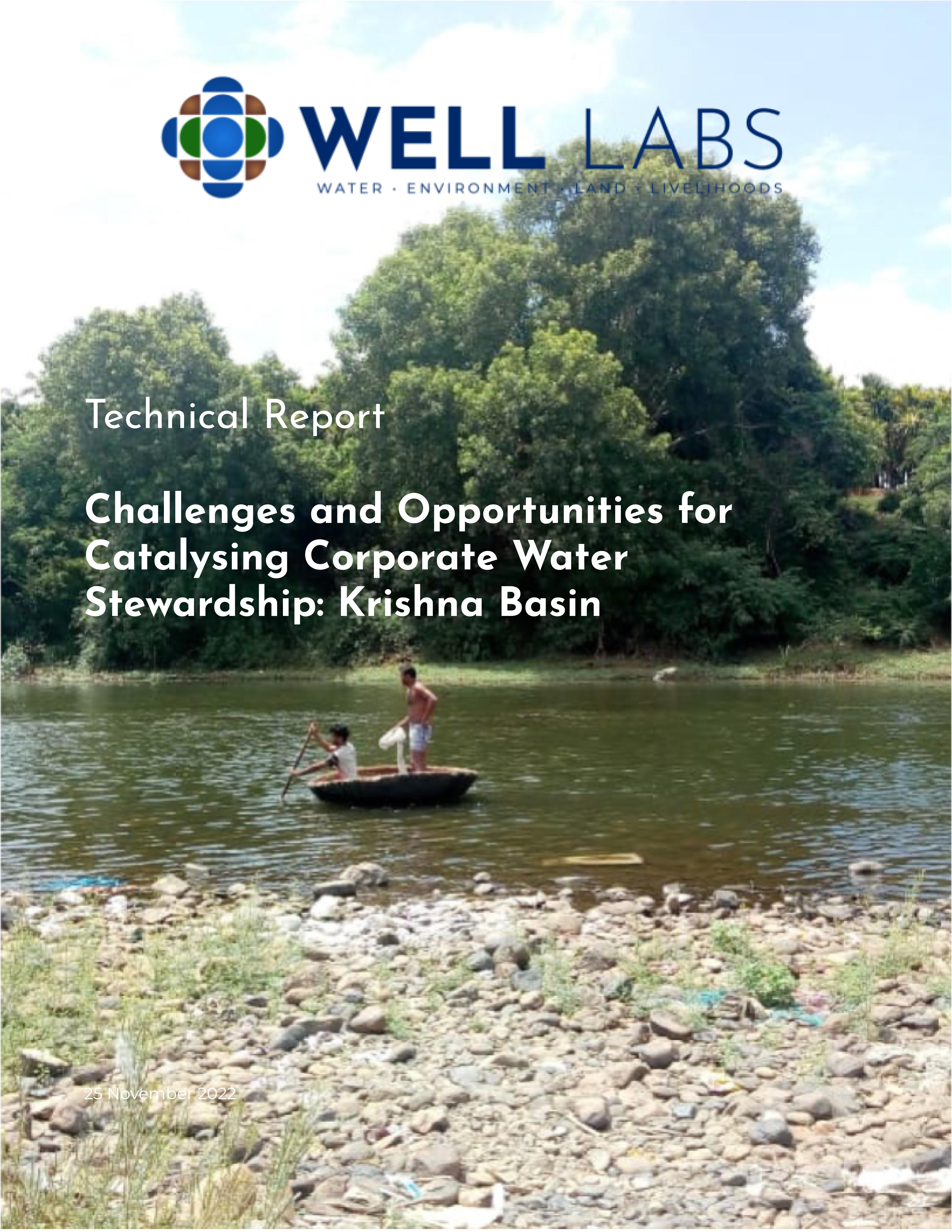

WELL LABS

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Technical Report

Challenges and Opportunities for Catalysing Corporate Water Stewardship: Krishna Basin

25 November 2022

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The CEO Water Mandate, an initiative of the United Nations Global Compact, has partnered with a number of leading global companies to launch an industry-driven, CEO-led initiative, the Water Resilience Coalition. The Coalition aims to preserve the world's freshwater resources through collective action in water-stressed basins and ambitious, quantifiable commitments. As part of this initiative, the Water Resilience Coalition has undertaken analyses to understand the status of water-stressed basins across the world in order to drive water-related collective action among companies with the goal to create positive impact in 100 basins across the world

Study duration: October 2021 to May 2022

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The authors conducted this work when they were with the Centre for Social and Environmental Innovation at the Ashoka Trust for Research in Ecology and the Environment (CSEI-ATREE). WELL Labs is now taking it forward in collaboration with ATREE.

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Executive Summary

The Krishna is the largest basin in South India. Some of the major cities in the basin include Hyderabad, Pune, Kolhapur, Vijayawada, and Belgaum. The river basin is economically important as it forms the backbone of agricultural activity for the four states of Maharashtra, Karnataka, Andhra Pradesh, and Telangana. Some notable companies located in the basin include Godrej Agrovet, Pepsi, Cadbury Kellogs, Bombay Dyeing, Whirlpool, Tata Steel, Tata Motors, and Mars International India Pvt Ltd.

This report contributes to a broader effort to mitigate water stress through facilitating corporate water stewardship by the Pacific Coalition, Pacific Institute, and the UNGC CEO Water Mandate via the Water Resilience Coalition. The Water Resilience Coalition's ongoing corporate water stewardship programme is an attempt to catalyse collective action in water-stressed basins toward the most pressing water challenges. The report presents our current understanding of six water challenges in the river basin. Water quality issues and water stress were identified as the main areas of concern. Opportunities to address these water challenges have also been identified.

In the Krishna basin, the following challenges were identified,

First, pollution due to the release of untreated sewage and industrial pollution is a major concern as most sub-basins have low treatment capacity. Insufficient monitoring also results in many water bodies being neglected.

Second, huge amounts of freshwater are being abstracted by the agricultural sector. Due to the boom of agriculture, many water-intensive crops are being grown in water-deficit regions, resulting in both surface and groundwater stress. A significant portion of the water used for agriculture comes from groundwater. A lack of groundwater monitoring and regulation systems in the basin worsens the situation. This, in turn, affects the base flows in many downstream rivers.

Table 1.1: Summary of the major water challenges identified in the Krishna basin

Water challenge	Major issues identified
WASH	• About 46.7 million people in the basin do not have access to functional tap connections. The primary reasons identified for this are inadequate infrastructure, contaminated sources of water, a lack of monitoring and penalty systems, and insufficient coordination between government departments. • Around 35.8 million people in the basin do not use safe sanitation facilities. The primary reasons identified for this are the lack of adequate water sources and systems/funds to ensure

	the maintenance of built toilets, especially in rural areas.
Water quantity	● All sub-basins are at a low to medium level of stress except for the Tungabhadra, Krishna delta, Musi, upper Krishna, Ghataprabha, and lower Bhima, which are under a high level of water stress. The basin is about 1361 billion cubic metres (BCM) of water short every year to remain within safe limits of use.The primary reason for this is the growth of water-intensive crops in dry regions, a lack of enforcement of localisation of irrigation (prescription of season of the irrigation, the type of irrigation) for water-intensive crops, leakages in the supply system due to old infrastructure, a lack of monitoring and regulating systems for groundwater abstraction, and no transparency in data sharing about water availability.
Water quality	● Treatment capacity in the basin is only 7.6% of the total effluents being generated. About 7539 million litres per day (MLD) of wastewater is not treated in the basin. The primary reason for this is the lack of funds available for the maintenance of treatment plants, the low skill level of the maintenance staff, and insufficient data on the amount of sewage being generated to plan for treatment capacity. ● Over 99% of lakes and rivers do not adhere to the water quality standards; this can damage ecosystem function or human health. The salinity of 78.8% and the nitrate levels of 37.5% of monitoring wells are above the permissible limits. The primary reason for this is insufficient monitoring of water bodies, a lack of sewerage network coverage, no proper solid waste management plans in place, and a lack of adequate centralised and decentralised treatment facilities.

Opportunities

Based on the assessment of the baseline indicators in the Krishna basin multiple opportunities for collective action were recommended. For solving the issue of water quality, increasing the capacity of treatment of wastewater and treatment of geogenic and industrial contaminants is needed. Nature-based solutions are needed to be installed across the basin to ensure water bodies have good ambient quality. To solve the water quantity issues, assistance needs to be provided to help farmers make sustainable transitions to low water using crops that also earn sufficient income. Recharge in the basin also needs to be increased, particularly of flood waters and potentially treated wastewater.

Chapter 1: Introduction

Krishna River is the third longest river in India and the fourth largest in terms of river basin area. The Krishna River basin lies between 73°17' to 81°9' east longitudes and 13°10' to 19°22' north latitudes (Figure 1.1), covering an area of 0.25 million sq. km. The total length of the river is about 1,400 km. It originates in the Mahadev range of the Western Ghats near Mahabaleshwar, at an altitude of 1,337 m above mean sea level. It flows through Maharashtra, Karnataka, Andhra Pradesh, and Telangana and drops into the Bay of Bengal in Andhra Pradesh (Figure 1.1). The Krishna River is the backbone of agricultural activity in the aforementioned states. The basin is roughly triangular in shape and is bounded by the Balaghat range in the north, the Eastern Ghats in the south and the east, and the Western Ghats in the west. The basin is mostly semi-arid. However, a dry sub-humid area in the deltaic region, an arid region in the rain-shadow eastern parts of the western periphery, and a little humid band (running north to south) along the western periphery are also present. The major land use practice in the basin is agriculture. The mean annual rainfall in the basin is around 859 mm. However, it varies from less than 400 mm in the northwest to a maximum of 3,000 mm on the western periphery and 1,000 mm in the deltaic region. The basin receives 85% of its annual rainfall during the southwest monsoon (Water Resources Department, 2021). The river basin has been divided into 12 sub-basins – Bhima, lower Bhima, middle Krishna, Muneru, Musi, upper Krishna, Ghataprabha, lower Krishna, Malaprabha, Tungabhadra, Vedavathi, and the Krishna Delta.

The population living in the basin is about 128.9 million, with 51% residing in urban areas and the rest in rural areas (Census 2011). Some significant economic activities carried out in the basin include agriculture and industries (textile, food processing, and beverages). Some notable companies active in the basin are Godrej Agrovet, Pepsi, Cadbury Kellogs, Bombay Dyeing, Whirlpool, Tata Steel, Tata Motors, and Mars International India Pvt Ltd.

The Western Ghats occupy only 9.5% of the basin area but receive 21% of the basin's rainfall (Biggs et al., 2007). Moreover, an increase in the growth of water-intensive crops and very few water treatment facilities have negatively impacted the water resources in the basin.

There are multiple water challenges in the basin. Identifying them helps to prioritise the water issues to which businesses can contribute. Using performance metrics and targets, businesses can make basin context–specific efforts which they can align with those of other stakeholders. This report, therefore, maps out the challenges in the basin and opportunities to address them through collective action using six themes: i) WASH, ii) water quantity, iii) water quality, iv) important water-related areas, v) water governance, and vi) water crisis. For each water challenge, there are different basin context metrics. Further, for each basin context metric or indicator used, the state of each sub-basin, challenges, gaps, and opportunities for businesses have been described. Along with this, the current and desired states for each basin context metric have been laid out. An analysis of each sub-basin was conducted using secondary data available on government websites, Geographical Information System (GIS) layers, and a review of the literature.

The Sustainable Development Goals or SDGs were agreed upon by world leaders in the year 2015. The 17 goals aim at creating a better world by the year 2030 by ending poverty, fighting inequality, and addressing the urgency of climate change. The 6th goal focuses on ensuring availability, sustainable management of water and sanitation for all, wastewater and ecosystems, and acknowledging the importance of an enabling environment. Each water challenge was analysed using various targets under this goal as indicators.

Base layers

The basin, sub-basin, stream, and river networks were delineated using the Cartosat DEM version 3 in the ArcGIS software. The district shapefile was downloaded from the Bhuvan-2D archive, compared with secondary data on government websites, and corrected accordingly (e.g. new districts were digitised). The district shapefile was then combined with the secondary data using the GIS tool. Values at the district level were then brought to the sub-basin level using the 'Tabulate Intersection' tool to get weighted averages.

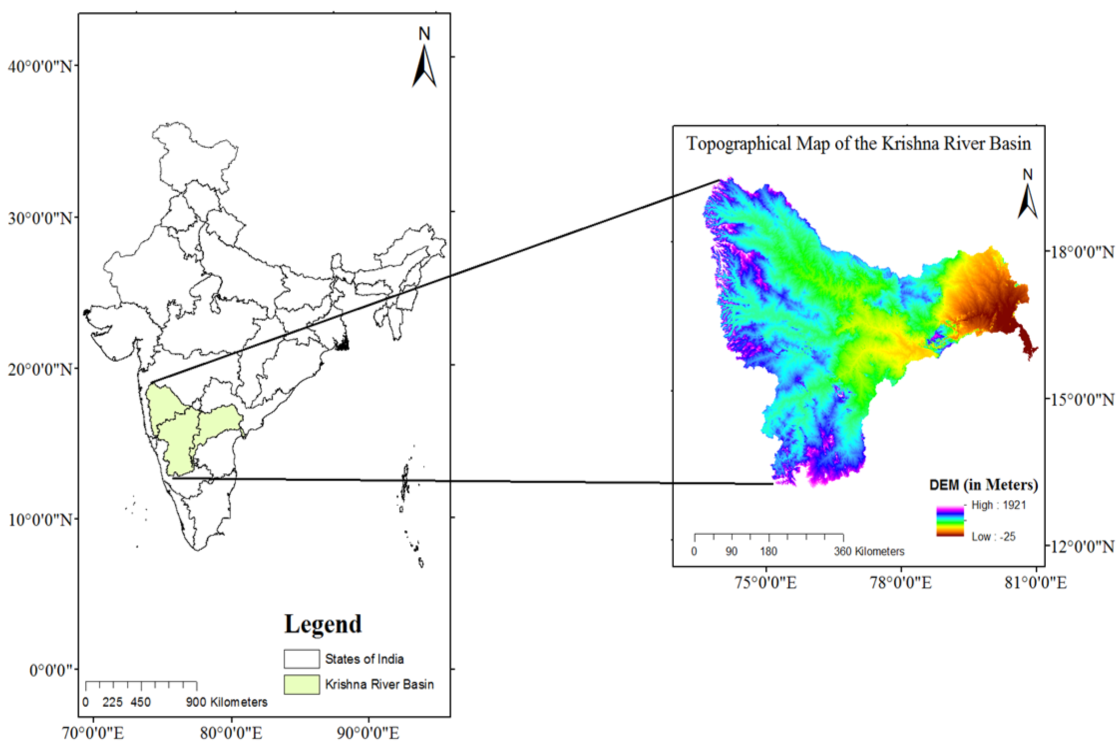

Figure 1.1: Geographical location (left) and elevation profile (right) of the Krishna River basin in India

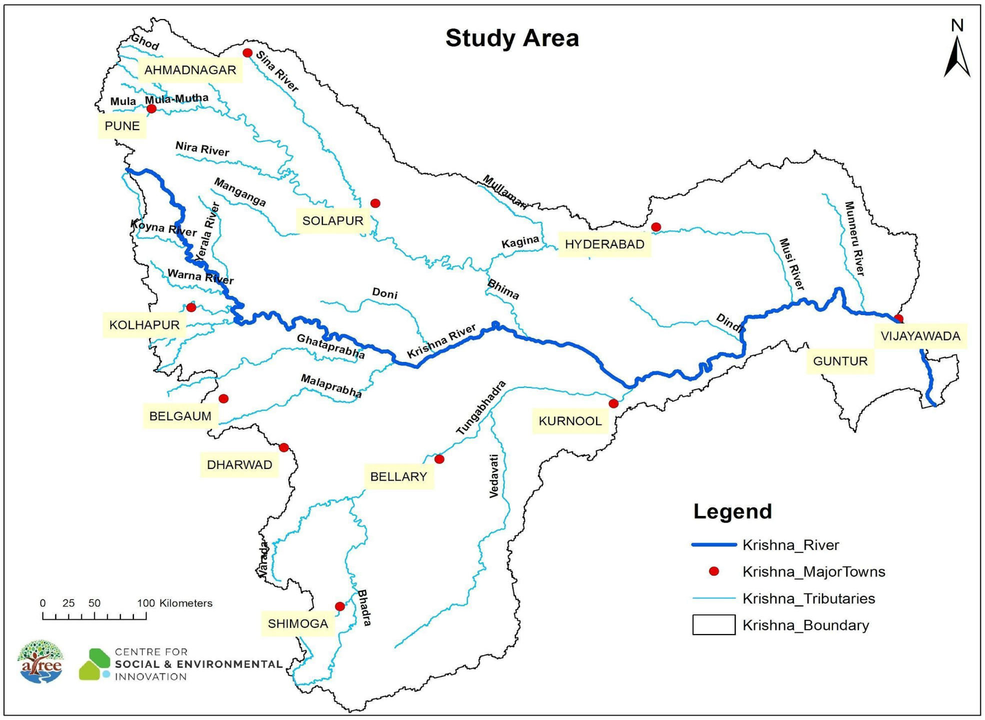

Figure 1.2: Study area map showing the Krishna basin, Krishna River, and its tributaries

Figure 1.3: Study area map showing the district boundary

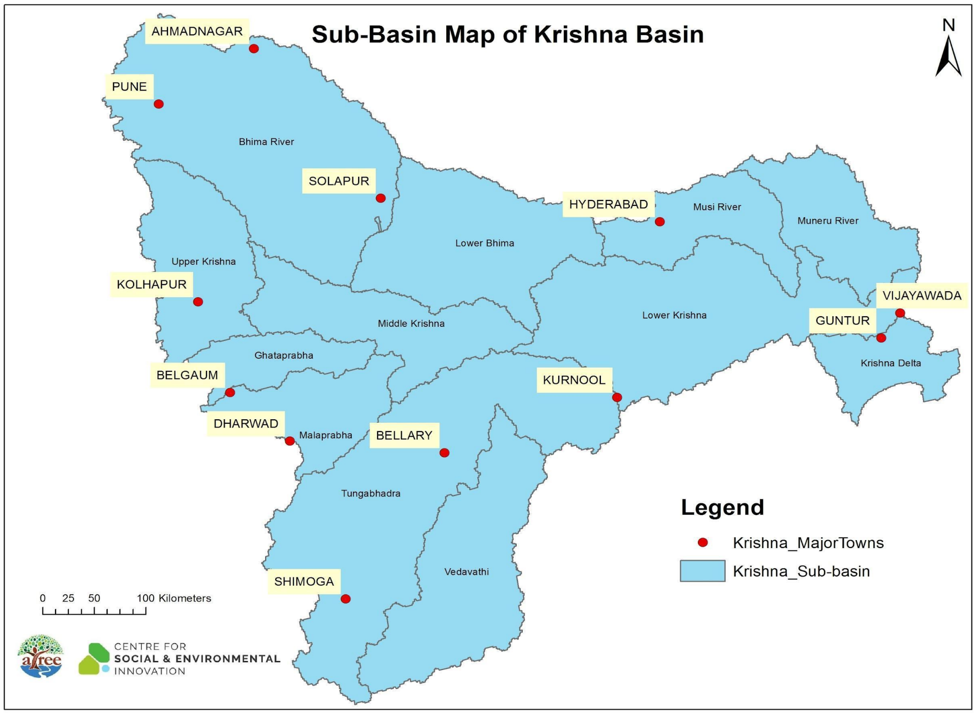

Figure 1.4: Study area map showing the Krishna sub-basins

Chapter 2: Access to Water, Sanitation and Hygiene

Access to safe drinking water

SDG 6.1 seeks to achieve access for all to safe drinking water. This indicator, therefore, tracks the population that has access to improved drinking water sources including piped water, boreholes or tubewells, protected dug wells, protected springs, rainwater, and packaged or delivered water.

The data on access to functional household tap connections (FHTC) was collected at the district level for all districts in the basin (NJJM, 2022). Using the weighted average method, the values were calculated at the sub-basin level. The percentage of households with functional tap connections was then estimated for each sub-basin.

In the Krishna basin, 74.8% of households have access to functional tap connections. The middle Krishna sub-basin has the lowest access, at 55.9%, while the Musi sub-basin has the highest access, at 100%. Sub-basins that are more urbanised have better access to functional household taps.

The Jal Jeevan Mission project by the Government of India aims to provide a functional tap connection with treated water to every rural household for drinking purposes. It aims to ensure access to 55 litres per capita per day (lpcd). Under this mission, which was launched in 2019, the government seeks to enable every household in every village to have an FHTC by 2024 (Ministry of Jalshakti, 2019).

A delay in the implementation of a piped water supply to all rural households is due to a lack of water sources, especially in drier regions. Most sources of water are seasonal or have no established plans for long-term sustenance. With over 7.8 million people living below the poverty line, many find it difficult to invest in installing the necessary infrastructure (Rajeev, 2015). The diversion of water for water-intensive agricultural needs also leaves limited water for drinking purposes (Harikanth, 2019).

Some existing gaps in the drinking water sector are as follows:

- There is inadequate infrastructure to raise the service level from 40 to 55 lpcd. There are no source sustainability measures in the form of rainwater harvesting or groundwater recharge structures. Also, greywater management is inadequate, which results in the contamination of water sources.
- Inadequate financial allocation to operations and management leads to the poor upkeep of assets, ultimately resulting in their falling into disuse.
- There are no monitoring and penalty systems to ensure efficient operation.
- There is a lack of convergence between various development programmes making decisions on broader water resource management and investments.

Access to safe sanitation

SDG 6.2 aims to achieve access to sanitation and hygiene for all. This indicator, therefore, tracks the population that has access to improved sanitation facilities including flush/pour flush to the piped sewer system, septic tanks, or pit latrines; and ventilated/improved pit latrines, composting toilets, or pit latrines with slabs.

Data on the number of households with access to toilets (SBM, 2021) and the proportion of the population using safe sanitation services (National Family Health Survey, 2020) was collected at the district level for all districts in the basin. Using the weighted average method, values were calculated at the sub-basin level. Then the following were estimated for each sub-basin: i) the percentage of households with access to individual or community toilets in the region and ii) the percentage of the population living in households that use an improved sanitation facility.

In the Krishna basin, 100% of households have access to toilets while only 73.4% of the population uses safe sanitation facilities. The lower Bhima sub-basin has the lowest access, at 48.3%, while the Krishna delta sub-basin has the highest access, at 81.0%.

The Swachh Bharat Mission was launched in 2014 with the aim of achieving universal sanitation coverage. The mission has strived to improve the living conditions of people by constructing individual and community toilets and eliminating open defecation (Ministry of Drinking Water and Sanitation, 2014). Complete (100%) coverage of toilets has been possible as the government has created community and public toilets wherever private toilets were impossible to build. Private toilets are difficult to build in many places due to the lack of awareness of the linkage between sanitation and health, the lack of space in which to build toilets in individual houses, and the sheer unaffordability of private toilets, even with external subsidies. While under the mission the government was able to achieve a high level of coverage, most toilets are either not functional or not used. For this reason, the proportion of the population using safe sanitation services has been used to get a better understanding of the on-ground situation.

Engaging and training frontline workers, community leaders, and volunteers have ensured that many places across the basin had appropriate behaviour change messages targeted at the individual and community levels. State initiatives like talk shows on sanitation have helped to spread awareness (PwC, n.d.). Some reasons for people not using safe sanitation services include a lack of access to water for the toilets and maintenance funds. Further, the toilets that have been constructed by the government also lack proper infrastructure (Institute for Resource Analysis and Policy, 2012).

Some existing gaps in the use of safe sanitation services are as follows:

- A lack of reliable sources of water.
- A lack of funds for the maintenance of toilets once built.

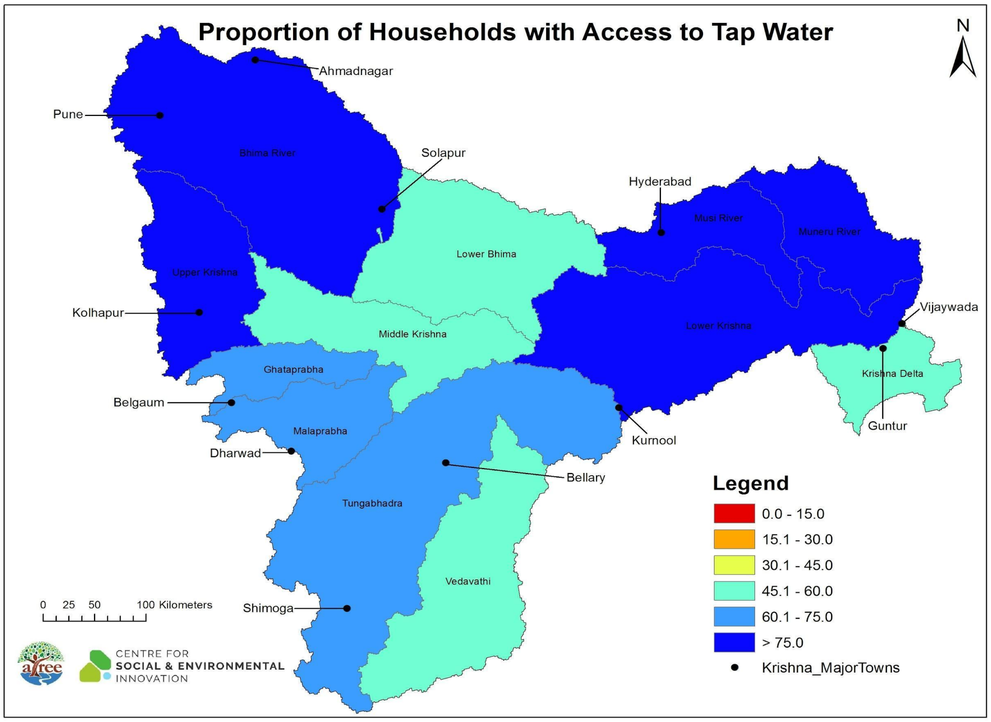

Figure 2.1: Map showing the proportion of households with access to tap water

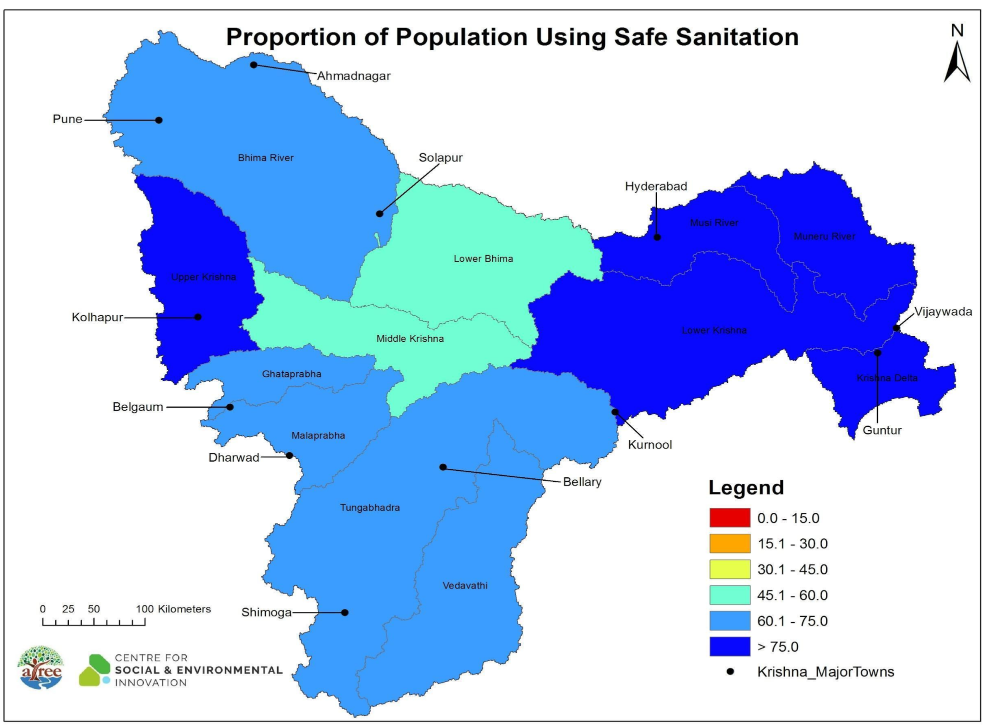

Figure 2.2: Map showing the proportion of the population using safe sanitation

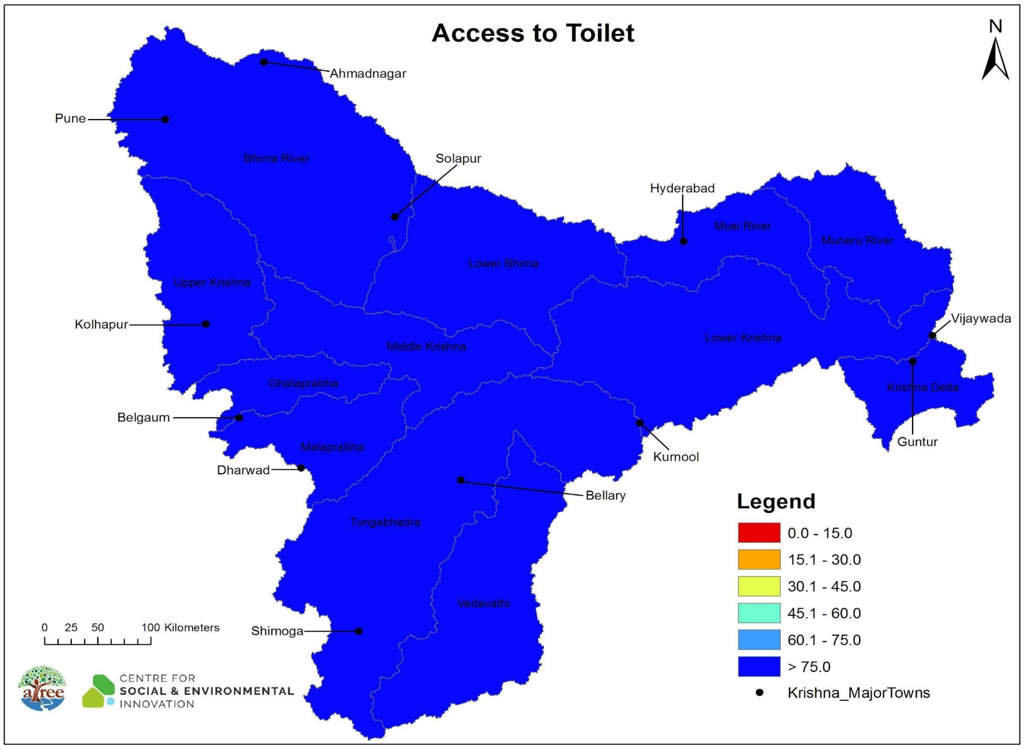

Figure 2.3: Map showing the proportion of households with access to toilets

Table 2.1: Basin Context Metrics- Access to water, sanitation and hygiene

Indicator	Current state	Desired end state
Proportion of the population receiving threshold drinking water services (%)	Around 74.8% of households have access to functional tap connections. About 46.7 million people in the basin still do not have access to functional tap connections.	All (100%) households must have access to functional tap connections.
Proportion of the population using safe sanitation (%)	Around 72.2% of the population uses safe sanitation facilities. About 35.8 million people in the basin still do not use safe sanitation facilities.	The entire (100%) population uses safely managed sanitation services.
Proportion of the population with access to threshold sanitation services (%)	All (100%) households have access to either private or community toilets.	All (100%) households have a water supply and access to functional toilets.

Chapter 3: Water Quantity

Level of water stress

SDG 6.4.2 seeks to ensure sustainable withdrawal and supply of freshwater by tracking how much freshwater is being drawn by all economic activities and comparing it to the total renewable freshwater resources available.

The amount of water abstracted was estimated for three sectors: agriculture, industry, and domestic. For the agriculture water demand, data for the area covered under each crop was obtained at the district level. The data for potential evapotranspiration (PET), rainfall (IMD, 2021), and crop coefficient (Kc) was also obtained at the district level. The effective rainfall (ER) table was used to estimate the portion of the rainfall that is necessary to meet crop water needs (Annexure A). The following formulae were then used to estimate the crop water requirement (CWR) and the irrigation water requirement (IWR) for each sub-basin:

CWR = PET × Kc × Area under crop

IWR = CWR – ER

For the domestic water demand, the population for each district was obtained. Water demand of 55 lpcd (DDWS, n.d.) and 135 lpcd (CPHEEO, 1999) was assumed for villages and towns, respectively. The domestic water demand for each district was then estimated using the following formula:

Domestic water demand = ((Population in villages × 55) + (Population × 135)) × 365

For industrial water demand, data for the type and number of manufacturing, commercial, and institutional industries in each district was obtained. Data on the number of employees in each establishment was also acquired. The litre per employee per day (lped) coefficient was applied to estimate industrial and commercial water use (R et al., 2021).

Using the weighted average method, the amount of water abstracted by each sector was calculated at the sub-basin level. The sum of the three water demands gave the total water demand of all sectors in the basin.

To estimate the water availability in the basin, the amount of utilisable surface water and groundwater recharge amounts were obtained from government reports(Central Ground Water Board, 2021; Central Water Commission, 2014)

The calculations are done with the assumption that all the runoff water in the basin can be captured entirely for use. This was done because the exact amount of water stored in reservoirs is unknown. The total water available is the sum of the recharge and surface runoff. The level of water stress was calculated as the proportion of water demand to the total water available after accounting for environmental flows. A threshold of 20% or 40% was used to demarcate medium or high water stress status, respectively (Xu & Wu, 2017).

For total freshwater, all sub-basins are at a medium to high level of stress except for the Lower Krishna sub-basin. In terms of surface water abstraction, the Musi, Krishna Delta, Tungabhadra sub-basins are at a high level of stress. The surface water stress level varies from 3.4% in Lower Krishna to 4379% in the Musi sub-basin. In terms of groundwater abstraction, all sub-basins have a high water stress status. Groundwater stress levels vary from 2.4% in the middle Krishna to 6248% in the Musi sub-basin. Krishna basin receives less rainfall. The hard rock aquifers in the region also cause less recharge of water. These attributes to the less water availability in the area The total water demand for the agricultural, domestic, and industrial sectors is 38,22,237.4 million litres per day (MLD). Agricultural water has the highest demand in the basin, requiring around 38,11,885.2 MLD of freshwater. The domestic sector accounts for the second highest freshwater consumption, requiring about 9,708.9 MLD. Preliminary estimates have shown that the industrial sector in the basin requires about 643.1 MLD of freshwater.

In many districts in the Krishna basin, the major crops grown are those with high water requirements, such as cotton, paddy, coconut, and arecanut. There is rainfed and irrigated agricultural land in the basin, but a significant part is cultivated by irrigation (Directorate of Economics and Statistics, 2018). Manufacturing industries in the basin consume about 70% of the industrial water share. Among these, the ones that consume the most water are involved in food processing, beverages, and the spinning and weaving of textiles. Among the commercial and institutional establishments, which consume about 30% of the industrial water, the major sectors are hotels, hospitals, and offices (Ministry of Statistics and Programme Implementation, 2013). Most areas in the basin depend on groundwater more than surface water because the temporal and spatial availability of surface water varies. This results in the over-exploitation of groundwater. In all sub-basins, groundwater abstraction exceeds what is available in a year, leading to extraction from previous stock.

Some existing gaps in the efficient use of freshwater are as follows:

- There has been an increase in the area under irrigation by both surface and groundwater in some sub-basins, resulting in high demand for agricultural water. The lack of enforcement of localisation of irrigation for water-intensive crops has resulted in water shortages in the basin. Closures in the upstream and downstream reaches of the basin have also resulted in inter-state disputes.
- With the increase in rural electrification, there has been a rise in groundwater abstraction. Rapid groundwater depletion has also reduced the baseflows and surface water availability by drawing on regional aquifers. Drier regions with less surface water have highly benefited from private groundwater exploitation options for irrigation.

- Due to the competition for water between sectors, there is no transparency in the sharing of data on water availability. This gap prevents policymakers from implementing innovative solutions for efficient water use (Biggs et al., 2007).

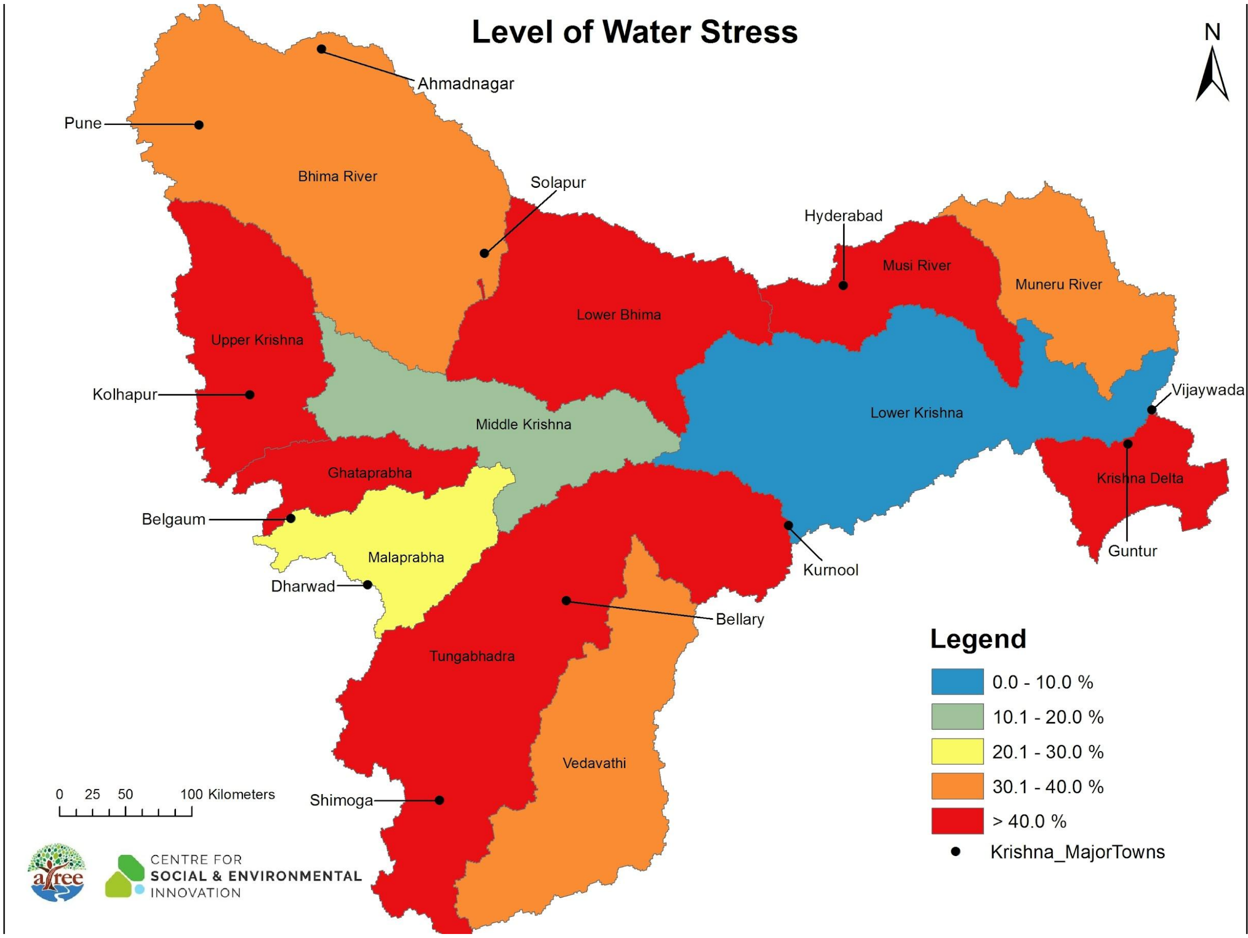

Figure 3.1: Map showing the level of water stress

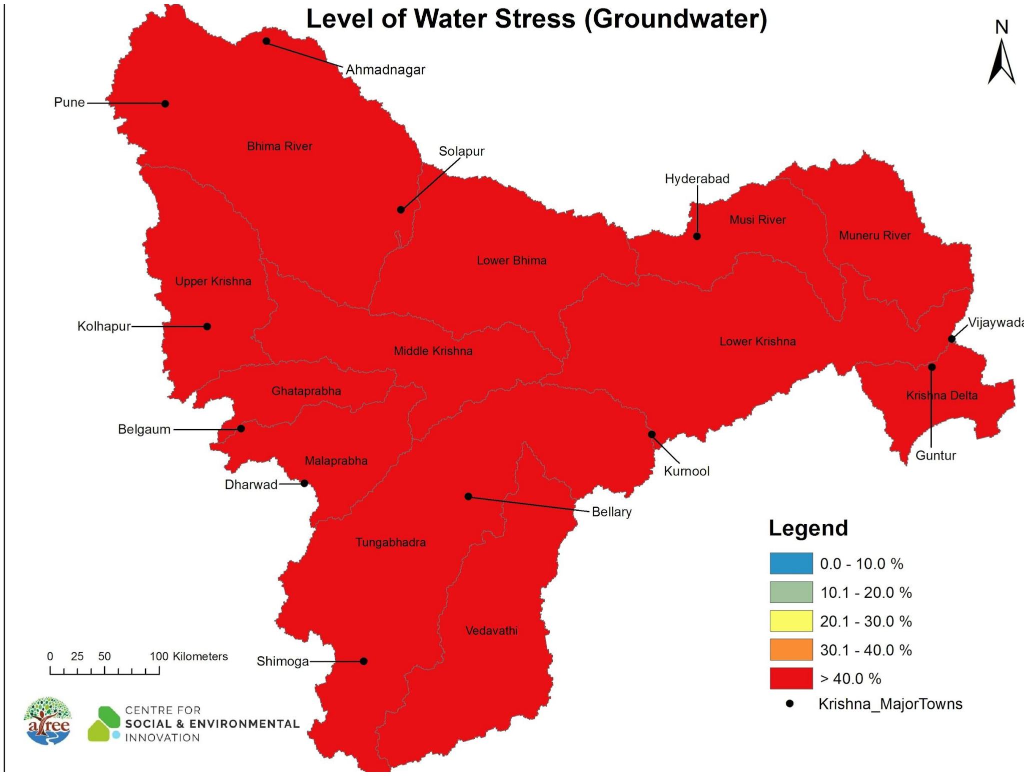

Figure 3.2: Map showing the level of water stress of the groundwater

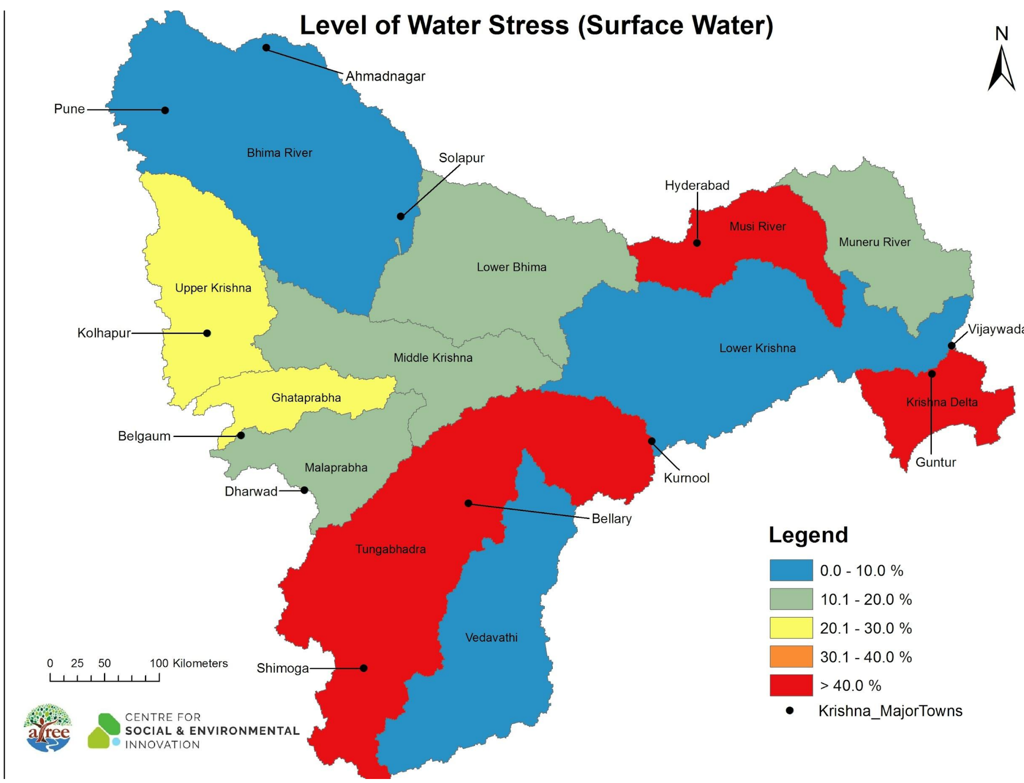

Figure 3.3: Map showing the level of water stress of the surface water

Table 3.1: Basin Context Metrics- Water Quantity

Indicator	Current state	Desired end state
Proportion of unsustainable water withdrawals reduced (%)	All sub-basins are at a low to medium level of stress except for the Tungabhadra, Krishna Delta, Musi, upper Krishna, Ghataprabha, and lower Bhima, which have a high level of water stress. The basin is about 1361 billion cubic meters(BCM) of water short every year to remain within safe limits of use. Groundwater is being over-abstracted in all sub-basins. The agricultural sector is a major freshwater user because of the increase in water-intensive crops and leakages from the distribution system. Government subsidies exist for drip irrigation, the practice of which is limited. The zero liquid discharge (ZLD) rule is applicable to the electroplating industry in Rajasthan; it requires units to recycle and reuse water to the maximum possible extent (90–95%). The present extent of wastewater recycling practised within these facilities is not known.	1. Less than 20% water stress. 2. Improved water use efficiency for irrigated crops. 3. Improved efficiency in industrial water use through process and technological improvements. Wastewater reuse and recycling wherever feasible or required by the law.

Chapter 4: Water Quality

Treatment of domestic and industrial wastewater

SDG 6.3.1 tracks the percentage of wastewater flows from households, services, and industrial premises that are treated in compliance with national or local standards.

The capacities of all the sewage treatment plants (STPs) and effluent treatment plants (ETPs) in each district were acquired. The water demand of both the domestic and industrial sectors was also obtained. Using the weighted average method, the values were calculated at the sub-basin level. A proportion of the total wastewater generated by the domestic and industrial sectors and the total capacity of the STPs and ETPs were then estimated for each sub-basin.

The amount of effluent generated by the domestic and industrial sectors is 8153 MLD. Of this, the domestic sector contributes 7767 MLD of wastewater, and the industrial sector 385 MLD. The existing treatment capacity is around 7.5% of the effluent generation. This shows the dismal position of wastewater treatment in the basin which is a major cause of the pollution of water bodies.

The treatment capacity in the basin is insufficient because not enough STPs and ETPs are set up to treat wastewater and effluents. The ones that exist also are not monitored to ensure they are functional. Treatment efficiency is low due to the poor maintenance of STPs, inadequate understanding of the biological processes, inadequate financial resources available for maintenance and operations, and regular power cuts. The majority of the area is not covered by the sewerage network. Many places have old sewerage networks which are difficult to maintain given the lack of municipal staff and sewer cleaning equipment (National Institute of Urban Affairs, 2018).

Some existing gaps in the wastewater treatment capacity are as follows:

- Union and state governments do not have the funds to bear maintenance and operation costs.
- There is a low level of skill among the maintenance staff.
- The lack of data on the total sewage generated is also a reason why states have not been able to plan for how much capacity is needed for treatment (DTE Staff, 2016).

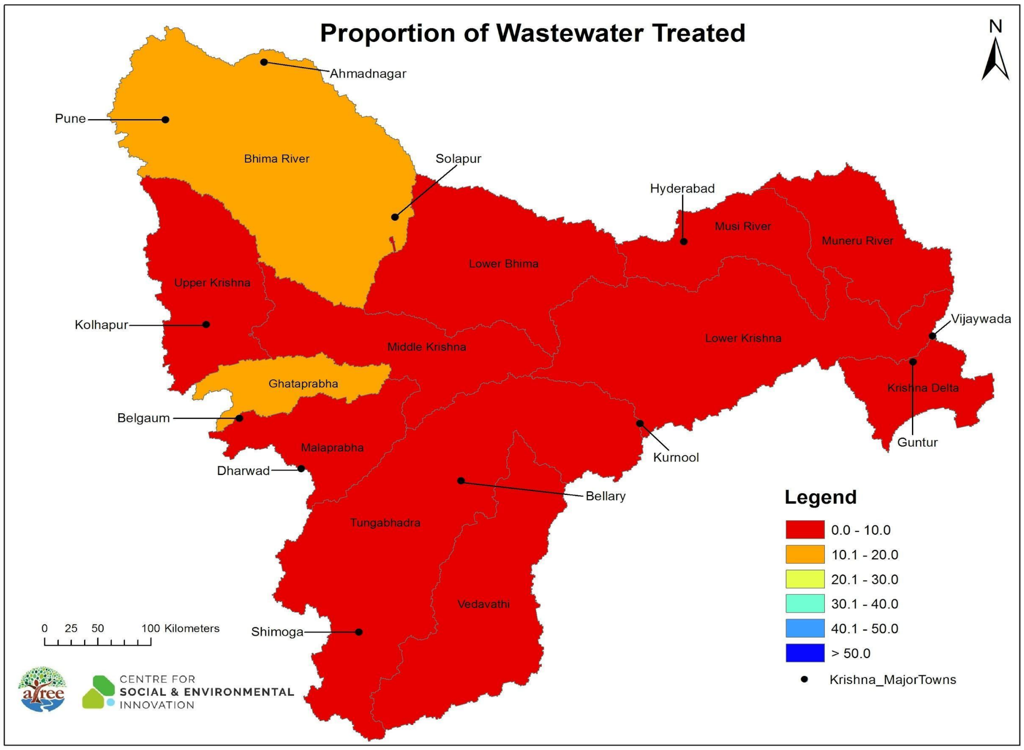

Figure 4.1: Map showing the proportion of wastewater being treated

Water bodies with good ambient water quality

SDG 6.3.2 tracks the percentage of water bodies (rivers, lakes, and groundwater wells) in a country with good ambient water quality. Good water quality according to this indicator is an ambient quality that does not damage ecosystem function or human health. For this indicator, the proportion of lakes, rivers, and groundwater wells with good ambient water was estimated.

The water quality for all lakes, rivers, and groundwater was obtained for different parameters. The water quality of these bodies was then compared with the local water quality standards and SDG targets (Annexure B) to see if they satisfied the standards of good ambient water quality. The percentage of waterbodies that meet the good ambient quality standard was estimated for each sub-basin as well. It was found that very little data was available for the water quality of surface waterbodies. Among the ones that were reported, it was observed that the overall ambient water quality was bad.

Due to the lack of proper treatment facilities available for managing domestic sewage, untreated sewage directly or indirectly enters into the river water through stormwater drains in villages and cities. Solid waste disposal is another major issue in the river basin. Effluents, domestic sewage, and solid waste are often disposed of together, making treatment more difficult (Mass Initiative for Truth Research & Action, 2014). The majority of the area is not covered by the sewerage network. The low efficiency in treatment is due to the poor maintenance of STPs, inadequate understanding of biological processes, inadequate financial resources for maintenance and operations, and regular power cuts (National Institute of Urban Affairs, 2018).

The surface water quality, in general, is also affected by the inadequate water treatment infrastructure in the basin; only around 5.9% of all the generated wastewater is treated. There needs to be a significant effort toward establishing a well-connected framework that addresses the demand for wastewater treatment.

Groundwater is contaminated in many regions because of the release of industrial effluents. Nitrates enter the groundwater from septic and sewage discharges in regions with improper sanitation facilities. Salinity is another problem for groundwater in the basin. The cause for this is either geogenic sources or over-pumping in the coastal regions (India WRIS, 2014).

Some existing barriers to achieving good ambient water quality for water bodies are as follows:

- Data is unavailable for a large number of surface water bodies as they are not monitored.
- Wastewater treatment facilities are inadequate.
- The coverage of the sewerage network is low.
- There is no proper system for the segregation, treatment, and disposal of municipal solid waste, industrial waste, or hazardous waste.

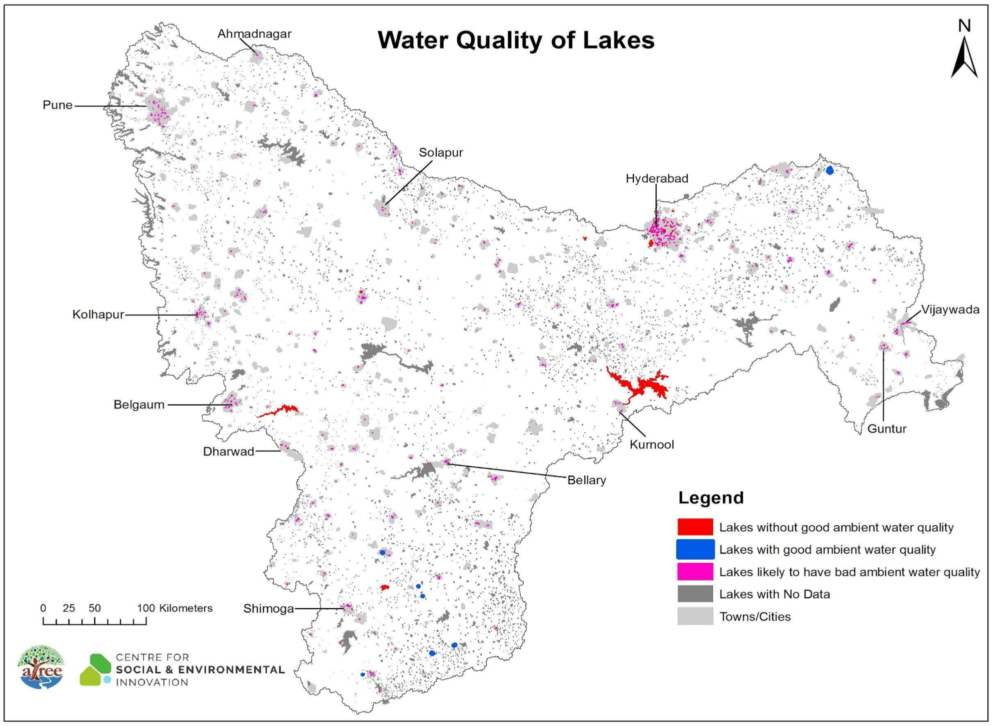

Figure 4.2: Map showing the water quality of lakes

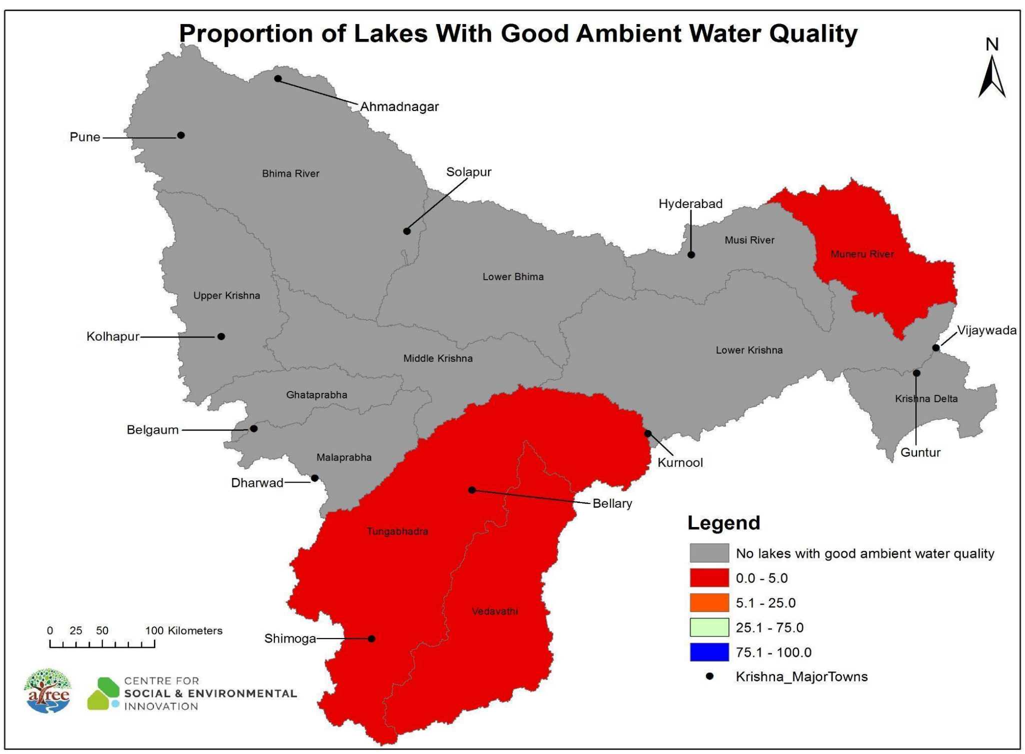

Figure 4.3: Map showing the proportion of lakes with good ambient water quality

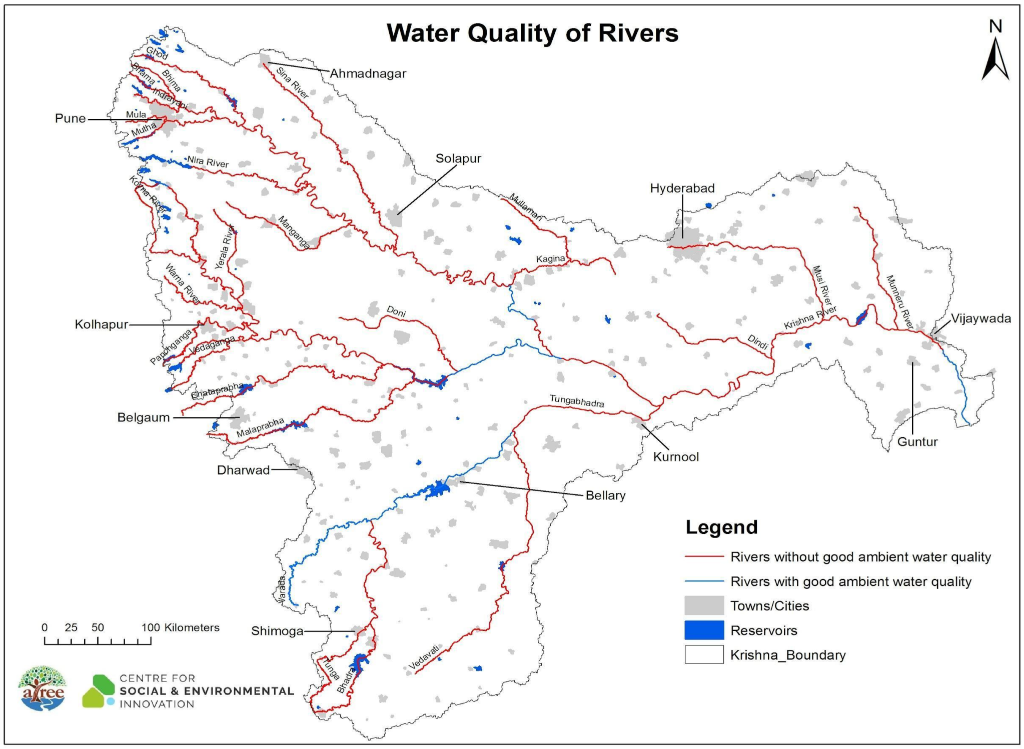

Figure 4.4: Map showing the water quality of rivers

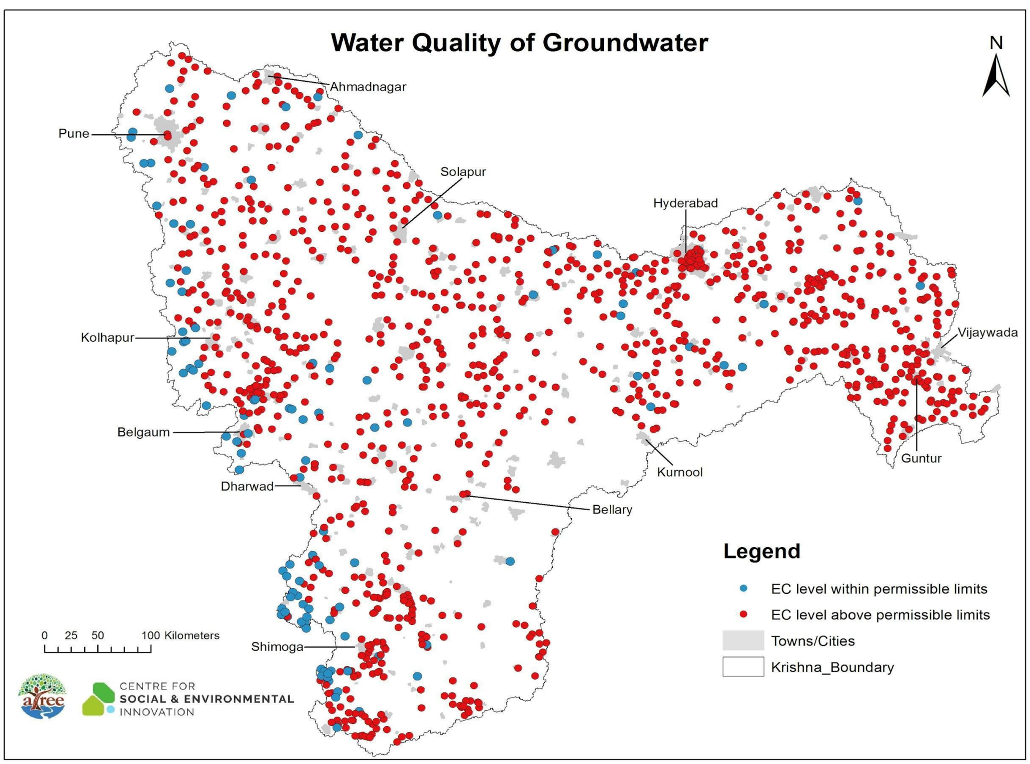

Figure 4.5: Map showing the water quality of groundwater – Electrical Conductivity (EC) (SDG)

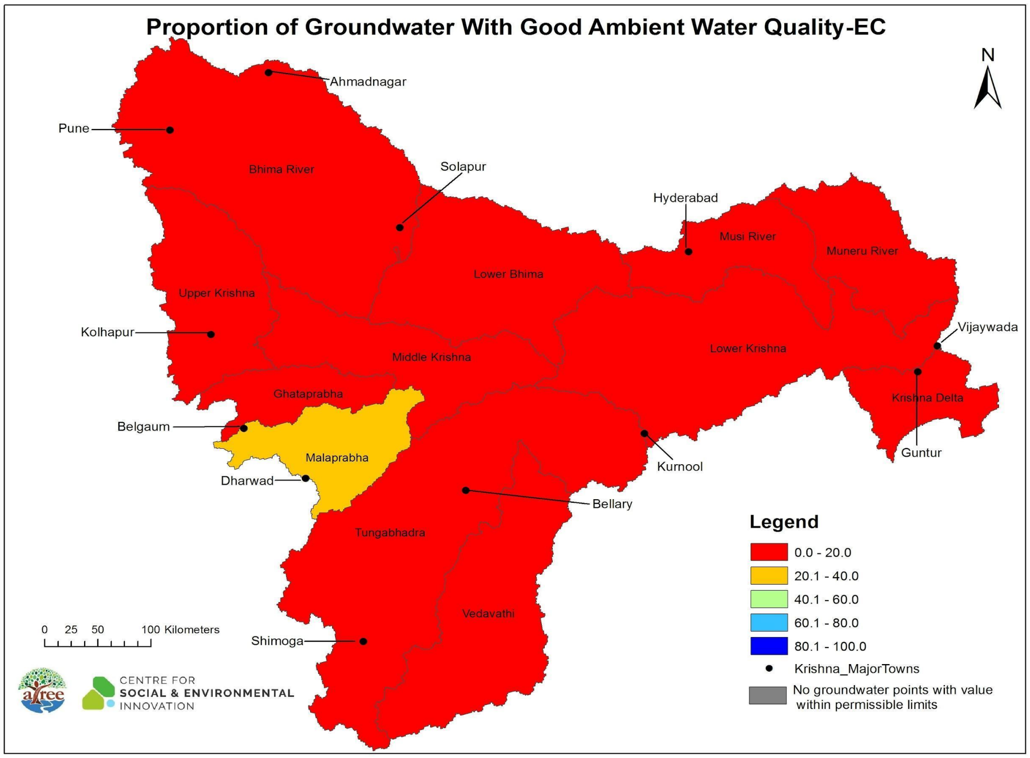

Figure 4.6: Map showing the percentage of groundwater with good ambient water quality – EC (SDG)

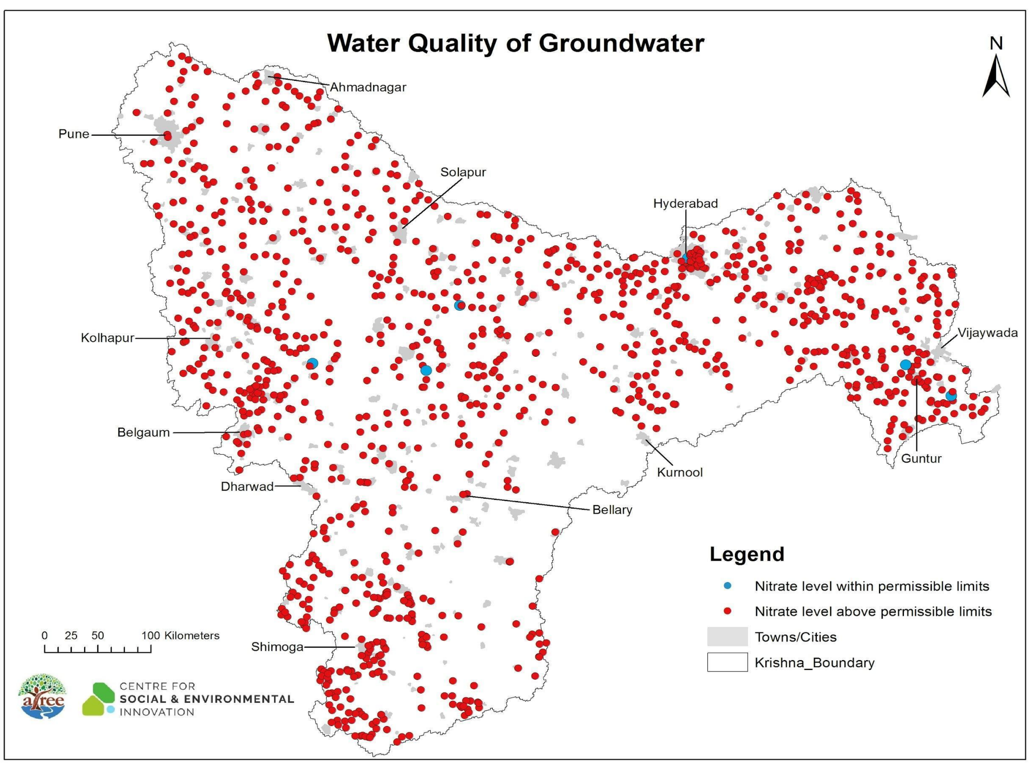

Figure 4.7: Map showing the water quality of groundwater–nitrate (SDG)

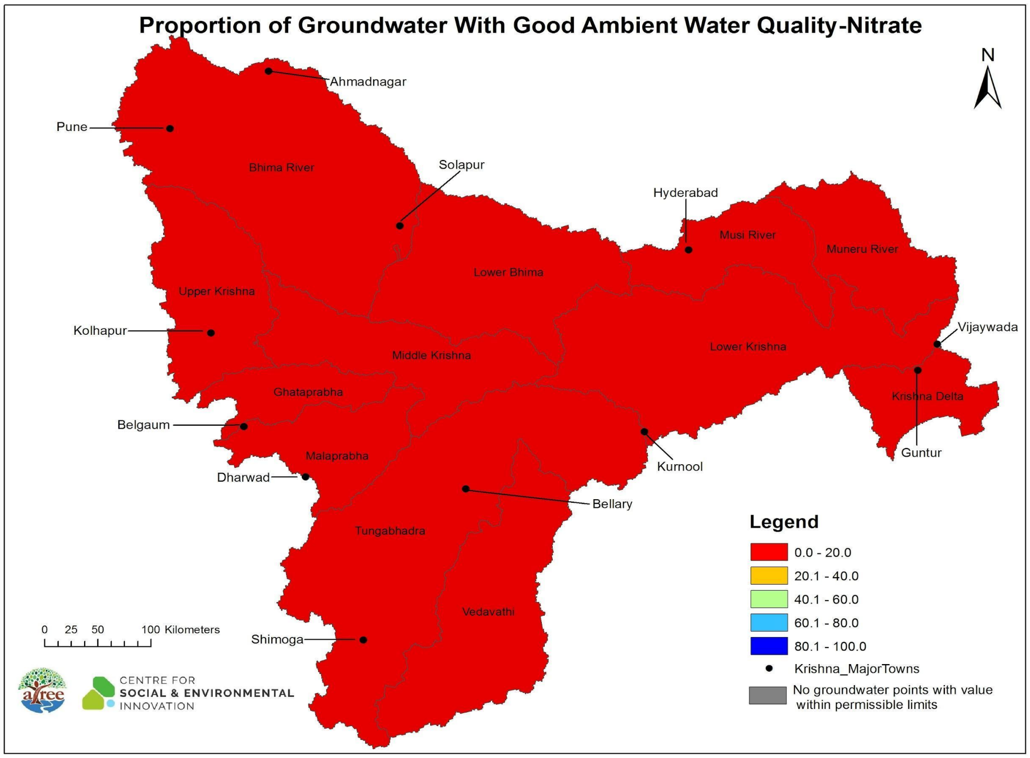

Figure 4.8: Map showing the percentage of groundwater with good ambient water quality – nitrate (SDG)

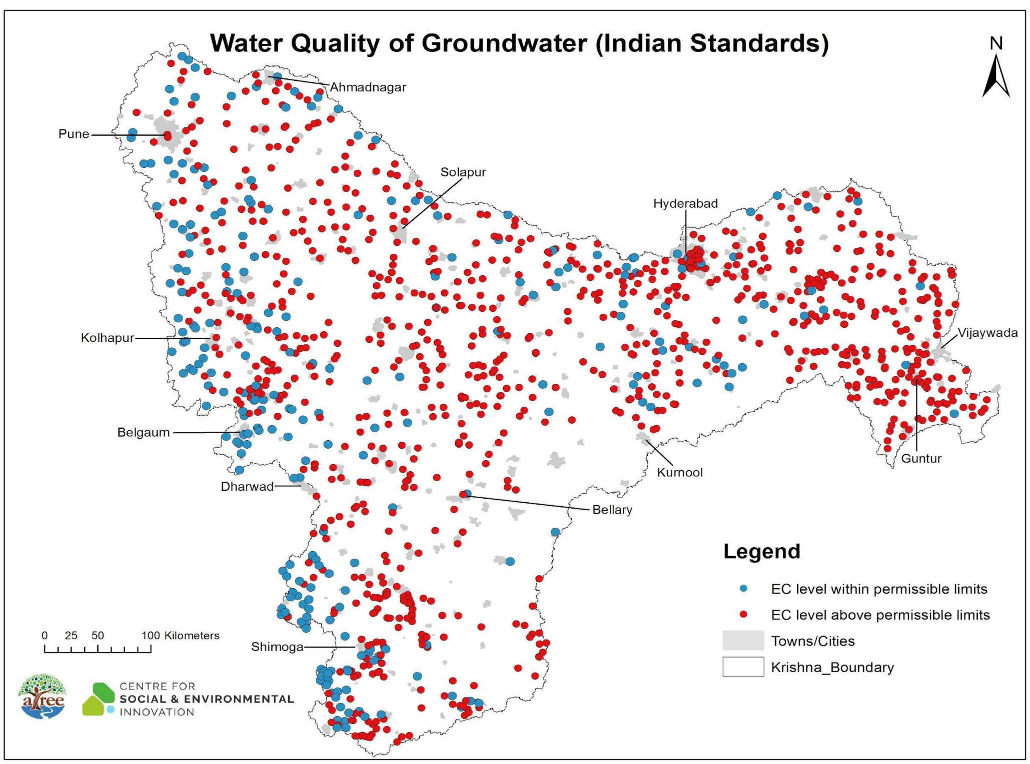

Figure 4.9: Map showing the water quality of groundwater – EC (Indian)

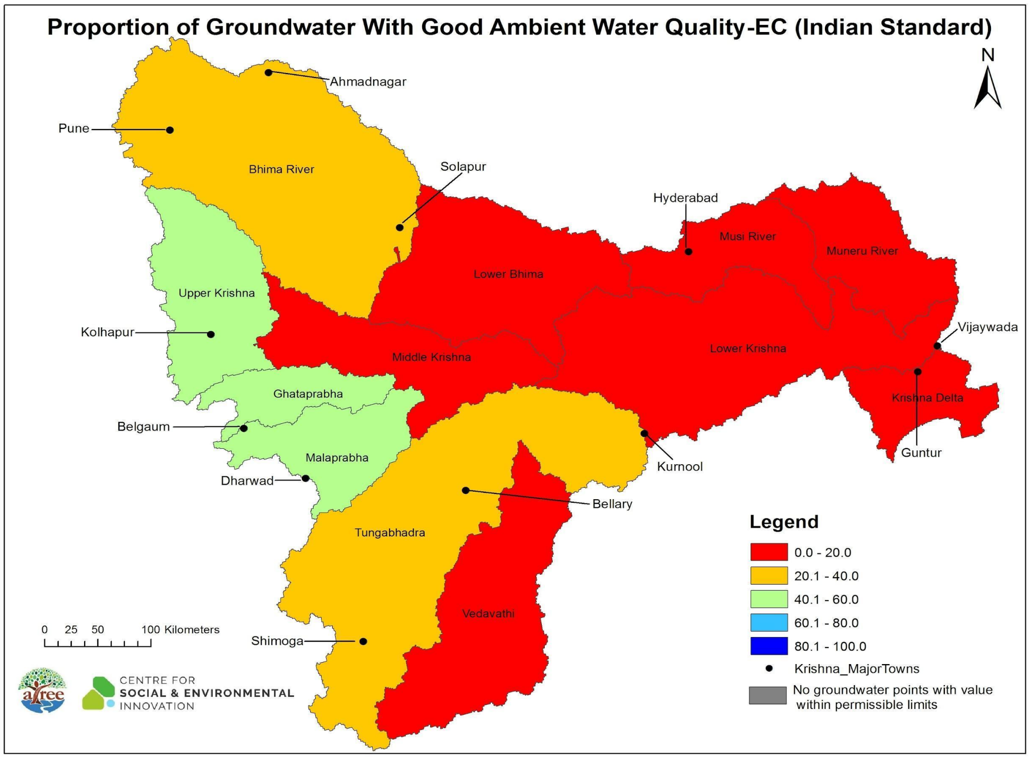

Figure 4.10: Map showing the percentage of groundwater with good ambient water quality – EC (Indian)

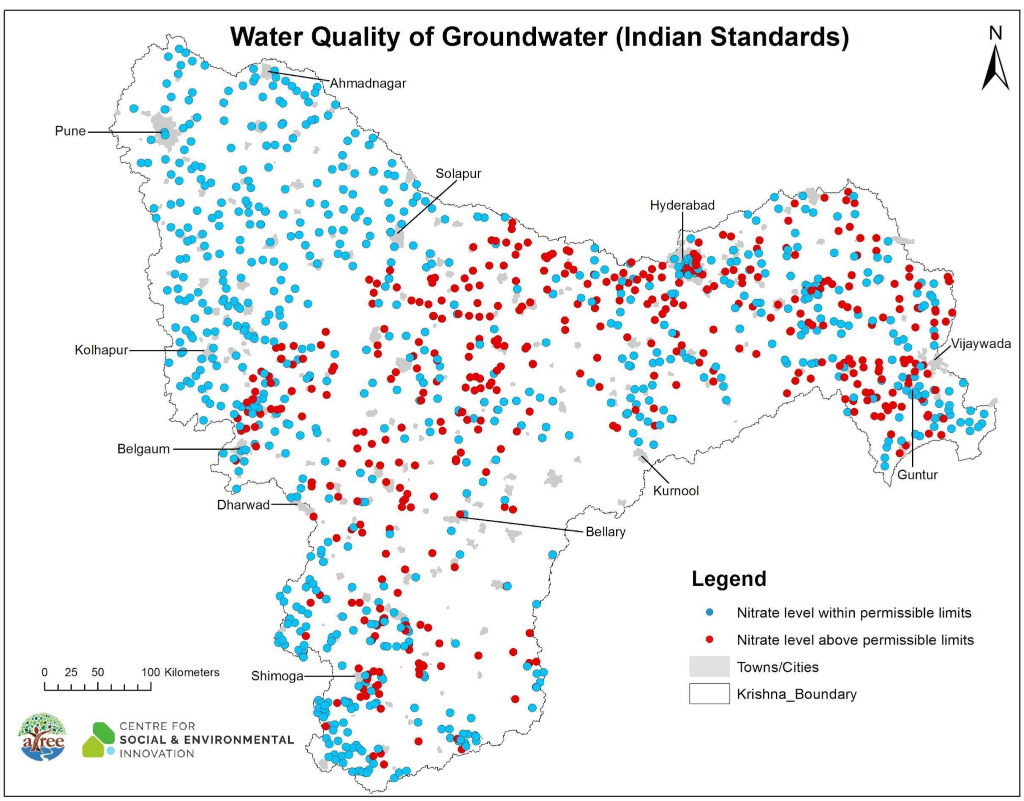

Figure 4.11: Map showing the water quality of the groundwater – nitrate (Indian)

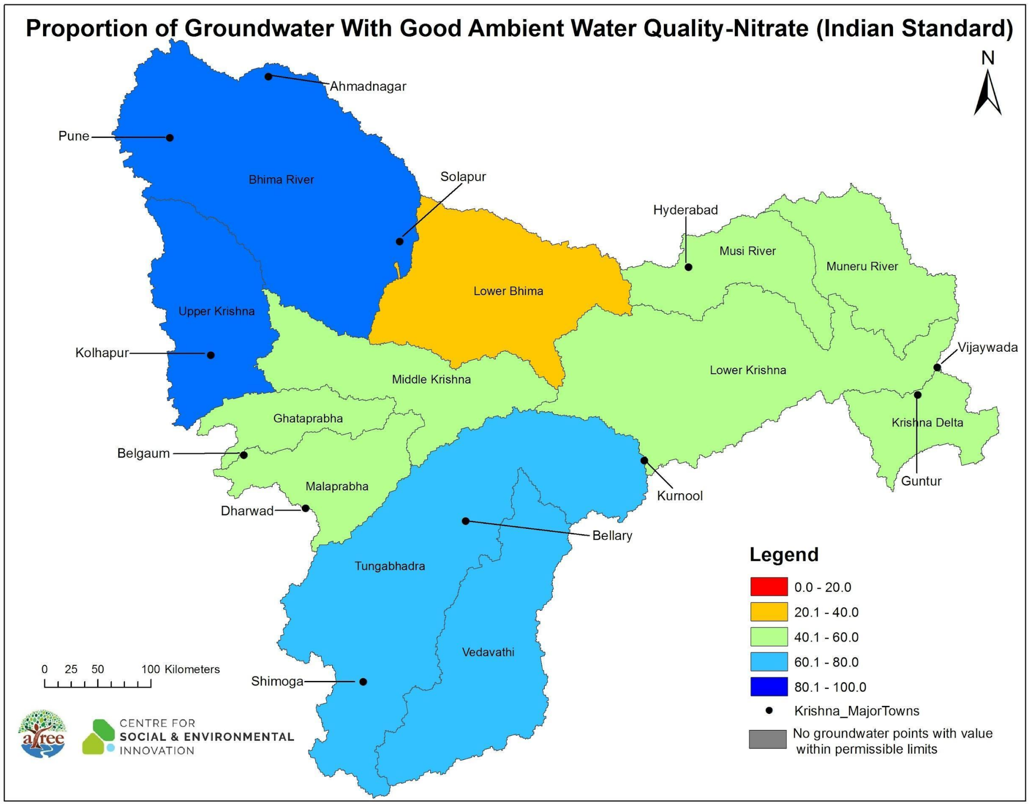

Figure 4.12: Map showing the percentage of groundwater with good ambient water quality – nitrate (Indian)

Table 4.1: Basin Context Metrics- Water Quality

Indicator	**Current state**	**Desired end state**
Proportion of excess pollutants removed (%)	The treatment capacity in the basin is just 7.5% of the total effluents being generated. The basin only has the capacity to treat 614 MLD of the total 8153 MLD of wastewater generated.	1. For urban settlements, 20% reuse and recycling of sewage is the service-level benchmark for Urban Local Bodies (ULBs). 2. Treat 100% of the generated industrial effluents. 3. Reuse within processes wherever possible. 4. Where legally permitted, discharge treated effluents on land/into the water body.

The proportion of lakes with good ambient water (%)	Less than 1% of lakes and rivers have water quality standards that do not damage ecosystem function or human health. For the rest of the water bodies, Dissolved Oxygen (DO)<9 mg/l, pH<6 or >8, and nitrate>45 mg/l. The salinity of 8.8% of the monitoring wells is within the permissible limit of EC<500 μS/cm and the nitrate levels of 0.4% are within the permissible limit of <0.25 mg/l (SDG standard). The salinity of 21.2% of the monitoring wells is within the permissible limit of EC<746 μS/cm and the nitrate levels of 62.5% are within the permissible limit of <0.25 mg/l (Indian standard).	Water bodies must have water quality standards that do not damage ecosystem function or human health. Surface water DO>9 mg/l, pH = 6–8, and nitrate<45 mg/l. Groundwater • Indian Standard EC<746 μS/cm and nitrate<45 mg/l. SDG standard, EC<500 μS/cm, and nitrate<0.25 mg/l.

Chapter 5: Important Water-Related Areas

SDG 6.6.1 aims to track changes in water-related ecosystems over time. Remote sensing data is used to determine the changes to surface water bodies, such as lakes, large rivers, flooded wetlands, and reservoirs. For this indicator, Joint Research Centre (JRC) data was used to analyse 20 years of data on the area covered by surface water bodies in the basin.

Water is necessary to sustain ecosystems, both terrestrial and aquatic, in addition to its use for human consumption. Different levels of flow (high, low, flow during the lean season, flood flows, and drought flows) are necessary to protect the biodiversity of aquatic habitats. There is a need to maintain a balance between how much water is abstracted for anthropogenic use and how much should be left to protect aquatic habitats (Anantha, Bhadbhade, & Dharmadhikary, n.d.).

An analysis of the 20 years of data showed that on average there has been an increase in the area covered by surface water bodies in all sub-basins except for the Vedavathi and Krishna deltas. The basin consists of water bodies like lakes, ponds, tanks, and reservoirs. Most of these water bodies supply water for either irrigation or hydropower generation. Of the 660 dams in the basin, 90% were built for irrigation (India WRIS, 2014).

There has been a reduction in the discharge of the Krishna River despite no significant change in the rainfall in the region. The main cause of this is the expansion of irrigation. Uncontrolled private groundwater abstraction has also resulted in a reduction in streamflow; this has mainly benefited the dry upland regions of Telangana and Rayalaseema. The rapid expansion of the area under irrigation was possible because of the large irrigation projects, small-scale interventions (tanks and river diversions), and increasing access to groundwater (Biggs et al., 2007).

Some existing barriers to maintaining an adequate quantity of water in surface water bodies are as follows:

- Not exploring alternatives like reusing and recycling wastewater is the reason for such high demand for freshwater.
- Lack of reuse of options for agricultural return flow.
- There is no monitoring system in place to regulate groundwater extraction
- There are no incentives to regulate groundwater extraction.
- Urbanisation and an increase in paved areas have resulted in reduced flow in many lakes in the basin. There is also a lack of understanding of hydrological systems and the connections between water bodies.

Table 5.1: Basin Context Metrics- Important water-related areas

Indicator	Current state	Desired end state
Ecosystem services status risk	Many sub-basins have experienced a decrease in the area under surface water due to reduced baseflows and blockages in the inlets. The area under surface water has increased in some basins because of the release of treated and untreated effluents into seasonal water bodies, which has turned them into perennials.	1. Adequate quantity and contiguity inflows in the rivers. 2. An adequate quantity of water is maintained in other surface bodies.

Chapter 6: Water Governance

Implementation of integrated water resources management

SDG 6.5.1 aims to track the degree to which integrated water resources management (IWRM) is implemented. This is assessed using four key components of IWRM: enabling environment, institutions and participation, management instruments, and financing. The Krishna basin got a score of 38 on the assessment. This score indicates a moderate level of IWRM implementation.

Water is a state issue as per the Indian Constitution – it falls under the control of state governments and there is no dedicated river basin organisation for the management of water resources. Two national laws i.e. the Interstate River Water Disputes Act, 1956 and River Boards Act, 1956 exist, but they are not strictly based on IWRM (India Code, 1956; Ministry of Water Resources, 1956). There are no basin-level institutional arrangements to monitor the actual operation of an inter-state river water agreement. Since IWRM has not been implemented in any Indian river basin, no revenue has been raised for IWRM elements.

There is no multilateral agreement between Karnataka, Maharashtra Telangana and Andhra Pradesh to integrate participatory management in accordance with IWRM. There is hardly any groundwater management in practice at the basin level. The management approach involves a complete disconnect between surface and groundwater. This approach has led to excessive groundwater abstraction, resulting in a decline in baseline flows, especially in the downstream part of the basin (Harsha, 2012).

Some existing barriers to implementing IWRM are as follows:

- Stakeholder participation, management instruments, and financing are low or non-existent at the basin level.
- There is no mechanism to regulate and monitor groundwater extraction and recharge at any level.
- Stakeholder participation and consultation are low in the context of making water management plans.

Operational arrangement for water cooperation

SDG 6.5.2 tracks any operational arrangement for water cooperation within a river basin. This arrangement can be a bilateral or multilateral treaty, convention, agreement, or other formal arrangement between riparian states that provides a framework for cooperation.

Due to the disputes between states over water allocation, the 1969 Krishna Water Disputes Tribunal (KWDT) was established. The second KWDT was instituted in 2004.

For a river basin, dependability is defined as the relationship between the amount of water available for utilisation and the period of time it will be available. In 2010, KWDT delivered its report, making allocations of the Krishna water at 65% dependability and of surplus flows as follows: 81 thousand million cubic feet (TMC) for Maharashtra, 177 TMC for Karnataka, and 190 TMC for Andhra Pradesh (The Hindu, 2022). The KWDT addressed three issues: i) the extent to which existing uses should be protected over future uses; ii) the quantity of water that can be diverted to another watershed; and iii) the rules governing preferential uses of water (RBIS, n.d.).

With the expansion of agriculture, the water demand has exceeded the amount of water allocated; this has generated conflicts, especially in dry years. The upstream and downstream basin closures have also resulted in inter-state disputes over water. More than 50 percent of the basin's irrigated area is supplied by small tanks and groundwater, which are not currently included in the allocations to the three states. Even though groundwater use has been included in the tribunal's estimation, it has been considered an independent source decoupled from the surface water allocation. A lack of access to data is another issue that constrains the planning around water resource management (Biggs et al., 2007).

Some existing barriers to the implementation of operational arrangements for water cooperation in the basin are as follows:

- Water from tanks for irrigation has not been accounted for in allocations.
- Groundwater is treated as an independent source without consideration for its contribution to baseflows.
- No guidance has been given on how water should be allocated when water levels decline due to anthropogenic effects and not rainfall reduction.

Amount of official development assistance received

SDG 6.a.1 tracks the amount of official development assistance (ODA) included in a government-coordinated spending plan. The following are some of the programmes in the Krishna basin that have received ODA:

1. The Asian Development Bank has provided a grant of USD 91 million to improve water availability in selected areas in the Krishna River basin by implementing IWRM. The project will also establish and strengthen 30 water user cooperative societies (WUCS) and provide gender sensitisation training by raising awareness of gender equality concerns among Water Resources Department (WRD) staff and WUCS (Asian Development Bank, 2018).
2. The Asian Development Bank has given a grant of USD 31 million to improve water and irrigation services for farmers in Karnataka. The programme will help government agencies and beneficiary communities adopt internationally

accepted practices for managing the water in river basins. It will focus on including women in trainee programmes and in management positions at community water associations (Asian Development Bank, 2017).

Participation by local communities

SDG 6.b.1 tracks the level of stakeholder participation in water and sanitation management within a country. There is no multidisciplinary institutional structure and few opportunities to bring non-state actors and water users together to actively participate in the consultation process. Decisions for water management are usually taken by state actors within government agencies, and such processes lack transparency. Public consultations are usually not conducted while taking management decisions. The current scheme has no provision for engagement with experts from multidisciplinary fields as well (Harsha, 2018). However, there are a few platforms that exist.

Karnataka, Andhra Pradesh, and Maharashtra have their own acts to enable public participation. Karnataka promulgated an ordinance on 7 June 2000 to amend the existing Karnataka Irrigation Act, 1957 (DPAL, 1965). This programme included founding water users' associations (WUAs) at the local level. Maharashtra set up WUAs under the Cooperative Societies' Act, 1960 (SOPPECOM, 2012). The WUAs focused on decentralising water resource control to local levels.

Under the Jal Jeevan Mission, a programme started by the central government, there is a provision for water groups at the village level (village water and sanitation committee (VWSC)/paani samiti/user group) to plan, implement, manage, operate, and maintain in-village water supply systems (Ministry of Jalshakti, 2021).

Mission Kakatiya was started by the Government of Telangana to improve agriculture-based income for small and marginal farmers, by accelerating the development of minor irrigation infrastructure and strengthening community-based irrigation management. Public participation in such initiatives will lead to ownership and help ensure the long-term sustainability of the interventions (Irrigation & CAD Department, 2015).

Some existing barriers to achieving local participation in water and sanitation management are as follows:

- Platforms for stakeholder consultation and engagement are either limited or non-existent.
- Management decisions are made only in consultation with engineers and bureaucrats instead of involving all the stakeholders.

Table 6.1: Basin Context Metrics- Water governance

Indicator	Current state	Desired end state
Implementation of IWRM	There are no basin-level institutional arrangements. There are no management instruments to regulate and monitor groundwater use. The IWRM programme is not being implemented.	1. Effective platforms for inclusive, multi-stakeholder discussions for river basin management. 2. Documentation of water use by sector as well as the total water availability and estimated future requirements.
Transboundary organisation for catchment management	A water regulation committee has been set up for the transboundary management of water, but it is not active. There are no schemes for managing water allocation in the basin.	Operational arrangement for water cooperation with regular, formal communication between riparian states and exchange of data and information.
Catchment management organisation	Decisions for water management are usually taken by state actors within government agencies; the processes lack transparency. Public consultations are usually not conducted while taking management decisions.	1. A river basin management plan that addresses aspects related to water quality, basin water security, sustainability, crisis preparedness, basin-level governance, and fair water allocations to different user groups. 2. Effective groundwater regulation law. 3. Procedures in law or policy for participation by service users and communities.

Chapter 7: Water Crisis

Disaster reduction strategy

SDG 13.1 tracks the measures that strengthen resilience and adaptive capacity for climate-related hazards and natural disasters in all countries. In India, the Disaster Management Act, 2005 provides for the effective management of disasters. Under this act, the National Disaster Management Authority has been set up; this body lays down all policies and national plans for managing disasters. It also establishes guidelines for states and government departments towards the prevention of disasters. The National Disaster Management Plan, 2016 aligns the national plan with the Sendai Framework for Disaster Risk Reduction 2015–2030. This framework that was adopted at the Third UN World Conference on Disaster Risk Reduction outlines targets and priorities for action to prevent new and reduce existing disaster risks. In addition to this the Telangana State Disaster Response and Fire Services, Andhra Pradesh State Disaster Management Authority, Maharashtra State Disaster Management Authority, Karnataka State Disaster Management Authority, and district disaster management authorities are responsible for coordinating mitigation, preparedness, response, and recovery measures at the local level. Each of these authorities has disaster management plans, in accordance with the Sendai Framework, which lay out the roles and responsibilities of different agencies during a disaster.

Several disaster risk reduction strategies have been adopted at the national and local levels. The following is a list of schemes initiated by the Disaster Management Division:

1. The National Cyclone Risk Mitigation Project (NCRMP) was launched by the Ministry of Home Affairs. It aims to minimise vulnerability to cyclones and make people and infrastructure disaster-resilient. The project costs INR 2,691 crore and is being funded by the central government with assistance from the World Bank (in the form of a loan) and state governments.
2. Infrastructure development for 10 battalions and 10 teams of the National Disaster Response Force (NDRF) scheme was sanctioned to increase the functional efficiency in administration, capacity building, and storage of specialised equipment for NDRF as well as relief stores and resources The National Disaster Response Reserve (NDRR), India was created to maintain a central inventory of necessary relief equipment for a population of at least 2,50,000 people in the plain areas and store availability for a minimum of 1,50,000 people in hilly areas. The project costs about INR 250 crore.
3. The Aapda Mitra Scheme is a centrally sponsored scheme that focuses on training community volunteers in disaster response in the 30 most flood-prone districts of 25 states in India. It aims to train community volunteers in the skills needed to respond to their community's immediate needs in the aftermath of a

disaster. These skills would enable them to complete basic relief and rescue tasks during emergencies. The project costs around INR 15.47 crore.

4. Strengthening of state disaster management authorities (SDMAs) and district disaster management authorities (DDMAs) was done by the National Disaster Management Authority. It aims to improve the effectiveness of all SDMAs and selected DDMAs and to make them operational by providing dedicated disaster management professionals to facilitate prevention, mitigation, preparedness, and capacity building in the context of threatening situations or disasters. The project costs INR 42.51 crore.
5. The NDRF Academy was set up in Nagpur to establish a dedicated practical training institution for first responders in the event of a disaster. The project costs INR 125.01 crore.
6. The National Emergency Communication Plan (Phase II) aims to set up reliable communication links between decision-makers at various levels and operational response teams at the disaster site. The project costs INR 16.4372 crore (Disaster Management Department, n.d.).

Financial assistance is provided to states through the Calamity Relief Fund (CRF) and National Calamity Contingency Fund (NCCF) for immediate rescue and relief operations. Allocations for state CRFs are made on the recommendation of finance commissions, contributed to by the central and state governments (National Institute of Disaster Management, 2018).

The Central Water Commission (CWC) is responsible for monitoring flood situations in the country during the designated flood periods by observing water levels/discharges along the major rivers in the country. It issues flood forecasts and warnings to the local administration/project authorities/state governments and other central ministries. The Indian Meteorological Department is the nodal agency that provides cyclone warnings in India. District Agriculture Contingency Plans (DACPs) provide guidance to the relevant government departments and farmers on what measures need to be taken during a natural disaster.

In the Krishna basin, the state and district disaster risk reduction plans are in line with the Sendai Framework for Disaster Risk Reduction 2015–2030. At the district level, flood control cells have been established to collect timely data on the reservoir levels and rainfall. All states have some funds allocated for disasters. The Government of Maharashtra developed real-time streamflow forecasting (RTSF) and a reservoir operation system (ROS) with a real-time data acquisition system (RTDAS) (Water Resources Department, 2021).

The Karnataka State Disaster Management Authority has also developed a flood preparation and evaluation matrix for all districts. Each district has to assess its vulnerability, early warning systems, evacuation, preparedness for emergency relief, and shelter management to plan accordingly for the monsoon (DHNS, 2021).

The National Remote Sensing Centre has prepared a Flood Vulnerability Index map for the whole country. The map was made by integrating the maximum probable precipitation, runoff potential, and probable maximum runoff layers in the spatial decision support system environment using a multi-criteria evaluation technique (NRSC, n.d.).

The Indian Meteorological Department also uses the standardised precipitation index to monitor droughts. The index is based on long-term precipitation records in a region. The long-term record is fitted to a probability distribution, which is then transformed into a normal distribution so that the mean Standard Precipitation Index (SPI) for the location and desired period is zero. Negative values indicate drought conditions and positive values indicate wet conditions (IMD, 2020).

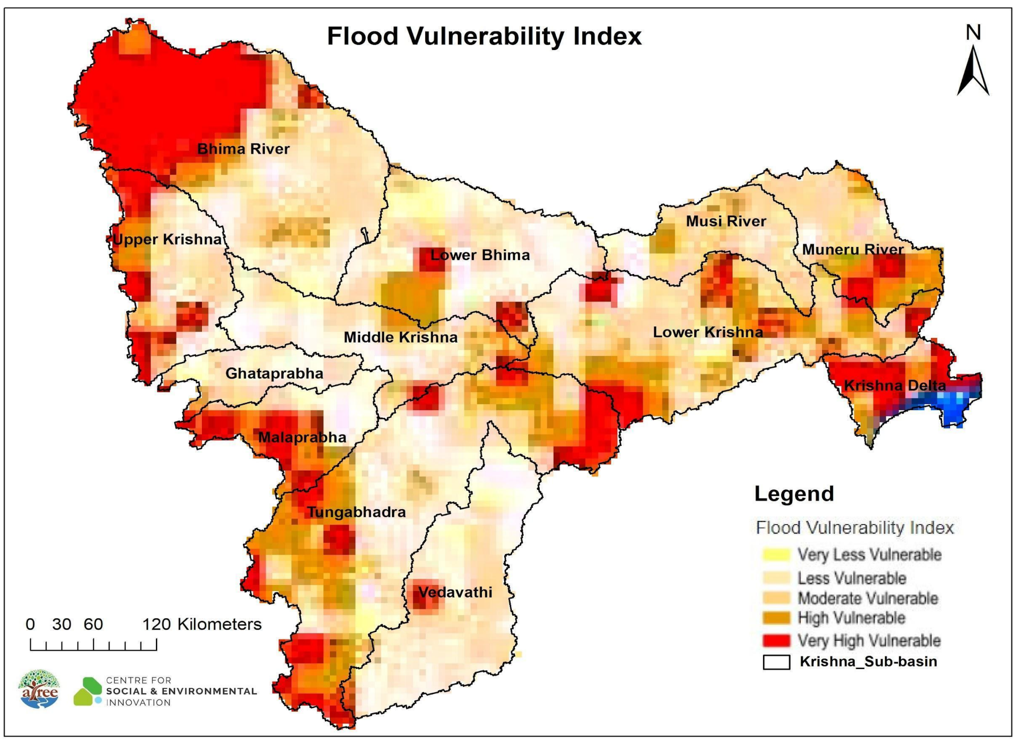

Figure 7.1: Map showing the Flood Vulnerability Index of the Krishna basin

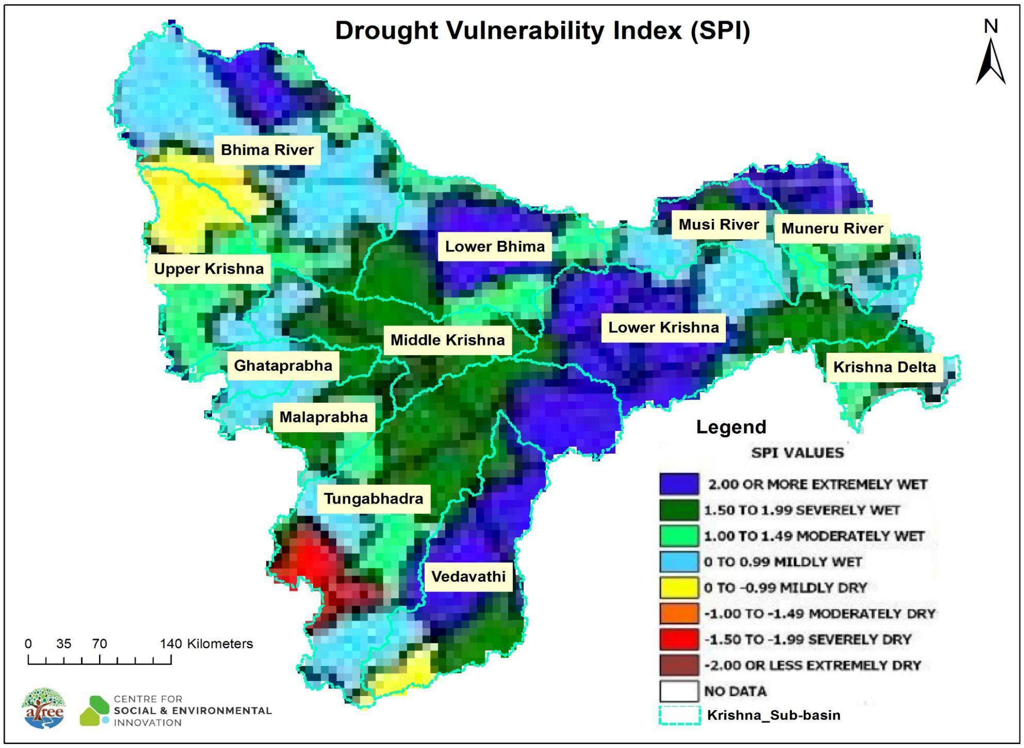

Figure 7.2: Map showing the Drought Vulnerability Index of the Krishna basin

Table 7.1: Basin Context Metrics- Water crisis

Indicator	Current state	Desired end state
Number of deaths, missing persons, and directly affected persons attributed to disasters per population of 1,00,000	Disaster reduction strategies exist at the national and local levels. There are enough funds allocated for disaster management. There are early warning systems in place.	Strong resilience and adaptive capacity to climate-related hazards and natural disasters in all countries by reducing the number of deaths, missing persons, and directly affected people.
Disaster risk reduction strategy at the national level	The Disaster Management Act, 2005 provides for the effective management of disasters.	National disaster risk reduction strategies in line with the Sendai Framework for Disaster Risk Reduction 2015–2030.
Disaster risk reduction strategy at the local level	In addition to the National Disaster Management Authority, each state has	Local-level disaster risk reduction strategies are in line with the Sendai

	its own state disaster management authorities and district disaster management authorities which are responsible for coordinating mitigation, preparedness, response, and recovery measures at the local level.	Framework.
Direct economic loss in relation to the global gross domestic product (GDP), damage to critical infrastructure, and the number of disruptions to basic services, attributed to disasters	There are enough funds allocated for disaster management. Early warning systems are in place.	Low levels of economic loss, relative to the global GDP, as a result of natural disasters.

Chapter 8: Recommendations

Based on our assessment of the baseline indicators in the Krishna basin, table 8 provides a list of opportunities for collective action.

Table 8: Opportunities for collective action

Indicator	**Severity***	**Current government efforts (schemes and acts)**	**Opportunities for collective action**		
			Funding	**Training**	**Implementation**
WASH	Low	Jal Jeevan Mission (JJM), Swachh Bharath	• Create innovative financing mechanisms for wastewater. • Provide funds for pump solarisation.	• Create and deploy games and audio-visual aids to train the public in safe sanitation practices.	• Provide drinking water and purification systems in rural areas. • Initiate schemes for source sustainability and protection.
Water quantity	High	National Water Policy, 2012, Command Area Development Programme (CADP), Atal Bhujal Yojana, NREGA, JJM, Pradhan Mantri Krishi Sinchayee Yojna (PM-KSY),	• Co-create water footprint benchmarks for crops and products that reflect reasonable levels of water consumption per unit of production.	• Ensure training and capacity building towards implementing modern agriculture and irrigation techniques in local	• Stimulate groundwater recharge through treated wastewater injection and rainwater harvesting. • Establish a repository of model water management plans and solutions, particularly for demand-side

		Telangana Water Sector Improvement Project (TSWSIP), Mission Kakatiya, Mission Bhagiratha, Chief Minister Water Conservation Programme Maharashtra, Neeru Chettu Andhra Pradesh, Neeti Samrakshana Udyamam, Maharashtra Groundwater (Development and Management) Act, 2009, Andhra Pradesh Water, Land and Trees Act and Rules, 2002	• Fund innovative technologies such as pump solarisation.	governments/farmer producer organisations (FPOs).	management. • Co-develop data and tools to help local governments (towns/gram panchayats) manage water resources better. • Implement watershed management programmes to increase the resilience of watersheds. • Ensure smart and efficient irrigation scheduling and improved soil and crop management.
Water quality	High	National Water Quality Monitoring Programme, Water Cess (Prevention and Control of Pollution) Act, 1977, National River Conservation Plan (NRCP) Scheme	• Fund innovative technologies for nature-based solutions.	• Run skill development training programmes for the maintenance of treatment facilities.	• Help towns plan and implement sewerage infrastructure. • Provide technical assistance to towns and gram panchayats for accessing government funds. • Pilot wastewater treatment facilities,

					especially in small towns. • Pilot Natural Biological System (NbS) solutions for treating agricultural runoff, which contaminates water bodies in agricultural areas. • Implement zero liquid discharge.
Water governance	Medium	Inter-state River Water Disputes Act, 1956, River Boards Act, 1956, Krishna Water Disputes Tribunal, Participatory Irrigation Management, JJM, Cooperative Societies' Act, Mission Kakatiya	• Demonstrate new funding mechanisms, such as water trusts and drought funds, that allow for the reallocation of water between sectors.	• Provide IWRM training to government officials.	• Create and maintain crowdsourced dashboards with quality and quantity data for different water sources. • Create platforms for stakeholder consultations and engagement, and share knowledge and data on water interventions.
Water crisis	Low	National Cyclone Risk Mitigation Project (NCRMP), Aapda Mitra Scheme, National Emergency Communication	• Fund early warning systems.	• Offer capacity building for early warning systems and better tools for management.	• Ensure the proper maintenance of water bodies, for instance by increasing their storage capacity so that they can act as

		Plan, Calamity Relief Fund			buffers during drought or flood events. • Implement watershed management programmes to increase the resilience of crops.

*Severity levels based on a qualitative assessment of sub-indicators.

Table 9: Existing multi-sector coalitions/partnerships in the water sector

Water challenge	**Organisations**	**Theory of change**	**Links**
WASH	Eawag and WaterAid	Evaluate the impact of behaviour change intervention using the risks, attitudes, norms, abilities, and self-regulation (RANAS) approach to improve toilet use.	https://www.wateraid.org/in/institutional-partnerships
WASH	WaterAid, UNICEF, Tribal Development Department	Renovate WASH facilities and implement behaviour change communication, capacity building, and operation and maintenance.	https://www.wateraid.org/in/institutional-partnerships
WASH	APMAS, water.org	Empower Self Help Groups federations in rural and urban areas to facilitate access to finances to improve the use of safe water and	http://www.apmas.org/waterorg.php#

		sanitation.	
Water quantity	Acwadam, Arghyam	• 1.Conduct extensive geo-hydrological studies of existing water sources. • Form water user groups (WUGs). • Implement community lift irrigation schemes. • Deepen existing wells.	https://arghyam.org/evolving-water-self-reliance-through-surface-and-groundwater-sharing-and-management/
Water quantity	Wassan, MGNREGA	• Create participatory watershed development plans. • Give training on participatory groundwater management to partners (NGOs). • Build the capacity of the community to measure and monitor groundwater and develop participatory aquifer mapping.	https://www.wassan.org/what-we-do/#ongoingprograms
Water quantity	Wassan, Commonwealth Scientific and Industrial Research Organisation (CSIRO), Western Sydney University (WSU), South Australian Research and Development Institute (SARDI), National Rainfed Area Authority (NRAA), Government of India's Ministry of Agriculture and Revitalisation of Rainfed Agriculture Network (RRAN)	Build the capacity of staff in effective water management in rainfed agriculture through the following: • Participatory groundwater management and aquifer mapping. • Participatory experimentation and learning in water use efficiency. Assessment of root-zone soil moisture.	https://www.wassan.org/what-we-do/#ongoingprograms

		Analyses of risk, e.g. sowing and irrigation decisions.	
Water governance	AFARM, Abhinav Bharat Samaj Seva Mandal, Jiyamukti Manavseva Sanstha, Yuva Gram Vikas Mandal	Implement watershed projects.	**https://www.afarm.org/Project_Partners.pdf**
Water crisis	The Timbaktu Collective, Accion Fraterna Ecology Centre, Social Animation Center for Rural Education & Development (SACRED), Palmyrah Workers Development Society (PWDS), Bharath Environment Seva Team, Environmental Defense Fund	• Establish research laboratories for NGO partners. • Develop methodologies for determining the extent of mitigation possible via several potential climate-smart (or low-carbon) farming practices.	**https://www.edf.org/sites/default/files/documents/77.62603Climate-smart-agriculture-India-EDF-report.pdf**

Chapter 9: Limitations

1. For assessing water stress,
    a. The total water availability(surface and groundwater) is not available at the sub-basin scale both in the literature as well as in the government reports. Thus, our study chose the basin-wise water availability and divided it between sub-basins based on the area.
    b. The environmental flow data is not available at the sub-basin scale both in the literature as well as in the government reports. Thus, our study has chosen the total quantity allocated at the basin level in the river basin treaties and then divided it between sub-basins based on their area.
2. For assessing the ambient water quality of surface water bodies, data was unavailable for most of the surface water bodies that fall within the limits of a town/city. For these water bodies, it was assumed that they are most likely to have bad ambient water quality given the low treatment capacity in the region.
3. For assessing the water crisis, due to data constraints the analysis had to be done at the state level, making it difficult to understand the severity of the situation at local levels like sub-basin.
4. All the water-related data provided by the government reports are present at the administrative boundary level (like the district of the state). While converting this data to a hydrological boundary could have led to the loss of some finer details.

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Annexure A

Crop water requirement is the amount of water needed to raise a crop. This includes water necessary to meet both consumptive and special needs, such as land preparation, land submergence, leaching, and so on. Effective rainfall refers to the useful or utilisable rainfall. (Figure 8) can be used to estimate the amount of effective rainfall as related to the mean monthly rainfall in the region (FAO, n.d.).

Figure 8: Table to estimate effective rainfall

Normal Monthly Rainfall (mm)	Average Monthly Consumptive Use (mm)																					
	25	50	75	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550
							Effective Rainfall															
12.5	7.5	8	8.7	9	9.2	10	10.5	11.2	11.7	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
25	15	16.2	17.5	18	18.5	19.7	20.5	22	24.5	25	25	25	25	25	25	25	25	25	25	25	25	25
37.5	22.5	24	26.2	27.5	28.2	29.2	30.5	33	36.2	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5
50	25	32.2	34.5	35.7	36.7	39	40.5	43.7	47	50	50	50	50	50	50	50	50	50	50	50	50	50
62.5	25	39.7	42.5	44.5	46	48.5	50.5	53.7	57.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5
75	25	46.2	49.7	52.7	55	57.5	60.2	63.7	67.5	73.7	75	75	75	75	75	75	75	75	75	75	75	75
87.5	25	50	56.7	60.2	63.7	66	69.7	73.7	77.7	84.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5
100	25	50	63.7	67.7	72	74.2	78.7	83	87.7	95	100	100	100	100	100	100	100	100	100	100	100	100
112.5	25	50	70.5	75	80.2	82.5	87.2	92.7	98	105	111	112	112	112	112	112	112	112	112	112	112	112
125	25	50	75	81.5	87.7	90.5	95.7	102	108	115	121	125	125	125	125	125	125	125	125	125	125	125
137.5	25	50	75	88.7	95.2	98.7	104	111	118	126	132	137	137	137	137	137	137	137	137	137	137	137
150	25	50	75	95.2	102	106	112	120	127	136	143	150	150	150	150	150	150	150	150	150	150	150
162.5	25	50	75	100	109	113	120	128	135	145	153	160	162	162	162	162	162	162	162	162	162	162
175	25	50	75	100	115	120	127	135	143	154	164	170	175	175	175	175	175	175	175	175	175	175
187.5	25	50	75	100	121	126	134	142	151	161	170	179	185	187	187	187	187	187	187	187	187	187
200	25	50	75	100	125	133	140	148	158	168	178	188	196	200	200	200	200	200	200	200	200	200
225	25	50	75	100	125	144	151	160	171	182												
250	25	50	75	100	125	150	161	170	183	194												
275	25	50	75	100	125	150	171	181	194	205												
300	25	50	75	100	125	150	175	190	203	215												
325	25	50	75	100	125	150	175	198	213	224												
350	25	50	75	100	125	150	175	200	220	232												
375	25	50	75	100	125	150	175	200	225	240												
400	25	50	75	100	125	150	175	200	225	247												
425	25	50	75	100	125	150	175	200	225	250												
450	25	50	75	100	125	150	175	200	225	250												

Annexure B

The Central Pollution Control Board classifies water bodies based on various values of a water quality parameter (CPCB, 2019). For our study, we have used Class D in Table 10 as a criterion to identify surface bodies with good ambient water quality that is suitable for the propagation of wildlife and fisheries.

Table 10: Water quality criteria to classify water bodies into designated best use

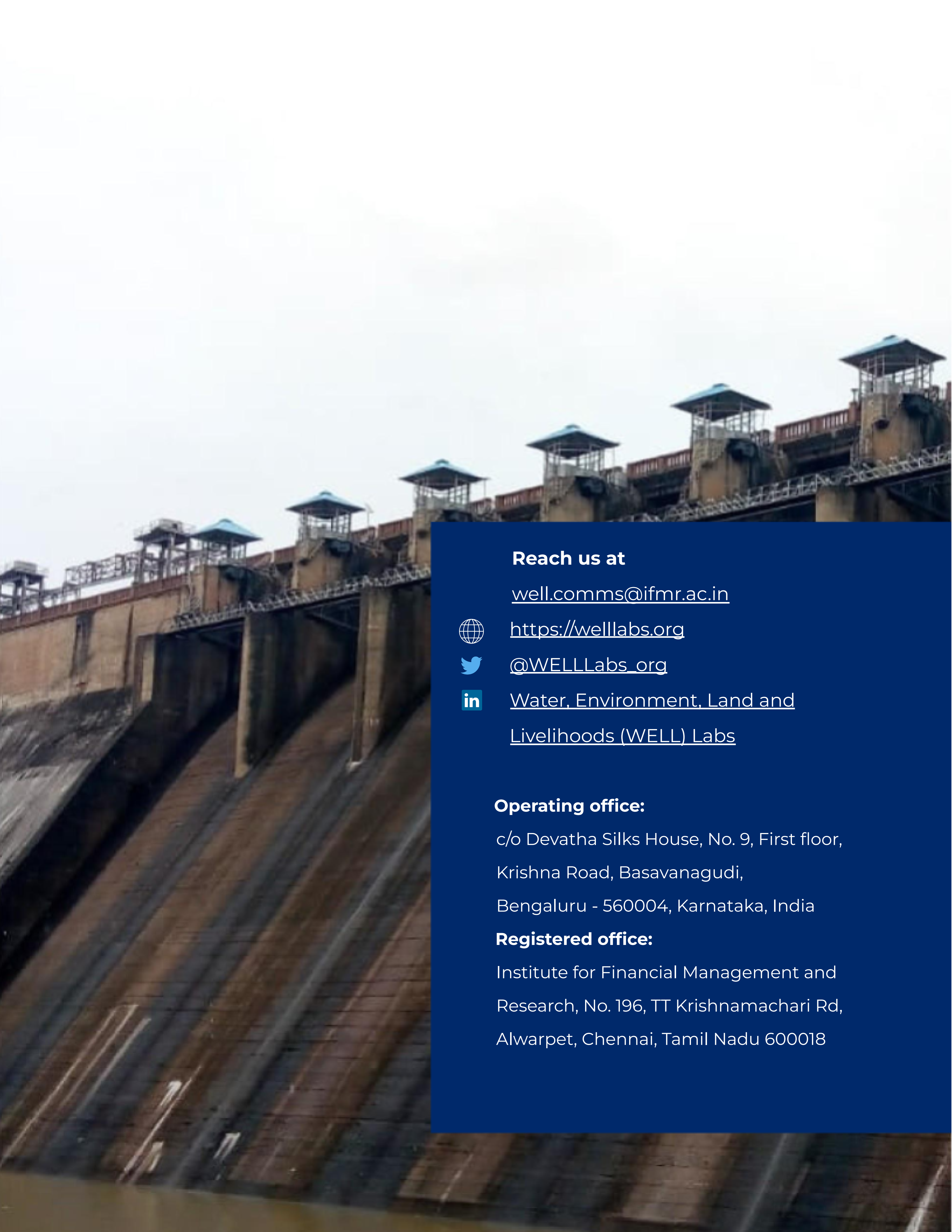
Designated-best-use	Class of water	Criteria
Drinking water source without conventional treatment but after disinfection	A	• Total coliforms organism Most Probable Number /100 ml shall be 50 or less • pH between 6.5 and 8.5 • Dissolved oxygen 6 mg/l or more • Biochemical oxygen demand over 5 days at 20 °C 2mg/l or less
Outdoor bathing (organised)	B	• Total coliforms organism MPN/100 ml shall be 500 or less • pH between 6.5 and 8.5 • Dissolved oxygen 5 mg/l or more • Biochemical oxygen demand 5 days 20C 3 mg/l or less
Drinking water source after conventional treatment and disinfection	C	• Total coliforms organism MPN/100 ml shall be 5,000 or less • pH between 6 to 9 • Dissolved oxygen 4 mg/l or more • Biochemical oxygen demand 5 days 20C 3 mg/l or less
Propagation of wildlife and fisheries	D	• pH between 6.5 to 8.5 • Dissolved oxygen 4 mg/l or more • Free ammonia (as N) 1.2 mg/l or less
Irrigation, industrial	E	• pH between 6.0 to 8.5

cooling, controlled waste disposal		● Electrical conductivity at 25C micromhos/cm max. 2,250 ● Sodium absorption ratio max. 26 ● Boron max. 2 mg/l

The Central Ground Water Board uses the BIS standards to classify the quality of groundwater levels. According to these standards, the nitrate level in the water should be less than or equal to 45 mg/l and the salinity level less than or equal to 746 µS/cm (BIS, 2012). The SDG indicator uses the criteria given in (Figure 9) to classify the ambient water quality (Warner, 2020).

Parameter Group	**Parameter**	**Target type**	**Rivers**	**Lakes**	**Groundwaters**
Oxygenation	Dissolved oxygen	range	80 – 120 (% sat)	80 – 120 (% sat)	-
Salinity	Electrical conductivity	upper	500 µS cm^{-1}	500 µS cm^{-1}	500 µS cm^{-1}
Nitrogen	Total Nitrogen	upper	700 µg N l^{-1}	500 µg N l^{-1}	-
	Oxidised nitrogen	upper	250 µg N l^{-1}	250 µg N l^{-1}	250 µg N l^{-1}
Phosphorus	Total phosphorus	upper	20 µg P l^{-1}	10 µg P l^{-1}	-
	Orthophosphate	upper	10 µg P l^{-1}	5 µg P l^{-1}	-
Acidification	pH	range	6 – 9	6 – 9	6 – 9

Figure 9: Water quality criteria by SG to classify water bodies with good ambient water quality that can support wildlife and fisheries.



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