LOTUS

LOW-COST INNOVATIVE TECHNOLOGY FOR WATER QUALITY MONITORING
AND WATER RESOURCES MANAGEMENT FOR URBAN AND RURAL WATER SYSTEMS IN INDIA

Deliverable D 3.1

Report on historical time series data, chemical species and operational targets for all cases

Lead: University of Thessaly

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Abstract

In LOTUS, time series data are needed for the modelling of water systems. Even though historical data collection is the first choice, in the absence of historical time series, alternative approaches are used, such as establishing baselines from the literature, using data from published data sets, or from relevant stakeholders, in order to complete the needed case study area. In this document, a collection of this data for the case studies is presented. Equal focus will be placed on water quality and quantity; for the former, a definition of relevant chemical and (micro)biological species to be monitored within the case studies will be defined based on water source and corresponding water use. This is a live document that will be constantly updated and enriched with new input, as more data become available from the case studies and the relevant stakeholders.

Keywords

Historical time series, Modelling of Water Systems, Water quantity, Water quality, Water Distribution Network, groundwater, river water, tanker-based water distribution

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The LOTUS Project

LOTUS is a project funded by DG Environment under the European Union Horizon 2020 Research and Innovation Programme and by the Indian Government. It brings together EU and prominent Indian organisations with the aim to co-create, co-design and co-develop innovative, robust, affordable low-cost sensing solutions for enhancing India's water and sanitation challenges in both rural and urban area.

The LOTUS solution is based on an innovative sensor and includes tailor-made decision support to exploit the capabilities of the sensor as well as a specific approach to co-creation. LOTUS aims to be co-designed and co-produced in India, and have a wide, diverse and lasting impact for the water sector in India due to intense collaborations with commercial and academic partners in India.

Based on the low-cost sensor platform, solutions for the early detection of water quality problems, decision support for countermeasures and optimal management of drinking and irrigation water systems, tailored on the functionalities of the new sensor, will be developed and integrated with the existing monitoring and control systems.

This sensor will be deployed in five different use cases: in a water-network, on groundwater, in irrigation, in an algae-based wastewater treatment plant and water tankers. The packaging of the sensor, as well as the online and offline software tools, will be tailored for each of the use cases. These last will enable us to test the sensors and improve them iteratively.

The project is based on co-creation, co-design and co-production between the different partners. Therefore, an important stakeholder engagement process will be implemented during the project lifetime and involve relevant stakeholders, including local authorities, water users and social communities, and will consider possible gender differences in the use and need of water. Broad outreach activities will take place both in India and in Europe, therefore contributing to LOTUS impact maximization.

The further development and exploitation (beyond the project) of the novel sensor platform will be done in cooperation with the Indian partners. This will create a level playing field for European and Indian industries and SMEs working in the water quality area.

Table of Contents

List of Figures

List of Tables

LOTUS is co-funded by the European Commission under the Horizon 2020 research and innovation programme under Grant Agreement N° 820881 and by the Indian Government, Ministry of Science and Technology.

Acronyms and Definitions

Acronyms	Defined as
WD	Water Distribution Network
IWS	Intermittent water supply
GMS	Groundwater modelling system
MODFLOW	Modular finite-difference flow model
MT3DMS	Modular three-dimensional transport model

1 Executive Summary

In LOTUS, time series data are needed for the modelling of water systems. Even though historical data collection is the first choice, in the absence of historical time series, alternative approaches are used, such as establishing baselines from the literature, using data from published data sets, or from relevant stakeholders, in order to complete the needed case study area. In this document, a collection of this data for the case studies is presented. Equal focus will be placed on water quality and quantity; for the former, a definition of relevant chemical and (micro)biological species to be monitored within the case studies will be defined based on water source and corresponding water use.

Relevant datasets that define the type of data that need to be collected are presented in three use cases namely,

- Use case 1: Water Distribution Network Guwahati
- Use case 2: Tanker based water distribution network
- Use case 4: Groundwater and river water monitoring

In addition, the purpose of this document is to define the sources of data, the gaps in data and the difficulties in collecting them by each case study. It also presents data structures and platforms that are used to store data, especially when the sets are large, and the data need to be easily retrievable in order to be used by models and algorithms.

This is a live document that will be constantly updated and enriched with new input, as more data become available from the case studies and the relevant stakeholders.

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2 Use case 1: Water Distribution Network Guwahati

2.1 Scope of the use case

The water distribution network of Guwahati city resembles other WDNs laid in various cities in India. This facilitates the application of the current use case study to multiple cities across India. The current WDN is located in the west zone of Guwahati (south). The total length of pipes laid is about 450 km spanning over an area of 100.95 sq.km. The water supply area is split into 13 DMAs, and 4 of these DMAs (33km pipe length) will be considered for the LOTUS sensor analysis. Out of the four DMAs, it was decided that the most suitable case study area to be considered for extended water supply demonstration in LOTUS project is DMA 1. A schematic of DMA 1 of the Guwahati water distribution network with sensor location is shown in Figure 1.

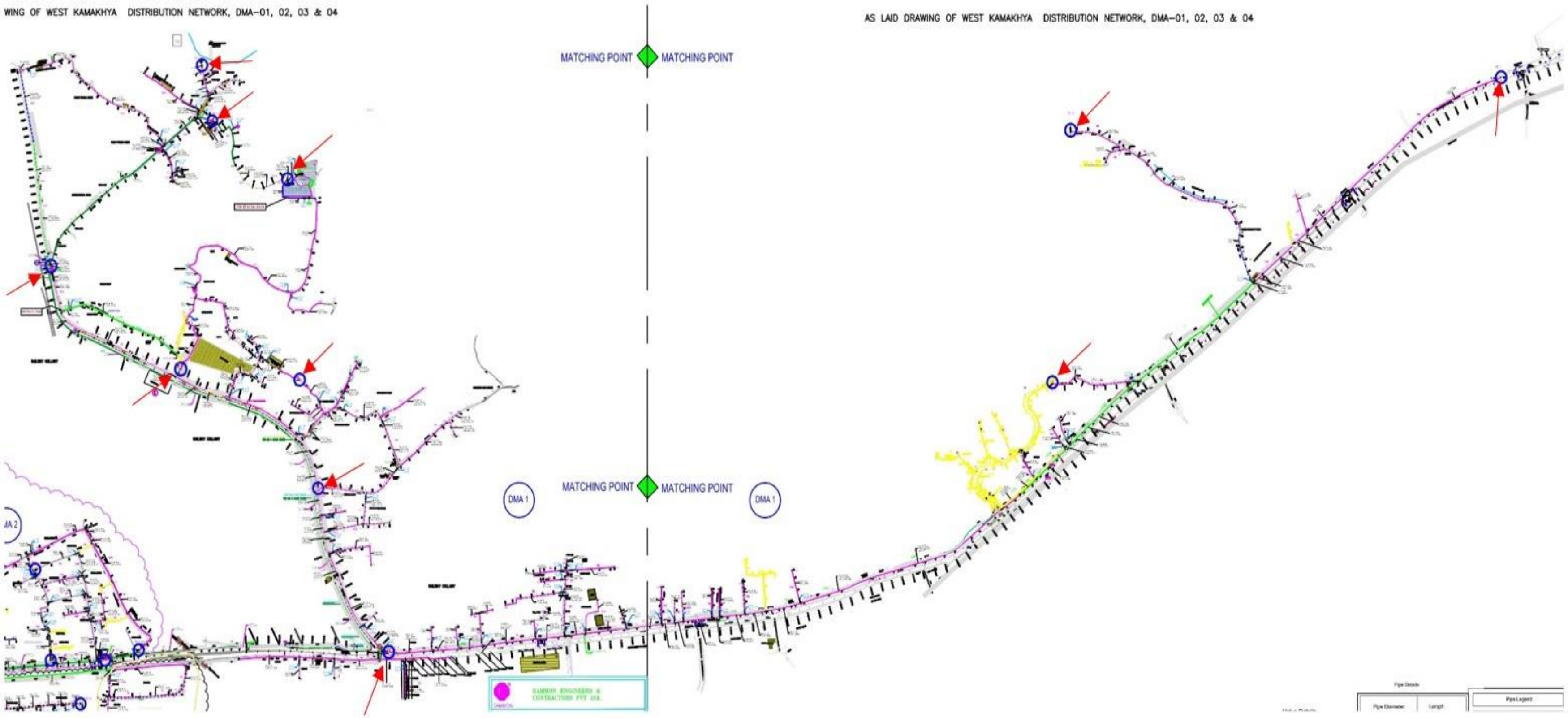

Figure 1 DMA-1 of Guwahati water distribution network—sensor locations are identified.

2.2 Description of Relevant Data

To assess the existing efficiency of the water distribution network and make improvements it is necessary to understand the current operational situation. The concept of the Water Balance has been developed by the International Water Association (IWA) Water Loss Specialist Group and provides a holistic picture of a water supply network management as it quantifies and categorizes water coming into the network, water used and water exiting the network.

To carry out the water balance calculation, collection of various data is required. The water balance are normally carried out on an annual basis, however shorter time frames can be used depending on the frequency of customer meter readings. These readings could be monthly, bimonthly, quarterly or every four months depending on the policy and practice of each utility. In this Use Case the time interval for meter readings and other parameters needed will be monthly. Appendix 1 presents a template that can be used to collect the relevant data. A description of the data required is given in Table 1.

Table 1 Description of data required

Required Data	Unit	Description
System input volume	m^3	is the volume of treated water supplied to the network for which the water balance calculation is carried out
Billed authorized metered consumption	m^3	is all metered consumption that is billed and includes all groups of customers, such as domestic, commercial, industrial and institutional
Billed authorised unmetered consumption	m^3	is all billed consumption that is calculated based on estimates or norms but is not metered
Bulk water supply (water exported)	m^3	is the volume of water transferred across operational boundaries that is either metered or unmetered and billed
Unbilled authorized metered consumption	m^3	is metered consumption that is for any reason unbilled, e.g. metered consumption by the utility itself or water provided to institutions free of charge.
Unbilled authorized bulk water supply (export)	m^3	includes any water transferred across operational boundaries metered and unbilled. This type of consumption is rarely unmetered.
Unbilled authorized unmetered consumption	m^3	is any kind of authorized consumption that is neither billed nor metered and typically includes items such

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Required Data	Unit	Description
		as firefighting, flushing of mains and sewers, street cleaning, etc.
Domestic Illegal connections	no.	is defined as a connection to domestic premises which is not formal and is not included in the utility's billing register
Average number of persons per household served by domestic illegal connection	no.	is normally the average number of people that are in the households served by the informal connections and if not known the average for the respective city/region
Per capita consumption in households served by domestic illegal connection	Litres / person / day	is an assumed per capita consumption which usually is much higher than the national average
Other Illegal connections	no.	is any connection to non-domestic premises which has been installed onto a main or another service pipe without the permission or authority of the utility. It is standard practice to estimate/assume number of illegal connections and to multiply this number by an assumed average consumption
Average consumption of other illegal connections	Litres / connection / day	is an estimated or assumed use based on local conditions and knowledge
Meter tampering, bypasses, etc. at registered customers	no.	is defined as the number of registered customers having meters who obtain water by fraudulently tampering with the meter or bypassing it
Average daily consumption from meter tampering, bypasses, etc. at registered customers	Litres / customer / day	is an estimated or assumed use based on local knowledge and conditions
Customer meter inaccuracies and data handling	%	these are caused by errors in the meter reading and billing system particularly if manual reading, registering and data transfer takes place. Normally a percentage of the billed volume is assumed

Required Data	Unit	Description
Under-registration of billed metered consumption by customer meters	%	is defined as the average percentage that the billed customer meters are under-registering the actual volume of water which passes through the meter
Under-registration of metered bulk supply to areas	%	is defined as the percentage that the bulk meters are under-registering the actual volume of water transferred across operational boundaries
Under-registration of unbilled metered consumption	%	is defined as the average percentage that the unbilled customer meters are under-registering the actual volume of water which passes
Corrupt meter reading practices	%	is defined as a percentage of the actual customer consumption representing possible malpractices by meter readers in entering the true consumption values in the billing system
Data handling errors	m^3	is the difference between the volume of true consumption and billed consumption due to billing or data handling errors
Total length transmission mains and distribution network	km	is the combined length of the transmission mains and distribution network but does not include the service connections
Possible under-estimation of the total length of transmission mains and distribution network	%	is defined as the possible underestimation of the total length in case the network is estimated without being accurately measured using GIS maps and drawings
Service connections of registered customer accounts	no.	is defined as the pipe from the main pipe in the street to the premises. One service connection may serve one customer account (meter) in the case of a single house, or several customer accounts, in the case of apartment blocks.
Active registered customer accounts	no.	registered customers who have active accounts and receive water from the utility

Required Data	Unit	Description
Inactive customer accounts with existing service connection	no.	customers that do not receive water and have deactivated their accounts but the service connection to their premises is still in place
Average length of service connection from property boundary to customer meter	m	is defined as the average length of pipe on private property from the property boundary to the customer meter or to the building in case of unmetered customers
Daily average pressure	m	is the 24-hour average operational pressure in the network. It should be noted that for the water balance calculation only the average pressure is required
Supply time	Hours / day Days / week	is the time period which the system is pressurised adequately to water maintain supply to customers
Average water tariff	price per m^3	is the average sale price of water for a unit volume of water
Marginal cost of water	cost per m^3	is the cost of producing and distributing an additional unit volume of water

2.2.1 Parameters to be monitored

For this use case, the parameters of interest are shown in Table 2:

Table 2 Guwahati WDN quality parameters

Parameter name	Range of measurement	Accuracy$^+$	Importance
Temperature	0 – 50 °C	±0.5%	High
Pressure	0.5 bar to 25 bar	±0.1%	High
Overall flow rate	5 - 6000 m^3/hour	±1%	High
Conductivity expressed as TDS	100 – 2500 mg/l*	±1%	High
free chlorine	0.05 - 5mg/l	±1%	High
pH	5 – 9	±1.5%	High
Iron	0.05mg/l - 2mg/l	±0.5%	High

Parameter name	Range of measurement	Accuracy+	Importance
microbial content	Yes/No	Not applicable	Medium
Arsenic	0.01 - 5 µg /l	±0.5%	Medium
Nitrates	10 - 500mg /l	±1%	Medium
Pesticide	0.01 - 200µg/l	±5%	Medium
Fluoride	0.1 - 5mg/l	±5%	Low
Turbidity	0.1 – 50 NTU	±5%	Low
Hardness (Mg^{2+} and Ca^{2+})	100 – 2000 mg/l	±5%	Low
Carbonate (CO_3)	100 – 2000 mg/l	±5%	Low
bi-carbonate (HCO_3^-)	100 – 2000 mg/l	±2%	Low

+ accuracy refers to maximum relative percentage error between actual to measured value by LOTUS sensor. * conductivity and TDS can be interchanged.

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3 Use case 2: Tanker based water distribution network

3.1 Scope of the use case

The LOTUS solution for tanker use case includes both sensor, chlorine dosage unit and software solution. Additionally the chlorine solution will be produced onsite at the bore well station. In this use case, the standalone tanker scheduling solution for demand and supply match will be demonstrated with a large number of Tanker system (~100 Nos). The main factor in determining the size of tanker water system scheduling (optimization problem) is not just number of tankers, rather it is number of water (sources) intake points, number of regions for distribution in a city, number of water treatment plants and customers. Secondly, in LOTUS project we will demonstrate the LOTUS sensor along with an integrated scheduling solution for 10 trucks. However, one chlorine dosage will be installed in the tanker and another one at the bore well station.

3.2 Description of Relevant Data

Different types of data are used for operation and scheduling of tanker water delivery system. These data types are described in the following Tables:

- Table 3 includes data used to define user details.
- Table 4 Includes data used to define administrative details of distributors.

- Table 5 includes data used to define driver details.
- Table 6 includes data used to define customer details
- Table 7 includes data used to define vehicle details
- Table 8 includes data used to define details about the water source
- Table 9 includes data used to define details about the water source quality
- Table 10 includes data used to define order details
- Table 11 includes data used to define user identity details
- Table 12 includes data used to define the 2nd factor for user identity details
- Table 13 includes data used to define water treatment plant details
- Table 14 includes data used to define driver-vehicle mapping details
- Table 15 includes the data used to define administrative distributor information with water source mapping details
- Table 16 includes data used to define water source information with treatment plant

- Table 17 includes the tanker-based water distribution quality parameters to be monitored by LOTUS sensor

Table 3 Data used to define user details

Field	Possible Values	Description
id	1, 2, 3, ...	Uniquely identifies the user
name	Junaid, ...	
email_id	abc@gmail.com, ...	
mobile_no	9596XXXX49, ...	
role	{customer, distributor, driver, admin}	Four possible roles of a user
confirmed	Yes or No	Whether user has confirmed his email_id and mobile_no or not

Table 4 Data used to define administrative details of distributors

Field	Possible Values	Description
id	1, 2, 3, ...	Uniquely identifies the distributor
area	Electronic city, ...	Location of the distributor
availability	Yes or no	Whether the distributor admin is available or not
status	Yes or no	Whether the distributor is active or not
is_validated	Yes or no	Whether the details provided by the distributor_admin have been validated by the system_admin or not
Number of Available Tankers	1, 2, 3, ...	Inventory of water tankers available with distributor for supplying water from one location to another

Table 5 Data used to define driver details

Field	Possible Values	Description
id	1, 2, 3, ...	Uniquely identifies the driver
license_no	HH981200	
app_installed	Yes or no	Whether the driver has installed the lotus app or not
distributor_id	1, 2, 3, ...	Indicates to which distributor_admin the driver is associated with

Table 6 Data used to define customer details

Field	Possible Values	Description
id	1, 2, 3, ...	Uniquely identifies the customer
address	BTM Layout, ...	
landmark	Jayadeva hospital, ...	
latitude	13.213475, ...	GPS coordinate
longitude	77.129645, ...	GPS coordinate
requires_motor	Yes or no	Whether the customer requires motor for pumping water at delivery location or not
requires_long_pipe	Yes or no	Whether the customer requires long pipe at delivery location or not

Table 7 Data used to define vehicle details

Field	Possible Values	Description
id	1, 2, 3, ...	Uniquely identifies the vehicle
registration_no	KA05 MB 3234, ...	
capacity	3000 litres, ...	
rate	1200 rupees, ...	
has_motor	Yes or no	Whether the vehicle/tanker has motor or not

Field	Possible Values	Description
has_long_pipe	Yes or no	Whether the vehicle/tanker has long pipe or not
distributor_id	1, 2, 3, ...	Indicates to which distributor_admin the driver is associated with
Tanker MOC type	SS, ESS...	Indicates material of construction of tanker (specially inner surface) to know its suitability with different water quality. It can be stainless steel, epoxy coated steel etc.
Avg speed	10,20,25...	Indicates average speed of vehicle (Kilometer/hr)
Cost per Km	INR 10, INR 15, INR 20...	Indicates cost of tanker per kilometer it travels (decided based on the fuel price and mileage of vehicle)

Table 8 Data used to define details about the water source

Field	Possible Values	Description
id	1, 2, 3, ...	Uniquely identifies the water source
name	Jaldhara, ...	
area	Electronic city, ...	
landmark	Wipro, ...	
latitude	13.548381	GPS coordinate
longitude	77.432412	GPS coordinate
water_source_type	Ground water, lake water, river...	
water_type	Raw water, treated water, ...	Raw water: which is unfit for drinking without any advanced treatment or appropriate disinfection

Field	Possible Values	Description
		Treated water: which is made fit for given purpose using the appropriate treatment technology
capacity	30000 litres, ...	Maximum pumping capacity from the source (1000 liters per hour)
availability	Yes or no	Whether the water source is available or not

Table 9 Data used to define details about the water source quality

Field	Possible Values	Description
id	1, 2, 3, ...	Uniquely identifies the water source quality row in a table
ph	8, 7.8, ...	
tds	300 mg/L, ...	
phosphorus	0.02 mg/L, ...	
nitrates	50 mg/L, ...	
faecal bacteria	0/100mL, ...	
hardness	300 mg/L, ...	
chlorine	0.15 mg/L, ...	
fluoride	0.5 mg/L, ...	
carbonates	500 mg/L, ...	
arsenic	0 µg/L, ...	
measurement_time	06-15-2020 08-35-55	Indicates when the reading was received from the lotus sensor

Table 10 Data used to define order details

Field	Possible Values	Description
id	Alphanumeric string like aa123234, ...	Uniquely identifies the order
customer_id	1, 2, 3, ...	Indicates which customer has placed the order
distributor_id	1, 2, 3, ...	Indicates which distributor will be delivering the order
quantity	1000 litres, ...	Quantity of water in litres for current order
amount	1200 rupees, ...	Price of current order in rupees
motor_required	Yes or no	Whether motor is required for current order or not
long_pipe_required	Yes or no	Whether long pipe is required for current order or not
order_time	06-15-2020 08-35-55	Indicates when the order was placed
dst_lat	13.757748	GPS latitude coordinate of order delivery location of order
dst_lng	77.853741	GPS longitude coordinate of order delivery location
dst_area	BTM layout	Address of order delivery location
Expected Time Slot of Tanker Delivery	6AM-7AM, 9AM-11 AM, 4 PM-7PM.....	Indicates customer expected delivery time
Tanker Type Constraints	Only small capacity, All capacity....	There may be delivery constraints w.r.t tanker size in some locations due to hilly areas/narrow roads etc.
Water_product	DPW, UPDW...	Indicates customer water use purpose (based on water quality) DPW: Domestic Purpose Water UPDW: Ultra Pure Drinking Water

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Table 11 Data used to define user identity details

Field	Possible Values	Description
id	1, 2, 3, ...	Id of a user
password_hash	158 bit hash	Hash of password is stored in database instead of actual one for security purpose

Table 12 Data used to define the 2nd factor for user identity details

Field	Possible Values	Description
user_id	1, 2, 3, ...	Id of a user
otp_hash	158 bit hash	
otp_gen_time	06-15-2020 08-35-55	Indicates when the otp that was generated. It will be required to check its validity.

Table 13 Data used to define water treatment plant details

Field	Possible Values	Description
Treatment plant_id	1,2,3	Uniquely identifiy treatment plant facilities in different regions of city
latitude	13.548381	GPS coordinate
longitude	77.432412	GPS coordinate
Throughput	50,80,100...	Designed Capacity of Treatment plant to produce treated water (1000 litres per hour)
Final Product Flag	0/1	1 for the water product type, if WTP is producing treated water of that quality 0 otherwise

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Field	Possible Values	Description
Yield of treatment process	0.5, 0.8, 0.9....	Indicates fraction of recovered water after treatment operation
Uptime	10, 12, 15..	Indicates minimum number of hours that a plant should run if it is in operation
Downtime	2, 4, 6...	Indicates minimum number of hours that a plant needs to restart the operation after it is stopped
Raw water storage max capacity	1000, 2000, 5000...	Indicates physical limitations of raw water reservoir capacity (1000 litres)
Treated water storage max capacity	1000, 1500, 3000...	Indicates physical limitations of treated water reservoir capacity (1000 litres)
Raw water storage min capacity	50, 75, 100...	Indicates minimum water capacity (hard limit) required in the raw water reservoir to pump smoothly (1000 litres)
Treated water storage min capacity	30,50,75....	Indicates minimum water capacity (hard limit) required in the treated water reservoir to pump smoothly (1000 litres)
current water capacity status in raw water reservoir	100, 200, 500...	Water available in the raw water reservoir of treatment plant at any time t (1000 litres)
current water capacity status in treated water reservoir	100, 200, 500...	Water available in the treated water reservoir of treatment plant at any time t (1000 litres)
Treated water reservoir target limit	500, 700, 1000...	Any targets of treated water to be maintained at the end of scheduling horizon in the

Field	Possible Values	Description
		corresponding reservoir for meeting future (anticipated) water demands (1000 litres)
Raw water reservoir buffer limit	100, 250,400...	Indicates capacity of raw water that should be usually maintained in the raw water reservoir (soft limit) for smooth pumping and treatment operations

Details of Mapping between different data sets

In this section, we present the data sets that map across different data sets, while in Figure 2, we present the flow of data among the different modules in the tanker-base case study.

Table 14 Data used to define driver-vehicle mapping details

Field	Possible Values	Description
driver_id	1, 2, 3, ...	Indicates which driver is driving a particular vehicle
vehicle_id	1, 2, 3, ...	Indicates which vehicle is driven by a particular driver

Table 15 Data used to define administrative distributor information with water source mapping details

Field	Possible Values	Description
distributor_id	1, 2, 3, ...	Indicates which distributor is taking water from a particular water source
water_source_id	1, 2, 3, ...	Indicates which water source is being used by a particular distributor

Table 16 Data used to define water source information with treatment plant

Field	Possible Values	Description
water_source_id	1,2,3...	Indicates which water source is sending water for treatment to which water treatment plant
treatment_plant_id	1,2,3....	Indicates which treatment plant is receiving water for treatment from which water sources

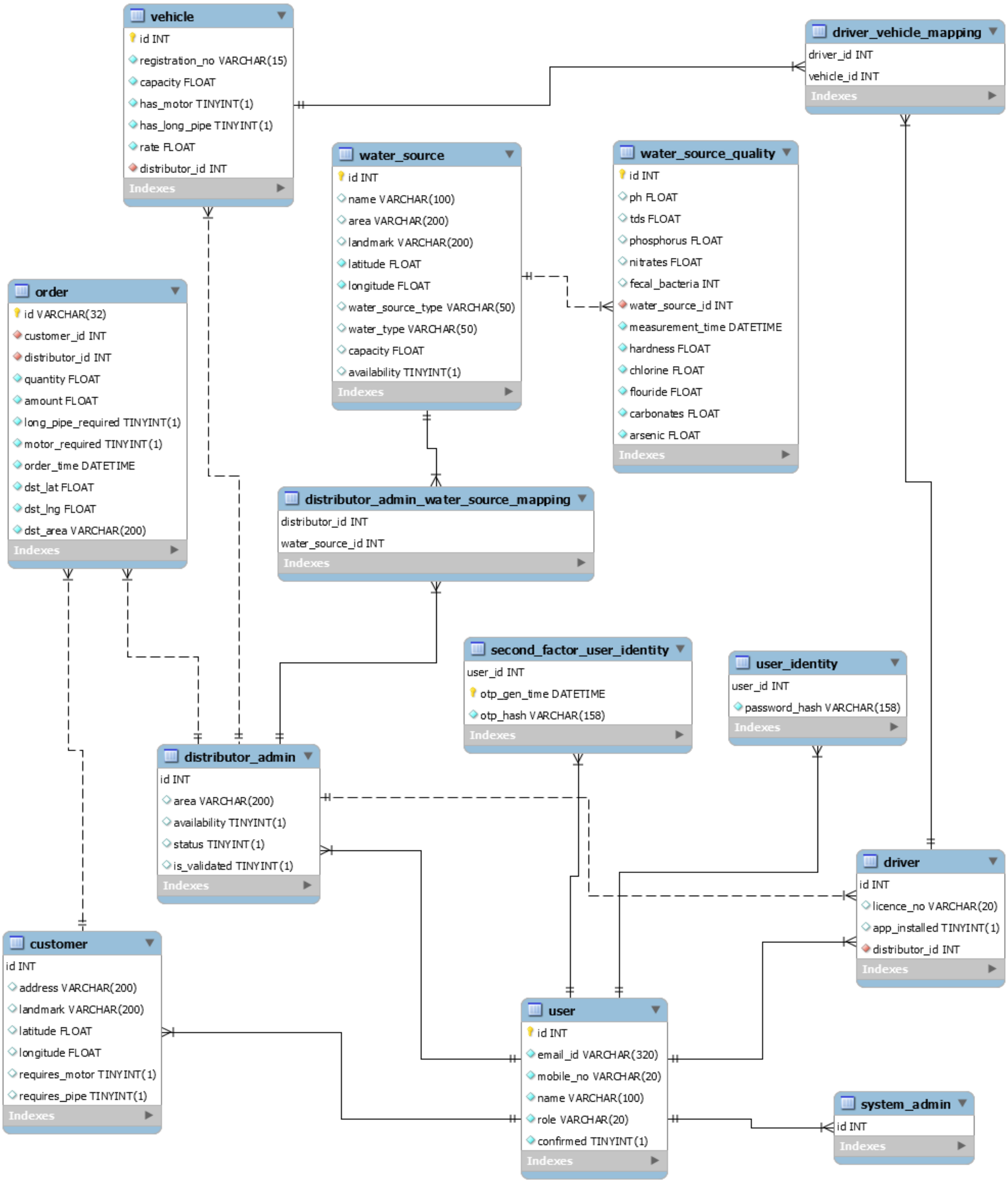

Figure 2 Flow of data among the different modules in the tanker-base case study

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3.2.1 Parameters to be monitored by LOTUS sensor

In Table 17, we show the Tanker-based water distribution quality parameters to be monitored by LOTUS sensor, while in Figure 3, we present a schematic for the tanker - based system water quality assurance.

Table 17 Tanker based water distribution quality parameters to be monitored by LOTUS sensor

Parameter name	Range of measurement	Accuracy	Criticality level
Temperature	0 – 50 C	±1%	High
Carbonate (CO_3)	0 to 1000 mg/L	±0.5%	High
Conductivity	expressed as TDS 100 – 4000 mg/l	±1%	High
pH	5 to 10	±1.5%	High
Chlorine	0.05-5 mg/L	±1%	High
Iron	0 to 10 mg/L	±0.5%	High
Microbial content	Binary (Yes/No)	Not applicable	High
Nitrates	0 to 500 mg/L	±1%	High
Arsenic	0 to 500 µg/L	±0.5%	High
Hardness (Ca, Mg)	0 to 1000 mg/L	±5%	High
Pesticide	0 to 500 mg/L	±5%	High
Fluoride	0 to 15 mg/L	±5%	High
Turbidity	0 to 25 NTU	±5%	Medium

+ accuracy refers to maximum relative percentage error between actual to measured value by LOTUS sensor.

Chlorine is the parameters to be considered in the use case. The Arsenic, fluoride, carbonate, pesticide, nitrates and iron will be required for checking the quality of the source groundwater.

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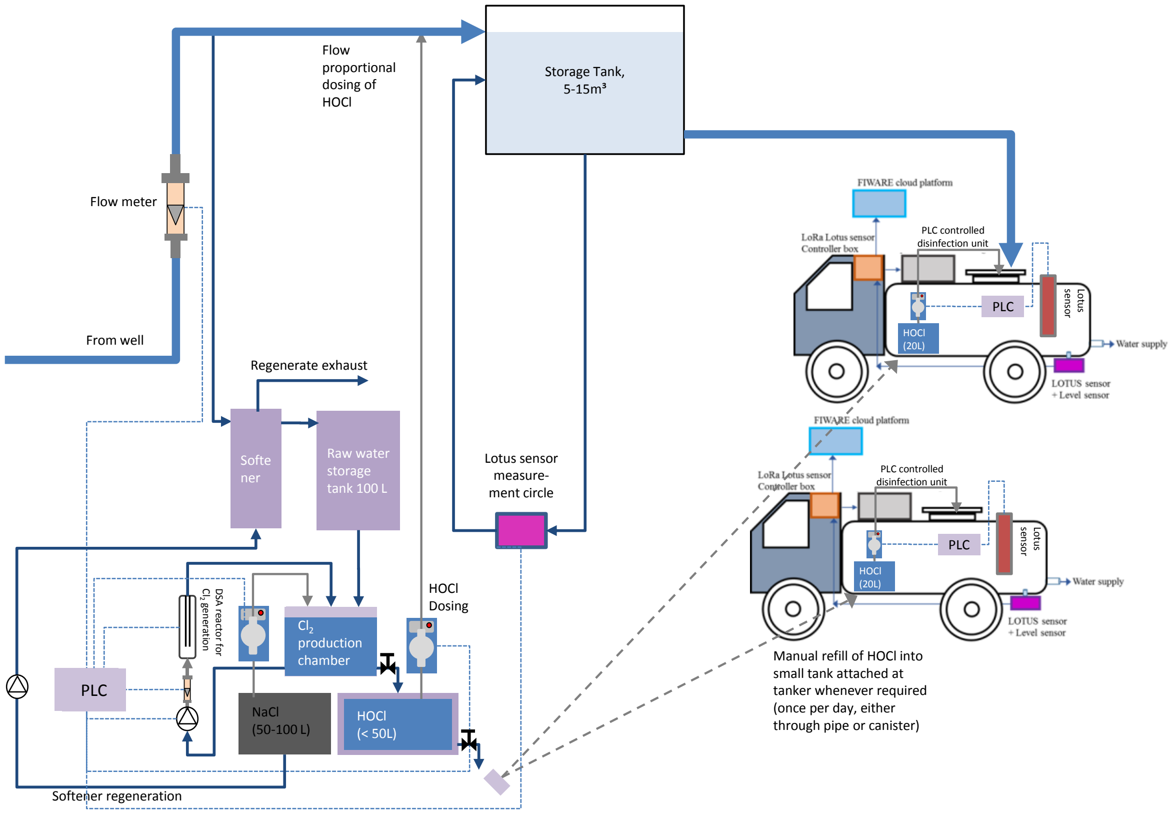

Figure 3 Schematic for tanker - based water quality assurance

4 Use case 4: Groundwater and river water monitoring

4.1 Scope and objective of the use case

4.1.1 Groundwater quality monitoring for Guwahati city

The key objectives of this specific task of LOTUS project is to develop a groundwater quality monitoring network in order to: assess the nature and extent of groundwater contamination, hydrologic processes that govern the main surface-groundwater interactions, analyse and interpret the environmental fate of different pollutants within the aquatic environment, evaluate the effectiveness of pollution control measures in place, detect and analyse the related water quality trends, and assess the suitability of water for different uses.

The collected hydrochemical and hydrogeological data for the Guwahati use case (location map shown in Figure 4) are based on the data requirements of the FREEWAT platform[1], a composite plugin for the well-known QGIS GIS open source desktop software. The module used for this deliverable, is developed in Python, while the Python-related dependencies that this module applies are the Qt version 4 Python wrapper (PyQt4), a Python 2D plotting library that creates quality figures in a variety of hardcopy formats and interactive environments across platforms, as shown in Figure 5.

[1] FREEWAT (FREE and open source software tools for WATer resource management) is an HORIZON 2020 project financed by the EU Commission under the call WATER INNOVATION: BOOSTING ITS VALUE FOR EUROPE (http://www.freewat.eu)

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Figure 4 Location map of Guwahati city

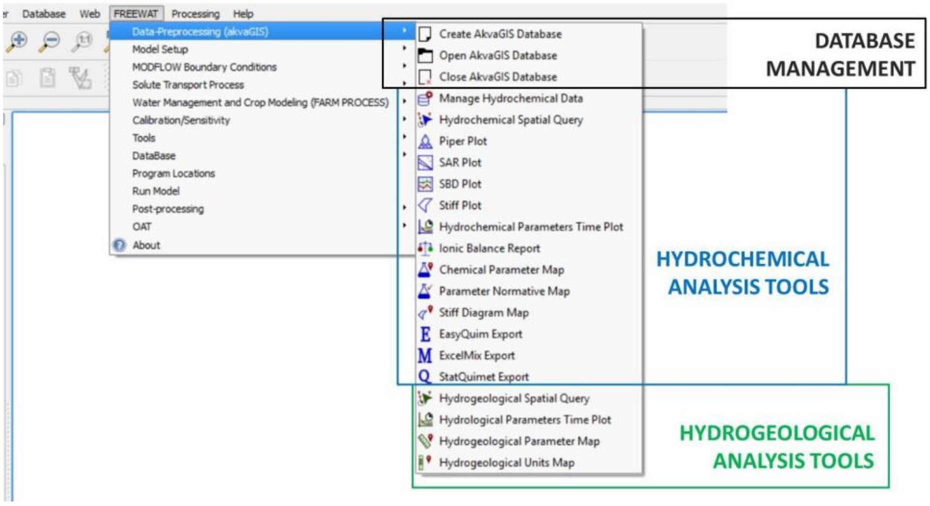

Figure 5 AkvaGIS module for the development of the hydrochemical/hydrogeological DB for Guwahati case study.

The introduction of the measurement results into the database was conducted using the following specific step-wise procedure (Figure 6).

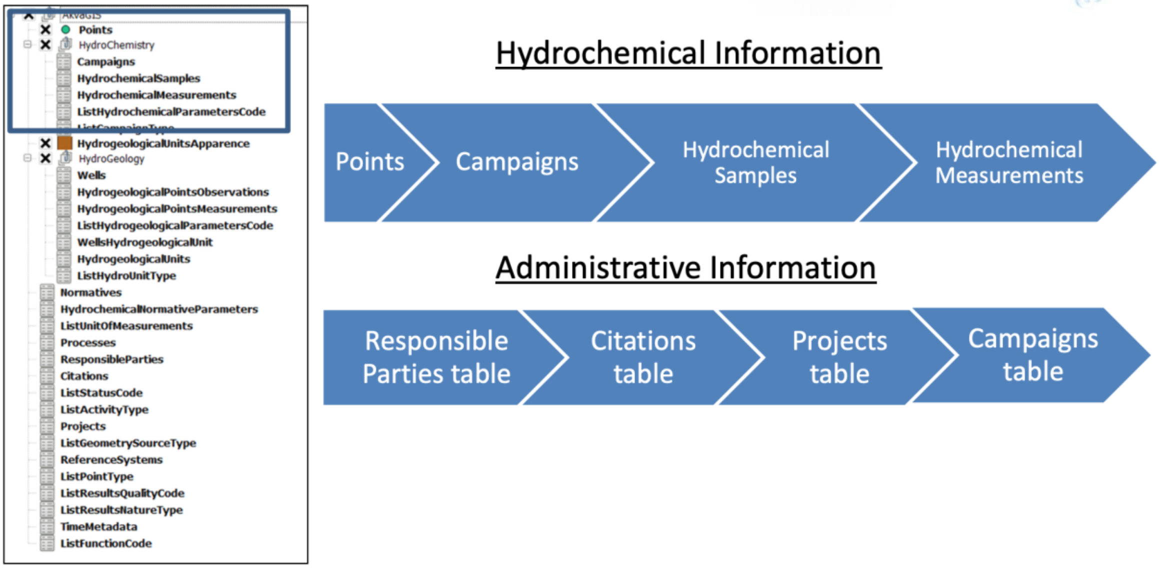

Figure 6 Workflow for the introduction of hydrochemical data within the database

In the Tables that follow (Tables 18 to 21), we describe the data used for the collected hydrochemical data as described in Figure 6 above.

Table 18 Data used for the groundwater monitoring points.

Name of the Field	Description
id*	unique identifier for each point with information
point	Name of the unique identifier for each point with information
beginLifespanVersion	Specifies the date and time at which this version of the spatial object was inserted or changed in the spatial data set (INSPIRE)
endLifespanVersion	Specifies the date and time at which this version of the spatial object was super- seded or retired in the spatial data set. If the endLifespanVersion is null, this indicates that the object is the current representation of the feature(INSPIRE) Place name of the point (popular name of the point, e.g. Well of the Major, Spring of the butterflies?)
name	Place name of the point (popular name of the point, e.g. Well of the Major, Spring of the butterflies?)
name2/name3/name4	Point’s name in different databases or references. Note that the same point can provide different information of different nature and origin and can

Name of the Field	Description
	be termed with different names in different reports
description	Text providing description of object
cooX	Coordinate X
cooY	Coordinate Y
elevation	Elevation (Z) in meters
geometryCooSourceType**	Type of CooX, CooY (e.g. BoreholeO&M, cartographicalO&M) ListGeome- trySourceType
geometryElevationSourceType**	Type of source of the geometry of Elevation (e.g. BoreholeO&M, Cartograph- icalO&M) ListGeometrySourceType
elevationReferenceSystemId**	reference System of the Elevation
cooReferenceSystemId**	reference System of the coordinators X, Y
sourceReferenceSystemId**	spatial reference system used by the source data
nameCitation / name2Citation / name3Citation / name4Citation**	Reference of the name indicated in Nam1-4Point. Here introduce the reference of the report/database were the information point were obtained
adressPoint	Adress of the point of interest (e.g. Palm Beach, 92, Cuenca)
accessPoint	Description of the access to the point (e.g. easy access, it is in the middle of the street, talk to the owner, its unknown) . In any case the information has to be accompanied with the date
pointType**	Type of point (spring, seep, swallowHole, well, seepoint, lakepoint)
otherPointDetails	Additional data
observations	Observations of the person that introduce the data into the database

Table 19 Data used for the conducted groundwater sampling campaigns

Name of the Field	Description
id*	Unique identifier for each field campaign
campaign	Name of the Unique identifier for each field campaign. E.g.Campaign01
campaignType**	Type of a campaign must be one of the item listed in ListCampaignType
projectId**	Unique identifier for each project related with the field campaign

Name of the Field	Description
beginDate/endDate	Start/End date of the campaign
clientId**	Party to which investigation is carried out
custodianId**	Party responsible to maintain data related to the campaign
dataOwnerId**	Responsible party that owns the data related to the campaign.
contractorId**	Party that carries out the survey
otherCampaignDetails	Additional data
observations	Observations of the person that introduce the data into the database

Table 20 Data used for the GW samples collected from each monitoring point.

Name of the Field	Description
pointId**	Unique identifier for each point where the sample has been taken (pointId from Points). In the O&M:The sampledFeature is the feature the SamplingFeature was sampled from, providing the ultimate context for the observation. An example of sampledFeature would be the river segment a specimen was taken from.In the O&M schema also the FoI is modelled as a SF_Specimen; the location pertaining to the measurement is provided by the attribute samplingLocation
samplingTime	Date of sample collection
Id	Unique identifier for each sample. In the O&M standard it is correspond with Specimen. A specimen is a feature sampled from a feature of interest to enable ex-situ observation, such as in a laboratory
sample	Unique name/identifier for each sample
campaignId**	Unique identifier for the campaign in which the sample was taken. CampaignId from campaigns; campaignId
fieldName	Name of the sample in the field before to send to the lab
currentLocation	If present, the attribute currentLocation: Location shall describe the location of a physical specimen. This may be a storage location, such as a shelf in a warehouse or in a laboratory
sampleSize	Size of the sample. Measure shall describe a physical extent of the specimen. This may be volume
sampleSizeUom	Unit of measurement (vol) of the sample Size
sampleLenght	Lenght/Depth where sample was obtained (m)
samplingMethodId	The attribute samplingMethodId shall describe the method used to obtain the specimen
samplingTime	The time the sample was taken. (based on O&M scheme)

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Name of the Field	Description
responsablePartyId**	Person /entity responsible of the sample collection
otherChemSampleDetails	Additional data
observations	Observations of the person that introduce the data into the database

Table 21 Data used for the hydrochemical measurements that were conducted (either in-situ or in the laboratory).

Name of the Field	Description
sampleId**	Unique identifier for each sample defined in HydrochemicalSamples
hydrochemicalParametersCode **	Unique Identify for each parameter from ListHydroChemicalParameters; field:parameterId
resultTime	Provides the time the results of the laboratory analysis were made available. If the measurement was done in situ, resultTime is equal to samplingTime (table HydrochemicalSamples)
value	Result, numeric value
compValue	censored values (which are the concentrations of some elements reported as non-detected?, or as less-than? or greater-than?)
responsiblePartyId**	Laboratory from ResponsibleParties where the sample was analyzed. If the measurement was done in situ, here the author of such measurement
processId**	Procedure of the analysis
citationId**	Citation to the laboratory report. From the table Citations
otherChemMeasurementDetails	Additional data
observations	Observations of the person that introduce the data into the database

The database sources for the hydrogeological / hydrochemical monitoring of Guwahati case study are shown in Table 22.

Table 22 Database sources for the hydrogeological / hydrochemical monitoring of Guwahati case study

Hydrogeological & hydrochemical information for the database
Lithology for 23 PHED wells have been collected, and request letter send for 63 location lithology

Hydrogeological & hydrochemical information for the database
Metrological data (daily rainfall, humidity, sunshine and temperature) collected from Regional Metrological Center (since 2014 to 2018)
Ground water samples have collected from 94 sources (22 from PHED and 72 from private sources)

The samples used for the application of AkvaGIS, collected from both private and public groundwater wells in two sampling periods, October-December 2019 and January-February 2020. Each sample was subjected to field measurements of Specific Electrical Conductivity, pH, Temperature and Dissolved Oxygen. The chemical analysis involved the measurement of specific ions concentration for every sample (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^{-}, SO_4^{2-}, Cl^{-}, NO_3^{-}, Mn, Fe).

In more detail, collected data from the Guwahati case study are imported in QGIS as a csv file with a specific tabular structure (see Figure 7, Figure 8, Figure 9). For hydrochemical analysis, the main information needed, is the sampling points for spatial representation, the sampling campaigns, the samples of all campaigns and finally the hydrochemical measurement of each sample in order to analyze and interpret the information given. The attribute table contents of the inserted csv files can be easily copied into the database, using the copy-paste options of the QGIS platform.

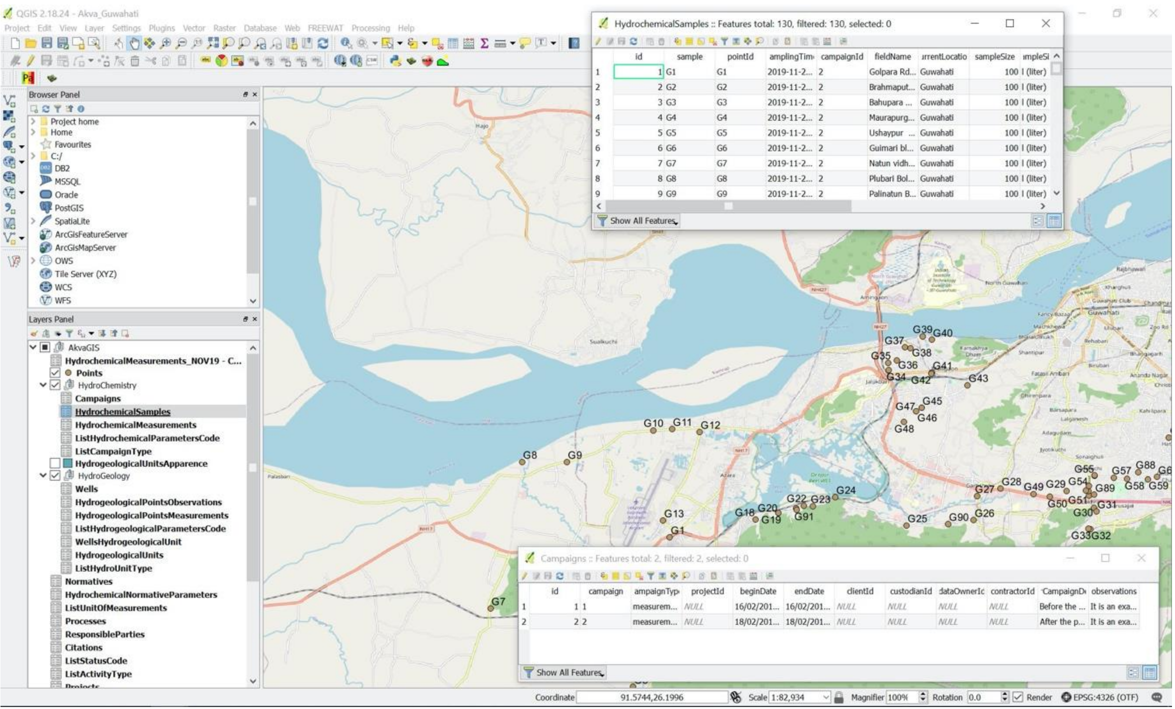

Figure 7 Introduction of the chemical samples and chemical campaigns that are conducted for the Guwahati case study

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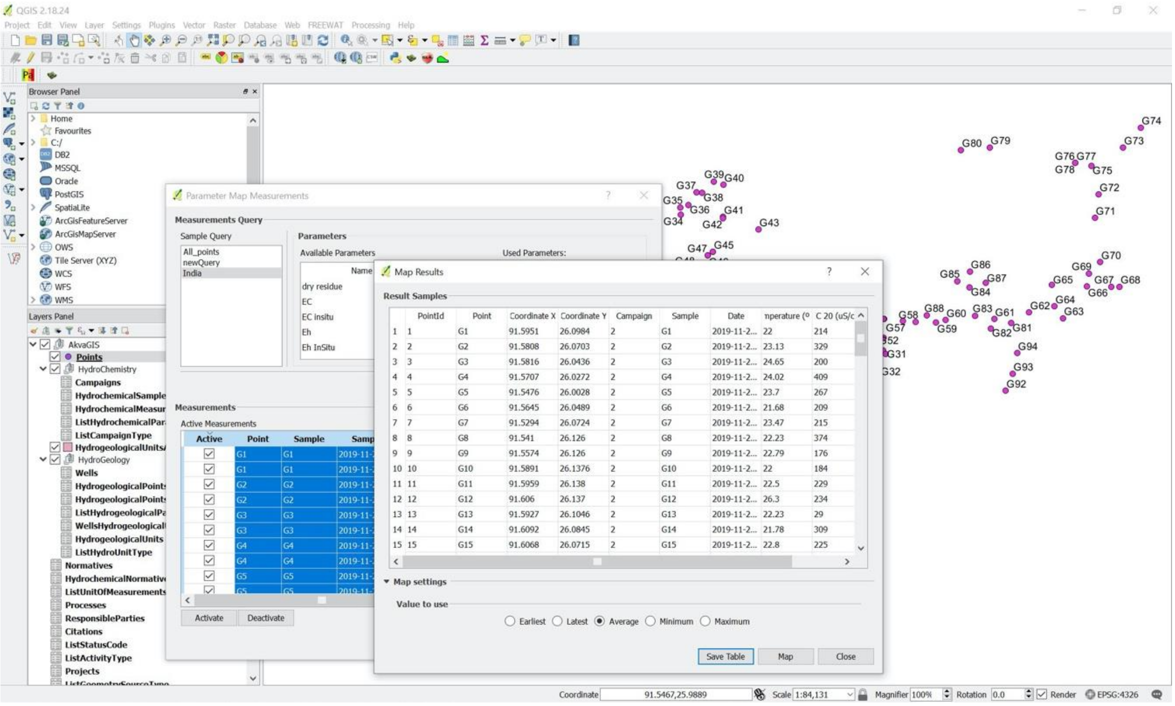

Figure 8 Design of parameter maps measurements for the Guwahati case study

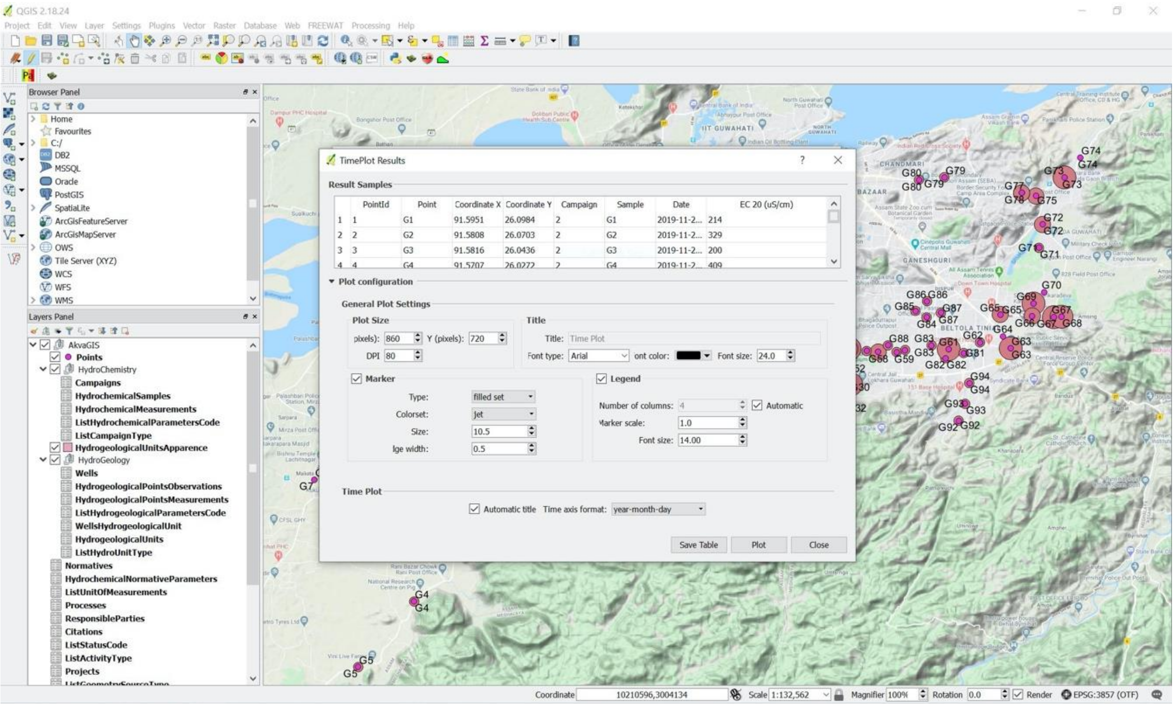

Figure 9 Sample of DB analysis of Guwahati case study using the FREEWAT DB module (normative parameter map and time plot results)

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Following are the essential groundwater quality parameters enlisted in Table 24, for monitoring and suggesting more suitable removal technology at Guwahati city.

Table 23 Sensor requirement for groundwater quality measurements at Guwahati city

LOTUS sensor for groundwater quality parameters measurement			
Parameter name	**Range of measurement**	**Accuracy**	**Importance**
Arsenic	Arsenic = 0 to 200 µg L^{-1}	± 5 µg L^{-1}	High
Iron	Iron = 0 to 100mg L^{-1}	± 0.01 mg L^{-1}	High
Manganese	Manganese = 0 to 20 mg L^{-1}	± 0.01 mg L^{-1}	High
Fluoride	Fluoride = 0 to 15 (mg L^{-1})	± 0.5 (mg L^{-1})	High
pH	pH = 5 to 10	± 0.2	High
Electrical Conductivity	Electrical Conductivity = 0.005 to 0.05 (S/m)	± 0.001 (S/m)	Low
Ca	Ca^{2+}= 0 to 600 (mg L^{-1})	± 10 (mg L^{-1})	Medium
Turbidity	Turbidity = 0 to 500 NTU	± 5 NTU	Medium
Bi- carbonate	Bi- carbonate = 0 to 1000 (mg L^{-1})	± 5 (mg L^{-1})	Low
Nitrates	Nitrates = 0 to 500 (mg L^{-1})	± 10 (mg L^{-1})	Low
Hardness	Hardness = 0 to 1000 (mg L^{-1})	± 10 (mg L^{-1})	Low
Pesticide	0.01 - 200µg/l	± 0.1 (µg L^{-1})	Low
Microbial content (E. coli or thermotolerant coliform bacteria)	Yes/No	Not applicable	Low
Other than LOTUS sensor for groundwater table measurement			
Parameter name	**Range of measurement**	**Accuracy**	**Importance**
Groundwater table	2 meters to 50 meters	± 1 meter	High

4.1.2 Groundwater quality monitoring for Bangalore city:

To achieve these main objectives following sub-objective are defined:

- In Bangalore city (Figure 10), groundwater quality will be monitored from different locations (at least 20 samples daily) and it will be central data base. This data will be used for identifying appropriate water treatment technologies by public.
- Develop mitigation advice/protocol regarding household treatment based on the groundwater quality to the general public.

Figure 10 Location map of Bangalore city

Following are the essential groundwater quality parameters enlisted in Table 24, for monitoring and suggesting more suitable removal technology at Bangalore city.

Table 24 Sensor requirement for groundwater quality measurements at Bangalore city

LOTUS sensor for groundwater quality measurement			
Parameter name	**Range of measurement**	**Accuracy**	**Importance**
Fluoride	Fluoride = 0 to 15 (mg L^{-1})	± 0.1 (mg L^{-1})	High
Arsenic	Arsenic = 0 to 200 (µg L^{-1})	± 0.5 (µg L^{-1})	High
Iron	Iron = 0 to 10 (mg L^{-1})	± 0.3 (mg L^{-1})	High
Ca	Ca= 0 to 600 (mg L^{-1})	± 10 (mg L^{-1})	High

Bi- carbonate (HCO_3^-)	Bi- carbonate = 0 to 1000 (mg L^{-1})	± 5 (mg L^{-1})	Low
Electrical Conductivity	Electrical Conductivity = 0.005 to 0.05 (S/m)	± 0.001(S/m)	Low
pH	pH = 6 to 10	± 0.2	Low
Nitrates	Nitrates = 0 to 500 (mg L^{-1})	± 10 (mg L^{-1})	Low
Hardness (Mg + Ca)	Hardness = 0 to 1000 (mg L^{-1})	± 10 (mg L^{-1})	Low
Microbial content (E. coli or thermotolerant coliform bacteria)	Yes/No	Not applicable	Low
Pesticide	0.01 - 200µg/l	± 0.1 (µg L^{-1})	Low

LOTUS is co-funded by the European Commission under the Horizon 2020 research and innovation programme under Grant Agreement N° 820881 and by the Indian Government, Ministry of Science and Technology.

5 References

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[7] Rossetto R, De Filippis G, Borsi I, Foglia L, Cannata M, Criollo R, Vázquez-Suñé E (2018) Integrating free and open source tools and distributed modelling codes in GIS environment for data-based groundwater management. *Environ Model Softw*, 107:210–230

Appendix 1 - Data Required for Water Balance Calculations

Year		
Water volumes are for the period of:		From(date) - To(date)
		Number of days
System Input Volume:		m^3
Billed Consumption:		
Metered		m^3
Unmetered		m^3
Bulk Water Supply (export):		m^3
metered		m^3
unmetered		m^3
Unbilled Consumption:		
Metered		m^3
Bulk Water Supply Metered (export)		m^3
Unmetered		m^3
Unauthorized consumption:		
Illegal connections – domestic		Estimated number
		Persons/house
		Consumption (litres/person/day)
Illegal connections – others		Estimated number
		Consumption (litres/connection/day)

Meter tampering, bypasses, etc. at registered customers		Estimated number
		Consumption (litres/customer/day)
Customer Meter Inaccuracies and Data Handling:		
Under-registration of Billed Metered Consumption		%
Under-registration of Metered Bulk Supply		%
Under-registration of Unbilled Metered Consumption		%
Corrupt Meter Reading Practices		% of under-reading
Data handling errors		m^3
Distribution and Transmission Mains:		
Total Length		km
Possible under-estimation		%
Service Connections:		
Service connections of registered customer accounts		Number
Active customer accounts		Number
Inactive customer accounts with existing service connection		Number
Average Length of Service Connection from Property Boundary to Customer Meter		m
Daily Average Pressure		m
Supply Time		Hours /day
		Days/week

Financial Data:		
Average Tariff		Cost/ m^3
		Currency
Marginal Cost of Water		Cost / m^3
		Currency

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