LOTUS

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

Deliverable D3.3

Report on offline tools developed for use cases

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Abstract

This report aims at elaborating the offline tools developed for each use cases for effective monitoring and managing of water supply in growing town and cities in India. The tools have been developed specifically for each of the following use cases: Guwahati water distribution network, tanker-based water distribution system and river and groundwater monitoring. Through this report, several aspects of each tool are elaborated such as a list of tools developed, the approach of the developed tools, a list of inputs required for the developed tools, software and hardware considered in the tools and finally the frequency of the utilization of tools.

Keywords

Offline tools development; Water distribution networks; Water management; India

Disclaimer

LOTUS has been financed with support from the European Commission and the Indian Government, Ministry of Science and Technology.

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 ground-water, 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
WDS/WDN	Water Distribution System/ Network
RTU	Remote Terminal Unit
WNTR	Water Network Tool for Resilience
GJB	Guwahati Jal Board
DMA	District Metered Areas
WTP	Water Treatment Plant
EPS	Extended Period Simulation
MILP	Mixed Integer Linear Programming
GMS	Groundwater modeling system
MODFLOW	Modular finite-difference flow model
MT3DMS	Modular three-dimensional transport model
IOT	Internet of Things

1 Executive Summary

The purpose of this document is to elaborate the offline tools developed for each use case for effective monitoring and managing of water supply. The tools have been developed specifically for each of the following use cases: Guwahati water distribution network, tanker-based water distribution system and river and groundwater monitoring. Offline tools for Guwahati WDN use case have been developed to analyse specific locations for data collection (like chlorine, pressure etc) and disinfection, and provide base case prediction of the network based on the initial status. The four tools developed for this use case are, sensor placement tool to monitor the water quality in the WDN, tool for leakage and burst management based on pressure monitoring, design tool for dosage units to maintain optimal chlorine levels in the network and water quality simulation tool for extended period simulation of the network. The short-term planning and management tool focuses on optimal management of water supply chain and timely delivery of tanker water to consumers. In groundwater quality monitoring specially focus on detection of arsenic concentration in the groundwater of Guwahati city and identify heavy metals contamination in Bengaluru city. Similarly, for river water quality monitoring, the LOTUS sensor will detect the river water pollution by industrial discharge or other sources, which would help to take essential treatment process in advance for water treatment for Varanasi city. The following aspects of each tool are elaborated:

- List of tools developed
- Approach of the developed tools
- List of inputs required for the developed tools
- Software and hardware considered in the tools
- Frequency of the utilization of tools

2 Use case 1: Water Distribution Network Guwahati

2.1 Introduction

The control and monitoring of the Guwahati water distribution network requires the following: a) sensor data from strategic locations that can illustrate the quality status of the network b) EPANET model capable of simulating the network for near future based on current status c) Dosing mechanisms to maintain sufficient free chlorine levels d) Pressure monitoring to detect leakages and bursts in network. The following sections discusses the tools developed to address each of the above-mentioned points.

2.2 List of tools developed

Sensor placement algorithm tool:

The water distribution monitoring and control strategies require real-time data from the network to perform various quantity and quality analysis. For a complete and precise picture of the network one would prefer to have sensors at all the nodes. But this approach is hindered due to the following reasons: a) economical constraints: This includes cost of the sensors (that can gather all the required data like flow, pressure, free chlorine etc.), cost of installation and support system and budget constraints and b) Geographical constraints: This constraint comes into play when installation of sensors is not possible owing to terrains, no power, underground pipelines.

This results paves way for the sensor placement problem, which can be roughly defined as 'choosing a subset of sensor locations from a given sensor location set such that some monitoring performance is guaranteed or at least maximized' [1]. The monitoring performances considered for Guwahati WDN are optimum free chlorine, flow and pressure management, and leakage and burst detections. The sensor placement tool developed for this use case focuses on quality of water supplied in terms of age, free chlorine and contaminant intrusion (natural/deliberate).

Leakage and pressure management tool:

An upstream analysis-based method is developed for the optimisation of pressure sensors. Based on the analysis of hydraulic upstream-downstream relationships between nodes and pipes, pressure sensors can be placed at nodes with the maximum coverage (for burst detection) and least overlap of upstream pipes (for burst localisation) in a water distribution system (WDS). This is because anomaly detection of leaks/bursts is usually based on the unusual pressure change at the sensors caused by the usual flow change, and anomalies at upstream pipes are more effectively captured than downstream pipes. Graph theory, which represents flow paths of a WDS as a directed graph, is employed to perform upstream analysis.

Design tool for dosage units:

Chlorine is used worldwide as the disinfecting agent for drinking water treatment and a sufficient residual chlorine concentration is typically mandated throughout the distribution system by global drinking water standards, to prevent microbiological contamination of the treated water as it transports through the pipes of the distribution network. However, applying large doses of the disinfectant at treatment facilities has traditionally been associated with several issues, including consumer complaints about water taste and odour near the treatment locations, and high disinfection by-product (DBP) levels. As an alternative, this tool is designed for implementing booster chlorination units along with source chlorination unit, to maintain a uniform residual concentration by injecting the disinfectant at multiple locations in the network with smaller, more distributed dosage. Such practice enables preservation of a sufficient residual at all points in the network, while simultaneously reducing the formation of DBPs. Booster chlorination units can also be activated in case a contamination event is detected, which can potentially curb the spread of contaminants by rapidly injecting large doses of the disinfectant in the proximity of the infected zones.

Water quality simulation tool:

The extended simulation analysis of the network based on the upstream quality can provide significant view of the water quality throughout the network. In the current use case, water quantity parameters (flow and pressure) and quality parameters (water age and free chlorine) can be simulated over an extended period based on the tank level and free chlorine at the hilltop reservoir. But these simulations require EPANET model which is calibrated model based on the experiments and real time data of the field.

2.3 Approach of the proposed tools

Sensor placement algorithm tool:

The Guwahati distribution network under LOTUS project expands to DMAs 1 to 4. The network CAD diagram of the WDN was provided by GJB to develop the EPANET model. Based on an assumed demand data the EPANET model was developed accompanied by physical verification of the network lines. The total length of pipeline in the 4 DMAs is 35.5 km and the number of nodes is 326. Out of the 326 nodes, about 145 nodes are dead end nodes. Observation of all the events that can occur in the WDN would require at least these many sensors placed at the dead ends assuming that each node is susceptible to intrusion. But with the constraint of number of sensors (20 sensors) allotted for Guwahati WDN use case, all the dead-end nodes cannot be covered. The major water quality performance criteria considered for implementation of sensors can be broadly as network coverage or visibility, accidental and/or deliberate contamination, level of service (based on permissible amount of contaminated water supplied before detection). Based on the contamination intrusion profile provided in the BWSN competition, a pollution matrix was developed by integrating EPANET model and MATLAB [2]. With only 326 nodes, contamination intrusion scheme at each point of the node given at 12 different times in a day was framed. Following this, the time taken of detection of the event at a node was noted in the pollution matrix. The time required for detection is the EPANET clock time at contaminant detection minus EPANET clock time at contaminant intrusion. In case of non-detection the value for the corresponding node was set to a very high value as a penalty. This allowed to frame a multi-objective optimization where the average time for detection was minimized and number of detections was maximized. Estimation of detection time requires calibrated demand data from the network, which is currently not available as new connections are being still provided. Thus, single objective of maximizing the number of detections was considered to maximize network visibility. It was observed that nearly 40% contamination events were undetected, owing to large number of dead-end nodes. Thus, a survey of the network was carried out to find the plausible locations with connectivity, power, ease of access and evenly spread out for installation of the LOTUS sensors. The list of these locations is shown below:

Table 1 Plausible sites for LOTUS sensor placement

S.No	Site	Latitude	Longitude	Electrical power	Internet connectivity	Sensor placement
1	Reservoir Exit point	26.17047	91.69149	RTU	RTU	Mandatory
2	DMA 1-1 (Entry point)	26.16733	91.68724	RTU	RTU	Mandatory
3	DMA 1-2	26.17152	91.69127	Intake well	Intake well	
4	DMA 1-4	26.16506	91.69374	electric post	3G/4G	
5	DMA 1-4	26.16263	91.69457	electric post	3G/4G	
6	DMA 1-5	26.15911	91.69656	RTU	RTU	
7	DMA 1-6	26.17225	91.72774	electric post	3G/4G	
8	DMA 1-7	26.16511	91.71492	electric post	3G/4G	
9	DMA 1-8	26.17022	91.71635	electric post	3G/4G	

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10	DMA 1A-1	26.16903	91.69347	Reservoir Unit	Reservoir Unit	
11	DMA 1A-2	26.16536	91.69088	electric post	3G/4G	Mandatory
12	DMA 2 -1 (Entry point)	26.15857	91.68528	electric post	RTU	Mandatory
13	DMA 2 -2	26.16212	91.68492	electric post	3G/4G	
14	DMA 2 -3	26.16162	91.68168	electric post	3G/4G	
15	DMA 2 -4	26.15941	91.68391	electric post	3G/4G	
16	DMA 2 -5	26.15884	91.6873	electric post	3G/4G	
17	DMA 2 -6	26.16083	91.68688	electric post	3G/4G	
18	DMA 2-7	26.15898	91.68949	RTU7	RTU	
19	DMA 3-1 (Entry point)	26.15898	91.68949	RTU	RTU	Mandatory
20	DMA 3-2	26.15791	91.68783	transformer	3G/4G	
21	DMA 3-3	26.15691	91.67695	electric post	3G/4G	
22	DMA 4 -1 (Entry point)	26.15824	91.67823	RTU	RTU	Mandatory
23	DMA 4 -2	26.16315	91.6789	transformer	3G/4G	
24	DMA 4 -3	26.16315	91.67533	3G/4G	3G/4G	
25	DMA 4 -4	26.16162	91.68168	electric post	3G/4G	
26	DMA 4 -5	26.15846	91.68371	electric post	3G/4G	
27	Gammon WTP	26.16361	91.66996	Gammon WTP	Gammon	Mandatory
28	Main line exit	26.15776	91.67564	electric post	3G/4G	Mandatory

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Out of the above plausible location, 8 locations have been marked as the 'Mandatory' as they are the crucial entry points to network, DMAs and reservoir. This reduces the available sensors for installation at the remaining 20 sites to 12. The simulations are to be performed again with these locations, once calibrated data from the field is available. The following figures provides the discussed locations on google map. The mandatory locations are marked in yellow while the red ones depict optional location points.

Figure 1 Plausible sites for sensor placement in Guwahati WDN

Leakage and pressure management tool:

One scenario simulation without modelling of bursts is in principle enough for the optimisation of sensor placement by the upstream analysis-based method, although more simulations can be used. The flow direction in all pipes in a WDS at each time step obtained from extended period simulation is converted to a directed graph, which is a mathematical representation of network status with vertices (representing junctions, reservoirs, tanks, etc.) connected by edges (representing pipes, pumps, valves, etc.) with direction (representing flow direction). This mathematical treatment allows for efficient analysis of flow paths as breadth first algorithm can be employed to trace upstream pipes of each node in a WDS based on the mathematical directed graph. Given that S sensors are to be placed, the combination of S nodes that has the largest union of upstream pipes (i.e. the maximum coverage) is selected as the best locations at the corresponding time step. As it is computationally expensive to enumerate and evaluate all combinations of S nodes especially when a WDS is large, greedy algorithm is employed to achieve a near optimal result in an efficient way. By this method, the node with the maximum coverage is selected first and the other S-1 locations are chosen one by one by evaluating the union of upstream pipes of the selected node(s). If there are multiple solutions with the same highest coverage rate, the one with the least overlap of upstream pipes (i.e. highest potential of localisation) is selected. Based on flow path analysis over the entire simulation, a matrix is generated whereby each row records the best sensor location(s) at each time step. The element value is 1 if the node of the corresponding column is selected at the time step of the corresponding row and is 0 if otherwise. By summing up the row values, nodes corresponding to the top S highest ranked values are the optimal location(s) of sensor(s).

Design tool for dosage units:

The tool is developed to find the optimal layout and operation of booster chlorination units in the water distribution network. The optimization problem is formulated in the tool with the aim of minimizing the total cost of placing, constructing, and operating the booster chlorination units, while ensuring that the residual concentrations at all network junctions are within the acceptable bounds. A genetic algorithm is used in the tool to solve the objective function to find the optimal locations and chlorination dosing profiles for a given number of chlorination units to be placed in the water distribution network. The complete mathematical formulation of this optimization problem can be referred in the research publication [3].

Water quality simulation tool:

The EPANET model required for Guwahati WDN has already been developed with assumed demand data. This model can be run for extended period simulations based on the chlorine content in the hilltop reservoir tank. Once the demand at the nodes are calibrated, water samples from various nodes should be collected and analysed for free chlorine concentration. The reaction order and constants for chlorine consumption in the WDN are calculated based on the experimental data. Then, reaction rates can be updated in the EPANET model. Fine tuning of reaction rates can be carried out by minimizing the error between experimental and simulated data.

2.4 List of inputs required for the tools

Sensor placement algorithm tool:

The inputs required for sensor placement algorithm are: a) .inp file of the Guwahati WDN b) number of sensors to be placed and set of plausible places where the sensors can be placed

Leakage and pressure management tool:

The following file or data are required: 1) .inp file of the water distribution system; 2) the number of sensors to be placed; 3) the junctions that are impossible for sensor placement (hence excluded as candidates in the optimisation).

Design tool for dosage units:

A well calibrated EPANET model of the water distribution network.

Water Quality simulation tool:

The following inputs are required for this tool: a) Well calibrated EPANET model of WDN. b) Free chlorine data at various nodes for calibration. This requires extensive collection of samples from the network (hilltop tank, DMA entrances and various nodes in each DMA) at different times intervals.

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2.5 Software and hardware considered in the tools

Sensor placement algorithm tool:

EPANET for simulating the Guwahati WDN.

MATLAB for providing contamination scenario to EPANET, developing the pollution matrix and running GA optimization tool.

Leakage and pressure management tool:

WNTR, greedy algorithm (in Python) and breadth first algorithm (in Python) are used for the optimisation of placement of pressure sensors.

- The Python package WNTR is adopted for extended period simulation (EPS) as it enables realistic simulation of the hydraulic processes in WDSs whereby nodal (junction or burst hole) discharges are a function of nodal pressure.
- Greedy algorithm is described in Section 2.2.

Breadth first algorithm is used for tracing upstream pipes of a sensor based on paths. It operates on the directed graph of the water distribution system.

Design tool for dosage units:

The tool uses EPANET and WUDESIM (for hydraulic and quality simulations) interfaced with Genetic Algorithm based optimizer in MATLAB.

Water quality simulation tool:

EPANET for WDN simulations.

2.6 Frequency of the tools to be utilized

Sensor placement algorithm tool:

The current WDN is a new one and connections are still being provided to the consumers. With this in view, it has to be run after these numbers reach a stable value. After the sensors are placed in the WDN, the algorithm can be applied again if there are major changes in the WDN to relocate the existing sensors or add new sensors in existing plan.

Leakage and pressure management tool:

The locations of pressure sensors are updated upon major changes in WDS (e.g. addition/removal of pipes, increased/decreased water demand at certain nodes) or the requirement of adding more sensors.

Design tool for dosage units:

The location of chlorine dosage units and stead state chlorine dosage amount can be decided by the single run of the tool. However, real-time control based optimization algorithm is required to decide the additional optimal chlorine dosage in the events of sudden contamination, which has been developed as part of WP4 [4].

Water quality simulation tool:

This model can be run every day for generalized analysis of chlorine content through the network. The updating of the reaction rates should be carried out every three months as deterioration of pipes and biofilm formation affect these values.

3 Use case 2: Tanker based water distribution network

3.1 List of tools developed

Short-Term Planning and Scheduling Tool: A scheduling optimization algorithm is developed (collaboratively by IITB & IITG) in FICO Xpress Optimizer for MILP (mixed integer linear programming) problem of planning and scheduling tanker delivery and treatment-operations in tanker-based water distribution systems. Such planning and optimization will ensure efficient and timely management of consumer water demands in tanker supply chain.

3.2 Approach of the proposed tools

To efficiently operate tanker water distribution systems, a large fleet of tanker trucks are required to transport water among several water sources, water treatment plants and consumers spanning across the regions. This requires tighter coordination between water suppliers, treatment plant operations, and user groups to use available water resources in a sustainable manner, along with the assurance of water quality and timely delivery. This planning and scheduling tool assists in decision making through an optimization formulation with an overall objective of minimizing the total operating cost such that all of the constraints related to the water demand, supply operations, and environmental and social aspects are honoured while supplying water to a maximum number of users. The tool solves mathematical optimization problem as a mixed integer linear programming (MILP) framework which captures all of the nuances related to (i) water availability limitations and quality constraints from different sources, (ii) maintaining water quality as it transports via tankers, (iii) water demands for various end-use purposes, and (iv) transportation across the components of tanker water supply system. Thus, the tool simultaneously optimize the water treatment and distribution aspects to assist in the following decisions for transparent operation of the entire tanker water supply system: (i) generating the water treatment and distribution plan for at least 1 week, (b) finding the optimal schedule for the movement of tanker trucks across the supply system (i.e., from the water source to treatment plants to consumers), (c) maximum utilization of the available tankers distribution capacity to minimize the distribution cost, (d) exploration of integration between treatment plant operations, water availability at sources, and consumer demands to use the available water resources in a sustainable manner, (e) maintaining the quality of water supplied to the consumers, and (f) deciding the optimal connection between the water source and consumer, which leads to minimum transportation costs, considering the realistic transit time, water demand type, and water demand timings. The tool generates Text files (.txt) which contains results of the solved problem. These files can be further converted to excel files for easy interpretation of the results for different requirements (drivers, distributors, treatment plant operators and customers).

The complete mathematical formulation of this optimization problem and detailed understanding of the characteristic features of the tool for efficient planning and management of tanker water supply system (an application case study) can be referred in the published research article [5].

3.3 List of inputs required for the tools

The optimizer in the tool requires input text files (.txt) containing algorithm input data structures (elucidated in earlier deliverable D3.1 document) having data of water sources location, distributors location, tankers availability, treatment facilities, customer location and demands. The input data structure is organized in rows and columns of each table to define details of water sources (location longitudes, region, source type), consumers (location longitudes, customer type, demands, delivery timings), distributors (location longitudes, region, tanker availability), tankers (average speed, average mileage, capacity) and water treatment plants (location longitudes, treatment capacity, raw water and treated water reservoir capacities) respectively.

3.4 Software and hardware considered in the tools

It is purely software based tool that requires internet server for data input and results output in the LOTUS platform and a MILP optimization problem solver (current version of algorithm uses Xpress MP solver of FICO optimizer). FICO is a commercial optimization solver having license requirements. Other alternatives can be GAMS optimization software.

3.5 Frequency of the tools to be utilized

Can be run on daily/weekly basis.

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4 Use case 4: River water and Groundwater quality monitoring

4.1 List of tools developed

The transient state MODFLOW and MT3DMS model will be calibrated and validated using inbuilt algorithms of software (viz. FREEWAT or GMS) for monitoring groundwater quality at Guwahati city.

4.2 Approach of the proposed tools

For both cases the approach is a five-stage action comprising:

1. AS per specification of smart sensors, groundwater table calibration and validation with monitoring wells using groundwater modelling software;
2. For river water quality monitoring, integrate the LOTUS sensors with a common probe with the wireless communication capability and IOT functionality;
3. Data collections at set time intervals and over a period of varied season viz., summer / winter / monsoon round the year;
4. Data transmission to the central server on a real time basis (per hr for river water quality monitoring and per week for groundwater quality monitoring);
5. Data validation, modelling and management and broadcasting for the key stake holders for a suitable remedial action (e.g. stopping illegally released effluents over open land, or the use of certain chemicals or untreated industrial waste water in river).

Essential site identified for sensor placement shown in figure 2 and table 2. Based on groundwater quality measurement and water quality index, the eight places were identified for LOTUS sensor placement.

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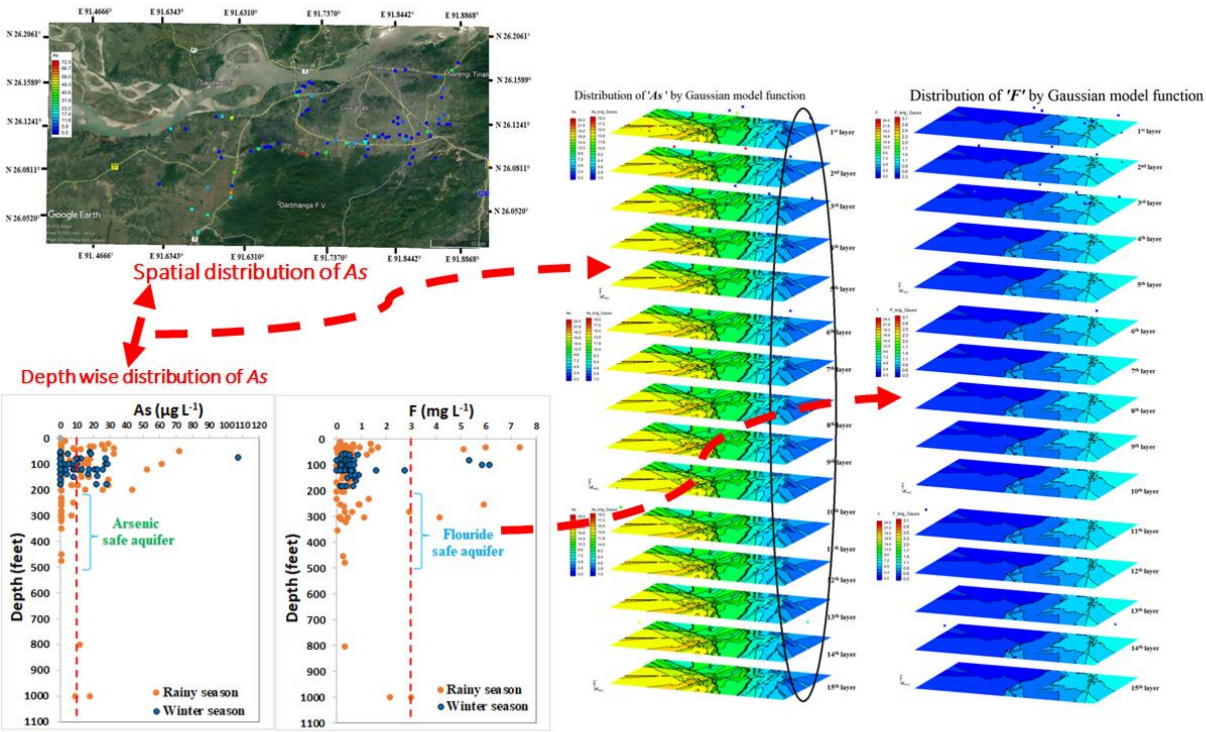

Figure 2 Plausible sites for sensor placement in Guwahati for ground water monitoring

Table 2 Plausible sites for LOTUS sensor placement for ground water monitoring

Sample ID	Latitude	Longitude	Total *As* (µg L^{-1})	Electrical power	Internet connectivity	Sensor placement
G2	26.0703	91.5809	13.7			
G3	26.0436	91.5816	28.3			Mandatory
G4	26.0272	91.5707	17.2			
G5	26.0028	91.5476	11.3			
G6	26.0489	91.5645	21.3			
G8	26.1260	91.5410	14.9			
G11	26.1380	91.5959	17.2			
G12	26.1370	91.6060	52			Mandatory
G14	26.0845	91.6092	43			Mandatory
G16	26.0650	91.6060	61			Mandatory
G17	26.0608	91.6053	14.6			
G19	26.1073	91.6349	24.6			
G25	26.1028	91.6818	71.3			Mandatory
G26	26.1047	9.7064	31.6			
G30	26.1091	91.7504	11.8			
G34	26.1597	91.6753	28.6			
G41	26.1588	91.6910	12.1			

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G42	26.1584	91.6909	16.7			
G49	26.1143	91.7283	24.9			
G50	26.1132	91.7343	10.3			
G51	26.1137	91.7486	26.3			
G52	26.1154	91.7485	19.5			
G53	26.1154	91.7475	16.2			
G57	26.1202	91.7578	17.4			
G64	26.1256	91.8140	28.5			
G73	26.0919	91.7956	31.6			Mandatory
G82	26.1081	91.8097	12			
2G9	26.0919	91.7956	12.8			
2G10	26.1081	91.8097	26.8			
2G12	26.1097	91.8036	107.4			Mandatory
2G14	26.1150	91.7983	17.4			
2G16	26.1169	91.7867	16.4			
2G17	26.1222	91.8033	17.3			
2G19	26.1192	91.7978	12.6			
2G21	26.1269	91.8033	27.4			
2G22	26.1267	91.8033	20.4			
2G23	26.1308	91.7736	11.9			
2G24	26.1328	91.7736	25.5			
2G25	26.1325	91.7822	27.2			
2G27	26.1347	91.7778	28.4			Mandatory
2G28	26.1342	91.7775	22.0			
2G29	26.1094	91.7742	21.8			
2G30	26.1156	91.7731	21.5			
2G34	26.1689	91.6735	17.9			
2G50	26.1691	91.6841	13.9			

4.3 List of inputs required for the tools

Following input are required for river water quality monitoring and groundwater quality monitoring tool are;

1. On field measured river water quality parameters
2. Groundwater table and concentration of arsenic and fluoride (once in a two week) at observation well station

One-time input data needed for the preparation of model;

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1. Bore well lithology in the study area (from representative area)
2. Meteorological data (viz. rainfall, humidity, temperature, infiltration rate, evapotranspiration rate)
3. Concentration of arsenic and fluoride at observation wells for initial conditions and model preparation

4.4 Software and hardware considered in the tools

1. Sample collection tool and sensor required to monitor river water quality monitoring
2. Software needed are FREEWAT and GMS (i.e. groundwater modelling system) for prediction of groundwater quality monitoring

4.5 Frequency of the tools to be utilized

1. River water quality is required to monitor at an interval of 24 hours
2. Groundwater quality is required to monitor at an interval once after a two week

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