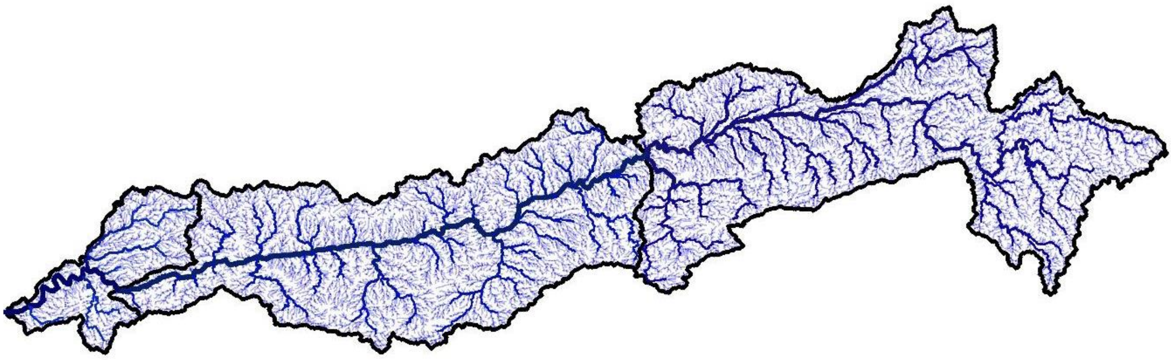
National River Conservation Directorate
Department of Water Resources,
River Development & Ganga Rejuvenation
Ministry of Jal Shakti,
Government of India

STATUS OF AERIAL/DRONE SURVEY OF NARMADA RIVER BASIN



September 2024

cNarmada

cGanga

STATUS OF AERIAL/DRONE SURVEY OF 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.

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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.

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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

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Preface

The Narmada River Basin holds immense ecological and hydrological significance, supporting diverse ecosystems and providing vital resources for the communities that depend on it. Its health is intricately linked to the balance between aquatic and terrestrial environments, yet the basin faces growing challenges from environmental changes and human interventions. In recent years, effective monitoring and management of this basin have been hampered by a lack of updated aerial survey data.

This report seeks to address the critical role of aerial surveys in the sustainable management of the Narmada River Basin, specifically focusing on the Lower Narmada Basin. It compiles findings from various authorities, outlining the extent and limitations of previous aerial survey efforts. Despite sporadic attempts at data collection, there remains a pressing need for comprehensive, high-resolution surveys that can offer insights into river morphology, land use, water quality, and more.

The report highlights the challenges faced during data collection, including bureaucratic hurdles and outdated information, and emphasizes the importance of a coordinated effort for future surveys. It also provides recommendations for establishing a dedicated mechanism to ensure the regular and accurate monitoring of the basin.

By presenting an overview of UAV technology and its applications in river basin management, this report aims to encourage informed decision-making and proactive conservation efforts. In doing so, it underscores the need for timely interventions and up-to-date data to safeguard the long-term resilience of the Narmada River Basin.

Centres for Narmada River Basin
Management and Studies (cNarmada)
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Abbreviations and Acronyms

ADC	Air Defence Clearance
AGL	Above Ground Level
CWC	Central Water Commission
DEM	Digital Elevation Model
DGCA	Directorate General of Civil Aviation
DSM	Digital Surface Model
DWDU	District Watershed Development Unit
FAO	Food and Agriculture Organization
FIC	Flight Information Centre
GIDM	Gujarat Institute of Disaster Management
GIS	Geographic Information Systems
GPCB	Gujarat Pollution Control Board
GPS	Global Positioning System
GSDMA	Gujarat State Disaster Management Authority
GUDM	Gujarat Urban Development Mission
LiDAR	Light Detection and Ranging
MoCA	Ministry of Civil Aviation
MPCB	Madhya Pradesh Pollution Control Board
NCA	Narmada Control Authority
NVDA	Narmada Valley Development Authority
SSNNL	Sardar Sarovar Narmada Nigam Limited
SWDC	State Water Data Centre (Gujarat)
UAV	Unmanned Aerial Vehicle
UIN	Unique Identification Number
VI-NIR	Visible-near-infrared
ABD	Area Based Development
CAMPA	Compensatory Afforestation Fund Management and Planning Authority
MPSEDC	Madhya Pradesh State Electronics Development Corporation Limited
MPRRDA	Madhya Pradesh Rural Road Development Authority
MVM	Motilal Vigyan Mahavidyalaya

1. Introduction

India's diverse landscapes are defined by its magnificent river systems, originating from the Himalayas to the Western and Eastern Ghats. These rivers are the lifelines of the nation, nourishing its vast plains, nurturing its ecosystems, and sustaining its people. These are integral to its geographical, cultural, and economic landscapes.

The Narmada River Basin is a vital riparian habitat, playing a critical role in maintaining the balance between aquatic and terrestrial ecosystems. It supports nutrient cycling, improves water quality by filtering sediments, nutrients, and pollutants, and helps stabilize riverbanks, preventing erosion. The basin also contributes to groundwater recharge and regulates water temperature, fostering aquatic life. Riparian vegetation, ranging from aquatic plants to trees, forms a protective buffer around the river, supporting biodiversity and serving as a migration corridor for wildlife. Despite its ecological importance, the Narmada River Basin is vulnerable to environmental changes, including fluctuating water levels, soil moisture, and extreme weather events. However, it remains resilient, acting as a buffer against floods and droughts. Due to its abundance of water, fertility, and great biodiversity, this basin is both vital and in high demand.

Since 1900, global water withdrawals and consumption have surged almost sixfold. Currently, around 69% of these withdrawals are allocated to agriculture, 19% to industrial activities, and 12% to municipal needs (FAO, 2020). Water systems globally are under stress due to anthropogenic disturbances and climate change, which also have an impact on the water cycle, supply, and demand (Haddeland et al., 2014). Globally, sustainable development and effective water management present difficult challenges. Worldwide, there is a major challenge in achieving sustainable development and effective water management.

Conventional methods for water monitoring and measurement tend to be labour-intensive, expensive, and often cover limited spatial and temporal scales. In recent decades, remote sensing data from airplanes and satellites has become a primary resource for gathering information on water resources. Satellite-based remote sensing technologies, along with the Global Positioning System (GPS) and Geographic Information Systems (GIS), offer valuable tools for habitat assessment. Advances in satellite imaging now deliver high-resolution data, enabling the monitoring and analysis of the spatial and temporal dynamics of riparian habitats (Larson and Sengupta, 2004). Cloud-based server-side processing and big data analytics have enhanced the capabilities of remote sensing technology for ecological monitoring. While satellite imagery like Landsat and Sentinel holds great potential, it also faces certain challenges, including low resolution, issues with cloud cover, and the need for considerable time and resources to process large volumes of data (Du et al., 2016).

Unmanned Aerial Vehicle (UAV)-based remote sensing offers a cost-effective alternative, providing high-resolution, real-time monitoring, immediate data access, on-demand data collection, customizable sensors, and flexible observation capabilities (Colomina and Molina, 2004; Adar et al., 2022). UAVs are particularly valuable for collecting high-resolution data in localized areas, making them ideal for detailed assessments, especially in hard-to-reach landscapes (Pajares, 2015). Recent advancements in sensors, cameras, rechargeable batteries, and image processing technologies (Chabot, 2018; Pajares, 2015) have made unmanned aerial vehicles (UAVs) a fast, precise, and cost-efficient tool for studying water resources on-demand, even in complex environments and at finer spatial scales (Sullivan, 2006; Anderson & Gaston, 2013; Bhardwaj et al., 2016; Rakha & Gorodetsky, 2018;).

UAVs provide a non-invasive means to remotely observe, assess, and analyse the shapes and structures of features within river catchments, as well as hydrological processes across various spatial and temporal scales. They combine spatial, temporal, spectral, and continuous data to facilitate soil and water characterization and hydrological forecasting (Quiquerez et al., 2014; Woodget et al., 2017). Due to their user-friendly nature and continuous advancements, drones are increasingly providing transformative solutions for habitat mapping, land surveying, and change detection. Equipped with cameras and sensors, drones capture high-resolution aerial images of riparian habitats, allowing the creation of detailed maps that assess riparian vegetation, water quality, and various other environmental factors.

Therefore, UAVs are vital tools for informed decision-making and the sustainable management of the Narmada River Basin. By providing high-resolution, real-time data on various ecological and hydrological parameters, UAVs help monitor changes in vegetation, water quality, and land use. This enables timely interventions, supports habitat conservation efforts, and ensures the long-term health and resilience of this critical ecosystem.

2. Unmanned Aerial Vehicles (UAV) Platforms

UAVs can be categorized according to their weight, endurance, altitude, and operational range (see Table 1). Conducting UAV surveys involves three key components: the data collection system (including the aerial platform and sensors), the data processing system (used for generating surface models and ortho mosaics), and the data analysis system (for visualization, extraction, and interpretation). UAV platforms are mainly classified by their aerodynamic design, operational features, and capabilities. Additionally, they can be distinguished by size, cost, and payload capacity.

Table 1. Classification of Unmanned Aerial Vehicles

Category	Weight (kg)	Altitude (ft AGL)	Radius (km)	Endurance (hr)
Micro	<2	Up to 200	<5	<1
Mini	2–20	Up to 3,000	<25	1–2
Small	20–150	Up to 5,000	<50	1–5
Tactical	150–600	Up to 10,000	100–300	4–15
MALE	>600	Up to 45,000	>500	>24
HALE	>600	Up to 60,000	Global	>24

Source: Adapted and modified from Qi et al. (2018)

Rotary-wing and fixed-wing UAVs are the two primary types of flight platforms utilized in hydrological and water management research. The selection of a platform depends on the objectives and scope of the study, taking into account factors such as required payload, manoeuvrability, flight range and other relevant considerations.

2.1 Sensors and Instruments

Table 2 provides an overview of various UAV sensors utilized in hydrology and water resource management, along with their respective advantages and disadvantages.

Table 2. Hydrological Applications, Advantages, and Disadvantages of Different Unmanned Aerial Vehicles Sensors (Source: Acharya, B. S. et al., 2021)

Sensors	Hydrological Applications	Advantages	Disadvantages
RGB	Aerial photogrammetry, DEM, bathymetry, flood monitoring, surface flow velocity, water quality, snow, and ice depth	Portable, common, relatively inexpensive, provide high-quality RGB images for ortho imagery and DSM, easy to integrate with different platforms	Wider bandwidth and lower spectral resolution, lack geometric and radiometric calibration

Multispectral	Bathymetry, flood monitoring, surface and groundwater interaction, water quality	Multiple wavelengths, allow geometric reconstruction and radiometric calibration	Relatively costly, image processing relatively complex compared to RGB, radiometric and atmospheric corrections may be required, limited compatibility to UAVs
Hyperspectral	Bathymetry, flood monitoring, surface and groundwater interaction, hydrogeochemistry, mapping rivers and wetlands	High spectral resolution data across various wavelength of VIS-NIR	Higher cost than multispectral, low signal-to-noise ratio, limited compatibility with standard UAV and flight control software packages, radiometric and atmospheric corrections may be required
Microwave	Flood monitoring, river level and discharge, soil moisture, altimetry, snow water equivalent, snow depth	Useful under low visibility weather conditions (e.g., cloud cover)	Sensitive to surface roughness
Thermal	Temperature mapping, tile drainage, evapotranspiration, soil moisture, turbidity plumes, groundwater discharge, wetland mapping	Sense a wide range of temperatures, relatively cheaper	Thermally sensitive, vignetting effects, low spatial resolution, radiometric corrections required, sensitive to change in surface roughness and emissivity changes
LiDAR	3D reconstruction, bathymetry, water surface elevation, flood monitoring, snow depth, erosion, wetland mapping	Generates dense cloud points, high quality data, direct geometric measurements	Higher cost, limited compatibility with UAVs, requires ground filtering corrections

3. Directorate General of Civil Aviation (DGCA) and Drone Rules

The Directorate General of Civil Aviation (DGCA) operates as part of the Ministry of Civil Aviation and serves as the primary regulatory authority for civil aviation, with a focus on safety. In India, the use of Unmanned Aerial Vehicles (UAVs), commonly referred to as drones, is permitted. On August 26, 2021, the Ministry of Civil Aviation (MoCA) introduced a new drone policy, known as the Drone Rules, which outlines the classification, authorization, and operation of drones. These rules also regulate the assignment of unique identification numbers to drones and the issuance of remote pilot licenses. The key highlights of the drone rules are as follows:

- All drones except those in the Nano category must be registered and issued a Unique Identification Number (UIN).
- A permit is required for commercial drone operations (except for those in the Nano category flown below 50 feet and those in the Micro category flown below 200 feet).
- Drone pilots must maintain a direct visual line of sight at all times while flying.
- Drones cannot be flown more than 400 feet vertically.
- Drones cannot be flown in areas specified as "No Fly Zones", which include areas near airports, international borders, Vijay Chowk in Delhi, State Secretariat Complex in State Capitals, strategic locations, and military installations.
- Permission to fly in controlled airspace can be obtained by filing a flight plan and obtaining a unique Air Defence Clearance (ADC)/Flight Information Center (FIC) number.

3.1 Flying Zones Under the Drone Rules, 2021

The Drone Rules, 2021, have divided Indian airspace into three primary zones based on the level of restrictions for drone operations:

1. **Green Zone**
   - Least restricted area.
   - Drones can fly up to a height of 400 feet (120 meters) without specific permission.
   - Most of India is categorized as a green zone.

2. **Yellow Zone**
   - Controlled airspace.
   - Requires specific permissions to operate drones.
   - Typically, areas near airports, military installations, and other sensitive areas. Height restrictions and other limitations may apply.

3. **Red Zone**
   - No-fly zone.
   - Drone operations are strictly prohibited unless under exceptional circumstances with
   - specific government approval.
   - Includes high-security areas and critical infrastructure.

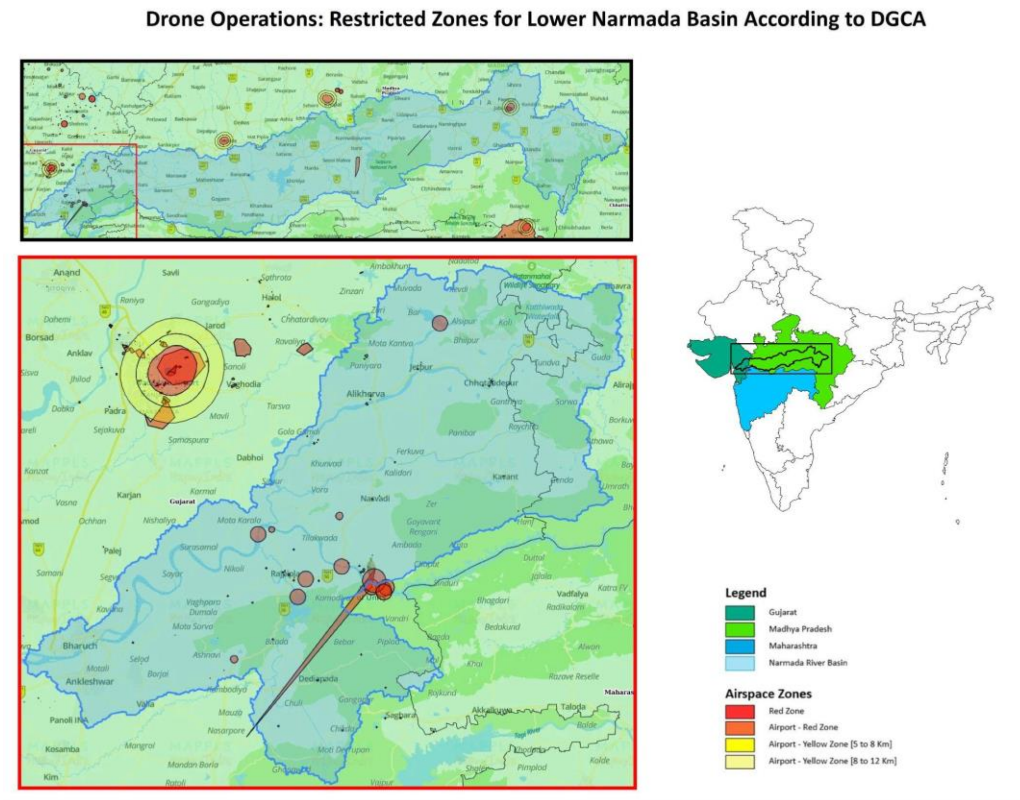

Figure 1. Restricted zones for Lower Narmada Basin

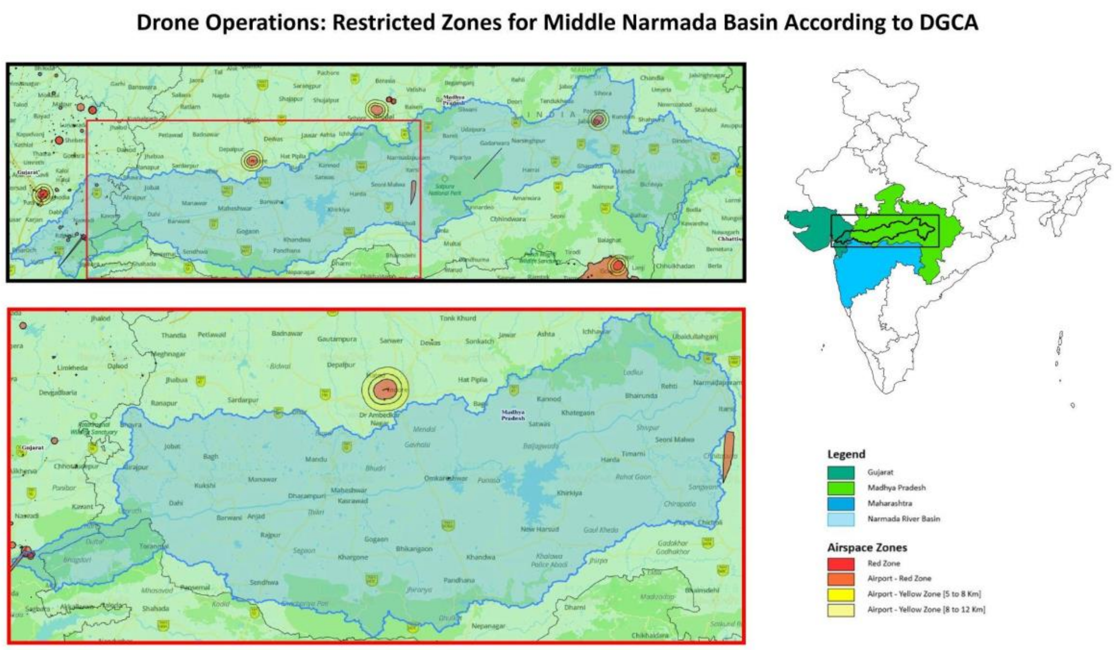

Figure 2. Restricted zones for Middle Narmada Basin

Drone Operations: Restricted Zones for Upper Narmada Basin According to DGCA

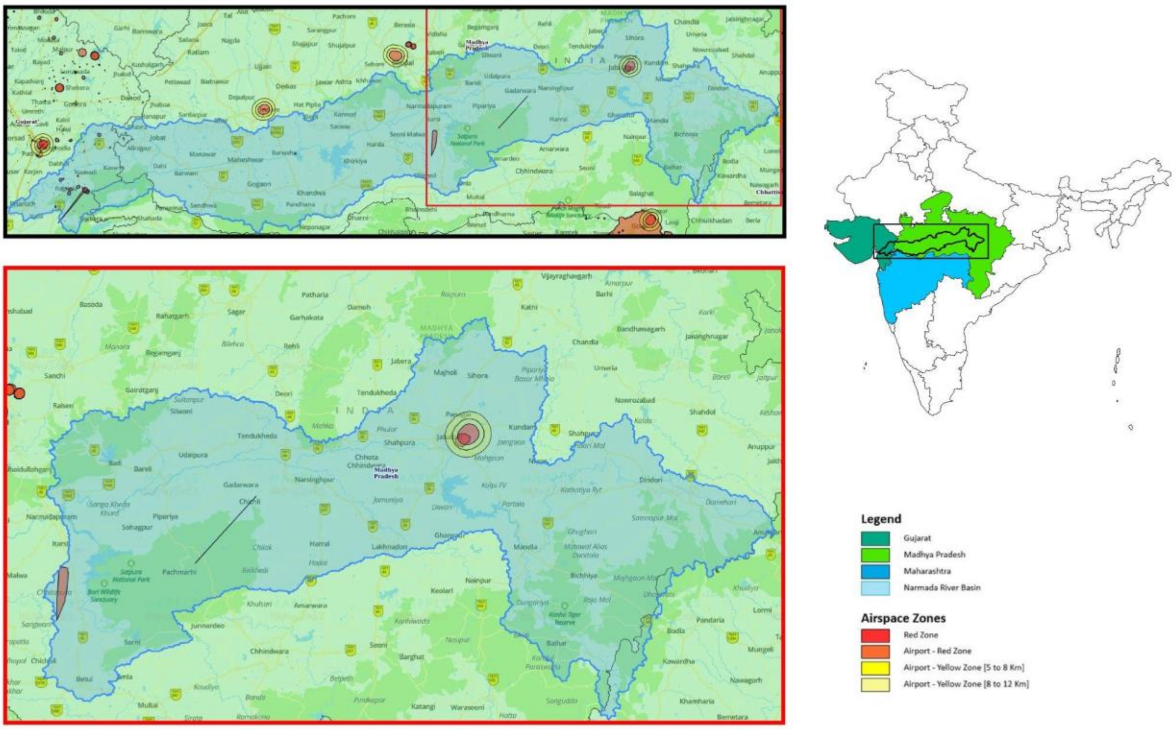

Figure 3. Restricted zones for Upper Narmada Basin

(Figure 1 – 3, Source: Digital Sky Platform, Prepared by c-Narmada Team)

It's important to know that, the specific boundaries of these zones can vary and are subject to change. The Digital Sky platform (https://digitalsky.dgca.gov.in) provides up-to-date information on zone classifications and restrictions. The portion of the Lower Narmada Basin within Gujarat state faces significant geographical, strategic and security challenges. As a result, several restricted zones for drone operations exist as shown in Figure 1 under the Drone Rules, 2021.

4. On-going Advancements

This section provides a comprehensive overview of the various data sources (Table 3), including a detailed list of various authorities (both government offices and private agencies) conducting the aerial surveys, that have been contacted during the study. It highlights the specific challenges encountered throughout the data collection process, such as data unavailability, delayed responses, bureaucratic hurdles, and difficulties in accessing relevant information. Furthermore, this section provides a summary of the current status of aerial surveys conducted within the Narmada River Basin, outlining the extent of the surveys completed, areas yet to be covered, and the quality of data collected thus far (Table 4).

Table 3. Data Sources

S. No.	Authority	Location
1	Ankleshwar Nagar Nigam	Ankleshwar, Gujarat
2	Gujarat Pollution Control Board Ankleshwar	Ankleshwar, Gujarat
3	Bharuch Municipal Corporation	Bharuch, Gujarat
4	District Emergency Operation Centre, Bharuch	Bharuch, Gujarat
5	District Water Works, Bharuch	Bharuch, Gujarat
6	District Watershed Development Unit, Bharuch	Bharuch, Gujarat
7	Gujarat Pollution Control Board Bharuch	Bharuch, Gujarat
8	Central Water Commission	Gandhinagar, Gujarat
9	Flood Control Cell Gandhinagar	Gandhinagar, Gujarat
10	Gujarat Institute of Disaster Management	Gandhinagar, Gujarat
11	Gujarat State Disaster Management Authority	Gandhinagar, Gujarat
12	Gujarat Urban Development Mission	Gandhinagar, Gujarat
13	Gujarat Water Resource Development Corporation	Gandhinagar, Gujarat
14	Sardar Sarovar Narmada Nigam Limited	Gandhinagar, Gujarat
15	State Water Data Centre	Gandhinagar, Gujarat
16	WAPCOS Pvt. Ltd.	Gandhinagar, Gujarat
17	Gujarat Pollution Control Board Surat	Surat, Gujarat
18	Gujarat Pollution Control Board Vadodara	Vadodara, Gujarat
19	Secon Pvt Ltd	Vadodara, Gujarat
20	Vadodara Municipal Corporation	Vadodara, Gujarat
21	Narmada Valley Development Authority	Madhya Pradesh
22	Environment Department of Madhya Pradesh	Madhya Pradesh
23	Water Resource Department of Madhya Pradesh	Madhya Pradesh
24	M.P State Electronics Development Corporation Ltd.	Madhya Pradesh
25	National Water Development Agency	Madhya Pradesh
26	Madhya Pradesh Pollution Control Board	Madhya Pradesh
27	Narmada Control Authority	Madhya Pradesh
28	Madhya Pradesh Urban Development Company Ltd.	Madhya Pradesh
29	National Water Development Agency	

Challenges faced in data collection:

- Data unavailability.
- Ease of obtaining data.
- Identifying and coordinating with a nodal officer to access specific data is a limiting factor.
- Instances of missing, incomplete, or inaccurate data.
- Data collection demands a substantial investment of time and manpower.

4.1 Review of Aerial Survey over Narmada Basin

Table 4. Overview of Surveys by Authorities in the Narmada River Basin

Sr. No	Authority	Remark
1	Ankleshwar Nagar Nigam	Not conducted aerial survey
2	Gujarat Pollution Control Board Ankleshwar	Not conducted aerial survey
3	Bharuch Municipal Corporation	Not conducted aerial survey
4	District Emergency Operation Centre, Bharuch	Not conducted aerial survey
5	District Water Works, Bharuch	Not conducted aerial survey
6	District Watershed Development Unit, Bharuch	Conducted Aerial surveys for three project River Rejuvation 1, Prandhan Mantri Krishi Sinchai Yojna and River Rejuvation 2. Data Available from 2018/19.
7	Gujarat Pollution Control Board Bharuch	Not aerial survey, water quality samples is collected on regular basis on water sampling site and identified major pollutant source sites.
8	Central Water Commission	Not conducted aerial survey
9	Flood Control Cell Gandhinagar	Not conducted aerial survey
10	Gujarat Institute of Disaster Management	Not conducted aerial survey
11	Gujarat State Disaster Management Authority	Not conducted aerial survey
12	Gujarat Urban Development Mission	Not conducted aerial survey
13	Gujarat Water Resource Development Corporation	Not able to connect but has given the contract to Secon Pvt. Ltd. of Flood Modelling
14	Sardar Sarovar Narmada Nigam Limited	Not conducted aerial survey
15	State Water Data Centre	No aerial survey data available.
16	WAPCOS Pvt. Ltd.	Instead of an aerial survey, they conducted a topographical survey.
17	Gujarat Pollution Control Board Surat	Not conducted aerial survey

18	Gujarat Pollution Control Board Vadodara	No aerial survey data available.
19	Secon Pvt Ltd	They conducted an aerial survey of the lower Narmada Basin from the Sardar Sarovar Dam to the Gulf of Khambhat, covering 5 km on either side of the river, for the Narmada Valley Development Authority.
20	Vadodara Municipal Corporation	Not conducted aerial survey
21	Narmada Valley Development Authority	They have conducted aerial survey (2003-2004) for Narmada River for proposal of schemes. Data is available in hard copy.
22	Environment Department of Madhya Pradesh	Not conducted aerial survey
23	Water Resource Department of Madhya Pradesh	Not conducted aerial survey
24	M.P State Electronics Development Corporation Ltd.	They have conducted drone surveys for various Departments details are attached in **Annexure 1**.
25	National Water Development Agency	Not aerial survey they have conducted topographical survey for river crossing.
26	Madhya Pradesh Pollution Control Board	Not conducted aerial survey
27	Narmada Control Authority	Not conducted aerial survey
28	Madhya Pradesh Urban Development Company Ltd.	Not conducted aerial survey
29	National Water Development Agency	Not aerial survey they have conducted topographical survey for river crossing.

5. Observations and Recommendations

Aerial surveys play a crucial role in the effective management and monitoring of river basins. They provide high-resolution, real-time data on various aspects of the landscape, hydrology, and ecological health, offering a more comprehensive view than ground surveys. In the context of river basins, aerial surveys help in tracking changes in river morphology, sediment deposition, land use, vegetation cover, and the impact of human interventions like dam construction or deforestation. This information is essential for informed decision-making regarding water resource management, flood control, and conservation efforts.

Despite its critical importance, the Narmada Basin has been inadequately surveyed. Information from the M.P. State Electronics Development Corporation Ltd. indicates that while drone surveys were conducted in the past, they were project-specific and did not focus solely on the basin itself. While aerial surveys have been conducted in the upper and middle sections of the Narmada Basin, the Lower Narmada Basin has had only a limited number of sporadic surveys. These surveys occurred at irregular intervals, often with significant time gaps between them, leaving large portions of the basin un-surveyed. These were primarily undertaken in the past and were linked to specific projects assigned to relevant authorities, rather than as part of a comprehensive, basin-wide initiative. Furthermore, the latest survey data is currently unavailable, as no recent aerial surveys have been conducted in the region.

Given the critical importance of up-to-date aerial data for effective basin management, this situation underscores three major recommendations:

1. A full-scale and far-reaching aerial survey of the basin is urgently needed to gather accurate and updated data. The estimated cost for data acquisition is provided in Table 05.

2. There is a need to establish a dedicated mechanism or institution that conducts aerial surveys at regular intervals.

3. Creating a centralized platform for easy access to updated data will ensure that future projects and authorities have reliable information to support long-term basin management and conservation efforts.

Table 5. Price Estimate for Drone Survey			
Sr. No.	**Type of Data**	**Specific Data**	**Rate (Per Sq. Km)**
1	DEM Creation:	DEM Creation: Generating Digital Elevation Models (DEMs) from classified point clouds to represent the terrain.	1000
2	DSM Creation:	DSM Creation: Creating Digital Surface Models (DSMs) to capture the surface of objects (e.g., buildings, vegetation) above the ground.	1000
3	Contour Generation:	Contour Generation: Producing contour lines from DEMs for topographic analysis.	800
4	Topographical Survey DGPS and Drone with centimeter accuracy. (For more than 100 SQKM km)	● Orthomosaic ● Dense Point Cloud (.laz/.las) ● RSME Report ● 3D Surface Model ● GIS-Based Map / .dwg ● Shape File / KML File ● GCP CSV Data with Both Projections (GCS & PCS)	5500
5	Point Cloud Data (LiDAR)	Point Cloud Classification: Distinguishing different types of points (e.g., ground, vegetation, buildings) to improve the accuracy of subsequent analyses.	3000
6	Feature Extraction Object Detection:	Object Detection: Identifying and classifying objects such as buildings, roads, and vegetation from LiDAR or photogrammetric data. Change Detection: Analyzing temporal changes in the landscape by comparing current data with historical datasets. Topographic Analysis: Identifying landforms, slopes, and drainage patterns for environmental and planning purposes.	2600
7	GIS Integration	Georeferencing: Aligning drone and LiDAR data with spatial reference systems to ensure proper location accuracy. Spatial Analysis: Performing operations like buffering, overlay analysis, and proximity analysis to derive insights from geospatial data. Data Visualization: Creating maps, charts, and other visual aids to effectively communicate findings.	3450
8	Lidar Survey	● DTM/ DEM/ DSM ● Tile Photos ● RSME Report ● Contour ● 3D Surface Model	15000

9	Thematic Mapping Land Use/Cover Mapping:	Identifying and classifying land use or land cover types based on remote sensing data. Vegetation Analysis: Assessing vegetation health, density, and distribution using spectral and LiDAR data. Understanding these types of GIS processing tasks can help effectively scope out and execute you drone and LiDAR mapping projects. Each type of data and processing method contributes to a comprehensive understanding of the surveyed area, in decision-making for planning, aiding analysis, and management.	
10	Data Management and Quality Control Data Cleaning:	Removing noise and erroneous data points from LiDAR point clouds or imagery. Data Fusion: Combining data from multiple sources (e.g., different drone flights or sensors) to create a comprehensive dataset. Metadata Ensuring that all data is Management: properly documented with metadata for future reference and use	

5.1 Need for Data

The data types listed in the table are crucial for aerial surveys and other geospatial analysis in the project. These datasets, such as Digital Elevation Models (DEMs), Digital Surface Models (DSMs), contour generation, and LiDAR-based point cloud classifications, provide detailed and high-accuracy representations of the terrain and landscape features. For example, DEMs and DSMs allow for precise tracking of changes in river morphology and sediment deposition, while contour generation aids in understanding topographic variations, crucial for flood control and water resource management. LiDAR and photogrammetry enable object detection, land use classification, and vegetation health assessment, supporting environmental monitoring and conservation efforts. Moreover, GIS integration enhances the visualization of data, providing insights for spatial analysis, while data management and quality control ensure that the datasets are accurate, reliable, and comprehensive. These tools are vital for informed decision-making, especially in river basins like the Lower Narmada Basin, where limited and sporadic surveys have left significant gaps in understanding the ecological and hydrological dynamics. Access to updated, detailed aerial survey data would significantly improve planning and conservation efforts in the region.

6. Conclusion

The Narmada River Basin is a vital riparian habitat, playing a critical role in maintaining the balance between aquatic and terrestrial ecosystems. It supports nutrient cycling, improves water quality by filtering sediments, nutrients, and pollutants, and helps stabilize riverbanks, preventing erosion. The basin also contributes to groundwater recharge and regulates water temperature, fostering aquatic life. Riparian vegetation, ranging from aquatic plants to trees, forms a protective buffer around the river, supporting biodiversity and serving as a migration corridor for wildlife. Despite its ecological importance, the Narmada River Basin is vulnerable to environmental changes, including fluctuating water levels, soil moisture, and extreme weather events. However, it remains resilient, acting as a buffer against floods and droughts. Due to its abundance of water, fertility, and great biodiversity, this basin is both vital and in high demand.

However, despite its critical importance, the Narmada basin has been inadequately surveyed, particularly in recent years, due to irregular and limited aerial surveys. This lack of updated data impedes effective management and conservation efforts.

Aerial surveys play a crucial role in the effective management and monitoring of river basins. They provide high-resolution, real-time data on various aspects of the landscape, hydrology, and ecological health, offering a more comprehensive view than ground surveys. In the context of river basins, aerial surveys help in tracking changes in river morphology, sediment deposition, land use, vegetation cover, and the impact of human interventions like dam construction or deforestation. This information is essential for informed decision-making regarding water resource management, flood control, and conservation efforts.

To address these challenges, there is an urgent need for a comprehensive aerial survey of the entire basin to provide up-to-date, high-resolution data on its ecological and hydrological conditions. Additionally, establishing a dedicated institution or mechanism to regularly conduct these surveys will ensure continuity and accuracy in monitoring. Finally, creating a centralized platform to facilitate easy access to this data will empower authorities and stakeholders with the reliable information needed for sustainable water resource management and long-term conservation of the Narmada River Basin.

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Annexures

Information obtained from **M.P State Electronics Development Corporation Ltd. (MPSEDC- Drone Unit)**

Sr. No.	Project	Information
1	Ekatma Dham Omkareshwa	Drone based survey of Ekatmdham (Omkareshwar) project site for the purpose of status & topography mapping
2	Jagdishpur Fort (Islamnagar)	
3	Ratibad Samasgarh Road	
4	Coralwood (Multi)	
5	Ruchi Lifescape (Multi)	
6	Solid Liquid Waste Management	Drone based survey and mapping for analyzing the suitable sites for Solid&Liquid waste management for Budhni Town
7	ABD SmartCity, Bhopal	Drone based survey for analyzing the status of ABD area in regards to work status running on ABD area of Smart-City, Bhopal
8	SmartCity Jabalpur	Drone based survey for analyzing the status of properties in a part of Smart-City, Jabapur
9	Govindpura Industrial Area	Drone based survey for layout planning and status mapping of the industrial area plots and topographical analysis
10	Mandideep Industrial Area	Drone based survey for layout planning and status mapping of the industrial area plots and topographical analysis
11	Command Area (Kaliasote)	
12	Submergence Status mapping (Kaith Medium Project)	Drone based survey for Kaith Meduim Project Submergence Status, Submerged assets status mapping
13	Ruchi Lifescape (Rowhouses)	
14	Chandbad Kadeem	Drone based survey for exploring the usage of drone in mining sector (To access Excavated volume and area)
15	Ken Betwa Link Project Authority	
16	Crop loss Rajgarh	
17	Forest Plantation Status Mapping (CAMPA)	Drone based survey for plantation status mapping of a CAMPA sites
18	Industry mohana,mawai land	Proposal for Drone Survey of Mawai, Bastapur, Badwari, MPIDC, Morena
19	MPSEDC Bhopal IT Park	

20	Urban Revenue Survey (Harsud)	Drone based survey of Harsud town (Indira Sagar Rehabilition Area) for creating urban land records
21	Forest Rehabilitation Survey (Narmadapuram)	Drone based survey of forest rehabilitation villages of Narmadapuram for converting these villages in to Revenue Villages
22	Urban Revenue Survey (Dharkothi-Indore)	Drone mapping survey for Urban Revenue Survey of Dharkothi (Indore)
23	Probable Rehabilitation Area (Satna)	Drone mapping survey of Probable rehabilitation villages of Satna
24	Urban Revenue Survey (Shahganj-Sehore)	Drone mapping survey for Urban Revenue survey of Shahganj (Sehore)
25	Status Mapping of Dewas ByPass	Drone based survey of linear project (Dewas by-pass) for the purpose of current status (Actual v/s Implemented) of the road on survey date
26	MPRRDA Harrakeda BudhorKalan	Drone Survey and Mapping of "Harrakheda – Budhore Kalan Road"
27	MPRRDA Guna PoC	Drone Survey and Mapping of Guna PoC Road
28	Sagar Pancham Nagar Canal	Drone Survey and Mapping of " Sagar Pancham Nagar Canal"
29	Tawa Canal	Drone Survey and Mapping of Tawa Canal
30	MVM Bhopal	Drone Survey and Mapping of MVM Bhopal
31	Harda Pataka Factory Blast	Techno-commercial proposal for Drone Survey of Harda Town
32	Kaliyasote River	Proposal for Drone Survey of Kaliyasot River
33	Sand Stock Volume Analysis	Drone based survey for analyzing the sand stock volume at each stockist location in the state
Source: https://drone.mp.gov.in/daas_app/projects		