or hosting agency
	Water and soap	Yes/No	Yes: both are available/No: both are not available
	Water only	Yes/No	Yes: it is available /No: it is not available
	Functionality status	Short text	Good condition/Bad condition
	Clean frequency	Number	Number of handwash cleaning per week
	Number of sinks	Number	Number of handwashes
	Average of people	Number	Number of people to one sink
	Services ladder category	Number	Percentage of service efficiency

❖Chamber for Girl

Identification	Attribute	Data type	Description
Chamber for Girl	Chamber ID	Short text	Chamber identification code
	Handwash ID	Number	Handwash identification code (Foreign Key)
	Latitude	Number	One of location indicators
	Longitude	Number	One of location indicators
	Elevation	Number	One of location indicators
	School	Short text	Name of school
	Bed	Yes/No	Yes: it is available ./No: it is not available
	Pads	Yes/No	Yes: They are available./ No: they are not available
	Bin for Pad	Yes/No	Yes: it is available /No: it is not available
	Soap	Yes/No	Yes: it is Available/ No: it is not available
	Bathroom		Bathroom is available
	Bathroom status	Long text	Description about the bathroom (it is clean, it is old….etc.)
	Water	Yes/No	Yes: it is available/ No: it is not available
	Toilet paper	Yes/No	Yes: it is available/ No: it is not available
	Taulo	Yes/No	Yes: it is available/ No: it is not available
	Body cosmetic	Yes/No	Yes: it is available/No: it is not available

A part from the above data which are collected and organized into the database as the main features of WSS information system, there exist various thematic base datasets which make the integrated Geospatial Information Framework for mapping activities and spatial analysis. Those data datasets are intended to support the development of WSS Geoportal. They are presented in the table below.

Table 11: Fundamental Geospatial Data Themes in WSS

Building and settlement	Address	Elevation and depth	Functional areas	Geographical names	Land cover and land use
					
Land parcel	**Orthoimagery**	**Physical infrastructure**	**Population Distribution**	**Transport networks**	**Water**
					

Source: https://storymaps.arcgis.com/stories/3a4625105caf4f6ca09a197eaea8612e

1. A building refers to any roofed structure permanently constructed or erected on its site, for the protection of humans, animals, things, or the production of economic goods. Settlements are collections of buildings and associated features where a community carries out various socio-economic activities. Data on those themes are required for guiding the assessment of access to water and sanitation services as well as planning the related projects.

2. An address is a structured label, containing a property number, a street name and a locality name. It is used to identify a plot of land, a building or part of a building, or some other construction, together with coordinates indicating their geographic position. Addresses are often used as a proxy for other data themes such as and Parcels.

3. The elevation and depth theme describes the surface of the Earth both on land and under a body of water, relative to a vertical datum. They are used to identify the areas which are at risks, like landslides, flooding issues so that the utilities can use the information for the assets management and/or design the project related to facilities protection.

4. Functional areas are the geographical extent of administrative, legislative, regulatory, electoral, statistical, governance, service delivery and activity management areas. The related data support the water nd sanitation mapping for a comprehensive record data on access and identification of the areas of intervention.

5. Geographical names provide orientation and identity to places. They are location identifiers for various physical features of the real world, such as regions,

settlements, or any feature of public or service providers interests. They are often used as a proxy for other data themes such as buildings and settlements that services providers have to collect.

6. Land cover represent the physical and biological cover of the Earth's surface. Land Use is the current and future planned management, and modification of the natural environment for different human purposes or economic activities.

7. Land parcels are areas of land or more generally of the Earth's surface (land and/or water) under common rights (such as ownership or easements), claims (such as minerals or indigenous land) or use. This theme can include individual fields and cadastral parcels.

8. Orthoimagery is a geo-referenced rectified image data of the Earth's surface, obtained from satellite or airborne sensors. The orthoimages are widely-used data source for many other data themes. They are also used to guide the data collection and mapping purposes. For instance, the customers mapping can help the services providers and regulators know the serviced areas and where new investments can be made for increased access to WSS services.

9. The Physical infrastructure theme includes the industrial and utility facilities, and the service delivery facilities associated with administrative and social governmental services such as utilities, transport, markets, schools and hospitals, etc.

10. The Population distribution theme covers the geographical distribution of people, including population characteristics.

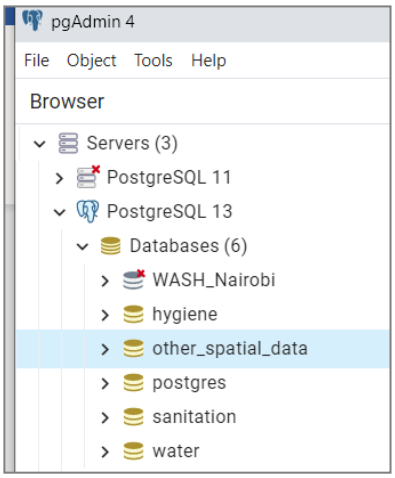
11. Transport networks are the suite of road, rail, air, cable and water transport routes and their connectivity.

12. The water theme covers the extent and conditions of all water features including rivers, lakes and marine features. They are important part of the WSS base data as they come the water sources alongside the water production process.

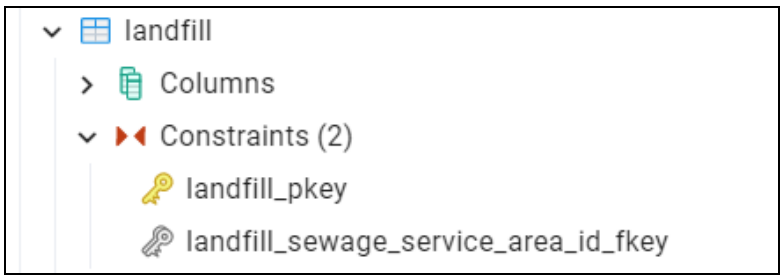
The structure of the main WSS data to be included in the database is presented in the next section.

5.7. Proposed Structure of WSS data and other base data into the database system

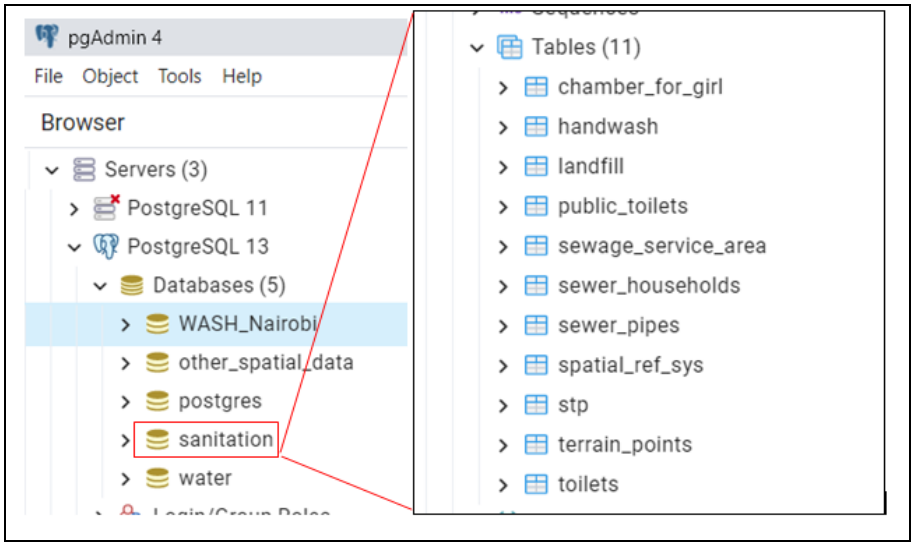
The following model of databases will be implemented in PostgreSQL server: water, sanitation, and other spatial data. The water database will include the following datasets: households, leakages, water customers, water kiosks, water meters, water pipes, water reservoirs, water service areas, water sources and water treatment plants. The sanitation database will include the following datasets: landfill, public toilets, sewage service areas, sewer pipes, toilets, handwashes, chamber for girl, STP and sewer households. The other spatial data database is included of rivers, road network, lakes, administrative boundaries, etc.



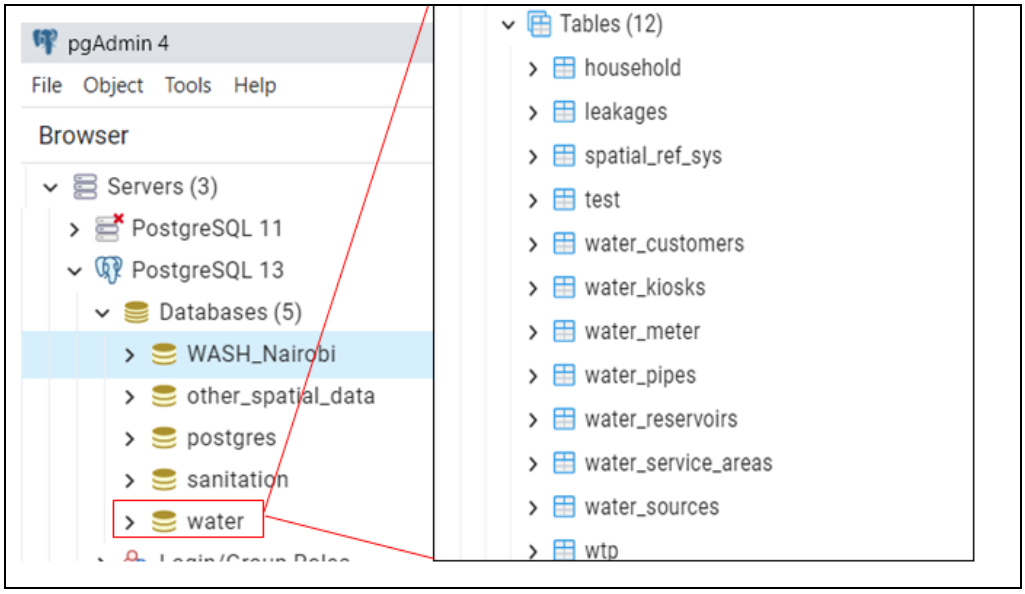
In the PostgreSQL server, the database will be structured in the way that related tables are linked to each other by the defined constraints: primary key in a table is linked to the foreign key in the other table. In the example below, “landfill” table is linked to “sewage_service_area” using the field “sewage_service_area_id”



The figure below shows the structure of the sanitation database in the PostgreSQL server.



The figure below shows the structure of water database in the PostgreSQL server.



5.8. Data and management of responsibilities

The overall WSS system management is illustrated on the below figure:

1. The National Central Data center: It is a central repository for all water and sanitation-related data. It must be equipped with robust infrastructure, well secured against unauthorized users and hackers other internet.

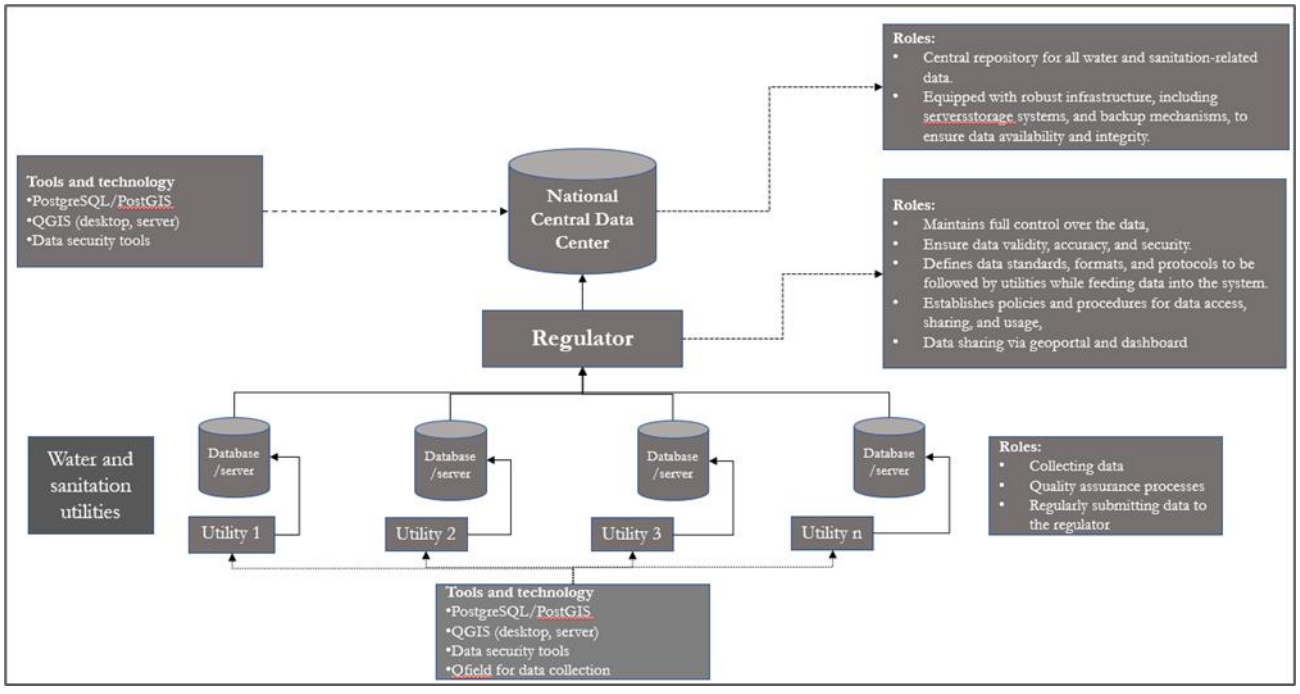


Figure 29: Overall WSS system management structure

2. The regulator: will ensure the full control over the data in national repository that they will feed into the system upon their validation from the databases developed by the

utilities. Regulators will also play the role of defining data standards that will be collected by utilities, establishing policies and procedures for data access as well as data sharing via geoportal.

3. Utilities: The roles of utilities will have to collect data, and check quality before their integration into the database

In the above data administration layers, the data is maintained into the PostgreSQL databases which are then connected to the national central database. The tool used to be connected to each database are the QGIS, QGIS and Qfield for QGIS application for data collection.

5.9. Security of data and risk management

A WASH database holds information that may be soft target for hackers if the database is accessed through network internet. There are different measures that can be implemented to fortify the security of the server holding this database and establish a safeguard against potential hackers that use malicious SQL code to access and manipulate backend database, and hence manipulate sensitive information. This is security vulnerability that can be mitigated in PostgreSQL using different measures explained here below.

- **Encryption**

Encryption is the method by which information is converted into secret code that hides the information's true meaning. In PostgreSQL database, encryption is implemented by enabling Secured Sockets Layer (SSL) authentication for all trusted connections to the server hosting the database. With SSL connections made to the database server, the organization is ensuring that all communications exchanged between the client and server are encrypted, thus information in the database is hidden to potential hackers and unauthorized users. This method of protecting data is also recommended to be applied to the WSS database before deploying it to the network.

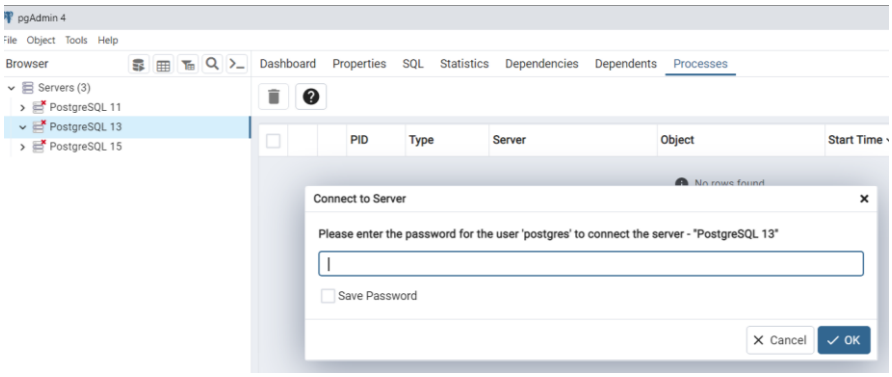
- **Managing connections through the network**

In this type of database security management, the system is configured to listen and accept connections from the network that are required. The system listens only to the localhost (machine hosting the database management system) of the accepted addresses set in the system configuration files. During installation, PostgreSQL is installed with two configuration files saved in the installation folder on the server or the machine. These two configuration files are the following: pg_hba.conf and postgresql.conf.
The pg_hba.config is edited by adding which IP addresses PostgreSQL will connect, ie. PostgreSQL allows those addresses to connect to it. In this configuration file, we specify either individual IP addresses or ranges of addresses in the “listen_addresses” parameter.
In the postgresql.conf, the default configuration is set to localhost (*listen_addresses = 'localhost'*). To enable connections set in the pg_hba.conf, this default value is changed to listen to all allowed connection (*listen_addresses = '*').*

- **Defining users, group roles and privileges of the database**

Best practices recommend that we grant users only the access that they need. In the suggested system, the security of data is managed as follows:

-The Server secured by a password of a superuser



-In each database, the superuser can grant different roles with different tasks. The following roles are suggested in this system design:

- ○Utility_team: They are in charge of data entry and they have the privileges to SELECT, INSERT, UPDATE and DELETE.
- ○Utility_validation_team: They have all privileges of utility_team along with the role to validate data on the “validated_by” column
- ○Regulator_team: They have all the privileges of utility team along with the role to confirm data validated by the utility_validation_team

This means that utility-team will view, add and update data in the system, but cannot validate nor confirm the data, whereas as validation-team and confirmation team have privileges to view data and validate it and confirm it.

Last but not the least, the superuser or administrator of the system should deny permission to created roles and users to access the public schema.

- **Row Level Security**

In each dataset of the database, a Row Level Security policy is implemented in each table. Row Level Security or RLS is a technology in Postgres that allows defining policies that limit the visibility of rows in a table to certain roles or unauthorized users. If anyone not belonging to a certain role wants to view data, he sees only data that he inserted and other rows are hidden to him. So, he can’t alter any table because he cannot view data inserted/edited by authorized roles or group users.

All the above-mentioned security measures will be efficiently implemented if the physical access of the server hosting the database is well managed, i.e the server or a computer hosting the database must be placed in a room with limited access to the database administrator only.

5.10. System back-up and restore

At each level of data management developed above, a back-up method should be applied to have a copy of the system and data in a safer place (which can be either a server, or hard driver or url and should be outside the central database or organisation office). PosgreSQL has different tools to do this tasks: pg_dump which is used to make a backup of the database management system, and pg_restore to restore database management system. The figure below summarizes the back-up of the database at each level of database management system.

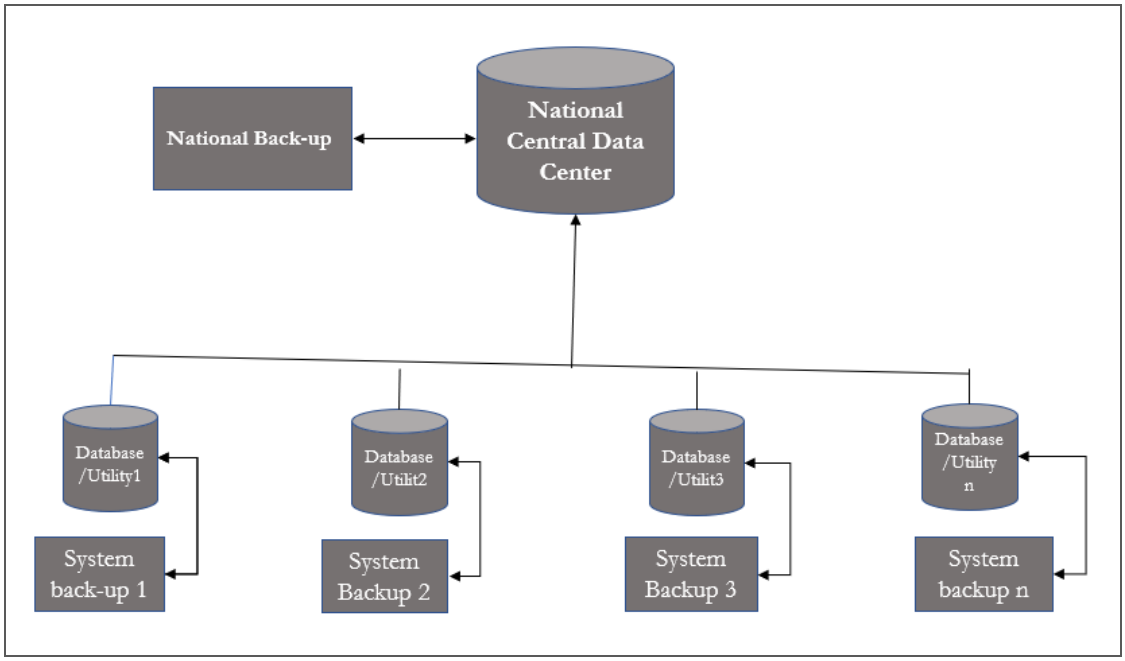


Figure 30: Back-up structure of the database

5.11. WSS data manipulation in desktop GIS

Desktop GIS software are programs that are installed onto and run on a personal computer and allows users to display, query, update, and analyse data about geographic locations and the information linked to those locations.
There exist various types of GIS software but, as required by ESAWAS, the attention is paid to free GIS software that can:

- ✓Perform hundreds of advanced GIS processing tasks.
- ✓Generate stunning cartography and mapping products.
- ✓Manage ESAWAS's geospatial assets and non-spatial data efficiently.

With QGIS, the WSS geodatabase can be imported from a database management system (Figure below) and be visualized and manipulated in QGIS desktop (Figure showing layers in QGIS Desktop).

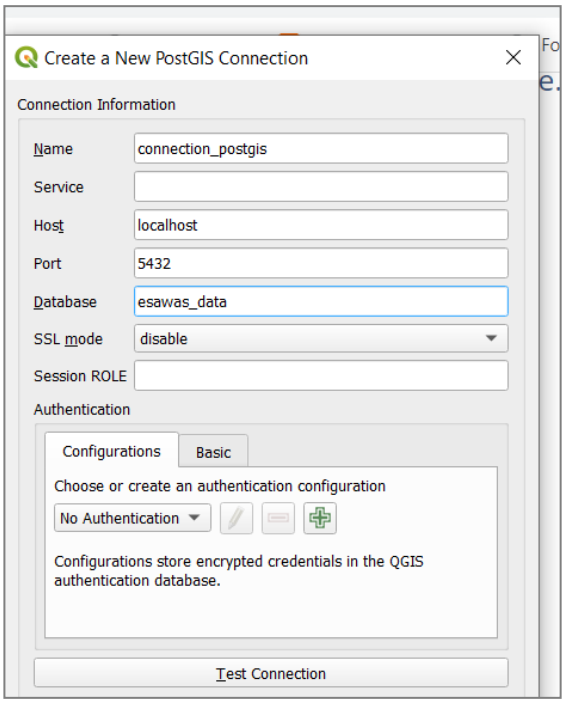


Figure 31:Connecting Desktop GIS to PostgreSQL database

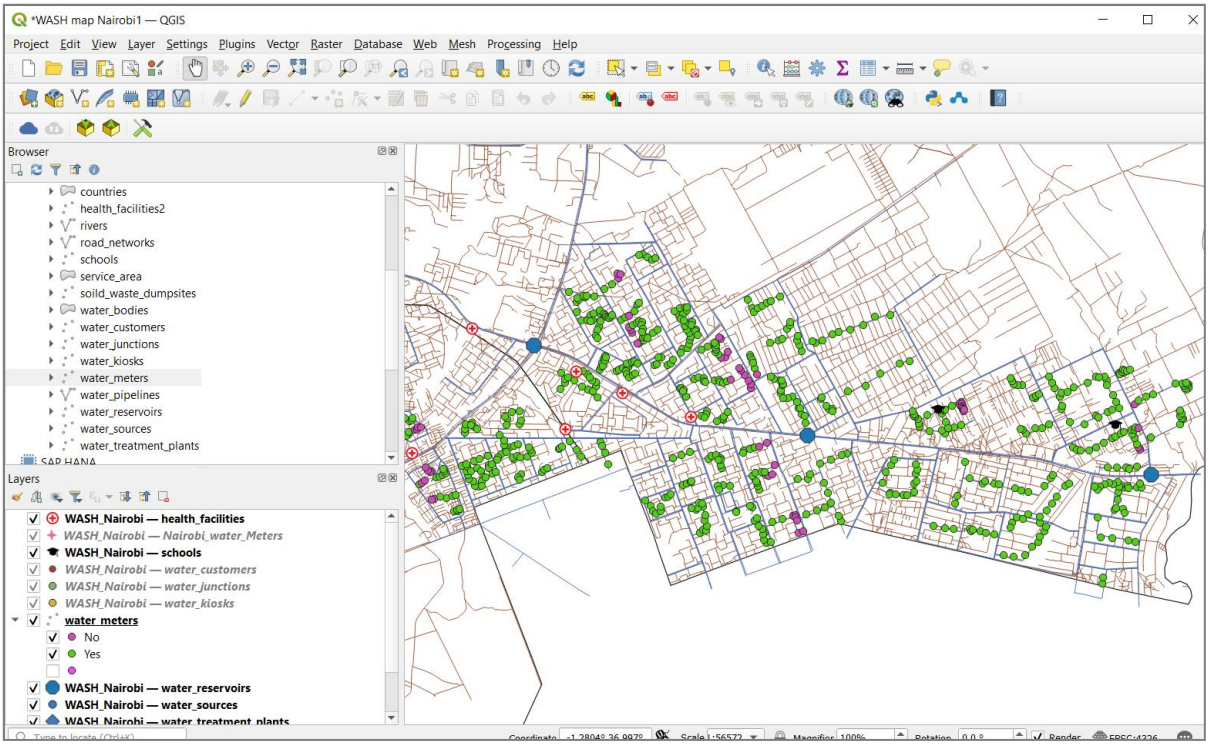


Figure 32:Visualization of PosgreSQL data in QGIS Desktop

Then in GIS Desktop, data can be edited, and the new edits are synchronized in the PostgreSQL database.

Other possible operations in QGIS desktop:

- ✓Spatial queries allowing the selection of features in a layer by their spatial relationships (intersect, contain, touch etc.) with features from another layer.
- ✓Performing other operations using available tools

Details on how to connect QGIS to PostgreSQL data base are presented in the training manual (in appendix).

5.12. WSS data updating in mobile GIS

WSS data can be collected and updated with the aid of Mobile devices including smartphones and tablets, amongst others, provided that the device has storage capability and integrated with GPS. These mobile devices can be used while collecting and updating data on WSS indicators. For the sake of data collection, there are plenty of mobile apps that can be used to collect and update WSS database. Some are open source and others are not. QGIS has also its own QField Sync plugin which facilitates packaging QGIS projects for QField app. Once a QGIS project is packaged then it is copied into smartphone with which data can be deployed to the field for updating existing ones or adding new data using QField app. QField app is the professional mobile app for QGIS, allowing users to deploy their existing projects to the field or collecting data from scratch for a new project.

Figure 33: Mobile app for collecting and updating WSS data in the field

For the use QField app, below are the required steps are illustrated in the figure below:

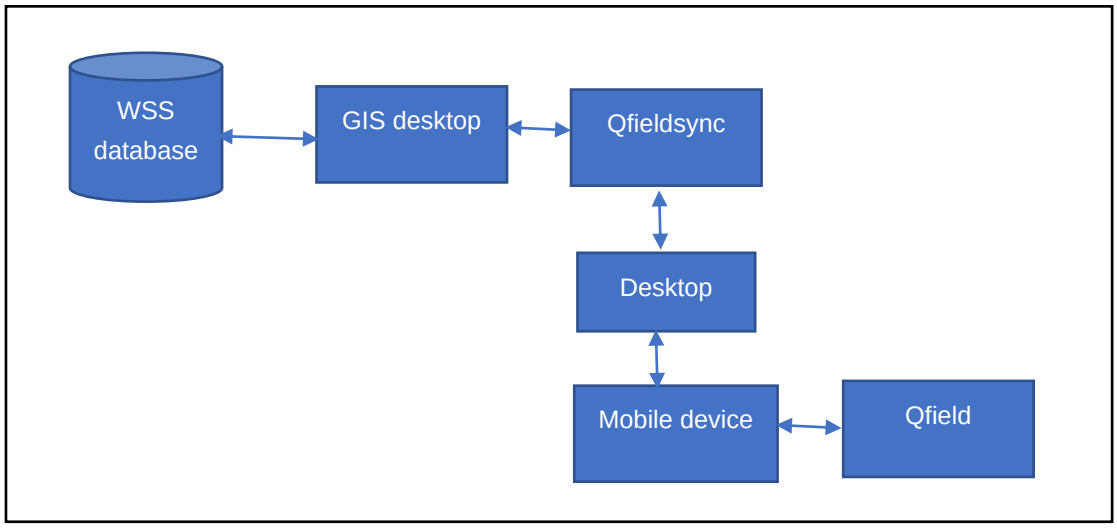
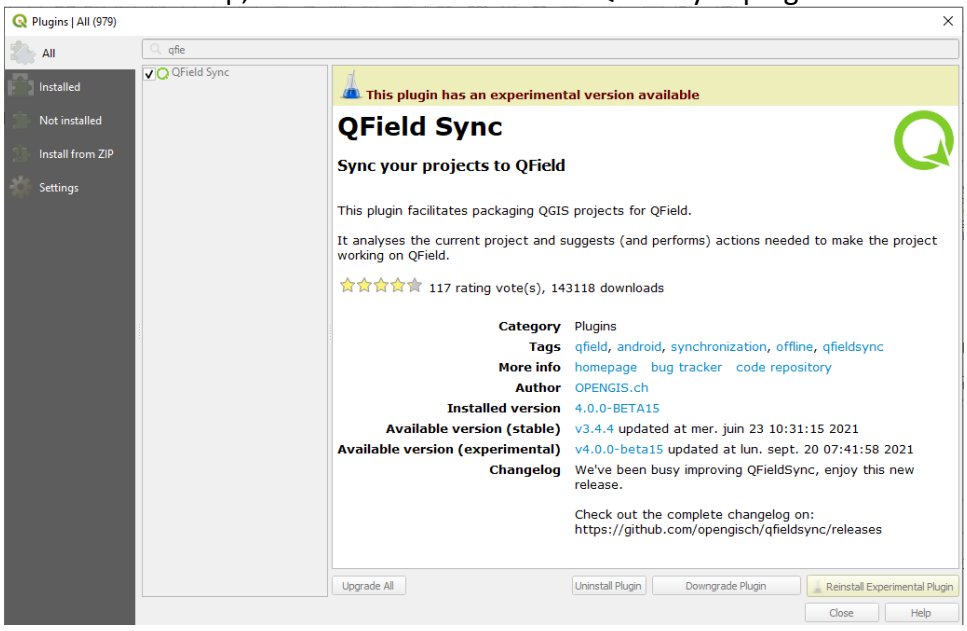


Figure 34: Use of QField app in data collection and updating

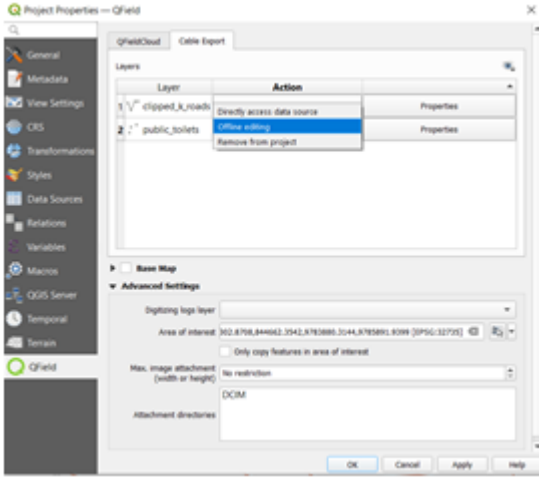
1. In GIS Desktop connect to the database and create a project comprising of layers to be updated
2. Create a QField package using QFieldsync. This is a working copy in a separate folder on the desktop.
3. Copy the QField package to the target mobile device.
4. Go out and collect data.
5. Copy the modified data back to your desktop computer.
6. Synchronize the modified data with your database or files.

In the second step, user will first activate the QFieldSync plugin available in the QGIS plugin.

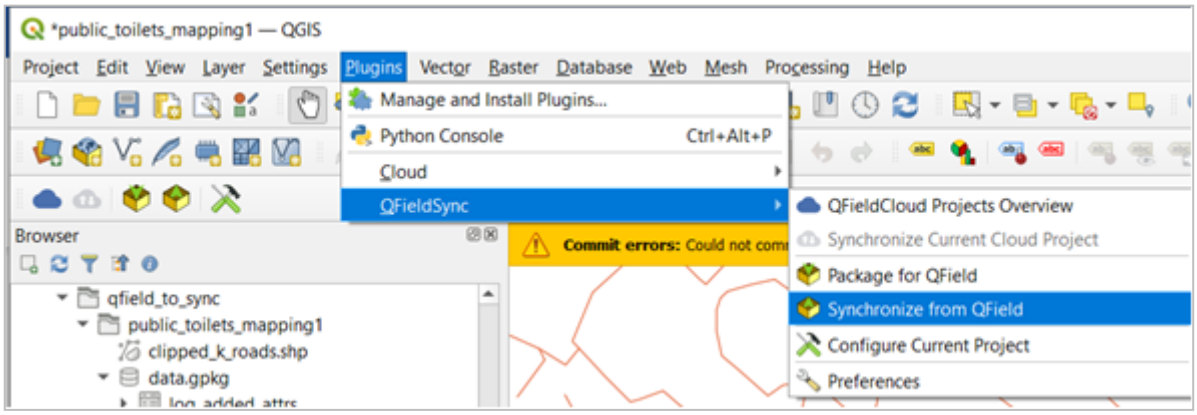


QField Sync in QGIS plugin repository

Use QFieldSync to configure the project: specify which layers to be edited offline and which layer to copy only.



After project configuration, package the project (Plugin/QFieldSync/Package for QField. Then proceed to step 2, step 3 and step 4. On step 5, synchronize your updated data in QGIS (Plugins/QFieldSync/Sysnchronize from QField.



The QField is suggested for use in data collection and updating, based on the benefits associated with its use, when compared with other apps as shown in the table below.

Table 12:Comparison among the most used spatial data collection apps

Tool	How it Works	Benefits	Disadvantages
Kobo Toolbox	▪Kobo Toolbox is an online data collection platform that is accessed through a web-based interface. ▪ Users can create customized surveys and forms, which can be accessed by survey takers through a web link. ▪The app provides advanced data analysis and visualization tools, and offers data security and privacy features.	▪Compatible with GIS software such as QGIS and ArcGIS, enabling mapping and analysis of data collected. ▪Data can be exported in various formats, including Excel, CSV, and KML. ▪Can be used online and offline. ▪Provides real-time monitoring and analysis of data collected. ▪Has a user-friendly interface and supports multiple languages.	▪Limited offline data collection features ▪Some features require a paid subscription ▪Limitations of data submissions and data storage ▪Limitations in editing geometries
Q Field	▪It allows users to collect data both online and offline, with the ability to synchronize data with a server when an internet connection is available. ▪The app provides advanced geospatial data collection and mapping features, and allows for customizable forms and surveys. ▪Users can collect a wide range of data types, including multimedia data types such as photos and audio recordings.	▪Compatible with QGIS software, enabling mapping and analysis of data collected, ▪Can be used offline, making it suitable for low-resource settings, ▪ Data can be exported in various formats, including Excel and CSV, ▪ Its functionality includes feature digitizing, geometry and attributes editing, attribute search, forms customizable through QGIS, etc. ▪Allows users to collect data on Android devices, which are widely available, ▪It allows for GPS positioning and camera integration. ▪Can edit/update geometries ▪It has no limitations of submissions ▪It has mo limitations on data storage	▪Some features require technical expertise to set up and configure

GeoODK	▪GeoODK is a free and open-source mobile data collection tool that is built on top of the Open Data Kit (ODK) platform. ▪It allows users to create forms for data collection on Android devices, and then collect, store, and share that data using a centralized server or cloud-based services.	▪GeoODK is compatible with most GIS software, such as QGIS and ArcGIS. ▪Data collected with GeoODK can be exported in a variety of formats, including CSV, KML, and GeoJSON. ▪It allows for real-time data collection and sharing, which is useful for monitoring and evaluating programs in the field.	▪GeoODK can be difficult to set up and use for those who are not familiar with the ODK platform. ▪There are limited options for customizing the interface and form design. ▪GeoODK does not have as large a user community as some of the other mobile data collection tools, which can make finding support more challenging. ▪It has some limitations in editing/updating existing spatial data
mWater	▪It is specifically designed for the WSS sector. ▪It allows users to collect and manage data related to water quality, water sources, and water infrastructure on mobile devices.	▪It is tailored to the needs of WSS professionals and organizations. ▪The app includes pre-built forms for common WSS data collection tasks, such as water quality testing and well surveys. ▪mWater is compatible with both Android and iOS devices.	▪The focus on the WSS sector means that mWater may not be as useful for organizations working in other sectors. ▪While mWater includes pre-built forms, it can be difficult to customize those forms or create new ones. ▪The data collected with mWater is stored in a centralized database of the app developers, which may not be suitable for organizations with limited internet connectivity ▪It raises some concerns about data privacy.

Open Data Kit (ODK)	ODK is an online data collection platform that is accessed through a web-based interface. Users can create customized surveys and forms, which can be accessed by survey takers through a web link. The platform provides advanced data analysis and visualization tools, and integrates with external tools and platforms. It supports a wide range of data types.	▪It is widely used and has a large user community, making it easier to find support and resources. ▪It is free and open-source, making it accessible to organizations with limited budgets. ▪The ability to customize data collection forms using Build and Collect allows for more tailored data collection.	▪It has limitations when used with some GIS software. ▪Setting up and managing the aggregate server is challenging. ▪Customization requires more technical expertise. ▪It has some limitations in editing/updating existing spatial data

Note: The QField is a good option for organizations that need to collect data offline in areas with limited internet connectivity. It also offers seamless integration with QGIS for data analysis and mapping,

5.13. WSS Geoportal

As stated above, the main Components of a WSS Geoportal will be composed with the spatial database management system (PostgreSQL\PostGIS) to manage the spatial databases but also the web server through Apache Tomcat, the GIS server (Geoserver) and Mapstore. GIS Server plays a fundamental role in spatial data mapping, analyzing and management for organization. GIS server is used to publish services and host layers to either connected or disconnected deployments (Peggion, et al., 2008). GIS Server is a back-end component part of a Database Management System and allows anyone to centrally manage, publish and serve map layers and associated data online. The browser on the other hand is the client-side (front-end component) that is used to call the web services from GIS Server. This communication between the server and client happens through HTTP requests from the client to server.

It's through GIS server that the publisher and/or the geospatial administrator publish web mapping services. Web Mapping services (WMS) are the geospatial data hosted through the internet and complying with standards as set by the Open Geospatial Consortium (OGC)[6,7]. In the context of WSS, Geoserver is recommended to fit the requirements to play a role OGC-compliant GIS server. Geoserver which is an open source server for sharing geospatial data is suitable for handling very large datasets, both raster and vector as shown in the figure below.

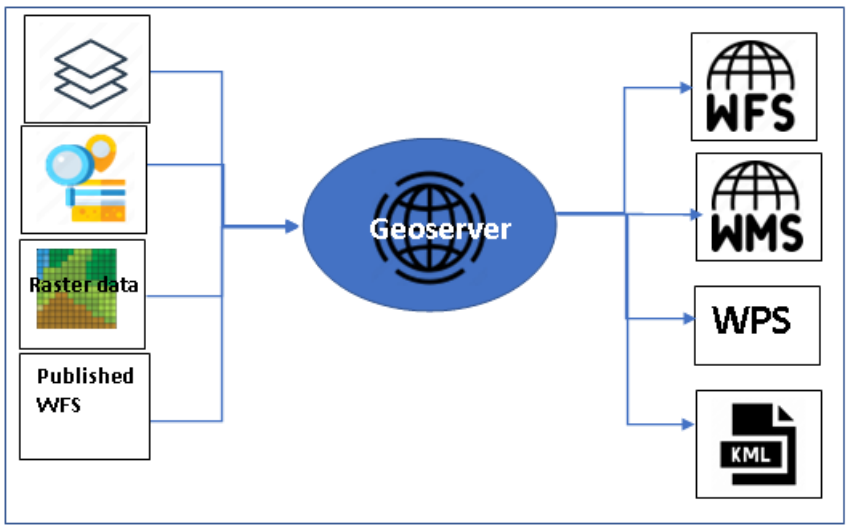


Figure 35 : Data sources and services in Geoserver

With Geoserver, people with admin/publishing roles can publish spatial data from data sources, for example PostgreSQL databases, into web services. Below is an example of published data into Geoserver.

[6] https://www.ogc.org/standards/wms

[7] https://docs.qgis.org/3.22/en/docs/user_manual/working_with_ogc/ogc_client_support.html

Type	Title	Name	Store	Enabled	Native SRS
	customers	esawas_workspace:customers	esawas_data	✔	EPSG:4326
	junction_pipelines	esawas_workspace:junction_pipelines	esawas_data	✔	EPSG:4326
	nairobi_health_facilities	esawas_workspace:nairobi_health_facilities	esawas_data	✔	EPSG:4326
	nairobi_neighbourhoods	esawas_workspace:nairobi_neighbourhoods	esawas_data	✔	EPSG:4326
	nairobi_pipelines	esawas_workspace:nairobi_pipelines	esawas_data	✔	EPSG:4326
	nairobi_road_network	esawas_workspace:nairobi_road_network	esawas_data	✔	EPSG:4326
	nairobi_schools	esawas_workspace:nairobi_schools	esawas_data	✔	EPSG:4326
	nairobi_water_kiosk	esawas_workspace:nairobi_water_kiosk	esawas_data	✔	EPSG:4326
	nairobi_water_meters	esawas_workspace:nairobi_water_meters	esawas_data	✔	EPSG:4326
	nairobi_water_reservoirs	esawas_workspace:nairobi_water_reservoirs	esawas_data	✔	EPSG:4326

<< < 1 > >> Results 1 to 10 (out of 10 items)

Figure 36: Publication spatial data with Geoserver

From Geoserver, data can be shared in different formats depending on the user need.

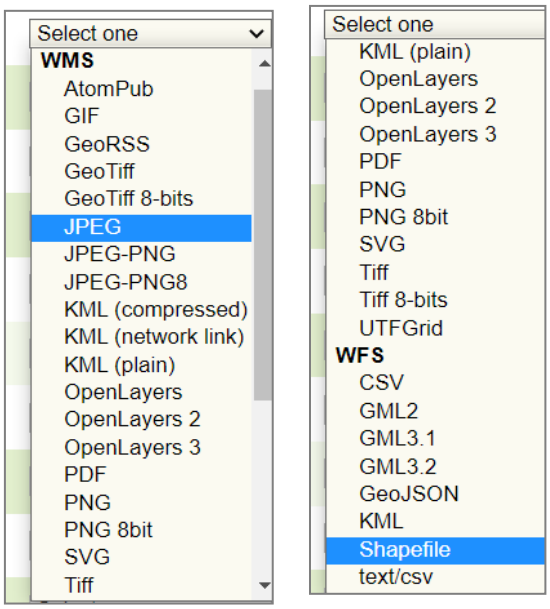


Figure 37: Extract of different formats published by Geoserver

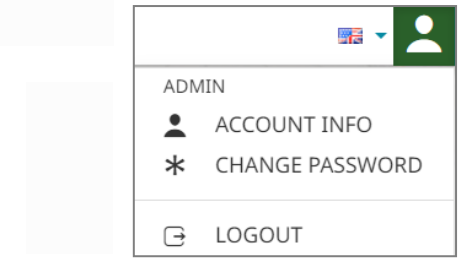
Details on how to install, administer and publish spatial data through geoserver are described in the training manual. MapStore is an Open Source WebGIS framework developed by GeoSolutions to create, manage and securely share maps. While geoserver is used to import different geospatial data sources and publish them as web services, Mapstore is used to create maps, geostories and dashboards from the published web services.

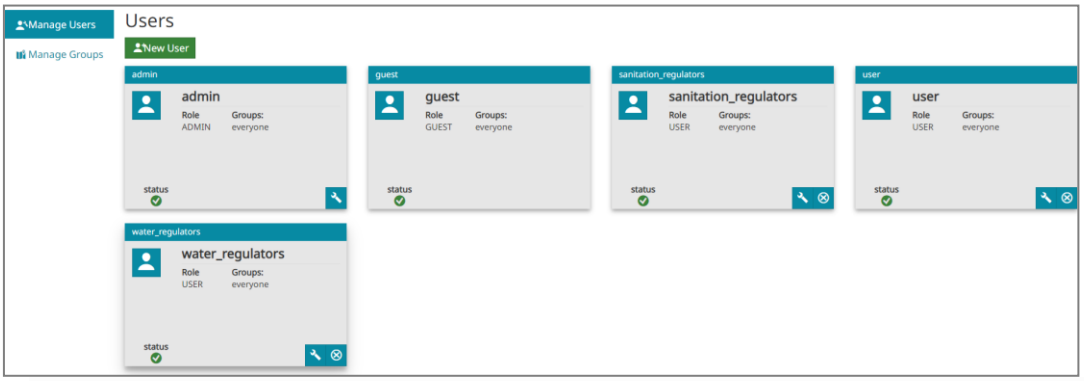
5.14. Roles of People in WSS Geoportal

In general, the geoportal has resources that are set as public or restricted to different group user. Logging as non-authorized user you will only see the public resources.

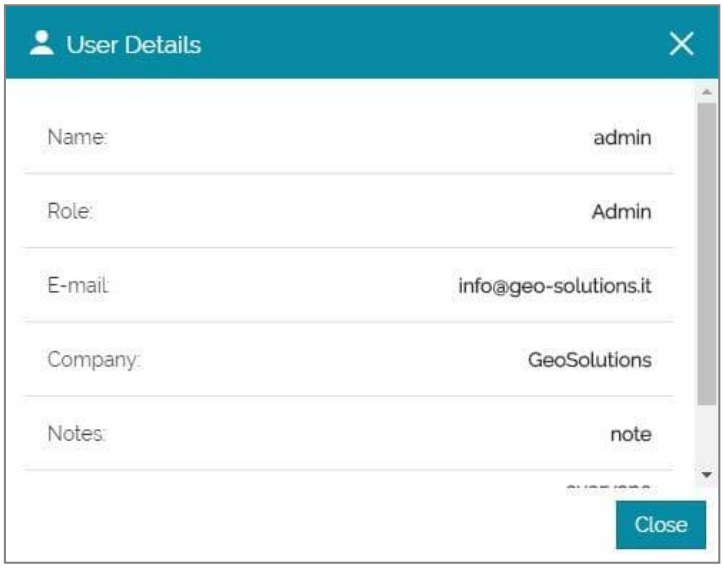
People involved in the GIS-based Portal are of three categories:

- ***Geoportal Manager:*** The manager's role is to manage accounts. He is administrator of the system, He can add, disable user or groups, creates user password, and manages datasets and other published documents and maps.





The administrator of the portal manages also details of the users such as name, role, e-mails, amongst other. The user can also change the password of all accounts.



- **Publisher:** The role of publisher is to publish datasets using desktop GIS software or edited online datasets.**Viewer*:*** A viewer is any user that can search and visualize the published information on the internet. Viewer can also be granted forms through which he can send requests or his points of views such as blogs.

5.15. Managing data in a geoportal

As stated previously, data available in a PostGreSQL/Postgis can be published into a GIS server. Geoserver is recommended here as a GIS server.

Data published in a Geoserver from a PostgreSQL can be used to make a webmap for data visualization. In this report we demonstrate how this can be achieved using Mapstore.

For the created map, it is possible to add details to the map. This is useful to associate some information to the map or an overview description of its content. In this case the *Edit properties* window is the following.

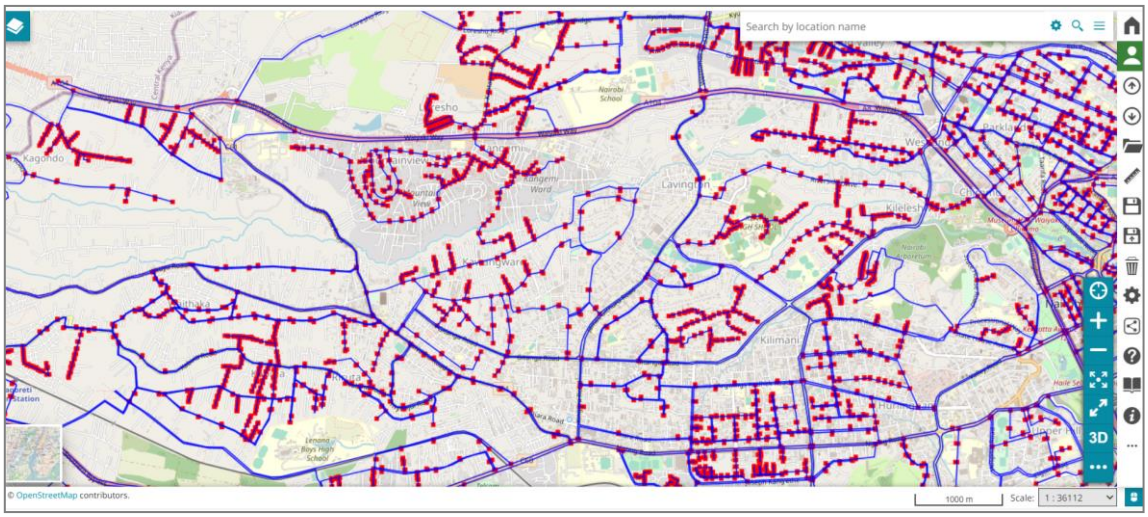


Figure 38:Web map created with layers published in Geoserver

- Editing properties of the web map

The publisher edits properties of the web map such as the name of the map, description and the groups permissions.

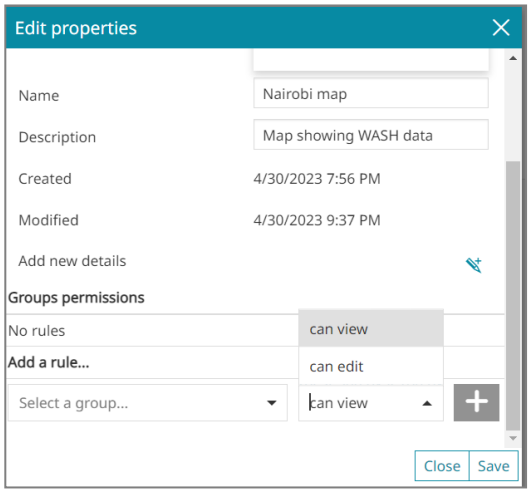


Figure 39: Editing properties of a created map

5.16. Dashboards in the WSS geoportal

A dashboard is a view of both map and associated data, allowing the viewer to have a simplified picture of main indicators generated from the spatial data. It allows people to make decisions. In other words, it offers a comprehensive view of the data providing key insights for decision making.

The following are the main components of a Dashboard:

- Chart
- Text
- Table
- Counter
- Map

In dashboards it is possible to connect the added widgets allowing the user to inspect and interact with more than one of them at the same time.

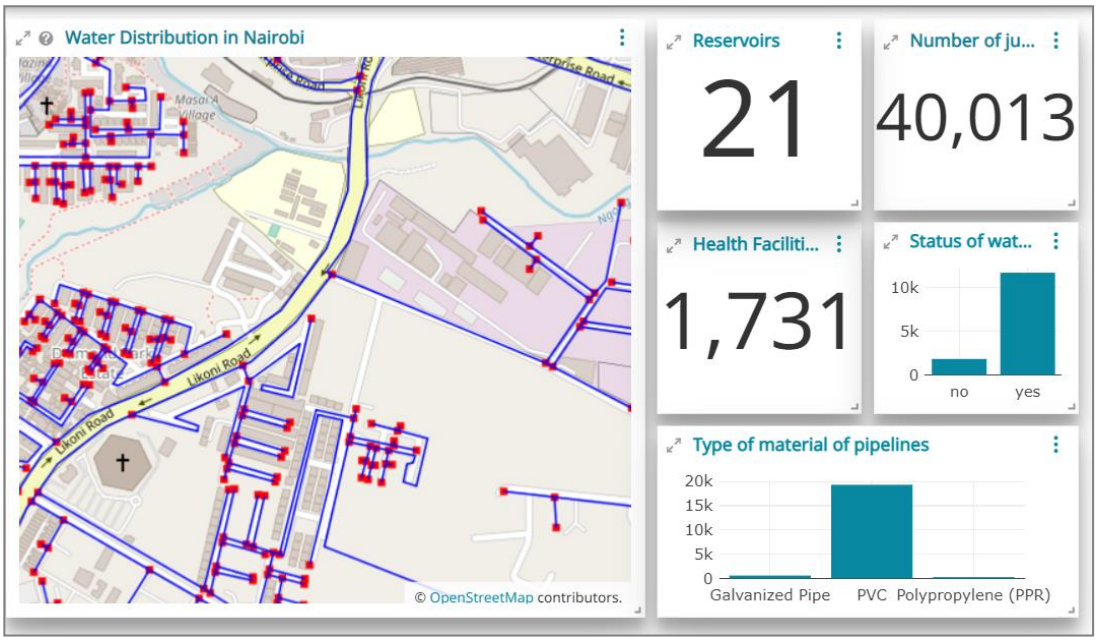
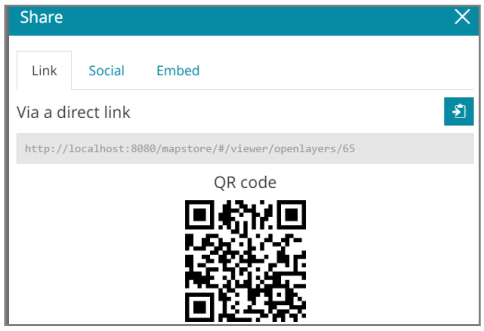


Figure 40: Example of Dashboard with WSS data

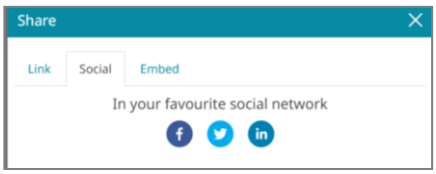
5.17. Resources sharing with WSS geoportal

The Geoportal will have the possibility to share resources (*maps*, *dashboards*, and other resources) through different ways such as:

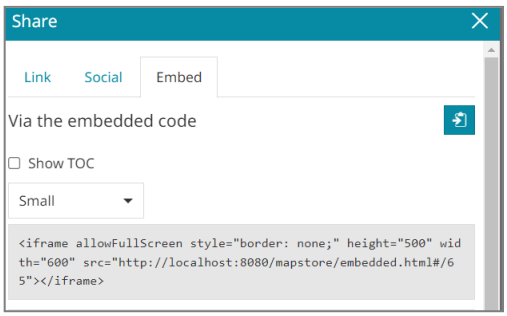
✓Directly by clicking on the Share button present in the toolbar of each resource.



✓Through a **social network:** The **Social** section allows the user to share the resource on the most common social networks such as **Facebook**, **Twitter** and **LinkedIn**



✓With **embedded code** or **APIs** (only available for *maps*)



Details on how to install, create web maps and dashboards and sharing geoportal resources are described in the training manual (appendix 2).

5.18. Implementation of WSS geoportal

The WSS geoportal implementation will be executed in the following phases:

- Prototype System design for one country: After assessing data on WSS and existing ICT assets, the GIS expert, will create a model consisting of the components described in previous chapters: Database management system, data preparation in GIS desktop, Portal components. Then they will proceed with installation of required tools.
- Duplicating and adapting the designed system in each country: System implementation in other ESAWAS countries should take into account the specificities of each country.
- Deploying country system in respective web hosting domain of each country: The tested system will be deployed at the web hosting of each country. The administrator of the web hosting domain will then share the link of their Geoportal to be referenced in html documents of thewebsites of each utility or any other user.
- Capacity building: The Geoportal administrator will be trained on how to install and set up required software, administering geodatabase, geoserver, web mapping applications, and dashboard as well as sharing resources available in the geoportal. Other users will be trained on various themes, from the spatial data collection to publication as indicated in the table below.
- System maintenance: It is advisable to continue providing technical assistance for the implemented system. After implementation, users of the system may encounter technical issues, so the GIS expert must be ready to provide the required technical assistance. It is assumed that the technical assistance may be scheduled on a period of 6 months. After this period, the administrators of WSS geoportal of each country will take the full ownership.

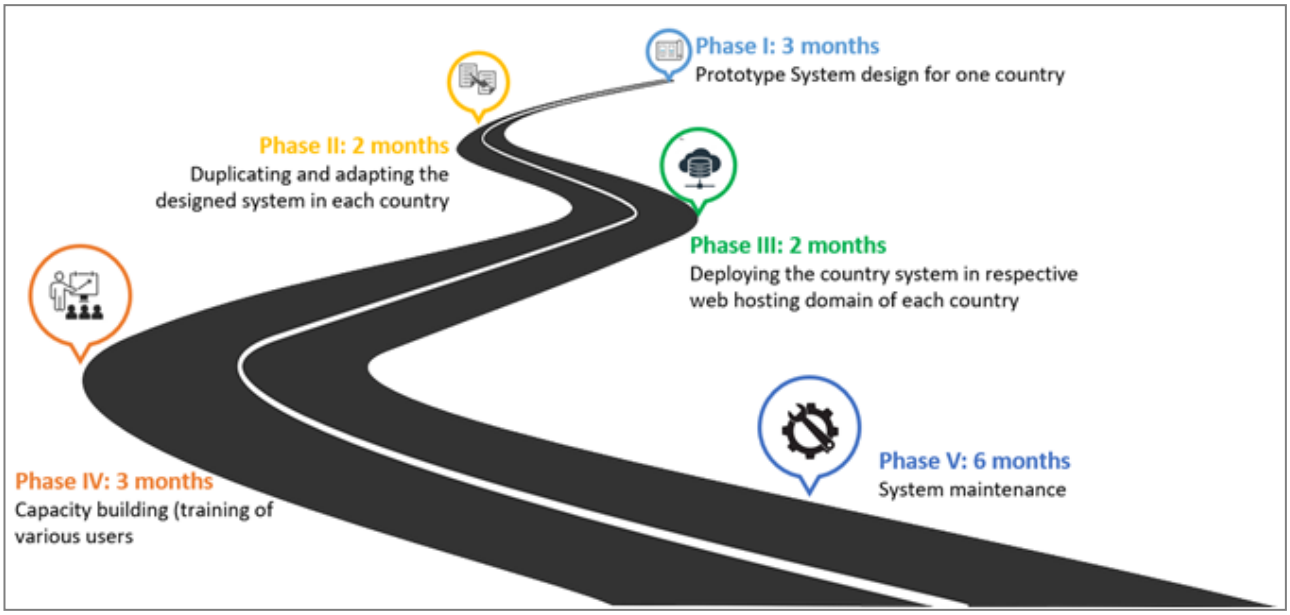


Figure 41: Phases of WSS geoportal implementation

5.19. Capacity building needs for running the Geoportal

Capacity building for people to operate the Geoportal, from data collection to dashboard management will cover the topics presented in the table 13.

Table 13:Capacity building need for the operation of WSS Geoportal

Key point	Details
Spatial data collection	The training will cover various aspects of spatial data collection, including the use of mobile data collection tools such as QField for QGIS, Kobo-Collect, among others. The training will also cover data quality assurance and quality control.
Data entry and editing	The training will cover data entry and editing, including the use of various data management tools, including data cleaning and validation.
Relational database development and management	The training will cover the development and management of relational databases, including the use of SQL, PostgreSQL, and PostGIS.
Map preparation	The training will cover map preparation, including the use of various GIS tools such as QGIS, and Google Earth.
Spatial data publishing	The training will cover spatial data publishing, including the use of various web mapping platforms such as GeoServer and MapServer.

Key point	Details
Web mapping	The training will cover the use of various web mapping tools such as Leaflet, OpenLayers, and Mapbox.
Dashboard	The training will cover dashboard development, including the use of various dashboarding tools

The participants in the training will be various staff from all utilities and regulators in the Eastern and Southern African Water and Sanitation (ESAWAS) Regulators Association as well as government agencies such as ministries playing a key role in the management of the existing information through data provision and which use data collected by both the utilities and regulators.

5.20. Cost for WSS geoportal implementation

Some costs were estimated for the implementation of the WSS geoportal. The estimates relate to the system design, maintenance and training of the users. Those costs are presented in the tables below.

Table 14: Main costs of the system set and maintenance

Item	Estimate Unit cost in USD	Number of units	Estimate of cost in the USD	Comments
Cost of infrastructure (Server, mobile gadgets etc.)	NA	NA	NA	- It is suggested to use the existing infrastructure - They can be purchased for the organizations that do not have them.
Cost of software (Geoserver, QGIs etc.)	NA	NA	NA	- They are open-sources that are available on the internet and can be downloaded at free of charge
Setup costs	800.00	5.0	4,000.00	- The system will be set up based on the existing data and ICT facilities within the hosting organization - The set-up will consist of the installation of the Open Source Spatial CMS, Setting web server and - Setting-up GIS server
Cost of hosting	NA	NA	NA	- It has to be hosted by any national institution dealing with WSS or the on in charge of managing the data center in each country - The use of the existing server and the institution website is recommended
Maintenance	600	24	14,400.00	- For the first two years - The maintenance operations will be performed every three months and for 3 days each time.

Item	Estimate Unit cost in USD	Number of units	Estimate of cost in the USD	Comments
				- The costs include the training on the system maintenance
Reimbursable expenses (Travels, accommodation during the system maintenance periods)	2000.00	8	16,000.00	- The unit cost is estimated at 2000.00 USD for each period of maintenance. The periods are 4 per year, which makes 8 for two years
Total			34,400.00	

The table below show the estimates for the training of the users (trainees) of the system. Those users should include the staff using the WSS MIS in the main utility, regulator, and some agencies like the Ministries dealing with the issues related to water supply and sanitation services in the country. A limited number of trainees is suggested, bearing in mind that they will train other staff upon the adoption of the system by different utilities within each country.

Table 15: Training cost in one country

Key point	Training details	Participants	Minimum number of participants[8]	Number of days	Training cost per day in USD[9]	Total Cost
Spatial data collection	- Using of Mobile Phones in collecting data on WSS indicators - Importing GPS data to Quantum GIS	Utility	4	2	650.00	1,300.00
		Regulator	2			
		Ministry of water	2			
		Ministry of Healthy	2			
Data entry and editing	- Description of data - Structuring a geodatabase	Utility	4	3	650.00	1,950.00
		Regulator	2			
		Ministry of water	2			
		Ministry of Healthy	2			
Relational database development and management	- Creating WSS layers - Spatially join spatial and non-spatial data - Setting-up geodatabase and permissions - Importing WSS data into the geodatabase management system - Datasets uploading - Setting sharing options - Datasets metadata - Dataset styling	Utility	4	4	650.00	2,600.00
		Regulator	2			
		Ministry of water	2			
		Ministry of Healthy	2			
Map preparation	Creating layout maps	Utility	4	2	650.00	1,300.00
		Regulator	2			

[8] Maximum number of staff from different agencies engaged in WSS. This number can be increased, based on the number of staff dealing with the information system within the utilities and regulators in each country.

[9] The cost for training preparation is included

Key point	Training details	Participants	Minimum number of participants[8]	Number of days	Training cost per day in USD[9]	Total Cost
		Ministry of water	2			
		Ministry of Healthy	2			
Geoportal user accounts and roles	- Creating users accounts - Creating groups	Utility	4	3	650.00	1,950
		Regulator	2			
		Ministry of water	2			
		Ministry of Healthy	2			
Spatial data publishing and Web mapping	- Creating interactive web maps - Creating maps metadata - Web map sharing with WSS geoportal	Utility	4	2	650.00	1,300.00
		Regulator	2			
		Ministry of water	2			
		Ministry of Healthy	2			
Interaction between geoportal and other application	- Connection between Geoportal and QGIS - Creation of WSS indicators dashboard	Utility	4	4	650.00	2,600.00
		Regulator	2			
		Ministry of water	2			
		Ministry of Healthy	2			
All training costs						**13,000.00**
Reimbursable expenses for the trainer during the training period (Travels, and accommodation)						**4,200.00**
All (Total) Costs in USD						**17,200.00**

The cost of the training of some staff that will be dealing with the WSS information system in one country can be estimated at 17,200.00. Upon the training, the trainees can train other staff within their respective agencies in order to ensure that there is a sufficient number of the system users. The development of the system will also require the collection of data for WSS in each country, especially for the utilities and regulators which do not have an operational GIS system. The cost of data collection can be estimated based on the total number of households in each country or any

area of interest like a city. On average, one surveyor can collect data on 20 households per day. The cost per day can be estimated at 30 Dollars for one enumerator. In order to cover the whole city, the number of enumerators is estimated: No. of households/Average Households per day/No. of days for data collection. The longer the survey period, the less number of enumerators required. The table below shows an example of the estimated costs for collecting data on WSS in the visited cities. The estimations are based on the assumption that no database exists. More accurate calculations can be done based on the areas to be covered during the data collection period.

Table 16:Costs of Data collection and data entry

Cities	Total number of households [10]	Number of enumerators	Households surveyed by one enumerator per day	Wage for enumerator per day ($)	Number of supervisors and data processor	Wage for supervisor and data processor per day ($)	Total days required for surveying the whole city	Wage for all enumerators ($)	Wage for all Supervisors ($)	Total cost ($)
Dar es Salaam	1,550,066	50	20	30	5	40	1,551.00	2,326,500.00	310,200.00	2,636,700.00
Nairobi	1,506,888	50	20	30	5	40	1,507.00	2,260,500.00	301,400.00	2,561,900.00
Lusaka	677,923	50	20	30	5	40	678.00	1,017,000.00	135,600.00	1,152,600.00

The cost for data collection was calculated based on the latest figures on the population of the three cities that were included in the study. Those figures are summarised as follows: Dar es Salaam had population of 5,383,728.00 in habitants in 2022 from 6,048,000.00 inhabitants recorded in 2018 with 1,550,066.00 households and 3.5 people per household (The United Republic of Tanzania, 2022). Nairobi had population of 4,397,073.00 inhabitants in 2019, corresponding to 1,506,888.00 households. The average of people per household is 2.9 inhabitants per household (Republic of Kenya, 2019). Lusaka had population of 3,079,964.00 inhabitants in 2022, corresponding to 677,923.00 households (Republic of Zambia, 2022).

[10] Data source: Republic of Kenya (2019). Kenya Population and Housing Census Volume I: Population by County and Sub-county. Kenya; Republic of Kenya (2019). Kenya Population and Housing Census Volume IV: Distribution of Population and Socio-Economic Characteristics.; Republic of Zambia (2022). Census of Population and Housing Preliminary. Zambia; The United Republic of Tanzania (2022). The 2022 Population and Housing Census: Administrative Units Population Distribution Report.

The enumerator has to record data (both spatial such as location, shapes, and non-spatial data on each household, as well as those related to the water and sanitation facilities) in the area assigned to him/her. There is a need to hire a GIS expert who will play the role of enumerator supervisor and datamanager. He/she will be responsible for monitoring the daily activities of the enumerators, ensuring the correctness of data collected, the transfer of those data to GIS database, and the organisation of those data into the database. One supervisor and data manager can be assigned to 10 surveyors. The supervisor's remuneration can be 40 Dollars per day.

In general, if the WSS information system has to be established in each city, the main costs to be taken into account can be summarised as follows:

Table 17: Summary of the costs for one country

Item	**Estimated costs in USD**
Setting-up Geoportal	34,400.00
Total costs for training the users of WSS GIS information system	17,200.00
Data collection and database development for 1,500,000.00 Households (an example)	2,562,000.00
Total costs for training of enumerators in one countries	4,500.00
The general total	**2,618,100.00**

6 The sustainability of WSS GIS based Information system

The sustainability of a geoportal for WSS will depend on various factors, including its financial capacity. A well-funded and adequately resourced system will be sustainable than one with limited financial resources. Below, are some considerations for ensuring the sustainability of the suggested geoportal for the WSS:

6.1. Funding sources

A significant funding and well-designed financing strategy is essential for the effective implementation and maintenance of the WSS Information System. Adequate financial resources can enable the system to maintain its operations and services in the long run. There are various funding sources available for geoportals and data management systems, including government grants, private investments, donations from various organizations such as donors, development banks and user fees. Government grants and hosting and user agencies budgets can be stable and long-term funding mechanisms for the system, while donations can help fill in the gaps and support specific projects or initiatives. User fees can also generate revenue and ensure the system's sustainability, especially if the system provides valuable and specific services to the public. Diversified funding sources can increase the system's resilience and reduce the risk of funding cuts or interruptions, while the geoportal or data management system that relies solely on government grants may face challenges if the funding is reduced or terminated. When the system has multiple funding sources, there are chances that it can continue to operate even if one source of funding is discontinued. The financial aspect in water and sanitation relates to the establishment and maintenance costs of the system and the availability of the underlying data and how the financial benefits of the users are allocated to the maintenance of the information system. A financing plan must also be designed to ensure the monitoring, maintenance, and improvement of the system. The financing plan must consider the long-term sustainability of the system and ensure that the necessary resources are available to maintain the infrastructure and keep the data up to date. One of the mechanisms for system funding can be the diversification of the agencies revenues which help can mitigate the risk of dependence on a single source of funding. The geoportals and data management systems can generate revenue through a variety of means, such as consulting services and value-added products. The availability of high-quality data and services that can save time, increase efficiency, and improve decision-making attract some clients. For example, Lusaka Water Supply & Sanitation Company (LWSC) sometimes sells the mapping products and undertakes the consulting services on water and sanitation mapping. They also undertake some GIS work for other agencies outside of the water and sanitation sector.

6.2. Partnerships among agencies

Partnerships can play a crucial role in ensuring the sustainability of WSS Information System by providing financial, technical, and institutional support. The effective partnerships can bring together various stakeholders, including governments, non-governmental organizations, private sector entities, and communities, to collaborate on data collection and analysis for decision-making purposes. Through partnerships, it is possible to pool resources,

knowledge, and expertise, which can lead to a more comprehensive understanding of water and sanitation service delivery challenges, as well as more effective solutions. Partnerships with various government agencies can offer financial support, as they may have budget allocations for data management system. Partnerships with universities and research institutions can provide technical support in developing and maintaining the system, and ensuring its continuous improvement, while collaboration with private companies can be beneficial through their financial support, technical expertise, and sometimes the in-kind contributions such as the IT equipment. Partnerships with international organizations and donors can also provide financial and technical support and can help to increase the sustainability of the system. In Asia, some water and sanitation utilities develop funding through the partnership and support from the Asian Development Bank (ADB). Ensuring free and open access to certain data and services can also attract potential users and stakeholders. This can contribute to the funding of new data collection, management and system maintenance. In the visited countries (Kenya, Tanzania and Zambia) the partnership among WSS, ministries and utilities has facilitated the establishment and maintenance of the existing IS, through funding, data sharing and technical supports. Partnerships with various users, including the local communities can ensure that the system is meeting their needs and requirements, and they can provide various support include sharing or collection of some of the data required for system development. Regular communication and collaboration among partners are also essential for the success of the partnership and the sustainability of the system. Collaborative partnerships can also help build trust and accountability between utilities and regulators as they work towards sharing data needed for tracking progress in relation to community's access to clean water and sanitation services. In addition, partnerships can help ensure that WSS information system is sustainable and can continue to provide accurate and reliable data over the long term.

6.3. Capacity development

Capacity development is a major focus area when it comes to the development of the sustainable WSS information system. Capacity development will involve the enhancing the skills and knowledge of individuals and institutions involved in water supply and sanitation service delivery as well as the regulators as they are the key actors in using the system and providing all resources (including data) for the well-functioning of that system. The capacity development can take many forms, such as training programs, mentoring and coaching, knowledge sharing and networking for all individuals at the utility and regulator levels who are involved in data collection, management, analysis, and their use for decision-making and performance evaluation for the supply and sanitation service delivery. Building the capacity will require putting in place a team of professionals with a deep understanding of the technical aspects of the system, including hardware, software, data management, and security. These professionals must also be knowledgeable about the latest technological advancements and trends to ensure that the system remains up-to-date and effective. The capacity development will include trainings on various types of software and devices required for data collection, management and analysis for reporting purposes. Capacity development can also involve building the capacity of staff from other institutions responsible for water and sanitation management, such as local government bodies to effectively collect data required for feeding the system, the transfer of those data to the system and its use through viewing the generated indicators, maps, and reports. Building the

capacity of individuals and institutions involved in water and sanitation management can also help ensure that utilities and regulators have the necessary skills and knowledge to use the related data in reporting and make the well-informed decisions about water and sanitation infrastructure investments, leading to improved health outcomes and quality of life for communities. Generally, ensuring the sustainability of the WSS information systems requires adequate technical capacity in various areas, including the hardware and software which are critical components of the system, data storage and management, the user support and training that helps users to fully understand the capabilities of the system and to utilize it to its fullest potential.

6.4. Technology adoption for collecting and managing data

Data plays a critical role in creating an effective sustainable WSS information system as it forms the foundation for all subsequent analysis and decision-making. The application of various GIS tools such as open source software and mobile data collection devices can significantly enhance the collection, management, and analysis of water and sanitation related data. The use of satellite and aerial images has become the cost-effective method for collecting data and development of base maps for water and sanitation infrastructure mapping. Innovative techniques such as programming can facilitate the processing of large data sets and identifying trends and patterns, contributing to effective performance evaluation in water and sanitation serviced delivery. Furthermore, technology can also support effective public participation in water and sanitation decision-making, through digital tools for data sharing and participatory mapping towards ensuring progress in improving access to clean water and sanitation services for communities, and making decisions about new investment plans.

6.5. Standards and data quality management

Standards provide a strategic pathway for the development, implementation, and management of WSS information systems as they are observed to ensure that the system meets the needs of users. The use of standards helps to promote interoperability, consistency, and quality in data collection, management, analysis, and decision-making processes. This is particularly important for information systems, which involve the integration of various data sources and technologies. Standards can also help to improve the accuracy and reliability of data, reduce data duplication and errors, and facilitate the sharing and exchange of data across different organizations and systems. The use of standards helps to ensure that information system is compatible with existing water and sanitation management systems, policies, and regulations. Data quality management involves the systematic and continuous process of monitoring, evaluating, and improving the quality of data within the system. The primary objective of data quality management is to ensure that the data is accurate, consistent, updated, complete, and reliable, and meets the needs of the users. To achieve data quality management, it is essential to establish quality control and assurance processes and procedures that ensure data integrity, consistency, and accuracy. These processes and procedures should involve data cleaning, validation, verification, profiling, and lineage analysis. The effective data quality management requires the collaboration and involvement of various stakeholders, including data providers, data custodians, and data users as they contribute to data collection and sharing and play an important role in ensuring data accuracy and completeness.

6.6. Advocacy and awareness

The advocacy and awareness are recognized as a strategy for building a sustainable WSS information system. Advocacy is the process of influencing public policy and decision-making at different levels of water supply and sanitation service delivery while awareness involves the capacity of the information system users about its importance in water and sanitation infrastructure development and management. This can help build support for the implementation of the system and ensure that it is effectively used to improve water and sanitation services. Through advocacy, the utilities and regulators can influence policymakers to support the development of WSS information system and allocate the required resources for the implementation. This can involve engaging with local and national government officials and other stakeholders to support the system development. Advocacy can also involve dissemination of the system benefits among various actors about the accurate, updated data and information on access to clean water and sanitation services, and ensure that they can support the development of the system which will be used to inform effective decision making towards the improved water and sanitation services delivery.

6.7. Governance structure

Governance structure is an essential consideration for assessing the institutional capacity of WSS information system. The governance structure defines the roles, responsibilities, decision-making processes of the organization responsible for operating the system, and its custodianship. A strong governance structure ensures that the system operates effectively, and remains sustainable over the long term. One important aspect of governance structure is stakeholder engagement. Effective engagement with stakeholders, including data providers, users, and other relevant parties, is critical for ensuring that the system meets their needs and remains relevant. This may involve developing formal mechanisms for stakeholder feedback and input, such as user groups or advisory committees, as well as ensuring that stakeholders are kept informed of system developments and changes. Additionally, a skilled and dedicated staff is necessary to manage the system and ensure that it operates effectively and efficiently. Finally, the governance structure should include clear reporting mechanisms for system performance and compliance with relevant policies and regulations. In regard to the custodian of the system, the regulator will be the right organization as it regularly ensures that the utilities feed the system with the accurate and updated data which are needed for effective reporting in term of performance, quality of services and progress in achieving the national targets in the WSS sector. This role of regulator requires that it ensures that the system is ell functioning and allows for the generation of the relevant reports, which are aligned with defined key indicators. The custodianship role of regulators will therefore compel them to ensure that the system is regularly operational and can be upgraded in line with the evolving changes in GIS and digital landscape.

6.8. Policies and procedures

Policies and procedures comprise a set of guidelines defining the processes, protocols, and standards for managing, operating, and maintaining a geoportal or data management

system. These policies and procedures are developed to ensure the efficient and effective management of the system, including the handling of data, metadata, user access, security, and other critical aspects. The development of policies and procedures should involve input from stakeholders, including system administrator, data providers, and users, to ensure that the policies are comprehensive, practical, and aligned with the needs and goals of the system. These policies and procedures should also be regularly reviewed and updated to reflect changes in technology, user requirements, and best practices in data management. A well-designed set of policies and procedures can enhance the institutional capacity of a geoportal or data management system, providing a framework for consistent, transparent, and accountable management practices. Effective policies and procedures can also help to ensure the sustainability of the system, providing a solid foundation for long-term management and development.

7. Conclusion

The GIS based information system for ESAWAS members will be developed based on the data in existing IMS which are used in reporting water and sanitation services in the members' countries. The structure of the system administration will be similar to that of the existing MIS. Hosting will be dependent on the agreed data governance structure for the sector. The regulator will be responsible for system administration while the utilities will be among the users, which will be also tasked to populate the system with all WSS related databasets.

The water dataset contains data related to households, leakages, water customers, water kiosks, water meters, water pipes, water reservoirs, water service areas, water sources, and water treatment plants. The sanitation dataset will include data for landfill, public toilets, sewage service areas, sewer pipes, toilets, handwashes, chambers for girls, STP (sewage treatment plant), and sewer households. There is also an additional spatial data database for rivers, road networks, lakes, and administrative boundaries, which will serve for the base maps.

The use of the Geoportal supported by the database management system comprising the above-mentioned that will allow for the evaluation of efficiency in the provision of WSS services in urban areas as follows:

- **Access to basic services** as a function of WSS facilities in relation the spatial distribution of all users, including the households,
- **Quality of service** as a function of service levels, functionality and physical condition of the infrastructure serving the customers, and the quality of WSS services measured on the basis of the defined standards,
- **Performance of service provider which is** a function of their level of operation,
- **Effectiveness of technical assistance,** reflected in the use of Information System for efficient management of WSS facilities, and support of decision-making for any related interventions.

As for the capacity needs, the proposed geoportal development will necessitate the ICT hardware and software that meet the following requirements.

Software	Hardware
QGIS desktop and its QField: with QGIS 3.28.6 that can be installed on different platforms.	➢QGIS desktop requires the following capacity: - Process-CPU. Core i3 2.7 Ghz. Core i7 3.5 Ghz - Memory RAM 2GB or more - Hard Disk 500Gb SATA, SSD de 128 Gb or more The QField minimum requirements: The mobile device with at least Android 9.
PostgreSQL/PostGIS that supports spatial data as well non spatial data is required.	➢The minimum hardware required to install and run PostgreSQL is: 1 GHz processor; 2 GB of RAM and 512 MB of HDD
Geoserver 2.23 will be required for sharing and publishing geospatial data as Web Feature Service (WFS), Web Map Service (WMS), and Web Coverage Service (WCS), Web Processing Service (WPS), and Web Map Tile Service (WMTS).	➢GeoServer requires a Java 11 or Java 17 environment (JRE) to be installed on your system.
Mapstore2: is needed for the web mapping application using open mapping libraries such openlayers and leaflet.	➢Mapstore2 requires 2 core for processor and 2GB of memory, but 4GB is recommended
Apache Tomcat: Apache Tomcat is a local java web container.	

The implementation of the WSS Geoportal will involve several phases, starting with the design of a prototype system for one country and then duplicating and adapting the system for other countries within the ESAWAS region. The country-specific systems will be deployed in respective web hosting domains, and capacity building will be undertaken for users on various topics related to operating the Geoportal.

The system will be designed in a way that set the security measures, such as securing the server with a password, regular backup of the data (a back-up method should be applied to have a copy of the system and data in a safer place, which can be either a server, or hard driver or URL and should be outside the central database or organisation office), system upgrading, assigning different roles to users with different privileges (data entry, validation,

confirmation), and implementation of the row-level security (RLS) to restrict data visibility based on roles.

For the operation of the system, the following components will be taken into account in the design:

- Data collection (offline and online) using mobile phones with the installed QField. The use of QField is suggested as it has made data collection easier and more efficient. This mobile data collection tool will allow field teams to collect data offline and upload it later when they have access to the internet.
- Data uploads remotely with internet connection (data transfer to database). With the availability of an internet connection, field teams will be easily uploading data remotely. This process will be automated, which means that data will be automatically transferred from the mobile data collection tools to the database.
- Data cleaning: this is an important process that will involve identifying and correcting errors, inconsistencies, and inaccuracies in the data. This process will ensure that the data is accurate, complete, and consistent.
- Data validation: it will be ensuring that the data meets certain criteria, standards, or rules. This process helps to identify errors or inconsistencies in the data that may affect its quality.
- Data updating: it will be used to add new data or modifying existing data using QField. This process will ensure that the data is up-to-date and reflects the current situation on the ground.
- Data manipulation from Database to web and Dashboard. After validating the data in database the next step will involve various processes such as data analysis, visualization, and sharing. Various tools such as Tables, and Google Data Studio will be used to manipulate data and create interactive dashboards.

Apart from the setting up of the system and its use in reporting on WSS, its sustainability of will be a key aspect to consider. This includes assessing the financial, institutional, and technical capacities required to ensure that the systems remain operational over time. The effective management of the system will be guaranteed by establishment of a single custodian who will ensure that required data are collected and updated on a regular basis and the required upgrading are timely performed. This role will be played by the Regulator in each country as it has to rely on accurate and update data provided by all utilities while monitoring the performance in WSS sector.

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Appendix

Appendix 1: List of WSS Indicators for reporting

NB	Identification	Description by regulator	Related spatial dataset	Attribute data for the spatial dataset[11]	Attribute data to be used for reporting[12]
1	Water production expenses as % of total O&M expenses	Total water production expenses / Total O&M expenses * 100	Water treatment plant	Yes[13]	Water production expenses
2	Water distribution expenses as % of Total O&M expenses	Total distribution expenses / Total O&M expenses * 100	Water treatment plant	Yes	Water distribution expenses
3	Sewerage disposal expenses as % of Total O&M expenses	Total sewerage disposal expenses / Total O&M expenses * 100	Sewerage treatment plant	Yes	Sewerage disposal expenses
4	Maintenance & repair expenses as % of Total O&M expenses (for sewerage)	Total maintenance & repair expenses / Total O&M expenses * 100	Sewerage treatment plant	Yes	Maintenance & repair expenses
5	Water Source Upkeep	These are activities associated with the environmental conservation measures in protecting the water sources from pollution or entrance including fencing, debris removal, cleaning of the surrounding and others related activities	Water source	Yes	Any environmental conservation activities
6	Sewerage coverage	(Domestic sewer connections * Average no. of people served per domestic sewer connection) / Total	Sewerage network	Yes	Number of domestic sewer connections

[11] The indicator can be generated using the attribute data of the related spatial dataset. The lists of all attribute data for all indicated spatial datasets will be provided in the report.

[12] This is the key attribute data required for generating the information related to the indicator

[13] It is possible to record data related to the indicator using the attribute table of the relevant dataset in GIS

NB	Identification	Description by regulator	Related spatial dataset	Attribute data for the spatial dataset[11]	Attribute data to be used for reporting[12]
		population * 100			
7	On site Sanitation activities	Is the whole of actions related to the treatment and disposal of domestic waste water that cannot be carried away by an off-site sanitation system. Example of on-site sanitation activities are emptying of pit latrines or septic tanks	Toilet	Yes	Maintenance undertaken for the household's toilet
8	Population with direct access to domestic connections or kiosks	(Total domestic connections * Average number of people served per domestic connection + Total no. of kiosks in operation * Average no. of people served per kiosk) / Total population * 100	Service area	Yes	Total number of active customers
			Customers	Yes	Population with direct access to domestic connections
					Access to water from Kiosks
9	Population with direct access to domestic connections	(Total domestic connections * Average number of people served per domestic connection) / Total population * 100	Service area	Yes	Total number of connections
			Pipes	Yes	
10	Moribund Domestic Customers	These are disconnected customers who have not transacted with Provider for a long time after being disconnected.	Water meter	Yes	Active/Inactive connection
11	Population with direct access to domestic connection	The number of people with direct access to domestic connection	Service area	Yes	Total number of served households
			Household	Yes	Access to domestic connection
12	Population with access to Kiosk	The number of people served at a kiosk connection	Household	Yes	Source of water (Kiosk)
			Kiosk	None.	Number of households

NB	Identification	Description by regulator	Related spatial dataset	Attribute data for the spatial dataset[11]	Attribute data to be used for reporting[12]
				Rather spatial analysis is possible	located within 250 meters from the water Kiosks
13	Population living in area with network	Population living in area with network / Total population * 100	Service area	Yes	Number of households
14	Non Revenue Water (NRW)	(1-(Total billed volume/Input into distribution network)) * 100	Water treatment plant	Yes	Tot water loss
15	Metering ratio	Total operating metered connections / Total water connections * 100	Meters	Yes	Operating meter (Yes/No)
16	Collection efficiency	(Total collection from water sales+ Total meter rent collection + Total sewerage collection) / (Total billing water sales + Total meter rent billing +Total sewerage billing) * 100	Service area	Yes	Collection efficiency in %
17	Disconnection ratio	Total customers currently disconnected / Total water connections * 100	Customers	Yes	Connection status (Connected/Disconnects)
18	Billing efficiency	Total billed volume / Estimated billable water * 100	Service area	Yes	Billing efficiency in %
19	Billing reliability	(Total no. of bills dispatched) / (Total active connections) * 100	Water meter	Yes	Billing reliability in %
			Service srea	Yes	
20	Billing correction ratio	Bills adjusted after complaints / Total no. of bills dispatched * 100	Water meter	Yes	Number of billing complaint
21	Billing complaints	Number of billing complaints and queries during the assessment period / Total number of registered customers	Water meters	Yes	Claim on billing (Yes/No)
			Service areas	Yes	Number of billing complaints
22	Timely resolution of billing	Percentage of the total number of	Service areas	Yes	Average number of

NB	Identification	Description by regulator	Related spatial dataset	Attribute data for the spatial dataset[11]	Attribute data to be used for reporting[12]
	complaints	billing complaints that are resolved within the maximum time specified in a local service commitment / Total Complaints			days taken to resolve billing complaints
23	Complaints per 1000 connections	Total complaints received / [(Total water connections + Total sewer connections)/1000]	Water meter	Yes	Complaint
			Sewer connection	Yes	
24	Average monthly water bill for domestic connections	(Total domestic billing water) / (Total domestic connections - Domestic customers currently disconnected)	Household	Yes	Average monthly payment for water
25	Average daily per capita consumption at metered domestic connections	[Domestic billing metered (in m3)] / [(Domestic connections metered – Domesticmetered customers currently disconnected) * Average number of people served perdomestic connection] * 1000 / 30.	Water meter	Yes	Billed water per month
26	Average daily per capita consumption at metered kiosks	[Billing at metered kiosks (in m3) / (Kiosks in operation metered * Average no. of people served per kiosk)] * 1000 / 30.	Water kiosk	Yes	Billed water per month
27	Daily water distribution per capita served	Input into distribution network / Population directly served * 1000 / 30	Service area	Yes	Daily water distribution in m^3
28	Total collection	Total collection from water and sewerage services including billing of water sales, sewerage, meter rent and other operating income	Service area	Yes	All collections based on billing
			Waste and water treatment plants	Yes	All collections based on billing
29	Commercial losses	Non Revenue water – Estimated technical water losses	Water treatment plant	Yes	Total water loss per month or day
30	Meter replacement	(Water meters replaced for technical	Water meter	Water meter	Water meter

NB	Identification	Description by regulator	Related spatial dataset	Attribute data for the spatial dataset[11]	Attribute data to be used for reporting[12]
		reasons + Water meters replaced due to vandalism) / [Total metered connections (July + August + …+ June)/12]*100		history	replacement date
31	Compliance with residual chlorine standards	Residual chlorine tests met standards / Residual chlorine tests conducted * 100	Water treatment plant Water reservoir Water Kiosk	Yes	Results of residual chlorine tests conducted
32	Compliance with E-coli standards	E-Coli tests met standards / E-Coli tests conducted * 100	Water treatment plant Water reservoir Water Kiosk	Yes	Results of E-Coli tests conducted
33	Compliance with turbidity standards	Turbidity tests met standards / Turbidity tests conducted * 100	Water treatment plant Water reservoir Water Kiosk	Yes	Results of Turbidity tests conducted
34	Compliance with pH standards	pH tests met standards/ pH tests conducted * 100	Water treatment plant Water reservoir Water Kiosk	Yes	Results of pH tests conducted
35	Compliance with Chlorides standards	Chlorides test met standards/ Chlorides tests conducted * 100	Water treatment plant Water reservoir Water Kiosk	Yes	Results of Chlorides test conducted
36	Compliance with Fluorides standards	Fluorides test met standards/ Fluorides tests conducted * 100	Water treatment plant Water reservoir Water Kiosk	Yes	Results of Fluorides test conducted

NB	Identification	Description by regulator	Related spatial dataset	Attribute data for the spatial dataset[11]	Attribute data to be used for reporting[12]
37	Compliance with Fe standards	Fe test met standards/ Fe tests conducted * 100	Water treatment plant Water reservoir Water Kiosk	Yes	Results of Fe test conducted
38	Compliance with Mn standards	Mn test met standards/ Mn tests conducted * 100	Water treatment plant Water reservoir Water Kiosk	Yes	Results of Mn test conducted
39	Compliance with Nitrates standards	Nitrates test met standards/ Nitrates tests conducted * 100	Water treatment plant Water reservoir Water Kiosk	Yes	Results of Nitrates test conducted
40	Average daily service hours	No of connections area 1 * Average daily service hrs area 1 + No of connections area 2 * Average daily service hrs area 2 + …+ No of connections area x * Average daily service hrs area x) / Total water connections	Service area	Yes	Service hours
41	Percentage of Connections with 24h supply	Connections with 24 hrs. supply / Total water connections * 100	Service area	Yes	Percentage of connections with 24 hours supply
			Household	Yes	Number of hours water supply per day
42	Technical water losses per km of mains per month	[Estimated technical water losses / 100 * Input into distribution network] / Length of distribution network	Service area	Yes	Water loss (in m^3)
43	Water losses per active connection per month	(Input into distribution network - Total billed volume) / Total active connections	Service area	Yes	Water losses per per month

NB	Identification	Description by regulator	Related spatial dataset	Attribute data for the spatial dataset[11]	Attribute data to be used for reporting[12]
44	Ratio of production losses	(Total water abstraction - Exported untreated water - Exported treated water +Imported untreated water + Imported treated water - Input into distribution network)/ Total water abstraction * 100	Water treatment plant	Yes	Water loss (in m^3)
45	Connections per km of network	Total water connections / Length of distribution network	Pipes Service area	Yes	Number of customers
46	Leaks per 100 km of mains per month	Leaks repaired / (Length of transmission and main distribution network / 100)	Main water pipes	Yes	Leakage frequencies
47	Quality of discharged effluent (BOD 5)	BOD 5 tests in compliance with standards / BOD 5 tests conducted	Waste water treatment plant	Yes	Results of BOD 5 tests conducted
48	Quality of discharged effluent (COD)	COD tests in compliance with standards / COD tests conducted	Waste water treatment plant	Yes	Results of COD tests conducted
49	Energy consumption per m3 distributed	Electricity for production & distribution / Input into distribution network	-Water treatment plant - Sewage treatment plant	Yes	Energy consumption per m^3
50	Percentage of population with safely managed sanitation (Use of improved facilities that are not shared with other households and where excreta are safely disposed of in situ or transported and treated off-site)"	Population with safely managed sanitation / Total Population	Household Toilet	Yes	Percentage of population with safely managed sanitation
51	Percentage of population with basic sanitation (Use of	Population with basic sanitation / Total Population	Household	Yes	Type of sanitation facility

NB	Identification	Description by regulator	Related spatial dataset	Attribute data for the spatial dataset[11]	Attribute data to be used for reporting[12]
	improved facilities that are not shared with other households)"				
52	Percentage of population with limited sanitation (Use of improved facilities shared between two or more households)	Population with limited sanitation / Total Population	Household	Yes	Type of sanitation facility
53	Percentage of population with unimproved sanitation (Use of pit latrines without a slab or platform, hanging latrines or bucket latrines)	Population with unimproved sanitation / Total Population	Household	Yes	Type of sanitation facility
54	Percentage of population practising open defecation (Disposal of human faeces in fields, forests, bushes, open bodies of water, beaches or other spaces, or with solid waste)	Population practising open defecation / Total Population	Household	Yes	Means of defecation
55	Sewer system coverage: Percentage of population that are connected to the sewer system	[Number of sewered connections x average household size] / Total Population	Household	Yes	Connection to sewer pipe (Yes/No)
			Sewer pipe	Yes	Number of connections
56	Utilisation of a sewerage system	Sewer network in service / Total Length of sewer network	Sewer pipe	Yes	Operational sewer pipe (Yes/No)
57	Sewer Flooding: Percentage of connected properties that are affected by flooding from sewers during the assessment	Total number of connections flooded from sewers / Total Connections	Households Customers	Yes	Experience with flooding (Yes/No)

NB	Identification	Description by regulator	Related spatial dataset	Attribute data for the spatial dataset[11]	Attribute data to be used for reporting[12]
	period				
58	Interruption of wastewater collection and transport services: Percentage of the number of properties affected by service interruption during assessment period	Number of connections with service interruptions / Total Sewer connections	Households Customers	Yes	Number of interruption in wastewater collection and transport services
59	Sewer blockages: the average number of blockages occurring per 100 km of sewers or 100 connections during the assessment period	(No.of blockages*100)/ km length of sewer network (No.of blockages*100)/No. of sewer connections	Sewer pipe	Yes	Number of blockage
			Sewer connection	Yes	Number of blockage
60	Percentage of wastewater delivered to treatment plant vs total wastewater discharged to sewers (i.e. not including leakages and/or discharges other than to WWTP)	Wastewater delivered to treatment plant / Total wastewater discharged to sewers	Sewerage treatment plant	Yes	Quantity of treated waste in m^3
61	Capacity of the treatment plant: inflow waste water (volume) as a percentage to the capacity of the treatment plant	Total volume of sewage received / Design capacity of the treatment plant	Sewerage treatment plant	Yes	▪Quantity of treated waste in m^3 ▪Design capacity of the treatment plant
62	Compliance to sewage quality standards: Percent of sewage (wastewater treated) effluent quality tests which meet the effluent quality standards	Number of effluent tests meeting quality standards / Total number of effluent tests carried out	Sewerage treatment plant	Yes	▪Results of effluent tests ▪Total number of effluent tests carried out
63	Proportion (percentage) of	Wastewater safely treated / Total	Sewerage		Quantity in m3 of

NB	Identification	Description by regulator	Related spatial dataset	Attribute data for the spatial dataset[11]	Attribute data to be used for reporting[12]
	wastewater generated by households and by economic activities which is safely treated (at least secondary treatment) compared to total wastewater generated by households and economic activities	Wastewater generated	treatment plant		wastewater treated
			Household	Yes	Quantity in m^3 of wastewater generated by households and economic activities
			Economic activities	Yes	Quantity in m3 of wastewater generated by economic activities
64	Re-use and recycling of treated sewage - treated sewage re-use/ recycled as a percentage of total treated sewage (%)	Treated sewage reused/Total treated sewage	Sewerage treatment plant	Yes	Treated and reused sewerage in %
65	Septic tank coverage: Percentage of population connected to septic tanks (%)	[Total number of septic tanks x average household size] / Total Population	Household toilet	Yes	Connection to septic tanks (Yes/No)
66	Population using emptiable facilities (%): Percentage of population using emptiable toilets in service area	{Total number of emptiable facilities x average household size] / Total Population	Household	Yes	Type of toilet facility
			Household toilet	Yes	Types
67	Collection efficiency of septage (%) – Percentage of septage which is collected to the total expected septage to be collected during the assessment period (can be broken down by containment type)	Septage collected / Total expected septage to be collected	Service area	Yes	Collected septage in %
68	Desludged facilities (%): Percentage of onsite sanitation	Total desludged facilities/Total onsite sanitation facilities	Household toilet	Yes	Desludging frequencies of the facility

NB	Identification	Description by regulator	Related spatial dataset	Attribute data for the spatial dataset[11]	Attribute data to be used for reporting[12]
	facilities that have been desludged		Public and private agency toilet	Yes	Desludging frequencies of the facility
			Public toilet	Yes	Desludging frequencies of the facility
69	Number of septage sucking machines (cesspit emptier) / 1000 septic tanks (Ratio)	(No. of septage sucking machines*1000) / No.of septic tanks	Service area	Yes	▪Number of septage sucking machines ▪Number of septic tanks
70	Percentage of septic tanks connected to soak pit for effluent disposal (%)	Number of septic tanks connected to soak pit / Total number of septic tanks	Household toilet	Yes	Connection to soak pit for effluent disposal (Yes/No)
			Public and private agency toilet	Yes	
			Public toilet	Yes	
71	Faecal sludge transport: Percentage of received septage at the treatment plant to total emptied septage during the assessment period (%)	Septage received at treatment plant / Total emptied septage	Sewerage treatment plant	Yes	Quantity of received and treated faecal sludge
			Septic tanks	Yes	Septage capacity
72	Capacity of Faecal Sludge (FS) treatment facility: FS treatment capacity as a percentage of current volume of sludge received	Total FS received at treatment plant / Design Capacity	Sewerage treatment plant	Yes	▪Quantity of treated FS in m^3 ▪Design capacity of the treatment plant
73	Sludge treatment: Percentage of faecal sludge that receives treatment of both solid and	Treated faecal sludge / Total faecal sludge delivered to treatment	Sewerage treatment plant	Yes	Total faecal sludge delivered to treatment

NB	Identification	Description by regulator	Related spatial dataset	Attribute data for the spatial dataset[11]	Attribute data to be used for reporting[12]
	liquid fraction to all faecal sludge delivered to treatment				Treated faecal sludge
74	Compliance to sludge quality standards: Percent of treated sludge quality tests which meet the sludge quality standards	Treated sludge tests which meet quality standards / Total number of treated sludge tests carried out	Sewerage treatment plant	Yes	▪Results of sludge tests ▪Total number of sludge tests carried out
75	Re-use of treated sludge: Percentage of reuse and recycling of treated effluent (from septic tank and grey water) to total treated effluent	Treat sludge or effluent reused / Total treated sludge or effluent	Sewerage treatment plant	Yes	▪Treated sludge in m^3 ▪ Treated and reused sludge in m^3
76	Personnel expenses as % of Total O&M expenses	Total personnel expenses / Total O&M expenses * 100	None[14]	NA[15]	NA
77	Personnel expenses as % of Revenue collection	Total personnel expenses / (Total water services collection + Total seweragecollection) * 100	None	NA	NA
78	Administration expenses as % of Total O&M expenses	Total administration expenses / Total O&M expenses * 100	None	NA	NA
79	Business promotion expenses as % of Total O&M expenses	Total business promotion expenses / Total O&M expenses * 100	None	NA	NA
80	Events & donation expenses as % of Total O&M expenses	Total events & donations expenses / Total O&M expenses * 100	None	NA	NA
81	Average monthly gross salary per staff	(Basic salary + House allowance + Lunch allowance + Hardship allowance +Acting allowance + Transport	None	NA	NA

[14] Data related to this indicator cannot be captured in the form of GIS layer

[15] There is no related attribute data as the indicator cannot be translated into GIS layer

NB	Identification	Description by regulator	Related spatial dataset	Attribute data for the spatial dataset[11]	Attribute data to be used for reporting[12]
		allowance + Incentives) / Total staff			
82	Incentives as % of gross salary	Incentives / (Basic salary + House allowance + Lunch allowance + Travelling allowance + Hardship allowance + Acting allowance + Transport allowance +Incentives) * 100	None	NA	NA
83	Training expenses as % of Personnel expenses	Training of staff / Total personnel expenses * 100	None	NA	NA
84	Staff per 1000 connections (W&S)	Total staff / [(Total water connections + Total sewer connections) / 1000]	None	NA	NA
85	Staff per 1000 active connections (W&S)	Total staff / [(Total active water connections +Total sewer connections) / 1000]	None	NA	NA
86	Total training rate	These are the total hours of training per staff per year. This includes external and in-house training. Only available in annual reports	None	NA	NA
87	Percentage of female staff	Total female staff / Total staff * 100	None	NA	NA
88	Staff turnover	No. of staff who left and have been replaced / Total staff * 100	None	NA	NA
89	Operating ratio	(O&M expenses+ Interest on bank overdrafts + Bank charges + Total provisions fordepreciation) / Total operating income	None	NA	NA
90	Operating ratio II (collection)	(Total O&M expenses + Interest on bank overdrafts + Bank charges + Totalprovisions for depreciation) / (Total water services collection + Total seweragecollection)	None	NA	NA

NB	Identification	Description by regulator	Related spatial dataset	Attribute data for the spatial dataset[11]	Attribute data to be used for reporting[12]
91	Total cost coverage	Total income / Total expenses * 100	None	NA	NA
92	Percentage of contracted service costs	Expenses for contracted services / Total O&M expenses * 100. Only available in annual reports	None	NA	NA
93	Cash ratio	Total cash & bank balances / Total accounts payable. Only available in annual reports	None	NA	NA
94	Accounts payable period	Total accounts payable / (Total income/12). Only available in annual reports	None	NA	NA
95	Accounts receivables in average monthly billing	Total accounts receivables / [(Total billing water sales + Total meter rent billing +Total sewerage billing)/12]. Only available in annual reports	None	NA	NA
96	Fixed assets turnover	Total operating income / Total fixed assets. Only available in annual reports	None	NA	NA
97	Recoverable Recoverable Charges	Expenses incurred by the utility which are allowed to be recouped from or paid backby customers including new connection, reconnection, etc.	None	NA	NA
98	Exchange Rate Gains	The amount that the base currency value of an asset or liability, denominated in aforeign currency, has increased due to a fluctuation of exchange rates over time.	None	NA	NA
99	Disposal Income	Income generated from sale of assets	None	NA	NA
100	Tender Documents	These are documents issued in response to a specific request from potential purchasers or buyers, e.g.	None	NA	NA

NB	Identification	Description by regulator	Related spatial dataset	Attribute data for the spatial dataset[11]	Attribute data to be used for reporting[12]
		government procurement			
101	Bad debt recovery	Is a recognition of the once written off bad debt which was proven to be uncollectible but due to some circumstances which were not foreseen by the time of writing off the bad debt, the amount has been collected.	None	NA	NA
102	Revenue Grants	Unlike capital grants, these are grants made by the Government or donors towards meeting the utility's annual running expenses	None	NA	NA
103	Amortisation of Capital Grants (value for the respective finacial year)	Is the recognition of grants in respect of Property, Plant and Equipment (PPE) over the useful economic life of those assets, thus matching the depreciation or amortization.	None	NA	NA
104	Asset Re-evaluation	An accounting concept which represents a reassessment of the value of a capital asset as at a particular date. An asset is originally recorded in the accounts at its cost and depreciated periodically over its estimated useful life as a measure of the amount of the assets value consumed in that period	None	NA	NA
105	Provision for Doubtful Debt	This is an account established to record a subtraction from ACCOUNTSRECEIVABLE, to allow for those accounts that may not be paid.	None	NA	NA

NB	Identification	Description by regulator	Related spatial dataset	Attribute data for the spatial dataset[11]	Attribute data to be used for reporting[12]
106	Provision for Impairment Loss	These are special, nonrecurring charges taken to write down assets with an overstated book value	None	NA	NA
107	Compensation	These are expenses given or received as an equivalent for services, debt, loss, etc.	None	NA	NA
108	Documentary and upkeep of Audio Visual	These are expenses associated with collection of news, reviews, features, interviews, images, audio and video on preparations of documentary for business promotion	None	NA	NA
109	Monthly operating income per staff	Total operating income / Total staff	None	NA	NA
110	Staff/Personnel per 1000 sewerage customers	(Staff*1000) / Total sewer connections	None	NA	NA

Appendix 2: Training Manual for Implementation of a WSS GIS Portal using open-source tools

This training manual is designed to help Geoportal administrators to implement the system using open-source tools.

2.1. DBMS : Spatial-enabled PostgreSQL

2.1.1. Install PostgreQSL

Prerequisites

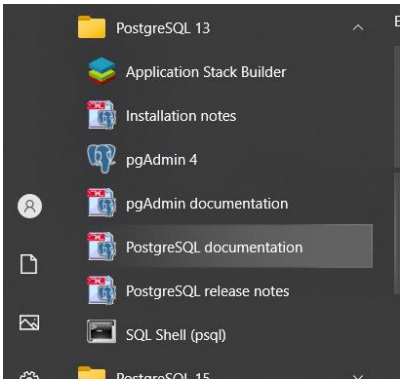
- A system running Windows 10
- Access to a user account with administrator privileges

▪ **Download PostgreSQL Installer**

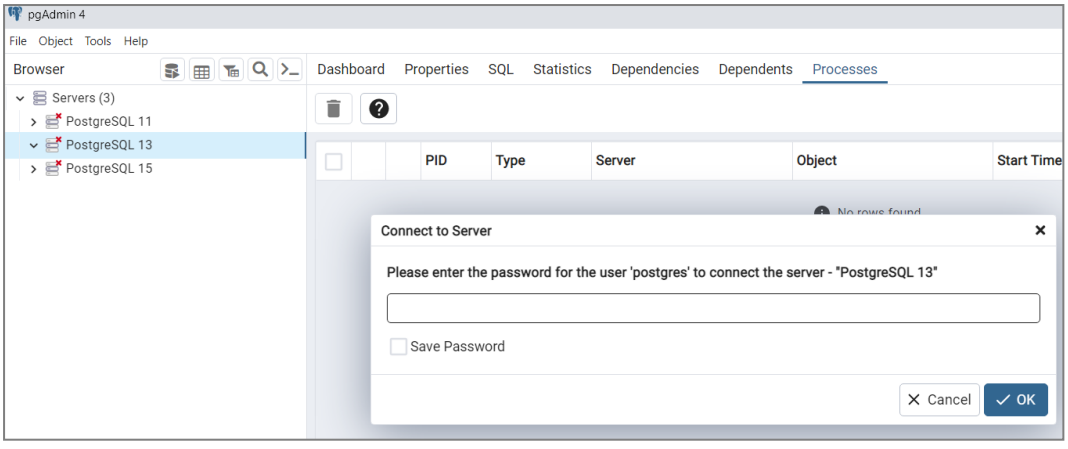
Before installing PostgreSQL, you need to download the installation file from the EDB website.

2.1.1. Create Database

Launch pgAdmin

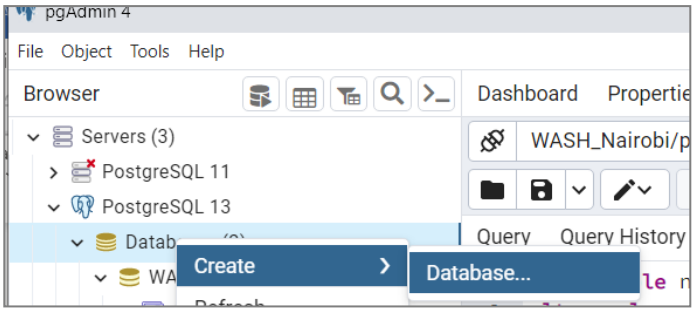


Login using the password you saved during installation, click on a server and provide your password for postgres.

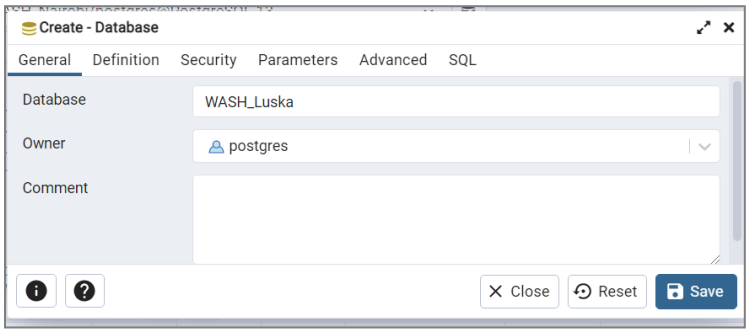


2.1.2. Create a database

To create a database in a connected server, right click on “Databases”

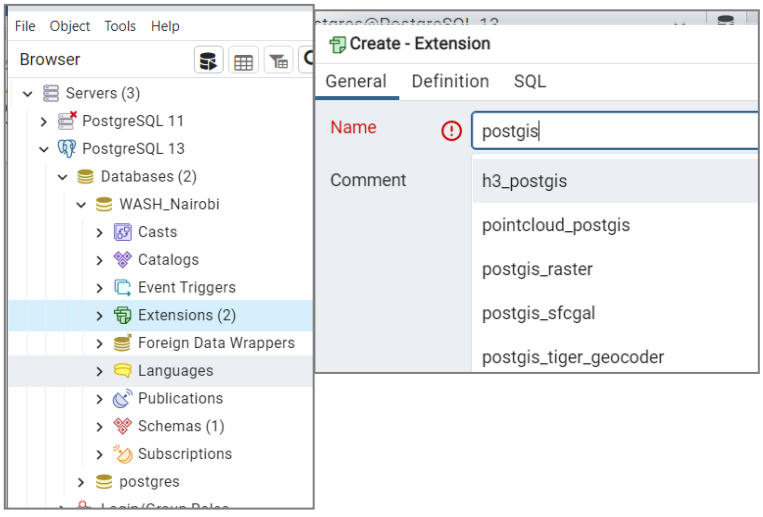


Then write the name of the database, and save



2.1.3. Creation of spatial extension for the created database

To create a spatial extension of the created database, right-click on Extensions, select the name of extension (or write postgis in the field like in the figure below, then click on create.



2.1.4. Importing geopackage into the created database

- With assumption that you have cleaned your data in QGIS and that your data have been packaged in one geopackage file, the easy and straightforward way to import a geopackage into PosgreSQL database “ogr2ogr” command line.
- ogr2ogr is a command line utility for converting data between GIS data formats, including common file formats and common spatial databases.
- Before running this command line make sure that gdal libraries are installed and set its bin path in system environment variables.
- GDAL is installed via OSGeo4W

Windows:

- Builds of ogr2ogr can be downloaded from GIS Internals.
- ogr2ogr is included as part of QGIS Install and accessible via OSGeo4W Shell -
- Builds of ogr2ogr can be downloaded from MS4W.

The user can check if the gdal libraries are installed by running this command line: gdalinfo --version

```
G:\Perso_hp\ESAWAS\data>gdalinfo --version
GDAL 3.6.3, released 2023/03/07
```

In windows explorer, you can search “gdal_translate.exe” to find all paths where gdal libraries are installed.

In order to import geopackage into PostgreSQL database, it is suggested to use this command (make sure you know the user name, password, database name and port number):

-Run cmd
-Activate your working directory where the geopackage is installed
-Run this command: ogr2ogr -f PosgreSQL PG:”user=yourUserName password=yourPassword dbname=YourDBName port=numberOfPort” nameOfGeopackage.gpkg

If the process is not successful, check if there is required missing parameter, or if you wrongly written the parameters

```
G:\Perso_hp\ESAWAS\data>ogr2ogr -f PostgreSQL "PG:user=postgres password=5691
dbname=WASH_Nairobi port=5434" WASH_Nairobi.gpkg -a_srs EPSG:4326

G:\Perso_hp\ESAWAS\data>
```

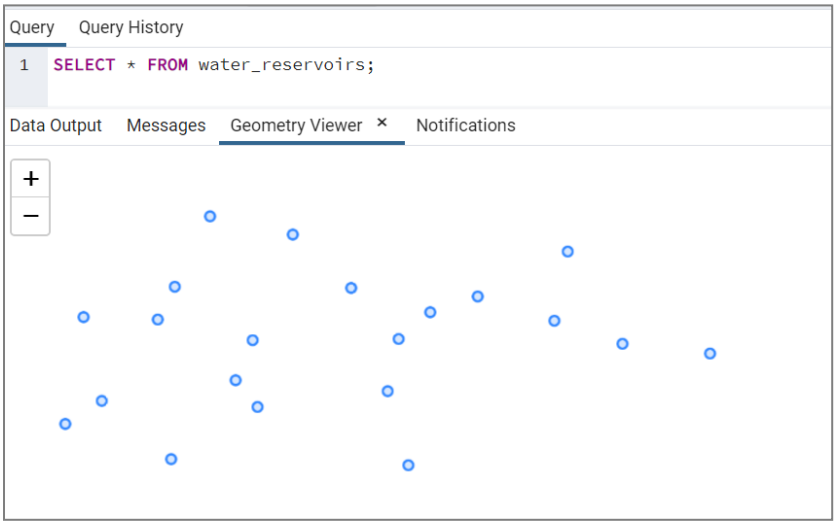
If the process is successful, you have the option to **visualize** the exported spatial data as tables by running the SQL query . Here there is an example: “SELECT * FROM table_name”

```
SELECT * FROM water_reservoirs;
```

Output | Messages | Notifications

fid [PK] integer	objectid bigint	resid_chlo double precision	chlor_stan double precision	bacteriolo double precision	compliance double precision	city character varying (30)	geom geometry
1	1	99.3782150927	88.7954944931	84.3796220214	97.6628688285	Nairobi	0101000020E61000005002
2	2	96.669	94.1542790346	82.3639455782	99.1327689449	Nairobi	0101000020E6100000F012
3	3	93.7962962963	89.4373149062	100	100	Nairobi	0101000020E610000098
4	4	96.875	96.9892473118	98.3333333333	97.5786924939	Nairobi	0101000020E6100000B0A
5	5	100	100	100	100	Nairobi	0101000020E610000010B
6	6	100	100	100	100	Nairobi	0101000020E6100000181
7	7	99.4550408719	100	80.174291939	99.7282608696	Nairobi	0101000020E6100000D85
8	8	100	100	100	100	Nairobi	0101000020E610000040

-It is also possible to visualize data as map, by clicking the icon in the geom field



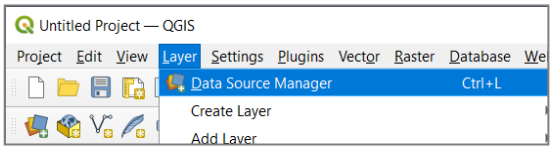
2.2. QGIS Desktop: Connecting to PostgrSQL

Prerequisites:

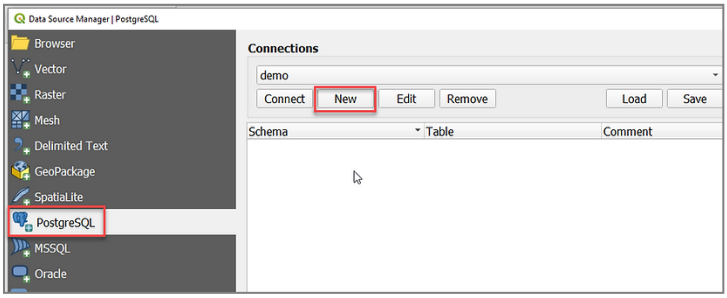
- Installed QGIS (Check this link to download and install the Long Term Release of QGIS installer: https://www.qgis.org/en/site/forusers/alldownloads.html#)
- Installed PosgreSQL with PostGIS Extension

2.2.1. Launch QGIS desktop

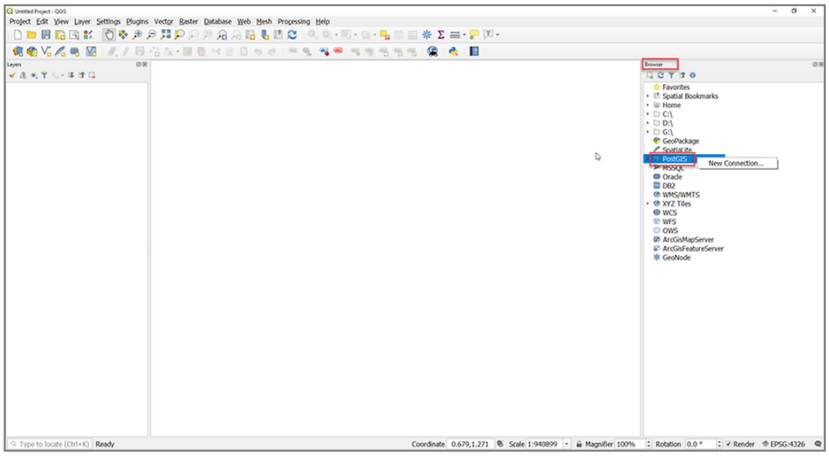
There is a couple of different places in QGIS where you can create a PostGIS connection. One is through the **Data Source Manager** which you can access through the toolbar:



Then click on PostgreSQL/New and write the name of the connection



Another is through the **Browser** which you can dock on the left or right side of QGIS:



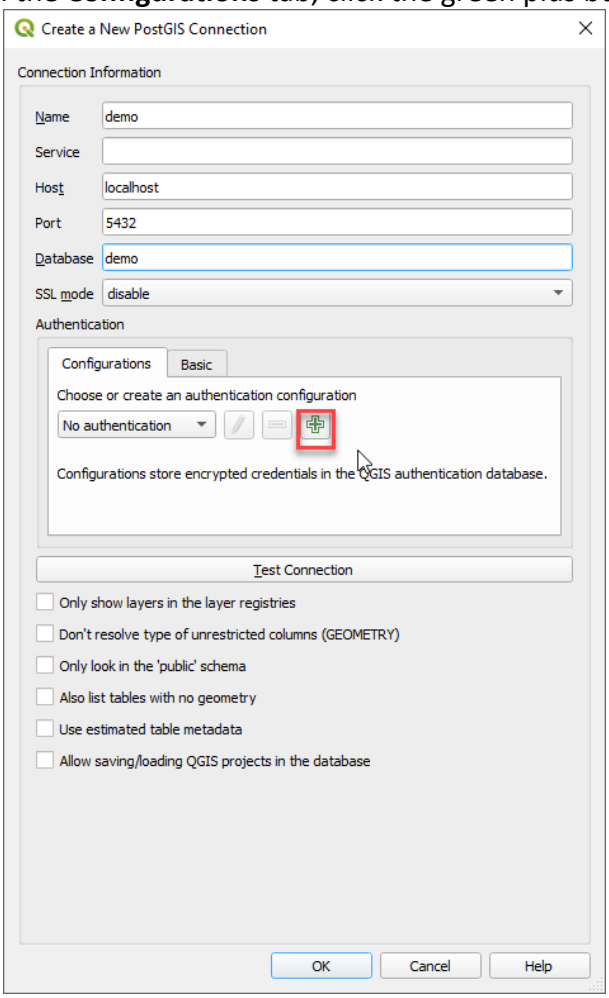
- In the **Browser**, right click on PostGIS and click *New Connection*

- Fill in the **Name**, **Host**, **Port**, and **Database**. The **Name** is the name of the connection so that it is possible to find it again later. You can call it whatever you'd like. I usually use

the name of the database. If you are working off your local machine, the **Host** will be *localhost*. The default **Port** for PostgreSQL is *5432*.

- There are two different types of authentication in QGIS: Basic and Configuration. You can type your PostgreSQL username and password (that you created during installation) into the Basic tab, and this will connect you to PostgreSQL. However, this will store your credentials as plain text in the QGIS project file. This means that anyone could open the QGIS project file in a text editor like Notepad and see your password. That is why it is recommended that you use an authentication configuration instead.

- On the **Configurations** tab, click the green plus button.

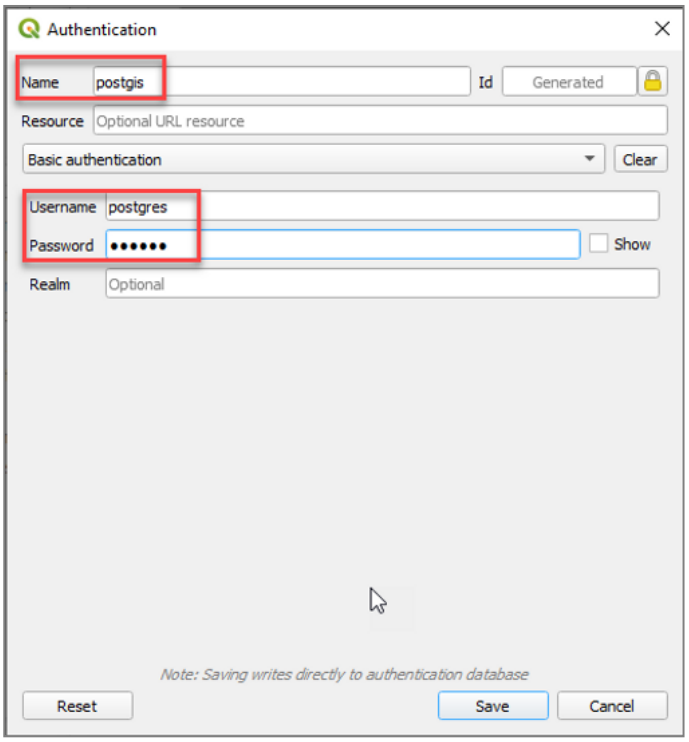


- If the user does not have a master password, he/she will be prompted to create one. It is necessary to enter this master password any time the user tries to access encrypted data (e.g. adding an authentication configuration).
- Once the master password is entered, by default it is cached until the user quits the QGIS, and he/she will not be prompted for it again during the ongoing session.

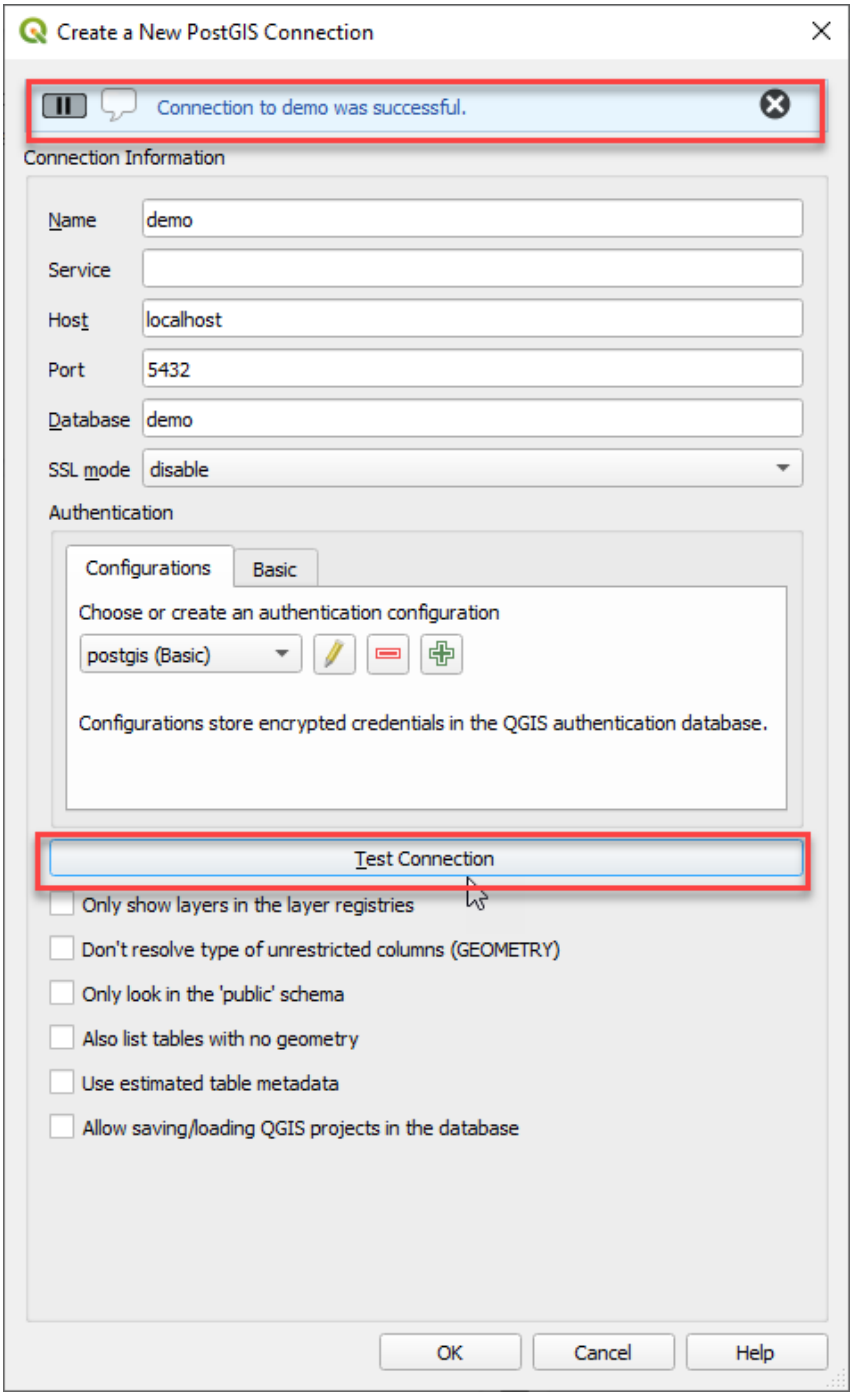
- NOTE: Make sure to remember this master password as it is not retrievable. If you forget it, you'll have to erase the entire authentication database in order to create a new master password.

- Once the created a master password is created, the user will be prompted to create the authentication configuration for PostgreSQL. This will be done by filling in the **Name** (again this can be anything he/she would like) and the **Username**/**Password** for PostgreSQL and click **Save**.

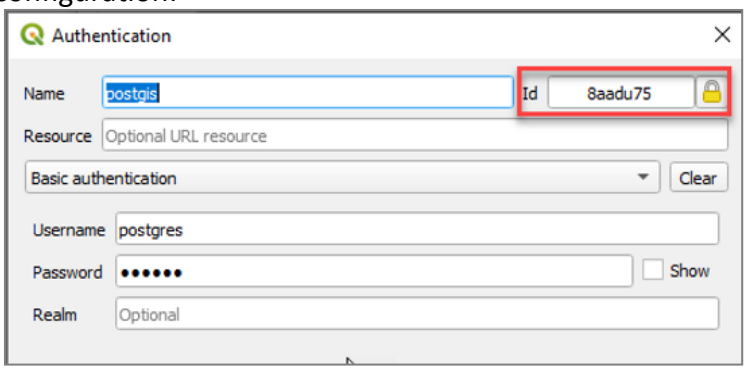
- One done, the connection can be tested:



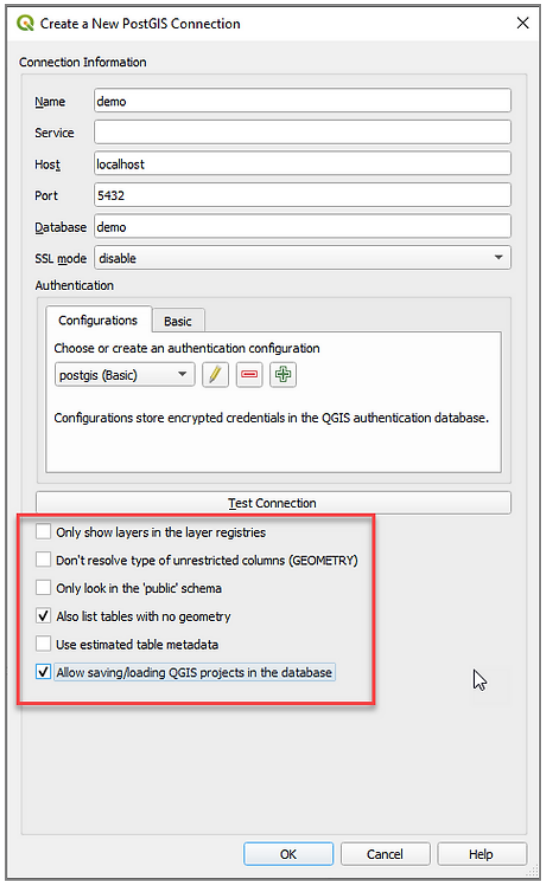
The test outcome is shown below:



- If you click the pencil button on the **Configuration** tab, you'll see that QGIS created an **Id** for the configuration:



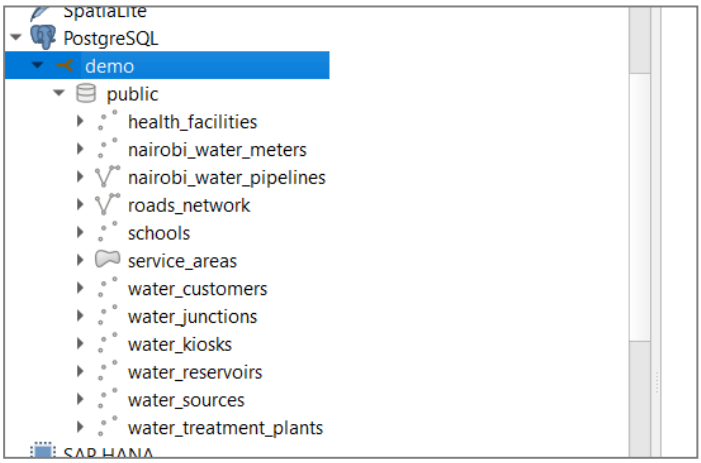
- You can leave this as is if you're working locally on your own database. However, if you are using PostGIS in an enterprise environment and multiple people are accessing the same database with QGIS, this ID field needs to be common throughout the organization.
- Before you create your PostGIS connection, check two boxes in the bottom part of the dialog: 'Also list tables with no geometry' and 'allow saving/loading QGIS projects in the database'. We'll get into these options later:

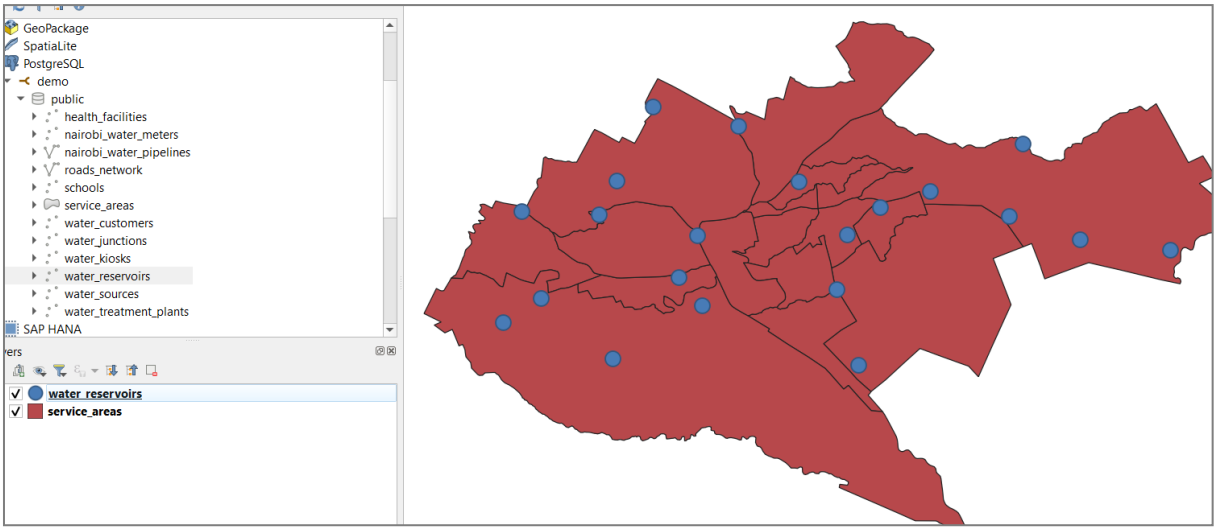


- Click **OK** to create the connection.
- Now you should be able to see your database in the **Browser** when you expand **PostGIS**.

2.2.2. Adding the PostgreSQL onto the Desktop

When you are connected to PostgreSQL database, you see all the tables in QGIS browser, from there the user can drag and drop any table/layer in QGIS desktop

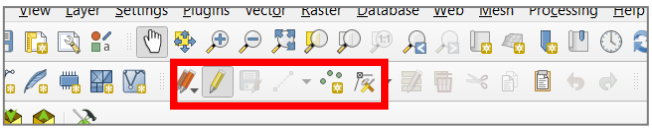




The user can now edit, add, or delete features in QGIS, and when he/she saves the changes they will be saved back to the PostgreSQL/PostGIS database.

- It is important to make sure that the desired layer in the **Layers** panel are selected.
- Then click the **Toggle Editing** button (the pencil icon).
- Use the available tools in the QGIS toolbar to make your desired changes. Below I've added a feature with the **Add Point Feature** button.
- When you click the **Save Layer Edits** button, your changes will be saved to the database.

- When you are done editing the layer, click the **Toggle Editing** button again to exit edit mode for the layer



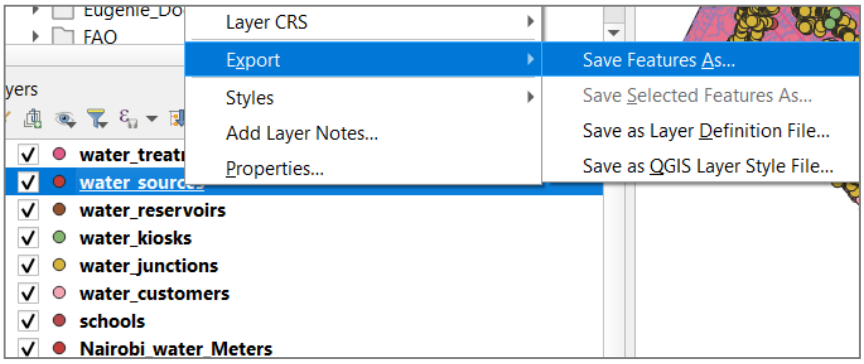
2.2.3. Using QField for data collection

It is easy to use the QField for QGIS app during the field data collection. The following processes are to be completed:

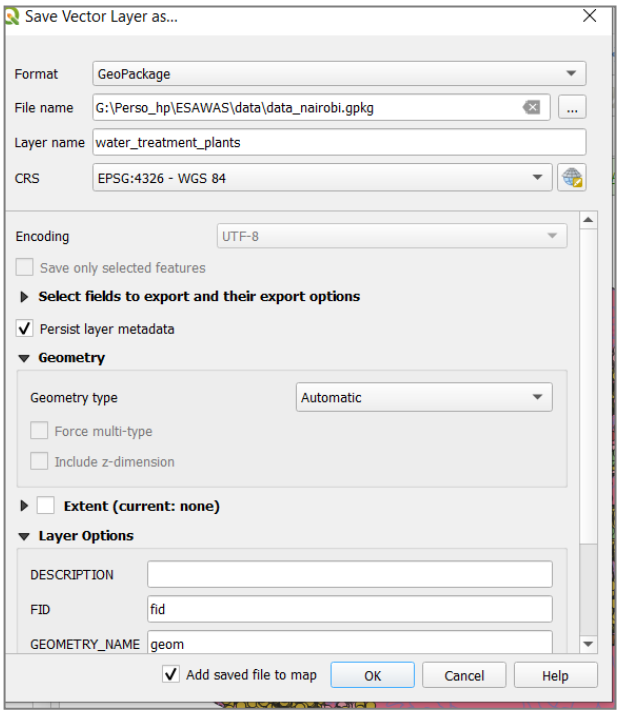
- On the mobile device, install the app
- Install the QField Sync (first time) in QGIS desktop
- Activate the Sync plugin
- Create geopackage with Package for QField

To create a Geopackage layer on QGIS

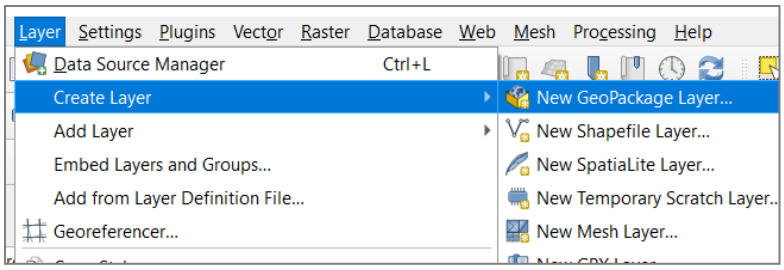
- Open QGIS
- Add all your layers you want to save in one package
- Right-click on the first layer
- Click on Export/Save feature As
- In a new window that displays, select the format as Geopackage, in the File Name, select the Geopackage name (if it is the first time, select a folder, and write the new Geopackage Name).
- Keep the layer name, or rename it as you wish
- Click OK



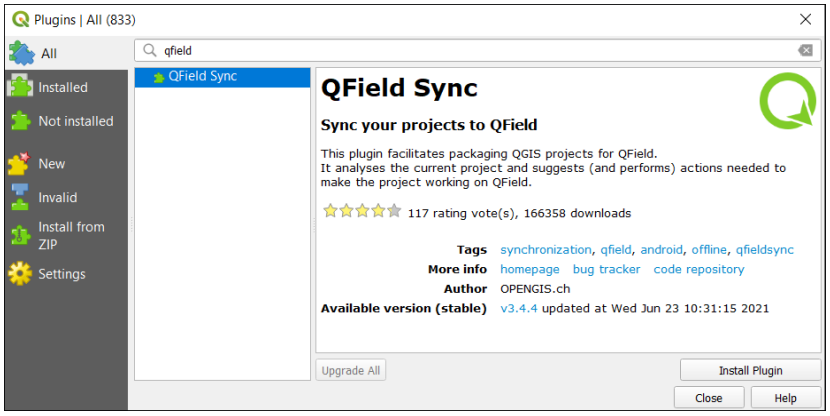
You can save it as follows:



Another option for creating a geopackage: Layer menu/Create Layer/ New Geopackage layer.



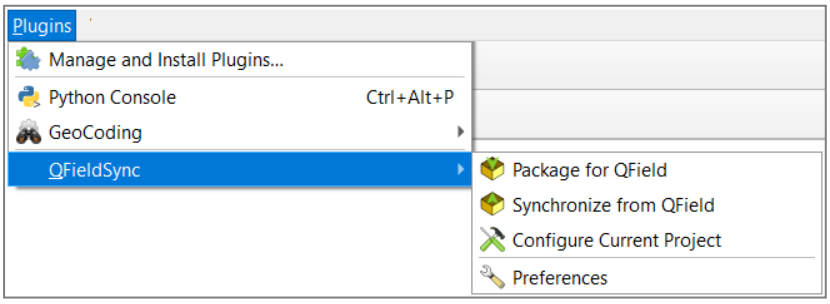
Another alternative is to use QField Sync: add layers to QGIS desktop, install the QField sync plugin (if not yet installed)

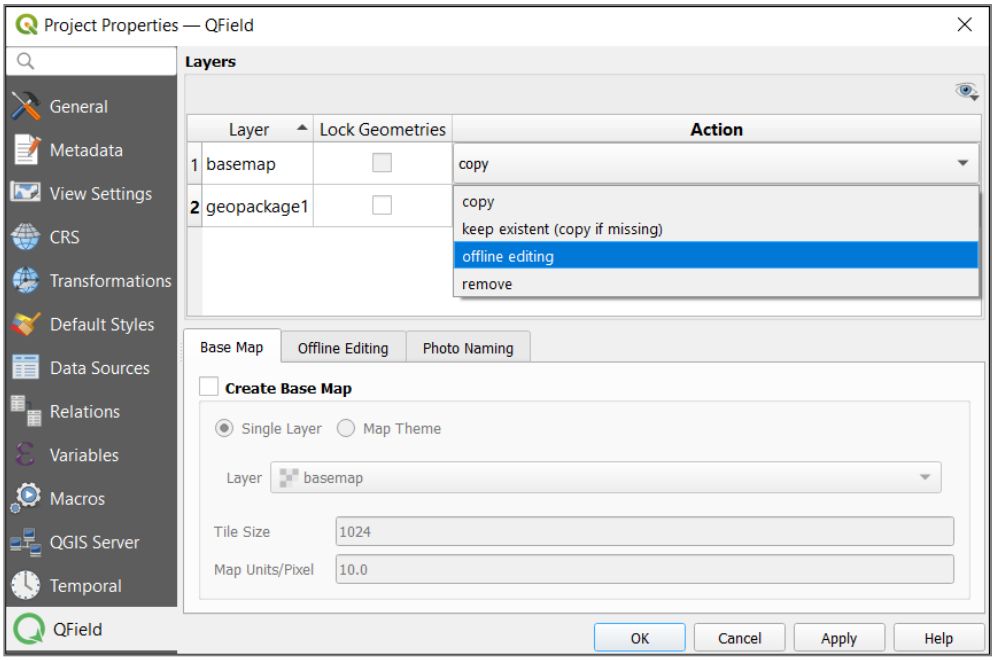


Add any layers that you want to be a part of your field campaign.

Start to configure and set up your QGIS project. All the configurations will save to your current QGIS project.

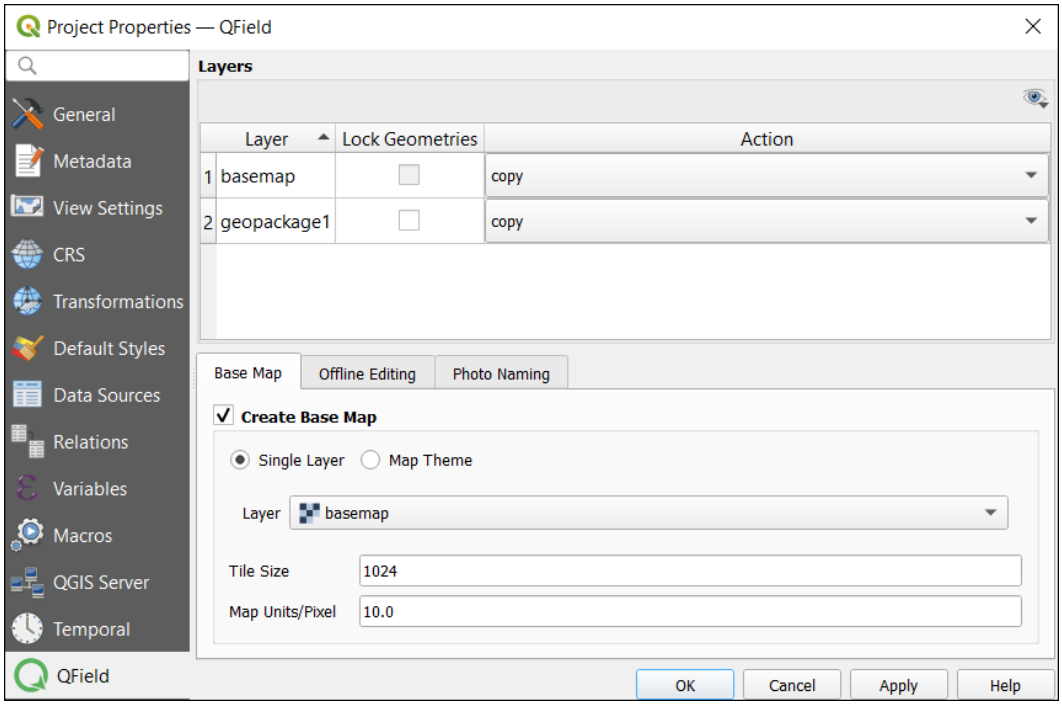
Plugins > QField Sync > Configure Current Project





The basemap serves as the underlying layer for your fieldwork. You can set it to your area of interest. There are two options for selecting the basemap.

Layer – This is a great option to generate an offline map of a WMS or raster layer like an ECW.
Map theme – A combination of several layers which can be used as a basemap for fieldwork.

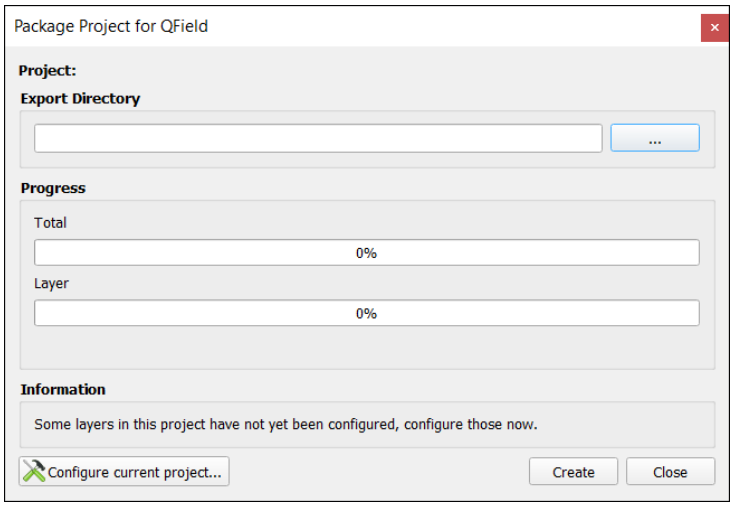


Creating a QField package

QField syncs with your QGIS project so you can take it out to the field. But before you can take your QGIS project to the field, you have to create a QField package.

In order to package your QGS file, you have to ensure that you've completed all the necessary configurations from above. Afterward, you can package it with the QGS file and associated data

Plugins > QField Sync > Package for QField



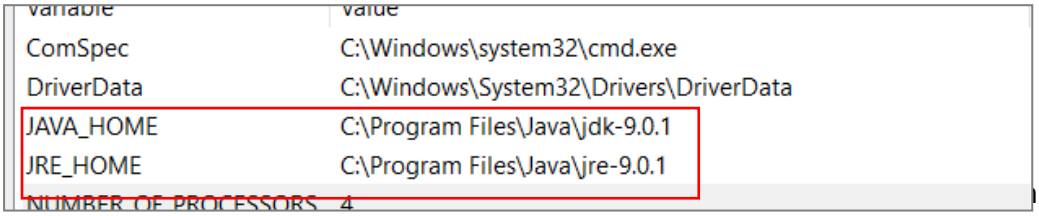
- Start the field work by launching the QField in your smartphone and opening the saved package.
- Sync edited with Database through QField Sync/Synchronize from QField

2.3. Geoserver and Mapstore

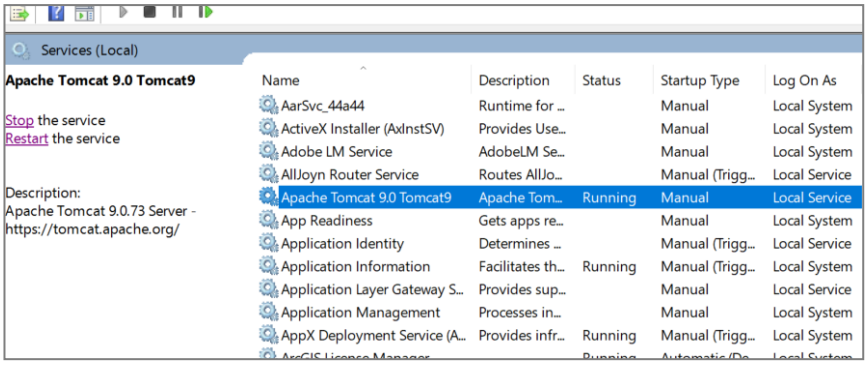
2.3.1. Installing Geoserver and mapstore

The following prerequisites are required for installing the Geoserver and mapstore:

-Apache Tomcat 9.0 running at your preferred port.
-Installed JDK
-Set system environment variables of JAVA_HOME and JRE_HOME

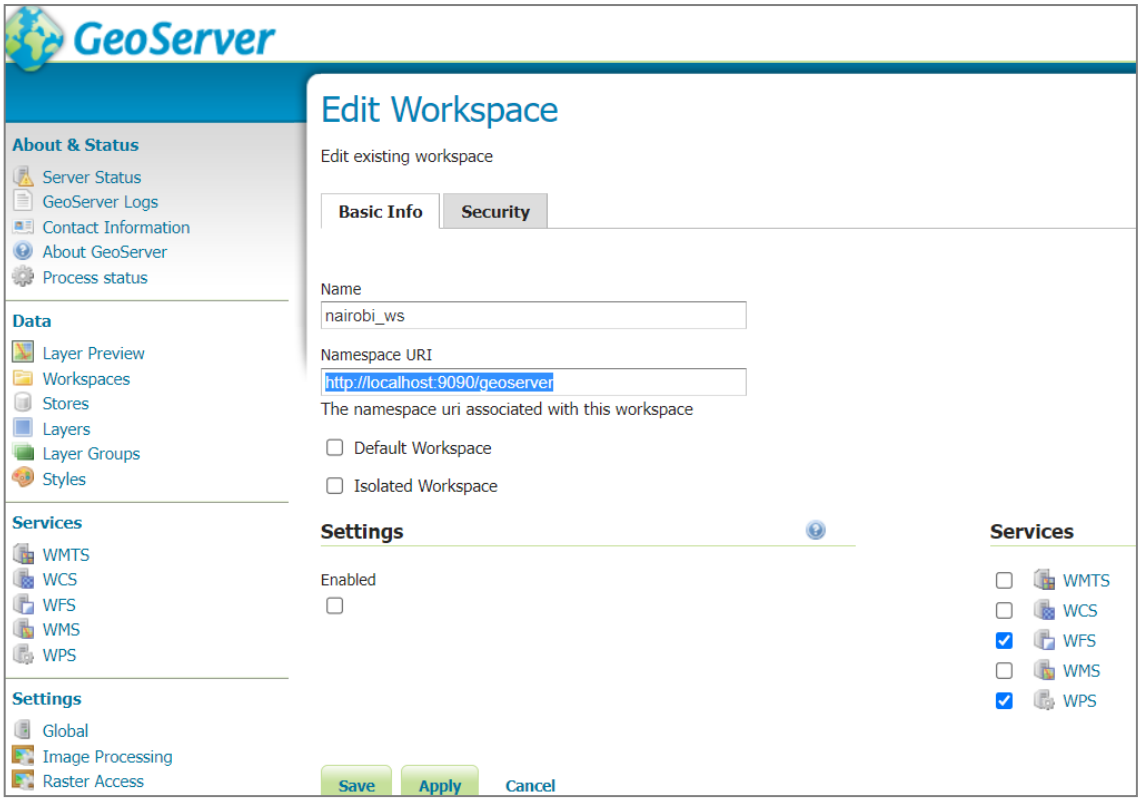


-(https://docs.geoserver.org/latest/en/user/installation/war.html) and mapstore.war (https://github.com/geosolutions-it/MapStore2/releases)
-Copy the geoserver.war and mapstore.war files in the web server, such as the Apache Tomcat/webbapp/
-Start the Apache service
-Check if Apache is running. Control Panel/Admin tools/Services. If not start the service/Start.



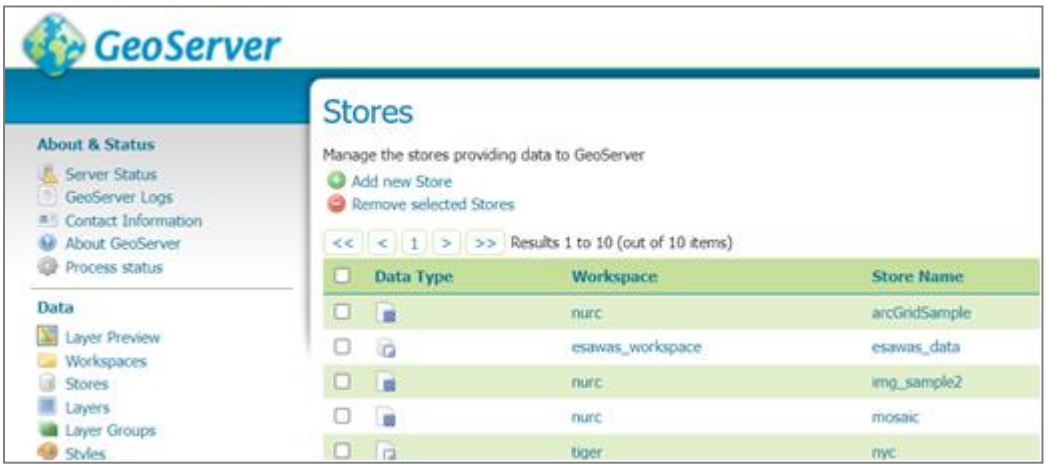
2.3.2. Creating workspace in Geoserver

Proceed as follows for creating the Geoserver:

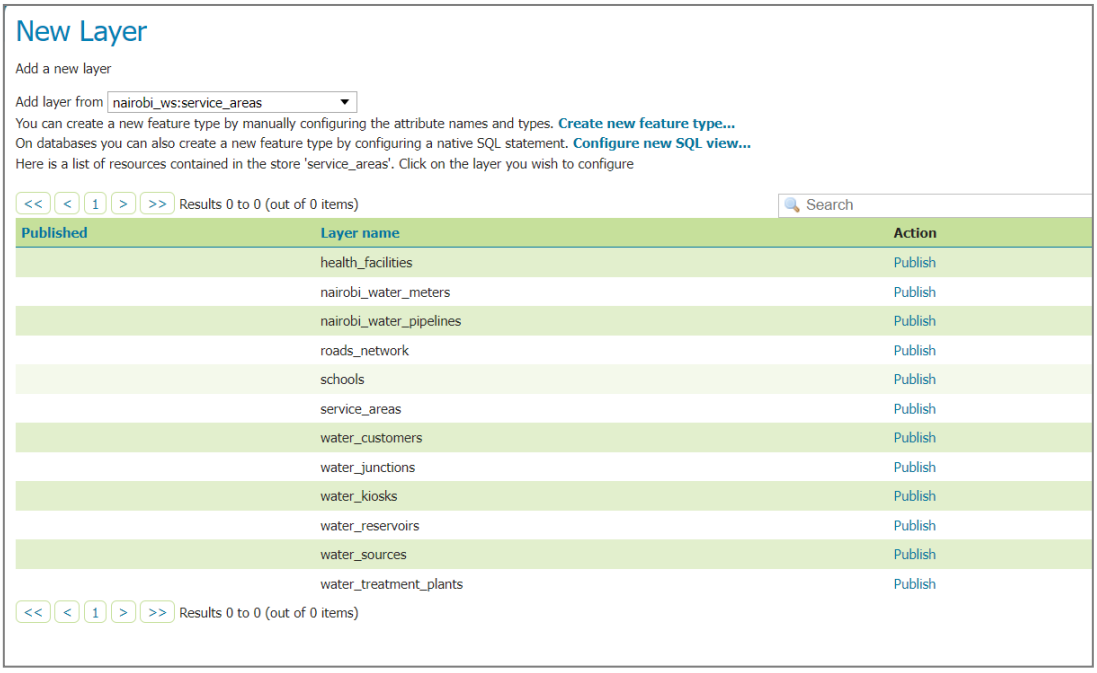


2.3.3. Creating Stores

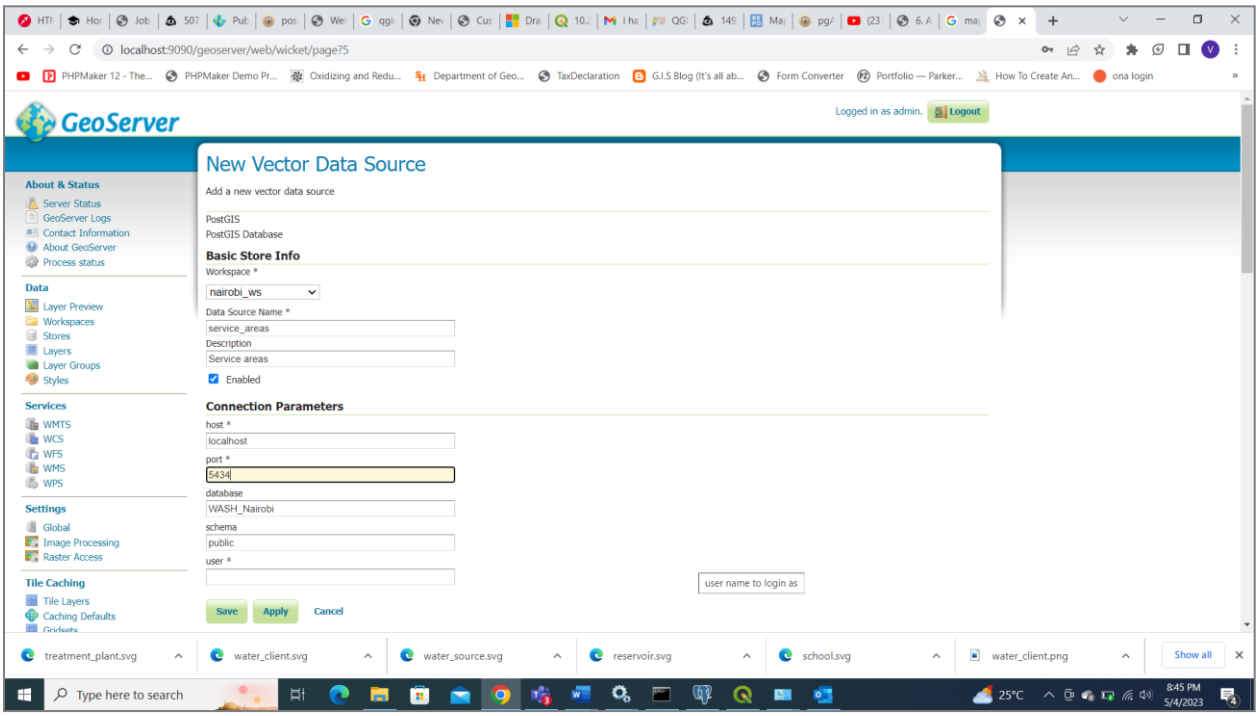
Select the data source: postgis



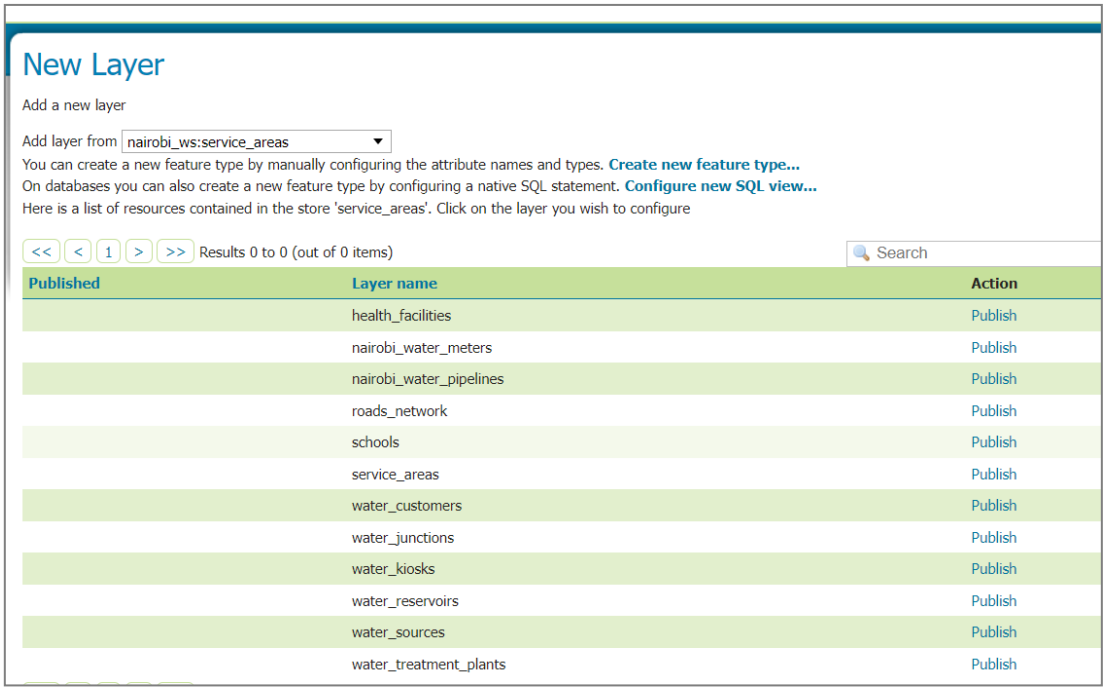
To publish the layer, click Layers/Add layer, select the store and workspace



Fill in all the required details:

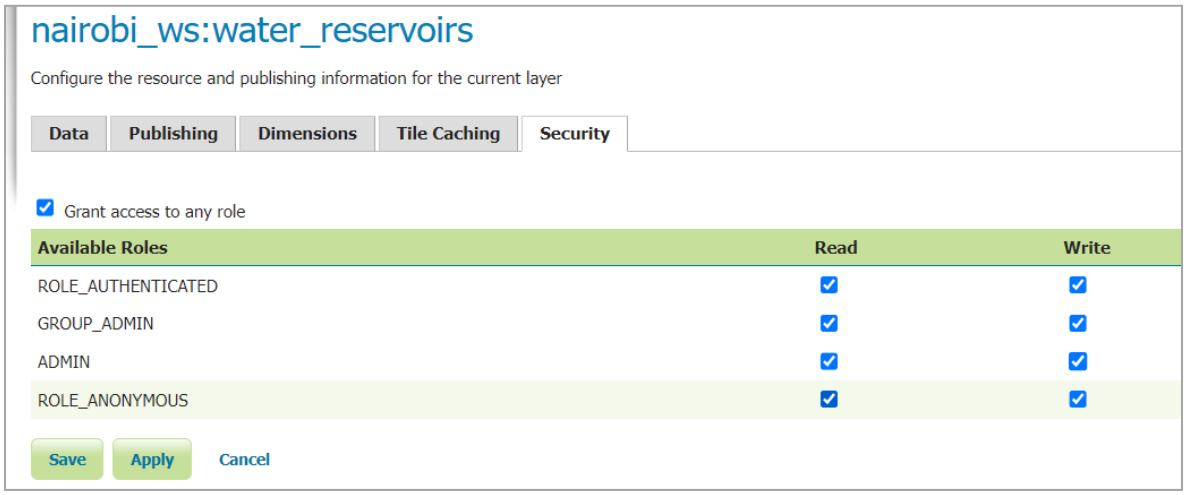


To publish layer, click layers/Add layers, Select the store, then in the list that displays, click publish to publish the layer. Complete required information in each tab: Data, Publishing, Dimensions, Tile caching and security. In this last tab, you may chose



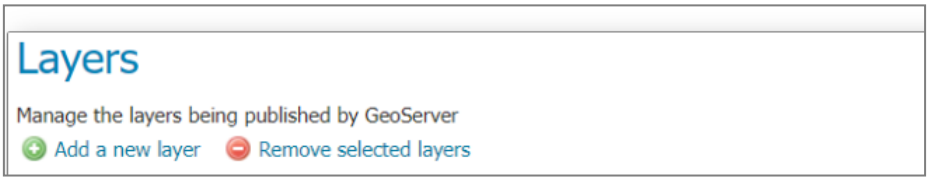
In the publishing tab: set the web services of the layer

In the Security tab, set the accessibility of the layer



2.3.4. Adding Layers to store

Click on Add new layer, and select a store in which this will be added in.

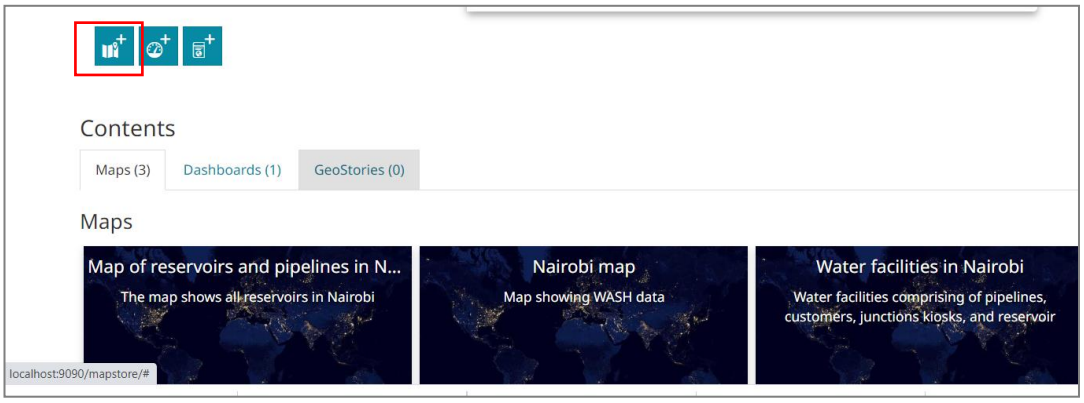


For more details, read the online manual: https://docs.geoserver.org/stable/en/user/

2.3.5. Creating a web map in Mapstore

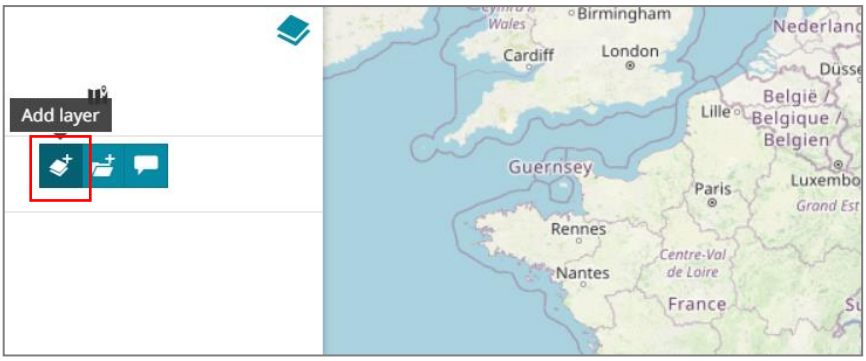
Log in as admin or publisher

Click on the icon New Map

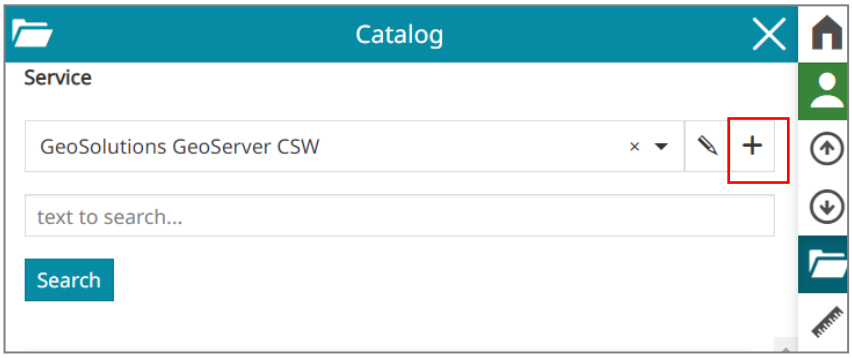


Click the layer icon on the map

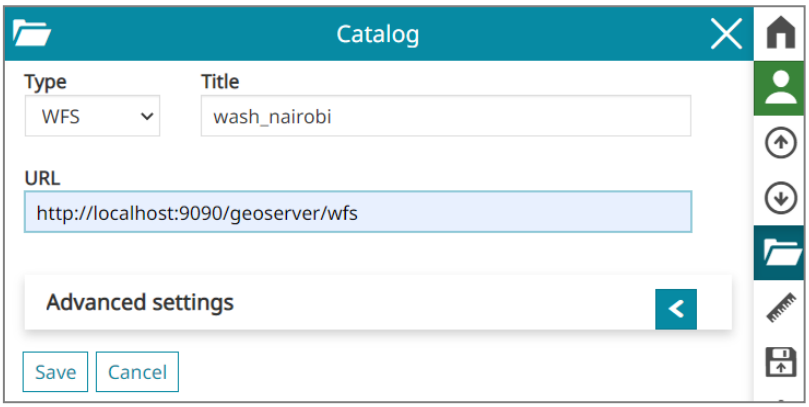
Click on add layer icon



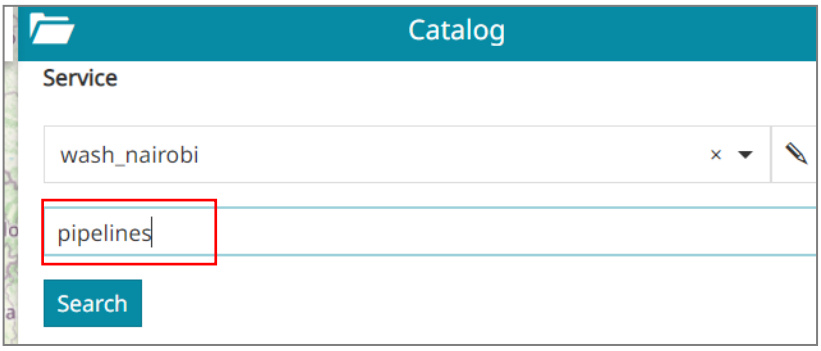
In the Catalog, click the + icon



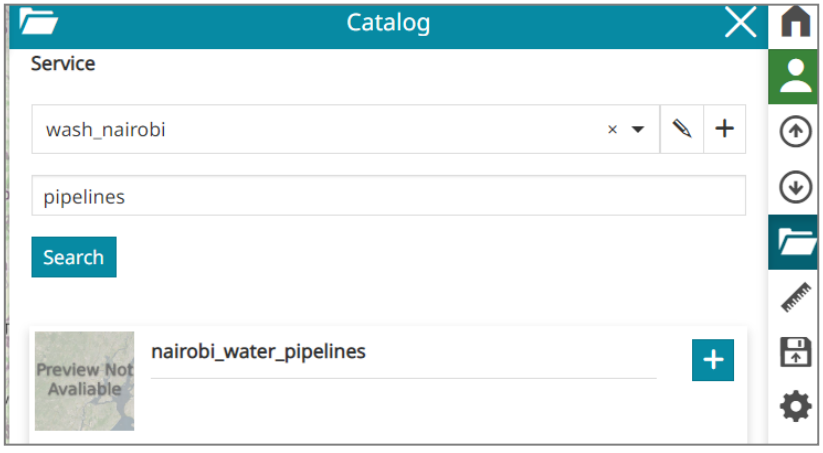
Write the new catalog name, and url and select the web service, then click on save



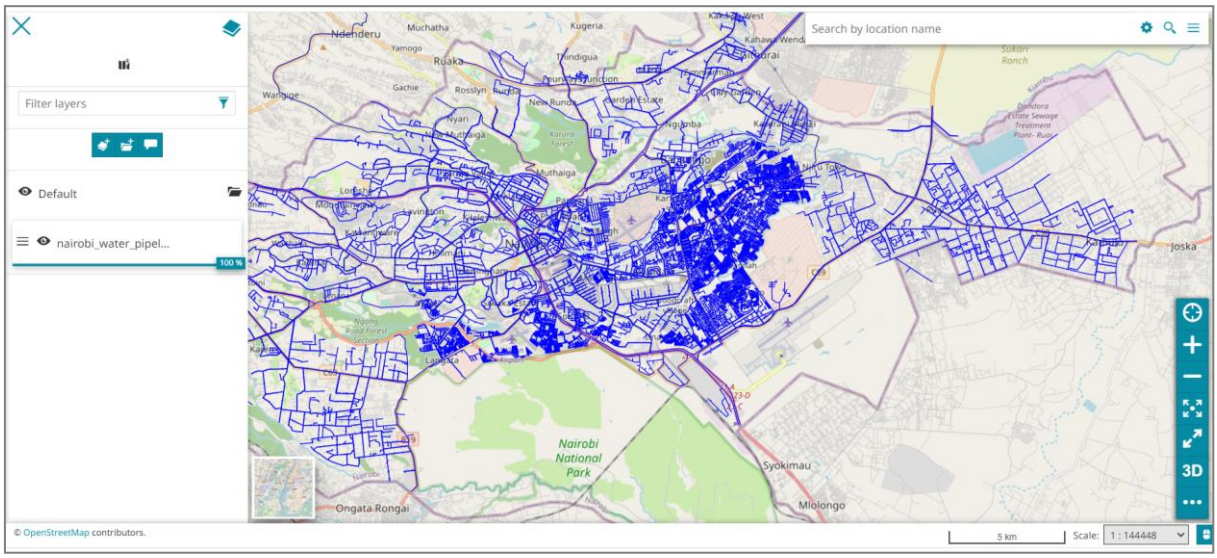
In the search write a word to search web services



The list of selected web services is displayed. Click on the + button to add to the map.

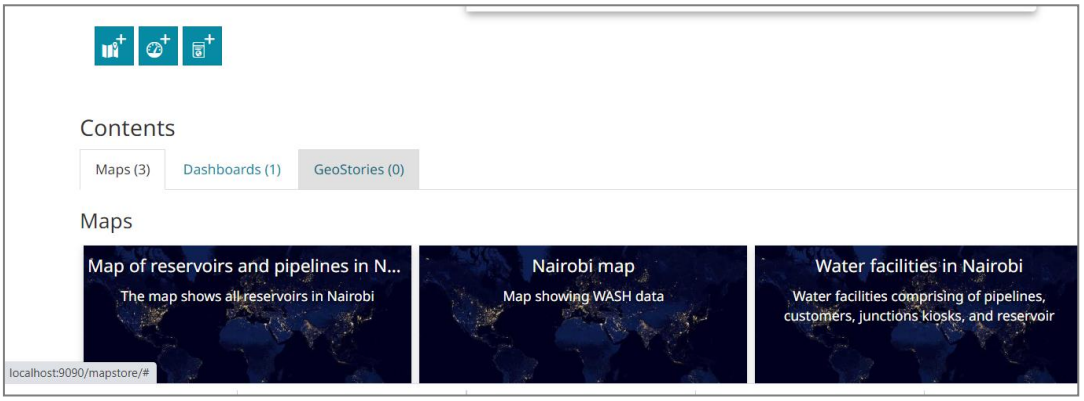


The layer is added to the map



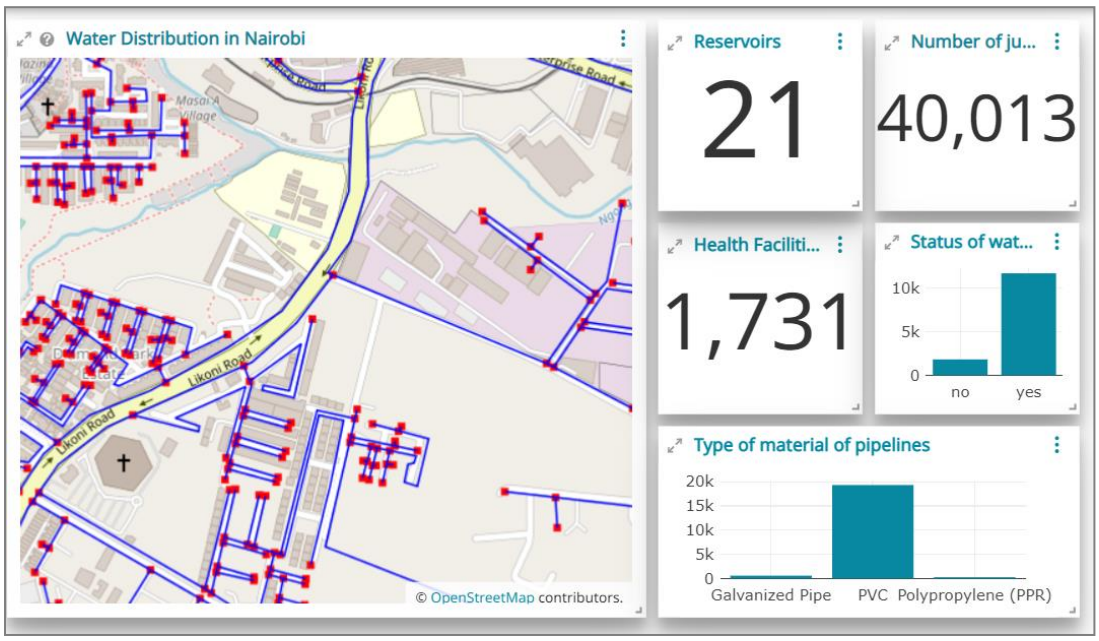
2.3.6. Creating Dashboard

Click on the icon New Dashboard



An empty dashboard is displayed. The user can click add widget to add your desired widget such as map, counter, text, chart and table.

You can add the created map and other published web services. For the widgets, there it is possible to add any desired web services. For the counter and chart widgets you will have to add WFS or WPS layers to get a dashboard like this below.



Appendix 3: GIS survey questionnaire at LUSAKA Water

- What property ownership documents does the owner have? (Don't Know)
- Is this property connected to Eastern water and sewerage network?
- What is your Water and Sanitation Customer (WSC) account number?
- What is your WSC account number? (Comments)
- Is your property metered?
- What type of meter do you have?
- Take a photo of the Meter Number
- Observe and indicate meter number
- Observe and indicate meter number (Comments)
- Is your meter functional?
- What kind of toilet facility do members of your household usually use?
- Do you share this facility with others who are not members of your household (Family)?
- How many households (Families) in total use this toilet facility including your own household?
- What is the total number of males in your household that access the toilet facility?
- What is the total number of females in your household that access the toilet facility?
- What is the total number of toilet facilities on this property?(If shared, enter all figures for shared numbers only on one of the shared properties)
- Where are the toilet facilities located?
- Has your pit latrine/Septic tank ever been full?
- What was done when your pit/septic tank was full?
- The last time your pit latrine/ septic tank was emptied, who emptied it?
- When was your pit latrine/ septic tank last emptied? (Give the approximate number of months ago)
- Assess access to the toilet facility (Access for Emptying)
- On average, how often does your pit latrine/septic tank get emptied?
- What was done with the material extracted from the pit/septic tank?
- What was done with the material extracted from the pit/septic tank? (Other (please specify)) - specify
- On average, how much do you pay for sanitation facility emptying services? (magnitude)
- On average, how much do you pay for sanitation facility emptying services? (units)
- Type of containment
- Type of containment (Other (please specify)) - specify
- Geometry of containment (Shape)
- Radius of containment
- Depth of containment
- Width of containment
- Length of containment
- Dimension measuring methodFill level of sludge
- Method used for measuring level of sludge
- What is the condition of the toilet?

- Do you have any plans to repair or rehabilitate your toilet facility?
- Do you have any plans to repair or rehabilitate your toilet facility? (Don't Know)
- Do you have any plans to construct a new toilet?
- Do you have any plans to construct a new toilet? (Don't Know)
- Are you willing to finance such toilet facilities improvements or new construction works?
- Are you willing to finance such toilet facilities improvements or new construction works? (Don't Know)
- Do you think you can raise enough money to finance such toilet improvements or new construction works?
- What is the source of your drinking Water?
- What is the source of your drinking Water? (Other (please specify)) - specify
- What is the location of water facility or drinking water source?
- Do you share any water facility located in this property with others who are not members of your household (Family)?
- What is the number of males in your household that access water from this drinking water source?
- What is the number of females in your household that access water from this drinking water source?
- How many households in total use this water facility, including your household?
- Is the drinking water facility functioning well?
- What is the average time taken to collect drinking water?
- On average, how many hours in a day is water available?
- Is there a hand wash facility within the yard or premise?
- Does hand washing facility have water and soap?
- Is the soap at the hand washing facility liquid soap?
- Is there a provision of a sanitary bin?
- Are you comfortable to answer questions on Menstrual Hygiene?
- Does the bin have a lid and a liner?
- What means do you have for disposal of menstrual hygiene waste?
- What means do you have for disposal of menstrual hygiene waste? (Other (please specify)) - specify
- Is there a place for cleaning and changing for women during menstruations?
- What menstrual hygiene products do women use in this household?
- What menstrual hygiene products do women use in this household? (Other (please specify)) - specify
- What menstrual hygiene products do women use in this household? (Don't Know)
- Is the head of this household in formal or informal income ?
- What are the average monthly income for this household ?
- What are the average monthly income for this household ? (Other (please specify)) - specify
- State any other observations (Suspected Illegal water or sewer connection, reconnection or connection from Water Utility requested, major customer complaint etc.)

Appendix 4: NIS list of Indicators

- Non-Revenue Water
- Safely Water Service Coverage - Safely service
- Water Service Coverage - basic service
- Water Service Coverage - Limited service
- Metering Ratio
- Total Sanitation Coverage - Safely managed sanitation service
- Total Sanitation Coverage - basic sanitation service
- Total Sanitation Coverage - limited sanitation service
- Water Quality Compliance - Chlorine Residual
- Water Quality Compliance - Bacteriological
- Water Quality Compliance - Physio-chemical
- Hours of Water Supply
- Unit Production Cost (Kwacha/m3)
- O+M Cost Coverage (%) by billing
- Full Cost Coverage (%) by Total Revenue
- Full Cost Coverage (%) by Total Revenue
- O+M Cost Covered by Water+Sewer Collection
- O+M Cost Covered by Total Collection
- Collection Efficiency
- Trade Receivables (Kwacha)
- Trade Payables (Kwacha)
- Operational Cost (Kwacha)
- Personnel Cost (Kwacha)
- Cost of Chemicals (Kwacha)
- Cost of Energy (Kwacha)
- Administration Cost (Kwacha)
- Maintenance Cost (Kwacha)