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

Hydrology Status of Krishna River Basin

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National River Conservation Directorate (NRCD)

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

www.nrcd.nic.in

Centres for Krishna River Basin Management and Studies (cKrishna)

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

www.ckrishna.org

Centres for Ganga River Basin Management and Studies (cGanga)

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

www.cganga.org

Acknowledgment

This report is a comprehensive outcome of the project jointly executed by NIT Warangal (Lead Institute) and NIT Surathkal (Fellow Institute) under the supervision of cGanga at IIT Kanpur. It was submitted to the National River Conservation Directorate (NRCD) in 2024. We gratefully acknowledge the individuals who provided information and photographs for this report.

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Preface

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

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

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

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

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

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Abbreviations and Acronyms

CV	Coefficient of Variation
CWC	Central Water Commission
CGWB	Central Ground Water Board
India-WRIS	India Water Resources Information System
ISRO	Indian Space Research Organization
DEM	Digital Elevation Model
ET	Evapotranspiration
GLEAM	Global Land Evaporation Amsterdam Model
MAR	Managed Aquifer Recharge
IWRM	Integrated Water Resources Management
mg/L	milligrams per liter
mbgl	meters below ground level
Rabi	Rabi season (post-monsoon cropping season in India)
Kharif	Kharif season (monsoon cropping season in India)

Chapter 1 Introduction

1.1 Background and Significance of Krishna River Basin

The Krishna River Basin is one of the largest and most complex river systems in peninsular India, spanning across the states of Maharashtra, Karnataka, Telangana, and Andhra Pradesh, with a total catchment area of approximately 258,948 km² (India-WRIS). The river originates in the Western Ghats near Mahabaleshwar and flows eastward for about 1,400 kilometers before emptying into the Bay of Bengal. It supports a population exceeding 80 million people and serves as a lifeline for agricultural, domestic, industrial, and ecological water demands (NRCD, 2024; Pande & Savenije, 2016). Geographically, the Krishna Basin features a wide spectrum of physiographic regions—from rugged mountainous terrain in the Western Ghats to the fertile plains in the east—and encompasses major sub-basins such as the Bhima, Tungabhadra, Ghataprabha, Malaprabha, and Musi rivers. This heterogeneity in topography, soils, and climate results in complex land use patterns and spatially variable hydrological responses (Biggs et al., 2006; GLEAM).

The river's hydrology is predominantly governed by monsoonal rainfall, leading to pronounced temporal variability in streamflow. The Southwest Monsoon (June–September) contributes to the bulk of the annual discharge, while the dry season often experiences water scarcity (Amarasinghe et al., 2008). This variability necessitates robust water storage and management infrastructure. Indeed, the basin is home to some of India's largest hydraulic structures, including Nagarjuna Sagar, Almatti, and Srisailam dams (India-WRIS; ISRO). These projects, while improving water availability and irrigation efficiency, have significantly modified the natural flow regimes, affecting downstream ecosystems and groundwater recharge (Reddy et al., 2014). Groundwater overexploitation has emerged as a critical challenge, especially in semi-arid subregions of the basin, driven by agricultural intensification and poor recharge mechanisms (Shankar et al.,2011). This has been exacerbated by policy disconnects, lack of demand-side management, and climate-induced variability in rainfall patterns (Scott & Sharma, 2009; Venot et al., 2011).

Hydrological modeling and data-driven assessment are essential tools to evaluate these challenges. Recent approaches have integrated remote sensing data (e.g., CartoSat DEM, Landsat) and global models (e.g., GLEAM) to enhance spatial and temporal resolution in streamflow and evapotranspiration estimates (Biggs et al., 2006; GLEAM). Moreover, socio-hydrological models help capture human-water interactions and inform sustainable water governance, especially in contexts of inter-state water disputes and competing sectoral demands (Pande & Savenije, 2016). With the growing pressures of climate change, population growth, and urbanization, the Krishna River Basin exemplifies the need for integrated water resources management (IWRM), ecosystem-based adaptation, and transboundary cooperation to secure long-term water security and ecological health (GWP, 2000; Bouwer et.al., 2006). This report presents a comprehensive hydrological assessment of the Krishna Basin, drawing on multi-source datasets and methodologies to evaluate streamflow dynamics, water availability, infrastructure performance, and resource sustainability.

1.2 Report Objectives

The objective of this hydrological data report is to provide a comprehensive analysis of the Krishna River Basin's hydrological characteristics, addressing the critical need for understanding the basin's water resource dynamics in the face of climatic variability and increasing human demands. By examining key hydrological parameters such as streamflow, water levels, sediment load and groundwater, alongside climatic variables evapotranspiration, evaporation, this report aims to offer a detailed account of the spatial and temporal variations influencing the basin.

The report consolidates data from diverse, reliable sources and applies rigorous methodological frameworks to ensure accuracy and relevance. Through its detailed analysis, it highlights trends, patterns, and interdependencies among these parameters, enabling a deeper understanding of the region's water balance and hydrological processes.

This report sets the stage for a comprehensive analysis of the Hydro climatology associated with the Krishna River.

Chapter 1: Introduction

This chapter introduces the Krishna River Basin, emphasizing its geographical, hydrological, and ecological significance. It provides a detailed overview of the basin's sub-divisions, key physiographic features, and the challenges posed by anthropogenic and climatic pressures.

Chapter 2: Data Acquisition and Methodology

The methodologies employed in this study are discussed, with a focus on data acquisition from reliable sources such as India-WRIS, CWC records, and CGWB. The chapter outlines the framework used for processing and analyzing hydrological and climatic data to ensure accuracy and consistency.

Chapter 3: Digital Elevation Model (DEM) Data

This chapter emphasizes the significance of Digital Elevation Models (DEMs) in hydrological studies, focusing on the CartoSat DEM derived from the CartoSat-1 satellite. The DEM used in the report and its applications in watershed delineation, drainage network extraction, and flood risk assessment.

Chapter 4: Streamflow, Water Level, Sediment Data

The chapter presents detailed analyses of time-series streamflow, water level data and sediment from key gauging stations across the basin. By examining variations across stations across Krishna river basin, the chapter provides insights into flow dynamics and seasonal patterns.

Chapter 5: Groundwater Data

The chapter focuses on the spatial and temporal variations in groundwater levels within the basin, including seasonal recharge patterns and long-term trends. By analyzing data from monitoring stations in the upper, middle, and lower basins, the chapter identifies stress areas and highlights the need for sustainable groundwater management practices.

Chapter 6: Evapotranspiration

This chapter examines the role of evapotranspiration in the basin's water balance, focusing on spatial distribution and seasonal variability. By utilizing remote sensing data the chapter quantifies water loss through evaporation and plant transpiration. The findings underscore the importance of integrating evapotranspiration data into basin-wide water management strategies.

Chapter 7: Conclusion and Recommendations

This concluding chapter synthesizes the findings and provides recommendations for sustainable management of the Krishna River Basin. It emphasizes the integration of hydrological data with policy frameworks and advocates for adaptive strategies to mitigate the impacts of climate variability and anthropogenic pressures.

Chapter 2: Data Acquisition and Methodology

2.1 Data Sources

Accurate and comprehensive data acquisition is essential for analyzing the hydrological characteristics of the Krishna River Basin. This study utilized multiple authoritative sources to ensure the reliability and robustness of the dataset:

India Water Resources Information System (India-WRIS): The India-WRIS platform, developed by the Ministry of Jal Shakti, provided detailed hydrological data, including river basin shape files, dam and canal information, and tributary details. This platform forms the backbone of the spatial and hydrological datasets used in this study. Source: https://indiawris.gov.in/wris

Central Ground Water Board (CGWB) Reports: Groundwater-related data, including spatial and temporal variations in groundwater levels, were obtained from the CGWB. These reports provided insights into seasonal groundwater recharge patterns and trends in groundwater resource availability. Source: https://cgwb.gov.in

Global Land Evaporation Amsterdam Model (GLEAM) data: It provides high-resolution, satellite-based estimates of terrestrial evapotranspiration (ET), a key variable in hydrological and climate studies. With a spatial resolution of approximately 0.25 degrees and data availability from 1980 to the present, GLEAM has become an essential tool for understanding water fluxes across different ecosystems and for applications in drought monitoring, agricultural planning, and water resource management. Source: https://www.gleam.eu

CartoSat DEM derived from the CartoSat-1 satellite. The CartoSat DEM, with a spatial resolution of approximately 10 meters, offers high-precision elevation data suitable for detailed terrain analysis. It plays a crucial role in watershed delineation, enabling accurate identification of catchment boundaries and flow directions. Source: https://bhuvan.nrsc.gov.in

2.2 Methodological Framework

The methodological framework integrates the collected data into a structured analysis process, ensuring accurate interpretation of hydrological and climatic parameters.

Data Preprocessing: All datasets were standardized for spatial resolution, temporal coverage, and format compatibility. DEMs were processed for hydrological applications, including watershed and drainage analysis.

Hydrological Analysis: Hydrological parameters such as discharge, sediment and groundwater levels were analyzed using time-series data. High-resolution DEMs were employed to model runoff patterns and delineate watersheds.

Comparative Studies: Data from diverse sources were compared and consolidated to ensure reliability. For example, groundwater level trends from CGWB were cross-referenced with India-WRIS records.

Chapter 3: Digital Elevation Model (DEM) Data

3.1 Introduction

CartoSat DEM refers to the Digital Elevation Model (DEM) data generated using the CartoSat series of satellites operated by the Indian Space Research Organization (ISRO). This chapter emphasizes the significance of Digital Elevation Models (DEMs) in hydrological studies, focusing on the CartoSat DEM derived from the CartoSat-1 satellite. The CartoSat DEM, with a spatial resolution of approximately 30 meters, offers high-precision elevation data suitable for detailed terrain analysis. It plays a crucial role in watershed delineation, enabling accurate identification of catchment boundaries and flow directions. The elevation information from CartoSat DEM is also instrumental in drainage network extraction, supporting the generation of realistic stream paths and hydrological connectivity. Furthermore, its high resolution and vertical accuracy make it a valuable resource in flood risk assessment, allowing the identification of vulnerable low-lying areas and aiding in effective disaster preparedness and mitigation planning.

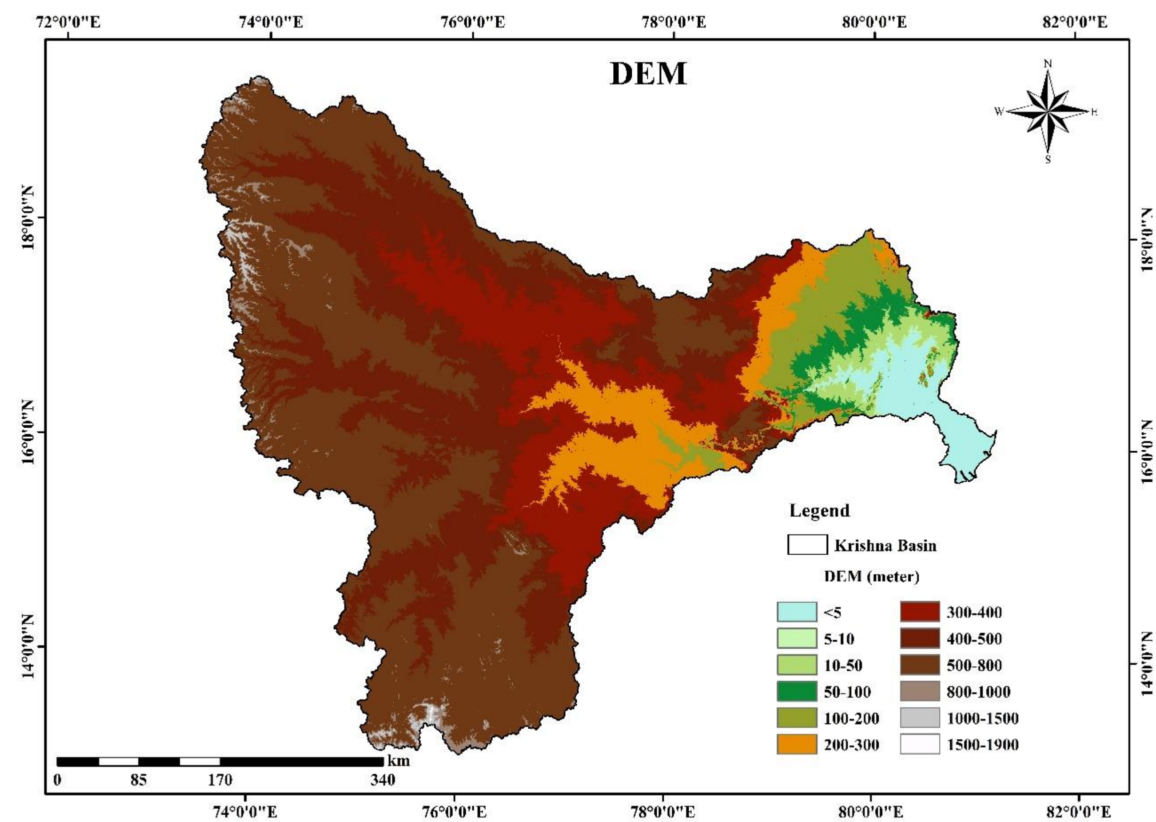

Figure 3. 1 DEM of the Krishna River Basin

Figure 3.1 shows the CartoSat 30m DEM of the Krishna River Basin, which provides detailed elevation information for hydrological analysis.

3.2 Applications in Hydrological Analysis

The CartoSat DEM has numerous applications in hydrological analysis:

- **Watershed Delineation:** The DEM can be used to accurately delineate watersheds and identify drainage networks.
- **Drainage Network Extraction:** The DEM enables the extraction of drainage networks, including streams, rivers, and their tributaries.
- **Hydrological Modeling:** The DEM can be used as input for hydrological models to simulate water flow, runoff, and other hydrological processes.
- **Flood Risk Assessment:** The DEM can be used to assess flood risk by identifying floodplains and simulating flood inundation scenarios.
- **Water Resource Management:** The DEM can be used to support water resource management decisions, such as the placement of dams and reservoirs.

Chapter 4: Streamflow, Water Level, Sediment Data

4.1 Discharge, Sediment and Water Level Data

This section presents a detailed analysis of discharge, sediment load and water level data collected from various gauging stations across the Krishna River Basin. These data provide critical insights into the hydrological dynamics of the river and its tributaries, reflecting seasonal patterns, spatial variability, and the impact of infrastructural developments. The analysis in this section is essential for understanding water resource availability, predicting hydrological extremes, and planning sustainable management strategies.

The monitoring stations selected for this study represent the upper, middle, and lower segments of the Krishna Basin. Each station captures unique characteristics influenced by physiography, climatic conditions, and anthropogenic factors. This section emphasizes the importance of long-term data for identifying trends and planning future interventions.

4.2 Data Collection and Sources

The discharge, sediment load and water level data used in this section were sourced from the India Water Resources Information System (India-WRIS). These time-series datasets encompass multiple decades, allowing for comprehensive temporal and spatial analyses. Each monitoring station was selected based on its strategic location, ensuring representative coverage of the basin's hydrological diversity. The Krishna River Basin hosts a comprehensive network of 28 discharge monitoring stations that span its key tributaries and sub-basins, reflecting the basin's diverse physiographic and climatic conditions. These stations, distributed across the Upper, Middle, Lower Krishna, Bhima, and Tungabhadra sub-basins**,** monitor vital tributaries such as the Bhima, Musi, Munneru, Wyra, Hundri, Malaprabha, and Koyna**.** The data collected from these locations covering both historical and recent periods, with several stations operational since the 1960s are instrumental in analyzing streamflow trends**,** flood forecasting**,** water availability, and climate variability impacts**.** Notably, the Lower Krishna sub-basin is extensively monitored, reflecting its high agricultural dependency and vulnerability to hydrological extremes. Stations like Keesara (since 1965) and Dameracherla (since 1968) exemplify long-term observation points critical for historical trend analysis. Meanwhile, newer entries like Khadakewada and Songe bange**,** active in the 2020s, highlight recent efforts to enhance monitoring in less represented upstream areas. This network serves as a backbone for hydrological modeling, water management planning, and interstate water-sharing negotiations, underscoring its significance in sustainable basin governance. Figure 4.1 represents the CWC Gauge Stations for Discharge measurement over Krishna River Basin. Table 4.1 represents the discharge monitoring stations over Krishna River which were maintained by CWC.

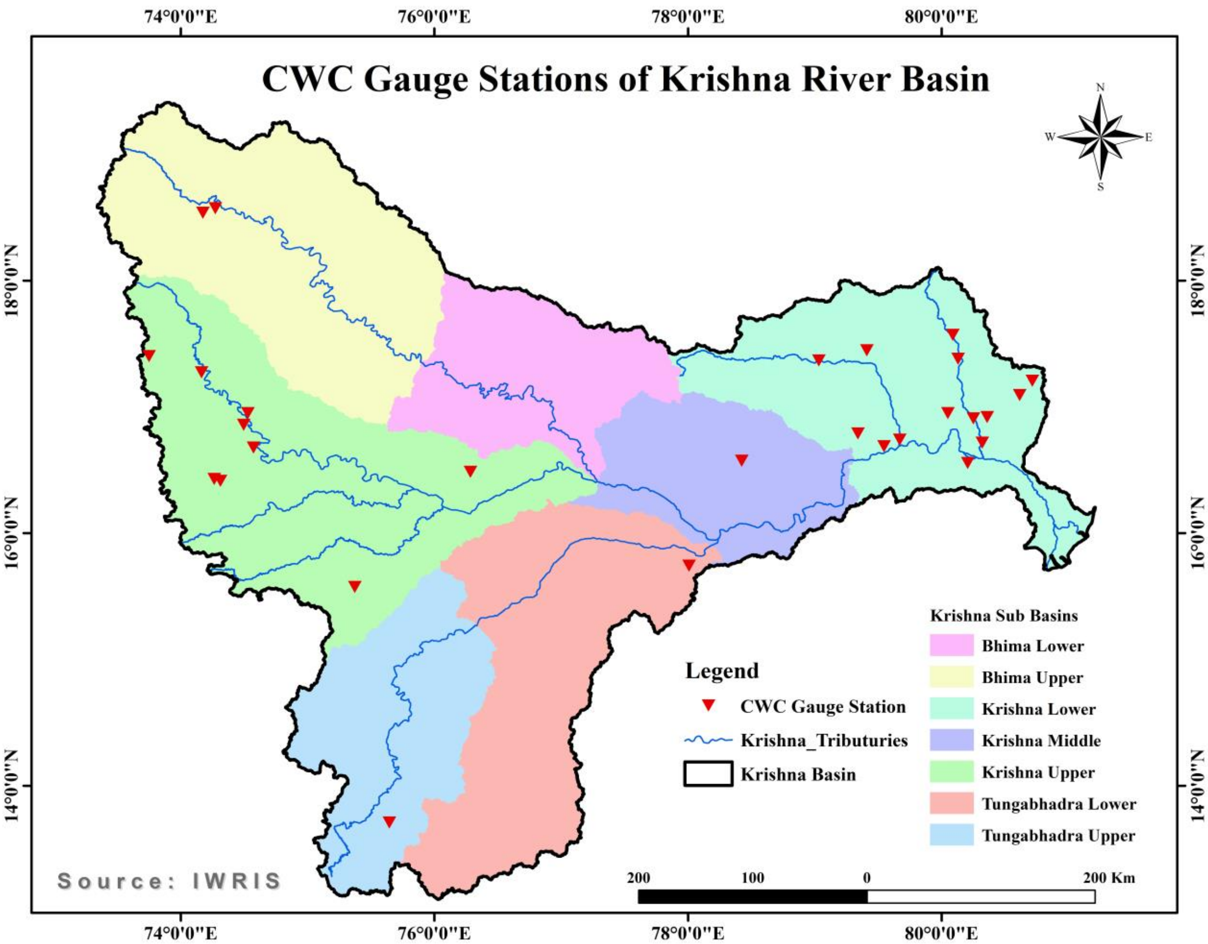

Figure 4. 1 CWC Gauge Stations for Discharge measurement over Krishna River Basin

Table 4. 1 Discharge monitoring stations over Krishna River Basin maintained by CWC

Sl. No.	Station Name	Latitude	Longitude	Tributary	Sub-Basin	From	To
1	Mirawadi	18.535	74.1747	Bhima	Bhima	7/1/2018	31/5/2023
2	Rahu	18.5722	74.2736	Bhima	Bhima	1/6/2023	9/1/2025
3	Halia	16.7882	79.3396	Halia	Lower Krishna	1/7/1984	31/3/2025
4	Mandalapadu	17.2047	80.715	Lothuvagu	Lower Krishna	1/1/2003	1/3/2008
5	Munugodu	16.5547	80.2064	Munugodu	Lower Krishna	24/10/2016	15/4/2025
6	Veerlapalem	16.6875	79.5461	Veerlapalem	Lower Krishna	1/11/2016	31/3/2025
7	Tiruvuru	17.0925	80.6156	Muniyeru	Lower Krishna	28/7/1999	30/10/2014
8	Bayyaram	17.5681	80.0875	Munneru	Lower Krishna	1/1/2003	31/3/2008
9	Daredu	17.3794	80.1303	Munneru	Lower Krishna	26/10/2016	28/1/2022
10	Keesara	16.7147	80.3203	Munneru	Lower Krishna	1/1/1965	31/3/2025
11	Penuganchi prolu	16.9072	80.2511	Munneru	Lower Krishna	5/1/2021	31/3/2025
12	Anantharam	17.4469	79.4097	Musi	Lower Krishna	26/10/2016	28/2/2025
13	Dameracherla	16.7392	79.6697	Musi	Lower Krishna	1/6/1968	28/2/2025
14	Valigonda	17.3656	79.0322	Musi	Lower Krishna	1/7/2019	24/3/2025
15	Paleru bridge	16.9489	80.0492	Paleru	Lower Krishna	1/6/1965	28/3/2025
16	Madhira	16.9181	80.3589	Wyra	Lower Krishna	1/6/1984	28/2/2025
17	Doddipadu	15.74	78.0081	Hundri	Lower Tungabadhra	11/1/2014	14/7/2025
18	Sudakkal	16.5728	78.4233	Dindi	Middile Krishna	1/6/2016	17/4/2025
19	Khadakewada	16.4125	74.3139	Chikotra	Upper Krishna	1/6/2020	31/8/2021
20	Talikot	16.4836	76.2844	Doni	Upper Krishna	21/9/1995	26/2/2025
21	Songe bange	16.4281	74.2636	Dudhganga	Upper Krishna	1/6/2020	31/10/2021
22	Koyna	17.4	73.75	Koyna	Upper Krishna	1/10/1972	31/5/2007
23	Warunji	17.2728	74.1647	Koyna	Upper Krishna	1/1/1966	19/4/2025
24	Navalgund	15.5731	75.3731	Malaprabha	Upper Krishna	1/6/1991	26/7/2017
25	Terwad	16.6764	74.5742	Panchganga	Upper Krishna	22/8/1979	19/4/2025
26	Samdoli	16.8564	74.4967	Warna	Upper Krishna	1/12/1964	19/4/2025
27	Nandre	16.9492	74.5297	Yerala	Upper Krishna	7/8/2018	19/4/2025
28	Lakkavalli	13.7064	75.6447	Tungabhadra	Upper Tungabadhra	13/12/2018	20/2/2025

The Krishna River Basin is extensively monitored through a robust network of 32 river water level monitoring stations, strategically positioned across its major tributaries and sub-basins. These stations span the Upper Krishna, Middle Krishna, Lower Krishna, Bhima, and Tungabhadra sub-basins, providing critical data for evaluating water dynamics and managing resources. The stations cover a wide range of tributaries including Musi, Munneru, Wyra, Dindi, Chikotra, Malaprabha, Koyna, and Tungabhadra, reflecting the hydrological diversity of the basin. Key long-term observation points like Keesara (since 1965), Madhira, and Dameracherla provide invaluable historical datasets, while newer stations such as Poduttur, Lingala, and Penuganchi Prolu enhance modern monitoring capacities, particularly in the Lower Krishna region. The presence of reservoirs like Bhadra, Lakkavalli, and Warna dam also highlights the importance of storage and flow regulation in the basin's water management framework. These stations play a vital role in tracking streamflow variations, flood forecasting, climate impact assessments, and interstate water-sharing strategies, making them essential for sustainable development and ecological balance within the Krishna River Basin. Figure 4.2 represents CWC Gauge Stations for Water Level measurement over Krishna River Basin. Table 4.2 represents River Water Level monitoring stations over Krishna River which were maintained by CWC.

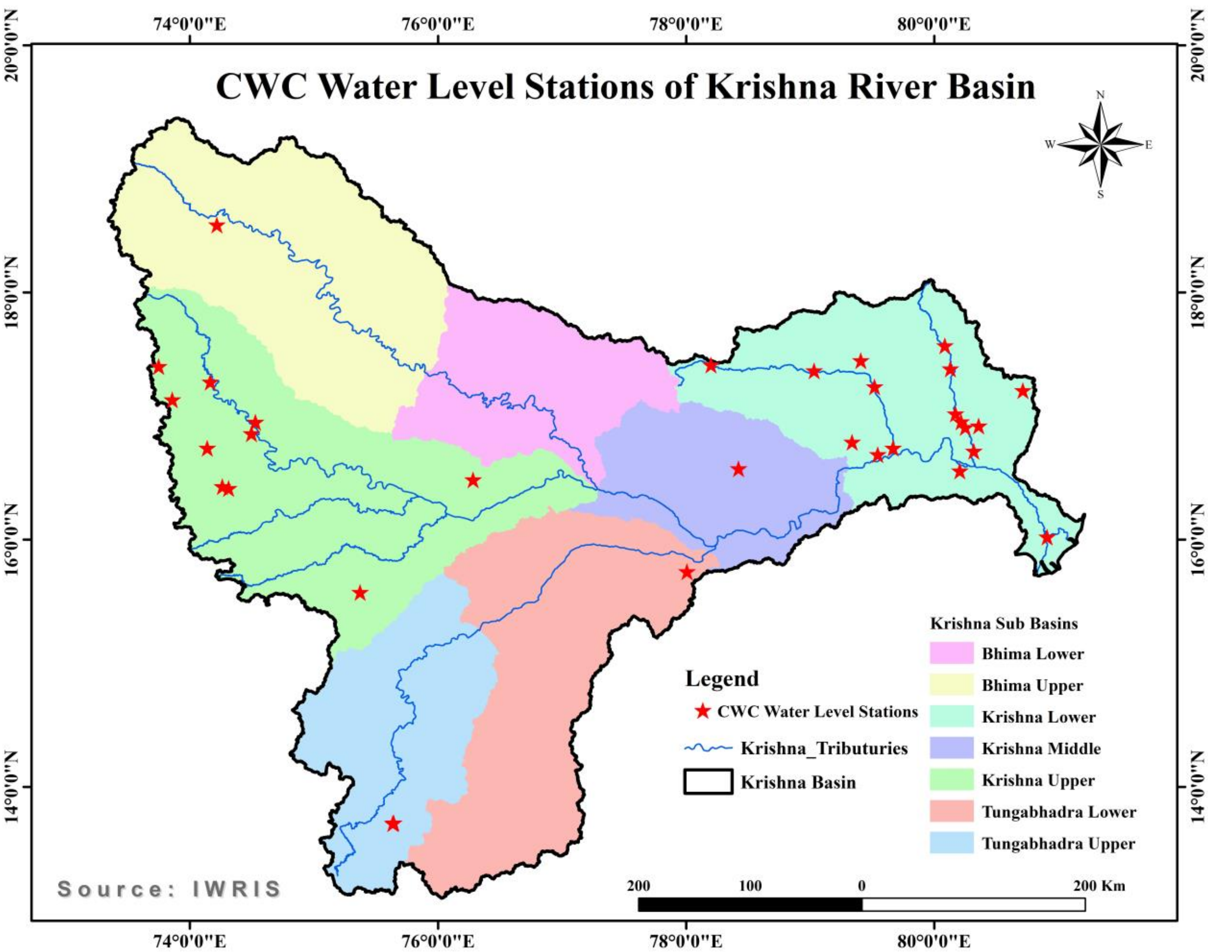

Figure 4. 2 CWC Gauge Stations for Water Level measurement over Krishna River Basin

Table 4. 2 River Water Level monitoring stations over Krishna River Basin maintained by CWC

Sl. No.	Station Name	Latitude	Longitude	Tributary	Sub-Basin	From	To
1	Anantharam	17.4469	79.4097	Musi	Lower Krishna	26/10/2016	21/04/2025
2	Avanigadda	16.02	80.91	Krishna	Lower Krishna	4/8/2018	1/11/2024
3	Bayyaram	17.5681	80.0875	Munneru	Lower Krishna	1/8/2006	30/6/2009
4	Bhadra reservoir	13.7014	75.6366	Tungabhadra	Upper Tungabadhra	21/6/2017	20/4/2025
5	Dameracherla	16.7392	79.6697	Musi	Lower Krishna	1/1/1968	21/4/2025
6	Daredu	17.3794	80.1303	Munneru	Lower Krishna	26/10/2016	5/7/2023
7	Doddipadu	15.74	78.0081	Hundri	Lower Tungabadhra	1/6/2016	21/4/2025
8	Halia	16.7882	79.3396	Halia	Lower Krishna	1/6/2016	21/4/2025
9	Keesara	16.7147	80.3203	Munneru	Lower Krishna	1/6/1965	21/4/2025
10	Khadakewada	16.4125	74.3139	Chikotra	Upper Krishna	11/6/2018	31/10/2023
11	Khamgaon	18.545	74.2186	Bhima	Bhima	12/2/2022	18/12/2024
12	Koyna	17.4	73.75	Koyna	Upper Krishna	23/9/2016	21/4/2025
13	Lakkavalli	13.7064	75.6447	Tungabhadra	Upper Tungabadhra	8/7/2017	2/1/2025
14	Lingala	16.9522	80.2183	Munneru	Lower Krishna	31/10/2019	20/4/2025
15	Madhira	16.9181	80.3589	Wyra	Lower Krishna	1/1/1970	21/4/2025
16	Mandalapadu	17.2047	80.715	Lothuvagu	Lower Krishna	1/8/2006	30/6/2009
17	Munugodu	16.5547	80.2064	Munugodu	Lower Krishna	24/10/2016	21/4/2025
18	Musi dam	17.235	79.52	Musi	Lower Krishna	26/6/2019	19/4/2025
19	Nandre	16.9492	74.5297	Yerala	Upper Krishna	19/6/2017	21/4/2025
20	Navalgund	15.5731	75.3731	Malaprabha	Upper Krishna	1/6/2015	21/4/2025
21	Nitawade	16.7386	74.1417	Panchganga	Upper Krishna	1/6/2018	31/10/2024
22	Penuganchi prolu	16.9072	80.2511	Munneru	Lower Krishna	6/7/2021	21/4/2025
23	Poduttur	17.4122	78.2014	Musi	Lower Krishna	17/1/2021	20/4/2025
24	Polampalli	17.0156	80.1717	Munneru	Lower Krishna	1/1/1970	18/4/2025
25	Samdoli	16.8564	74.4967	Warna	Upper Krishna	1/6/2015	21/4/2025
26	Songe bange	16.4281	74.2636	Dudhganga	Upper Krishna	1/6/2018	31/10/2024
27	Sudakkal	16.5728	78.4233	Dindi	Middile Krishna	1/6/2016	21/4/2025
28	Talikot	16.4836	76.2844	Doni	Upper Krishna	1/6/2015	21/4/2025
29	Valigonda	17.3656	79.0322	Musi	Lower Krishna	7/6/2019	21/4/2025
30	Veerlapalem	16.6875	79.5461	Krishna	Lower Krishna	21/10/2016	21/4/2025
31	Warna dam	17.13	73.86	Warna	Upper Krishna	23/9/2016	21/4/2025
32	Warunji	17.2728	74.1647	Koyna	Upper Krishna	1/6/2015	21/4/2025

The Krishna River Basin's sediment load monitoring network is further enriched by additional stations that enhance spatial and temporal coverage, particularly in the Upper Krishna and Upper Tungabhadra sub-basins. Stations like Airani, Kuppelur, and Lakkavalli situated in the Upper Tungabhadra region, are vital for observing upstream flow regimes influenced by the Tunga and Tungabhadra tributaries. Notably, Oollenur has historical significance with over three decades of operational data since 1973, contributing to long-term hydrological trend analysis in the Lower Tungabhadra. In the Upper Krishna region, stations such as Nandre, Terwad, and Warunji provide monitoring coverage for smaller but critical tributaries like Yerala, Panchganga, and Koyna, respectively. The Sarati station, located on the Nira River in the Bhima sub-basin, has been functional since 1966, making it one of the oldest stations in the network, offering crucial insights into regional hydrology and water management practices. Collectively, these stations support a nuanced understanding of river behavior across varied terrains and climatic zones, assisting in flood management, irrigation planning, and ecological conservation within the Krishna River system. Figure 4.3 represents CWC Gauge Stations for suspended sediment load measurement over Krishna River Basin. Table 4.3 represents sediment load monitoring stations over Krishna River Basin which were maintained by CWC.

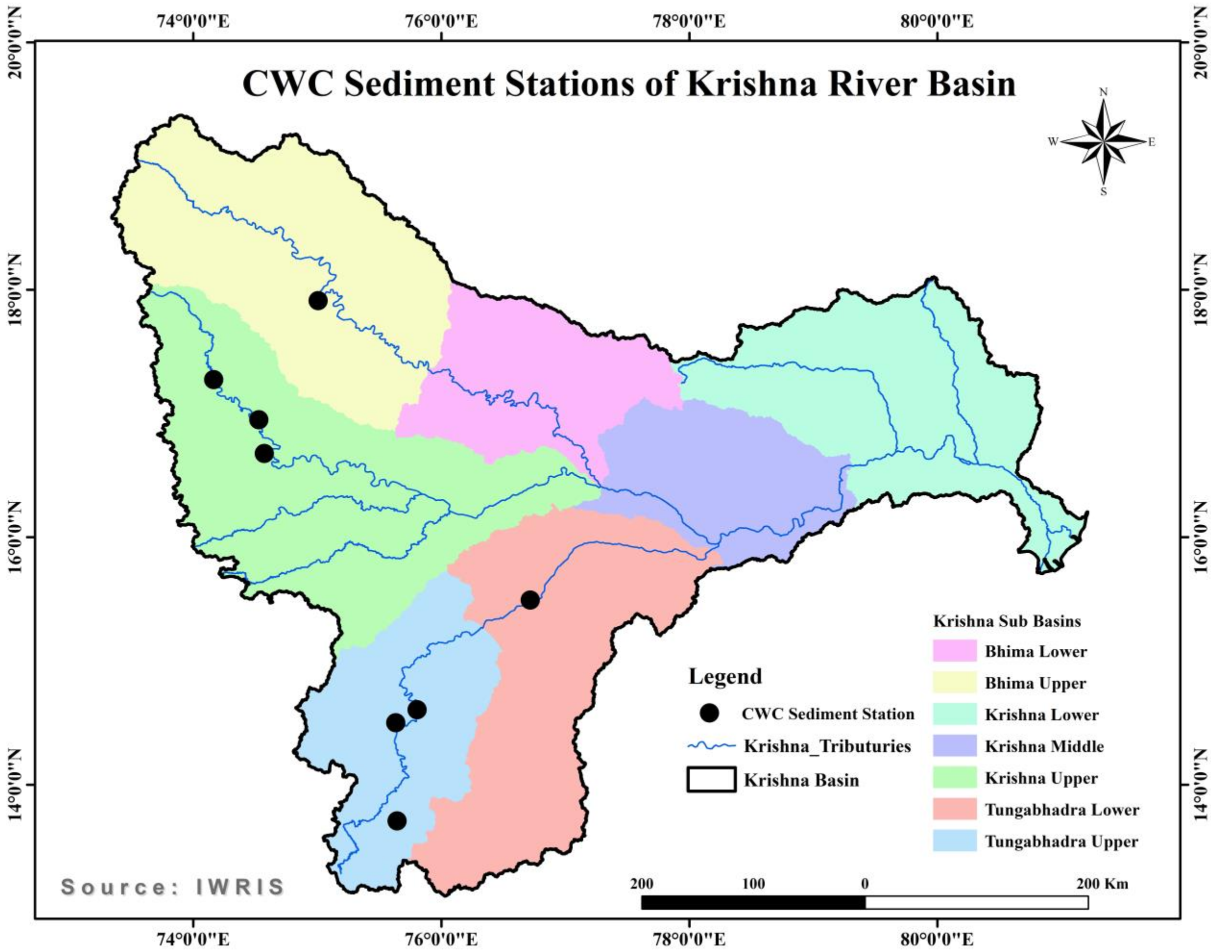

Figure 4. 3 CWC Gauge Stations for suspended sediment load measurement over Krishna River Basin

Table 4. 3 Sediment load monitoring stations over Krishna River Basin maintained by CWC

Sl. No.	Station Name	Latitude	Longitude	Tributary	Sub-Basin	From	To
1	Airani	14.6058	75.8053	Tunga	Upper Tungabadhra	28/3/2023	28/3/2023
2	Kuppelur	14.5	75.6339	Tungabhadra	Upper Tungabadhra	18/11/2013	13/11/2024
3	Lakkavalli	13.7064	75.6447	Tungabhadra	Upper Tungabadhra	15/04/2024	13/05/2024
4	Nandre	16.9492	74.5297	Yerala	Upper Krishna	1/12/2023	1/1/2024
5	Oollenur	15.4919	76.7175	Tungabhadra	Lower Tungabadhra	1/6/1973	10/3/2003
6	Sarati	17.9119	75.0075	Nira	Bhima	1/6/1966	30/10/2023
7	Terwad	16.6764	74.5742	Panchganga	Upper Krishna	1/12/2023	2/12/2023
8	Warunji	17.2728	74.1647	Koyna	Upper Krishna	1/6/1974	31/3/2025

4.2 Analysis of Discharge at Key Stations

The analysis of key stations provides detailed insights into the hydrological characteristics of the Krishna River Basin. Each station has been carefully examined to understand its unique flow patterns, seasonal variations, and the implications of observed trends. By focusing on these stations, the study highlights the spatial and temporal diversity of hydrological processes across the basin. Below is the detailed analysis of the selected monitoring stations:

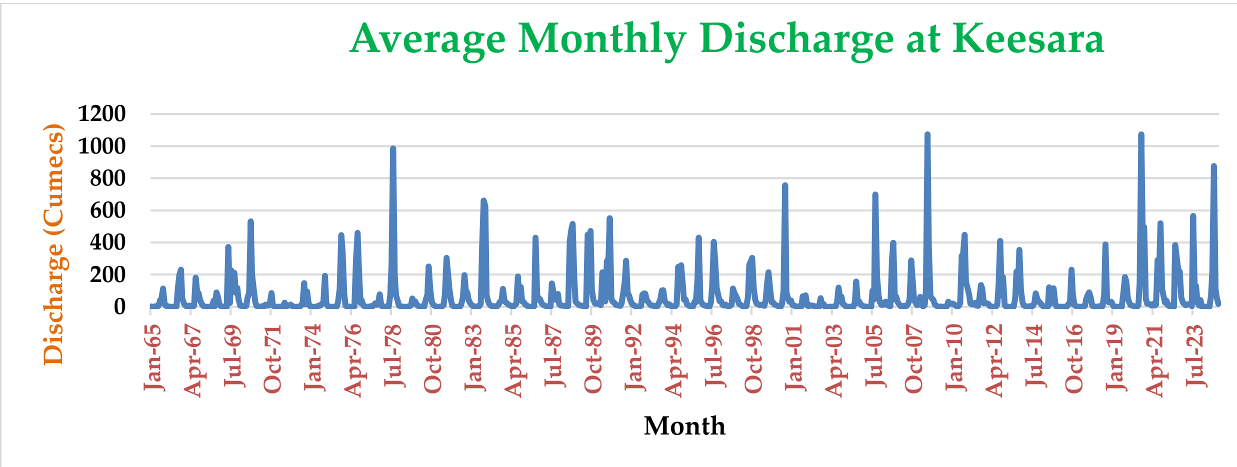

Figure 4. 4 Average monthly discharge at Keesara

Average monthly discharge at Keesara station was represented in Figure 4.4. The average monthly discharge data reveals a clear seasonal trend influenced by snowmelt and precipitation. Discharge begins to rise in March (2155.97 m^3/s) and increases sharply to reach a peak in May (4732.93 m^3/s) the highest flow recorded likely due to snowmelt from mountainous regions and spring rains. This high level continues into June (4060.10 m^3/s), before beginning a consistent decline as summer sets in. July (2526.67 m^3/s) and August (1641.66 m^3/s) mark the onset of significantly lower flows, with September (1397.30 m^3/s) showing the lowest average discharge of the year. This decline is typical of reduced rainfall and increased evaporation. A slight recovery is seen in October (1745.13 m^3/s), followed by modest increases in November (2287.10 m^3/s) and December (2477.70 m^3/s). The flow then stabilizes through the winter months with January (2544.67 m^3/s) and February (2264.67 m^3/s) maintaining steady discharge levels. This pattern illustrates the hydrological response to seasonal climatic shifts, especially the influence of snowmelt and rainfall on river discharge.

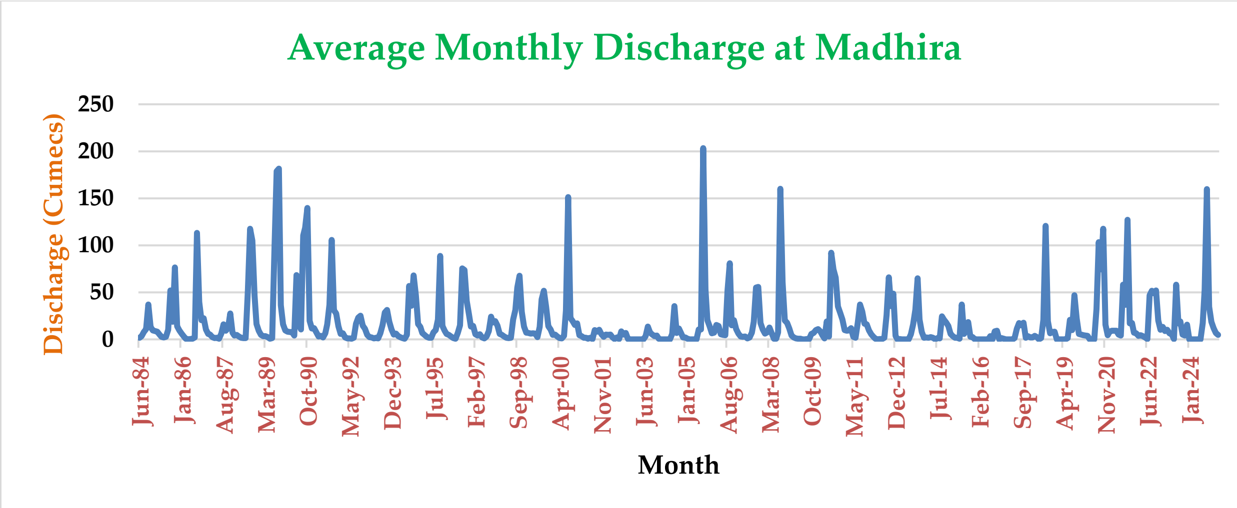

Figure 4. 5 Average monthly discharge at Madhira

The average monthly discharge at Madhira was represented in Figure 4.5. The values reveals significant seasonal and interannual variability, closely tied to the monsoon cycle. Analyzing the data from June 1984 to February 2025, we observe that the discharge values peak during the monsoon months, particularly in August and September, and are lowest during the pre-monsoon and post-monsoon months. For instance, in August 1986, the discharge reached a remarkable 113.12 m^3/sec, while in September 1989, it peaked at 181.46 m^3/sec, indicating intense monsoonal activity. Conversely, during the dry months like April and May, the discharge values often dropped below 1 m^3/sec, with April 1986 recording a minimal 0.13 m^3/sec. This pattern underscores the heavy reliance of the region's hydrology on monsoonal rains. The variability in discharge also reflects the broader climatic trends affecting the area. According to a study on rainfall trends at Madhira, the coefficient of variation (CV) for monthly rainfall ranged from 43.91% to 300.56%, highlighting significant fluctuations in precipitation patterns. Such fluctuations in discharge have profound implications for water resource management, agriculture, and flood control in the region. Understanding these patterns is crucial for developing adaptive strategies to mitigate the impacts of climate variability and ensure sustainable water availability for the local population.

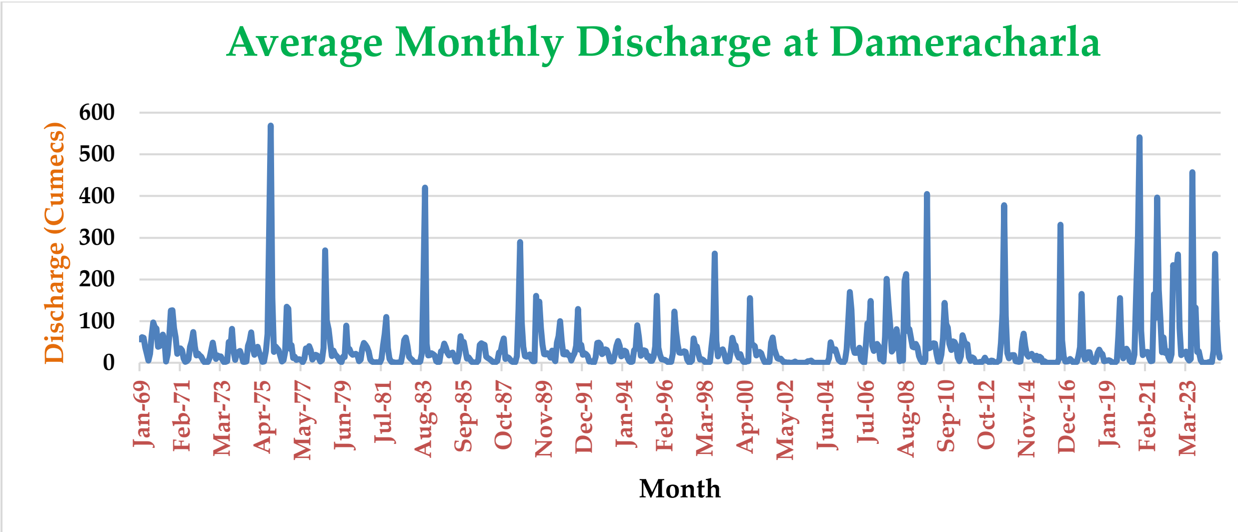

Figure 4. 6 Average monthly discharge at Dameracharla

The average monthly discharge at Dameracharla was represented in Figure 4.6. The 56-year discharge record at Damaracherla (1969–2024) reveals a textbook monsoonal regime punctuated by extreme interannual swings. Winter months (January–March) sustain moderate baseflows often between 30 and 60 m^3/s (e.g. 56 m^3/s in Jan-69; 61 m^3/s in Feb-69) before a steep pre-monsoon drawdown: April averages fall to ~37 m^3/s, May to ~21 m^3/s, and June to single figures (often <5 m^3/s). The Southwest Monsoon's arrival in July reverses this trend (~20 m^3/s), leading to dramatic peaks in August and September (averaging 65 m^3/s and 96 m^3/s, respectively, but surging to over 300 m^3/s in extreme years such as Sep-75 or Jul-23). Post-monsoon flows remain high in October (~85 m^3/s) and November (~82 m^3/s) before tapering to ~39 m^3/s in December. Wide year-to-year variability from near-zero summer flows in severe droughts to floods exceeding 500 m^3/s underscores the basin's reliance on monsoonal rains and the critical need for storage and flood-mitigation infrastructure to buffer its wet–dry extremes.

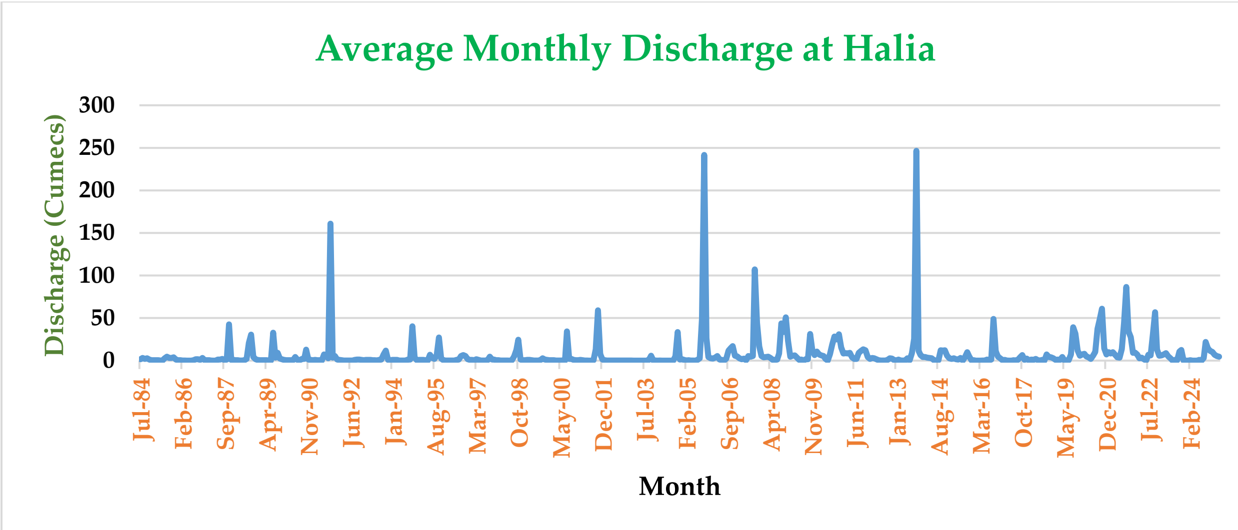

Figure 4. 7 Average monthly discharge at Halia

The average monthly discharge at Halia was represented in Figure 4.7. The average monthly discharge data at Damaracherla from 1969 to 2024 illustrates a classic monsoonal hydrological pattern, with clear seasonal fluctuations in river flow. During the dry season, from April to June, discharge values are significantly lower, with May and June seeing some of the lowest values, often dropping to below 5 m³/s. As the monsoon begins in July, the discharge starts to rise, reaching its peak in August and September, where values can reach upwards of 300 m³/s in extreme years. This surge is due to the heavy rainfall brought on by the Southwest Monsoon. Post-monsoon months, from October to December, see a decrease in flow, although the discharge remains relatively high, averaging around 85 m³/s in October and 82 m³/s in November. The flow then stabilizes during the winter months, with discharge averaging between 30 to 60 m³/s. This pattern highlights the strong dependence of the river's flow on seasonal rainfall and the importance of effective water management systems to cope with both floods and droughts.

4.3 Analysis of River Water Level at Key Stations

Upon reviewing the available datasets, it has been observed that the river water level measurements monitoring by the Central Water Commission (CWC) at various stations were not being recorded on a continuous and consistent basis. Figure 4.8 represents the Average Monthly River Water Level (m) at Keesara Station. The river water levels at Keesara station display relatively moderate fluctuations throughout the year, indicating a more stable flow regime. The highest average level is observed in September (29.08m), followed by August (28.74m) and October (28.64m), suggesting a delayed peak relative to monsoonal input. The lowest water levels occur during March (26.98m) and February (27.14m), pointing to the dry season's impact. The data indicate consistent river behavior with slight seasonal influence, emphasizing the importance of monitoring for early signs of stress or changes due to climatic or anthropogenic factors. Figure 4.9 represents the Average Monthly River Water Level (m) at Madhira station. The river water levels at Madhira gauge station show notable seasonal variation throughout the year. The highest average level is observed in July (60.16m), likely due to monsoonal inflows or upstream releases. In contrast, the lowest levels occur in August (24.30m) and June (25.27m), indicating a sharp decline immediately after the peak, potentially due to increased downstream withdrawals or reduced inflow. Moderate levels are maintained during the winter and spring months, with values ranging from 28.8m to 30.1m between January and May. This pattern suggests a strong monsoonal influence and highlights the need for adaptive water resource management during both high and low flow periods.

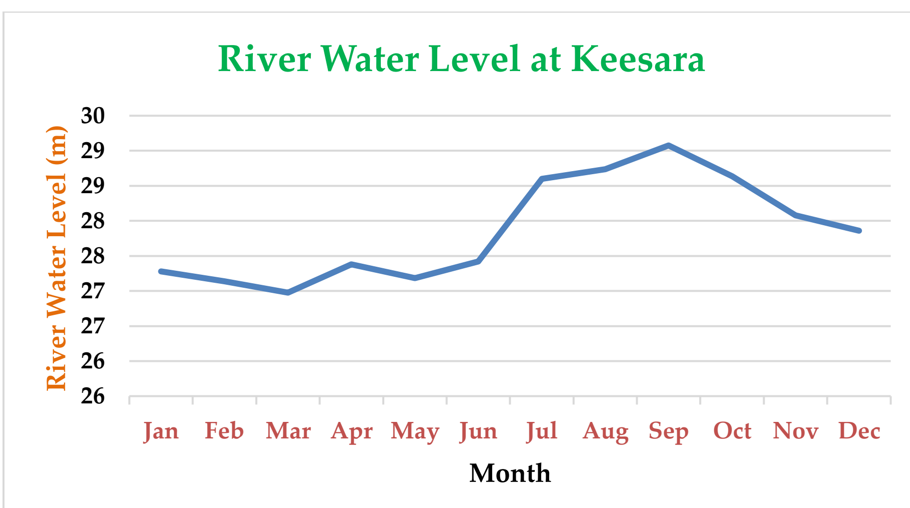

Figure 4. 8 Average Monthly River Water Level (m) at Keesara

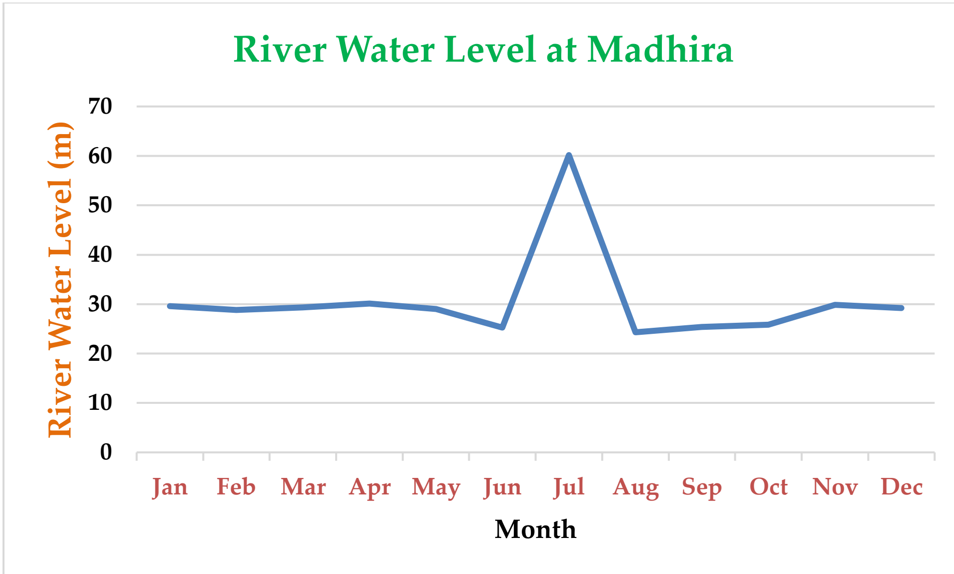

Figure 4. 9 Average Monthly River Water Level (m) at Madhira

4.4 Analysis of Suspended Sediment Load at Key Stations

It has been observed that the suspended sediment measurements monitoring by the Central Water Commission (CWC) at various stations were not being recorded on a continuous and consistent basis as like as River Water Level. Figure 4.10 represents suspended sediment (mg/L) at Warunji station. Suspended sediment concentrations at Warunji station exhibit significant seasonal variation, closely tied to monsoonal rainfall and runoff patterns. The peak occurs in July (170.01 mg/L), aligning with maximum flow and erosion activity, followed by elevated levels in August (79.52 mg/L) and June (74.86 mg/L). These high sediment loads are indicative of intense surface runoff and upstream soil disturbance during the rainy season. In contrast, January to May and November to December show markedly lower concentrations, typically below 13 mg/L, reflecting stable flow conditions with minimal erosion. This data underscores the importance of sediment monitoring for managing reservoir siltation and maintaining water quality in the basin. Figure 4.11 represents suspended sediment (mg/L) at Sarati station. The suspended sediment levels at Sarati station reveal sharp seasonal dynamics, with a distinct peak during the monsoon months. September (230.78 mg/L) records the highest sediment concentration, followed closely by June (147.60 mg/L), August (141.78 mg/L), and July (134.19 mg/L). These elevated values suggest intense erosion and runoff during the peak rainfall period, contributing significantly to sediment transport. In contrast, January to April consistently show low sediment levels—below 9 mg/L—indicating minimal disturbance and stable flow conditions. The abrupt rise beginning in May

(21.98 mg/L) and declining after October (129.77 mg/L) further reinforces the influence of seasonal precipitation. This pattern emphasizes the need for targeted sediment control strategies, especially during the monsoon to protect downstream infrastructure and aquatic habitats.

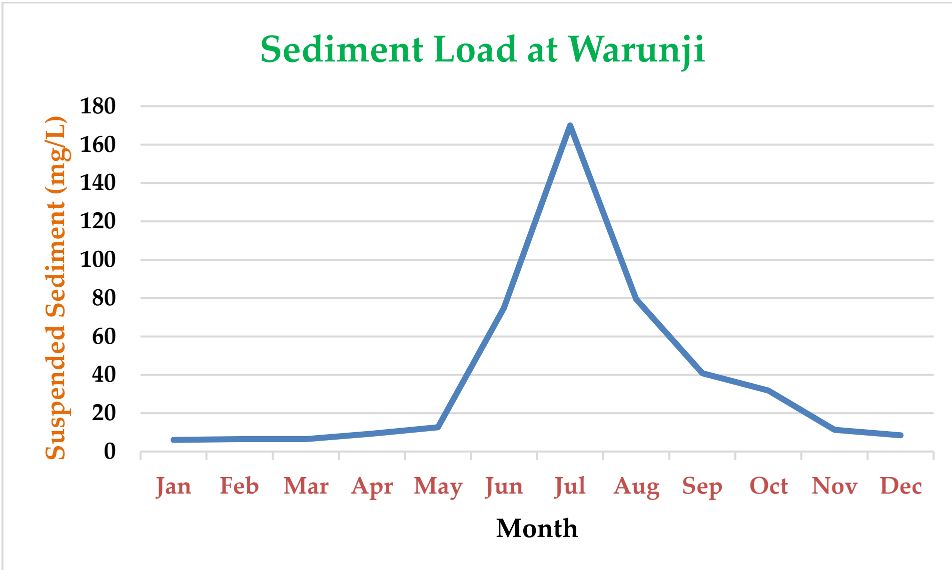

Figure 4. 10 Suspended Sediment (mg/L) at Warunji

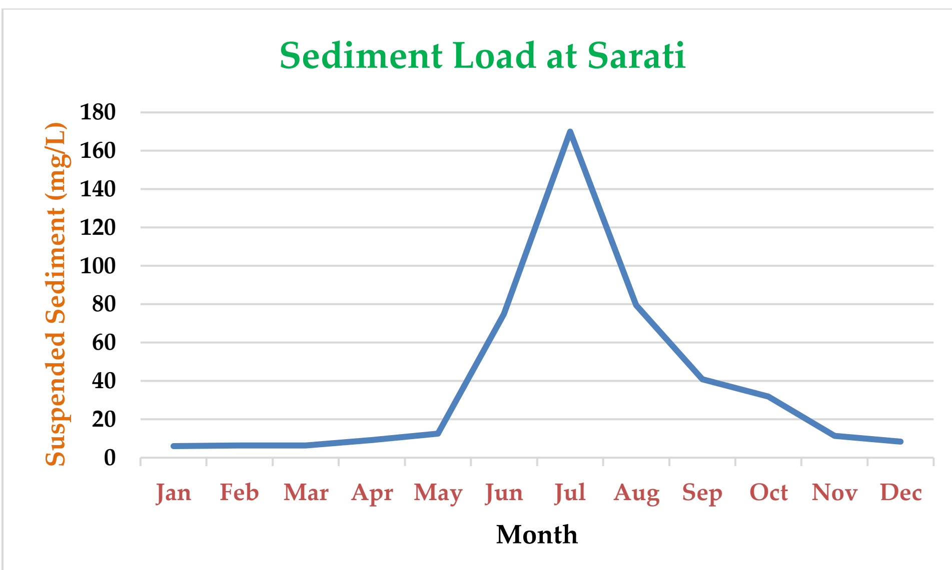

Figure 4. 11 Suspended Sediment (mg/L) at Sarati

Chapter 5: Groundwater Data

5.1 Data Source and Methodology

Groundwater is essential for obtaining freshwater and plays a crucial role in promoting sustainable development in agriculture, industry, and the socioeconomic status of an area. However, due to the extensive use of groundwater, many areas over Krishna River Basin were facing a decline in their groundwater levels. Four seasons were considered for identifying the trends in groundwater levels i.e. Post-Monsoon Rabi, Monsoon, Pre-Monsoon and Post-Monsoon Kharif seasons from 1996 to 2018. The assessment of groundwater resources within the Krishna River Basin, as detailed in this chapter, is founded on data sourced from the India Water Resource Information System (India-WRIS) website. To ensure the accuracy and reliability of our analysis, the locations of the monitoring sites used in this study were meticulously cross-referenced with a comprehensive report on groundwater published by the Central Ground Water Board (CGWB). The outcomes of the study are going to help the groundwater development authorities in the respective states for resource management, water supply planning, groundwater recharge management, environmental protection and policy formulation and regulation. The data proves valuable insights into the dynamics of groundwater resources within the Krishna River Basin. The locations of groundwater observation wells are shown in Figure 5.1.

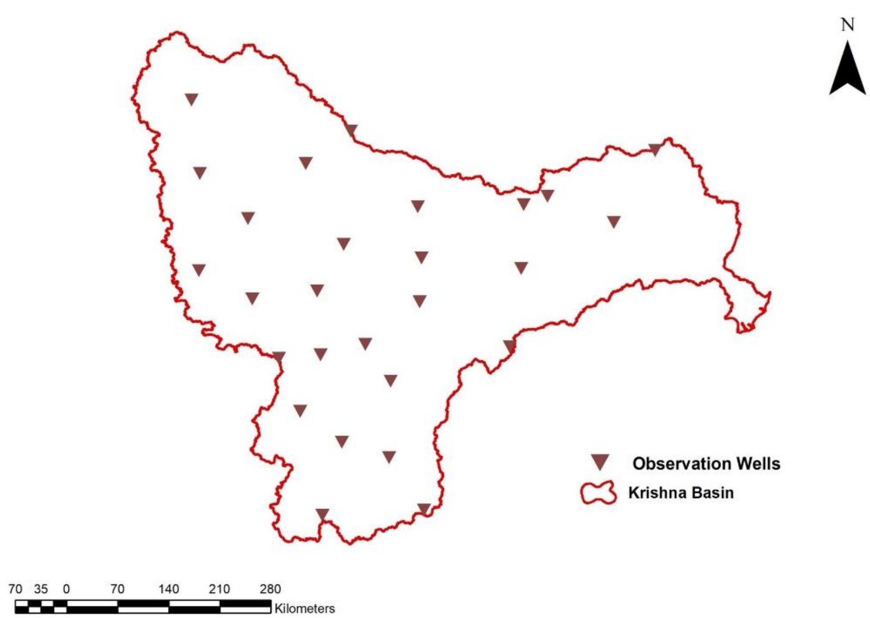

Figure 5. 1 Groundwater Level Observation well data over Krishna Basin

5.2 Spatial Variation of Groundwater Levels

This section delves into the spatial variations in groundwater levels across the Krishna River Basin. Table 5.1 represents the groundwater levels (mbgl) for the selected stations over Krishna River Basin.

Table 5. 1 the groundwater levels (mbgl) for the selected stations over Krishna River Basin

ID	Station Name	Monsoon (mbgl)	Post Monsoon Rabi (mbgl)	Post Monsoon Kharif (mbgl)	Premonsoon (mbgl)
1	Kurnool	4.58	3.23	3.07	4.99
2	Bagalkot	5.46	5.75	5.49	7.28
3	Belgaum	4.93	5.59	4.55	6.86
4	Bellary	6.04	6.24	5.82	6.40
5	Bijapur	0.76	4.38	1.77	5.70
6	Chikmagalur	4.72	5.62	5.01	6.48
7	Chitradurga	5.97	6.13	5.57	7.02
8	Davanagere	4.87	5.49	4.80	5.76
9	Dharwad	6.52	7.26	6.46	8.12
10	Gadag	7.06	8.60	8.29	8.97
11	Gulbarga	4.36	4.81	3.91	7.14
12	Haveri	5.64	7.41	6.51	8.59
13	Koppal	5.05	5.12	4.83	5.91
14	Raichur	3.88	3.50	3.27	4.47
15	Tumkur	7.34	7.71	6.77	8.14
16	Yadgir	4.20	4.34	3.63	5.57
17	Kolhapur	2.31	4.00	3.03	5.31
18	Osmanabad	4.26	5.74	4.45	6.85
19	Pune	3.23	4.08	3.34	5.34
20	Sangli	3.93	4.88	3.61	5.93
21	Satara	3.37	4.77	3.56	5.96
22	Solapur	5.04	5.29	4.28	6.84
23	Hyderabad	5.42	6.47	4.96	8.95
24	Mahbubnagar	7.34	8.08	6.76	9.65
25	Nalgonda	5.59	5.66	4.80	7.09
26	Rangareddi	6.31	7.62	6.33	9.43
27	Warangal	4.46	5.69	4.54	7.25

The groundwater level data across the Krishna River Basin shows distinct seasonal and spatial variations, reflecting the interplay between rainfall, recharge capacity, land use, and groundwater extraction. During the monsoon season, most districts experience relatively shallow groundwater levels due to active recharge from rainfall. For instance, Bijapur shows the shallowest depth (0.76 mbgl), indicating high recharge or a perched aquifer system, whereas Tumkur records deeper levels (7.34 mbgl), possibly due to limited infiltration or high groundwater withdrawal. As the year progresses into the post-monsoon Rabi season, groundwater levels in several districts start to decline slightly, reflecting the beginning of irrigation demand. Districts like Gadag (8.60 mbgl) and Tumkur (7.71 mbgl) experience a marked drop, suggesting heavy dependence on groundwater for Rabi crops. This depletion trend intensifies during the post-monsoon Kharif and pre-monsoon seasons. By the pre-monsoon period, which is the driest part of the year, groundwater levels reach their lowest, indicating critical stress. Districts such as Mahbubnagar (9.64 mbgl), Hyderabad (8.95 mbgl), and Gadag (8.97 mbgl) record dangerously low levels, which may signal overexploitation and declining aquifer health. Spatially, western districts like Kolhapur, Sangli, and Belgaum fare better due to higher rainfall and more permeable soils, sustaining groundwater levels below 5 mbgl for most of the year. In contrast, eastern and central districts, particularly those with growing urban areas such as Hyderabad, Rangareddi, and Warangal, show persistent groundwater stress. These regions may be affected by reduced recharge due to impervious surfaces and increasing water demand. Overall, the data suggests that while some regions of the Krishna River Basin benefit from favorable hydrogeological conditions, others are approaching critical groundwater depletion. There is an urgent need for interventions such as rainwater harvesting, crop pattern modification toward less water-intensive farming, and managed aquifer recharge. Regular monitoring and zoning based on groundwater availability can also help ensure sustainable management across this vital river basin. Figure 5.2 represents the spatial variation of groundwater level over Krishna River Basin (1996 to 2018) in Pre-monsoon period, Figure 5.3 represents the spatial variation of groundwater level over Krishna River Basin (1996 to 2018) in monsoon period, Figure 5.4 represents the spatial variation of groundwater level over Krishna River Basin (1996 to 2018) in Post-monsoon Kharif and Figure 5.5 represents the spatial variation of groundwater level over Krishna River Basin (1996 to 2018) in Post-monsoon Rabi periods.

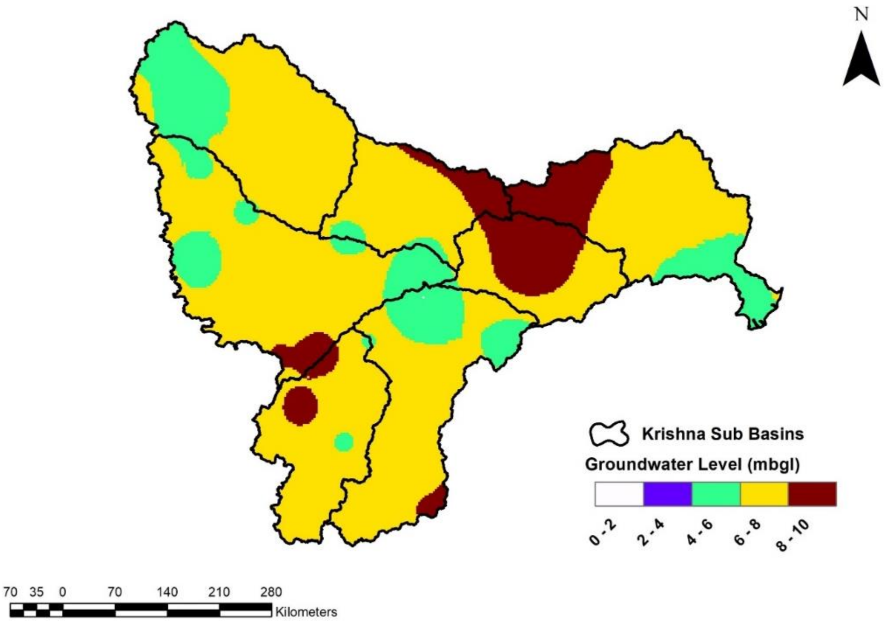

Figure 5. 2 Spatial Variation of Groundwater level over Krishna River Basin (1996 to 2018) in Pre-monsoon period

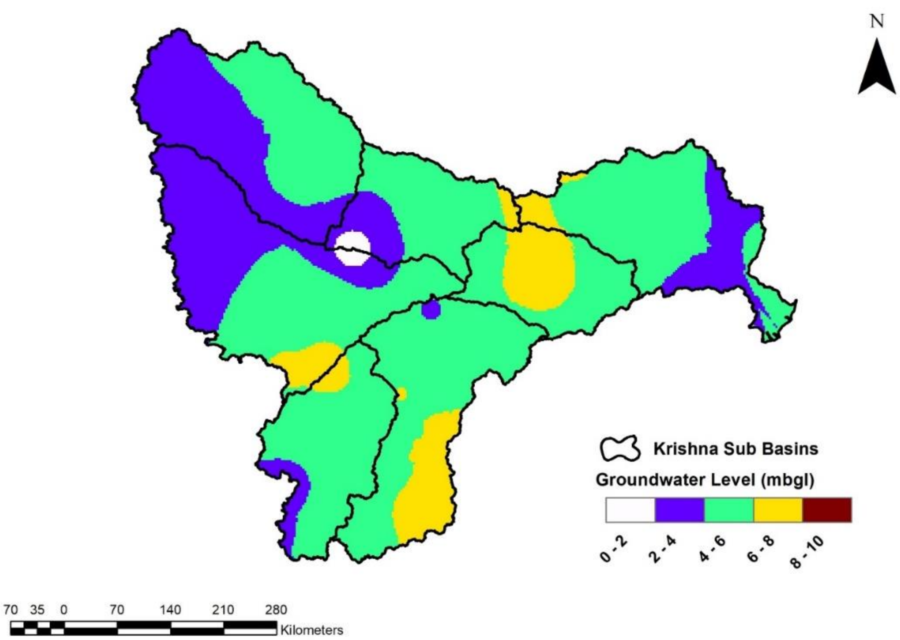

Figure 5. 3 Spatial Variation of Groundwater level over Krishna River Basin (1996 to 2018) in Monsoon period

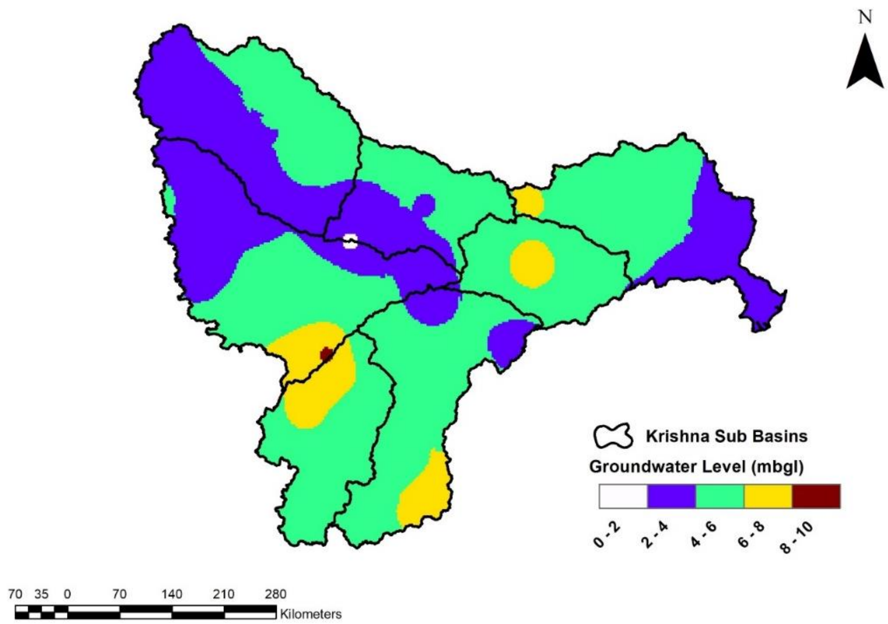

Figure 5. 4 Spatial Variation of Groundwater level over Krishna River Basin (1996 to 2018) in Post-monsoon Kharif period

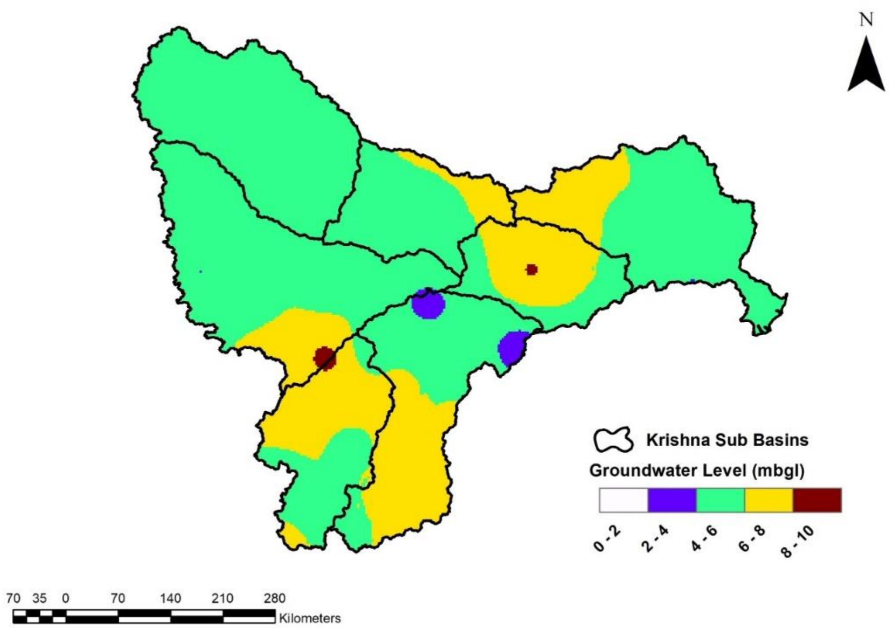

Figure 5. 5 Spatial Variation of Groundwater level over Krishna River Basin (1996 to 2018) in Post-monsoon Rabi period

Chapter 6: Evapotranspiration Data

A decadal analysis of evapotranspiration (ET) from 1981 to 2023 across the Krishna River Basin reveals significant spatial and temporal patterns linked to climatic shifts, land use changes, and vegetation dynamics. Average Annual Evapotranspiration for the Decade 1981–1990 depicted in Figure 6.1 represents the spatial distribution of evapotranspiration (ET) across the Krishna River Basin**,** based on GLEAM data. This map illustrates the average annual evapotranspiration (ET) across the Krishna River Basin for the decade 1981–1990, showing a clear spatial gradient in water loss through evaporation and plant transpiration. ET values range from below 265 mm/year in the eastern and central parts of the basin to above 1328 mm/year in the southwestern regions, particularly near the Western Ghats. The higher ET values in the southwest can be attributed to dense vegetation, higher rainfall, and more humid conditions, while the lower ET values in the north and east reflect drier climates and possibly more arid land cover types. This spatial variation highlights the importance of regional climate and land use in influencing evapotranspiration, and underscores the need to factor in ET in water resource planning, especially in agricultural zones where efficient irrigation practices can help balance water demand with natural loss rates. Figure 6.2 represents the average annual evapotranspiration for 1991–2000 over Krishna River Basin, similarly Figure 6.3, Figure 6.4 and Figure 6.5 represents the average annual evapotranspiration for 2001–2010, 2011-2020 and 2021-23 respectively. ET values were moderate, with higher intensities localized in the southernmost regions, particularly along the Western Ghats. Moving into the 1991–2000 decade, a subtle intensification is evident, with ET hot spots expanding and central basin areas showing moderate increases. This trend continues and becomes more prominent in the 2001–2010 period, where the spatial footprint of high ET zones spreads toward the central and northern basin areas, indicating rising atmospheric demand, likely driven by warming and agricultural intensification. In the latest period (2021–2023), the ET distribution remains widespread, with many areas across the basin maintaining higher ET rates—especially in the southern and central zones—though some stabilization is seen in localized pockets. This progression suggests increasing pressure on the basin's water resources due to elevated water loss through evaporation and plant transpiration, and it highlights the critical need to integrate ET data into regional water budgeting, irrigation planning, and climate resilience strategies.

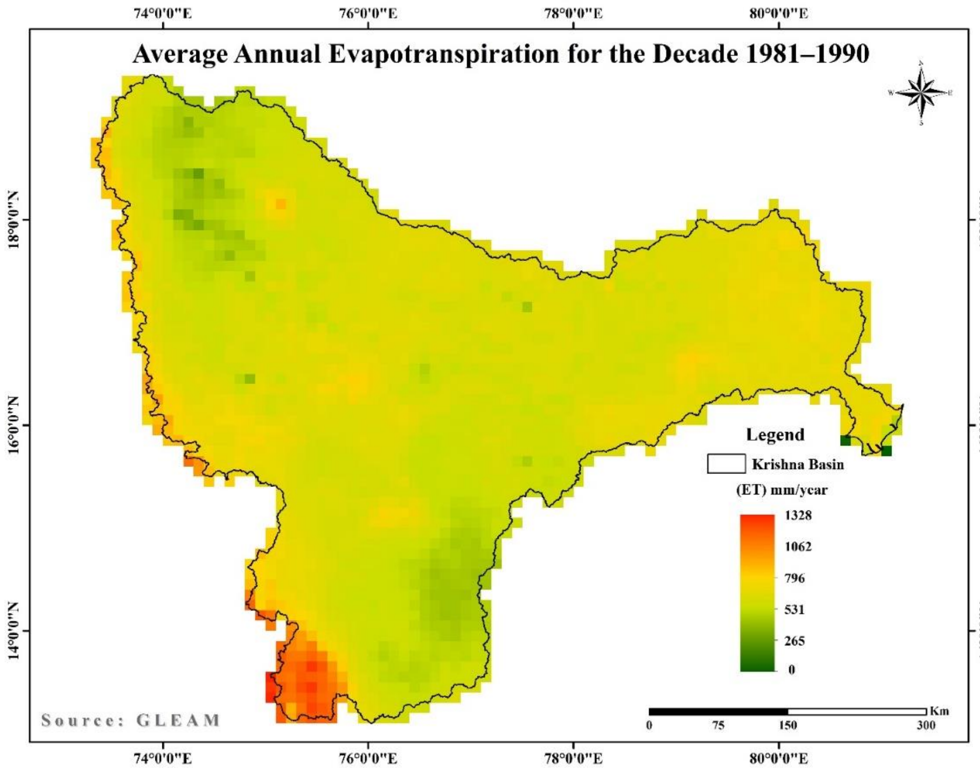

Figure 6. 1 Average Annual Evapotranspiration for 1981–1990 over Krishna River Basin

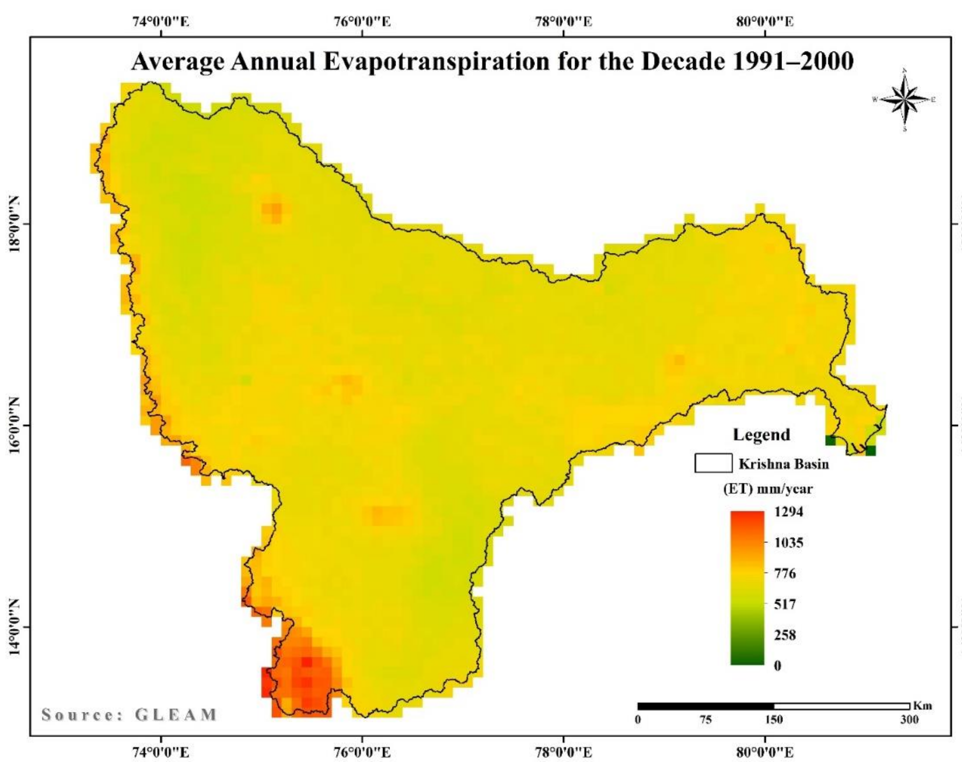

Figure 6. 2 Average Annual Evapotranspiration for 1991–2000 over Krishna River Basin

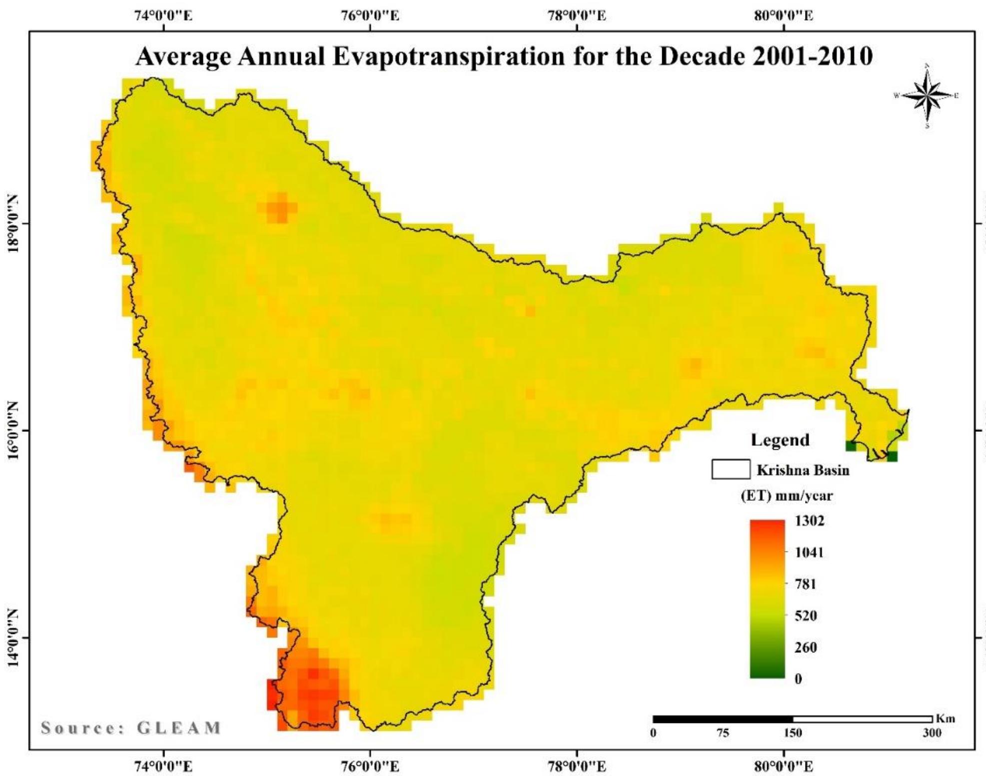

Figure 6. 3 Average Annual Evapotranspiration for 2001–2010 over Krishna River Basin

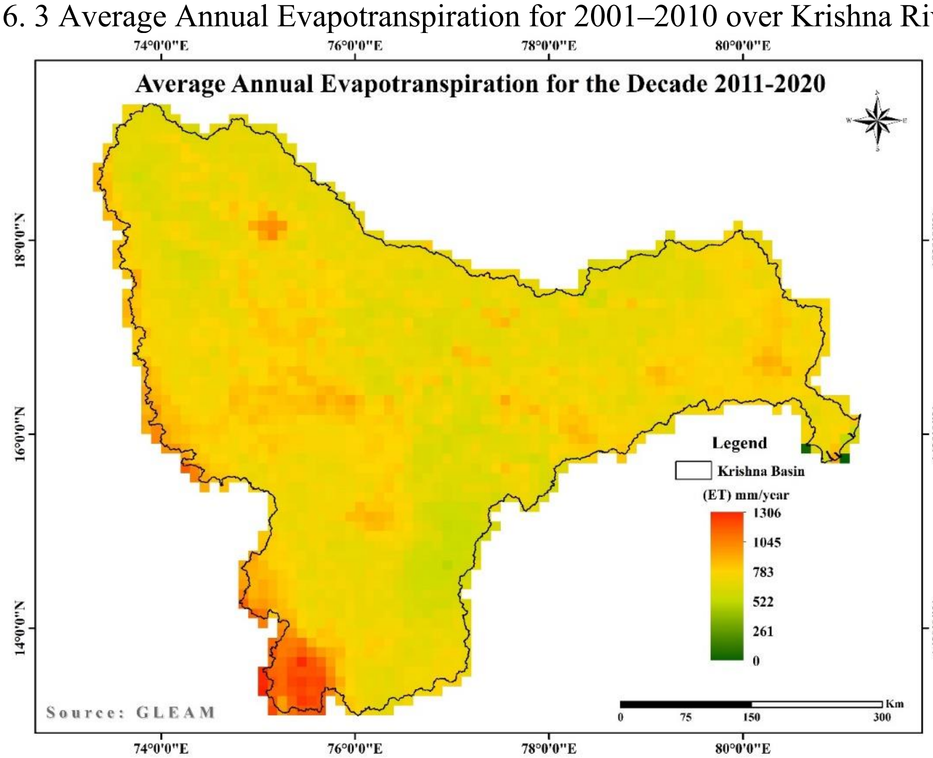

Figure 6. 4 Average Annual Evapotranspiration for 2011–2020 over Krishna River Basin

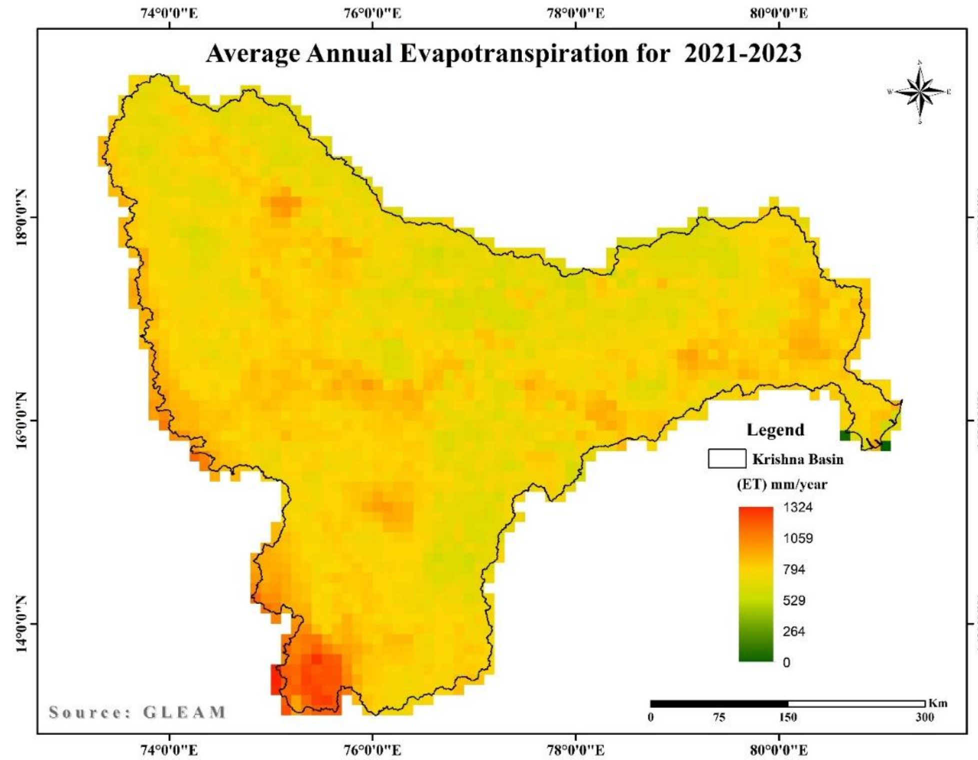

Figure 6. 5 Table 5. 2Average Annual Evapotranspiration for 2021–2023 over Krishna River Basin

Chapter 7: Conclusions and Recommendations

7.1 Conclusions

The comprehensive hydrological analysis of the Krishna River Basin reveals complex interrelations among streamflow, groundwater dynamics, sediment load, and evapotranspiration patterns across spatial and temporal scales. The study underscores the heavy dependence of the basin's water systems on the monsoon, which governs streamflow peaks, groundwater recharge, and sediment transport. However, this reliance also exposes the region to significant hydrological variability and risk, particularly under the influence of climate change and increasing anthropogenic pressures. A key finding is the seasonal depletion of groundwater resources, especially during the pre-monsoon period, with critical stress levels observed in districts like Mahbubnagar, Gadag, and Hyderabad. These patterns suggest unsustainable extraction trends that require urgent attention. Similarly, sediment analysis at key stations indicates intense erosion and sediment flux during the monsoon months, highlighting the need for catchment area protection and upstream soil conservation efforts. The evapotranspiration data further emphasizes the role of land use and climate in influencing water loss, especially in agricultural zones. This necessitates improved irrigation efficiency and better water budgeting to ensure sustainable supply for crops and other uses.

7.2 Recommendations:

Strengthen Monitoring Infrastructure:

Expand and modernize hydrological and groundwater monitoring networks to ensure consistent, real-time data availability across all sub-basins.

Groundwater Regulation and Recharge:

Promote managed aquifer recharge (MAR) techniques, including check dams, recharge wells, and rooftop Rainwater harvesting, especially in overexploited zones.

Land Use and Soil Conservation:

Implement soil erosion control measures in high-sediment-yield areas through reforestation, contour bunding, and regulated agricultural practices.

Crop Pattern Modification:

Encourage a shift to less water-intensive crops, particularly in groundwater-stressed districts, and incentivize efficient irrigation methods such as drip and sprinkler systems.

Integrated Water Resources Management (IWRM):

Develop basin-wide frameworks that integrate surface water, groundwater, and climate data for holistic planning, supported by stakeholder engagement and interstate collaboration.

Policy and Institutional Reforms:

Support the development of groundwater zoning policies and enforce restrictions on borewell drilling in critical areas, backed by state-level regulatory bodies.

Public Awareness and Community Participation:

Foster public engagement through education, capacity building, and community-based water governance initiatives to strengthen decentralized water management.

This chapter concludes by reiterating that sustainable water resource management in the Krishna Basin requires a coordinated approach that blends scientific insight, institutional support, and participatory governance.

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