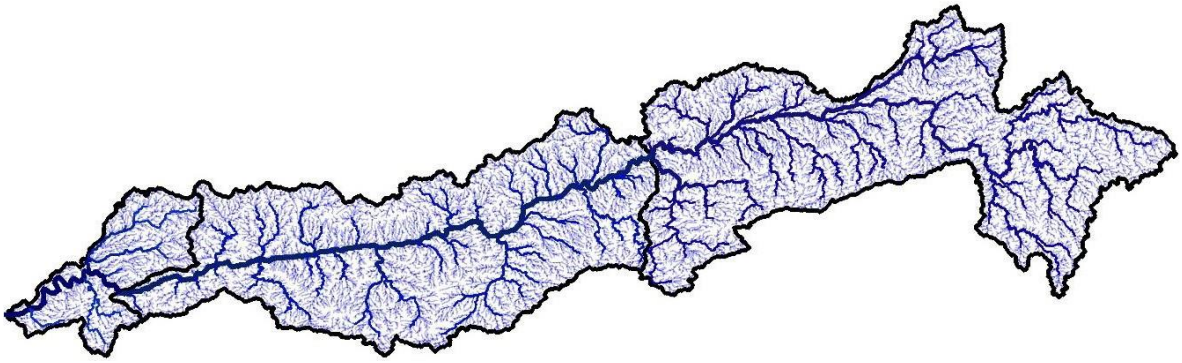
National River Conservation Directorate
Ministry of Jal Shakti,
Department of Water Resources,
River Development & Ganga Rejuvenation
Government of India

River Monitoring Protocol for Narmada River Basin



March 2025

River Monitoring Protocol for Narmada 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 Narmada River Basin Management and Studies (cNarmada)

The Center for Narmada River Basin Management and Studies (cNarmada) is a Brain Trust dedicated to River Science and River Basin Management. Established in 2024 by IIT Gandhinagar and IIT Indore, under the supervision of cGanga at IIT Kanpur, the center serves as a knowledge wing of the National River Conservation Directorate (NRCD). cNarmada is committed to restoring and conserving the Narmada River and its resources through the collation of information and knowledge, research and development, planning, monitoring, education, advocacy, and stakeholder engagement.

www.cnarmada.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

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PREFACE

The Narmada River, flowing through the heart of India, is far more than just a geographical feature. It's a cultural, spiritual, and economic lifeline for millions across Madhya Pradesh, Chhattisgarh, Gujarat, and Maharashtra. Revered as a living goddess, this sacred river now faces a range of challenges in the 21st century that threaten its ecological balance and the communities that depend on it.

The report on Narmada River Monitoring Protocol has been developed in response to these critical issues, offering a structured approach to monitor and protect the river's health through systematic observation and evaluation.

This report is grounded in the understanding that the challenges facing the Narmada are complex and interconnected. The river suffers from competing demands - from massive irrigation projects like the Sardar Sarovar Dam and industrial pollution from the basin's industrial zones. Climate change has only made things worse indicating towards the basin's vulnerability. Addressing these diverse and intersecting issues requires innovative solutions that balance human needs with environmental conservation.

What sets this report apart is its holistic approach to river management. Instead of offering a one-size-fits-all solution, it presents a flexible set of monitoring approaches that can be adapted to the different regions and requirements of the basin. The protocol combines advanced techniques, like AI-driven water quality prediction, with community-based methods that draw on traditional tribal water management practices. It emphasizes the importance of continuous, real-time data collection through automated stations and satellite monitoring while also recognizing the vital role of local communities in caring for the river.

This report introduces approaches suited to India's federal structure and the unique characteristics of the Narmada. The protocol also acknowledges the river's cultural and spiritual significance, integrating these aspects with traditional ecological indicators to form a more comprehensive assessment of the river's health.

Implementing this protocol will require an unprecedented level of cooperation between riparian states, central agencies, researchers, and civil society. Key recommendations include forming a joint state-level monitoring team, creating a public data hub, and conducting regular participatory assessments. These steps could revolutionize how we study and protect this critical river system.

This document is not the end of the journey but rather the beginning of a continuous, adaptive effort for management of Narmada River Basin. It is presented with the hope that, through shared responsibility and sustained effort, the Narmada will continue to flow freely and purely, supporting ecosystems and human life for generations to come.

Centres for Narmada River Basin Management and Studies (cNarmada)

IIT Gandhinagar, IIT Indore

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1 Introduction

The Narmada basin is home to a diverse array of communities, stakeholders, and states, along with a rich and varied ecology. It is one of the most revered rivers in the country, yet it remains highly contested due to the competing claims of various stakeholders. The conflicting claims along some parts of the basin are quite infamous. The vast expanse of the river makes it difficult to assess and monitor its health and sustainability.

This report outlines various monitoring and evaluation approaches to assess different outcomes in the Narmada basin. It should be viewed as a guideline rather than a tool for conducting monitoring exercises. The choice of a specific monitoring approach will depend on the particular outcome that needs to be assessed. Based on these outcomes, policymakers can determine the most suitable method for monitoring and evaluation, identify the appropriate individuals or organizations to conduct the assessment, and select the right type of data required. It is also important to emphasize that monitoring and evaluation is a continuous process that should be carried out regularly.

The report begins by presenting different approaches to monitoring and evaluation, followed by an overview of various data sources that can be utilized for the Narmada basin. The subsequent section reviews relevant domestic and international studies that have proposed methods for monitoring the river or basin. Finally, the report highlights potential outcomes that can be monitored in the Narmada basin and concludes with key recommendations for improving monitoring and evaluation efforts.

2 Approaches to monitoring and evaluation

In this section we discuss different Monitoring and Evaluation (M&E) approaches and how they would be relevant for monitoring along the Narmada basin. For carrying out an extensive monitoring across the basin for ensuring good health of the river and optimal river-people connect, a multipronged approach will have to be carried out. So, our suggestion is to carry out a mix of multiple approaches laid out below.

M&E play a critical role in ensuring the success and sustainability of community development programs. These approaches provide a systematic way to assess the progress of initiatives, measure their impact, and identify areas for improvement. By applying suitable M&E approaches, policymakers can ensure that resources are used effectively and that intended outcomes are achieved. Different approaches to M&E offer various methods to analyze

program performance, identify gaps, and promote accountability. Below are some of the most effective M&E approaches used in community development programs.

i. Results-Based Monitoring and Evaluation: The Results-Based Monitoring and Evaluation (RBM&E) approach, which is also called Impact Evaluation, is widely used in community development programs to ensure that projects achieve desired outcomes. This approach focuses on setting SMART (Specific, Measurable, Achievable, Relevant, and Time-bound) indicators and tracking progress against these targets. RBM&E helps in measuring the effectiveness of programs by analyzing outputs, outcomes, and long-term impacts rather than merely tracking activities. In community development, this approach is particularly useful for ensuring that interventions are addressing community needs and delivering tangible benefits. By continuously monitoring key performance indicators, organizations can make informed decisions and adjust their strategies to maximize impact.

   Relevance for Narmada basin: In the case of Narmada basin, this could include quality of water, the reserves of flora and fauna in the basin, and the standard of living of people connected to the river. The idea will be to define the desired outcomes which will require obtaining inputs from the relevant stakeholders such as indigenous communities, the civil society and the governments at local and state levels. In order to carry out robust impact evaluation, cutting edge methods from the field of Economics would be quite relevant.

ii. Participatory Monitoring and Evaluation: Participatory Monitoring and Evaluation (PM&E) involves engaging key stakeholders, including community members, in the evaluation process. This approach ensures that the perspectives, needs, and priorities of the beneficiaries are included, leading to more relevant and sustainable outcomes. PM&E encourages community ownership, transparency, and accountability, making it an effective tool for fostering long-term success in development programs. In community development, participatory approaches often include community meetings, focus group discussions, and participatory rural appraisals (PRAs). By involving local populations in the design, implementation, and evaluation phases, PM&E enhances the relevance and effectiveness of interventions.

   Relevance for Narmada basin: It will be about bringing together stakeholders from local communities, local governments, the three state governments (viz. Madhya Pradesh, Gujarat and Maharashtra), the Narmada Control Authority (NCA), and those

involved in the Narmada Bachao Andolan (NBA), at a regular frequency. For water usage, it will be pertinent to include those involved in agriculture. But, for water quality, it will be important to include the relevant pollution control boards. Responsibilities for participatory monitoring will have to be devolved to each of these units which will further depend on their specific roles and the aspects that they are equipped to monitor. This will also require building capacities of local stakeholders to engage in monitoring at local levels.

iii. Theory-Based Evaluation for Understanding Change: The Theory-Based Evaluation (TBE) approach focuses on understanding the underlying theory of change that guides a program's implementation. This approach helps organizations analyze whether the assumptions about how a program will achieve its intended goals are valid. For community development projects, TBE provides insights into the causal relationships between activities, outputs, and desired outcomes. It enables organizations to assess the validity of their intervention models and adjust their strategies to maximize impact. TBE also helps identify contextual factors that influence program outcomes, allowing for a deeper understanding of the complexities involved in achieving lasting change.

Relevance for Narmada basin: For Narmada basin, the theory of change can be developed from the five pillars that the Ministry of Jal Shakti has laid out for the Ganga River: 1. River connectivity and continuity (Aviral Narmada), 2. Flow bereft of manmade pollution (Niramal Narmada), 3. River Conservation and Synchronised Development (Arth Narmada), 4. Connecting People with Narmada (Jan-Narmada), 5. River Science and Management (Gyan Narmada). Theory of change will need to be developed for each of these pillars, and then different nodes along the theory of change would have to be tested out.

iv. Utilization-Focused Evaluation for Practical Results: Utilization-Focused Evaluation (UFE) prioritizes the practical application of evaluation results by focusing on the needs of the intended users of the evaluation. This approach involves engaging stakeholders throughout the evaluation process, ensuring that the findings are relevant, actionable, and easily applicable to decision-making. In community development programs, UFE ensures that evaluation results lead to informed decision-making and program improvements. By tailoring the evaluation to the needs of stakeholders, UFE maximizes the likelihood that findings will be used to refine strategies, allocate resources effectively, and achieve program objectives.

Relevance for Narmada basin: Some evaluations will have to be tied to the location of the basin, given the extent of basin. One end of the basin is the famous Amarkantak and Omkareshwar temple in Madhya Pradesh, while on the other end is the Statue of Unity. Communities residing in these vicinities could have different purposes with respect to the river, hence, it is important to have some focused evaluations pertaining to their needs.

v. Process Monitoring and Evaluation for Implementation Analysis: Process Monitoring and Evaluation (PME) emphasizes assessing how a project is implemented rather than solely focusing on outcomes. This approach tracks project activities, timelines, and budgetary expenditures to ensure that interventions are delivered as planned. For community development initiatives, PME helps identify operational challenges, delays, and resource constraints, allowing organizations to make timely adjustments. This approach enhances program efficiency by providing ongoing feedback on implementation quality, ensuring that corrective actions are taken to maintain project momentum.

Relevance for Narmada basin: This would potentially involve major infrastructural and other developments carried out across the river, for instance, dam construction activities, restoration of riparian areas, or any development that pertains to the connection of people with river. The parameters to assess the success of process could be determined by designing the theory of change and focusing on the process part.

vi. Case Study Evaluation for In-Depth Understanding: The Case Study Evaluation (CSE) approach provides an in-depth examination of a specific program or intervention by analyzing qualitative and quantitative data. It allows evaluators to assess the effectiveness of a program by exploring the experiences, behaviors, and outcomes of beneficiaries. For community development initiatives, CSE can offer rich insights into the strengths and challenges of a program. This approach is particularly valuable for understanding the unique dynamics of community settings, capturing lessons learned, and informing future program design.

Relevance for Narmada basin: In various cases, large scale data would not be quite suitable, or representative data may not be available. Hence, it would make sense to carry out case studies. These could also form the basis for the other kind of evaluations discussed above. For instance, for evaluating the effect of increased footfall of tourists during certain months around popular destinations of Narmada basin, such as the Statue of Unity or the Omkareshwar temple, in-depth case studies would be quite useful.

3 Guiding Principles for evaluations and monitoring

The following are consolidated principles borrowed from the OECD DAC Quality Standards and the SEVAL Standards to guide high-quality evaluation practices. This can be considered as a framework for conducting credible, ethical, and effective evaluations across contexts.

3.1 General Principles

1) Impartiality and Transparency
    a) Evaluations are conducted impartially and transparently, ensuring that the process remains free of biases and undue influence.
    b) The purpose, procedures, and results are clearly documented to allow verification and understanding by stakeholders.
2) Ethics and Respect
    a) Evaluations are carried out with integrity, respecting cultural, social, and ethical considerations.
    b) The rights and dignity of all participants are protected, ensuring privacy, confidentiality, and fairness.
3) Stakeholder Inclusion and Partnership
    a) Stakeholders, including government, civil society, and intended beneficiaries, are actively involved throughout the evaluation process.
    b) The process encourages ownership and mutual accountability.
4) Utility and Use of Results
    a) Evaluations are designed to meet the information needs of users and ensure that findings and recommendations are relevant, timely, and actionable.
5) Capacity Development and Learning
    a) Evaluations contribute to building local evaluation capacity by enhancing knowledge, skills, and demand for quality evaluation.

3.2 Planning and Design

1) Purpose, Scope, and Objectives
    a) The purpose, scope, and intended use of the evaluation are clearly defined.
    b) Evaluation questions address relevant concerns, including cross-cutting issues such as gender, environment, and human rights.
2) Contextual Considerations

a) The evaluation design considers the broader policy, socio-economic, and institutional contexts, ensuring relevance and applicability.

3) Feasibility and Cost-Benefit
   a) Evaluations are planned to optimize resource use while maintaining quality, balancing cost and benefit to ensure maximum impact.
4) Joint Evaluations and Coordination
   a) Where appropriate, joint evaluations involving multiple partners and agencies are systematically considered to promote harmonization and alignment.
5) Selection of Methodology and Approach
   a) Evaluation methodologies are selected based on the purpose, scope, and evaluation questions.
   b) Data collection methods adhere to rigorous scientific standards, ensuring validity and reliability of information.
6) Governance and Management Structure
   a) Clear governance and management structures ensure credibility, inclusiveness, and transparency throughout the evaluation.

3.3 Implementation and Reporting

1) Evaluator Independence and Competence
   a) Evaluators operate independently and maintain objectivity throughout the evaluation.
   b) The evaluation team possesses a balance of thematic knowledge, technical expertise, and cultural awareness.
2) Stakeholder Consultation and Protection
   a) Stakeholders are consulted during all phases, ensuring their input is reflected and ethical standards are upheld.
3) Timeliness and Budget Management
   a) Evaluations are conducted within the allocated timeframe and budget, with any necessary adjustments transparently communicated.
4) Evaluation Report Standards
   a) Evaluation reports include:
      i) A clear executive summary outlining main findings, conclusions, and recommendations.
      ii) A description of the intervention context, intervention logic, and methodology used.

iii) Acknowledgment of any limitations or constraints encountered during the evaluation.

3.4 Validity and Reliability of Data

b) Information sources are critically assessed for validity and reliability.

c) Sampling methods and limitations are explicitly documented.

3.5 Follow-up, Use, and Learning

1) Use and Dissemination of Results
   a) Evaluation findings are presented in accessible formats and systematically shared internally and externally to facilitate learning and accountability.
2) Systematic Follow-up on Recommendations
   a) A formal response mechanism ensures that recommendations are addressed, and actions are tracked for accountability.
3) Documentation and Archiving
   a) Evaluation reports and supporting documentation are archived to allow future reference and verification.

3.6 Quality Assurance and Review

1) Internal and External Quality Control
   a) Peer reviews, advisory panels, or reference groups provide quality assurance at different stages of the evaluation.
2) Periodic Review and Adaptation
   a) Evaluation standards are periodically reviewed to incorporate emerging international best practices and ensure continued relevance.

4 Relevant Data Sources

Monitoring the Narmada River Basin effectively requires reliable data sources to assess water availability, groundwater levels, rainfall patterns, and environmental changes. Key agencies like the Central Water Commission (CWC) and India-WRIS provide real-time river discharge and reservoir data, while the Central Ground Water Board (CGWB) offers groundwater level and quality reports. The National Remote Sensing Centre (NRSC-ISRO) aids in basin mapping through satellite imagery, and the India Meteorological Department (IMD) supplies crucial rainfall data affecting river flow and recharge. Additionally, the Narmada Control Authority (NCA) oversees dam regulations and water sharing among states. Integrating these datasets

ensures sustainable water management in the Narmada Basin. However, apart from these data sources, some other data sources covering the socioeconomic condition of the basin's residents are also essential, as socioeconomic data sets also cover the status of water accessibility to the people. A brief description of data sources which can play a significant role in monitoring the basin is given below-

4.1 Administrative data

4.1.1 Groundwater data

India's groundwater monitoring and management system relies on a network of key agencies providing critical water-related data. The Central Ground Water Board (CGWB), under the Ministry of Jal Shakti, serves as the primary agency for groundwater assessment, offering data on water levels, quality, aquifer maps, and annual reports through its portal (https://cgwb.gov.in/). To access water-related resources, the agency makes available different portals, such as In-GRES (India Ground Water Resource Estimation System), AIMS (Aquifer Information and Management System), and FAMES (Field Activities Monitoring and Evaluation System). The National Water Informatics Centre (NWIC) maintains a centralized water resources database with real-time and historical groundwater levels (https://nwic.gov.in/), while India-WRIS provides a comprehensive web-based platform for groundwater trends, recharge data, and basin-wise reports (https://indiawris.gov.in/wris/). The Central Water Commission (CWC) monitors surface and groundwater interactions, including extraction rates and river basin assessments (https://cwc.gov.in/). For spatial analysis, the National Remote Sensing Centre (NRSC-ISRO) delivers GIS-based groundwater potential maps using satellite data (https://nrsc.gov.in/). The Jal Jeevan Mission (JJM) tracks groundwater sustainability for drinking water supply (https://jaljeevanmission.gov.in/). The Jal Jeevan Mission (JJM) tracks groundwater sustainability for drinking water supply (https://jaljeevanmission.gov.in/), and the India Meteorological Department (IMD) provides essential rainfall data influencing recharge patterns (https://mausam.imd.gov.in/). Together, these sources enable integrated water resource management across India.

4.1.2 Mission Antyodaya

Mission Antyodaya, an initiative of the Government of India, serves as a comprehensive framework for rural development by assessing infrastructure and service delivery at the Gram Panchayat level. This data set becomes important for

monitoring river basins as its annual survey collects critical data on water security, covering key aspects such as drinking water availability, quality, and conservation efforts. Specifically, it evaluates the penetration of piped water supply under schemes like the Jal Jeevan Mission, identifies seasonal water scarcity, and documents alternative water sources like hand pumps and wells. By monitoring convergence with programs like MGNREGA for watershed projects and JJM for household tap connections, the dataset enables targeted interventions in water-stressed regions. This granular, village-level information supports evidence-based policymaking, aligns with SDG 6 (Clean Water and Sanitation), and helps bridge gaps in rural water infrastructure. The findings are accessible through the Mission Antyodaya portal (https://missionantyodaya.nic.in/), providing actionable insights for improving water sustainability across India's villages.

4.1.3 Dam related data

India maintains a robust system for dam data collection and monitoring, managed by multiple government agencies. The Central Water Commission (CWC) serves as the primary authority, hosting the National Register of Large Dams (https://cwc.gov.in/national-register-large-dams), which provides technical specifications (height, capacity, purpose), locations, and safety status of dams taller than 15 meters. For GIS-based interactive data, India-WRIS (https://indiawris.gov.in/wris/#/dams) offers comprehensive details on catchment areas, live storage, and command zones. The National Hydrology Project (NHP) (https://nhp.mowr.gov.in/) focuses on dam health monitoring, tracking structural integrity through instrumentation data and safety reports. The Central Electricity Authority (CEA) (https://cea.nic.in/) registers hydropower dams, detailing generation capacity and locations. Satellite-based monitoring is facilitated by ISRO's National Remote Sensing Centre (NRSC) (https://nrsc.gov.in/), which analyzes reservoir surface areas and sedimentation. Additionally, the Dam Rehabilitation and Improvement Project (DRIP) (https://drip.gov.in/), a World Bank initiative, publishes safety audits and rehabilitation progress. These sources provide critical data on dam specifications, reservoir levels, hydropower generation, and structural health, supporting water resource management and disaster preparedness across India.

4.1.4 State reports

India's state-level water data reporting provides critical insights into regional water resource management. With special context to Narmada River Basin covering four states - Madhya Pradesh, Maharashtra, Gujarat, and Chhattisgarh offer datasets through their respective water resource departments. In Madhya Pradesh, the Water Resources Department (https://waterresources.mp.gov.in/) monitors key indicators including real-time dam storage levels for major reservoirs like Indira Sagar. Maharashtra delivers water data systems through its Groundwater Surveys and Development Agency (https://gsda.maharashtra.gov.in/) and Water Resources Department (https://wrd.maharashtra.gov.in/), featuring annual aquifer health reports, real-time monitoring of dams via Maharashtra WRIS, and drought vulnerability assessments, all supporting initiatives like Jalyukt Shivar for watershed development. Gujarat's Water Resources Department (https://guj-nwrws.gujarat.gov.in/) provides specialized datasets on the Narmada basin including Sardar Sarovar operations, groundwater quality reports from CGWB Ahmedabad, and performance metrics for coastal desalination plants, aligned with the Sujalam Sufalam recharge program. Chhattisgarh (https://wrd.cg.gov.in/) focuses tribal water access under JJM, and CGWB's groundwater assessments, while implementing the Narva Vikas scheme for stream rejuvenation. All four states integrate their monitoring with national platforms like India-WRIS and align with central schemes such as Jal Jeevan Mission.

4.1.5 Ecological data

The Forest Survey of India (FSI) serves as the primary authority for forest cover assessments through its biennial India State of Forest Report (ISFR), available on its portal (https://fsi.nic.in/), while the Ministry of Environment, Forest and Climate Change (MoEF&CC) (https://moef.gov.in/) oversees national conservation policies and maintains the PARIVESH portal for environmental impact data. For wildlife monitoring, the Wildlife Institute of India (WII) (https://wii.gov.in/) provides datasets like tiger census reports and endangered species distributions through its National Wildlife Database. Satellite-based ecological mapping comes from ISRO's Bhuvan portal (https://bhuvan.nrsc.gov.in/), offering high-resolution land use, wetland, and desertification maps. Biodiversity documentation falls to specialized institutions like the Zoological Survey of India (ZSI) (https://zsi.gov.in/) and Botanical Survey of India (BSI) (https://bsi.gov.in/), which maintain exhaustive species inventories and red lists.

India Biodiversity Portal (https://indiabiodiversity.org/) and eBird India (https://ebird.org/india) crowdsource species observations, while the Open Government Data Platform (https://data.gov.in/) consolidates national datasets on climate, forests, and wildlife.

4.2 Satellite data

Satellite data plays a crucial role in monitoring river basins by enabling real-time tracking of water resources, floods, and droughts through missions like ISRO's Resourcesat and RISAT, along with global systems like Sentinel-2 and Landsat. It helps assess water quality sediment load and reservoir levels. Key insights as Nightlights, land-use and infrastructure related data can be obtained from the sources discussed below.

4.2.1 Nightlights

Nightlight data (https://eogdata.mines.edu/products/vnl/) captured by satellites like NASA's VIIRS and DMSP-OLS, can help monitor human activity near river basins by detecting artificial lighting patterns as this data can reveal settlement growth, and urbanization along rivers. This data bridges the gap between human presence and environmental health, aiding smarter river management.

4.2.2 Land use

Land-use data is critical for managing river basins, agriculture, forests, and urban planning. Key data sources include ISRO's Bhuvan portal (https://bhuvan.nrsc.gov.in), which provides high-resolution Land Use/Land Cover (LULC) maps at 1:50,000 scale, classifying areas into categories like cropland, forests, wetlands, and built-up zones. The National Remote Sensing Centre (NRSC) (https://nrsc.gov.in) offers LULC maps every 5 years, detailing changes in urban expansion, deforestation, and water bodies. The Forest Survey of India (FSI) (https://fsi.nic.in) focuses on forest cover changes, including encroachments and afforestation near river basins. Global datasets like ESA's WorldCover (https://esa-worldcover.org) and USGS Landsat (https://earthexplorer.usgs.gov) provide 10–30m resolution data, useful for cross-validation.

4.2.3 Infrastructure Data

Satellite-based infrastructure monitoring leverages high-resolution optical, radar, and crowdsourced data to track urban expansion, transport networks, and critical utilities. ISRO's high-resolution satellites, such as the Cartosat series (30 cm–1m) and

Resourcesat (5.8m–56m), provide detailed imagery of roads, buildings, and dams, accessible via the Bhuvan Portal (https://nrsc.gov.in). Synthetic Aperture Radar (SAR) data from ISRO's RISAT-1/2 (https://www.isro.gov.in) (publicly not available) and ESA's Sentinel-1 (https://scihub.copernicus.eu) enable all-weather monitoring of infrastructure health, such as dam deformations or flood impacts. Open platforms like Google Earth Engine aggregate multi-sensor data (Landsat, Sentinel) for large-scale analysis, while OpenStreetMap crowdsources road and railway networks. For thematic infrastructure mapping, India's NIC-Maps (https://maps.nic.in) provides official GIS layers of highways and railways, and water-related infrastructure, such as dams and canals, is documented in WRIS-India while NASA's VIIRS nighttime lights can help to asses electrification trends and industrial activity in a basin.

4.3 Individual/Household Survey data

Individual and household survey data in India, collected through large-scale national surveys such as the National Sample Survey Office (NSSO), India Human Development Survey (IHDS), National Family Health Survey (NFHS), and the decadal Census, provide critical insights into socio-economic, demographic, and health conditions across the country.

4.3.1 National Sample Survey Office (NSSO)

The NSSO, conducted annually (with major rounds every 5–10 years), collects detailed data on consumption expenditure, employment, education, and health at the household and individual levels, with reports like the "Key Indicators of Household Social Consumption" and "Employment-Unemployment Surveys" being widely used for policy formulation. Its Employment-Unemployment Surveys (EUS) collecting data on labor force participation, occupation types, wages, and working conditions at household and individual levels, published in reports like "Key Indicators of Employment and Unemployment".

The Periodic Labour Force Survey (PLFS), introduced in 2017–18, has succeeded the earlier five-yearly Employment–Unemployment Surveys and now provides up-to-date estimates of employment, unemployment, and labor force participation. By employing a rotating panel design for urban areas and repeated cross-sectional sampling for rural areas—along with using different reference periods such as the current weekly status and the usual status—the PLFS captures both short-term fluctuations and long-term trends in the labor market. This shift ensures that data is available more frequently,

thereby enabling timely policy responses to economic shocks and structural changes in the workforce.

Similarly, the Household Consumption Expenditure Survey (HCES) has been revived on an annual basis, with the first round under the new methodology conducted in 2022–23. Unlike the earlier quinquennial surveys, which relied on a single-visit, one-questionnaire approach, the new HCES now divides the survey into separate modules covering food, consumables and services, and durable goods, and collects data over multiple visits. It further updates the consumption basket to reflect current consumption patterns, including the addition of new items such as free goods and subsidies that were previously under-captured. Although these methodological enhancements yield more timely and detailed data, they also pose challenges for direct comparability with historical data from the quinquennial surveys.

These reforms through the PLFS and the new HCES represent a major shift toward a more responsive data collection, ensuring that policymakers have access to current information on both the labor market and household consumption, even as they navigate the complexities of aligning new data with long-established trends.

NSSO also covers water-related questions, specifically regarding the source of drinking water, availability of water, source of irrigation, and access to public schemes (e.g., JJM). It is important to note that the NSS 76th round (July–December 2018) focused on 'Drinking Water, Sanitation, Hygiene, and Housing Conditions.' This survey included questions on major sources of drinking water, distance to drinking water sources, sufficiency of drinking water, access to the principal source of drinking water, responsibility for fetching drinking water, the number of trips required for fetching water, supplementary sources of drinking water, frequency of water supply, and wastewater disposal systems. Thus, NSSO provides deep insights into water-related issues and can play an important role in monitoring river basins.

4.3.2 India Human Development Survey (IHDS)

The India Human Development Survey (IHDS), a panel survey conducted in two waves (2004–05 and 2011–12), covers topics like income, education, gender disparities, and social mobility at the household level, with its findings published in reports such as "Human Development in India."

IHDS also collects data on the sources and cost of drinking water. In IHDS-1 and IHDS-2, data were collected on common sources of drinking water in villages, access to safe drinking water, and the cost of irrigation water. In the 'Education and Health Questionnaire' under Section Five, more than 12 water-related questions were included. These questions covered aspects such as the distance to the water source, supply hours of piped water, whether the source of water remains the same in all seasons, and the adequacy of water availability. This data is crucial for monitoring river basins, as it highlights the status of water access at the unit or household level.

4.3.3 National Family Health Survey (NFHS)

The National Family Health Survey (NFHS), conducted every 3–5 years, focuses on health and nutrition indicators, including maternal and child health, family planning, and immunization, with data available down to the district level. Its major reports, such as the NFHS State Fact Sheets, are crucial for assessing progress toward the Sustainable Development Goals (SDGs). The survey also includes essential questions on household water access, quality, and sanitation. It primarily examines drinking water sources, availability, and treatment methods, linking these factors to health and demographic outcomes.

4.3.4 The Periodic Labour Force Survey (PLFS)

The Periodic Labour Force Survey (PLFS), launched in 2017-18 and conducted annually, now serves as India's primary labor market tracker, providing quarterly urban and annual rural/urban estimates on employment status, sectoral distribution, and informalization trends through reports like "Annual PLFS Report".

4.3.5 Census of India

The Census of India, conducted every decade, is the most comprehensive survey, covering demographic, economic, and housing characteristics at the household level, with its primary reports, such as the "Primary Census Abstract" and "Housing Census," serving as foundational datasets for governance and research. Together, these surveys provide multi-dimensional, granular data at state, district, and household levels, enabling evidence-based policymaking and tracking basin-level progress and changes.

The Census of India also includes important questions about household water access and usage as part of its broader data collection on housing and amenities. These questions are primarily featured in the Housing Schedule, which gathers detailed information about drinking water sources and availability. The census collects data on

the primary source of drinking water for households, distinguishing between piped water (treated or untreated), groundwater sources like hand pumps and tube wells, and surface water sources such as rivers, ponds, or tanks. The census also explores the link between water and sanitation by recording whether households have toilets with water access, reflecting the integration of WASH (Water, Sanitation, and Hygiene) infrastructure.

Although these surveys (NSSO, IHDS, NFHS, PLFS) provide invaluable socio-economic data, they present several limitations for river basin-level studies. A key constraint is their sampling design - these surveys typically use administrative boundaries (states/districts/villages) rather than hydrological units, meaning sample households may not align neatly within river basin boundaries. This creates analytical challenges when trying to correlate socio-economic indicators with basin-specific factors.

4.4 Primary survey

Conducting a primary survey to assess all water-related aspects of a river basin—including hydrology, water quality, usage patterns, and ecosystem health—requires a comprehensive approach that moves beyond traditional administrative boundaries. In India, most surveys (such as the Census, NFHS, or NSSO) follow district or state boundaries, which often fail to capture the hydrological interconnectedness of river basins. A basin-specific survey is crucial because rivers flow across political jurisdictions, and their health depends on cumulative upstream-downstream interactions. These surveys should integrate ground-level household/community questionnaires (covering water access, agricultural use, pollution sources, and conservation practices) with scientific measurements (e.g., water sampling, discharge rates, and groundwater levels).

It is important to note that drone surveys can revolutionize spatial analysis by providing high-resolution imagery for: a) Morphological Mapping: Tracking river course changes, erosion, and sedimentation. b) Land Use/Land Cover (LULC): Identifying encroachments, agricultural patterns, and urban sprawl affecting water flow. c) Pollution Hotspots: Detecting untreated sewage discharge or industrial effluents via thermal/spectral sensors. d) Flood/Drought Risk Zones: Assessing vulnerability through topographic and vegetation health data. Drones complement ground surveys by covering hard-to-reach areas and generating GIS-ready datasets for basin-wide modelling. For policy relevance, these surveys should focus on river basins as unified governance units, aligning with initiatives like the River Basin Management

Plan (RBMP) under India's National Water Policy. By combining community insights, drone-based spatial data, and hydrological modelling, primary surveys can fill the gap between administrative silos and ecological realities, offering a blueprint for integrated water resource management.

5 Relevant Stakeholders for Monitoring and Evaluation

1. Public officials at different levels (state, district, block and village)
2. Academic researchers across different areas (Engineers, Scientists, Legal, and Social Science)
3. Non-academic researchers across different areas (Engineering, Scientists, Legal practitioners, and social scientists)
4. NGOs
5. Local communities

6 Some examples of existing approaches to monitoring Narmada basin

6.1 Use of Remote-Sensing-Based Global Products for Agricultural Drought Assessment in the Narmada Basin[1]

The study, in the journal *Sustainability,* provides an analysis of the Narmada drought situation, highlighting the key environmental, socio-economic, and policy-related challenges faced by the region. It outlines the impact of the drought on agriculture, water availability, and livelihoods while also assessing the effectiveness of existing management practices. Droughts in Narmada have exacerbated water scarcity, leading to declining groundwater levels, crop failures, and reduced hydroelectric power generation. Climate variability, deforestation, and excessive water extraction have further aggravated the situation. The study finds that severe reduction in water flow has led to the failure of major crops, causing food insecurity and increased migration from affected areas. Second, reduced water levels in reservoirs have resulted in decreased power generation and disruptions in industrial operations. Third, deforestation and loss of vegetation in the Narmada basin have led to soil erosion and degradation of ecosystems, further reducing the region's resilience to drought.

This study utilized openly available local and global data to monitor agricultural droughts in the Narmada River Basin, where over half of the land is used for farming. The assessment analyzed long-term rainfall patterns and the effects of weakened monsoons in 2017 and 2018 using remote-sensing global data, local information, and various drought indicators. A slight

[1] Source: https://research.utwente.nl/files/286574635/10.3390_su142013050.pdf

decreasing trend in rainfall was observed over the past 30 years (1989–2018), accompanied by an increase in dry days. The simplified rainfall index demonstrated moderate to severe drought in 2016/2017 and severe drought in 2017/2018, particularly in the middle basin region. Consecutive years of drought did not show significant differences in crop health based on NDVI (Normalized Difference Vegetation Index), although a slight decline was noted in 2017/2018. NDVI may not be the most reliable indicator for agricultural drought assessment in areas with high irrigation dependence. Soil moisture patterns followed seasonal trends, with the lowest moisture levels from January to March and the highest during the monsoon season. Lower soil moisture values in the subsequent quarters reflected the weakened monsoon of 2017.

The NDWI (Normalized Difference Water Index) analysis for water area detection closely tracked actual water level changes in the three main reservoirs of the region. The prolonged drought conditions most significantly impacted the Tawa and Indira Sagar reservoirs in the middle part of the Narmada basin. While weakened monsoons can be classified as meteorological droughts, it remains uncertain whether these conditions directly resulted in agricultural, hydrological, or socio-economic droughts. Despite reduced precipitation in 2017 and 2018, a considerable amount of rainfall was recorded. The slight decline in annual rainfall does not appear to have had a significant impact on the socio-economic sector, with localized rainfall deficiencies being a more likely cause. Since the region is supported by an established irrigation system, the impacts of meteorological droughts were likely mitigated by groundwater or reservoir-based irrigation. This study highlights that freely available data can effectively monitor drought indices, providing valuable insights into their spatial and temporal variations. However, due to the predominance of irrigated land, it remains difficult to conclude whether an agricultural drought occurred in 2017 and 2018.

The study concludes that: “Near-real-time information (i.e., status of water availability, precipitation) is useful when communicating to stakeholders in a meaningful manner to move forward with the proper management of water resources and timely decision-making.”

6.2 NITI Aayog’s Composite Water Management Index (CWMI)[2]

NITI Aayog has introduced the Composite Water Management Index (CWMI), which provides a framework for tracking and improving water management across Indian states. CWMI is the

[2] Source: https://www.niti.gov.in/sites/default/files/2023-03/CompositeWaterManagementIndex.pdf

first initiative of its kind to compile comprehensive national water data using structured questionnaires and focus group discussions to generate qualitative insights. This index not only sets a benchmark for evaluating state-level performance on critical water indicators but also fosters a culture of "competitive and cooperative federalism" by encouraging states to improve their water governance. Additionally, it helps identify high-performing and under-performing states, offering valuable insights for deeper engagement and investment in water management.

CWMI tracks a wide range of upstream and downstream water management metrics, such as piped water supply coverage, groundwater management, and source protection. Developed in close collaboration with national and state-level stakeholders, the index went through a rigorous data validation process. The data collection and validation process involved significant coordination across 25 states and 2 Union Territories. State governments were required to submit data through a NITI Aayog portal accessible to the public. This data was reviewed and validated by an Independent Validation Agency (IVA), IPE Global, which liaised with relevant state departments to verify and update the information. The IVA also conducted field visits across nine states and Union Territories as part of its thorough validation process.

The method for CWMI as reported in the NITI Aayog report is as follows. The Index comprises nine themes (each having an attached weight), covering groundwater and surface water restoration, major and medium irrigation, watershed development, participatory irrigation management, on-farm water use, rural and urban water supply, and policy and governance. The themes are further subdivided into 28 indicators. The data collection exercise necessary to develop and populate the Index is unprecedented.

6.3 Monitoring and assessments in the U.S. basins[3]

Here we present an approach taken in the U.S. to monitor its basins. The US Geological Survey (USGS) works to provide reliable data and unbiased science about the country's natural resources. Over multiple years attempts were made to carry out large scale assessments. However, conducting such large-scale assessments involves challenges, including selecting appropriate monitoring locations and gathering data for comprehensive analysis. While some federal agencies, such as the US Environmental Protection Agency (EPA), have used probabilistic sampling to assess water conditions nationwide, the USGS has focused on

[3] Source: https://link.springer.com/article/10.1007/s10661-020-08403-1#Sec1

stratified random designs for groundwater assessments to capture critical data on major aquifers.

The USGS has explored alternative approaches for large-scale water assessments by conducting intensive studies in selected sub-regions. The aim is to improve monitoring technology, enhance hydrologic modelling, and address critical water resource challenges by focusing on selected "priority basins," which represent a range of socio-economic, environmental, and climatic conditions. To guide the selection of these priority basins, a Basin Selection Team (BST) of 15 USGS scientists from across the country was composed.

The BST developed a systematic, quantitative approach to rank basins for intensive study, ensuring that the selected basins would address high-priority water issues and support advancements in hydrologic modelling. The team's work produced a short list of candidate basins for further evaluation. The next step in the selection process involved gathering input from stakeholders, including USGS Water Science Centers, federal and state agencies, and non-governmental organizations interested in water resources. Based on this input, final decision would be made on which basins to prioritize for long-term monitoring and assessment. This rigorous and collaborative process ensures that the selected basins will provide valuable data to improve water management and inform decision-making across the country.

Three main criteria were used to rank basins for selection, along with several qualitative factors considered for the final decision. The criteria include: (1) **Natural factors**, which ensure that selected basins represent diverse terrain and hydrologic settings to improve hydrologic models by capturing a range of important natural conditions across the contiguous United States (CONUS); (2) **Anthropogenic factors**, which prioritize regions where water resources are under high stress from human activities such as land use, climate change, and water use, ensuring that USGS studies focus on critical water challenges. These criteria aim to select basins that address both natural diversity and human impact, helping to advance hydrologic modelling and resource management.

6.4 Use of predictive modelling for river health monitoring[4]

To assess the overall quality of water bodies, the Water Quality Index (WQI) is widely used. It evaluates multiple physical, chemical, and biological parameters, such as turbidity, pH, and biochemical oxygen demand (BOD), and combines them into a single value that indicates water quality. WQI serves as a

[4] https://www.sciencedirect.com/science/article/pii/S1470160X23013328

valuable tool for water management agencies, public health organizations, and other stakeholders, enabling them to monitor changes in water quality and make informed decisions about pollution control and resource management. However, traditional methods of calculating WQI are time-consuming, costly, and require extensive laboratory analyses, making it challenging to ensure regular monitoring.

To address these challenges, Artificial Intelligence (AI) and Machine Learning (ML) have emerged as powerful tools for water quality prediction. Among these, Artificial Neural Networks (ANNs) and Feedforward Artificial Neural Networks (FANNs) have proven to be particularly effective in predicting water quality by analyzing large datasets and identifying complex patterns. FANNs, in particular, offer accurate predictions with minimal computation time by processing multiple inputs and generating a single output, making them ideal for water quality monitoring. Studies have demonstrated the superiority of ANNs over traditional methods, achieving higher accuracy in predicting water quality parameters such as dissolved oxygen (DO) and chemical oxygen demand (COD).

Creating an accurate and reliable WQI prediction model using FANNs can strengthen pollution control strategies and improve the management of water resources. Regular monitoring, public awareness, and collaboration among stakeholders are essential to ensure the success of these initiatives. By adopting advanced technologies like AI and ML, communities can take a proactive approach to protecting water resources, ultimately contributing to a healthier and more sustainable environment.

7 Potential outcomes for the Narmada basin

Based on monitoring protocols, the Narmada River basin's potential outcomes aim to ensure the river functions sustainably for the environment, communities, and industries. These outcomes reflect goals for the river itself, its banks, people, and ecology. Potential outcomes are the desired results or goals that the monitoring and evaluation protocols aim to achieve or measure. They reflect the health of the river, the well-being of communities, and the sustainability of the environment and economy around the basin. Given the Narmada River's significance, with its cultural, ecological, and economic importance, and the controversies around dam construction and water allocation, these outcomes must be comprehensive and balanced. Potential outcomes can be categorized based on major themes considering hydrology, flora-fauna, people, industries and culture etc. These outcomes may further be modified by involving relevant stakeholders into discussions.

7.1 Potential Outcomes “in River”

7.1.1 Aviral Dhara (Uninterrupted Flow)

Aviral Dhara refers to maintaining an uninterrupted flow of the Narmada River throughout its course, crucial for preserving ecological integrity and supporting aquatic life. Research suggests that a minimum environmental flow of approximately 361.5 m^3/s, based on 30% of the Mean Annual Runoff (MAR) of 1,205 m^3/s, should be maintained throughout the year to support aquatic life and mimic natural flow patterns (Dubey et al., 2019). With dams like Sardar Sarovar impacting flow, managing operations to release sufficient water is key. The Narmada Control Authority (NCA) guidelines suggest maintaining at least 20% of the average annual flow as minimum environmental flow (MEF) to sustain ecosystems (NCA, 2020). Regular monitoring and assessments ensure compliance, with specific goals to prevent dry sections, especially during low seasons.

7.1.2 Nirmal Narmada (Pollution-Free Water)

Nirmal Narmada aims for the river's water to be free from pollutants, meeting CPCB standards for designated uses like drinking or bathing. Given the river's role in agriculture and culture, this is vital for human health and aquatic life. The CPCB classifies parts of Narmada as class A or B, requiring BOD $\leq$ 3 mg/L and fecal coliform $\leq$ 500 MPN/100 ml (CPCB, 2022). A Study shows that water quality varies from excellent to very poor, with 71% poor in post-monsoon samples, influenced by domestic sewage and agricultural runoff (Gupta et al., 2020). Implementing measures to control point and non-point pollution sources, such as treating industrial effluents and managing agricultural runoff, is essential. It can include controlling industrial discharges, upgrading sewage plants, and promoting sustainable agriculture, with regular monitoring to track progress.

7.1.3 Healthy Aquatic Biodiversity

This potential outcome focuses on maintaining a diverse and thriving population of aquatic species, essential for ecological balance and resilience. The Narmada River supports species like the endangered Mahseer fish, and conservation is critical. Goals include protecting habitats, ensuring sustainable fishing, and conducting biodiversity assessments annually. Healthy aquatic biodiversity in the Narmada River involves

protecting and restoring habitats for endangered species like the Mahseer fish, declared endangered by the Madhya Pradesh Biodiversity Board, with a 76% population decline over five decades. The river supports over 118 fish species, 4,000+ plant species, and other aquatic life, threatened by dams and pollution. Conservation programs should focus on creating fish passages across dams, monitoring population trends, and restoring habitats to maintain ecological balance, ensuring the river remains a vital ecosystem for biodiversity (Khedkar et al., 2014).

7.1.4 Sediment Balance

Sediment Balance ensures the river maintains natural sediment deposition and erosion patterns, preventing issues like erosion or excessive sedimentation that affect aquatic life and infrastructure. Dams can trap sediment, reducing downstream flow, so managing operations to allow passage is key. The Central Water Commission recommends sediment flushing techniques, with goals to monitor and manage loads to maintain riverbed elevation (Central Water Commission, 2020). Maintaining sediment balance is critical, especially with the Sardar Sarovar Dam trapping 60-80% of sediments, affecting downstream erosion and river health (Vengadesan et al., 2022).

7.2 Potential Outcomes on “the Banks of the River”

7.2.1 Restored Riparian Zones

Restored Riparian Zones involve restoring areas along the river's banks with native vegetation, enhancing biodiversity, preventing erosion, and filtering pollutants. This is crucial for maintaining ecosystem services, with goals to increase coverage by 5% over five years. There is an example of a project ‘Narmada Riparian Restoration Guide’, launched by The Nature Conservancy (TNC) in 2022, aimed to rejuvenate riverside areas, involving local communities in the Hoshangabad district. These efforts focus on revegetating banks, reducing soil erosion, and improving water quality, with a target to restore 66 sites under the Narmada Seva Mission, enhancing ecosystem services for people dependent on the river.

7.2.2 Flood-Resilient Infrastructure

Flood-resilient infrastructure ensures buildings and infrastructure can withstand flood events, minimizing damage and risk. Given Narmada's flood-prone areas, critical

infrastructure should be above flood levels. Goals include mapping flood zones and enforcing resistant designs.

7.2.3 Controlled Sand Mining

Controlled Sand Mining regulates sand extraction to prevent over-extraction, which causes erosion and ecological damage. State mining departments report excessive mining in some stretches, with goals to enforce limits and monitor compliance.

7.2.4 Cultural Heritage Preservation

Cultural Heritage Preservation protects historical sites like Omkareshwar temple and the Statue of Unity, vital for cultural identity and tourism.

7.3 Potential Outcomes “for Communities and People”

7.3.1 Safe Drinking Water Access

Safe Drinking Water Access ensures all communities have safe and adequate water, crucial for health. The Jal Jeevan Mission reports 85% coverage by 2024, with goals to reach 100% by 2026, providing piped water to all households (Jal Jeevan Mission, 2024). In this context, safe drinking water access should be ensured keeping in mind Narmada River Basin’s characteristics and limitations.

7.3.2 Sustainable Agriculture

Sustainable Agriculture promotes water-efficient methods like drip irrigation, reducing environmental impact. Efficient and sustainable agricultural methods will ensure health of the Narmada basin due to the efficient use of basin water.

7.3.3 Livelihood Security

Livelihood Security ensures stable income, reducing dependency on river resources. This aspect becomes important specifically for the people living close to the river. In case of insecure livelihood, the residents living close to the river may adopt unsustainable livelihood practices causing health risk to the river. For example, boat operators in Narmada River, Omkareshwar operate diesel/oil driven boats causing pollution in the river.

7.3.4 Reduced Disease Burden

Reduced Disease Burden minimizes water-related diseases through better water quality and sanitation. It is important to minimize waterborne diseases (e.g., diarrhea) through sewage treatment in urban centers like Jabalapur, Hoshangabad, Bharuch, Khandawa and other major cities of the basin.

7.4 Potential Outcomes “for Industries”

7.4.1 Zero Liquid Discharge (ZLD) Compliance

Zero Liquid Discharge (ZLD) Compliance requires industries to treat wastewater, preventing discharge. With the proper monitoring, it is necessary to implement ZLD strictly, especially for the industries under CPCB norms.

7.4.2 Corporate Water Stewardship

Corporate water stewardship involves industries adopting water-efficient technologies, with outcomes including reducing water use and contributing to conservation. Initiatives encourage reuse and recycling, aligning with sustainability goals, ensuring industries support the basin's ecological health Corporate water stewardship initiatives for example TATA power’s involvement in Omkareshwar floating project.

7.5 Potential “Ecological” Outcomes

7.5.1 Wetland Conservation

Wetland conservation protects critical habitats, with outcomes including mapping and restoring wetlands to support biodiversity, as per FSI. Monitoring of wetland under the protocols may enhance ecosystem services like flood control and water purification, benefiting the basin's ecology

7.5.2 Forest Cover Expansion

Forest Cover Expansion aims to increase cover by 5% over five years, enhancing biodiversity and water retention. Forest Survey of India data shows 65% cover in 2023, with afforestation plans in place (Forest Survey of India, 2023). However, in case of Narmada River Basin, northern part i.e. Upper Narmada Basin is rich in terms of dense forest area, and it needs to be expanded in the remaining two sub-basins of Narmada Basin.

7.5.3 Reduced Human-Wildlife Conflict

Reduced human-wildlife conflict involves managing habitats to minimize interactions, with outcomes including creating buffer zones and educating communities. Due to dependency on the forest, tribal areas not limited to, face human-wild conflict. It is necessary to reduce the conflict with initiatives to ensure coexistence, protecting both human and wildlife interests.

7.6 Potential Outcomes "for Governance and Data"

7.6.1 Real-Time Monitoring Network and Public Data Hub

Real-Time Monitoring Network sets up stations for flow, quality, and weather data, crucial for emergencies. CWC reports show 20 stations by 2024, with goals to expand to 50 by 2027. At the same time Public Data Hub creates a platform for basin data, enhancing transparency for academic as well other stakeholders of the basin. However India-WRIS already provides data, but the accessibility of data and reports can be enhanced for real-time monitoring and research.

7.6.2 Inter-State Coordination

Inter-State Coordination involves states via NCA, resolving conflicts. Despite its mandate, the NCA faces persistent inter-state disputes, particularly between Madhya Pradesh (MP) and Gujarat, over water sharing, dam operations, and compliance with environmental flow norms.

As per NCA's 2023 Annual Report, there are 15 unresolved disputes related to water allocation, reservoir management, and hydropower generation. A major contention is Gujarat's Sardar Sarovar Dam operations, which MP alleges disrupt downstream flow, affecting agriculture and drinking water supply in its districts like Barwani and Dhar. The Comptroller and Auditor General (CAG) of India (2021) further criticized the NCA for its lack of real-time monitoring systems, leading to unaccounted water diversions and ecological damage. So, it becomes important to develop protocol keeping in mind states' demands and laws to avoid inter-state conflict.

7.7 Potential Outcomes "for Climate Resilience and Adaptation"

7.7.1 Drought Preparedness

The Narmada Basin is drought-prone, with the 2018–2019 drought severely impacting agriculture and water security. The India Meteorological Department (IMD) confirmed a 30% rainfall deficit in Madhya Pradesh's Narmada catchment during this period, exacerbating water scarcity (IMD, 2019). To become climate resilient, drought preparedness is essential with proper monitoring.

7.7.2 Floodplain Zoning

Floodplain zoning is a land use planning tool that designates areas at risk of flooding and imposes regulations on development and activities within these zones to minimize damage and ensure human safety. Floodplain Zoning maps flood-prone areas, restricting development, with state revenue reports identifying 15% of land at risk, aiming for zoning by 2027 (State Revenue Departments, 2024).

7.8 Potential Outcomes "for Cultural & Spiritual Connectivity"

7.8.1 Heritage Riverfront Development and Pilgrimage Tourism

The Narmada River's banks are adorned with ancient ghats, temples, and pilgrimage sites of immense cultural and religious significance, serving as vital centers of spiritual and community life. However, these heritage structures face growing threats from unchecked urbanization, pollution, and inadequate maintenance. For instance, the historic Maheshwar Ghats in Madhya Pradesh attract over 50,000 pilgrims annually (MP Tourism Board), yet the lack of proper sewage infrastructure has led to untreated wastewater flowing directly into the river, compromising both water quality and the sanctity of the site. Similarly, Omkareshwar, a sacred island town and UNESCO-proposed heritage site, has seen a 30% increase in plastic waste accumulation between 2015 and 2022, endangering its ecological and cultural integrity.

It is essential to acknowledge these challenges for conserving the river's health as well as its historicity to which people have been connected historically. With proper protocols and monitoring these issues should be addressed as well as monitored.

7.8.2 Revival of Traditional Water Wisdom

The revival of traditional water wisdom is crucial for sustainable water management, especially in tribal communities. Historically, tribal groups such as the Bhils and Gonds

have practiced sustainable water management techniques that have withstood the test of time. One prominent example is the Bhil tribe of Alirajpur, Madhya Pradesh, who practiced the "Khadin" system. This traditional method, which has been in use for over 200 years, effectively conserved water by capturing rainwater and allowing it to percolate into the ground A recent study by the NGO "Dhara" (2022) highlighted the importance of such traditional practices by documenting 32 indigenous techniques for rainwater harvesting within the basin. These methods, developed through generations of local knowledge and environmental adaptation, offer valuable insights into sustainable water management. Integrating traditional wisdom with modern water conservation policies could provide a more holistic approach to managing water resources, particularly in tribal regions where such practices are deeply rooted in community life. Along with the revival of water wisdom it is equally important to learn from existing water-wisdom practices from the indigenous people.

8 Recommendations for monitoring across Narmada basin

8.1 Create a joint state-level team that covers the entire basin and is representative of local communities:

Narmada crosses majorly through Madhya Pradesh and Gujarat, and some parts fall in Maharashtra. Given this fact, it is advised to form a team that would involve public officials at least from Madhya Pradesh and Gujarat, minimum one each. It should also involve representatives from local communities who have historically been part of the basin. The objective of this team would be to hold regular meetings (biannual) to assess the situation of the basin, formulate plans for ongoing monitoring, and outsource monitoring activities. The eventual goal will be to ensure good health of Narmada River and to ensure sustainable connection between the river and people around it.

8.2 Identify a set of experts, for regular ongoing analysis:

Any monitoring is as good as its frequency and the rigour of monitoring. For this, our recommendation is to tie up with academic as well as non-academic experts, if possible from the three states covering Narmada river to make it cost effective, who will carry out regular analysis on different aspects of the basin.

8.3 Create publicly accessible data hub:

From a long term perspective, it would be advantageous to create a data platform that would have all the relevant data pertaining to the Narmada basin. It would be

constructive to make the data platform open to the public for inviting researchers and analysts to use them for carrying out studies which could help towards monitoring activities. The objective of this platform would be to serve as a one stop shop in regards to the basin.

8.4 Socioeconomic data, representative at basin level:

A major challenge with the attempts to understand the socioeconomic dynamics around the basin is valid data that would be representative at the basin level. Only data like census or satellite-based data can be used to provide reliable estimates that would apply to the basin with consistency. Other data, even the information-rich data like IHDS, are not available at the right level of representation and hence it is difficult to assess any socio-economic dynamics of the basin based on those data.

8.5 Involve community, through existing institutions like village Panchayat:

The Indian dencentralized system has in-built institutions like Panchayats that can be effectively utilized to carry out monitoring activities. There can be a resource person in selected Panchayats who would help with monitoring activities along the river.

8.6 Monitoring systems:

A slew of measures should be taken to develop monitoring systems for various purposes. The objective of these monitoring systems would be to provide real-time information or data on a regular basis. Some examples include flood monitoring systems, groundwater monitoring systems, etc. The data from these systems should be widely accessible for carrying out research specific to the basin. It could also be tied to the data hub proposed above.

Finally, for effective and focussed monitoring, our recommendation is to follow the path laid out in the flow diagram below. The monitoring and evaluation (M&E) process begins by **identifying and defining the problem or outcome** through consultation with relevant stakeholders to ensure alignment with organizational goals. Next, **relevant experts** are identified to provide technical support, followed by **determining the appropriate method** of monitoring and evaluation, whether qualitative, quantitative, or mixed-method. After selecting the method, **relevant data or evidence** is gathered to support the evaluation. The process then moves to **carrying out the monitoring and evaluation** to assess progress and effectiveness. **Findings and outcomes are disseminated and discussed** with stakeholders to promote shared

understanding and encourage informed decision-making. Finally, **action is taken based on the findings**, and the process is repeated to ensure continuous improvement.

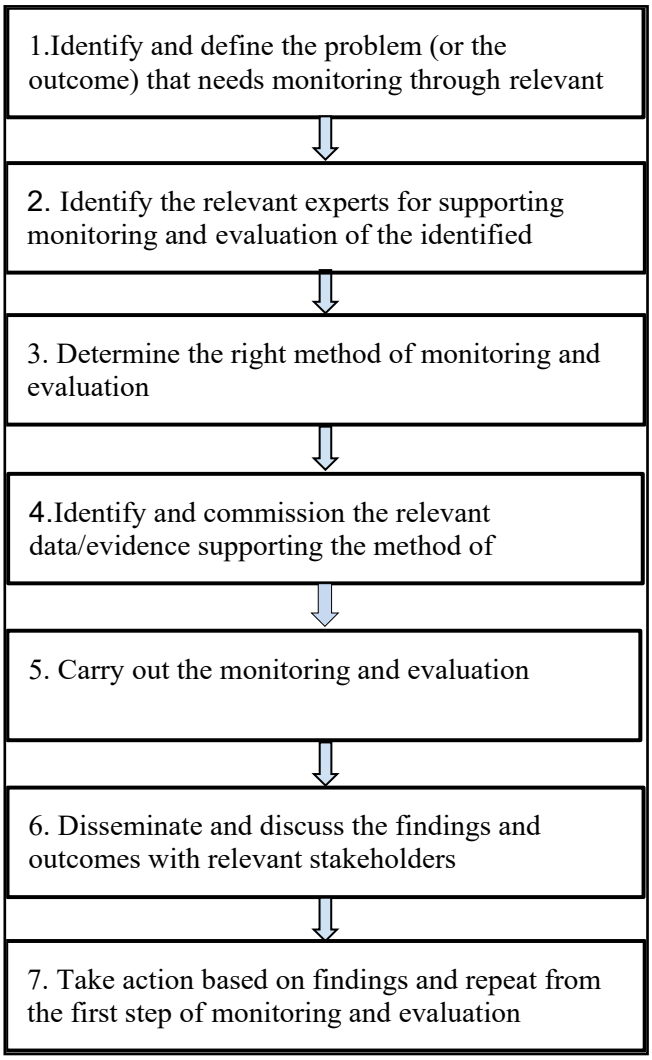

Figure 1. Flow Chart for monitoring and Evaluation

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