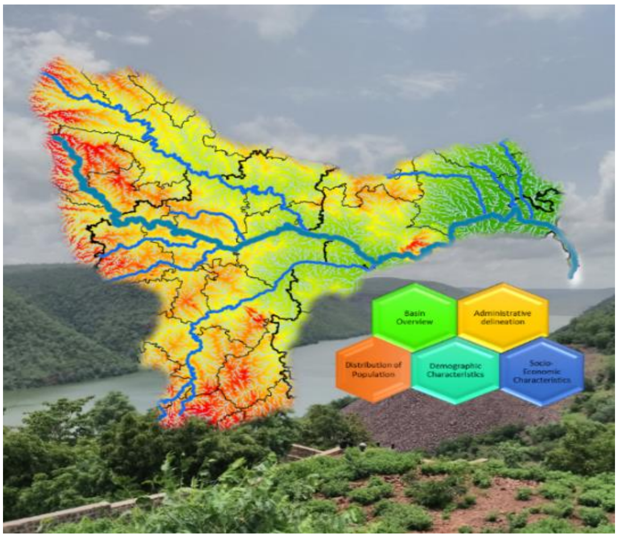
National River Conservation Directorate
Department of Water Resources,
River Development and Ganga Rejuvenation
Ministry of Jal Shakti
Government of India

Developing Protocol for Initiating Monitoring and Feedback in Krishna River Basin



October 2025

Developing Protocol for Initiating Monitoring and Feedback in Krishna River Basin

National River Conservation Directorate (NRCD)

The National River Conservation Directorate, functioning under the Department of Water Resources, River Development & Ganga Rejuvenation, and Ministry of Jal Shakti providing financial assistance to the State Government for conservation of rivers under the Centrally Sponsored Schemes of 'National River Conservation Plan (NRCP)'. National River Conservation Plan to the State Governments/ local bodies to set up infrastructure for pollution abatement of rivers in identified polluted river stretches based on proposals received from the State Governments/ local bodies.

www.nrcd.nic.in

Centres for Krishna River Basin Management Studies (cKrishna)

The Centre for Krishna River Basin Management Studies (cKrishna) is a Brain Trust dedicated to River Science and River Basin Management. Established in 2024 by NIT Warangal and NITK Surathkal, under the supervision of cGanga at IIT Kanpur, the centre serves as a knowledge wing of the National River Conservation Directorate (NRCD). cKrishna is committed to restoring and conserving the Krishna River and its resources through the collation of information and knowledge, research and development, planning, monitoring, education, advocacy, and stakeholder engagement.

www.ckrishna.org

Centres for Ganga River Basin Management and Studies (cGanga)

cGanga is a think tank formed under the aegis of NMCG, and one of its stated objectives is to make India a world leader in river and water science. The Centre is headquartered at IIT Kanpur and has representation from most leading science and technological institutes of the country. cGanga's mandate is to serve as think-tank in implementation and dynamic evolution of Ganga River Basin Management Plan (GRBMP) prepared by the Consortium of 7 IITs. In addition to this, it is also responsible for introducing new technologies, innovations, and solutions into India.

www.cganga.org

Acknowledgment

This report is a comprehensive outcome of the project jointly executed by NIT Warangal (Lead Institute) and NITK Surathkal (Fellow Institute) under the supervision of cGanga at IIT Kanpur. It was submitted to the National River Conservation Directorate (NRCD) in 2025. We gratefully acknowledge the individuals who provided information and photographs for this report.

Disclaimer

This report is a preliminary version prepared as part of the ongoing Condition Assessment and Management Plan (CAMP) project. The analyses, interpretations and data presented in the report are subject to further validation and revision. Certain datasets or assessments may contain provisional or incomplete information, which will be updated and refined in the final version of the report after comprehensive review and verification.

Team

N V Umamahesh, cKrishna, NIT Warangal
M. Chandra Sekhar, cKrishna, NIT Warangal
K Venkata Reddy, cKrishna, NIT Warangal
Jew Das, cKrishna, NIT Warangal
G Gowtham, cKrishna, NIT Warangal
Prasantha Majee, cKrishna, NIT Warangal
Eswar Sai Buri, cKrishna, NIT Warangal
Kandula Srikanth, cKrishna, NIT Warangal
Dr Vinod Tare, cGanga, IIT Kanpur

B. Manu, cKrishna, NITK Surathkal
S. Shrihari, cKrishna, NITK, Surathkal
G.S. Dwarakish, cKrishna, NITK, Surathkal
Lakshman Nandagiri, cKrishna, NITK, Surathkal
Jacklin Jeke Nilling, cKrishna, NITK, Surathkal
Saranya P, cKrishna, NITK, Surathkal
Nishanth B, cKrishna, NITK, Surathkal
Karunasindhu Jha, cKrishna, NITK, Surathkal
Ms. Hullavva Undi, cKrishna, NITK, Surathkal
Ms. Priyanka, cKrishna, NITK Surathkal

PREFACE

In an era of unprecedented environmental change, understanding our rivers and their ecosystems has never been more critical. This report aims to provide a comprehensive overview of our rivers, highlighting their importance, current health, and the challenges they face. As we explore the various facets of river systems, we aim to equip readers with the knowledge necessary to appreciate and protect these vital waterways.

Throughout the following pages, you will find an in-depth analysis of the principles and practices that support healthy river ecosystems. Our team of experts has meticulously compiled data, case studies, and testimonials to illustrate the significant impact of rivers on both natural environments and human communities. By sharing these insights, we hope to inspire and empower our readers to engage in river conservation efforts.

This report is not merely a collection of statistics and theories; it is a call to action. We urge all stakeholders to recognize the value of our rivers and to take proactive steps to ensure their preservation. Whether you are an environmental professional, a policy maker, or simply someone who cares about our planet, this guide is designed to support you in your efforts to protect our rivers.

We extend our heartfelt gratitude to the numerous contributors who have generously shared their stories and expertise. Their invaluable input has enriched this report, making it a beacon of knowledge and a practical resource for all who read it. It is our hope that this report will serve as a catalyst for positive environmental action, fostering a culture of stewardship that benefits both current and future generations.

As you delve into this overview of our rivers, we invite you to embrace the opportunities and challenges that lie ahead. Together, we can ensure that our rivers continue to thrive and sustain life for generations to come.

Centers for Krishna River Basin Management and Studies (cKrishna)

NIT Warangal, NITK Surathkal

Table of Contents

List of Figures

1. Introduction

The Krishna River Basin, one of India's major and most dynamic river systems, has witnessed the implementation of numerous strategies, plans, programmes, and projects aimed at managing its water resources, improving environmental sustainability, and supporting socio-economic development. However, the lack of a unified and systematic mechanism for monitoring and feedback has often led to fragmented evaluations and limited understanding of the cumulative impacts of these initiatives. The focus is on developing a comprehensive protocol for initiating monitoring and feedback of various implementation strategies within the basin. The proposed protocol will serve as a standardized framework to assess the performance, effectiveness, and sustainability of ongoing and future interventions through the integration of hydrological, ecological, and socio-economic indicators. By ensuring regular data-driven evaluation, promoting inter-agency coordination, and establishing adaptive feedback mechanisms, the protocol aims to enhance transparency, accountability, and informed decision-making for sustainable river basin management in the Krishna River Basin.

2. Existing Frameworks and Their Relevance

India has a history of river conservation and management initiatives that provide valuable insights for the river basin protocol:

- **National River Conservation Plan (NRCP):** Focused on pollution abatement, including interception, diversion, and treatment of municipal wastewater, riverfront development, and public participation. It highlights the importance of sewage treatment capacity and improving water quality.
- **Namami Gange Programme:** This flagship program for the Ganga River offers a holistic, multi-sectoral approach encompassing pollution abatement, ecological restoration, environmental flow maintenance, and stakeholder engagement. It emphasizes a multi-tier governance structure (National, State, District level), continuous monitoring, and the use of technology.
- **Urban River Management Plans:** Strategic frameworks designed for specific urban river stretches, focusing on a multi-point agenda for urban river health.
- **State-level Initiatives:** Many states have their own water resource and pollution control boards (e.g., Maharashtra Water Resources Department, Karnataka State Pollution Control

Board, Telangana Water Resources Department, Telangana Pollution control board) which manage projects and data at the state level.

These existing frameworks underscore the necessity of a multi-stakeholder approach, integrated water resource management, and the crucial role of continuous monitoring and participatory engagement.

2.1 Role of Participatory Monitoring in Existing Frameworks

Participatory monitoring, also known as community-based or citizen science monitoring, plays a crucial role in strengthening existing environmental and river basin management frameworks. It enhances the inclusiveness, efficiency, and sustainability of management systems by involving local stakeholders in data collection, analysis, and feedback processes. The integration of participatory approaches expands the spatial and temporal reach of monitoring efforts, enabling continuous observation of hydrological, ecological, and socio-economic parameters that are often difficult to capture through conventional methods alone.

Examples of Participatory Monitoring:

- **Community-based Water Quality Monitoring:** Initiatives like those demonstrated in low-resource communities, where trained local individuals, especially women, use portable sensor technologies and mobile apps (e.g., Hach strips, AquaGenX E. coli kits, multi-sensor kits) for reliable water quality data collection. Data reliability can be assessed using agreement proportions and Kappa coefficients.
- **Citizen Science for Ecological Monitoring:** Platforms like eBird in India facilitate community participation in biodiversity monitoring (e.g., bird counts), contributing valuable data on ecological health. This involves training community members and leveraging online platforms for data submission and analysis.
- **Community-based Flood Early Warning Systems:** Local communities, with support from technical agencies, can be trained to monitor water levels and disseminate alerts, thereby enhancing disaster preparedness.

2.2 Key Components

The protocol focuses on four core components:

1. **Performance Evaluation:** Key Performance Indicators (KPI)s are defined for water quality, flow, ecological health, and project progress, tailored to the basin's semi-arid climate and agricultural dominance.
2. **Feedback Mechanisms:** Digital platforms (e.g., mobile apps, public dashboards), community forums, and third-party audits ensure transparency and responsiveness.
3. **Stakeholder Engagement:** Farmers, local communities, industries, and technical experts are involved to address water allocation disputes and pollution issues.
4. **Resource Management:** Efficient allocation of human, financial, and technical resources prioritizes high-impact areas like drought-prone regions (e.g., Rayalaseema, Bellary).

2.3 Steps to Develop the Protocol

The development of a structured protocol for initiating monitoring and feedback of implementation strategies in the Krishna River Basin involves a systematic, multi-tiered process that integrates administrative, technical, and participatory components. The Figure 1 below illustrates the sequential steps adopted in developing the protocol.

Figure 1: Sequential steps adopted in developing the protocol.

1. **Define Objectives and KPIs:** The primary objectives are to improve water quality, ensure environmental flows (E-flows), reduce flood risks, and enhance agricultural sustainability. Key Performance Indicators (KPIs) include maintaining water quality standards such as Dissolved Oxygen (DO) above 5 mg/L, Biological Oxygen Demand (BOD) below 5 mg/L, and reduced

faecal coliform counts. To sustain flow conditions (Aviral Dhara), E-flows should be maintained at 10–20% of the average flow during lean seasons through hydrological assessments, ecological and socio-cultural evaluations, and methodologies like the Building Block Methodology (BBM) to determine flow releases from dams and barrages. Ecological health (Jaiv Vividhta) targets a 10% annual increase in aquatic biodiversity, restoration of riparian vegetation with a 10% increase in green cover along riverbanks, and revival of key species such as otters, turtles, and specific fish. Flood management aims to reduce flood frequency in delta areas by improving channel capacity, reflected in reduced flood events and peak flows. Agricultural sustainability focuses on stabilizing irrigated areas through balanced use of groundwater and surface water, monitored via irrigated area percentages, groundwater level trends, and soil moisture indices.

2. **Map Administrative and Natural Boundaries:** Delineate monitoring zones based on administrative units (districts) and natural sub-basins (e.g., Bhima, Tungabhadra). Use Geographic Information System (GIS) tools to map pollution sources (e.g., industrial effluents in Hyderabad) and agricultural areas.
3. **Identify Stakeholders:** The key stakeholders include national-level agencies such as the Central Water Commission (CWC) and the Ministry of Jal Shakti, which provide policy direction, regulation, and technical oversight for water resources management. At the state level, the primary stakeholders are the State Water Resources Departments and the State Pollution Control Boards, responsible for implementing water management programs. Local-level stakeholders include District Magistrates, farmers' cooperatives, and local NGOs, who play a crucial role in on-ground implementation, community participation, and awareness generation. Technical support and expertise are provided by premier academic and research institutions such as the National Institutes of Technology (NITs), Indian Institutes of Technology (IITs), and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), which contribute through scientific studies, modeling, and technology-driven interventions.
4. **Establish Monitoring Tools:** Deploy real-time sensors for water quality and flow at key dams (e.g., Almatti, Srisailam, Nagarjuna Sagar). Utilize MODIS satellite imagery (250m resolution) for land use and water stress monitoring. Develop mobile apps for community reporting of pollution incidents, such as those in the Musi River.
5. **Set Feedback Loops:** Generate monthly reports on water quality and project progress. Create public dashboards, like Bhuvan Ganga, for transparency. Hold quarterly stakeholder forums to address interstate water disputes.

3. Identification of Issues that Policy Can and Should Monitor and Converting into Quantifiable Measures

The Krishna River Basin (KRB), spanning across Maharashtra, Karnataka, Telangana, and Andhra Pradesh, faces a diverse range of hydrological, ecological, and socio-economic challenges that require systematic monitoring and evidence-based policy intervention. These issues—ranging from water quality deterioration, sedimentation in reservoirs, and frequent flooding, to inequitable water sharing, encroachment of floodplains, and delayed infrastructure projects—affect both the ecological integrity and socio-economic stability of the basin. Effective river basin governance thus depends on identifying such critical issues and translating them into quantifiable indicators or Key Performance Measures (KPIs) that enable continuous tracking, evaluation, and adaptive management. The following section presents key issues observed across the four riparian states of the Krishna River Basin, supported by recent reports, newspaper articles, and official data, along with measurable indicators to guide policy formulation and monitoring.

- **Flooding / Extreme Flow Events:** Flooding in the Krishna River Basin has emerged as a recurrent and escalating issue, primarily driven by intense monsoonal precipitation, unregulated reservoir releases, encroachment of floodplains, and inadequate channel conveyance capacity. Such events not only disrupt livelihoods and agriculture but also damage critical infrastructure and erode riverbanks, thereby altering the basin's geomorphology. In October 2024, for instance, heavy and sustained rainfall across Karnataka and in the Rayalaseema (region of Andhra Pradesh) led to severe flooding, forcing authorities to open floodgates at major reservoirs such as Srisailam and Nagarjuna Sagar, and issue alerts downstream in vulnerable settlements. According to The Times of India (October 2024), the flooding resulted in widespread inundation of agricultural lands and partial submergence of low-lying villages along the Krishna and its tributaries. Heavy rains across Andhra Pradesh and Telangana triggered massive inflows into the Krishna River, prompting authorities to issue a second danger warning at the Prakasam Barrage on Sunday evening. By 28th September Sunday 6 pm, the outflow at the barrage touched 6.2 lakh cusecs, with officials warning that the surge could rise to 7 lakh cusecs by Monday afternoon. The flood situation is severe across reservoirs along the Krishna River basin. Flooding continues to affect areas downstream, even as the AP State Disaster Management Authority urged residents in low-lying areas to remain alert. In Vijayawada, authorities are balancing flood control with Dussehra celebrations at Kanaka Durga Temple. Barrage staff and police are preventing devotees from entering the river, using microphones at

Durga Ghat, Bhavani Ghat, and Punnami Ghat to issue warnings. Temporary shower facilities have


THE TIMES OF INDIA

City | Vijayawada | Mumbai | Delhi | Bengaluru | Hyderabad | Kolkata | Chennai | Agra | Agartala | Ahmedabad | Ajmer

WEATHER ANDHRA ELECTIONS

NEWS / CITY NEWS / VIJAYAWADA NEWS / Heavy Rains In Karnataka, Rayalaseema Cause Flooding In Kris...

TRENDING | Nandini Mysore Pak | Amit Thackeray | Maharashtra Elections | Delhi AQI Today | Ayodhya Deepotsav

Heavy rains in Karnataka, Rayalaseema cause flooding in Krishna river

Venu Lanka / Oct 20, 2024, 23:21 IST

Vijayawada: Continuous heavy rains in Karnataka and Rayalaseema has led to severe flooding in the Krishna river, prompting officials to issue a flood alert in the river's catchment areas. The water levels have risen significantly at key locations such as Srisailam, Nagarjunasagar, and Prakasam Barrage.

The Krishna river, which has already faced flooding earlier this year, is once again overflowing due to heavy inflows from the Tungabhadra catchment area and floodwaters from the Jurala project in


Printed from THE TIMES OF INDIA

Heavy rains cause severe flooding, prompt danger warning at Prakasam barrage

Sep 28, 2025, 11.27 PM IST

Vijayawada: Heavy rains across Andhra Pradesh and Telangana triggered massive inflows into the Krishna River, prompting authorities to issue a second danger warning at the Prakasam Barrage on Sunday evening. By 6 pm, the outflow at the barrage touched 6.2 lakh cusecs, with officials warning that the surge could rise to 7 lakh cusecs by Monday afternoon.

The flood situation is severe across reservoirs along the Krishna basin. At Srisailam, the inflow was 5.93 lakh cusecs with an equal outflow. Nagarjunasagar reported 5.88 lakh cusecs inflow and outflow, while Pulichintala recorded 6.30 lakh cusecs inflow and 6.09 lakh cusecs outflow. At Prakasam Barrage, inflow and outflow stood at 6.43 lakh cusecs. Flooding continues to affect areas downstream, even as the AP State Disaster Management Authority urged residents in low-lying areas to remain alert.

been arranged for devotees to bathe safely before visiting the temple. Below Figure 2 represents the flooding issues in Karnataka and Ralayaseema and Figure 3 shows the flooding issue in Prakasasm barrage.

Figure 2: Flooding Issues in Karnataka & Rayalaseema

Figure 3: Flooding Issues in Prakasam

Quantifiable Measures:

- To effectively monitor and manage such occurrences, flood-related issues can be quantified through measurable parameters such as peak discharge at key barrage or dam sites (expressed in m^3/s or cusecs).
- Number of flood days per year, area inundated (in km^2) across affected districts
- Estimated economic and infrastructural damage (₹ value)
- Flood frequency and return period (e.g., 10-year or 25-year flood events).

- **Pollution / Water Quality Degradation:** The Krishna River Basin faces severe pollution due to industrial effluents, urban sewage, and human activities such as bathing and washing clothes. Key pollutants include muck, diesel, synthetic chemicals, and large volumes of treated or untreated wastewater from paper, polyfibre, and pharmaceutical industries. These contaminants have harmed the river's aquatic ecosystem, leading to the disappearance of sensitive species like golden mahseer (Tor) and nielli, while only pollution-tolerant species such as gambusia survive. Specific hotspots include Telangana (pharmaceutical and chemical effluents affecting Nagarjunasagar), Andhra Pradesh (high organic load with BOD ~3.3 lakh kg/day), Maharashtra (urban sewage and oil at Wai, Haripur ghat, Bhima at Pandharpur), and Karnataka (polyfibre industry discharging 33,000 m^3/day downstream). Below Figure 4 represents pollution status of Krishna River Basin in Maharashtra, Karnataka and Andhra Pradesh States.

Printed from
THE TIMES OF INDIA

Telangana, Andhra Pradesh, Karnataka & Maharashtra have polluted their lifeline Krishna river, reveals new report

TNN | Dec 16, 2024, 08.16 AM IST

HYDERABAD: The Krishna, India's third longest river, is severely polluted due to unchecked sewage and industrial effluent being dumped into it by Telangana, Andhra Pradesh, Karnataka and Maharashtra, according to a preliminary report by the National Institute of Technology (NIT), Warangal. Spanning around 1,400 km between Mahabaleshwar in Maharashtra and Krishnapatnam in AP, Krishna is the lifeline for the four states, which use it as a key source for power generation, irrigation, and drinking water.

Figure 4: Pollution Issue in Krishna River Basin.

Quantifiable measures:

- Biochemical Oxygen Demand (BOD) – mg/L or kg/day (e.g., AP urban areas: 3.3×10^5 kg/day)
- Chemical Oxygen Demand (COD) – mg/L
- Dissolved Oxygen (DO) – mg/L (low DO <5 mg/L harmful for aquatic life)
- pH – standard units (6.5–8.5 desirable)
- Total Suspended Solids (TSS) – mg/L

- **Dam Siltation & Loss of Storage Capacity:** Reservoir siltation is a critical issue affecting water storage, flood management, irrigation, and hydropower generation in river basins. Over time, sediment transported by the river accumulates in the reservoir, reducing its active storage capacity and altering its designed water retention and release characteristics. Siltation also increases the risk of upstream flooding, affects reservoir operations, and can shorten the effective lifespan of the dam. Almatti Dam in Karnataka has lost approximately 6% of its storage capacity (from 123 TMC to 115.5 TMC) due to around 7.5 TMC of silt deposition. From a theoretical perspective, sedimentation in reservoirs is governed by hydrological processes such as catchment erosion, river flow velocity, and sediment transport dynamics. The sediment deposition rate depends on rainfall intensity, land use, soil type, and upstream deforestation or construction activities. Understanding siltation is essential for designing desiltation measures, estimating reservoir life, and planning water allocation strategies. Below Figure 5 represents the Almatti dam losing storage capacity issue highlighted by Times of India.

Printed from
THE TIMES OF INDIA

Almatti dam loses storage capacity due to silt accumulation

Oct 11, 2025, 02.34 AM IST

Vijayapura: Almatti dam, one of Asia's largest reservoirs, has lost 6% of its storage capacity due to silt accumulation. A report submitted by the director (chief engineer), Karnataka Engineering Research Station, Krishnarajasagara, to the govt warns that the dam's capacity has dropped from 123 tmc to 115 tmc as silt has occupied the space. It was tabled in the legislative council by the deputy chief minister DK Shivakumar in Aug. The findings highlight the urgent need for desilting to prevent further reduction in water storage.

The report said that the level of silt is being controlled using river sluice during flood inflow at Almatti and Narayanapur dams. Construction of Almatti Dam was completed in 2000 after 36 years of the foundation stone being laid by then Prime Minister Lal Bahadur Shastri in 1964. Its storage capacity is 123 tmc. It should be noted that silt was absolutely zero in the first survey conducted in 2001. With the accumulated silt of 7.5 tmc in the 2023 survey, storage capacity is reduced to 115.5 tmc. Almatti dam has the highest reservoir area of 493.4 sq kms.

Figure 5: Almatti dam losses its storage capacity due to silt accumulation.

Quantifiable Measures:

- **% Loss in Storage Capacity:** Measures reduction in active reservoir storage compared to design or original capacity (~6% for Almatti).
- **Volume of Silt Accumulation per Year:** Indicates the sediment deposition rate (TMC or million m^3), critical for reservoir maintenance planning.
- **Annual Sediment Inflow Rate / Sediment Load:** Evaluates the quantity of sediment entering the reservoir per year (m^3/year or tons/year), linked to upstream land use and erosion.
- **Change in Reservoir Bottom Elevation:** Bathymetric surveys quantify reservoir bed aggradation (m), helping predict remaining storage life and plan dredging or desiltation.

- **Infrastructure Delays / Unfulfilled Flood Protection Projects:** Timely execution of flood protection infrastructure is critical for minimizing damage during extreme flow events. Delays in constructing levees, embankments, or retaining walls increase the vulnerability of flood-prone communities, as observed in Vijayawada. The works to raise the flood protection wall at Ramalingeswara Nagar have not yet begun, despite prior approval. During the 2024 floods, water levels exceeded the original design capacity of the wall (11.40 lakh cusecs observed vs 10.50 lakh cusecs design), exposing areas like Krishna Lanka to inundation. From a theoretical perspective, flood protection structures are designed using hydrological and hydraulic analyses, considering factors such as peak discharge, return period of floods, floodplain topography, and expected safety margins. Delays or under-execution compromise the design assumptions, leading to structural vulnerability, increased economic losses, and heightened risk to human lives. Monitoring the status and performance of flood infrastructure is therefore essential for risk management and adaptive planning in river basins. Below Figure 6 presents the infrastructure delay issue in Vijayawada.

Printed from
THE TIMES OF INDIA

Works to raise flood protection wall height at Ramalingeswara Nagar in Vijayawada yet to begin

Oct 16, 2025, 10.58 PM IST

Vijayawada: Four months after receiving approval from the Vijayawada municipal corporation (VMC) to raise the height of the flood protection wall at Ramalingeswara Nagar, adjacent to the Krishna River, the project works are yet to begin in the area.

The state govt constructed an approximately 3.5-km-long retaining wall downstream of Prakasam Barrage to shield low-lying areas such as Krishna Lanka, Ranigarithota, Ramalingeswara Nagar, Yanamalakuduru, and other areas from floods in the Krishna River.

It is worth mentioning that the irrigation department designed and constructed the flood protection wall to withstand a maximum of 10.50 lakh cusecs of floodwaters, the highest flood recorded in the Krishna River at Prakasam Barrage in 2009. However, in 2024, the Prakasam Barrage received an unprecedented 11.40 lakh cusecs of floodwaters, leading to floodwater overflowing from the retaining wall and entering Ramalingeswara Nagar and neighbouring areas, submerging them for days and crippling normal life.

Figure 6: Infrastructure delay issue in Vijayawada.

Quantifiable Measures:

- **Design Discharge Capacity vs Actual Flood Discharges:** Compares infrastructure capability (cusecs or m^3/s) with observed peak flows to evaluate adequacy.
- **Delay Time:** Duration (in months) between project approval and actual execution, indicating administrative or logistical bottlenecks.
- **Number of Pending vs Completed Projects:** Reflects overall preparedness and resilience in flood-vulnerable zones.
- **Cost Overruns / Funds Utilized:** Compares allocated funds versus actual expenditure, highlighting financial management efficiency.

4. Identification of the Right Nodes/People/Agencies Who Can Help in Commissioning Evidence

Effective monitoring requires a clear delineation of responsibilities for commissioning and overseeing the collection of various types of evidence.

- **National Level:** At the national level, the Central Water Commission (CWC) plays a crucial role in commissioning hydrological and hydro-meteorological data collection, including river flow measurements, water level monitoring, sediment transport analysis, and flood forecasting, along with undertaking major basin-wide hydrological surveys. The Central Pollution Control Board (CPCB) is responsible for national-level water quality monitoring and the development of pollution load assessments, as well as conducting specialized studies on the impacts of industrial and municipal pollution on river systems. The Ministry of Jal Shakti (MoJS), serving as the apex body, oversees and commissions large-scale national programs and policy-driven studies related to water resources management. The Ministry of Environment, Forest and Climate Change (MoEF&CC) commissions ecological surveys, biodiversity assessments, and environmental impact assessments, often engaging specialized research institutions and wildlife organizations to ensure ecosystem integrity and conservation. Additionally, the Indian Meteorological Department (IMD) plays a vital role in collecting and analyzing meteorological data, providing weather and climate forecasts essential for flood management, drought assessment, and overall basin hydrological planning.

- **State Level:** At the state level, the key agencies across all four states of the Krishna River Basin—Maharashtra, Karnataka, Telangana, and Andhra Pradesh—play vital roles in data collection, monitoring, and implementation of basin management initiatives. The respective State Water Resources Departments (SWRDs), such as the Maharashtra Water Resources Department, Karnataka State Water Resources Department, Telangana Irrigation and Command Area Development Department, and the Andhra Pradesh Water Resources Department, are responsible for conducting detailed hydrological surveys, managing irrigation projects, maintaining reservoir operations, and carrying out state-specific environmental flow (E-flow) assessments for their river stretches. The State Pollution Control Boards (SPCBs)—including MPCB, KSPCB, TSPCB, and APPCB—are tasked with state-level water quality monitoring within the Krishna River Basin, regulating industrial discharges, and identifying pollution hotspots through detailed monitoring and source assessment surveys. The State Agriculture Departments, namely those of Maharashtra, Karnataka, Telangana, and Andhra Pradesh, conduct agricultural land use mapping, crop health monitoring to support sustainable irrigation and resource utilization. Additionally, the State Biodiversity Boards and Forest Departments across these states are responsible for ecological surveys, riparian zone assessments, habitat conservation, and biodiversity restoration initiatives that enhance the ecological resilience of the Krishna River Basin. Together, these state-level institutions ensure coordinated efforts in water, agriculture, and ecosystem management aligned with the broader objectives of integrated basin planning.
- **Local Level (District/Block/Gram Panchayat):** At the local level, District Magistrates and Collectors play a pivotal role in overseeing and commissioning localized primary surveys related to community water use, pollution incidents, and socio-economic impacts associated with river basin management. The Urban Local Bodies (ULBs) and Panchayat Raj Institutions (PRIs) are instrumental in commissioning studies on local wastewater management, assessing the impacts of solid waste disposal on nearby water bodies, and mobilizing community volunteers for participatory monitoring

and awareness programs. Additionally, farmers' cooperatives and local NGOs contribute significantly by commissioning studies on water use efficiency, facilitating community-led assessments of water-related interventions, and promoting participatory monitoring to ensure that local concerns and traditional knowledge are effectively integrated into broader basin management efforts.

- **Technical Partners (Commissioned by various levels):** At the technical level, various expert institutions are commissioned by national, state, and local agencies to provide scientific, analytical, and technological support for evidence-based river basin management. The Indian Institutes of Technology (IITs), National Institutes of Technology (NITs), and Central and State Universities are engaged for specialized research, data analysis, and hydrological and hydraulic modeling using tools such as HEC-HMS, SWAT, and MIKE-Flood. These institutions also contribute to developing monitoring technologies, conducting third-party audits, and supporting capacity-building initiatives. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) undertakes studies focused on agricultural sustainability, water-efficient farming practices, and soil moisture analysis, particularly relevant to the semi-arid regions within the Krishna River Basin. Additionally, ISRO and its National Remote Sensing Centre (NRSC) play a crucial role in acquiring, processing, and analyzing satellite data for applications such as land use and land cover mapping, water stress detection, and flood inundation assessment, thereby enabling data-driven planning and management across the basin.

5. What Kind of Evidence to Commission, and Ways in Which to Commission

The monitoring protocol relies on a diverse range of evidence types and collection methodologies, often integrated for a holistic view:

- **Primary Surveys:** Evidence for river basin management can be commissioned through a combination of field-based, laboratory, and community-driven approaches. Water quality monitoring involves weekly or monthly collection of water samples from designated sites of Krishna River Basin for laboratory analysis of parameters such as BOD, COD, DO, coliform counts, pH, TDS, nutrients (N, P), and heavy metals, often using multi-parameter probes like YSI or Hach instruments, and MPN kits for coliform detection. For instance, in Karnataka, a study installed IoT-based real-time sensors at six stations along the Krishna River stretch for parameters such as pH, conductivity, dissolved oxygen, temperature, BOD, TDS etc. This enabled faster, continuous water quality monitoring rather than manual, periodic sampling.

Biodiversity surveys include methods such as electrofishing, netting, and environmental DNA (eDNA) sampling for aquatic species, along with transect walks and quadrat sampling to assess riparian vegetation, and direct observation or camera trapping to monitor key faunal species. Socio-economic surveys are conducted at the household level to document water access, usage patterns, health impacts, and community perceptions of river health. Agricultural surveys involve field plot diaries, crop-cutting experiments, and farmer interviews to evaluate irrigation practices, water use efficiency, and crop yields. Collectively, these methods generate comprehensive evidence to support informed decision-making and sustainable management of the river basin.

- **Administrative Data:** Existing secondary evidence for the Krishna River Basin can be sourced from various official records maintained by state-level agencies across Maharashtra, Karnataka, Telangana, and Andhra Pradesh. Water Resources Department logs from each state provide detailed information on dam releases, canal diversions, groundwater abstraction permits, and the progress of irrigation projects. State Pollution Control Board records—including those of MPCB, KSPCB, TSPCB, and APPCB—contain data on industrial discharges, performance of sewage treatment plants (STPs), and compliance reports for pollution regulations. Census data offer demographic insights, land use statistics, and economic activity patterns within the basin, supporting socio-economic assessments. Additionally, Disaster Management Authority records from each state document flood events, damage assessments, and relief operations, providing critical information for flood risk management and planning interventions. Collectively, these secondary data sources complement primary surveys and technical studies to build a comprehensive evidence base for integrated river basin management.
- **Aerial & Satellite Data (Remote Sensing):** Aerial and satellite data play a crucial role in monitoring and managing the Krishna River Basin. Satellite imagery from various platforms provides multi-scale and multi-temporal information: MODIS (250 m resolution) is used for routine monitoring of large-scale land use and land cover changes, vegetation health through NDVI, and water stress; Sentinel-1 (SAR) is particularly useful for flood inundation mapping, even under cloudy conditions; Sentinel-2 (optical, 20 m resolution) enables detailed land use mapping, riparian vegetation assessment using NDVI, and monitoring of irrigated areas; while Landsat imagery supports historical trend analysis of land use patterns and changes in water bodies. Complementing these, drone imagery provides high-resolution aerial data for localized monitoring, including riverbank erosion, identification of small-scale pollution sources,

detection of illegal encroachments, and detailed mapping of riparian zones, thereby enhancing both precision and timeliness of evidence collection for river basin management.

- **Real-time Monitoring:** Real-time monitoring is a key component of evidence-based management of the Krishna River Basin. Automated Water Quality Monitoring Stations (AWQMS) are deployed at critical locations, such as upstream and downstream of major urban and industrial centers or key dams, to continuously measure parameters including dissolved oxygen (DO), pH, conductivity, turbidity, temperature, and selected nutrients. Hydro-meteorological gauging stations provide real-time data on streamflow, water levels using ADCP or radar sensors, and weather parameters like precipitation and temperature, which are essential for managing environmental flows (E-flows) and flood risks. Piezometers and Automated Water Level Recorders (AWLRs) facilitate continuous monitoring of groundwater levels, enabling assessment of aquifer health and sustainable groundwater use. Additionally, IoT-based soil sensors allow real-time tracking of soil moisture in agricultural fields, supporting optimized irrigation practices and enhancing water use efficiency.

Ways to Commission Evidence:

- **Tenders and Contracts:** Government agencies at national and state levels issue tenders for large-scale surveys (e.g., comprehensive water quality monitoring, E-flow assessments, satellite data analysis projects) to specialized consulting firms, research institutions (IITs, NITs), or private companies.
- **Memorandam of Understanding (MoUs):** Collaborations with academic institutions (IITs, universities) and research organizations (ICRISAT, Wildlife Institute of India) for long-term studies, data analysis, and capacity building.
- **Internal Teams:** Government departments (CWC, CPCB, State WRDs) have their own field staff and laboratories for routine data collection and analysis.
- **Community Engagement Programs:** Through NGOs, local bodies, and dedicated project staff, communities are mobilized and trained for participatory data collection using simplified tools and mobile applications.

6. Role of Independent Audits or Third-Party Monitoring

Independent audits or third-party monitoring serve as crucial mechanisms to ensure accountability, transparency, and objectivity in the implementation of strategies, plans, programmes, and projects in the Krishna River Basin. Their roles include:

- **Verifying Data, Usage, & Compliance:** Third parties help to check whether the project implementers (government agencies, contractors etc.) are following the prescribed technical, environmental, and legal standards. In the KRB context, discrepancies in water usage share between states have raised questions that independent verification could help resolve. For example, Telangana has raised concerns over Andhra Pradesh exceeding its utilizable share of Krishna River water, partly citing issues with measurement and gauge inaccuracies.
- **Bridging Trust between States & Stakeholders:** Because the Krishna River Basin is shared across multiple states, mutual suspicion can arise over water flows, diversions, or project impacts. Independent third-party monitoring (e.g., via telemetry or similar technical instruments operated or verified by bodies outside the directly involved state governments) helps build confidence. For instance, during recent meetings, Telangana and Andhra Pradesh agreed to install telemetry instruments at off-take points in the Krishna basin for more reliable measurement and transparency.
- **Providing Objective Evidence for Dispute Resolution & Policy Input**: Independent audits can generate credible evidence, needed by inter-state water management boards, tribunals, or high-power committees. In Krishna River Basin, many water sharing disputes (e.g. over allocations from reservoirs like Srisailam, Nagarjuna Sagar etc.) hinge on accurate measurements, flow records and usage, which independent monitoring can help authenticate. While there is no published audit that specifically covers all four states working together for a single project, the establishment of Monitoring & Appraisal Directorates under the Krishna Godavari Basin Organization (CWC) plays a similar role for assessing state schemes under central assistance.
- **Ensuring Performance of Centrally Assisted and Major Projects:** Many large irrigation and water management projects in the KRB are funded under central programs such as the Accelerated Irrigation Benefit Programme (AIBP) or command-area development programmes, which require monitoring of physical and financial progress, cost overruns, delays etc. Independent audits or third-party reviews offer oversight beyond internal agency reports. The Monitoring & Appraisal Directorate of KGBO tracks these for states like Telangana and Andhra Pradesh, ensuring they meet timelines, meet the technical specifications, and financial discipline.
- **Environmental & Pollution Audits**: Independent monitoring can assess water quality, ecological

impacts, pollution from industries, effluents etc. In the Krishna River Basin across Karnataka, Maharashtra, Telangana, Andhra Pradesh, studies (e.g. by academic institutions) have shown industrial-effluent pollution and sewage loads affecting the river. An independent audit in such cases helps identify sources, quantify damage, propose corrective action, and monitor compliance with standards. For example, the NIT Warangal / NITK Surathkal report on Krishna River pollution body covering all four states highlights these issues.

Who Conducts Independent Audits:

- **Independent Audit Firms:** Specialized environmental auditing firms with expertise in water resources and pollution control.
- **Academic Institutions:** Reputable IITs, NITs, and other universities with relevant departments can be commissioned for third-party assessments due to their technical expertise and impartiality.
- **Comptroller and Auditor General of India (CAG):** As a constitutional authority, CAG can audit government programs and schemes, including those related to river basin management, focusing on financial propriety, efficiency, and effectiveness.

Methodologies:

- **ISO Standards:** Adherence to international standards like ISO 14001 (Environmental Management Systems) and ISO 14011 (Guidelines for Auditing Management Systems).
- **Checklists and Protocols:** Development of comprehensive audit checklists covering all aspects of the monitoring protocol and project implementation.
- **Random Sampling:** For data verification and site inspections.
- **Reporting:** Generation of detailed audit reports outlining findings, observations, and recommendations, often with a clear grading or rating system.

7. Analyzing Data and Evidence:

Analyzing Data and Evidence presents a comprehensive assessment of the Krishna River Basin by integrating descriptive and causal analyses. Descriptive analysis focuses on summarizing and visualizing raw data to reveal trends, anomalies, and spatial patterns. Statistical measures such as mean, median, standard deviation, and ranges are applied to key parameters including river flow, Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO), pH, Total Suspended

Solids (TSS), and heavy metals. Time-series plots, histograms, and GIS maps are used to identify seasonal variations, pollution hotspots, flood-prone areas, and irrigated regions. Analyzing evidence focuses on establishing or understanding cause-and-effect relationships, evaluating the impacts of human interventions such as wastewater treatment, dam operations, flood management measures, and irrigation practices, and providing a scientific basis for decision-making and policy formulation.

To support this analysis, several spatial datasets and monitoring networks have been compiled for the Krishna River Basin (KRB) across the four riparian states — Maharashtra, Karnataka, Telangana, and Andhra Pradesh. The spatial distribution of Central Water Commission (CWC) hydrometeorological and river gauge/discharge stations. These stations form the backbone for surface water monitoring, recording parameters discharge data that are vital for flow trend analysis, flood forecasting, and E-flow assessments. Below Figure 7 represents the CWC Hydrometeorological stations in the Krishna River Basin.

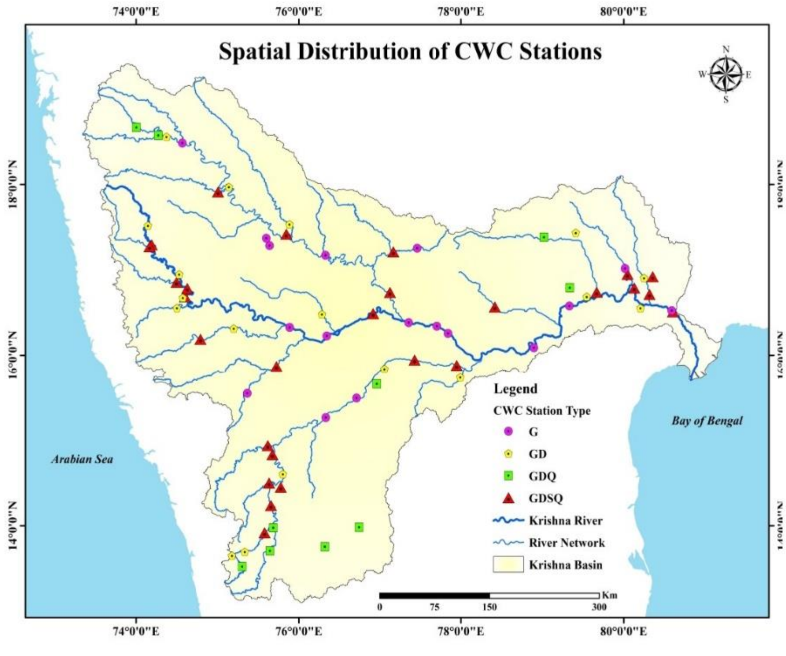


Figure 7: CWC Hydrometeorological Stations in Krishna River Basin.

The Central Ground Water Board (CGWB) and State Groundwater Department monitoring wells and quality sampling stations provide long-term groundwater level and chemical quality data, essential for assessing aquifer behavior, seasonal recharge patterns, and contamination risks. Figure 8 below represents the Ground water quality monitoring stations in Krishna River Basin.

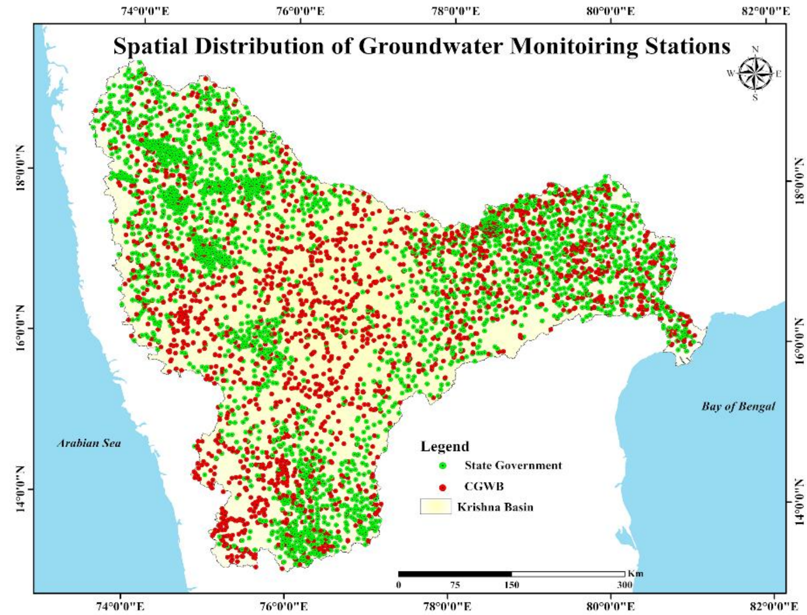


Figure 8: Groundwater Quality Monitoring Stations in Krishna River Basin.

The Annual Average Precipitation Distribution (mm/year) in the Krishna River Basin This map below illustrates the spatial variation in long-term annual average rainfall across the Krishna River Basin, derived from IMD gridded precipitation datasets (2001-2024). The rainfall ranges from less than 500 mm in the semi-arid interiors of northern Karnataka and Telangana to over 2,800 mm in the Western Ghats of Maharashtra. The gradient reflects the influence of topography and monsoon intensity, with decreasing precipitation toward the east. Below Figure 9 represents the Spatial variations of Annual Average Precipitation over Krishna River Basin.

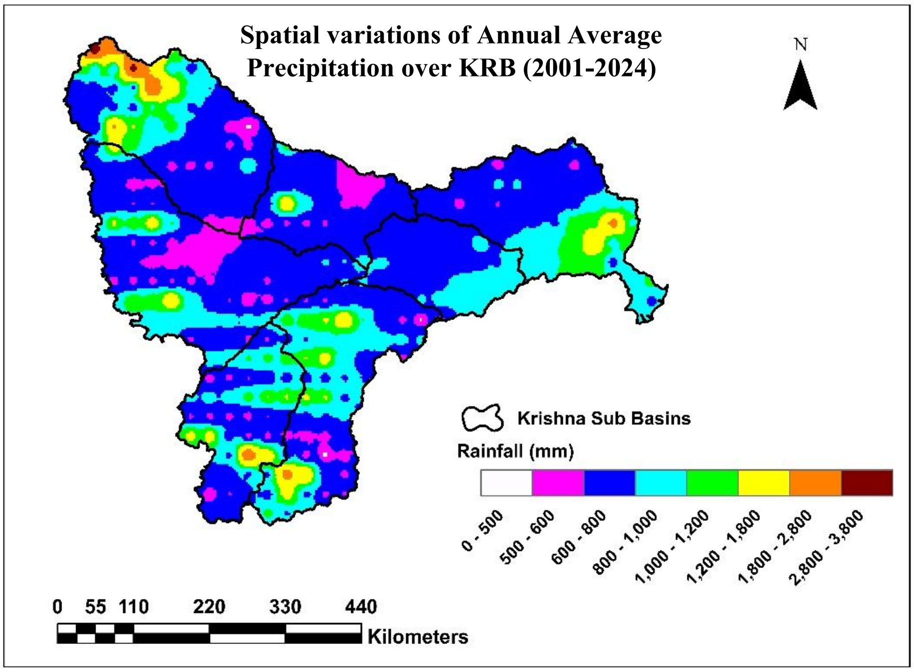


Figure 9: Spatial variations of Annual Average Precipitation over Krishna River Basin.

Evidence-based or causal analysis, aligning with the Analyzing Evidence aspect. The distribution of Central Water Commission (CWC) hydrometeorological and river gauging stations (Figure 7), Ground water quality monitoring location stations (Figure 8) and Spatial and temporal datasets, such as annual average precipitation (Figure 9) provide a strong empirical foundation for understanding basin dynamics. These visual evidences support advanced analyses — including regression modeling, trend assessment, and causal inference — to establish relationships between human interventions (such as dam operations, irrigation withdrawals, and wastewater discharge) and hydrological or ecological responses, like variations in streamflow, water quality, and sediment load. Integrating field measurements, remote sensing data, and hydrological modeling ensures that the conclusions are scientifically robust and spatially validated. Quantitative indicators such as reduction in BOD levels, improvement in groundwater levels, or enhanced flood regulation capacity serve as measurable evidence of intervention outcomes. This approach strengthens science-based decision-making, helping policymakers and managers implement targeted strategies for pollution abatement, flood management, and sustainable water allocation

Overall, this chapter effectively addresses the needs of the Krishna River Basin by integrating multiple datasets across the four basin states, linking data to real-world challenges such as pollution, floods, and ecological degradation, and combining descriptive and causal analyses. It provides both the "what" (state of the basin) and the "why/how" (drivers and impacts), thereby delivering a robust evidence base to support informed management decisions and policy formulation for the sustainable governance of the basin.

8. Conclusion:

The development of this monitoring and evaluation protocol for the Krishna River Basin provides a comprehensive, science-based framework for addressing the basin's key challenges across Maharashtra, Telangana, Andhra Pradesh, and Karnataka. It integrates data-driven, participatory, and evidence-based approaches to ensure effective river basin governance. The report systematically identifies critical issues such as flooding, pollution, sedimentation, and ecological degradation, converting them into measurable indicators like peak discharge, BOD, DO, and biodiversity indices. Institutional roles of agencies such as CWC, CGWB, SPCBs, and local departments are clearly defined to strengthen coordination and data reliability. Through descriptive and causal analyses, the report examines both the current state and the underlying drivers of change in the basin, supported by spatial datasets and maps — including CWC hydrometeorological stations, groundwater monitoring networks, and annual average precipitation distribution. By linking human interventions such as dam operations, wastewater treatment, and land-use practices to measurable ecological and hydrological outcomes, the protocol emphasizes evidence-based decision-making. Overall, this protocol serves as a strategic roadmap to promote sustainable water management, informed policymaking, and inter-state collaboration, ensuring the long-term resilience, ecological integrity, and equitable resource utilization within the Krishna River Basin.

References:

- cGanga and NMCG. (2017). VISION GANGA. www.nmcg.in
- cKrishna, & cGanga. (2024). Krishna river at a Glance. www.nrcd.nic.in
- CWC, & NRSC. (2021). Krishna Basin (IWRM 2021) Version 2.0. www.india-wris.nrsc.gov.in
- The Times of India. (2024, October). Severe Flooding and Pollution in Krishna River Basin Reported across Karnataka and Andhra Pradesh.

https://timesofindia.indiatimes.com/city/vijayawada/severe-flooding-in-krishna-river-due-to-heavy-rains-in-karnataka-and-rayalaseema/articleshow/114403374.cms?utm_source=chatgpt.com

- The Times of India. (2024 December). Pollution in Karnataka, Telangana, Maharashtra, Andhra Pradesh, Krishna river lifeline https://timesofindia.indiatimes.com/city/hyderabad/telangana-andhra-pradesh-karnataka-maharashtra-have-polluted-their-lifeline-krishna-river-reveals-new-report/articleshow/116350764.cms?utm_source=chatgpt.com

- Minister of Jal Shakti. (2020). NGP-At a Glance. Ganga River Basin-Fact Sheet. https://nmcg.nic.in/pdf/NGP_At%20a%20Glance%20(Final%20Version%20Printed).pdf

- Press Information Bureau. (2025, January 25). Ganga Rejuvenation. https://www.pib.gov.in/PressReleasePage.aspx?PRID=2096022

- Press information Bureau. (2025, March 7). NGP milestones. https://www.pib.gov.in/PressReleasePage.aspx?PRID=2109118