FRANK WATER

Beyond the Boundary 2022-23:

Recommendations Report

Beyond the Boundary

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Acknowledgements

The project would not have been possible without the time and effort of our project partners, who have gone above and beyond in helping us to wrestle with the challenge of connecting the on-the-ground needs of the people of Anekal with expertise in hydrological modelling.

Local partner Myrada demonstrated an unparalleled understanding of the needs of the people of Anekal, and through extensive water use surveys and two workshops they were able to bring the “voice on the ground” right into the project. The Foundation for Ecological Security similarly worked on the ground to map out the role that changing institutions are playing in a rapidly growing peri-urban area like Anekal, with wide applicability to other parts of India.

DHI (formerly the Danish Hydrological Institute) brought their world-class knowledge to bear at the watershed-level, and have applied and adapted their experience to the task through the development of the hydrological model and online portal.

We would also like to thank Friends of Lakes and WELL Labs for their invaluable contributions in our workshops, and we have no doubt that our collaborations will continue into the second year of the project. Finally, we would like to extend our thanks to our funder Apple for putting faith in the project and granting us an environmental partnership.

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Executive Summary

This report includes the design of, implementation process for, and findings of the water stewardship project "Beyond the Boundary (BtB)" in India. The project aims to support collective action for better watershed-level management amongst diverse stakeholders. In the first year, the project brought together state of the art hydrological modelling, local knowledge and approaches to water governance to facilitate decisive action in seven pilot watersheds in Anekal, Karnataka, India.

In common with other areas of India, Anekal, adjacent to Bengaluru, is a peri-urban area facing rapid urbanisation and industrialisation, partly due to the growth of corporate supply chain sites. The project work is the foundation for a Decision Support System (DSS) with wide geographical applicability.

The project framed key questions in the relevant watersheds, developed an indicator framework to answer those questions and then modelled the question-indicator relationship into a coherent hydrological model. The model, the basis for a Decision Support System (DSS), is capable of answering questions around water use and dynamics in the present but also helps in predictive analysis with respect to climate change, population growth and land use changes. Based on the model this report includes recommendations for how to achieve an effective and practicable water stewardship practice in a watershed through collective action.

The total amount of water received annually in Anekal taluk, as simulated by the model for 11 hydrological years from 2010 to 2021, is 43 million cubic metres (mcm) on average. At the same time, the total current water demand in Anekal taluk is 46 mcm per year on average and it is expected to increase by 48 mcm per year on average by 2030. The agriculture water demand constitutes by far the greatest percentage of the total water demand (>90%).

Urban land use, driven by urbanisation and industrialisation has led to rapid growth of the 'Urban / built up' class from around 9% to 17% between 2010 and 2022. About 93% of the current water demand is being met currently whereas in future it is likely to be 90% for low and moderate climate change emission scenarios and 99% in high emission scenarios as outlined by the IPCC models.

The report concludes with a set of guidelines and recommended actions for businesses to initiate water stewardship processes in their locations.

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Introduction

Background

Watershed management has long been an active part of approaches to agricultural development and livelihood promotion in India. Specific policy intentions like food and livelihood security have been achieved through programmes like the National Watershed Development Programme for Rainfed Areas (NWDPRA) of the Ministry of Agriculture. These have shaped watershed development through guidelines for the investments needed to achieve specific outcomes such as soil and water conservation, more efficient agronomical practices, participatory planning, livestock management and institutional development. When implemented in a coordinated way, these help to achieve water security for domestic, agricultural and industrial needs and optimal utilisation of land and water resources. However, watersheds across the country have been under severe stress with overexploitation of water stocks leading to recurring droughts.

The Beyond the Boundary (BtB) project is set in the context of watershed-level planning and management of water such that it can increase access to safe water in a just and sustainable way. It proposes a shift from an approach of optimal resource planning to that of data-led collective action amongst watershed-level stakeholders and responds to the urgent global call for better corporate water stewardship beyond their site boundaries.

The project attempts this by developing a relevant, appropriate and actionable set of methodologies that diverse watershed stakeholders and businesses in particular can adopt and lead sustainable water management in their watersheds. Frank Water's focus on communities and their water security drives this work towards collective action by active watershed management driven by watershed-level data and models.

It is a pioneering approach in the practice of water management because it brings together state of the art hydrological modelling and approaches in water governance to understand and take decisive action at watershed level.

The impact of the project will be felt locally through direct assessment and planning of actions to improve local conditions for businesses and communities. At a larger scale the impact will be through documented, scalable methodologies for corporate and local government water governance that can improve sustainability in supply chains globally. These learnings will be shared and further developed at a series of stakeholder workshops and through the creation of a community of practice to develop, demonstrate and contribute to the practice of water stewardship globally.

Beyond the Boundary

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Introduction

Scope

The project intends to develop a collective action based, practicable water stewardship approach that can be applied to various watershed contexts with appropriate modifications. For the first year of the project, the team focussed on the potential for collective action in seven pilot watersheds.

Project location selection

For Frank Water (FW) and its partners, three Indian states (Karnataka, Tamil Nadu and Telangana) were identified as significant due to their development trajectory and interactions between industry and water resources. From these, FW assessed Karnataka and its capital Bengaluru to be the most suited in terms of logistics convenience, prior exposure of FW and industrial growth projections. The other guiding factors for the choice of location were:

- Data availability;
- Potential and readiness of collaborators; and
- Availability of leverage with water sector institutions and government departments to take on the project outcomes.

Within Bengaluru, there are two major industrial clusters that present the context of our interest - areas on the urban periphery with a high level of industrial growth that places a high and increasing demand on water resources in the area. In such areas, due to this causal chain, several water resource conflicts among stakeholders - local communities, industry, agriculture and local ecology - can arise.
The two candidate industrial clusters are located as follows:

- Anekal Taluk[1] , Bengaluru Urban District (within this lies the Jigani Industrial Area)
- Hoskote Taluk, Bengaluru Rural District (within this lies the Hoskote Industrial Area)

The Karnataka state watershed atlas was used as a reference to understand water boundaries and compare it with the locations[2]. Criteria for pilot study area are presented in Table 1.

	Criteria	Emphasis	Relationship
a	Industrial cluster size (land area covered) and/or extent of industrial growth (any other metric like revenue)	Very High	A large size is more suitable
b	Stage of ground and surface water exploitation	Very High	Higher level of exploitation is more suitable
c	Population residing in the area	High	Higher population and higher density is more suitable
d	Total water demand in the area of study	High	Higher total water demand in relation to the stage of water exploitation leads, leading to potential future water shortages, makes the area well suited for the study
e	Ecology - presence of lakes, rivers, forest patches, wildlife etc	Moderate	Presence of critical species or environments will be an advantage
f	Distance from the urban core of Bengaluru	Moderate	Closely situated area is desirable

Table 1. Site selection criteria for Beyond the Boundary

[1] Taluk is an administrative unit under the Indian governance and administrative system hierarchy. It is a subdivision of a district and typically comprises a cluster of villages.
[2] See Karnataka State Watershed Atlas. Link: https://ksrsac.karnataka.gov.in/ksrsac_website_data/Documents/Watershed_Atlas.pdf

Introduction

Project location selection

The balance between prioritising model outcomes and achieving a governance framework that can be demonstrated on the ground was also considered an important factor for the project design. A highly accurate model in a location where key stakeholders, local government institutions and residing communities cannot be involved, will not be useful. Compromises of similar nature are required to achieve the project goals and ensure scientific rigour.

Anekal Taluk, which comprises seven watersheds, was selected for BtB's first year of work. Figure 1 and Figure 2 below indicate the identified water boundaries and water resources.

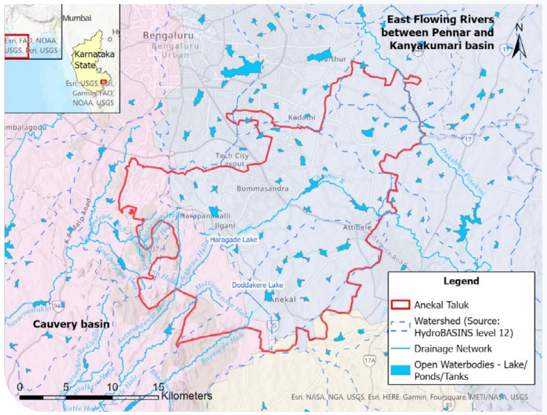

Figure 1. The boundary of Anekal Taluk

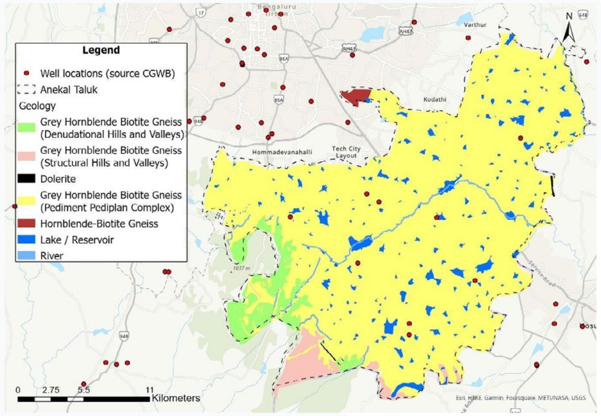

Figure 2. Key water resource features in Anekal Taluk

Figure 3. Watersheds in Anekal

Methodology

Project timeline, key dates and deliverables

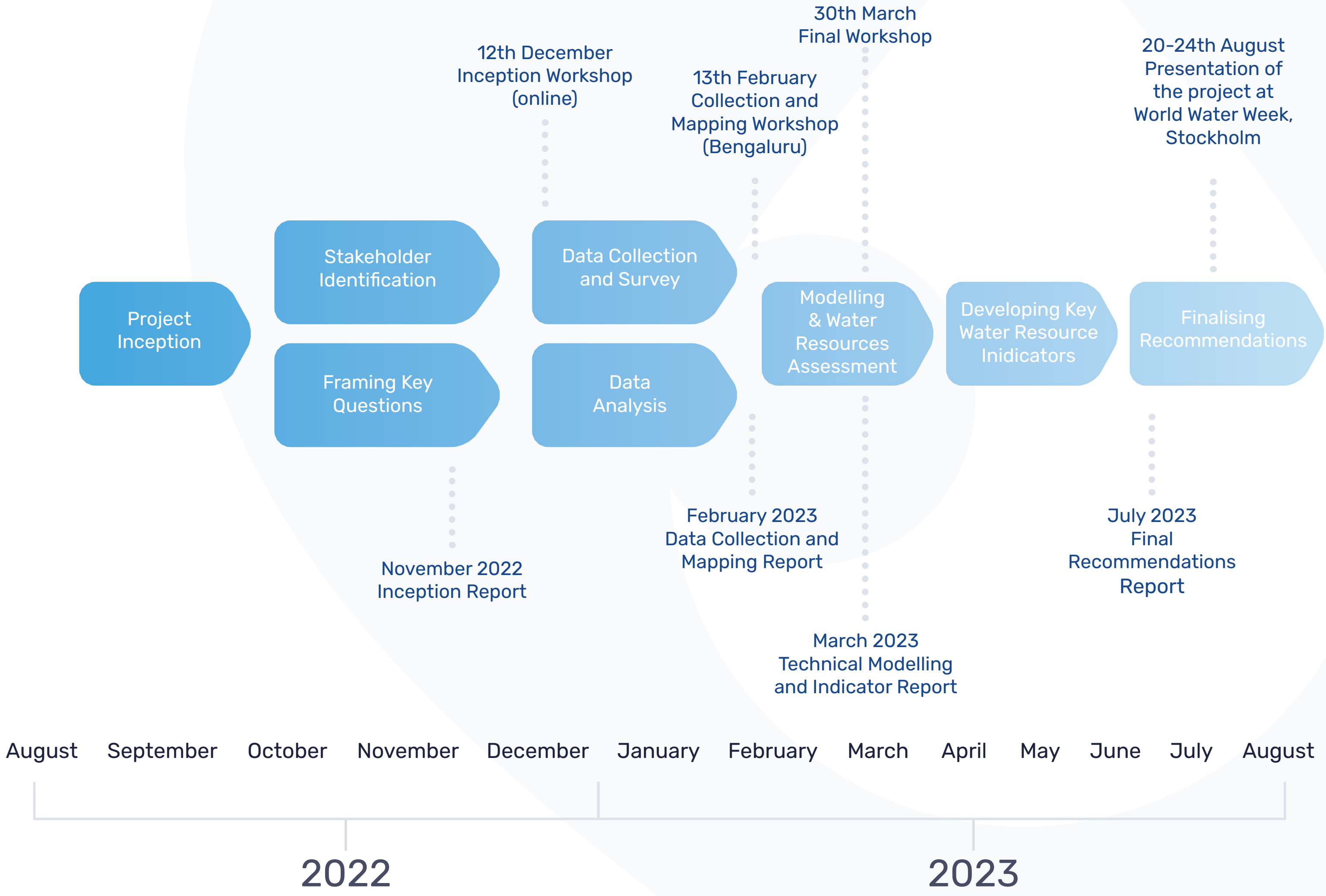

Figure 4: Project Timeine

Beyond the Boundary

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Methodology

Stakeholder identification and engagement

Successful implementation of Beyond the Boundary (BtB) required engagement with a wide variety of stakeholders including local business, community, civil society and the water stewardship sector.

Our initial engagement centred around contextual engagements with organisations working in the Indian water stewardship sectors, such as Alliance for Water Stewardship (AWS) and DHI (formerly the Danish Hydrological Institute). We supplemented these by building relationships with civil society organisations such as Water for People and WaterAid whom, like Frank Water, have experience of working with local communities on water stewardship improvements.

As the project gained momentum, we engaged stakeholders with a deep knowledge of local issues and a track record in watershed improvements. Myrada, Foundation for Ecological Security (FES) and Friends of Lakes (FoL) provided hyper-local contextual information and knowledge on the project locations and gave a 'reality check' to conversations concerning the history and current context of water management in the area. Additionally, stakeholders such as ACWADAM and Bala Vikasa, two of India's leading NGOs were engaged to provide insights and strategic support in pulling together the vast amounts of data and knowledge into a comprehensive database of the watershed.

Table 2 lists all the identified stakeholders and their relationship with the project.

	Stakeholder	Sector	Location	Relationship with project outcomes	Likely impact on stakeholder from the project	Assigned stakeholder priority
1	People and households living in villages	Community	Within the watershed	Direct	High	Very High
2	Private Companies	Corporate	Within the watershed	Direct	High	Very High
3	Local Governance Institutions (Water User Associations, Panchayat)	Government	Within the watershed	Direct	High	High
4	Public Water and Sewerage Utility Operators	Government	Within the watershed	Direct	High	High
5	District Administration	Government	Outside the watershed	Indirect	Medium	High
6	Rural Development and Panchayat Raj Department, Government of Karnataka	Government	Outside the watershed	Indirect	Low	Medium
7	Karnataka State Small Industries Development Corporation	Government	Outside the watershed	Direct	Medium	High
8	NGO Panel Members	Civil Society	Within the watershed	Direct	High	Very High
9	Karnataka State Industrial & Infrastructure Development Corporation Limited	Government	Within the watershed	Direct	Medium	High
10	Karnataka Industrial Areas Development Board	Government	Within the watershed	Direct	Medium	High
11	Frank Water & Funding Partners - Project Implementing Agency	Civil Society	Outside the watershed	Direct	High	Very High
12	Frank Water - Knowledge Partners	Civil Society	Outside the watershed	Indirect	Medium	Medium

Table 2. Beyond the Boundary's stakeholders for year one

Methodology

Stakeholder identification and engagement

Outside of the frequent communications and meetings with each organisation, stakeholders attended two in-person workshops in Bengaluru and one virtual workshop to ensure all organisations could input and contribute to the project's goals and provide valuable, bespoke recommendations to guide the work.

The engagement and assessment matrix indicates current and desired states of a stakeholder's involvement in the project. The status type also indicates the aspiration of the project design.

Status	
Unaware	Not aware of the project and its impact
Resistant	Aware of the impact and is resistant to change
Neutral	Is aware of the project, but is neither supportive nor has resistance
Supportive	Is aware of the project, supports it but does not take proactive actions
Leading	Takes proactive actions to further the aims of the project

Table 3. Stakeholder status

	Status				
Stakeholder	Unaware	Resistant	Neutral	Supportive	Leading
People and households living in villages			Current		Desired
Private Companies				Current	Desired
Local Governance Institutions (Water User Associations, Panchayat)			Current		Desired
Public Water and Sewerage Utility Operators			Current	Desired	
District Administration			Current	Desired	
Rural Development and Panchayat Raj Department, Government of Karnataka		Current			Desired
Karnataka State Small Industries Development Corporation		Current			Desired
NGO Panel Members				Current	Desired
Karnataka State Industrial & Infrastructure Development Corporation Limited				Current	Desired
Karnataka Industrial Areas Development Board			Current		Desired
Frank Water & Funding Partners - Project Implementing Agency					Current
Frank Water - Knowledge Partners				Current	Current

Table 4. Types of stakeholders and their status

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Methodology

Framing key questions and definitions

The project was further refined to develop an approach to a watershed-level governance and management framework in which key stakeholders assume and effectively perform the role of water stewards. Two stakeholders that are of primary focus in the project are: the villages and households located in the selected watershed that are dependent on the watershed; and private companies which conduct their activities in the same watershed.

A governance and management framework for water resources is typically based on a comprehensive database that includes hydrological, social, economic and political information. This multi-dimensional data must enable planners to answer key questions about the watershed. These key questions provide a basis for dialogue, identification of problems in the watershed and also provide direction towards addressing the problems. Using the above logic, ey questions were framed. These key questions were deemed as core to the project's conceptualisation and outcomes. Mapping involves the delineation of the watersheds including features like the drainage stream network and outlets. Watershed mapping prepares the ground for building a hydrological model of the watershed using multi-indicator data obtained from earth observation sources. The model then enables answering the key questions that are listed under 'Key Questions' below:

1. What is the current total quantum of water received in the selected watersheds from all sources?

2. How has the land use and land cover changed (in terms of net area and percentage changes) over the period 2010 - 2022? What are the percent changes in various LULC (Land Use / Land Cover) classes - such as built up, agriculture, forest, grass/ grazing, barren/wasteland and wetlands/ water bodies.

3. What is the quantity of current water demand in the selected watersheds for:

- **Domestic use (and split for drinking water demand)**
- **Industrial use;**
- **Agricultural use; and**
- **Remaining water that is not drawn/used**

4. What is the total quantum of water available for use in the watershed?

5. What is the percentage of current demand that is being met by available and usable water?

6. What is the current water storage capacity in the watershed?

7. What is the available storage potential in the watershed?

8. What percentage of future demand can it meet?

9. What projections or demand scenarios can be made for sector-wise water demand for the next 10 and 20 years?

10. What projections for land use and land cover change can be made for the next 10 and 20 years?

11. What has been the precipitation trend over the period 2010-2022? How will it change in the next 10 and 20 years?

12. What is the temperature and relative humidity trend over the period 2010-2022 in the watershed? How will it change in the next 10 and 20 years?

13. What is the current aquifer recharge rate and potential? How is it likely to change in next 10 and 20 years?

14. How has water quality changed over the period 2010 - 2022?

15. What are the locations of critical/stressed groundwater levels within the watershed, overlaid with a land-use map?

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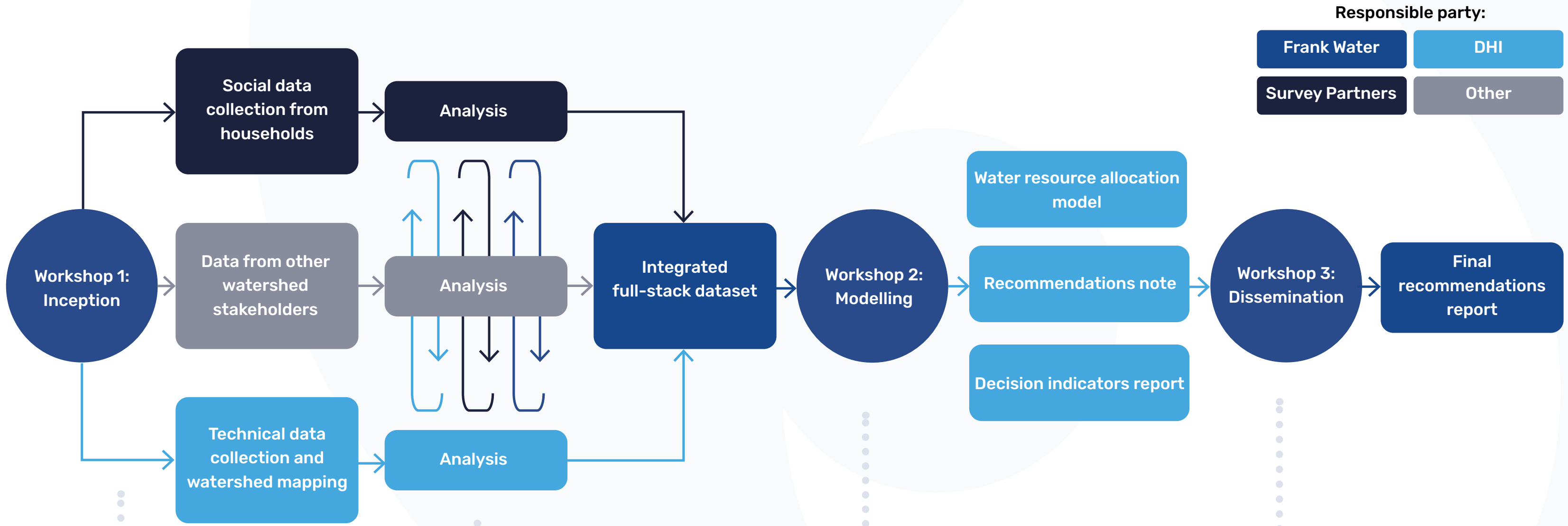
Methodology

Framing key questions continued

The key questions were transformed into a structured process through which the project was implemented. The process included a set of protocols through which data was managed and relevant information and insights were developed, as shown in Figure 4.



Workshop hosted by Frank Water

Workshop outcome:

- Project introduced to a wider group of stakeholders
- Finalisation of objectives, work plan, outputs and status and project outputs
- Discussion of household survey questions

Process of integration and ground truthing of diverse qualitative and quantitave datasets is facilitated by Frank Water, with the active involvement of DHI and Household Survery Partners

Workshop hosted by Dr Himanshu Kulkarni

Workshop outcomes:

- Finalisation of knowledge-base for the water resources allocation model
- Agreement of the key decision indicators
- Discussion of discrepencies between datasets and reliability issues

Workshop hosted by Dr Himanshu Kulkarni

Workshop outcomes:

- Presentation of final outputs to a wider group of stakeholders
- Critical analysis of usefulness of outcomes
- Agreement of Table of Contents for the Final Recommendations Report

Figure 5. Beyond the Boundary Data Management process

Methodology

Data collection and analysis

During the inception stage of the project a data portal for presenting observation-based (EO) data and modelling outcomes was developed with DHI.

The datasets presented for Karnataka and Anekal taluk were the following:

- Historical rainfall estimates by the Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS); [4]
- Daytime land surface temperature by National Aeronautics and Space Administration (NASA)[5] ; and
- Global available climate change projections for rainfall, by the United Nations Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6).

Regarding the latter, the available projection periods and future scenarios were only briefly introduced, as the purpose was to provide an overview and set the scene for the workshop that follows where key stakeholders will be provided with in-depth explanation of these and other datasets of relevance to the project.

[4] For more information about this dataset please visit https://www.chc.ucsb.edu/data/chirps
[5] For more information visit https://lpdaac.usgs.gov/products/mod11c2v006/

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Methodology

Assessment of the water resources

DHI's WaterDSS portal is used as the technology that drives the modelling component of this project. A public link for Frank Water and the BtB project was set up[6] for assembling key datasets, visualisation and further analysis of water context as well as to address the key questions framed at the beginning of the project[7].

The portal comes with one web application (app) named 'EO-based Data', which has functionality for mapping, viewing, analysing and downloading data. The datasets are intended to provide near real-time and historic models and ground-based observations made public free of charge by reputable international and national agencies and academic institutions.

Figure 5 overleaf shows a snapshot of the app. The available data types are listed by choosing Dataset selection (blue button on the left panel). When this menu is opened, it is possible to select which data should be made available (this selection can be changed later on as the final results are added). The selected data can be viewed on the map by clicking on the dataset name of interest on the left panel, the time bar underneath the map allows the user to view each time step.

The right hand-side panel has the tools to download and process the selected data. The spatially distributed data can be downloaded as NETCDF files with extension ".nc" that can be opened in most GIS tools (such as QGIS). In addition to the "Download" option, the tools panel contains several different options for processing and analysing the selected data types.

The options are:

- All focus area (the tool produces an area weighted time series for the entire focus area);
- Area (time series processed as an area weighted time series for predefined subcatchments);
- Subarea layer (time series processed as area weighted time series for a user specified subarea);
- Stations (time series extracted at predefined user specified point locations); and
- User location (time series extracted at user specified locations).

[6]https://beyondtheboundary.waterdss.com
[7]See Watershed-level Governance and Management Framework in a Pilot Catchment in India:Inception Report. Date Published: 23 December 2022

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Methodology

Assessment of the water resources continued

For analysis of datasets, the different applicable tools become available depending on the data type which was selected and being displayed on the map. These options may be:

- Time series: The time series option produces an area weighted time series for the selected area. The time series uses the same temporal resolution as in the data file. It is possible to zoom in on part of the time series by clicking on the lower chart and selecting a time period. Once a shorter time period has been selected it is possible to move the window through the full period by clicking on the top chart.
- Time series (monthly and long-term mean) charts: This time series option produces an area weighted time series for the selected area. The time series chart contains monthly accumulated values including an item with the actual data (light blue) and an item with the long-term mean of each of the monthly time steps (blue).
- Envelope plots: This option is only available for ensemble-based data types, for example climate change data and produces a plot showing the median, 25th percentile and 75th percentile of the ensemble values.
- Column plots: The column chart option is only available for selected indices, and produces a plot showing the coverage, in percentage, of different drought or flood categories.

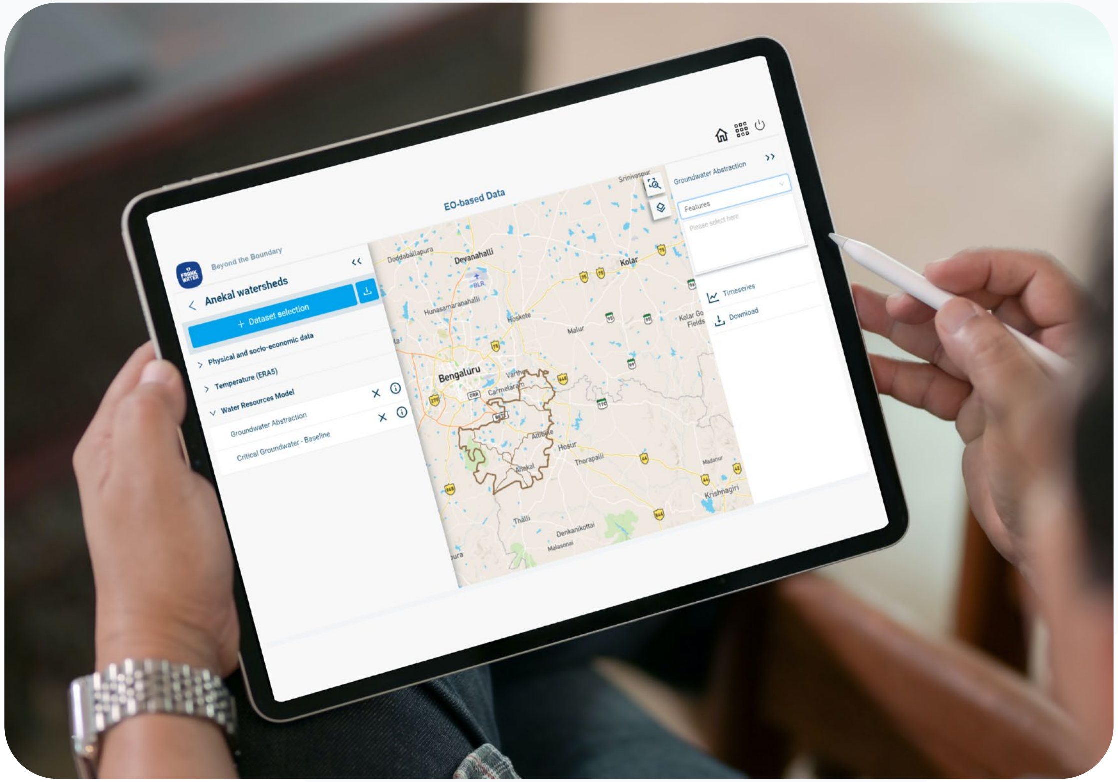

Figure 6. Snapshot of the app

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Watershed Model and Indicator Framework

Context

Anekal taluk is located in the southwest of Bengaluru Urban district. It includes a mix of industrial and agricultural activities. However, the taluk has traditionally been agricultural and has slowly transitioned to industrial land uses. It includes over 3000 acres of designated industrial area. Water supply for the district is managed by Bangalore Water Supply and Sewerage Board (BWSSB).

A portion of the water needs of the taluk is supplied by BWSSB drawing from Arakavathi river and Cauvery river for drinking purposes. Furthermore, Bengaluru Urban has 461 water tanks of various capacities serving irrigation needs.

As per the district industrial profile document, the total capacity of water supply in 2016 was 1480 megalitres/day (MLD). There are 52 reservoirs and 118 ground-level reservoirs. Average consumption stood at 522.4 MLD for industrial use and 21 MLD for domestic use in 2016.

Decision indicator framework

With the project's technical partner, a framework of indicators was developed to answer the key questions posed as scope and to serve as a starting point for the hydrological model.

The indicators were selected to be relevant for monitoring the state of the resource or issue in question, be easy to interpret, be able to give information on the current status and the status in relation to the historical change and be based on available data or information. Also, the more narrowly defined the indicator, the less room there is for later confusion or complications.

The indicator framework proposed helped partners to understand the current state of water resources in Anekal, the changes in these resources and whether or not interventions produce the desired effect. It is also possible to use it to identify risks. In addition, the indicators and the tools piloted can be used as a learning tool for basin or catchment organisations or other users.

We consider the approach and indicators provide a starting point that can be adjusted and complemented to match Frank Water specific user needs, provides an online tool for stakeholders to share their indicator assessment with others to allow for consistency (it helps when actors are all measuring the same thing) and, used as a tool for storing indicator information to support future design of decision support systems (DSS).

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Watershed Model and Indicator Framework

Decision indicator framework continued

1. Monthly precipitation and temperature: monthly accumulated and average monthly time series for a specific area
2. Long term mean monthly precipitation and temperature: monthly mean considering the period of record for a specific area
3. Climate change factors: ratio (in the case of delta change factors) or the difference (in the case of absolute change factors) between the average in the historical model run (1995-2014) and the projection model run for the five socioeconomic pathways (SSPs) SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5 evaluated in the IPCC AR6
4. Current water demand disaggregated by sector: amount of water required in the baseline scenario by domestic, agricultural, industrial and construction sectors in Anekal
5. Current water use disaggregated by sector: simulated amount of water used by each category: domestic, agricultural, industrial usage in Anekal
6. Current total amount of water available for use: simulated groundwater recharge minus the natural discharges
7. Projected water demand disaggregated by sector: amount of water required in the future scenarios by domestic, agricultural, industrial sectors in Anekal
8. Projected water use disaggregated by sector: simulated amount of water used by each category, domestic, agricultural, industrial, in Anekal
9. Projected total amount of water available for use: simulated groundwater recharge minus the natural discharges
10. Groundwater Recharge Index: index describing the groundwater recharge as a percentage of the recharge in the baseline scenario
11. Critical/stressed groundwater: official formulation used by the District Groundwater Office, Groundwater Directorate, and the Central Ground Water Board, South Western Region, Bangalore
12. Lake storage volume: simulated mean annual stored volume in a lake

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Watershed Model and Indicator Framework

Hydrological modelling

Groundwater being the major source of supply to most of the users in Anekal taluk, sustainable development and management of this resource is key to ensure access for local communities, productive industries, and a healthy environment.

Therefore, focus was placed on assessing the status of groundwater resources at the watershed level. The modelling approach was adopted to understand the baseline conditions in the Anekal taluk by establishing a water resource model to account for the major water use categories - Domestic, Industrial and Agriculture - and for future urban development plans and projected climatic conditions.

DHI's own water modelling software MIKE HYDRO Basin (MHB) was used in this assignment, a simulation tool for water resources modelling and water allocation investigations.

Baseline conditions - climatic, hydrological, land use along with different water usages - are defined in the model for simulation period 2010 to 2021 (known as S0). Four future scenarios (S1 to S4) were built to understand the implications on the state of water resources in Anekal taluk considering the projected water uses (based on the proposed urban developments until year 2031) and projected climate (until year 2040).

S0

Conditions in the watersheds in the baseline period from 2010 to 2021; no planned developments, no climate change projections

S1

Developments inferred from land use/land cover mapping and available masterplans, expected to be in place by 2031, no climate change projections

S2

S1 and SSP1-1.9 climate change projections, near future (2021-2040) 'low emissions'

S3

S1 and SSP2-4.5 climate change projections, near future (2021-2040) 'middle of the road'

S4

S1 and SSP3-7.0 climate change projections, near future (2021-2040), 'high emissions'

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Findings

Household water use data

A household-level sample survey in Anekal Taluk was undertaken to understand water needs, current use and water security. This informed the domestic water use and provided contextual data for building the hydrological model. The survey was also intended as a ground-truthing opportunity for the hydrological model. Anekal Taluk comprises 27 urban wards with over 4000 households.

Domestic water use survey

Of the 27 wards, a household survey was conducted in 17 wards. The household survey covered 200 households in 17 of Anekal's 27 wards, especially in the urban part of the Taluk. In addition, two focus group discussions took place - one with a focus on urban stakeholders, and one on rural farmers. Each discussion was attended by around 60 people.

The urban wards get part of their water needs met by municipal supply once in 15 days and only 350 out of 600 households in a ward have in house water tap connection. The quality of water supplied through the municipality is poor, and wastewater is connected to the Doddakere lake which is also used for fishery.

The rural focus group discussion was held in the rural village of Kammasandra. Here, water is supplied from 40 borewells, one open well and Kammasandra lake. Unseasonable and erratic rainfall distribution has affected the livelihoods of farmers, who also suffer from low productivity due to degraded land. Farmers lack the agricultural practices and knowledge needed to adapt to a changing climate.

Agriculture water use survey

The agriculture water use survey was conducted in 150 farmer households in 16 wards in Anekal.

The sample farmers were selected to be representative of the various land holdings categories: small & marginal (smaller than 2 hectares) , medium (between 2 and 5 hectares) and large (greater than 5 hectares). The survey represented the majority of crops grown in the taluk.

Reported field crops grown were finger millet, vegetables, flowers and maize, along with small areas of agroforestry. Sericulture (silk farming) which was a tradition of the region is hardly practised by farmers anymore.

The proximity to Bangalore has also altered the quantum of land under agriculture and also the crops grown in the land. A significant landmass has transitioned from rainfed crops like ragi to water intensive vegetables to service the needs of the metropolitan city. Livestock water demand : The livestock numbers for the taluk is very low compared to any other rural block, indicative of it transitioning to becoming an urban geography. There are around 100,000 livestock in the taluk of Anekal composed of cattle, goats, sheep, buffaloes. The water demand of livestock on a daily basis amounts to 5.2 million litres per day.

Crop	Area (acres)	Percentage of total
RAGI and other cereals	131	38%
Maize	15	4%
Vegetables and leafy greens	105.5	31%
Floriculture	77.5	23%
Sericulture	1	0%
Agroforestry	10	3%
Others	5	1%

Table 5: Crops in surveyed farms in Anekal

Findings

Water asset survey

Along with the water use survey, a survey was also conducted to assess the various water exploitation infrastructure like borewells, ground water, and a few of the major lakes in the Anekal town.

During the focus group discussions it was reported that the groundwater level around the villages has dropped significantly, plummeting to 1800 feet below ground level in many locations. Moreover, one in three attempts at drilling fail to strike water.

During the focus group discussions it was reported that the groundwater level around the villages has dropped significantly, plummeting to 1800 feet below ground level in many locations. Moreover, one in three attempts at drilling fail to strike water.

Borewells across 16 villages were surveyed to understand water use context. In these villages 79 borewells were assessed. The average depth of water in these borewells was as follows:

- 9 borewells 0-300 feet;
- 50 borewells 301-1200 feet; and
- 8 borewells 1201-1500 feet.

There were very few open wells found in the taluk. 23 open wells were surveyed, and of these only one was functional and had water at the depth ranging from 50-100 feet across various seasons.

The lakes identified in the taluk receive industrial effluents from the adjoining industrial units, with pharmaceutical manufacturing units being the most prevalent. Doddakere and Haragadde lakes were observed as sample sites for the project. Doddakere lake's water sample was found to contain excess chloride, hardness and total dissolved solids and high levels of eutrophication.

Workshop outcomes and stakeholder perspectives

The project began with an inception workshop conducted online. The workshop introduced the project to key partners, stakeholders and other interested parties.

Working relationships, consensus on project design and a refinement of the project scope was achieved during this workshop.

Findings

First physical workshop: 13-14th February 2023

The first physical workshop, "Data Collection and Mapping Workshop" was primarily focused on DHI's hydrological modelling process along with initial assessments of the state of water supply, demand and use from data collection partners Myrada and FES.

The workshop was a notable meeting point between those with hyper-local knowledge of water resources in Anekal and the needs of users, and a more generalised top-down understanding from DHI. There was a notable divergence amongst attendees between those able to grasp the principles of hydrological modelling, and those for whom it was a new concept without obvious applications to their on-the-ground work. The workshop revealed some crucial limitations of the conceptual hydrological model and the proposed set of decision indicators. It was clear that a hydrological model may not, on face value, support local-level decision making without very close collaboration with local actors to explain the value of modelling and to align a model with their needs as part of a chain of decision-making. **The team concluded that time and effort needs to be put in with local partners to contextualise the model in the context of crucial local needs.**

Moreover, it was not clear how the valuable insight from the tool would or could be aimed at different types of stakeholders, and how it can meet their needs with regards to water resources management. At present, stakeholders engage in the evolution of water management projects at different conceptual stages - from needs assessment to project design, implementation and monitoring. **It was gauged that a hydrological model can contribute to improvements at each stage, but only by carefully mapping the requirements at each stage and aligning the model with the needs of each stakeholder.**

Moreover, a hydrological model should include relevant local water-related structures, such as lakes and storage ponds, that are identified by local partners as having a significant or potentially significant role in water management. The first iteration of the model missed these vital structures. Similarly, the model did not address the very poor understanding of aquifer base flows in India, which are currently estimated by government authorities using crude and generalised assumptions. **Early engagement from a modelling partner can help modellers to integrate key local hydrological structures, and to verify these against local data.**

Project partner the Foundation for Ecological Security (FES) provided a comprehensive map of stakeholders and governance processes for water management in Anekal. There is a lack of regulatory mechanisms for managing

Figure 7. Dr Kulkarni, host for the physical workshops

Findings

First physical workshop: 13-14th February 2023 continued

water supply and use at present and it is these mechanisms that present the greatest challenge to sustainable water management. Partner Myrada demonstrated the value of local knowledge, qualitative and quantitative, through their detailed assessment of water resources in Anekal.

This included data around water demand and supply for domestic and agricultural use, including detailed information around cropping patterns, use of fertilisers, and the condition of boreholes - such as the proportion which are dysfunctional or polluted sites. There are a number of wards and villages which face more acute problems with safe water supply than others - observing that each ward only receives safe drinking water once every 15 days, and it will not necessarily reach each house. **It was clear that local knowledge and narrative adds vital information to any hydrological modelling exercise.**

Stakeholders agreed that a general problem faced in India is that the availability of water is generally exaggerated, and that consumption is under-reported. This makes any assessment of availability difficult, with Anekal being no exception. In addition, stakeholders were asked to explore climate change scenarios that were relevant to the modelling exercise, based on the IPCC emission pathways. There was again a lack of understanding and consensus around which pathway was most relevant - and that additional research and knowledge-building was required. **Effort is needed to integrate meaningful climate scenarios.**

Figure 8. A site visit carried out as part of the workshop

Figure 9. Workshop discussions

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Findings

Second physical workshop: 30th March 2023

The second workshop was more orientated towards a presentation of the outcomes from each partner, and included a wider attendee list such a local civil society group Friends of Lakes, and the WELL Labs Foundation.

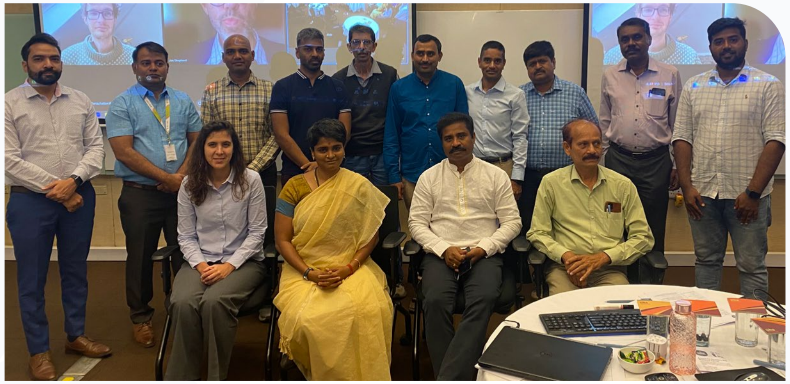
Myrada gave detailed information on their water resources survey work, and highlighted the dramatic drop in groundwater levels over the last 25 years, which have typically dropped from 50-60 feet below the surface to 900-1200 feet today and the increasing number of boreholes which are consequently failing.

FES added how this is consequent on the huge reliance on groundwater sources, from around 0% in 1975 to 100% today, with 197% exploitation of groundwater. **Data confirms that groundwater in Anekal is under unsustainable pressure.** DHI presented a map of groundwater exploitation, which shows only the southern area of Anekal as being over-exploited at present.

Myrada presented new data on the conditions of lakes and tanks, important historical water management features, which have suffered from neglect and pollution - but have the potential to form a part of a suite of water management improvements.

Agriculture, by far the dominant user of water, could reduce water consumption through better cropping patterns, more efficient irrigation, improved agronomic practices, and through using more drought-resistant crops.

However, a lack of knowledge on water management, difficulties in introducing new methods and technologies, and a continued increase in irrigated area are all barriers to solving these.



Beyond the Boundary

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Findings

Second physical workshop: 30th March 2023

Similarly, more erratic rainfall patterns and the degradation of land are putting additional external pressures on the livelihoods of farmers. Myrada presented a wide range of solutions, both to manage water demand, supply and quality. Civil Society organisation Friends of Lakes (FoL) presented their ambitious plan for the restoration of many of the lakes in Anekal and presented examples of how surface water canals have been restored in Karnataka, funded entirely by local time, equipment and money - without any contributions from NGOs or government.

Treated sewage has the potential to refill tanks, but the problem is more difficult for industrial effluents, where industry is unwilling to pay for treatment. Within Anekal, FoL is proposing the rehabilitation of three chains of canals connecting eleven lakes in collaboration with government, Bangalore University and other civil society actors. Benefits of the scheme will include groundwater recharge, better surface water availability, reduced flooding, improved lake water quality and opportunities for irrigation.

However, the benefits have not been quantified at present**. It was clear that restoring historic water management structures, along with agricultural supply and demand management, has the potential to improve water resources management in Anekal - but this is not quantified.**

FES provided valuable insights on social, cultural and industrial changes in Anekal - in particular, changes from a rural landscape to a peri-urban one, and the risks of chaotic and unplanned development (see Figure 6).

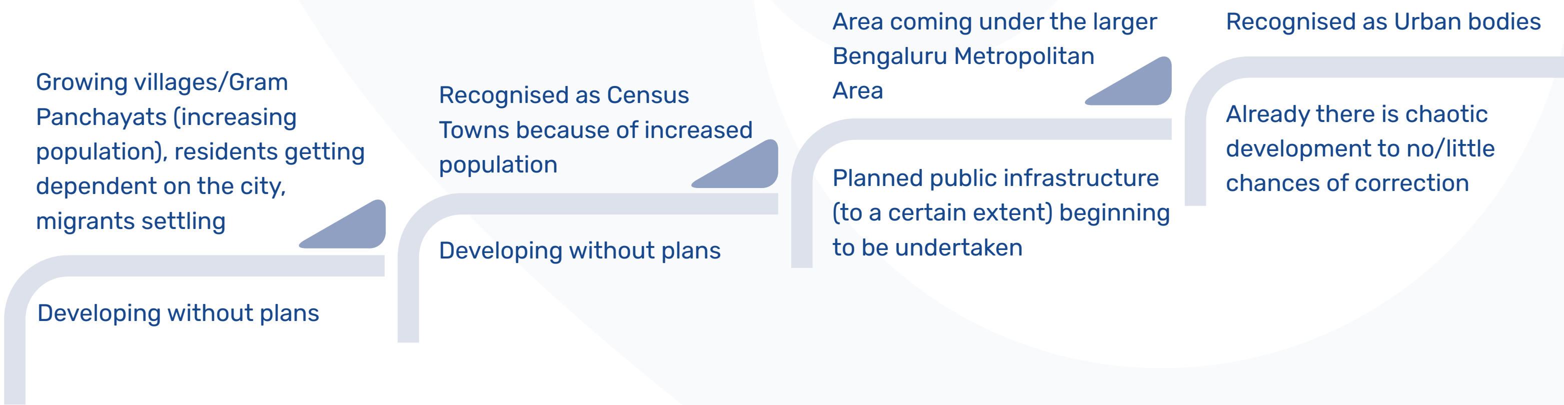

Figure 10. The risks of chaotic development at different spatial scale in Anekal

Findings

Second physical workshop: 30th March 2023

FES highlighted how the built-up area of Anekal doubled from 2005-2020. Waste and fallow land has increased, as land is bought-up by real estate agents but left to turn fallow.

Similarly farmers are switching from growing cereals and millets to floricultural activities, whilst common land is being encroached upon.

Anekal is increasingly supporting the needs of Bangalore as an urban centre whilst many people with smallholdings are leaving agriculture and moving to cities.

The role of institutions is also changing, with a breakdown of traditional village-level structures as they struggle in their new role as peri-urban managers, as shown in Table 4 on the next page.

External agencies and volunteer bodies, along with formal decision-making institutions, are increasingly steering decision-making that was previously taken collectively by traditional leaders or collectively. Gram Panchayats face a capacity gap in terms of information, guidance and human resources.

FES proposes strengthening Gram Panchayats by providing guidelines for development, investing in human resources, performing land use planning, investing in data architecture, and building synergies between the need for both urban and rural development.

Institutions and decision-making mechanisms suitable for the rural context in Anekal are not suitable for the peri-urban one.

This situation, along with the projected urbanisation levels, if left unplanned and sub-optimally managed, may be detrimental to the society, economy, and environment.

- Niti Aayog,
discussing unregulated development
in India Reforms in Urban Planning Capacity
in India, September 2021

Findings

Second physical workshop: 30th March 2023

Sl. No.	Attributes	Rural Context	Peri-urban Context
1	Institutional arrangement	Existence on formal and informal institutions. There is a strong bond between people. There is a common interest to work forward. Eg: Tank User Groups, irrigation mgt, Village Institutions, self help groups (SHGs).	There is no common interest. Strong SHGs for micro finance activities. Eg: SHGs with an interest of credit management
2	Protection of common resources	Community has taken over the responsibility of protection and management of common resources and trying to leverage funds from government/other sources.	Commons are seen as government resources. External Agencies or Volunteer bodies take action.
3	Decision making	Community believes in collective decision making. Village traditional leaders play major roles in negotiation.	Gram Panchayat and other formal institutions take decision.
4	Conflict resolution	Through traditional leaders of village institution leader with the active participation of village institution members.	Resolved by external institutions/agencies.

Table 6: Governance mechanisms in the rural and peri-urban context

Monitoring and quantifying the benefits of such interventions in a consistent manner is a challenge. Lake User Groups have previously been identified by the World Bank for this task, but they are now largely no longer functional. A data-management architecture and up-skilling programme could strengthen the case for funding and maintaining water resources management interventions.

Data and insights from DHI, FES and Myrada provide a strong case for institutional strengthening and the development of supply-side and demand-side projects focused on agriculture. Given the dominance of this sector as a consumer of water in Anekal, the greatest benefits are likely to be realised here. However it is not yet clear how useful the current model and set of decision indicators is for driving such developments in small watersheds, such as those under study in Anekal.

Findings

Identified challenges in achieving water stewardship management initiatives

The project identified a set of challenges to achieving effective water stewardship in Anekal's watershed, which have wider applicability to other growing peri-urban areas due to similarities across the basic governance, administrative and policy contexts in different Indian states.

The identified challenges are as follows:

Fragmented Institutional Framework:

There is inadequate coordination and collaboration among various government agencies responsible for water management, such as the Water Resources Department, Municipal Corporation, and State Pollution Control Board. There is a lack of a unified and integrated approach to water governance, resulting in overlapping responsibilities and gaps in decision-making.

Limited Local Governance Capacity:

Stakeholder consultations revealed challenges in terms of local governance capacity, including limited financial resources, technical expertise, and institutional capacity to manage water resources effectively. Insufficient participation and involvement of local communities in decision-making processes also limits the degree to which any single stakeholder in a watershed can act on an emerging water-related stress and build consensus for a solution. This also leads to a lack of ownership and accountability in water management initiatives.

Inadequate Infrastructure and Service Delivery:

Inadequate water supply infrastructure includes a lack of storage facilities, distribution networks, and treatment plants, resulting in intermittent water supply and poor service delivery. This is a typical challenge faced by domestic as well as industrial users. It can reduce the incentive for collective action in a watershed, as the gains from public infrastructure are marginal when key users opt out of public provisioning and switch to private supply of water-related goods and services. Further, inefficient water management practices lead to high levels of non-revenue water (leakage and unauthorised connections) and water losses, creating a negative feedback loop.

Water Pollution and Quality:

The following are challenges related to pollution of water sources:

- Discharge of untreated or partially treated wastewater into water bodies, leading to pollution and degradation of water quality.
- Insufficient monitoring and enforcement of pollution control regulations, resulting in the contamination of water sources and posing risks to public health.

The problem is illustrated in a report titled "Action Plan for Improvement of Environmental Quality in Jigani & Bommasandra Industrial Areas (Under CEPI), Bengaluru Urban District 2019-20" prepared by the Karnataka State Pollution Control Board and submitted to the National Green Tribunal dated 19 February 2020.

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Findings

Identified challenges in achieving water stewardship management initiatives continued

"The Board is monitoring the water quality of nearby tanks under various monitoring programmes. At present the Board is regularly monitoring 22 lakes on a monthly basis and the results of the water analysis are compared to the designated best use classification of CPCB, New Delhi.

Out of 21 Lakes, there are 13 lakes water quality falls under the Class D and remaining 8 falls under the Class E, which are attributed due to entry of untreated sewage into the Lakes.

Action taken by the Board so far: Before identification of the said industrial area as a critically polluted area, the Board has issued directions to industries located adjacent to the water bodies to prevent storm water / sewage entering the lakes. The Board has also directed the industries to adopt the lake and to take-up the rejuvenation works such as diversion canals to divert the entry of sewage, providing wetland treatment for treatment of storm water / sewage, desilting of lakes."

Water Scarcity and Inequitable Access:

Anekal Town may experience water scarcity due to overexploitation of groundwater resources, inadequate storage capacity, and inconsistent rainfall patterns. Unequal distribution of water resources, with certain sections of the population, facing limited access to safe and reliable water supply can limit participation from all the stakeholders in a watershed.

Climate Change Impacts:

Anekal Town may be vulnerable to the impacts of climate change, such as changing rainfall patterns, increased frequency of droughts, and variability in water availability. Furthermore, there may be insufficient integration of climate change considerations in water management strategies and policies, hindering adaptive capacity and resilience.

Inefficient Water Pricing and Financial Sustainability:

There may be inadequate cost recovery mechanisms and inefficient water pricing structures, resulting in financial challenges for water service providers and hindered investment in infrastructure development and maintenance. There are limited financial incentives for water conservation and demand management, leading to inefficient water use practices.

Lack of Data and Information:

Insufficient availability and accessibility of accurate and up-to-date data on water resources, water demand, and consumption patterns, hinders evidence-based decision-making and planning. There is limited dissemination of information and awareness among stakeholders about water-related challenges, opportunities, and best practices.

Data Collected

Summary of data

Figure 7 below presents the status of data collected and compiled for the water resources model in Anekal Taluk. Data types along with available sources are listed which highlights the importance of satellite data products. However, there was a significant gap in the 'water use' data category which is difficult to bridge through the available satellite data products.[8]

In the hydrological modelling exercise (development of the baseline model) the aim was to simulate the response of watersheds to the various hydro-climatic forcings such as rainfall, temperature, amongst others, along with anthropogenic forcings such as water consumption and use. However, presence of data gaps in these forcings often results in poor prediction or behaviour of the model, both in space and in time as there will be errors in volume estimation, errors in the timing of hydrological events during simulation such as overland flow generation, infiltration, groundwater recharge, baseflow etc. Lack of information on water use makes it difficult to segregate sector wise information on demand vs supply. However, the baseline survey being conducted is expected to assist with generating data capturing water use by different sectors. The baseline survey results will be used to improve the estimates on agriculture, domestic and industrial use.

Finally, hydrometeorological data was also required for model calibration and validation, securing sufficient time coverage of such datasets will determine the soundness of the model and its applicability.[9]

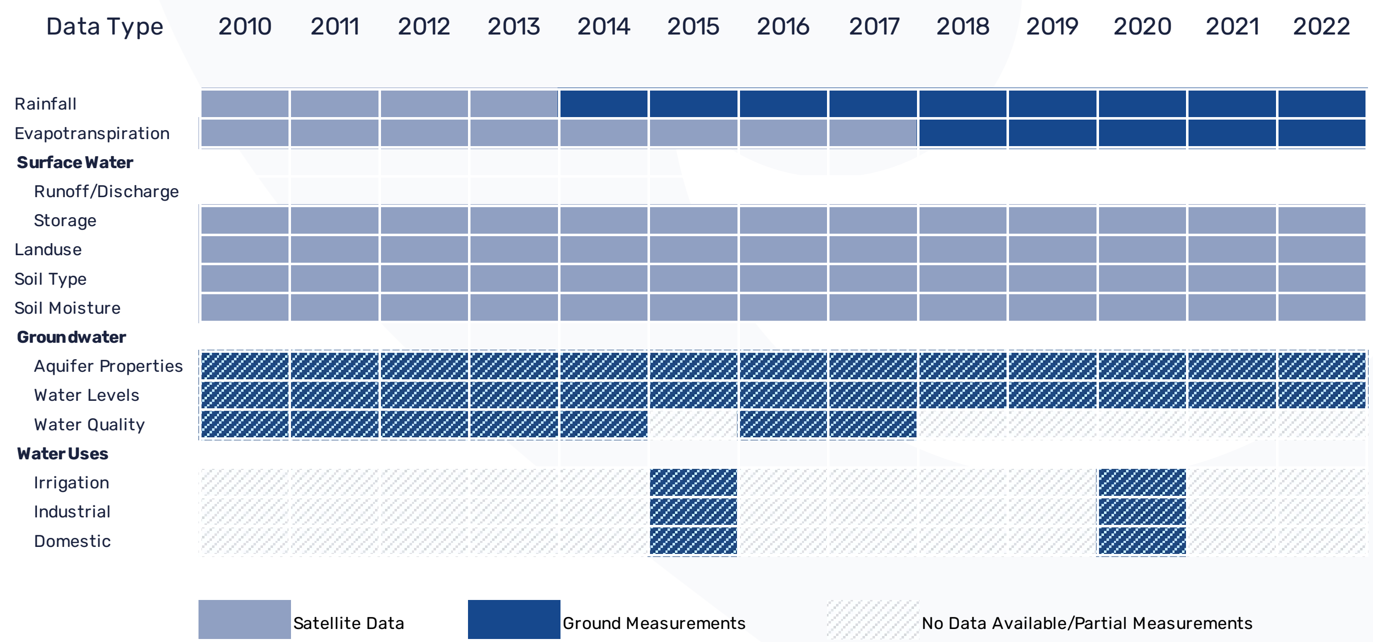

Figure 11. Summary of data collected for the construction of the Hydrological Model

[8] See Data Collection and Mapping Report. Date Published: 23 February 2023

[9] See Data Collection and Mapping Report. Date Published: 23 February 2023

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Data Collected

Key findings from Anekal

Through the modelling exercise, it was observed that during dry years, when there is less rainfall, less recharge is generated which puts the Taluk's groundwater under significant stress and groundwater storage declines. On the other hand in high rainfall years, where annual rainfall exceeds 800mm, the watersheds receive sufficient recharge, having a stabilising and replenishing effect on the aquifer.
Below are the key findings from the data collection and modelling exercise[10]:

a. The total amount of water received annually in Anekal taluk as simulated by the model (for 11 hydrological years from 2010 to 2021) is 43 million cubic metres (mcm) per year on average.

b. Land use from 2010 to 2022 changed, with a dramatic increase in built up and fallow areas and a decrease in cultivated areas and woodland. The proportion of 'Urban / built up' land use class increased from 8.82% to 16.62%, 'Bare/sparse vegetation' from 1.59% to 1.62%, and 'Permanent water bodies' from 2.45% to 2.65%. This change was at the expense of decreases in 'Cultivated and managed vegetation/ agriculture (cropland)' 67.24% to 64.57%, Open forest – mixed' from 8.56% to 6.59%, 'Herbaceous vegetation' 6.87% to 2.23% and 'Shrubs' 4.47% to 3.43%.

c. The total current water demand in Anekal taluk is 46 mcm per year on average and it is expected to increase by 48 mcm per year on average by 2030. The agriculture water demand shares the maximum percentage of the total water demand (>90%).

d. About 93% of the current water demand is being met in Aneka taluk, where in future it is likely to be 90% for low and moderate emission scenarios and 99% in high emission scenarios as evaluated in IPCC's AR 6 report.

As summarised in Table 5 below, the proposed scenarios will consist of a combination of urban development and Climate Change projections. Three climate change scenarios were considered for the near future period of 2021 to 2040 in this study: 'Low' SSP1-1.9, 'Medium' SSP2-4.5 and 'High' SSP3-7.0 in reference to the level of mitigation and adaptation challenges and emissions in each. The table describes the four future scenarios built on top of the baseline.

No.	Description
S0	Conditions in the watersheds in the baseline period from 2010 to 2021 [1] [SL2] No planned developments No climate change projections
S1	Developments inferred from land use / land cover (LULC) map and available masterplans, expected to be in place by 2031 No climate change projections
S2	Developments expected to be in place by 2031, and S1 and SSP1-1.9 climate change projections Near Future (2021-2040) 'low emissions'
S3	Developments expected to be in place by 2031, S1 and SSP2-4.5 climate change projections Near Future (2021-2040) 'middle of the road'
S4	Developments expected to be in place by 2031, S1 and SSP3-7.0 climate change projections Near Future (2021-2040), 'high emissions'

Table 7. Scenario descriptions

[10] All the results are available on the BtB portal developed.

Beyond the Boundary

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Data Collected

Findings from Anekal continued

Proposed Urban Development and Climate scenarios are based on the Revised Master Anekal Plan and IPCC AR-6 reports from which factors were inferred and applied to the baseline's climate and water demands.

The current aquifer recharge or groundwater recharge is 43 mcm per year on average. The **groundwater recharge index** reflects the proportion of groundwater recharge in relation to demand. The relative change in the index for the future scenarios is maximum for the high emission scenario where recharge is expected to **increase by 17%** due to high variability in monsoon months. For other low and moderate emission scenarios, the **relative change is minimal** and falls in the range of 0 to 3%. The area in the east and south of Anekal taluk are more likely to be under stress due to overall high agriculture demand. The severity is expected to be high in dry years.

Limitations and uncertainties

It is important to note that the models used for this study, while checked and calibrated to the best extent possible, have some limitations and uncertainties. Most importantly, there has been a lack of data for observed river discharge and groundwater levels, population, agricultural and industrial demands, amongst other datasets - and therefore some assumptions were made in the development of the model. In addition, climate change scenario projections are, by their very nature, uncertain.

For these reasons, the conclusions presented should be taken as an indication of the impact and trends of future development and climate change rather than taken as representing the absolute magnitude of impacts. More accurate data on surface water, groundwater, water demand and use can lead to this, reduction of error would be expected, but moreover, other methods may become available. Future work on climate change projections should focus on clustering a large number of climate change scenarios with statistical analysis of likelihood and confidence in the different scenarios.

In the long run, it is important to have sustainable water use and resource management in the taluk. If use is unsustainable, the shallow dug wells may run out of water impacting local livelihoods, a situation that has occurred in the past and is being ameliorated with mitigation measures supported by Frank Water's partners such as Myrada's community percolation tanks. In the near future, based on the projections, the groundwater availability is likely to reduce, thus more judicious planning is recommended.

Regarding groundwater quality, the results presented in this study are inconclusive, due to the lack of data. They were reported to demonstrate how a quality indicator could be estimated and used, should the input data be sound enough to support the analysis.

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Data Collected

Answers to key questions

The answers to the key questions posed by the team in the early stages of the project are outlined below:

1. What is the current total quantum of water received in the selected watersheds from all sources?

The total amount of water received annually in Anekal taluk as simulated by the model (for 11 hydrological years from 2010 to 2021) is 43 million cubic metres (mcm) per year an average.

2. How has the land use and land cover changed (in terms of net area and percentage changes) over the period 2010 - 2022?

What are the percent changes in various LULC (Land Use / Land Cover) classes - such as built up, agriculture, forest, grass/grazing, barren/ wasteland and wetlands/water bodies.

Using indicator LULC change, the classes with increased area from 2010 to 2022 were:

- Urban / built up' from 8.82% to 16.62%,
- Bare/sparse vegetation' from 1.59% to 1.62%
- Open forest – mixed' from 8.56% to 6.59%
- Permanent water bodies' from 2.45% to 2.65%.

This change was at the expense of decreases in:

- Cultivated and managed vegetation/ agriculture (cropland)' 67.24% to 64.57%
- Herbaceous vegetation 6.87% to 2.23%
- Shrubs 4.47% to 3.43%.

3. What is the quantity of current water demand in the selected watersheds for domestic use (and split for drinking water demand), industrial use, agricultural use, and remaining water that is not drawn/used

There are three major sectors or categories identified for the water use in Anekal: Domestic, Industrial and Agriculture.

- The current water demand for 'Domestic' category water user in Anekal taluk is 4.26 mcm per year on average.
- The current water demand for 'Industrial' category water user in Aneka taluk is 0.65 mcm per year on average.
- The current water demand for 'Agriculture' category water user in Aneka taluk is 41 mcm per year on average.

4. What is the total quantum of water available for use in the watershed?

The total amount of water available for use in Anekal taluk as simulated by the model (for 11 hydrological years from 2010 to 2021) is 43 mcm per year on an average.

5. What is the percentage of current demand that is being met by available and usable water?

The total demand of all the three major categorical water users, Domestic, Industrial and Agriculture is 46 mcm. The net amount of water available for use, as explained in above sections, is 43 mcm per year on an average. Thus, about 93% of the current demand is being met.

6. What is the current water storage capacity in the watershed?

The current water storage capacity simulated based on the above indicator varies in the range of 10 mcm (in dry year) to 151 mcm (in high rainfall year) per year on an average in Anekal taluk.

7. What is the available storage potential in the watershed? What percentage of future demand can it meet?

The total projected amount of water available for use in Anekal taluk for the climate change scenarios (S2-S4) is expected to vary during high and low rainfall years depending on the scenarios (low or high).

The projected water demand disaggregated by sector is calculated to vary in the range of 2% to 18% depending upon the category of the water use compared to baseline period.
Anekal taluk would be able to meet 93% its current water demands. In future scenario S1, S2 and S3,

Beyond the Boundary

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Data Collected

Answers to key questions continued

about 90% the future demands will be met while for S4 scenario, 99% of future demand is expected to be met.

8. What projections or demand scenarios can be made for sector-wise water demand for the next 10 and 20 years?

The projections for the water demand by 2036 are calculated based on the population projections, and relative urban developmental changes from 2010 to 2021.

- The domestic water demand is going to increase by 18% i.e., from 4.26 mcm/yr to 5.03 mcm/yr.
- The industrial water demand is going to increase by 18% i.e., from 0.65 mcm/yr to 0.77 mcm/yr.
- The agriculture water demand is going to increase by 2% i.e., from 41 mcm/yr to 42 mcm/yr.

9. What projections for land use and land cover change can be made for the next 10 and 20 years?

The official 2031 masterplan for Anekal was the source, hampered by uncertainty around actual implementation of the plan and mechanisms to monitor it.

The projections for land use changes are therefore estimated for the next 10 years. In sum, the expansion of 'Urban / built up' from 8.82% in 2012 to 53.39% of the total area in 2031 is the most significant change alongside a corresponding decrease in 'Cultivated and managed vegetation/ agriculture (cropland)', is expected to decrease from 67.24% in 2010 to 28.56% according to the 2031 plan.

10. What has been the precipitation trend over the period 2010-2022 ? How will it change in the next 10 and 20 years?

Based on the IMD gridded dataset for the time period 2010-2022, Anekal taluk received an average annual rainfall of 850 mm and receives early monsoon showers in month of May. The overall trend has been on the rise for the decade 2010-2022, where 5 out 12 years received above average rainfall.

However, to develop more understanding on the historical trend of rainfall, it is advised to use long-term rainfall datasets such as the CHIRPS dataset which is available in the BtB portal.

The three climate change scenarios: Low emission (S2), Moderate emission (S3) and High emission (S4), considered in the present study cover the time period 2021-2040 and presents the median climate change factors. These change factors inform the likelihood of the relative change in rainfall (for each scenario) compared to the baseline.

11. What is the current aquifer recharge rate and potential? How is it likely to change in the next 10 and 20 years?

The simulated aquifer recharge can be best described by two water-resource indicators groundwater recharge and groundwater recharge index. The aquifer recharge or groundwater recharge as estimated by the model on an average is 43 mcm per year and can go up to 150 mcm per year in high rainfall years.

Groundwater recharge index reflects on the percentage change of the groundwater recharge with respect to the baseline. The relative change is maximum for high emission scenario S4 aka SSP3-7.0 where recharge is expected to increase by 17% due to high variability in monsoon months. For other scenarios, the relative change is minimal and falls in the range of 0 to 3% for S1 and S2 scenarios respectively.

12. How has water quality changed over the period 2010 - 2022?

Due to the lack of available data that is consistent in time, it was not possible to respond to the question when it comes to groundwater. Focus for this question was on groundwater throughout the assignment.

Towards the end it was decided to look at lakes in Anekal, therefore the project team sought for (within the available time) an indicator that could

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Data Collected

Answers to key questions continued

support assessing water quality of surface water bodies.

Water quality tests at Doddakere and Haragadde lakes revealed that parameters exceed both the maximum acceptable and or permissible limits in the absence of an alternative source as per IS:10500-2012.

A visual survey of lakes in Anekal also reveals that they are generally in poor condition with industrial waste and domestic waste water outlets connected to lakes without any primary treatment. Lake infrastructure is generally in a poor condition with extensive littering observed in and around them.

13. What are the locations of critical/stressed groundwater levels within the watershed, overlaid with a land-use map?

This is described by the water resource indicator "critical / stressed groundwater". The indicator is defined by the Central Ground Board (CGWB) definition of stress which is the ratio of annual abstraction to annual recharge (after deducting natural discharge). The present indicator is in itself offering more resolution where the stress level is estimated monthly.

There are in total seven watersheds delineated for the present pilot assignment. It is inferred that the watersheds in the south-southeast C2, C3, C4 exhibit more stress than the other watersheds. The primary reason is that the relative area under agriculture to the watershed area is high in these watersheds and has high agricultural water demands.

The stress level is highly dependent on the recharge which is related to the amount of rainfall received in the area. The results on a monthly time scale are available on the BtB portal.

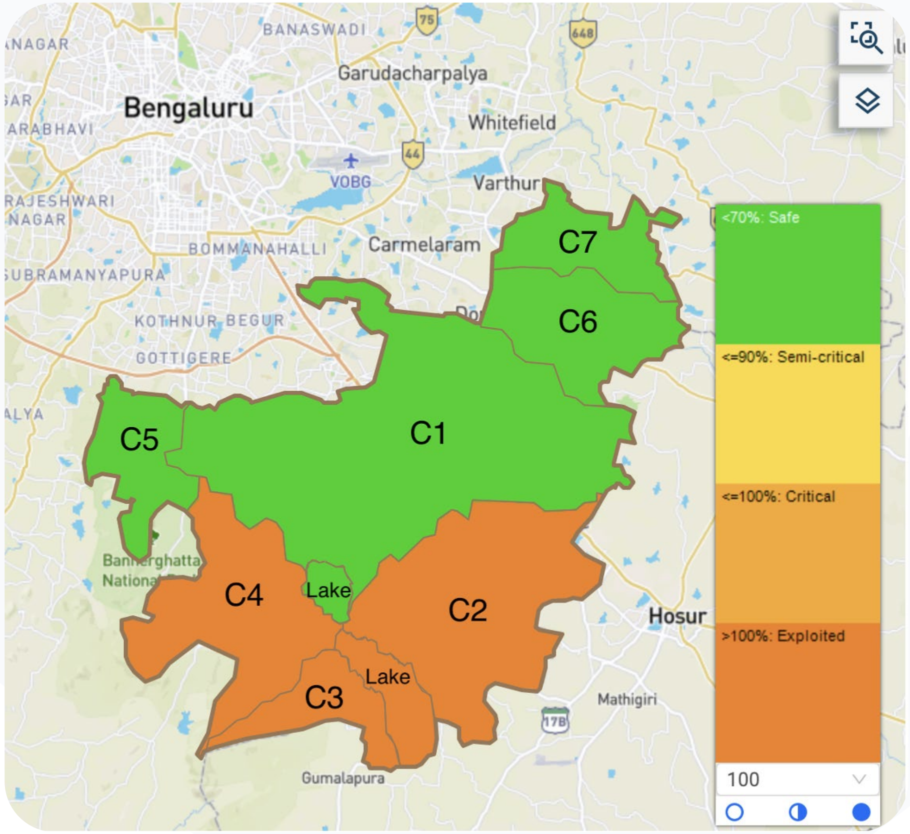

Figure 12. The Critical Groundwater State in Anekal in May 2021

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Recommendations for Effective Water Stewardship at Watershed-Level

Based on the hydrological model and stakeholder consultations, the following guidelines and actions are recommended for businesses to achieve effective water stewardship.

Guidelines for corporate water stewardship

Corporate water stewardship encompasses various actions and strategies aimed at protecting and preserving water sources, such as rivers, lakes, groundwater, and wetlands. The focus on these elements may vary according to context and their health status in an area. It involves the engagement of multiple stakeholders, including governments, businesses, communities, and individuals, to collectively address water challenges.

Key elements of water stewardship can include:

1. **Water Governance:** Establishing effective policies, regulations, and institutions to manage water resources at local, regional, and national levels. This includes ensuring equitable access to water and promoting participatory decision-making processes.
2. **Water Conservation:** Implementing measures to reduce water consumption, improve efficiency, and minimise waste in various sectors such as agriculture, industry, and households. This can involve the adoption of efficient irrigation systems, water-efficient technologies, and water reuse/recycling practices.
3. **Source Protection:** Preserving and restoring the quality and quantity of water sources through measures like watershed management, erosion control, reforestation, and wetland conservation. Protecting ecosystems that provide water services is crucial for maintaining sustainable water supplies.
4. **Collaboration and Partnerships:** Encouraging collaboration among different stakeholders, including governments, businesses, non-governmental organisations, and local communities, to develop and implement water management initiatives. Collective action can lead to more effective and inclusive solutions.
5. **Awareness and Education:** Promoting awareness and understanding of water-related challenges, encouraging responsible water use practices, and fostering a sense of shared responsibility for water resources. Education plays a vital role in driving behavioural change and fostering a culture of water stewardship.

To put these guidelines into practice a set of actions are recommended in the following section.

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Recommendations for Effective Water Stewardship at Watershed-Level

Recommended actions

Assess water resources:

- Conduct a comprehensive assessment of the watershed's water resources, including surface water bodies, groundwater, and associated ecosystems.
- Identify the key water challenges, such as water scarcity, pollution sources, or habitat degradation.

Stakeholder engagement:

- Collaborate with other stakeholders, including government agencies, local communities, non-governmental organisations, and businesses, to foster a shared understanding of water-related issues and goals.
- Establish a multi-stakeholder platform or forum for regular communication, information sharing, and decision-making processes.

Develop a water stewardship strategy:

- Formulate a clear vision and goals for water stewardship in the watershed, considering social, environmental, and economic aspects.
- Identify priority areas for intervention and establish specific objectives and targets to guide action.

Water governance and policy:

- Advocate for effective water governance mechanisms and policies that support sustainable water management.
- Engage with local authorities and policymakers to influence decision-making processes related to water allocation, pollution control, and watershed protection.

Water conservation and efficiency:

- Promote water conservation practices among stakeholders, such as implementing water-efficient technologies and practices in agriculture, industry, and households.
- Provide training and support to farmers, industries, and communities to optimise water use and minimise wastage.

Source protection and ecosystem restoration:

- Identify critical areas for source water protection, such as riparian zones, wetlands, and forests, and develop conservation and restoration plans.
- Collaborate with relevant stakeholders to implement measures to reduce sedimentation, erosion, and pollution sources that affect water quality.

Recommendations for Effective Water Stewardship at Watershed-Level

Recommended actions continued

Monitoring and data collection:

- Establish a robust monitoring system to regularly assess the quantity and quality of water resources in the watershed.
- Collect data on water usage, water levels, water quality parameters, and ecological indicators to inform decision-making and track progress.

Education and awareness:

- Develop educational campaigns and awareness programs to engage local communities and stakeholders in water stewardship efforts.
- Raise awareness about the value of water, sustainable water use practices, and the importance of preserving water resources for future generations.

Collaboration and partnerships:

- Forge partnerships with businesses, non-governmental organisations, and research institutions to leverage resources, expertise, and funding for water stewardship initiatives.
- Seek opportunities to collaborate on joint projects, research, and knowledge sharing to enhance the effectiveness of water management efforts.

Continuous improvement and adaption:

- Regularly review and evaluate the effectiveness of implemented actions and strategies.
- Adapt the water stewardship plan based on new knowledge, changing circumstances, and emerging challenges.

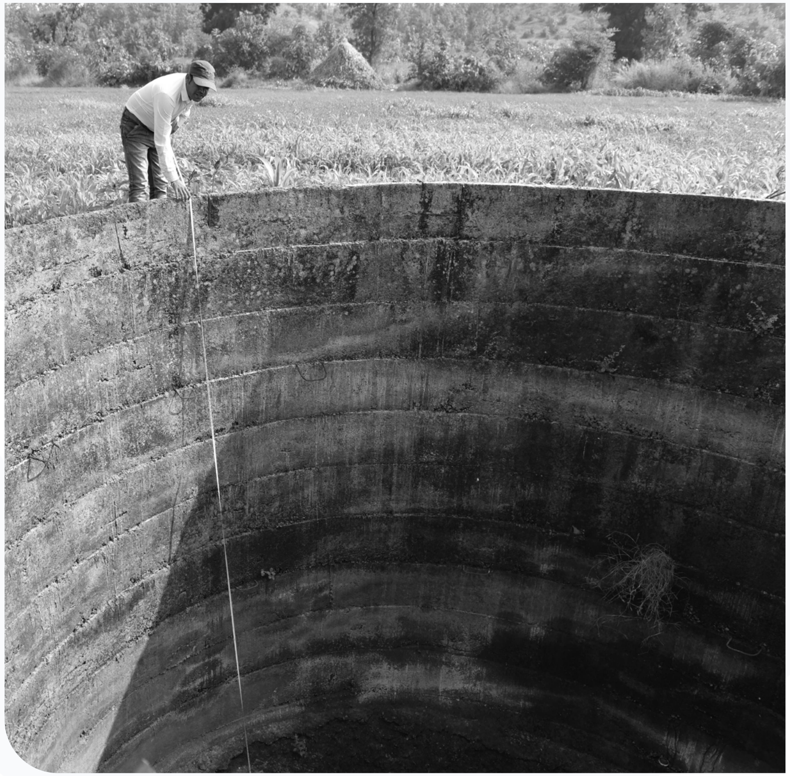
By following this action plan, a stakeholder in a watershed can contribute to the sustainable management and conservation of water resources, promoting water stewardship and addressing water-related challenges effectively.

Recommendations for Effective Water Stewardship at Watershed-Level

Benefits of using hydrological modelling

The benefits of using hydrological modelling in this project and watershed-scale are numerous. Firstly, it can provide stakeholders with a scientific basis for developing water management plans and policies, enabling them to prioritise actions and investments for most efficiently achieving desired outcomes. Secondly, hydrological modelling can help stakeholders to anticipate and manage water-related risks, such as droughts, floods, and water quality issues, reducing the potential for negative impacts on businesses and local communities. Finally, the use of hydrological modelling can enhance stakeholder collaboration and engagement, as it provides a common language and framework for discussing water management issues and solutions.

The model enables stakeholders to develop a better understanding of the water balance in the watershed and the interconnections between various water users and sources. This information can be used to identify priority areas for water management interventions, such as water conservation measures, water reuse and recycling, and source water protection. Furthermore, hydrological modelling can help assess the effectiveness of different water management strategies, supporting evidence-based decision-making and adaptive management.



In summary, modelling can offer:

- An improved accuracy of water resource assessments through a more complete understanding of the water balance;
- An enhanced understanding of water resource dynamics, including the impact of land use changes and climate variability; and
- More effective identification of water management strategies, including the potential benefits of various interventions such as rainwater harvesting, groundwater recharge, and water use efficiency improvements.

Way Forward

The current state of practice in corporate water stewardship continues to evolve independently as well as in tandem with ESG (Environmental, Social and Governance) compliance. Corporate water disclosure is firmly established as a part of ESG reporting with well defined targets and actions to be taken.

Responsible water use also has linkages across other sustainability issues like food and energy consumption. Therefore, responsible use of water resources and by extension, the necessity to assume water stewardship in their local watershed, is being felt by businesses.

Responsible business mandates are being enforced by regulatory bodies in several countries. For instance, the Business Responsibility and Sustainability Reporting, (BRSR) introduced by the Indian market regulator SEBI states[11] the following:

> *The BRSR is intended towards having quantitative and standardised disclosures on ESG parameters to enable comparability across companies, sectors and time. Such disclosures will be helpful for investors to make better investment decisions.*
>
> *The BRSR shall also enable companies to engage more meaningfully with their stakeholders, by encouraging them to look beyond financials and towards social and environmental impacts.*

To enable businesses deliver on their own as well as regulator defined expectation on responsible use of water resources, the next phase of Beyond the Boundary project intends to focus on the following:

1. Establish proof of concepts and working protocols for achieving corporate water stewardship through collective action at watershed scale
2. Scale up the approach and working protocols through institutions like Center for Water Stewardship. The Center will be mandated to:

    a. Develop a cloud-based DSSaaS[12] platform that allows multiple users across different regions to access and utilise the system remotely.
    b. Provide user-friendly interfaces and tutorials to facilitate easy adoption of the DSS by stakeholders with varying technical expertise.
    c. Offer technical support and training to users to enhance their understanding and proficiency in utilising the DSS

    Besides the core mandate, the Center will aim to achieve policy and planning integration . This will be achieved through the following:

    a. Integrate the DSS outputs and recommendations into regional water resource management policies, plans, and strategies.
    b. Collaborate with decision-makers and policymakers to incorporate the DSS as a tool for evidence-based decision-making.
    c. Provide decision-makers with tailored reports and visualisations that align with their specific information needs and policy objectives.
    d. Continuously update and improve the DSS based on feedback and lessons learned from large-scale implementation, fostering a cycle of iterative improvement and optimization.

3. Projectise small packages of work that can benefit watersheds independently in addition to serving as meaningful examples to progress the larger water stewardship paradigm.

[11] See Business Responsibility and Sustainability Reporting, SEBI https://www.sebi.gov.in/legal/circulars/may-2021/business-responsibility-and-sustainability-reporting-by-listed-entities_50096.html
[12] DSSaaS - Decision Support System as a Service

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Way Forward

Decision Support System (DSS) for corporate water stewardship

The Decision Support System (DSS) outlined below is designed to assist water managers in making informed decisions regarding watershed-level water conservation activities.

The DSS utilises a hydrological model to analyse various factors influencing water availability and determine whether the manager should undertake conservation efforts internally or finance other stakeholders to carry out the activities. By considering multiple parameters and scenarios, the DSS aims to optimise water resource management in the watershed.

Components of the Decision Support System:

Stakeholder Analysis

- Identify and assess other stakeholders within the watershed who may have an interest in water conservation.
- Evaluate their willingness and capacity to participate in conservation activities.
- Analyse potential collaboration opportunities and the costs associated with financing stakeholders' involvement.

Water Availability Analysis

- Utilise the hydrological model to estimate water availability within the watershed under different conditions.
- Evaluate the impact of factors such as precipitation patterns, land use changes, and climate variability on water resources.
- Generate water availability scenarios based on varying conservation efforts and stakeholders' involvement.

Hydrological Model

- Develop or adopt an appropriate hydrological model capable of simulating water balance within the watershed.
- Calibrate the model using historical data to ensure accurate representation of the catchment's hydrological processes.
- Validate the model's performance against independent datasets.

Cost-Benefit Analysis

- Quantify the costs associated with conducting catchment-level water conservation activities internally, including manpower, infrastructure, and maintenance expenses.
- Estimate the potential benefits in terms of increased water availability, reduced vulnerability to drought, and improved ecosystem health.
- Assess the economic feasibility and return on investment for internal conservation activities.

Way Forward

Decision Support System (DSS) for corporate water stewardship continued

Data Collection and Management

- Gather historical and real-time data on precipitation, evaporation, streamflow, groundwater levels, land use, soil properties, and other relevant hydrological variables.
- Store and manage the collected data in a structured database for further analysis.

Visualisation and Reporting

- Develop an intuitive and user-friendly interface to visualise the hydrological model outputs, scenarios, and analysis results.
- Generate comprehensive reports summarising the findings, including graphical representations and key metrics.
- Present the information in a format that allows the manager to easily understand and communicate the results to stakeholders.

Decision Analysis and Recommendations

- Combine the results of water availability analysis, cost-benefit analysis, and stakeholder analysis to generate decision alternatives.
- Apply decision analysis techniques (e.g., multi-criteria decision analysis, cost-effectiveness analysis) to evaluate and rank the alternatives.
- Provide recommendations based on the analysis to the watershed manager regarding the most suitable approach—internal conservation or financing other stakeholders.

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