Participatory Groundwater Mapping

Aquifer systems: Surface Subsurface water interaction

Case study

Living Lab in

Devanahalli

Ayushi Biswas

Hydrogeologist

Biome Environmental Trust

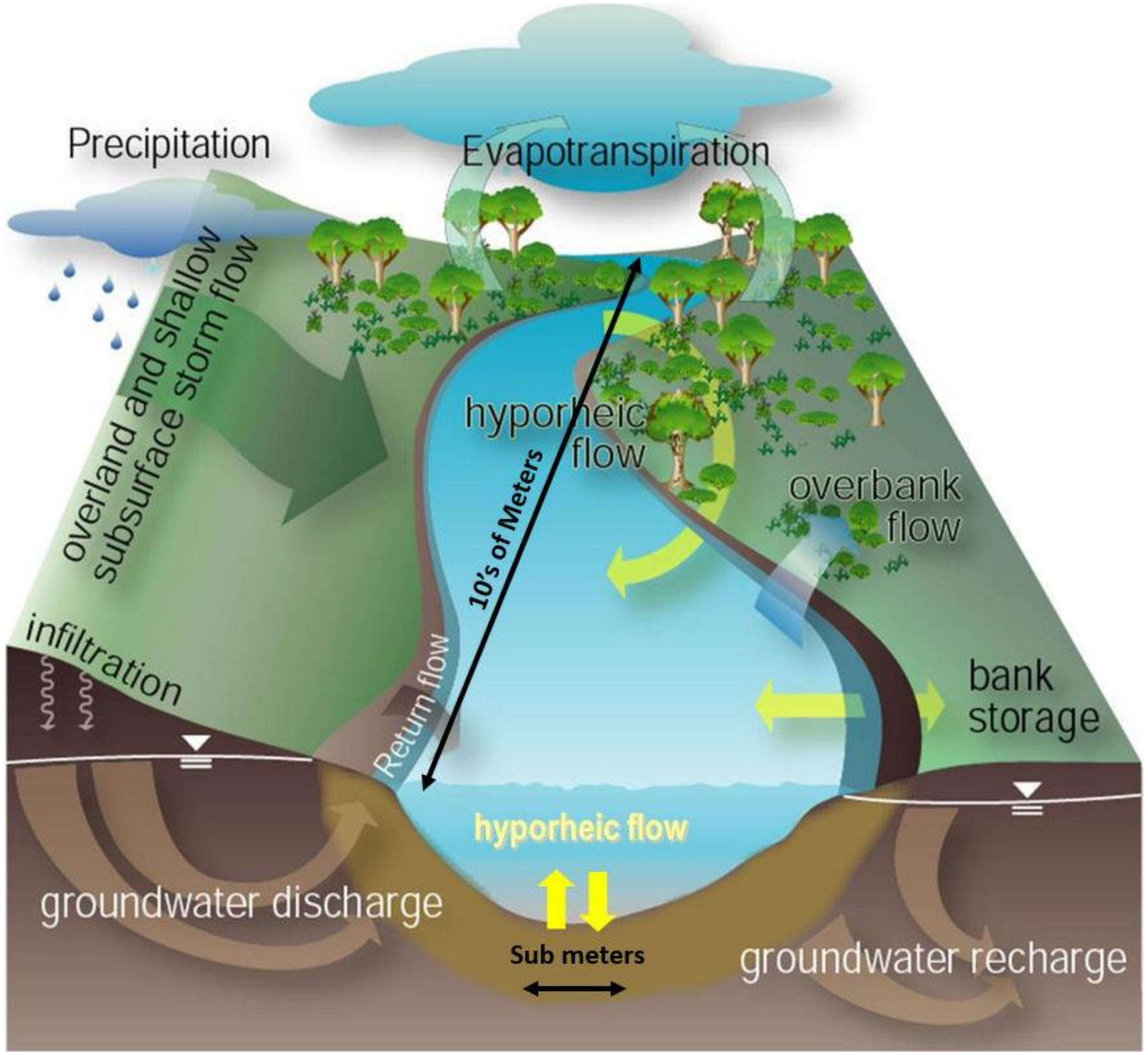
Bengaluru

Content of the presentation

- Surface water bodies interaction with Subsurface groundwater (aquifers)
    - Gaining and Loosing Streams/Lakes
- Case Study - Devanahalli
    - Context - Challanges
    - Quick glance at Devanahalli's Aquifer system
    - Karnataka's Treated used water - Lift irrigation project
    - Overview of Shallow Aquifer - Water System - integrated to Town's water supply
    - **Living Lab in Devanahalli - Participatory Groundwater Mapping**
        - Instrumentation
        - Catchment: Mapping and Characterization
        - Aquifer: Mapping and Characterization
        - Water quality

Surface waterbody and Subsurface ground water - Interaction

- Surface water and groundwater are part of one connected hydrological system.
- Water moves continuously between rivers, lakes, wetlands, and the groundwater system.
- This exchange is important because it supports water availability, water quality, and ecosystem health.
- In India, this is especially relevant because groundwater is heavily relied upon for drinking water, irrigation, and urban supply.
- Understanding the link between surface water and groundwater is essential for better management.



- Figure 1 – Schematic of a river systems with groundwater exchange (hyporheic flow) at the 10's of meters to sub-meter scale (modified from USGS, 2015) Image Ref: Groundwater Project

- Gaining (effluent): groundwater discharges to the stream; supports baseflow.
- Losing (influent): stream recharges the aquifer; can be partial or full-channel loss.
- Disconnected/perched: losing stream separated from the water table by an unsaturated zone; leakage still possible.

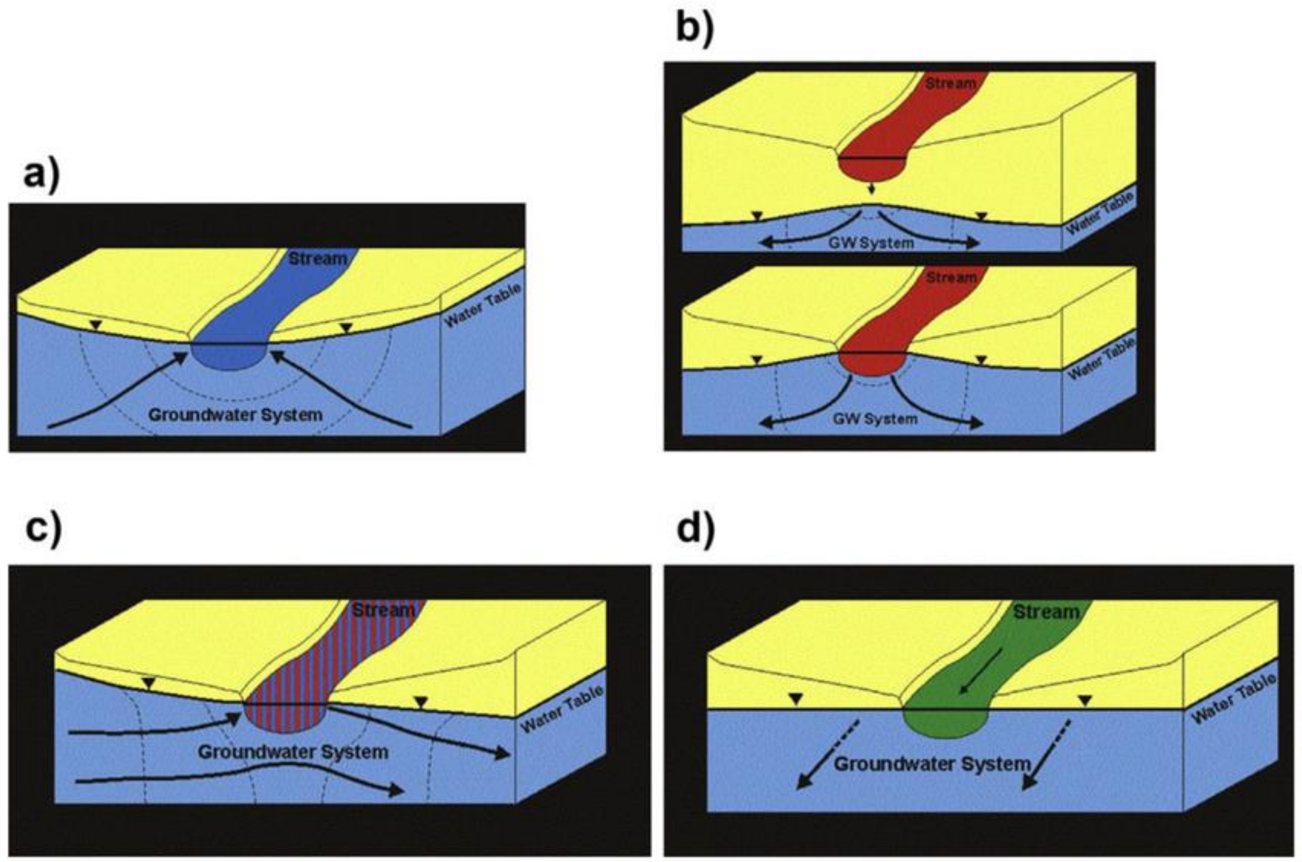


Figure 2 – Conceptual models of groundwater stream exchange. a) Effluent conditions (gaining stream); b) Influent conditions (losing stream); c) Flow-through conditions (flow-through stream); d) Parallel flow conditions, zero-exchange stream (Anderson et al., 2015).

- Hydraulic gradients: surface-water stage vs groundwater head; 3-D gradient distribution sets direction/magnitude.
- Aquifer & sediment properties: heterogeneity/anisotropy; hydraulic conductivity of bed/bottom deposits (often fine, organic-rich).
- Geomorphology: valley/floodplain setting, channel form, and bed/bank structure that promote local circulation.
- Hydrologic forcing & human modification: recharge patterns, pumping, reservoirs, channelization; exchange can change quickly with operations.

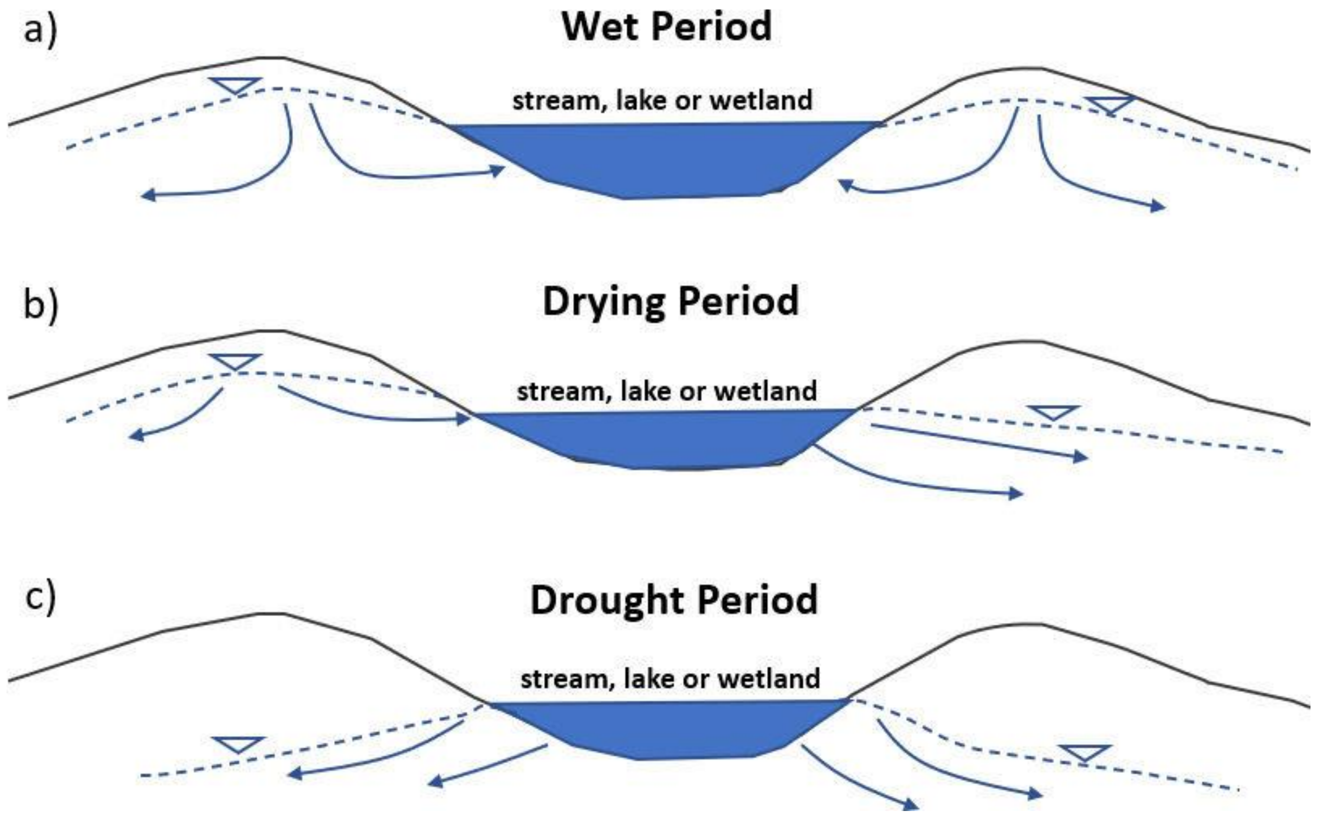


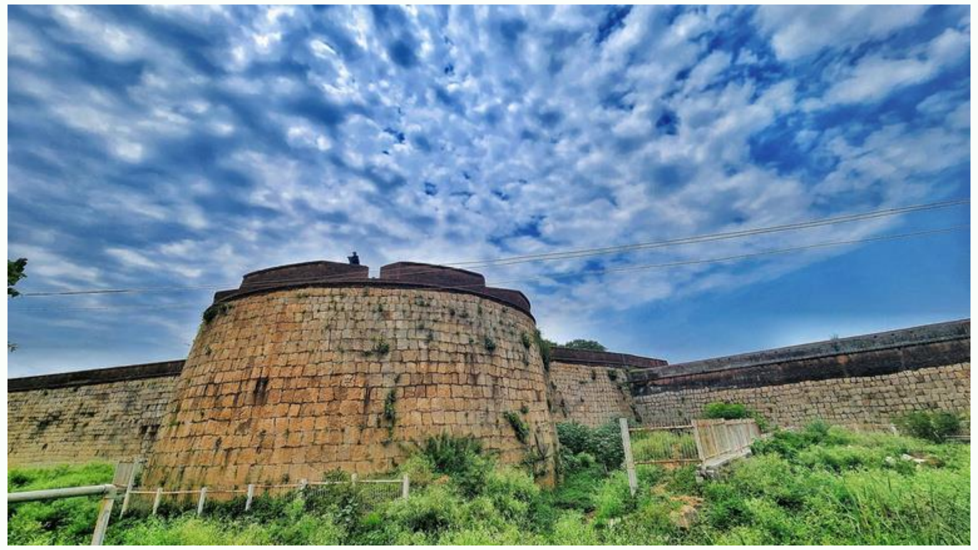
Figure 3: Seasonal variation changes the exchange process.

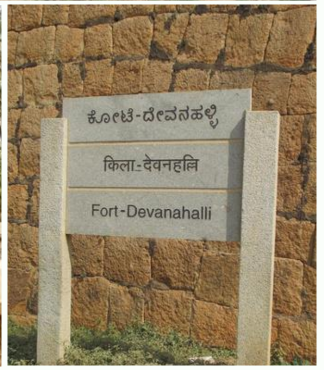
Case Study

Integrating shallow aquifer to town’s Muncipal water supply via Managed Aquifer recharge using domestic Treated-used water

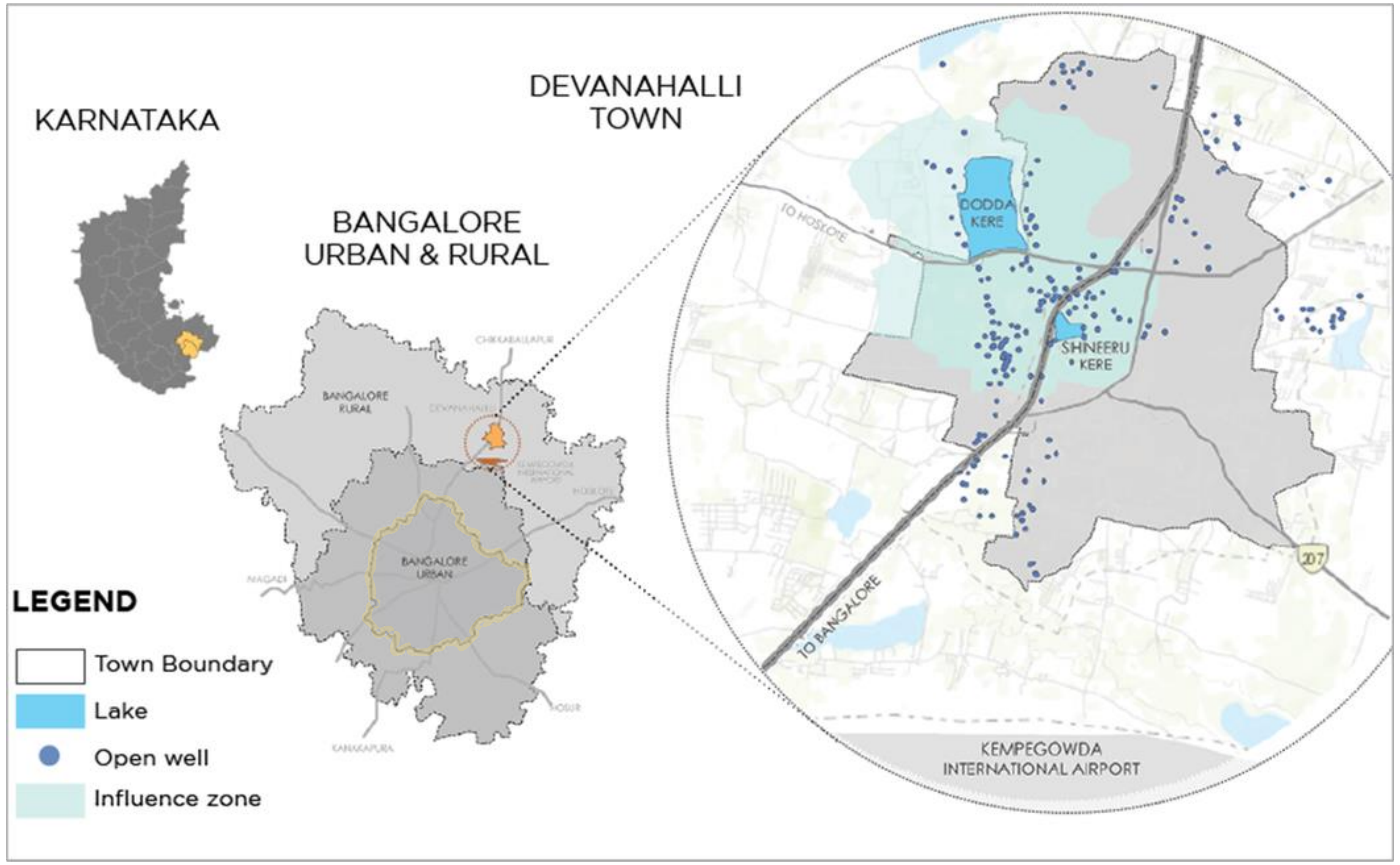
Heritage Town of Devanahalli

Chieftain Malla Byre Gowda of Avathi



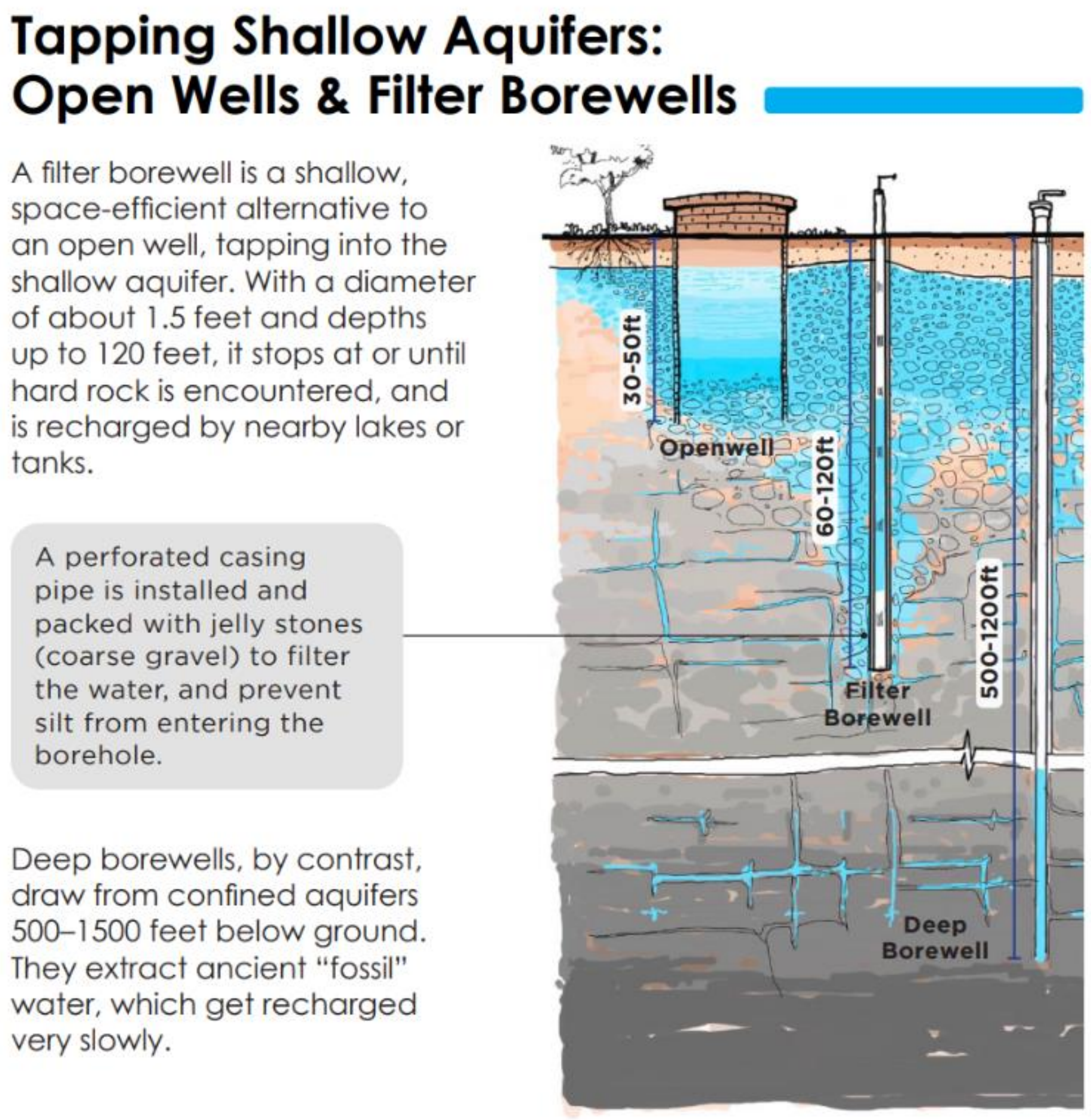


Context - Challanges



- Urban Development: The town is experiencing rapid urbanization
- Location: It is located near Bengaluru International Airport and a Special Economic Zone.
- Water Requirements: The town's current total water demand ranges from 5.4 to 6 million liters per day (MLD), serving a population of 45,000 to 48,000
- Water Source Dependence: relies entirely on deep borewells that reach depths of 1,200 to 1,500 feet and beyond.
- Borewell Functionality: Out of 132 borewells, only 92 are operational, with many producing low yields.
- Water Quality Concerns: Most water quality parameters exceed both desirable and permissible limits, including Total Dissolved Solids (TDS), Sulphates, and Chlorites, as per BIS 10500:2012 drinking water standards.
- Drinking Water Sources: The town depends on 17 reverse osmosis (RO) plants and private RO systems to meet its drinking water needs.

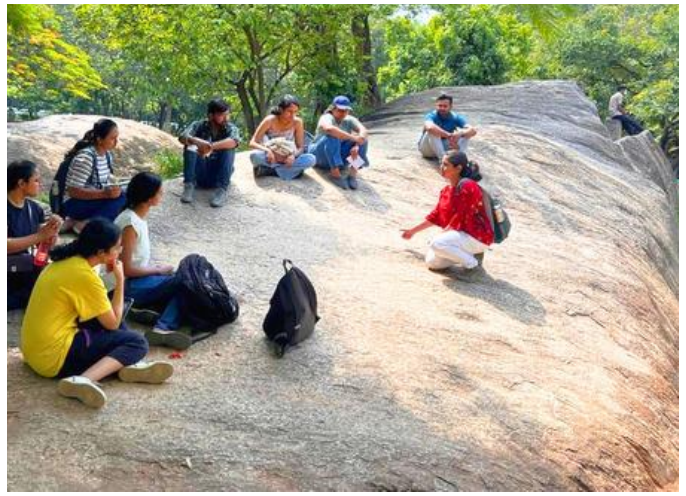
Quick Look at the Geology and aquifer systems in Devanahalli



Regolith
Top Soil

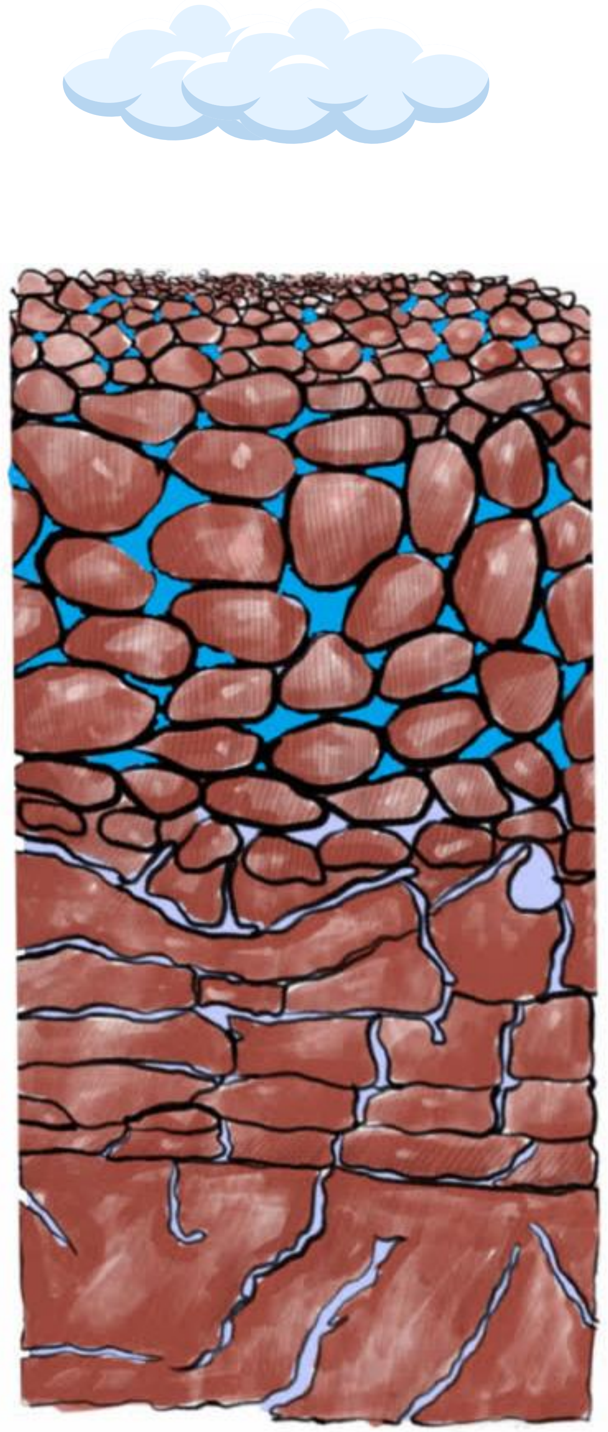
Weathered zone
Shallow Aquifer

Fissured Granite
Deep Aquifer



Basement/ Bed rock

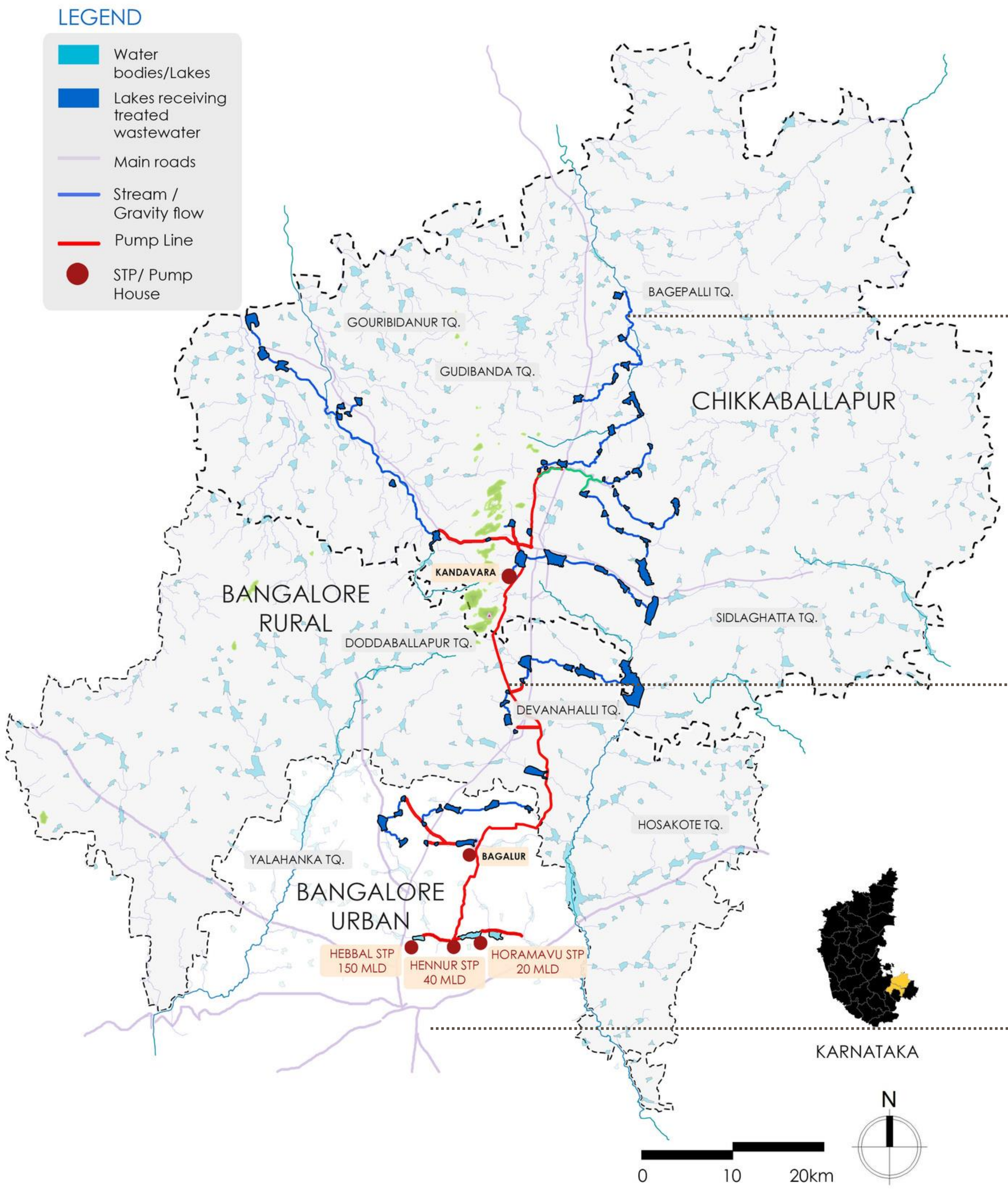
Post
Monsoon
2024



**GIF for representation purpose*

Gov of Karnataka's - Lift irrigation of domestic Secondary Treated Waste Water from Bengaluru city to several lakes in adjacent districts

Since 2020



Pumped to 69 lakes

Pumping TWW via Pipeline

Sewage Treatment Plant

Pictures for representation purpose

Impact of TWW and Rainfall filling the Lakes Increased water table in Shallow aquifer

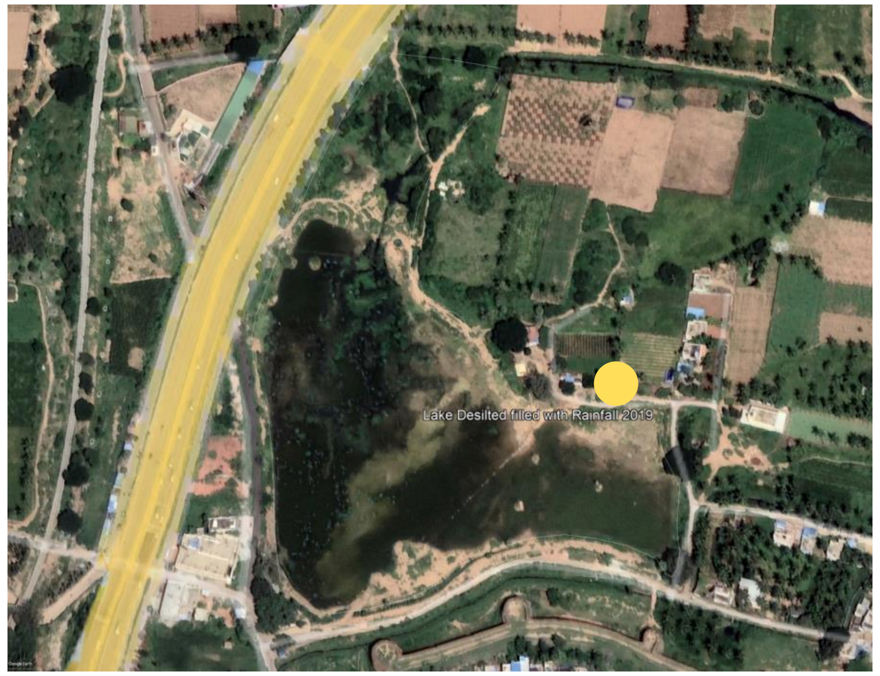
Location of Open Well wrt Lake

Lake desilted

2017

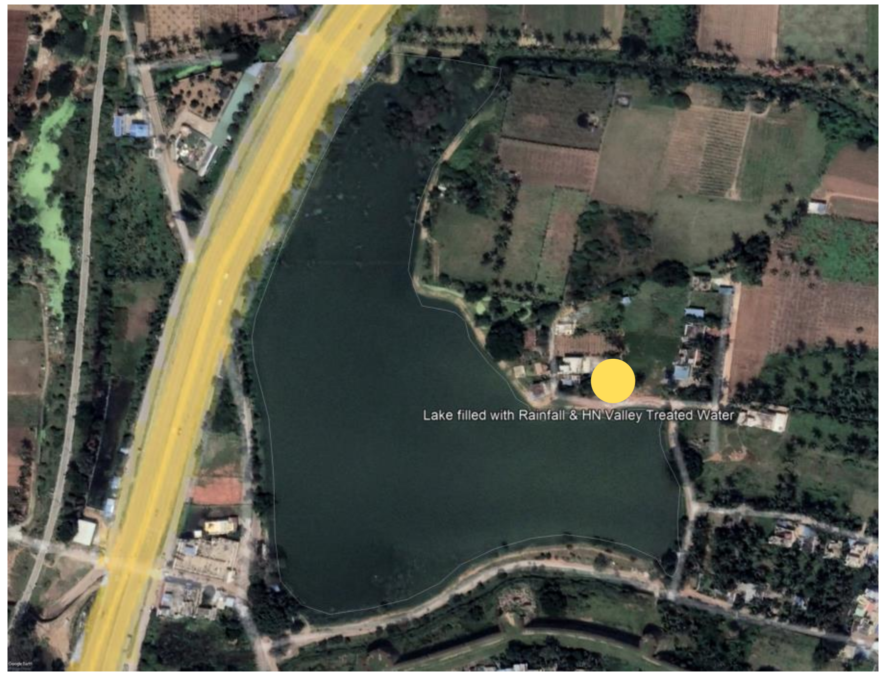
Lake filled with Rainfall runoff -

2019



Lake Filled with treated water and rainfall

2020



Similar Pattern observed for Other open wells around the lake and in the region that were dry previously.

Open well Rejuvenated

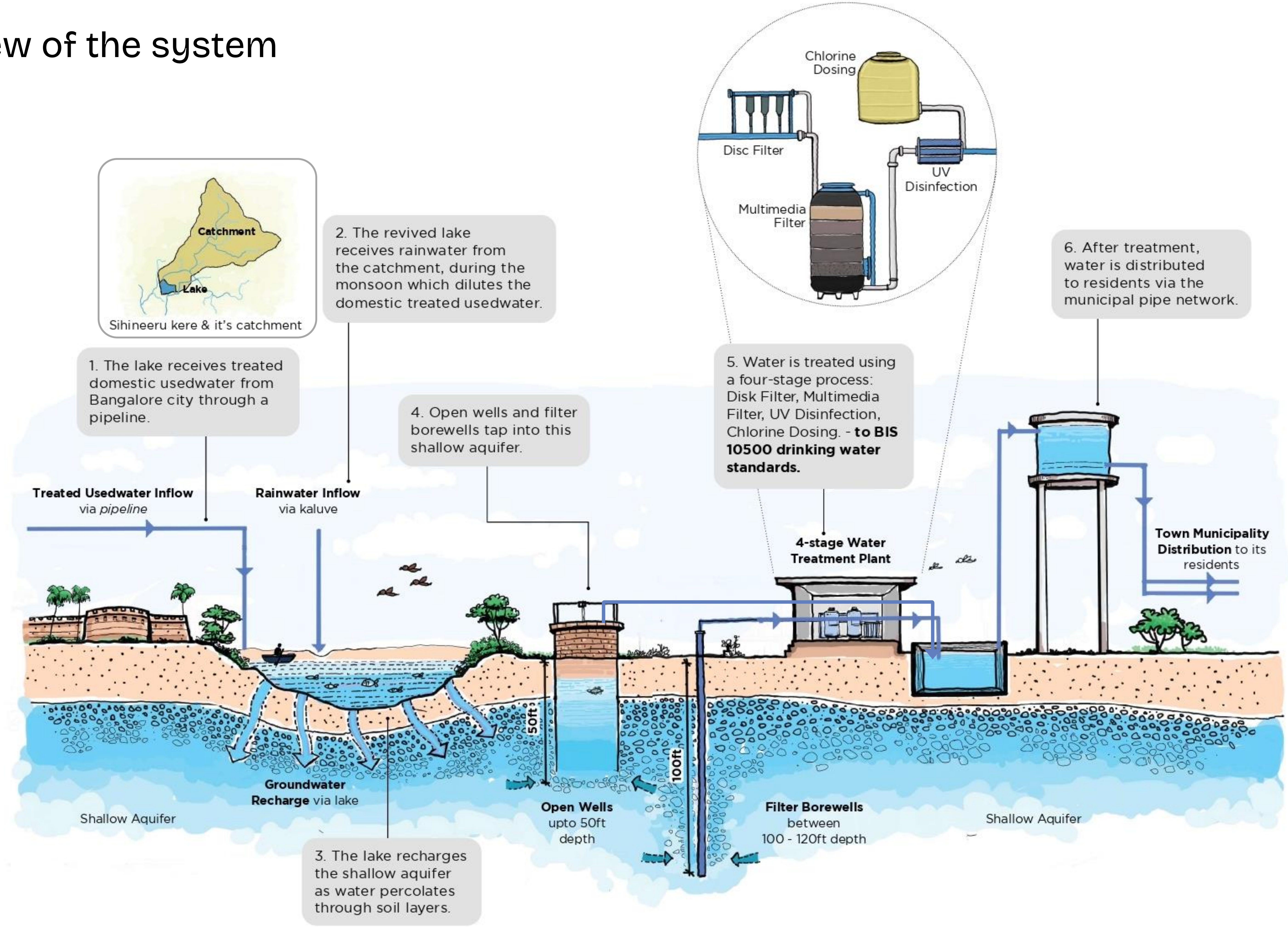
2019

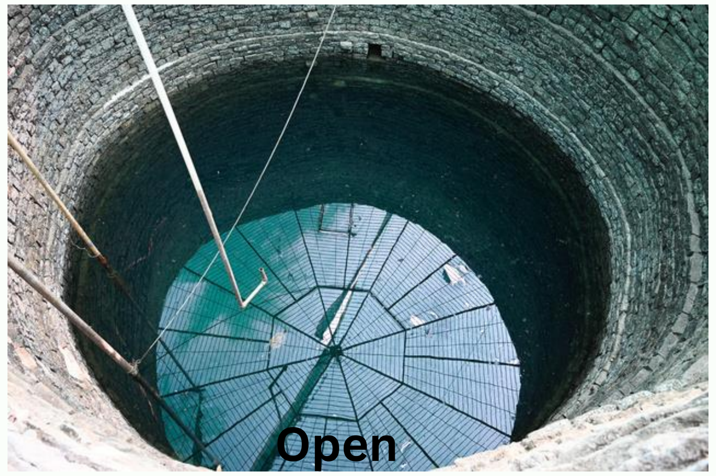
Open well water table rises:

Lake recharged shallow aquifer

2020

Overview of the system





Open
Well

Filter
Borewell

Disk
Filter

Multimedia filter
with activated charcoal

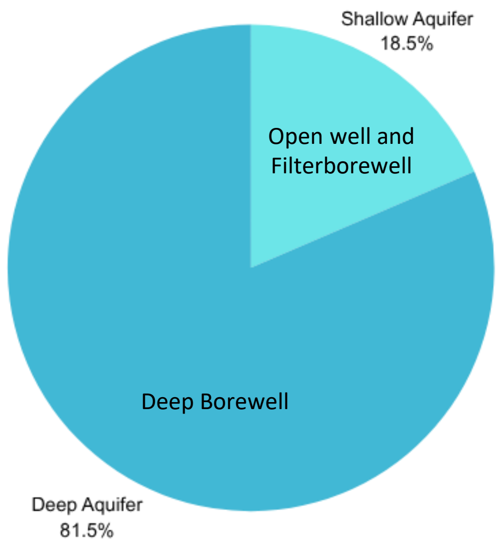
UV
Radiations

Chlorine
Dose

Overhead
Tank

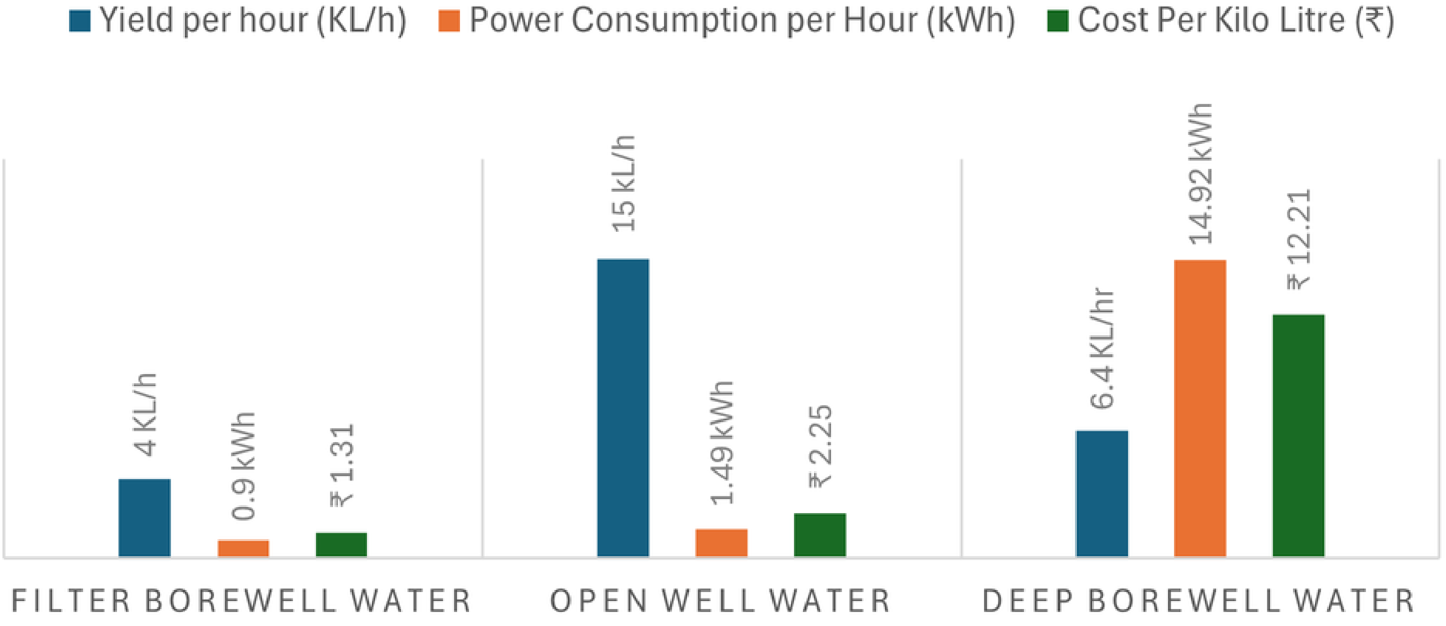
Town

Current water supply sources



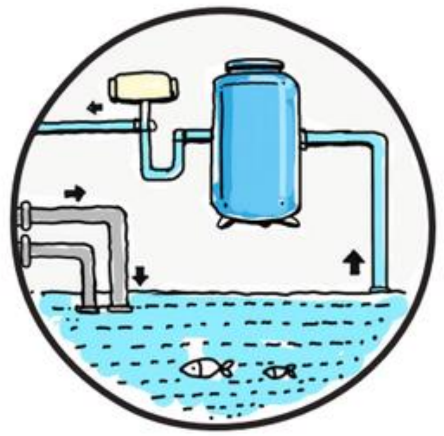
Town’s total water need:
5.4 MLD at 135 LPCD

COMPARISON OF WATER SOURCES: YIELD, ENERGY USE, AND COSTS



Diversified Integrated Water Resources

Source sustainability



A Circular Water Economy for Climate Resilience

Circular economy

Energy & Cost Savings - Climate Mitigation

Low cost of pumping water

Participatory Water Managment

Community managed & driven

Living Lab Approach

Instrumentatio n

Staff Gaguge - Lake

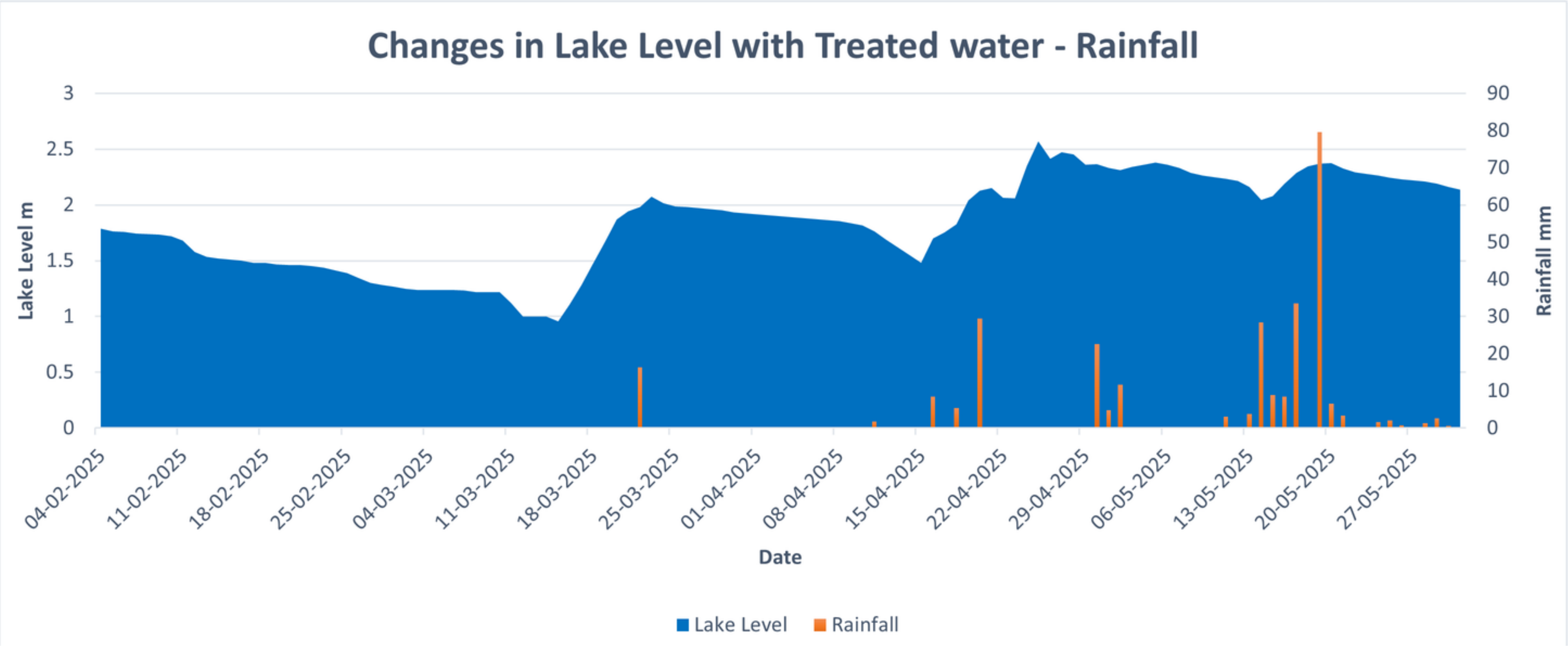
Manual - Pan Evaporimeter

Rain Gauge

Water level sensor

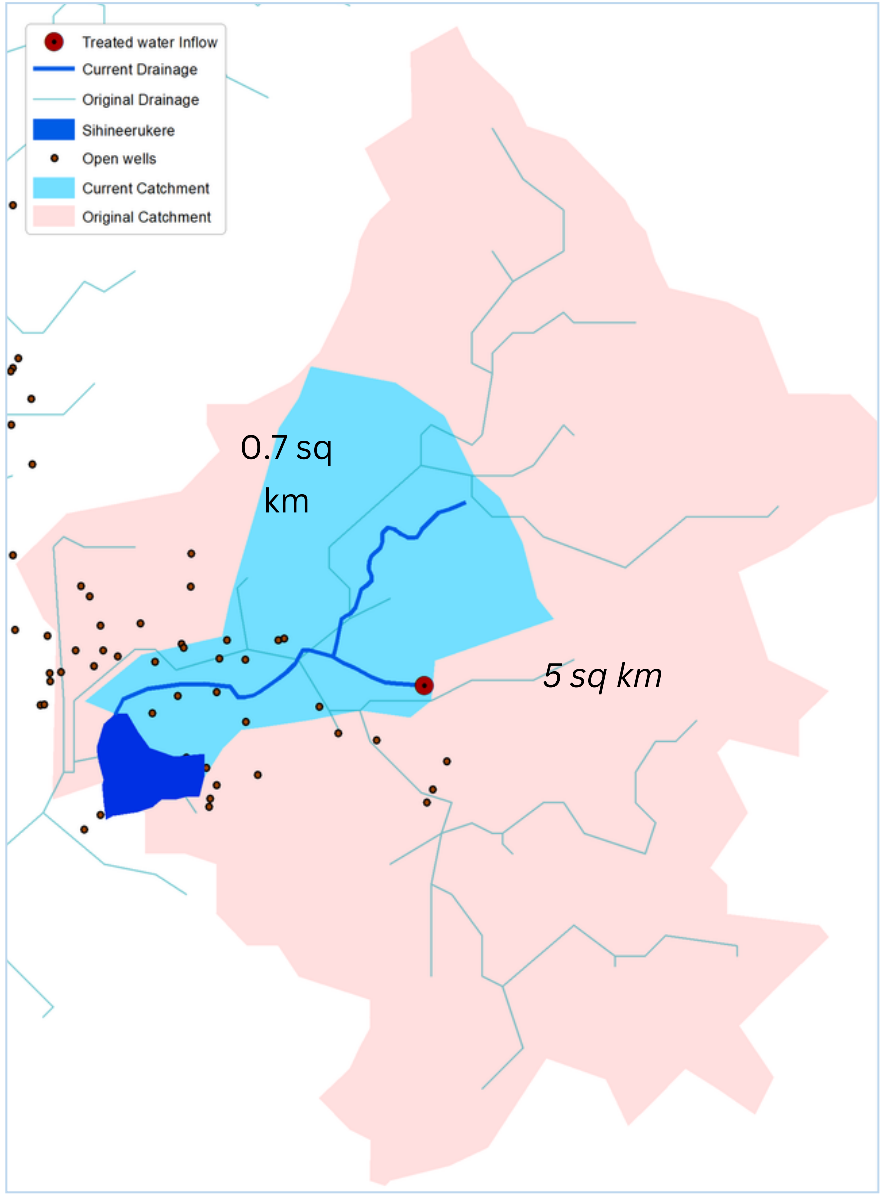
Estimate -

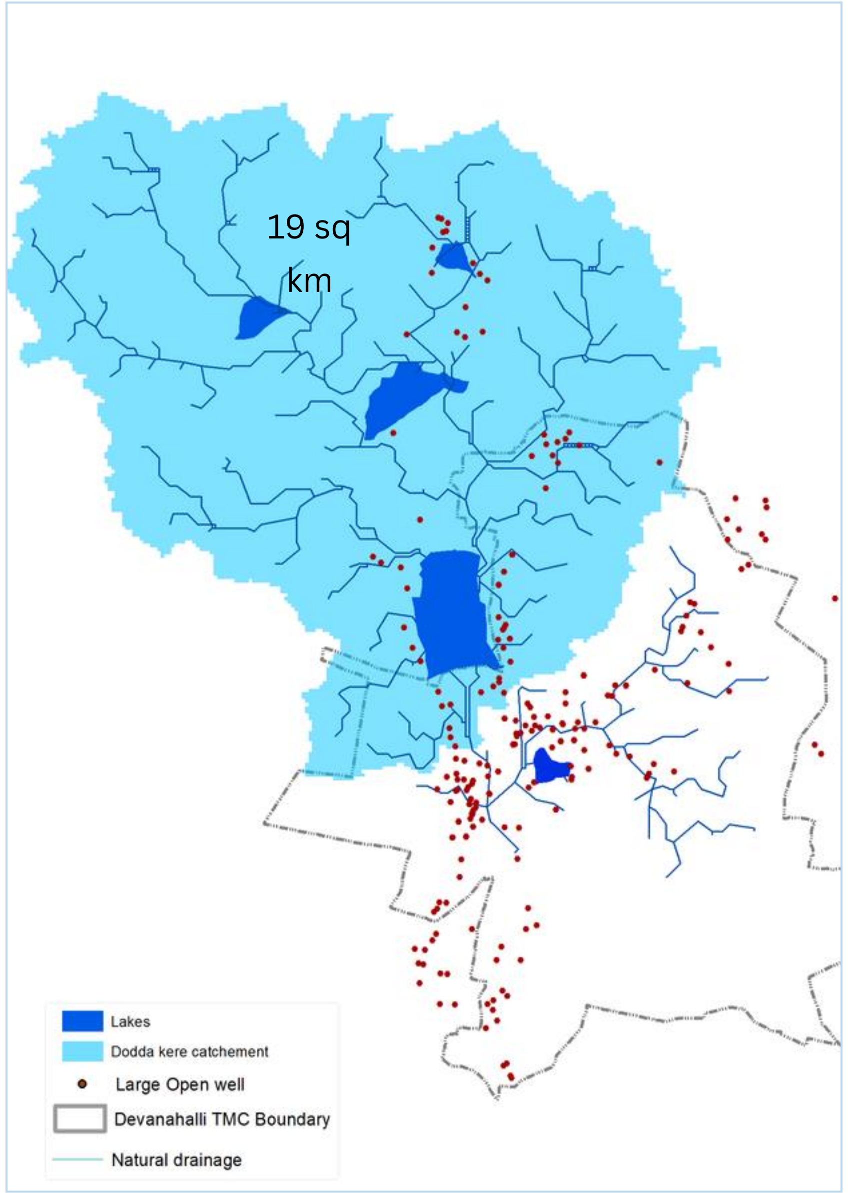
1. Change in Lake water level
2. Treated water, Rainfall and Runoff
3. Evaporation rates
4. Water levels in Open wells



Mapping the Catchment

- **Catchment**
  - Natural catchment using DEM data
  - Changes in catchment based on ground truthing
  - Runoff coeffiecients
  - Rainfall runoff





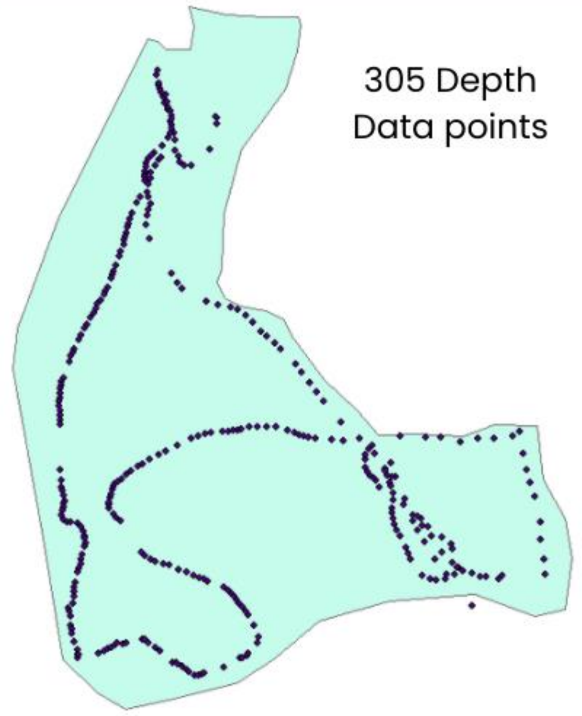
Catchment Mapping

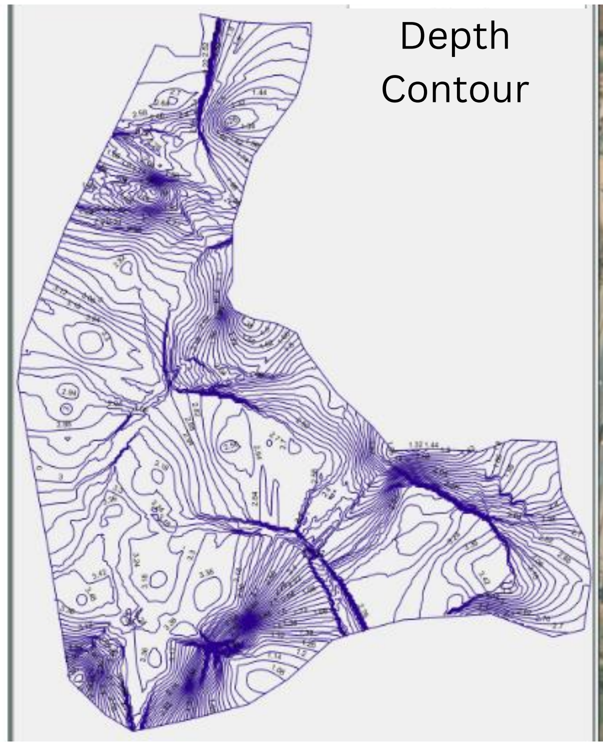
- Lake
  - Historic:
    - Inlet
    - Outlets
  - Current:
    - Inlet
    - Outlet
  - Lake Area - Satelite Data and Volume using Bathymetry

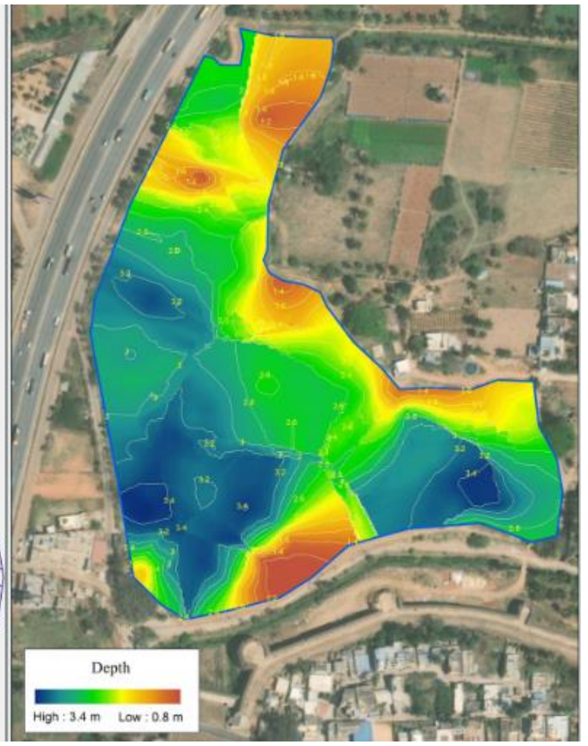
Before the Highway

After the Highway

Historical land use land cover change - Landsat Data 2001. Change in the Lakes' s Hydrology, Inlet outlet system, and surrounding Land use land cover







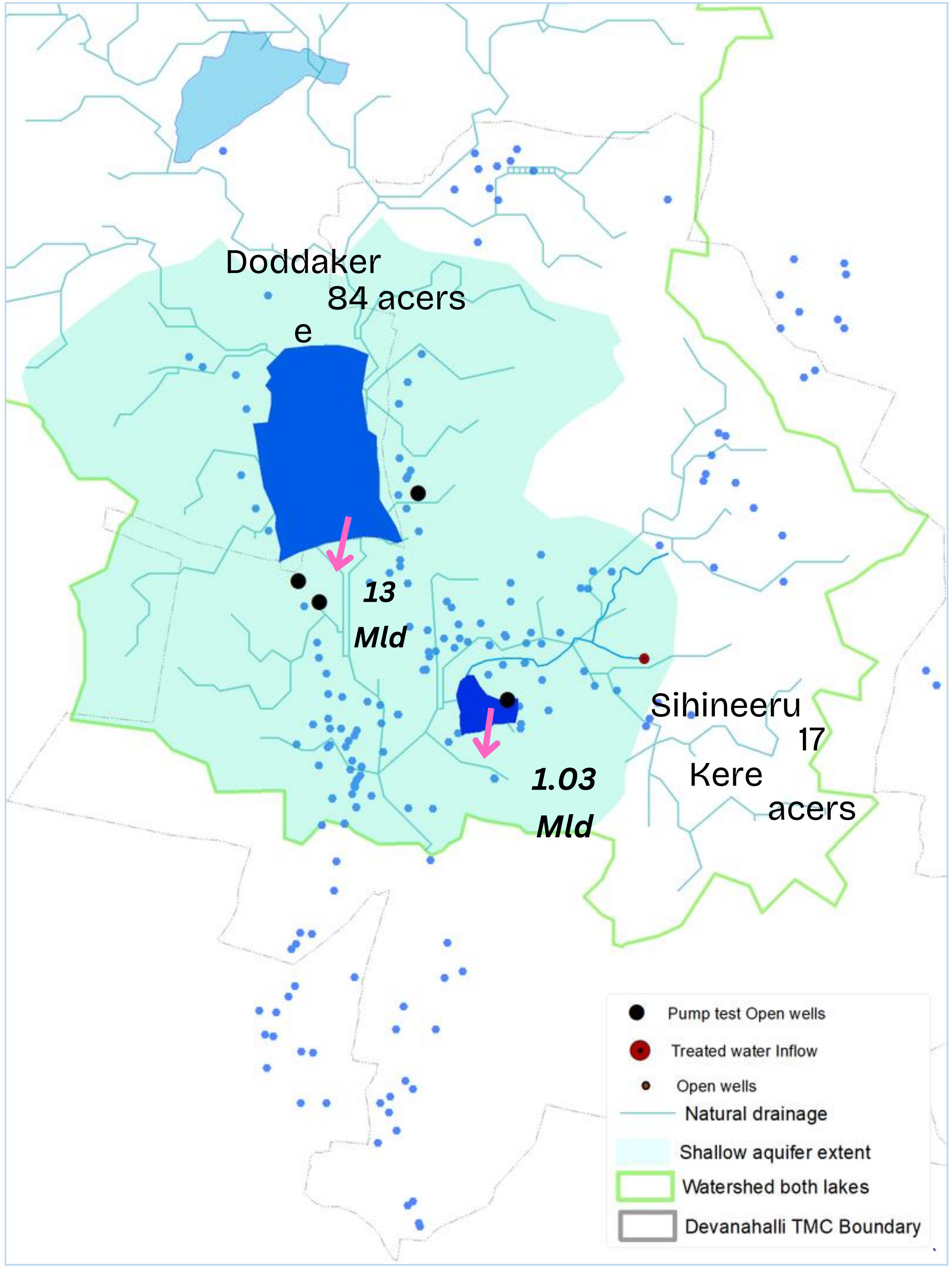
Lake Bathymetry with Fisherman and Pumphouse operator

Recharge rate and Volume

Recharge Rate: 15mm/sqm to 27mm/sq m based on water level in lake.

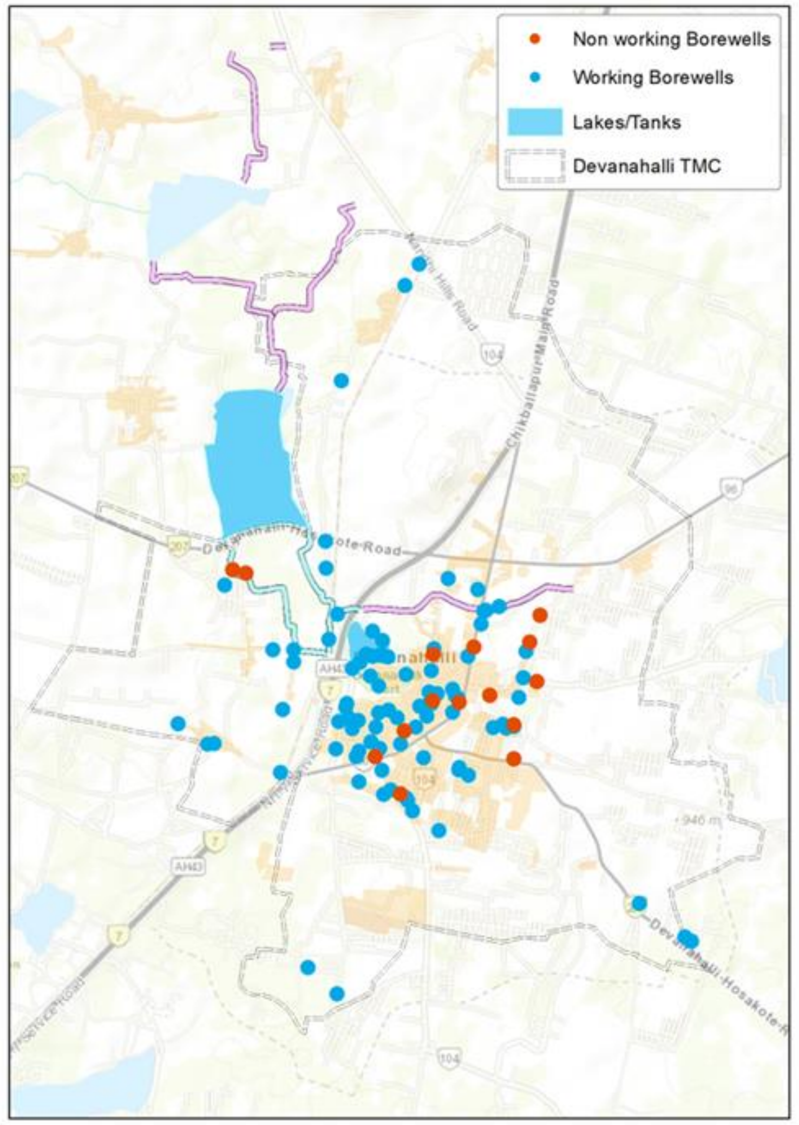
Sihineeru kere - Annual average 1.03ML/Day

Dodda kere - Annaual average 13 ML/day

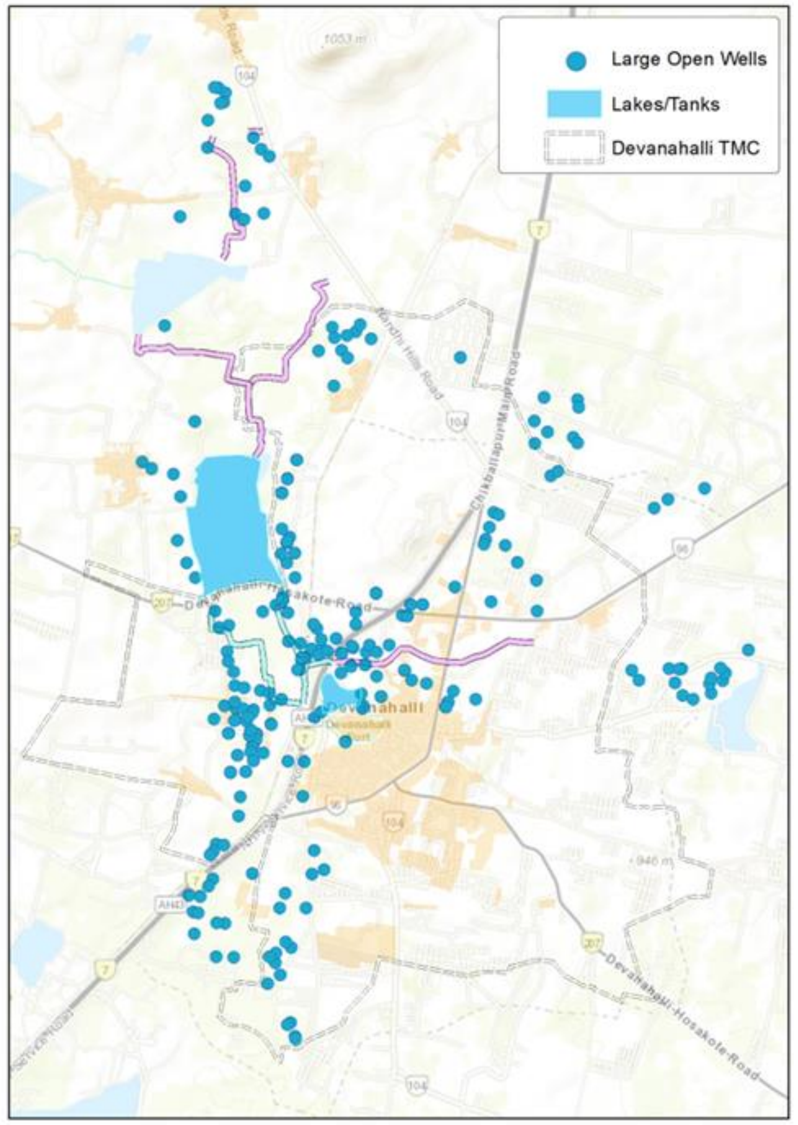


Aquifer Mapping

Well Inventory - Open and Deep bore wells in Town



132 deep borewells – 32 non working



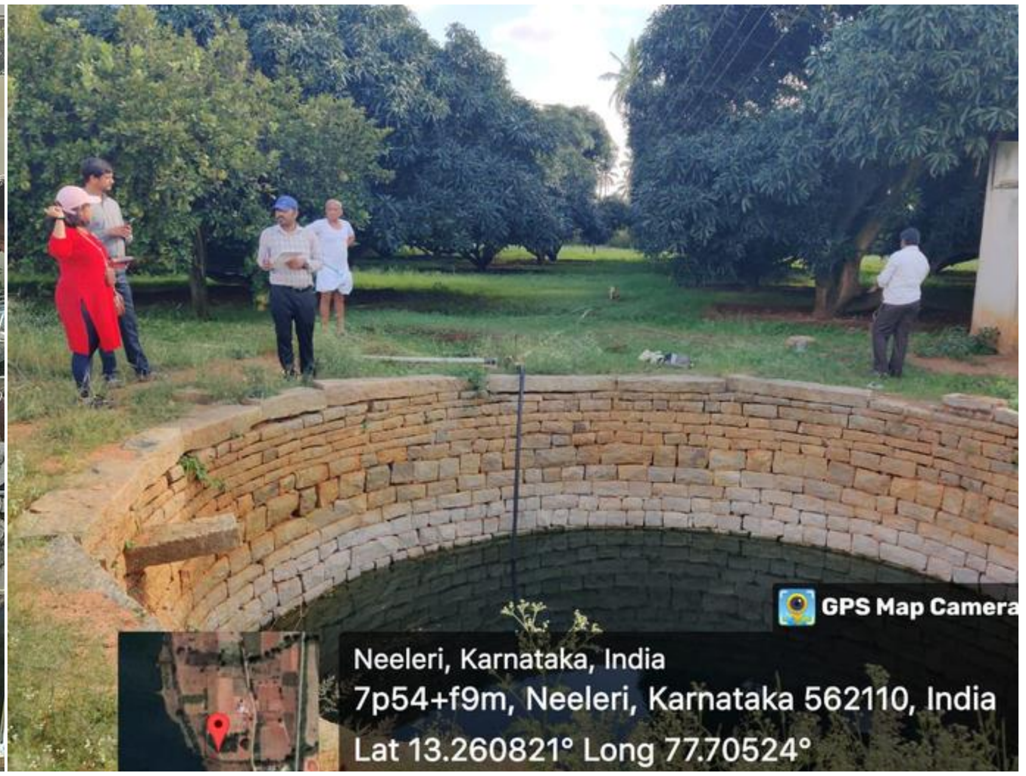
200 Large irrigation Open wells

watermen of each ward in town sharing on ground observations and understandings of groundwater

Borewell data from TMC Data base, Open well Data from Satellite data and ground data

Aquifer Mapping

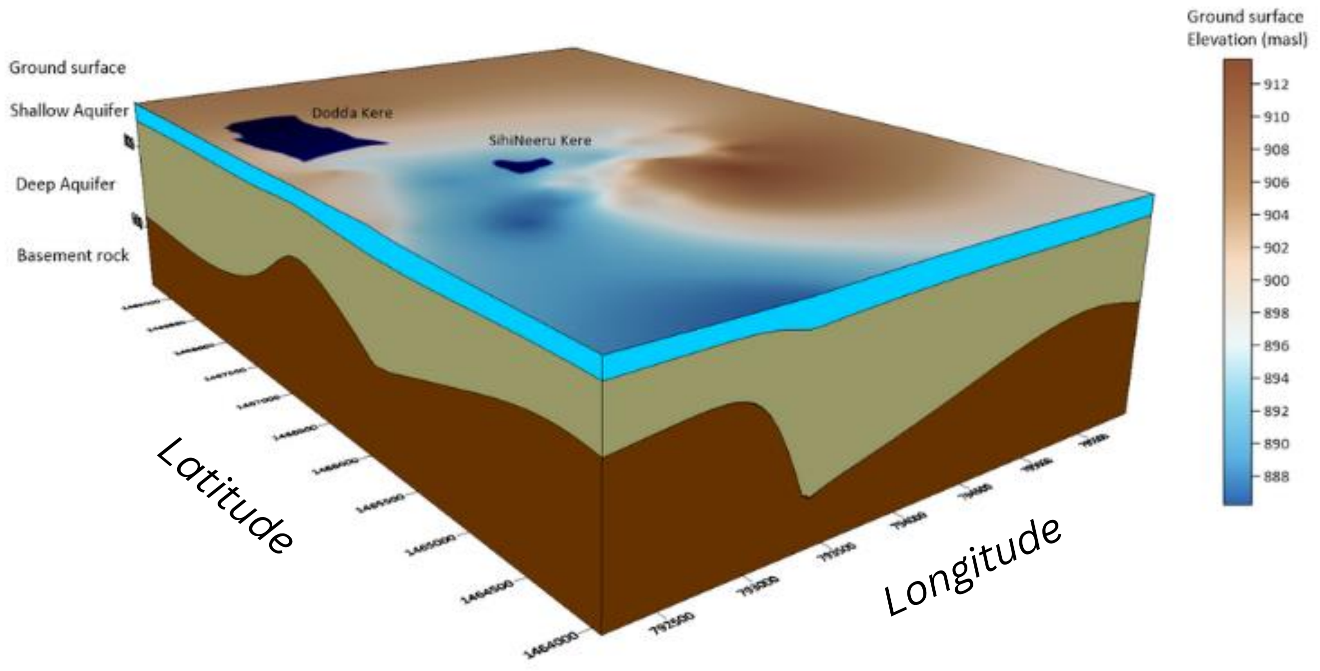
Open well and Borewell inventory, data collection, conducting Pump and yield tests - with Watermen, Pump house operators, Borewell and filter borewell drillers, Traditional well diggers, Community members - Farmers, local residents, ward members, TMC Engineer and other staff.



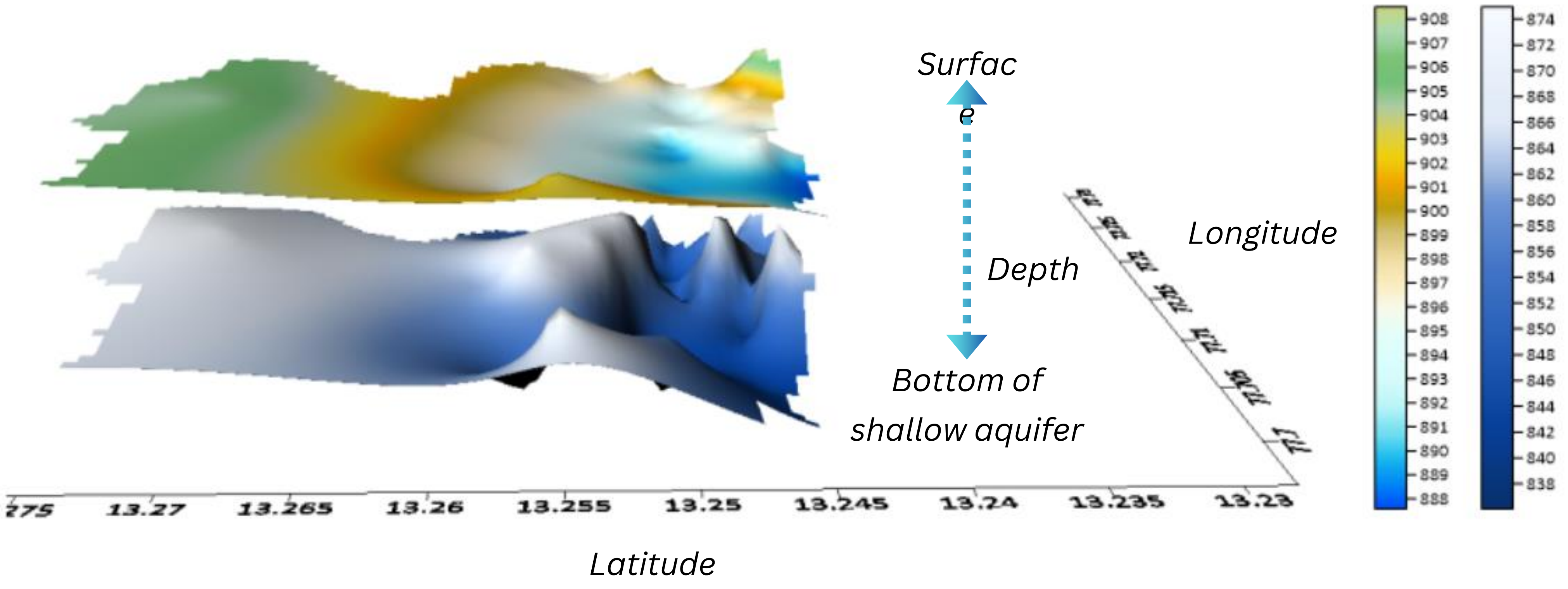
Aquifer Mapping

Area, Depth, and

Volume



3D diagram representation of Aquifer system of Shallow and Deep Aquifer in Devanahalli Town



Shallow aquifer volume obtained using well inventory of 132 Borewells

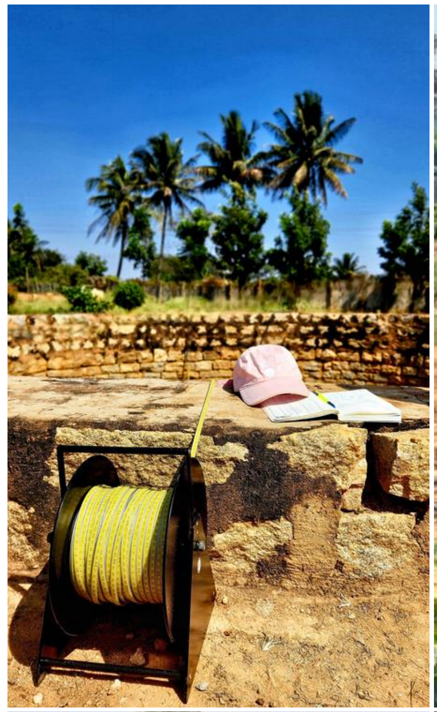
Aquifer charecterization

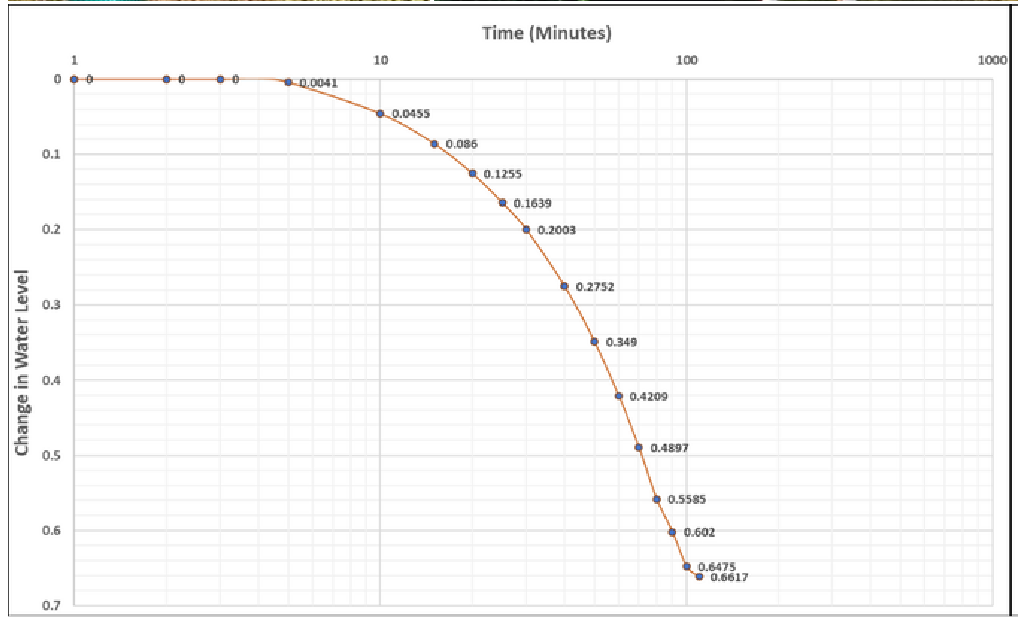
Pumptest and sustainable Yield test

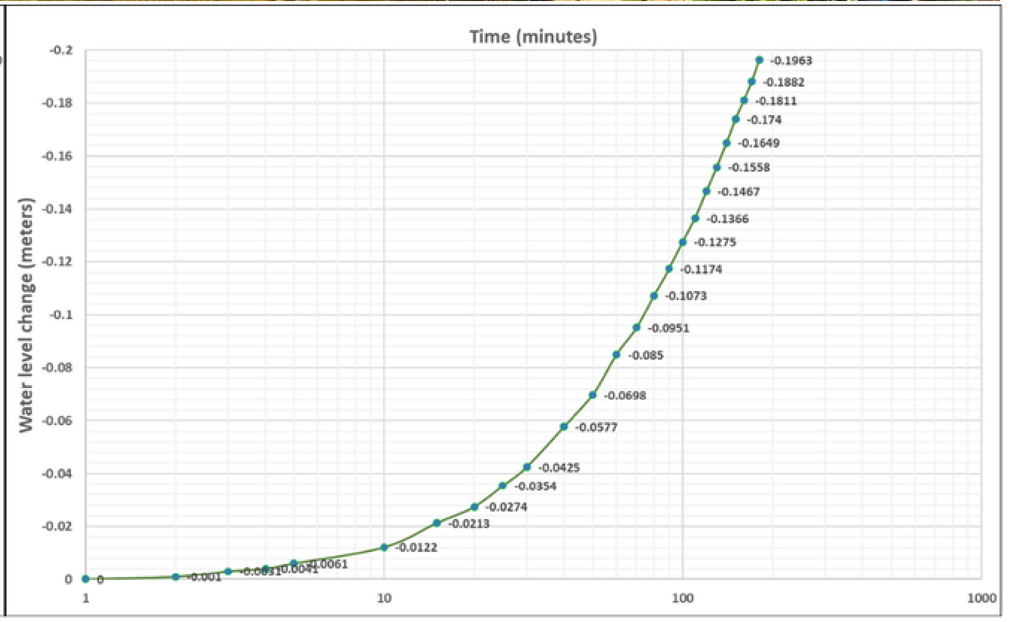
Aquifer parameters

- Storativity (Specific yield
- Transmissivity
- Sustainable yield from Open wells
- and filter borewells

- Total Aquifer Spatial extent: 8 sq km
- Depth max: 36.5m (120 Feet)
- Storativity - 8% to 11%
- Aquifer water holding capacity - 21,000 Mil Liters



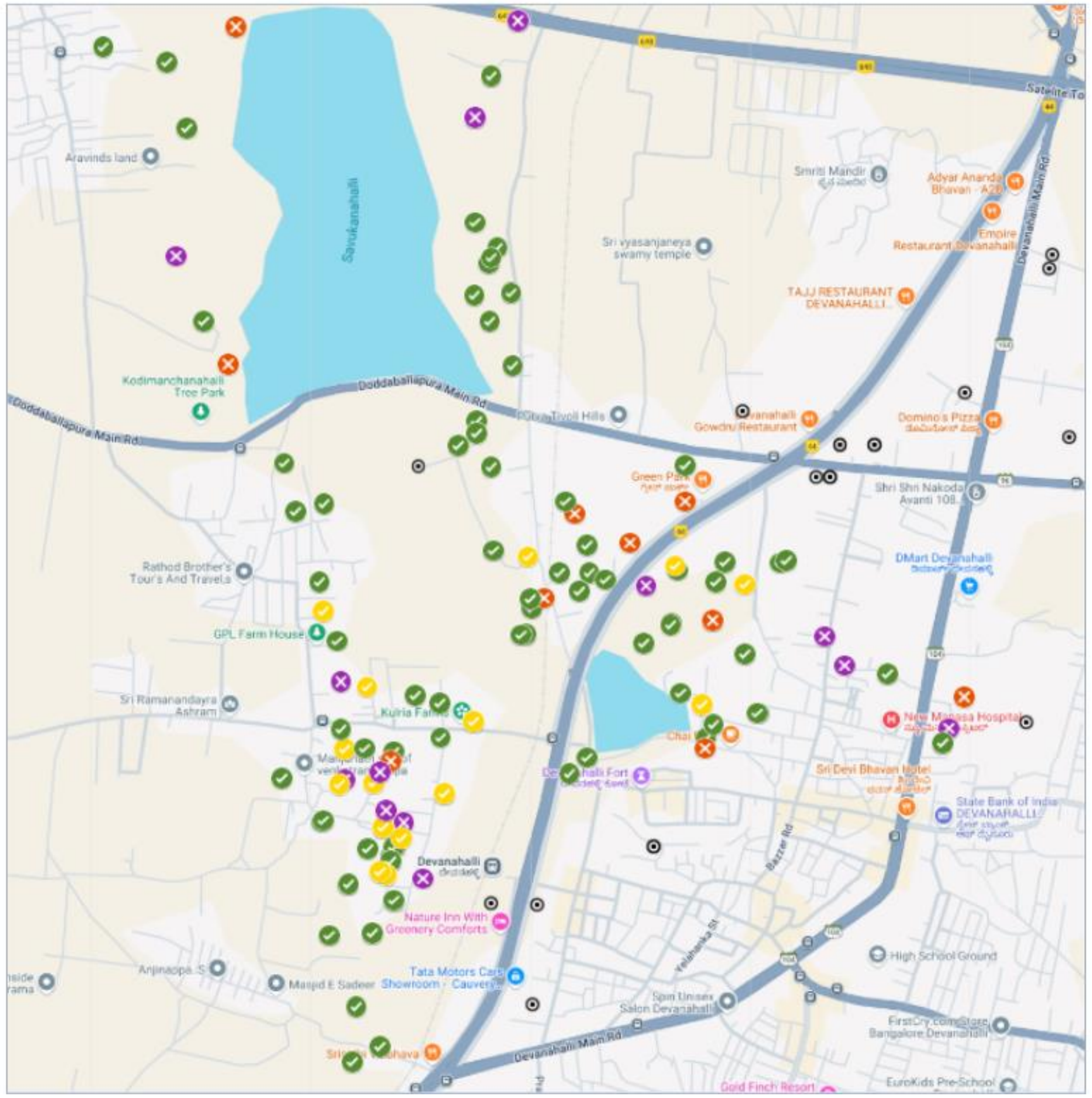


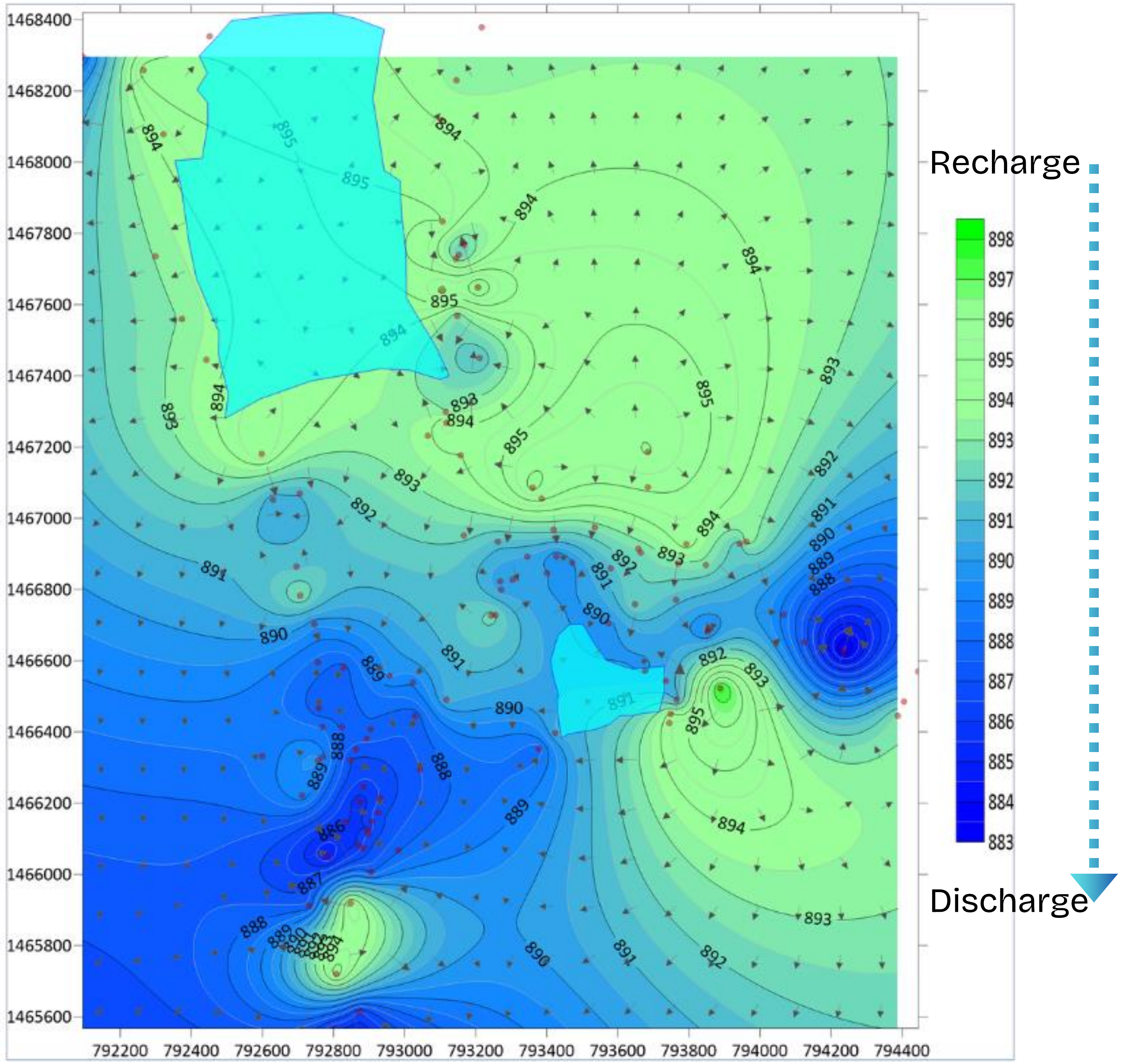


Groundwater Movement in shallow aquifer

Water Table Contour, Identify Recharge and Discharge zones

Open wells	Number
surveyed	107
Water level	69
Closed	13
Not Rechable	10
Dry	15





Water quality data

All water sources are sampled - Lake, Open wells, Filter borewells, Water treatment plant, deep borewells

- Biome and TMC - Monthly Water quality tests - BIS 10500 2012
- IISc - Quaterly Water Quality tests BIS 10500 2012
- Biome and TMC - 90 parameters water quality tests





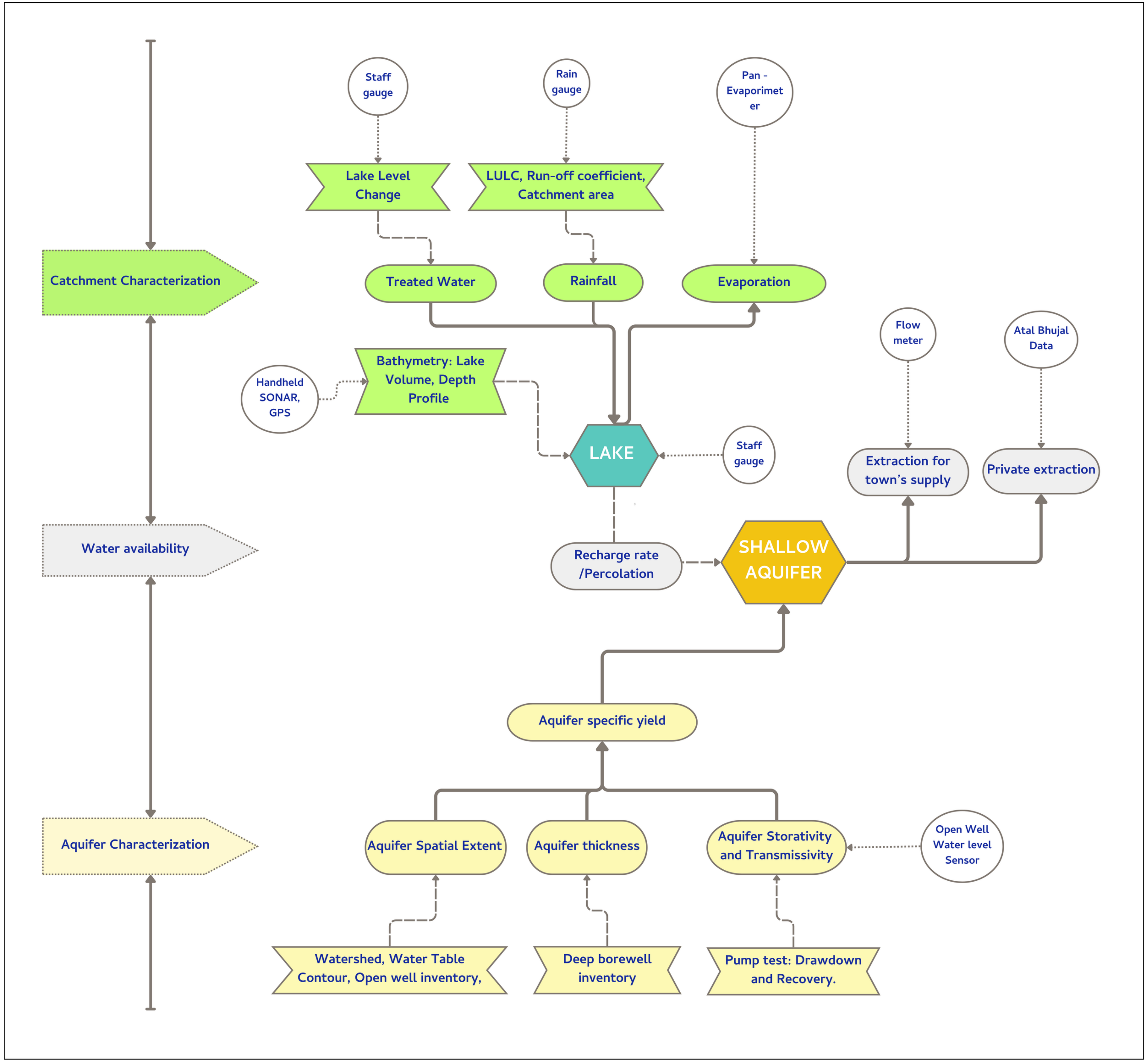
Ensuring - WTP Output is BIS 10500 Drinking water standard.
No concerns around heavy metal, TDS, Nitrate, or other chemical is observed over 2 years.
Microbial contamination is present and requires UV and chlorination for disinfection.

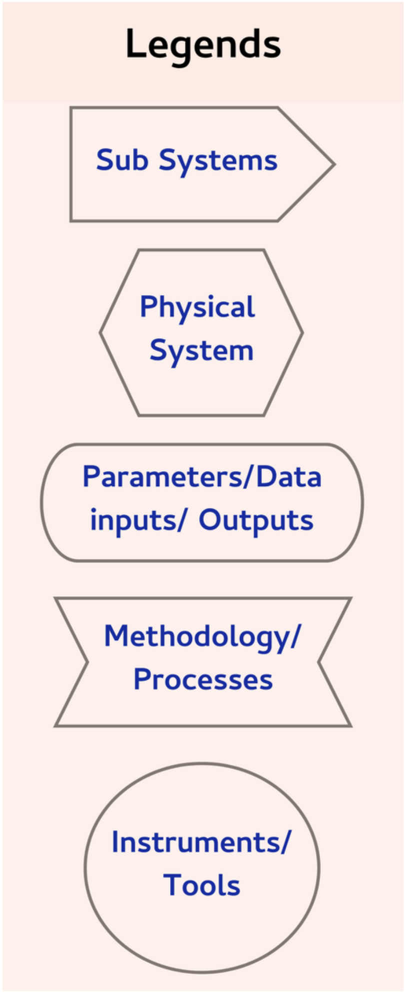
Summary - Living Lab

Catchment	Sihineeru Kere	0.7 sq km
	Doddakere	20.8 sq km
Lake Area	Sihineeru Kere	5.7 Ha
	Doddakere	75 Ha
Lake Volume	Sihineeru Kere	94 ML
	Doddakere	~ 2200 ML
Average- Recharrge to Shallow Aquifer	Sihineeru Kere	1.03 ML/Day
	Doddakere	~ 13.38 ML/Day
Shallow Aquifer storage capacity	Both Sihineeru Kere and Dodda Kere	~ 21000 ML
Extraction from shallow aquifer for Municipal supply	From Sihineeru and dodda kere	1 MLD
Average sustainable yields from Open wells and Filter borewells	Open wells Filter borewells	- 30Kl/Hr (12hr pumping) 4-4.5Kl/Hr(16hr Pumping)

Annexur
e

Methodolog
y





Thank you

Ayushi Biswas
ayushi@biome-solutions.com
biome environmental trust
Bengaluru

Yield Test for Filter borewells in Dodda kere

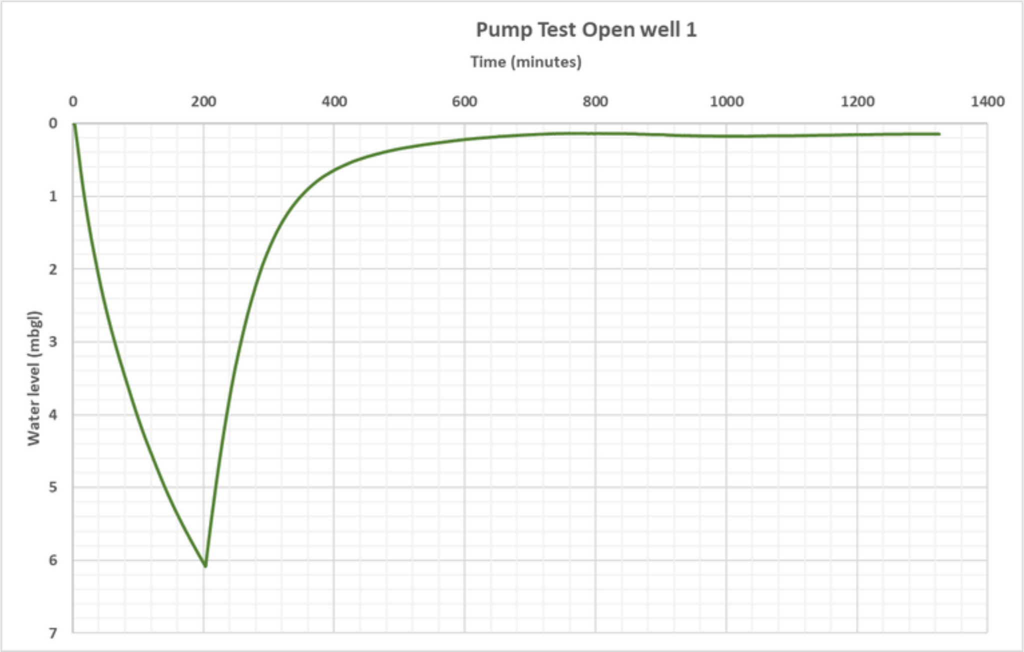
- The same filter borewell in the Doddakere command area was tested twice, and both tests gave promising results.
- Yield test 1 showed a stable discharge of 4,000–4,500 L/hr, averaging 4,386 L/hr, with only minor water-level fluctuation.
- Yield test 2 showed an even better discharge of 4,800–5,143 L/hr, averaging 4,834 L/hr, along with quick water-level recovery after pumping.
- the water level declined from 6.40 m to 7.88 m during pumping, the borewell showed rapid recovery, returning to around 6.40 m within about 30 minutes, which is a very positive indicator of aquifer recharge response.
- Overall, the tests indicate that the borewell has good and sustainable yield potential of 4000 - 45000 kl/Hr

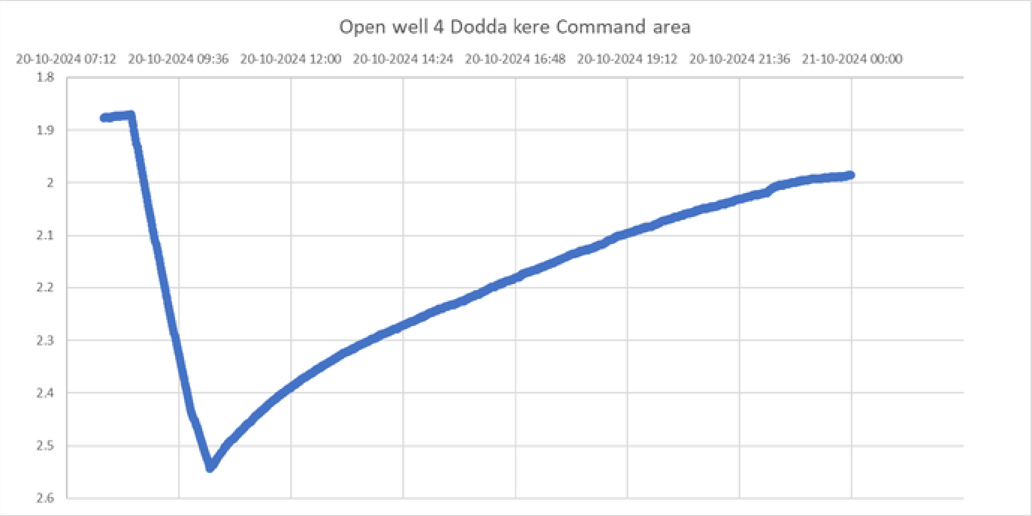
Yield Test for Open wells in Doddakere command area

- Post-pumping recovery observation indicate that both open wells returned to near-static water levels within approximately 6–12 hours.

- The relatively quick recovery is attributed to continuous hydraulic replenishment from the adjacent Doddakere Lake, which provides sustained recharge and maintains groundwater table.

- Considering the abstraction volumes, pumping durations, and the observed favorable recovery behavior, it is recommended that future open wells proposed within the Doddekere command area be designed with a sustainable operational yield of 30,000 litres per hour for 12hours.





Summary of understandings from Living Lab Project

Sihineeru Kere

Lake Volume- 94.1 ML, Lake Catchment- 0.7 sq km

Data for 2024-2025

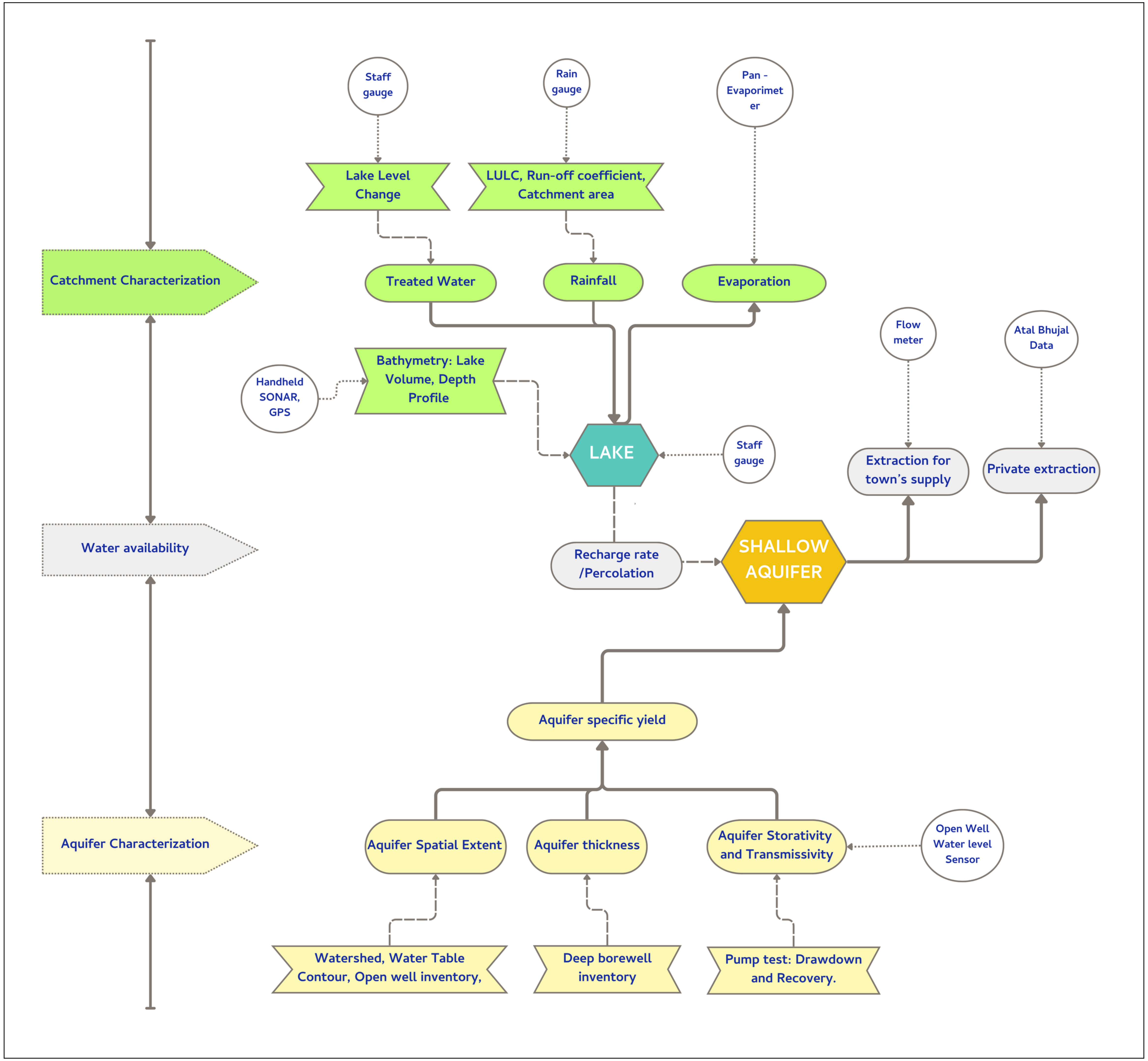
- Rainfall: 1191 mm
- Evaporation Rates: 2.45 to 4.41mm
- Percolation Rate: 15 to 27mm
- Total Treated water inflow- 195 ML

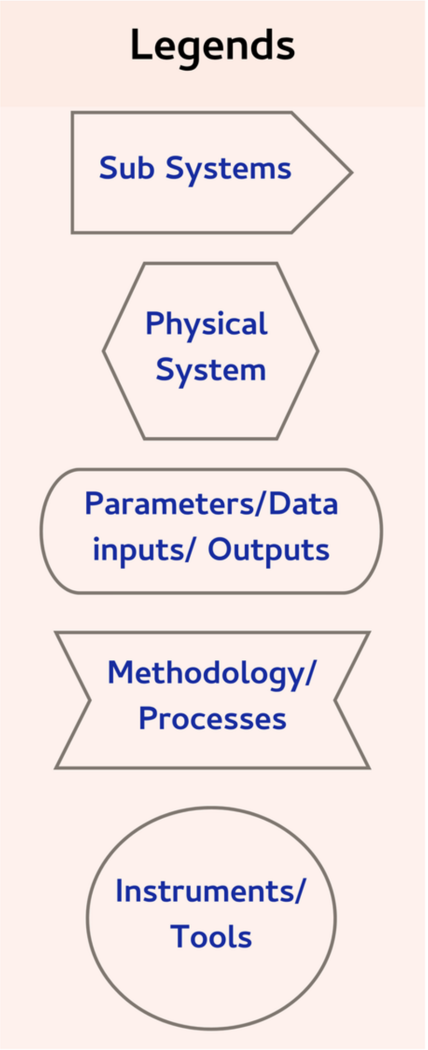
Shallow Aquifer

- Storativity - 8% to 11%, spatial extent: 8 sq km; depth- 30 to 120 feet
- Shallow aquifer storage 21,000 ML at 6% storativity (Based on well inventory - spatial extent

- Relative contribution of Rainfall & Treated water to Lake: 318.8 ML & 159 ML
- Recharge from Sihineeru to shallow aquifer - 1.03 MLD (at 18 mm recharge rate)
- Recharge from Dodda kere to shallow aquifer - 13.38 MLD (at 18 mm recharge rate)
- Evaporation Loss from Lake - 0.184 MLD (at 3.22mm average evaporation rate)
- Rainfall and Runoff - Eg. a 16.25 mm rainfall event - 4.1 ML to lake.

Methodology





Instrumentation

Lake Gauge

Water level sensor

Pan Evaporimeter

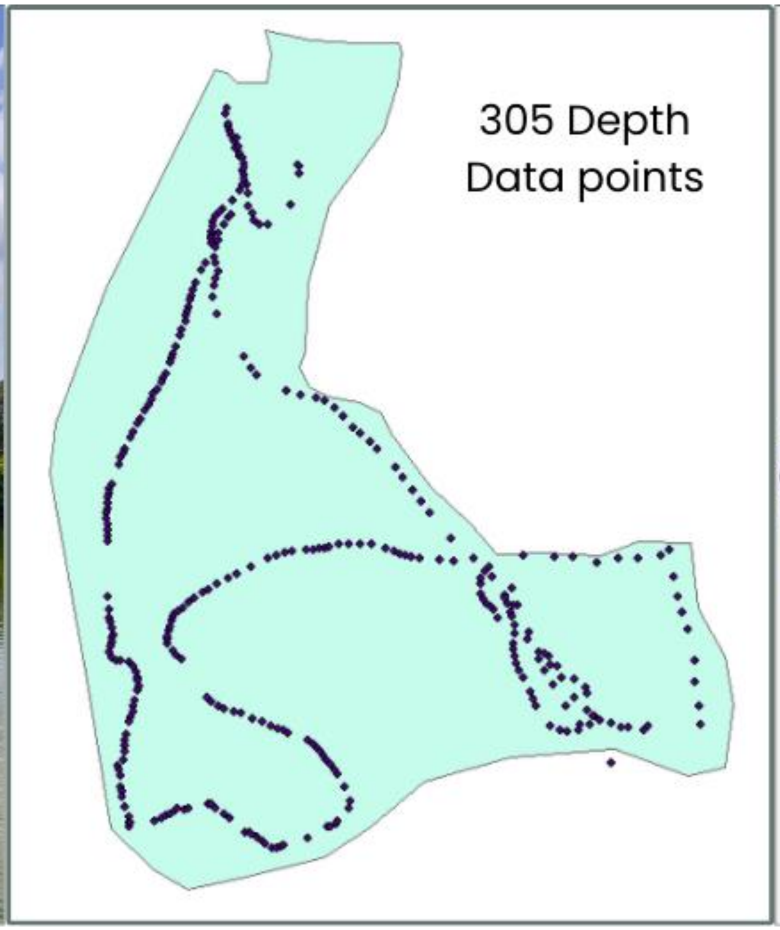
Rain Gauge

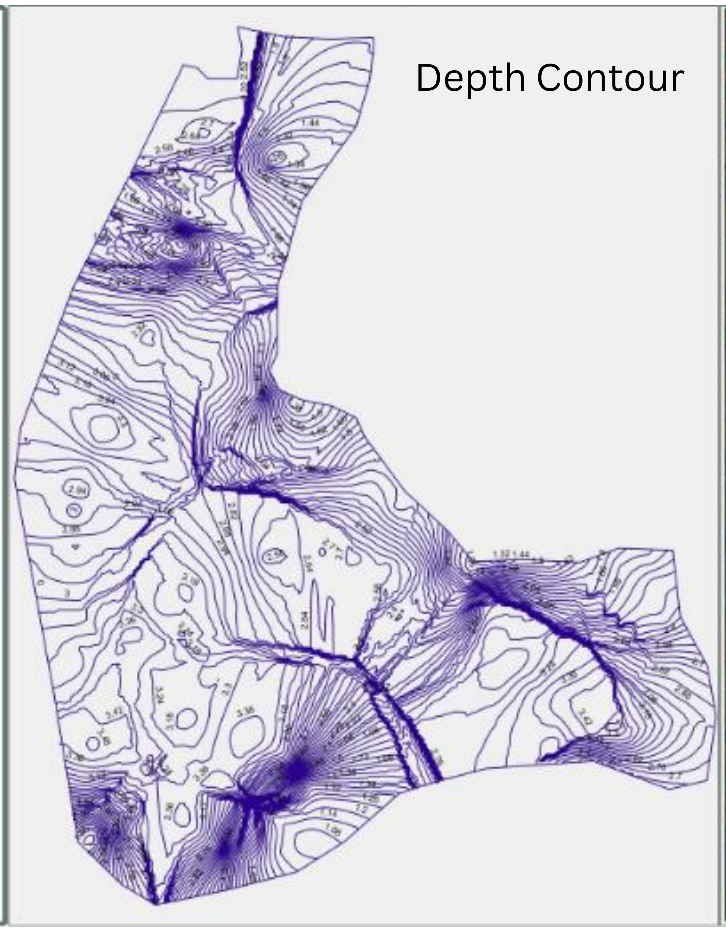
Water level sensor

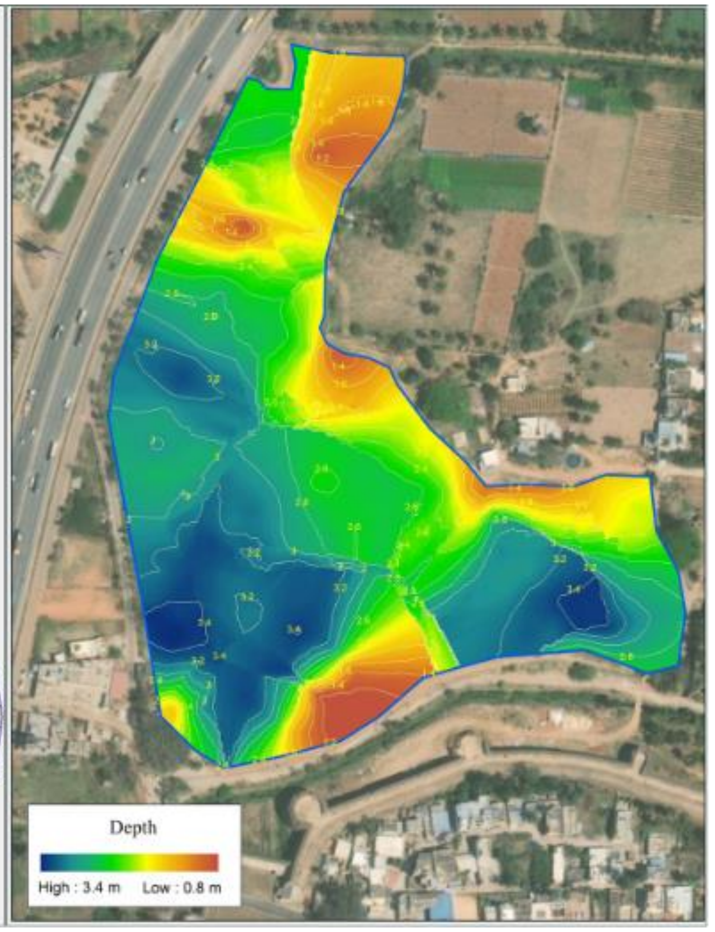
Catchment

Lake Bathymetry: Handheld SONAR, GPS, GIS
Lake Volume: 94.1 ML
Depth Range: 0.8m to 3.4m

Based on Devanahalli TMC Data: 200 Mil Liters
Based on Minor Irrigations dept: 48.99 ML - *Based on this lake volume treated water release has been decided - 0.143 MLD = 52 ML while between July 2024 to June 2025 - 159 ML received.*







Catchment

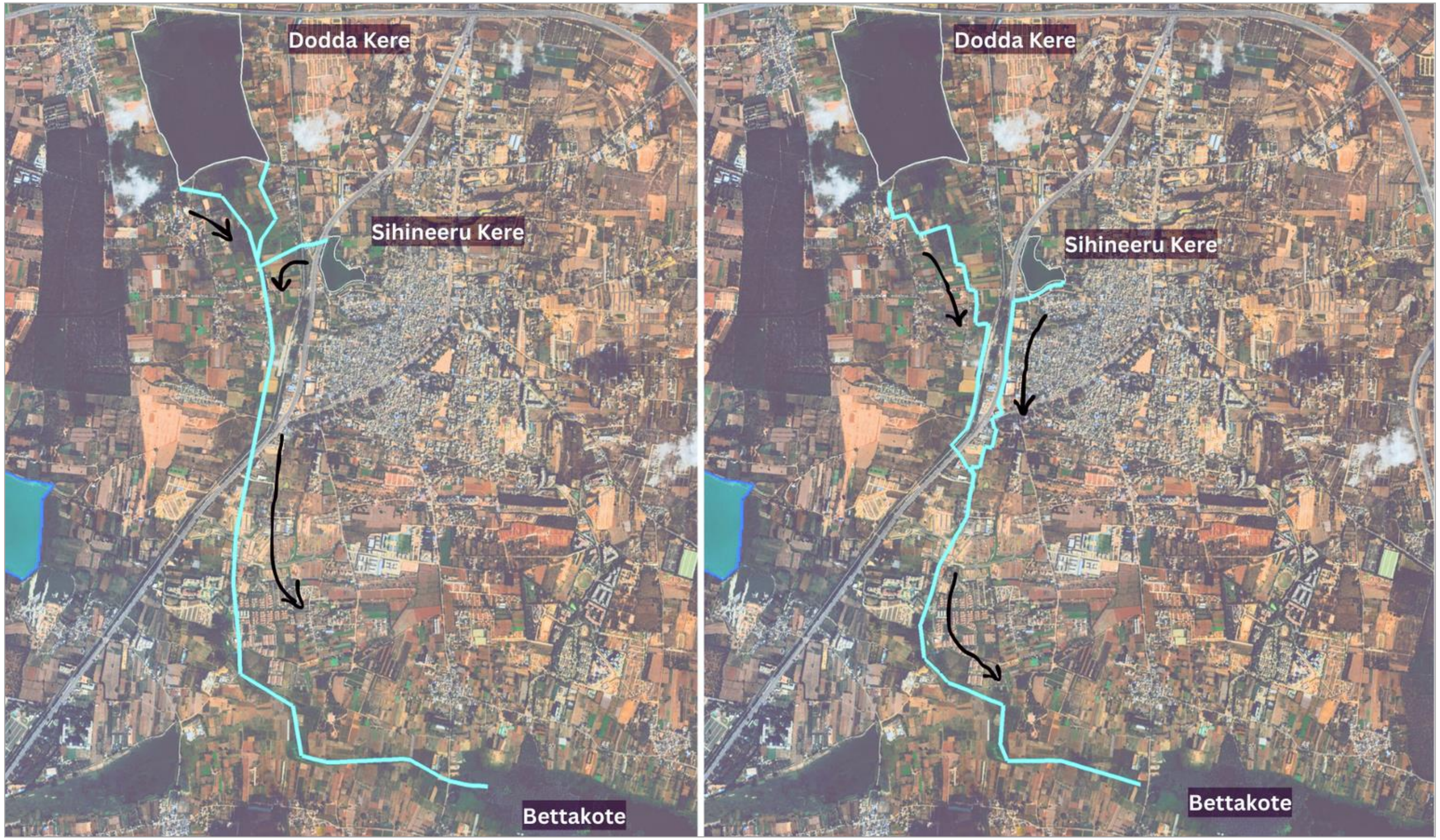
Changes in inflow/Inlets

Before the Highway

After the Highway

Historical land use land cover change - Landsat Data 2001. Change in the Lakes' s Hydrology,
Inlet outlet system, and surrounding Land use land cover

Changes in Overflow/Outlet



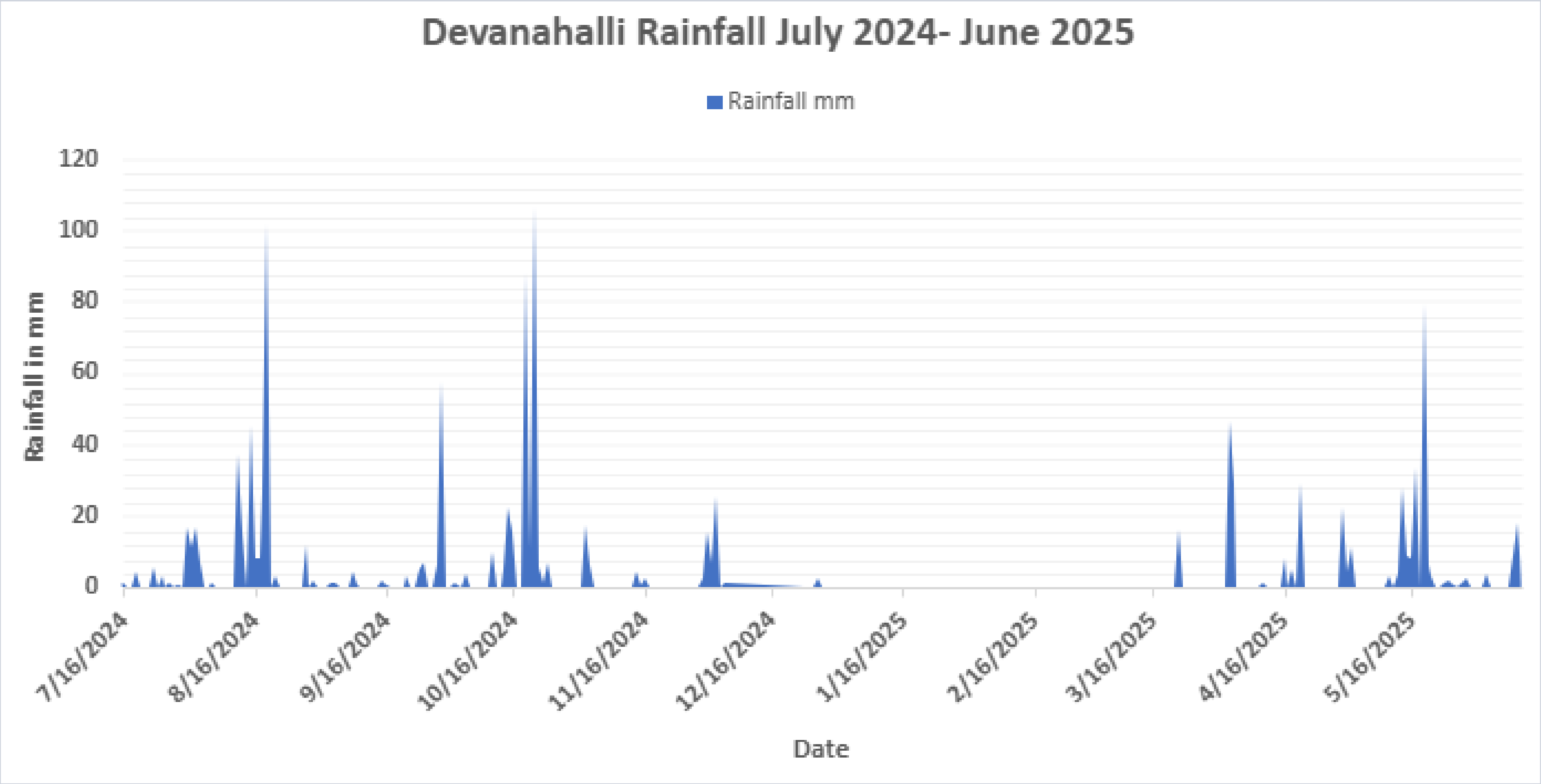
Hydrological Parameters

Rainfall

Total Annual: 1191 mm

Highest Rainfall in a day - 106 mm

Dry Period - Jan to March



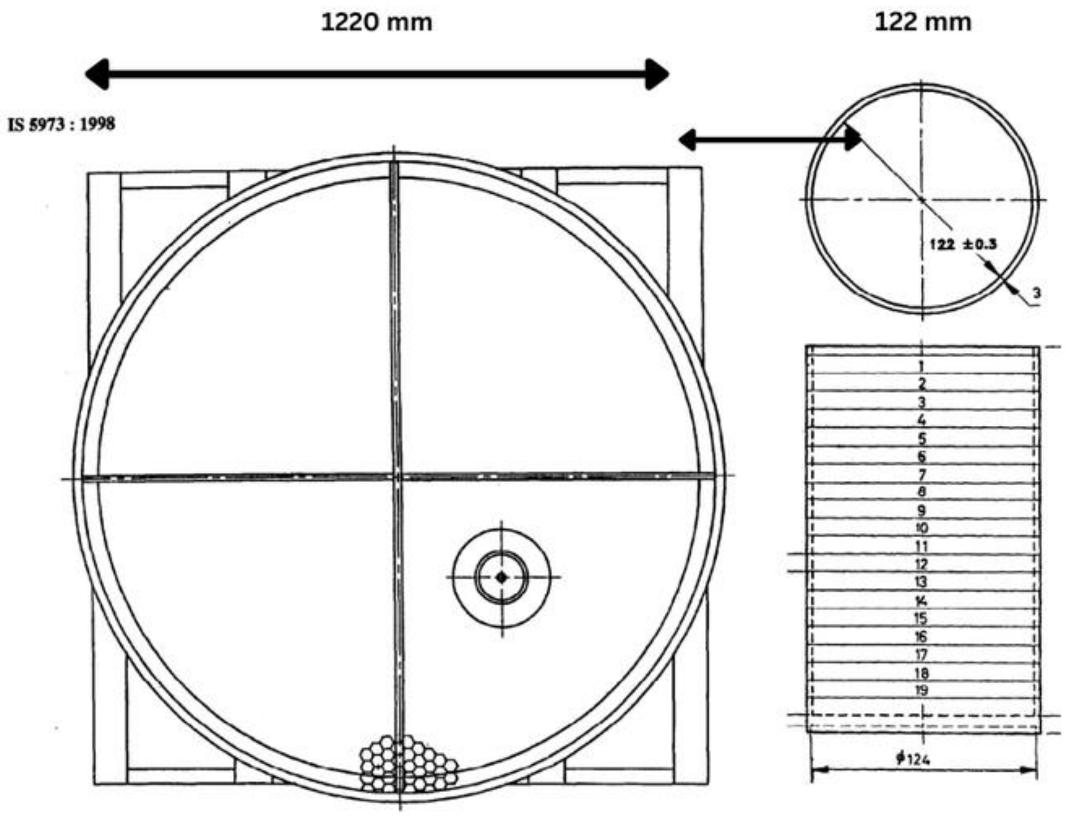
Average rainfall for 42 years is still 1011 mm - IMD

High rainfall days

Date	Rainfall mm
10/21/2024	106.68
8/19/2024	101.854
10/19/2024	88.392
5/19/2025	79.502
9/29/2024	58.166
4/3/2025	46.482
8/15/2024	45.466

Evaporation rate

Year	Months	Evaporation Rate	Units
2024	July	Nil	
2024	August	3.02	mm
2024	September	2.81	mm
2024	October	2.52	mm
2024	November	2.61	mm
2024	December	2.45	mm
2025	January	2.8	mm
2025	February	Nil	
2025	March	4.4	mm
2025	April	4.41	mm



A calibrated measuring cylinder is used to add or remove water at each observation to bring the water level to the fixed point. The cross-sectional area of the measuring cylinder is such that, the number of millimeters of water added from the measuring cylinder divided by 100 gives the amount of water in millimeters which has evaporated from the pan ~during a given interval of time.

https://law.resource.org/pub/in/bis/S01/is.5973.1998.pdf

Measuring jar = 20cm

For the Pan evaporimeter = Water added in mm/1

Actual evaporation = Evaporation from pan * Evap

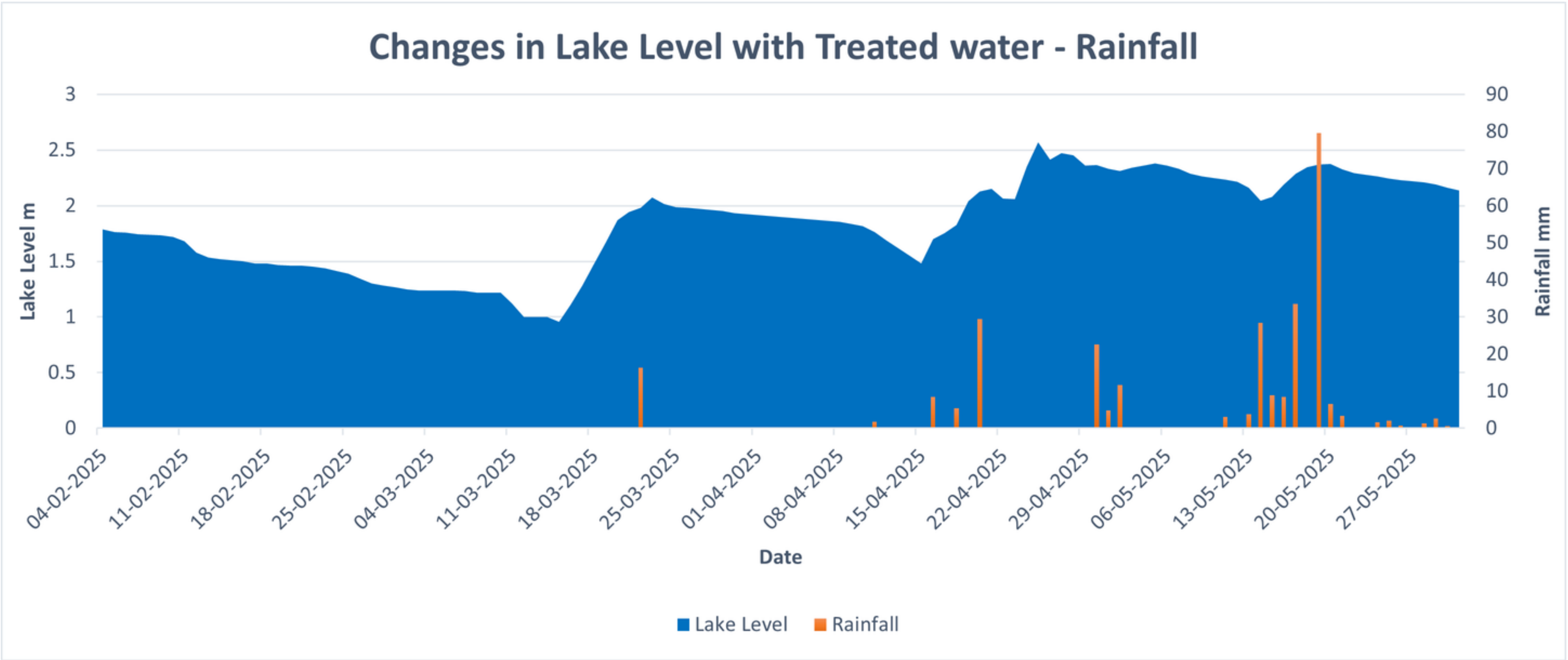
Evaporation from lake = Evaporation rate * Lake a

Treated Water Inflow, Recharge Rate and Evaporation

Estimating Evaporation Rates, Recharge from lake to shallow aquifer and quantifying Treated water inflow.

**No rainfall events all days*

Data collection with IIIT Hyd - IOT based sensor. *Requires further improvement.*



Water Quality

Water quality data

Water Quality

- Living Lab Monthly Water quality: Microbiological and Physical Parameters
- Indian Institute of Sciences - Quarterly Water quality
- Microbiological , Organoleptic and physical parameters, Toxic substances, Pesticide residues - **90 parameters**

Ensuring - WTP Output is BIS 10500 Drinking water standard

TDS (mg/L)

- Borewells: 1100 - 1400
- Lake, Open well filter borewells: 400 - 550
- Two out of 6 filter borewells initially showed TDS 600 to 800, now have 400.

Nitrates (mg/L)

- Borewell nitrates is always high (Varying from 16.4 - 45)

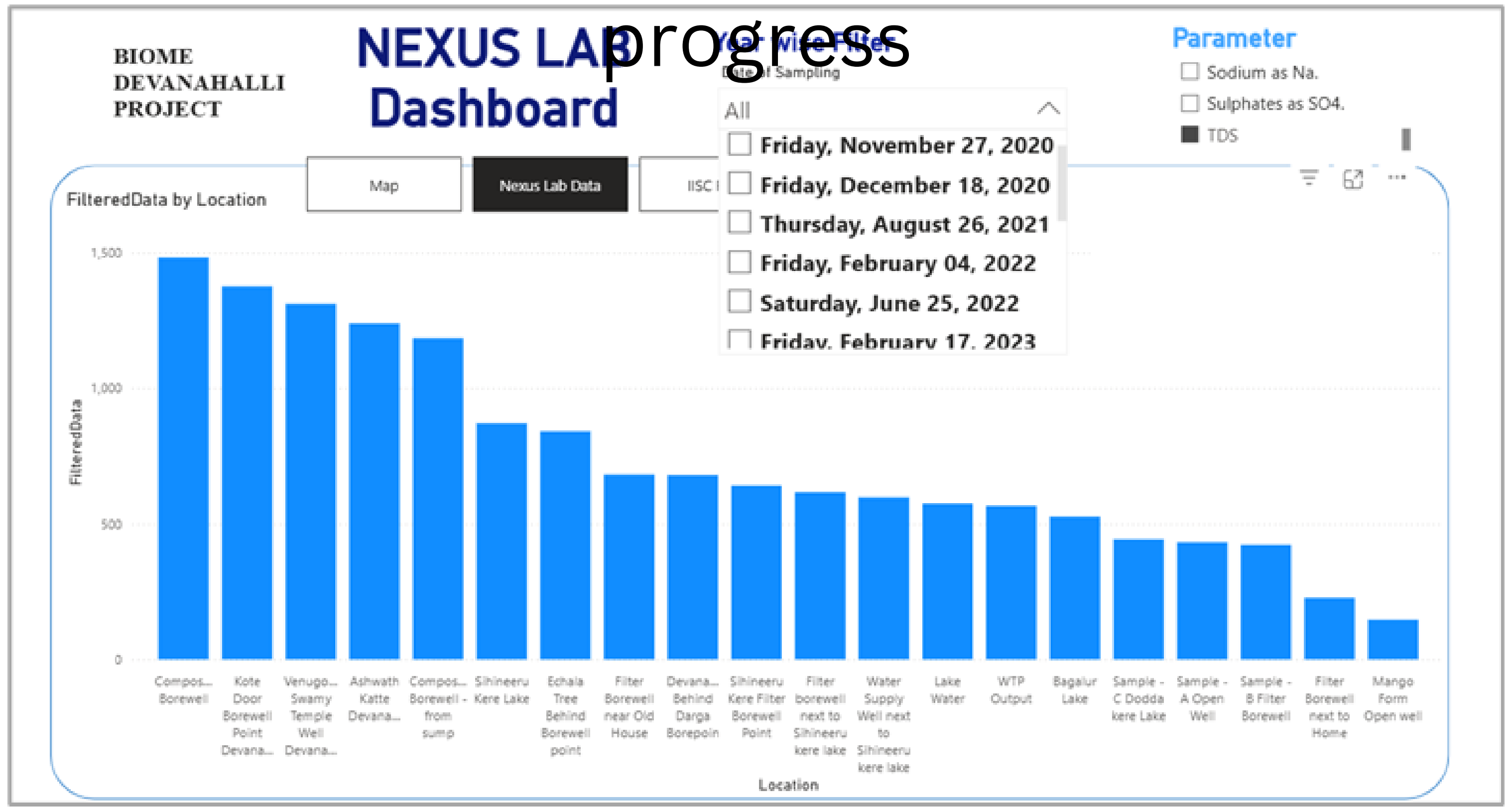
Chlorites(mg/L)

- Borewells shows high Chlorites >300, Higher than desirable limits,

Ecoli and coliform/100ml

- Present in Borewells, Lake, Open well and filter borewells.

Water Quality Dashboard - in progress



Water Quality - Heavy metal test

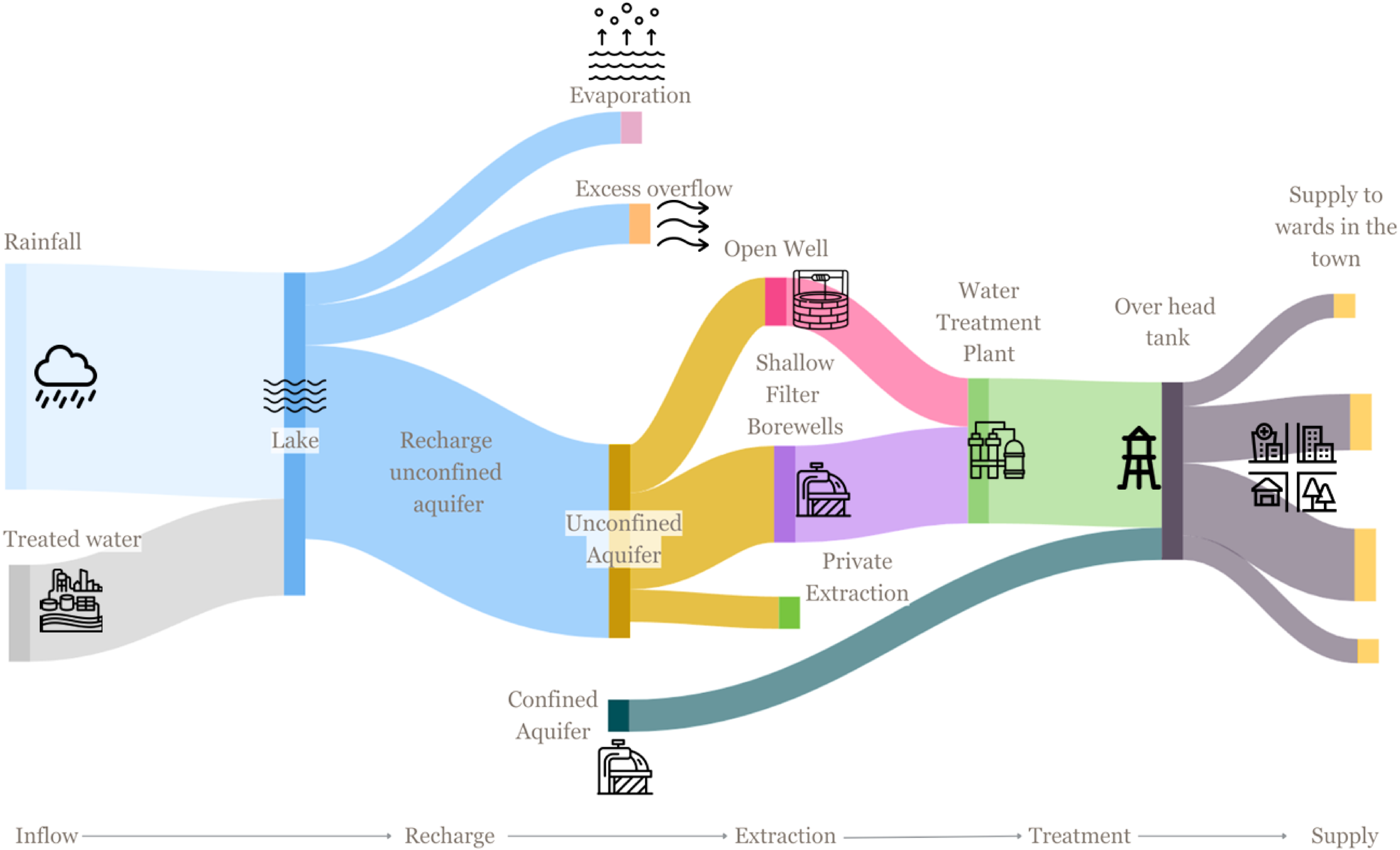
Slides from Dr. Varsha Sridhar MSCH - heavy metal test,

- No heavy metals found.
- 1st heavy metals test was done before project implementation by Indian Institute of Sciences Bengaluru - No heavy metals were found

We checked the levels of 21 heavy metals (excluding Mercury). All were found to be significantly lower than maximum acceptable and permissible limits.

Metal	Average reading across all lakes	Max permissible
Al	0.02	0.2
B	0.03	1
Ba	0.14	2
Ca	59.71	200
Cd	0.00	0.005
Co	0.00	0.01
Cr	0.00	0.05
Cu	0.00	2
Fe	0.02	0.3
Pb	0.00	0.05
Zn	0.02	5

Other parameters as per BIS and WHO standards such as TDS, BOD, COD, coliforms etc: routinely found to be within safe parameters


Evaporation
Excess overflow
Rainfall
Open Well
Supply to wards in the town
Water Treatment Plant
Over head tank
Shallow Filter Borewells
Lake
Recharge unconfined aquifer
Treated water
Unconfined Aquifer
Private Extraction
Confined Aquifer
Inflow
Recharge
Extraction
Treatment
Supply

Pump test in Open wells to understand the Aquifer charecteritics

Installing water level sensor

Retrieving data from water level senor