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

Hydraulic Status of Godavari River Basin

December 2024

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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 Mahanadi River Basin Management and Studies (cMahanadi)

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

www.cGodavari.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 CSIR-NEERI (Lead Institute) and IIT Hyderabad (Fellow Institute) under the supervision of cGanga at IIT Kanpur. It is 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.

Centre for the Godavari River Basin
Management and Studies (cGodavari)
CSIR-NEERI, IIT Hyderabad

Introduction

The river Godavari is the second largest in the country and the largest in Southern India. It rises in the Sahyadri hills at an altitude of about 1067 m near Trimbakeshwar in the Nashik district of Maharashtra State and flows for about 1465 km in a general southeastern direction through the States of Maharashtra, Telangana and Andhra Pradesh before joining the Bay of Bengal at about 97 km south of Rajahmundry in Andhra Pradesh. The basin extends over an area of 312813 km² covering the States of Maharashtra, Karnataka, Madhya Pradesh, Chhattisgarh, Odisha, Telangana and Andhra Pradesh which is nearly 10% of the total geographical area of the country. The major tributaries joining the Godavari are the Pravara, the Purna, the Manjra, the Maner, the Pranhita, the Penganga, the Wardha, the Indravati and the Sabari.

The River Godavari plays a crucial role in the water supply, irrigation, and flood management of the region. Given its size and variability in flow, understanding the hydraulic behavior of the river is essential for effective water resource management. This report outlines hydraulic data of Godavari river and its tributaries based on discharge and cross-sectional data collected at various locations along the river basin.

River hydraulics is the study of moving water in open channels under the influence of gravity. A river's morphology, cross-section, discharge, slope, type of flow, flow depth, velocity, and direction of flow at any location are analysed. Hydraulics can help locate habitat areas and erosion/deposition patterns. Any changes to the river valley (anthropogenic or natural) over time will also affect the hydraulics of the river system
(River Hydraulics | Josh Wyrick.).

Natural factors include excessive precipitation, tectonic movements, cyclonic disruptions, among others. Anthropogenic factors include sand mining, deforestation, concretization of river banks, damming and diversion of river water, etc. Designing of dams, spillways, levees, etc. needs not only hydrological but also *hydraulic* computations. Hydraulic measurements such as water level, currents, waves, temperature, and salinity are needed for planning, designing, monitoring of reclamation works for short and long-term impact assessment. For example, extreme water levels primarily determine the heights of the defence structures and the level of the reclamation. *(Hydraulic data include measurements regarding water level, currents and waves, which can be influenced by weather-related and environmental events)*

Data Collection

The cross-sectional data was collected from CWC for 147 stations along the Godavari River and tributaries. These data include elevations at different points of the riverbed (CGL) at various reduced distances. Daily discharge data was collected for 102 gauging stations for different time periods.

We have selected 20 stations across the Godavari River Basin, covering all the sub-basins based on the availability of data.

S.No	Station Name	Station Code	Sub Basin	Latitude	Longitude
1	Ashti	AGH40A4	Weinganga	19°41'12"	79°47'02"
2	Bamni	AGH30E2	Wardha	19°48'50"	79°22'46"
3	Bhatpalli	AGH10L0	Pranhita	19°19'47"	79°30'15"
4	Chindnar	AGG00N7	Indravati Subbasin	19°05'00"	81°18'00"
5	Degloor	AGP20F4	Manjira	18°33'43"	77°34'59"
6	Gandlapet	AGM00G6	Pranhita	18°49'45"	78°26'10"
7	Hivra	AGH30Q1	Wardha	20°32'50"	78°19'29"
8	Jagdalpur	AGG00R9	Indravati Subbasin	19°06'29"	82°01'22"
9	Murthahandi	AGC40E9	Lower Godavari Subbasin	19°03'34"	82°16'33"
10	Nandgaon	AGH3AF4	Wardha	20°31'32"	78°48'32"
11	Pachegaon	AGU00D3	Upper Godavari Subbasin	19°32'04"	74°50'02"
12	Pathagudem	AGG00B5	Indravati Subbasin	18°49'00"	80°21'00"
13	Perur	AG000G7	Lower Godavari Subbasin	18°31'57"	80°22'59"
14	Polavaram	AG000C3	Lower Godavari Subbasin	17°15'06"	81°39'09"
15	Sakmur	AGH30B6	Wardha	19°33'38"	79°36'55"
16	Saradaput	AGC00N4	Lower Godavari Subbasin	18°36'45"	82°08'34"
17	Sonarpal	AGG91F2	Indravati Subbasin	19°16'11"	81°53'02"
18	Tumnar	AGG60B1	Indravati Subbasin	19°00'44"	81°13'57"
19	Yelli	AG000P3	Middle Godavari Subbasin	19°02'39"	77°27'11"
20	Zari	AGR10C6	Middle Godavari Subbasin	19°23'44"	76°45'16"

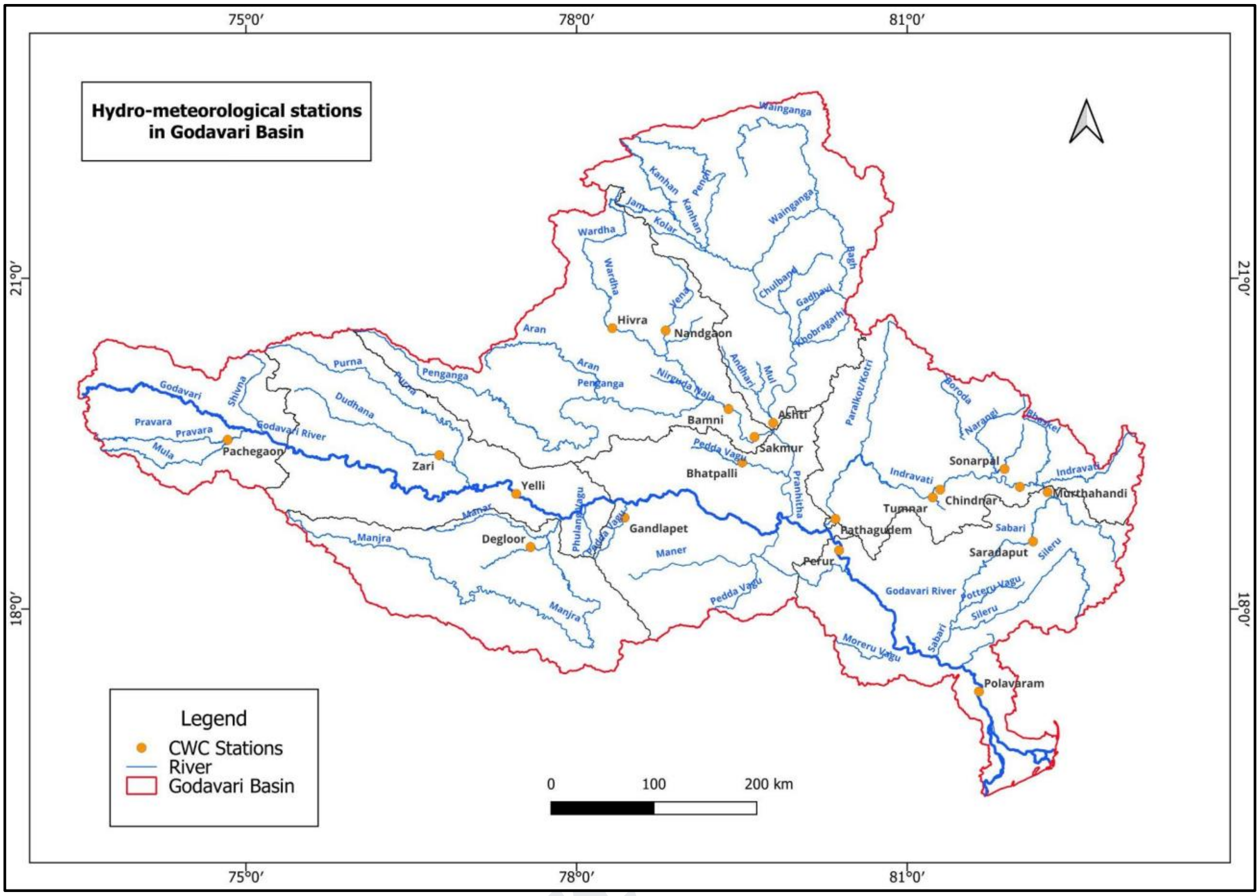


Figure:1 Hydrometeorological Stations in the Godavari River Basin

Analysis of Discharge Data

Flow discharge in a natural stream has significant variance in time and space scale. Whereas, flow regime along a riverbed may change from, hour-to-hour, days to days and so on.To understand flow characteristics and hydraulic regime related to the natural stream, precise measurements are needed. Therefore, management of water resources, especially surface water is a challenging task for engineers and stakeholders as well.

Annual Hydrographs

Annual hydrographs depict the flow variation within a river over a year, highlighting the impact of seasonal changes on river discharge systems.

Water usually flows much more in some seasons, creating periods of drought and floods at extremes. The pattern of water flow in a river is the “annual hydrograph.” Its shape depends on the precipitation patterns and shape of the above-stream catchment. Water flow management is often done with dams, straightening some river sections, and treatment of wastewater.

Seasonal Variations

These variations are influenced by climatic factors such as precipitation, temperature, and evapotranspiration.

Base Flow

Base flow is the regular, sustained contribution to a river's discharge from sources like groundwater and delayed throughflow. It maintains river ecosystems during dry periods and is a critical factor in water resource management.

Direct Runoff

Direct runoff is the portion of river flow that enters the river channel directly from the surface. This component highly affects rainfall intensity and significantly affects the river's discharge during and immediately after rainfall events.

The sources of stream flow include rain, snow and springs. The flow might be seasonal or perennial. Steam reaches flow through steep canyons or across broad flood plains. Over the course of their lifetime, a stream might pass through a range of habitat types: meadows, forests, chaparral, savannas, grasslands, and tidal marshes.

Because stream flows depend on a number of sources, their flow rates can vary dramatically, but often depend on precipitation as an important driver of variation. Of course, even the idea of a normal rainfall year is a widely accepted misnomer—no yearly patterns reflect "the average." In spite of some dominant seasonal trends, rain events patterns vary dramatically from year to year. The variation in stream behavior then influences the variations in the ecology of streams. Understanding the flood-return intervals, for example, allow planners to reduce the risk of catastrophic flooding.

One of the simplest ways to characterize flow in a stream channel is to quantify discharge through time. Discharge, usually expressed in cubic meters or cubic feet per second, is volume of flow per unit time. Discharge is calculated by measuring the velocity, or rate of flow (meters per second) within a cross-sectional area (square meters) calculated from mean width and depth of the flow. Continuous records of discharge come from stream-gaging stations where calibrated rating curves are used to convert measurements of stage, or flow depth, into discharge. These continuous records can then be used to construct a hydrograph, which is a plot of discharge versus time. A flood hydrograph represents a discrete event, whereas an annual hydrograph represents variations in discharge over the course of a year. An average annual hydrograph uses the average of flow for each day of the year based on multiple years of record.

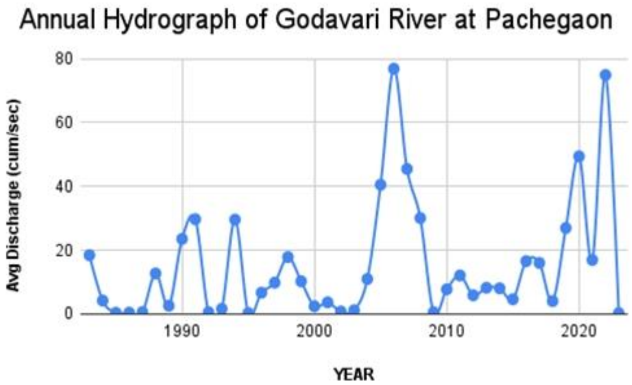
Trends and Variability of Peak Discharge Years Across Stations (1980-2020)

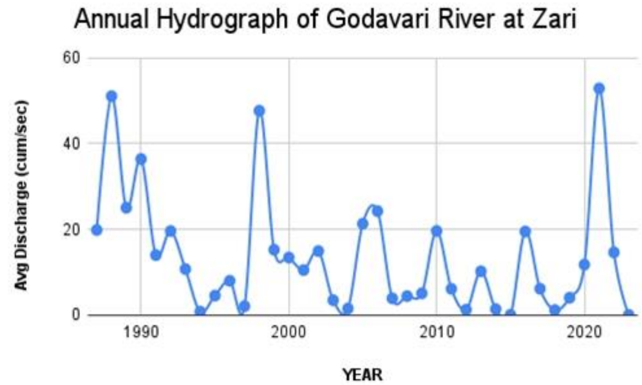
The peak discharge years across different stations mostly fall between 1980 and 2020, with a few key years standing out, like 1985, 1995, 2010, 2015, and 2020. These years show a pattern of major events, but the highest flow levels happen in different years at different stations. For instance, the highest peaks at Perur and Polavaram were recorded in 1980 and 2010, reaching up to 3800 cumecs and 5800 cumecs, respectively. On the other hand, stations like Yelli and Bamni saw their highest peaks in 1985, at 475 cumecs and 850 cumecs. This shows that extreme flow events can vary a lot depending on the station, with each one being affected by its own local factors and weather patterns at different times.

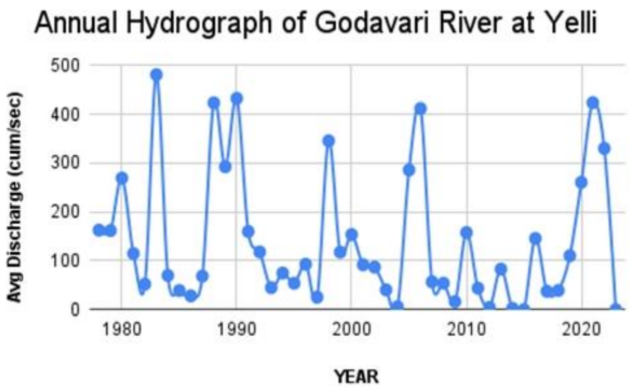
Flow of Water

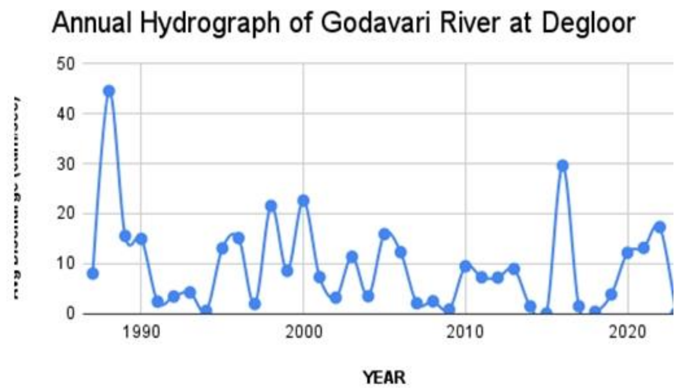
Most of our planned use of a river and its channel depends on knowledge of its *hydrograph*, data on its discharge or water level over time. These data, collected over as many years as possible, provide a basis for estimating the maxima and minima as well as all of the seasonal changes in runoffs and levels. The hydrograph supplies essential information for all water users and designers of all structures in the channel.

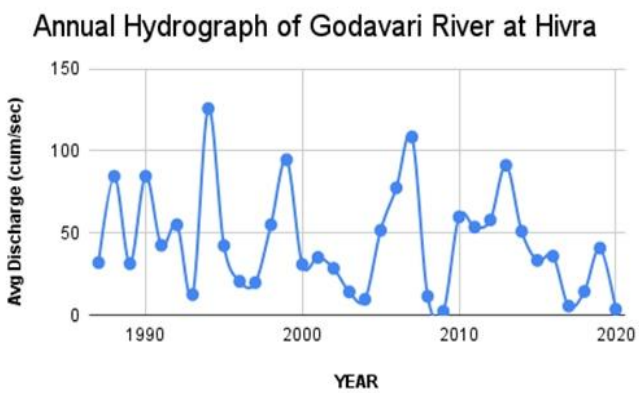
Source [Hydrograph - an overview | ScienceDirect Topics]

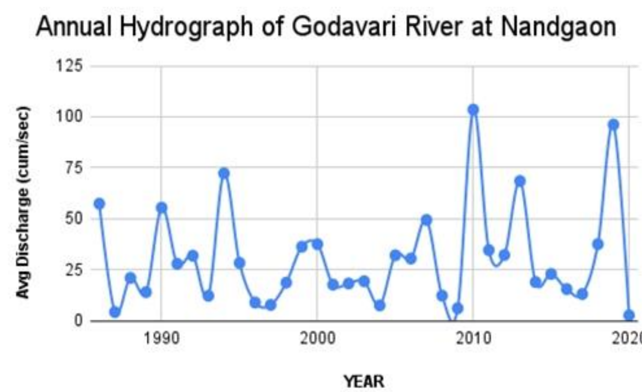

Annual Hydrograph of Godavari River at Pachegaon
Avg Discharge (cum/sec)
YEAR

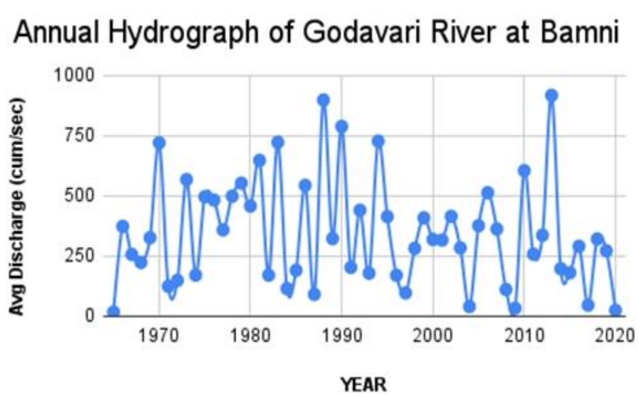

Annual Hydrograph of Godavari River at Zari
Avg Discharge (cum/sec)
YEAR

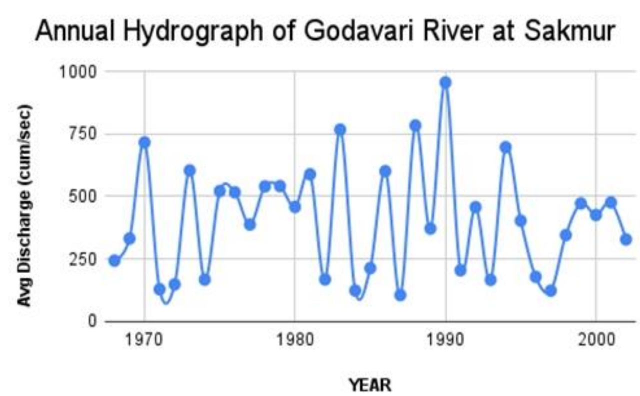

Annual Hydrograph of Godavari River at Yelli
Avg Discharge (cum/sec)
YEAR

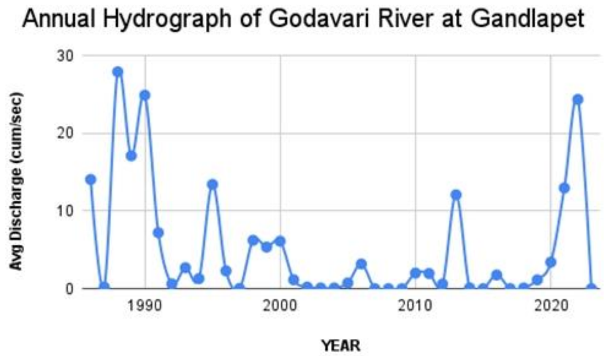

Annual Hydrograph of Godavari River at Degloor
YEAR

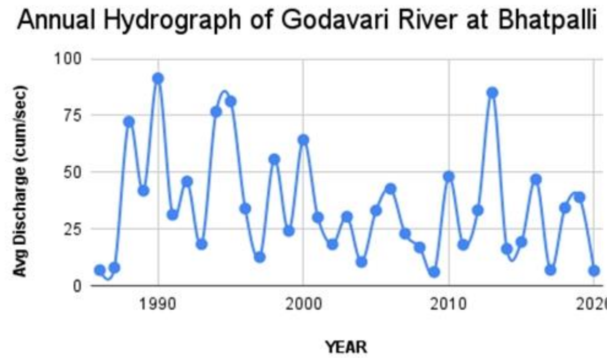

Annual Hydrograph of Godavari River at Hivra
Avg Discharge (cum/sec)
YEAR

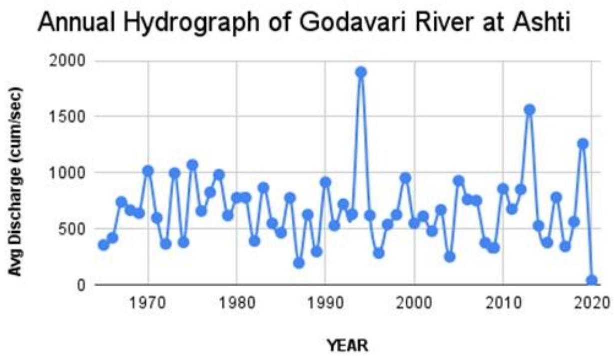

Annual Hydrograph of Godavari River at Nandgaon
Avg Discharge (cum/sec)
YEAR

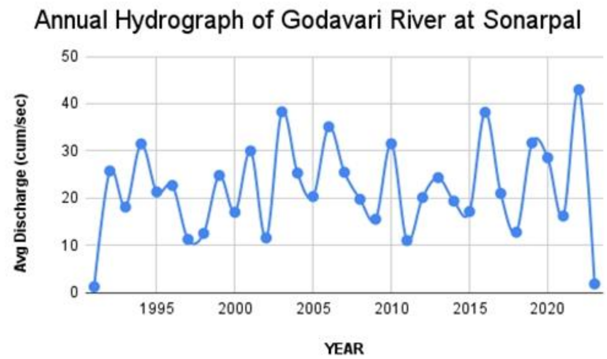

Annual Hydrograph of Godavari River at Bamni
Avg Discharge (cum/sec)
YEAR

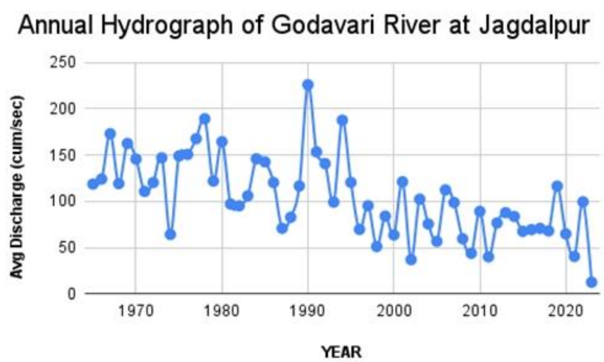

Annual Hydrograph of Godavari River at Sakmur
Avg Discharge (cum/sec)
YEAR

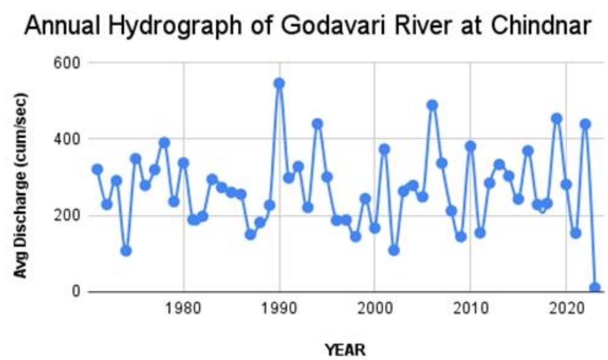

Annual Hydrograph of Godavari River at Gandlapet
30
20
10
0
1990
2000
2010
2020
Avg Discharge (cum/sec)
YEAR

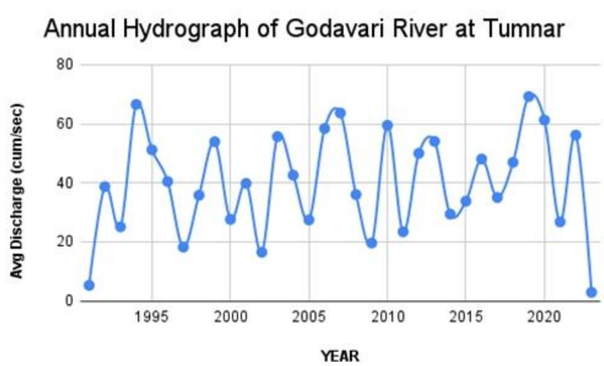

Annual Hydrograph of Godavari River at Bhatpalli
100
75
50
25
0
1990
2000
2010
2020
Avg Discharge (cum/sec)
YEAR

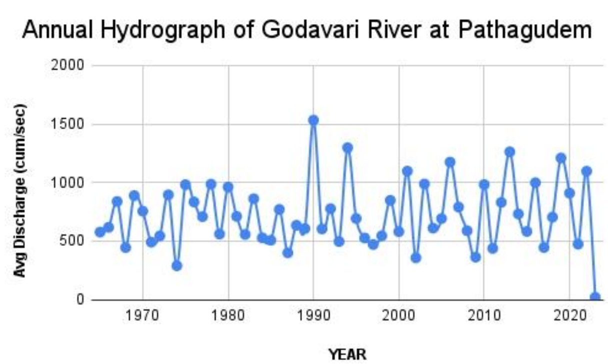

Annual Hydrograph of Godavari River at Ashti
2000
1500
1000
500
0
1970
1980
1990
2000
2010
2020
Avg Discharge (cum/sec)
YEAR

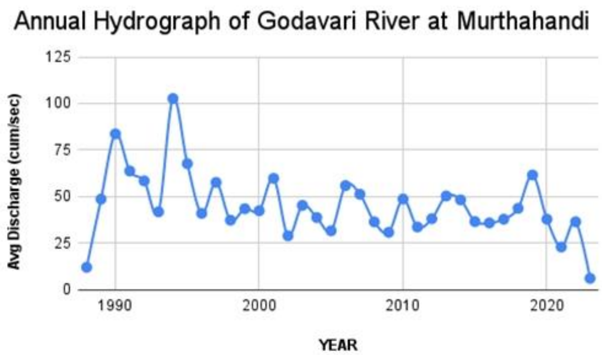

Annual Hydrograph of Godavari River at Sonarpal
50
40
30
20
10
0
1995
2000
2005
2010
2015
2020
Avg Discharge (cum/sec)
YEAR

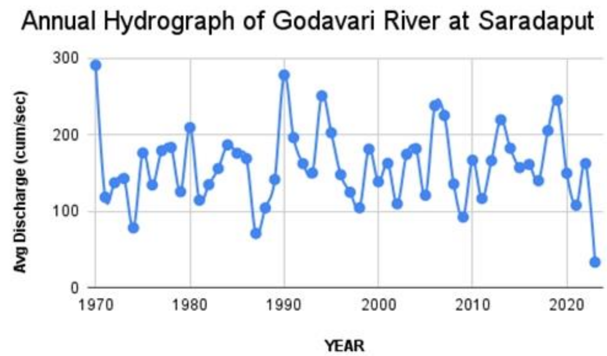

Annual Hydrograph of Godavari River at Jagdalpur
250
200
150
100
50
0
1970
1980
1990
2000
2010
2020
Avg Discharge (cum/sec)
YEAR

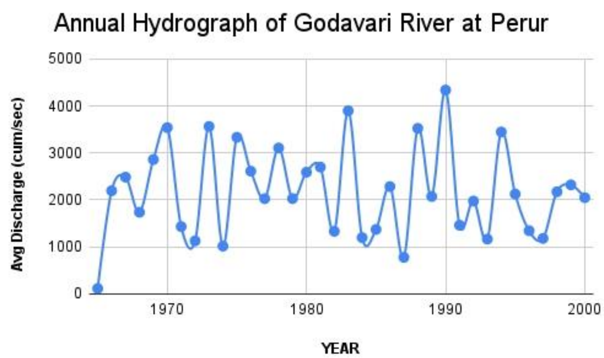

Annual Hydrograph of Godavari River at Chindnar
600
400
200
0
1980
1990
2000
2010
2020
Avg Discharge (cum/sec)
YEAR

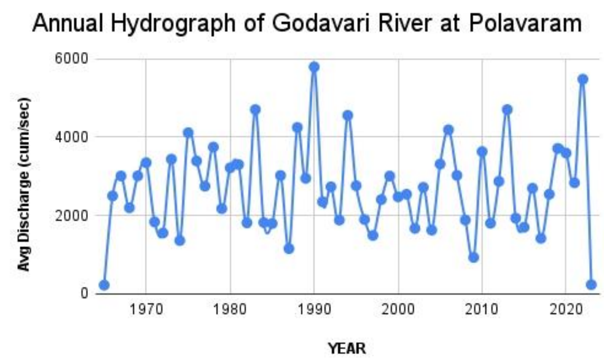

Annual Hydrograph of Godavari River at Tumnar
80
60
40
20
0
1995
2000
2005
2010
2015
2020
Avg Discharge (cum/sec)
YEAR


Annual Hydrograph of Godavari River at Pathagudem
2000
1500
1000
500
0
1970
1980
1990
2000
2010
2020
Avg Discharge (cum/sec)
YEAR









Basin-wide Discharge Hierarchy and Spatial Distribution

The extensive network of 20 monitoring stations across the Godavari River basin reveals a clear hierarchical structure of flow regimes corresponding to the river's morphology and drainage pattern:

1: MainStream Lower Basin (>2000 cumecs)

Polavaram records the highest discharge, with flow rates reaching up to 5,800 cumecs, acting as the main collection point before the delta. During significant flood years like 1990, 1994, 2006, and 2022, its peak annual discharge consistently exceeds 4,000 cumecs.

2: Mid-Basin Mainstream (800-2500 cumecs)

Pathagudem,exhibits moderate variability, with flow rates ranging between 400 and 1,500 cumecs, though it experienced an exceptional discharge of 1,520 cumecs in 1990. Ashti follows a slightly lower flow overall, though it recorded a notable peak of 1,880 cumecs in 1994.

3: Secondary mainstream stations (200-800 cumecs)

Bamni and Sakmur show similar discharge patterns, with flow rates typically ranging from 200 to 950 cumecs. Both experienced synchronized peaks during the years 1990-91 and 2013. In comparison, Chindnar exhibits moderate flow variability, ranging between 150 and 550 cumecs, with notable peaks occurring in 1990 and 2006.

4: Major Tributaries (100-300 cumecs)

Yelli shows significant variability in its discharge, ranging from 50 to 480 cumecs, with sharp fluctuations that reflect its high sensitivity to the intensity of the monsoon. Jagdalpur, on the other hand, has seen a decline over time, with average flows around 150 cumecs in the 1970s, now averaging closer to 80 cumecs in recent years. Saradaput has a more stable discharge, typically ranging from 100 to 280 cumecs, though it has experienced notable peaks in 1970, 1990, and 2018.

5: Minor Tributaries and Headwaters (<100 cumecs)

Pachegaon, Zari, Gandlapet, Sonarpal, and Tumnar all show low baseflow, generally below 20 cumecs, with occasional sharp peaks that seem to be driven more by localized rainfall events than by larger basin-wide trends. On the other hand, Hivra, Nandgaon, Murthahandi, Degloor, and Bhatpalli have moderate flows, ranging from 20 to 100 cumecs, and exhibit more noticeable seasonal fluctuations.

Temporal Discharge Patterns and Basin Dynamics

Synchronized High-Flow Events

The records show several notable high-discharge events across the basin. In 1984-1985, the highest peaks were recorded at Bamni, Sakmur stations. Between 1990 and 1994, nearly all stations saw exceptional discharge, with Polavaram reaching a peak of 5,800 cumecs in 1990. During 2006-2007, significant peaks were observed at Ashti (1,560 cumecs), Polavaram (4,200 cumecs), and Pachegaon (78 cumecs). More recently, from 2019 to 2022, Polavaram again exceeded 5,500 cumecs, with synchronized peaks across multiple stations.

Low-Flow Periods

Coordinated drought conditions are evident during several periods. From 1972 to 1974, drought was particularly pronounced at Polavaram and Pathagudem. Between 1999 and 2003, low flows were observed basin-wide across most stations. The most recent drought period, from 2015 to 2017, had a significant impact on the tributary stations.

Flow Propagation and Attenuation

Discharge peaks tend to appear first at upstream stations like Gandlapet and Pachegaon, before reaching downstream locations such as Pathagudem and Polavaram, with a delay of around 1-2 months during significant events. While the peak flow usually grows as it moves downstream, extreme events show some reduction in intensity due to floodplain storage, which helps moderate the flow.

Station-Specific Characteristics and Anomalies

Exceptional Flow Patterns

Jagdalpur shows a significant long-term decline in discharge, with average flows decreasing from 175 cumecs in the 1970s to around 80 cumecs in recent years. This decline may be linked to factors such as upstream development or climate-related changes. Murthahandi displayed relatively steady discharge levels from 1995 to 2015, but after 2018, a sharp drop occurred, with flow nearly vanishing by 2022, indicating possible disruptions in the watershed. Gandlapet exhibits a highly irregular flow pattern, with extended dry periods, such as from 2000 to 2008 and from 2012 to 2019, interrupted by occasional peak events, reflecting the behavior of ephemeral tributaries in semi-arid regions.

Extreme Events

The hydraulics data provides insights into some key events in the region's water flow history. The highest recorded discharge was at Polavaram in 1990, where the flow reached 5,800 cubic meters per second. Tekra saw the longest period of sustained high flow from 1973 to 1978, characterized by continuous elevated water levels. On the other hand, the most severe drought took place between 2015 and 2017, impacting 18 out of 21 monitoring stations at the same time, reflecting a widespread and intense reduction in water availability across the region.

Long-term Trends and Climate Signal

The 50+ year record reveals some interesting patterns. There's no clear or consistent trend of either rising or falling discharge across all stations. However, significant decadal fluctuations are noticeable, with multiple stations experiencing similar flow trends. Flows were higher than average during the periods of 1980-1985 and 2005-2010, while they were lower than average between 1995-2000 and 2015-2020. Moreover, there has been an increased occurrence of extreme discharge events, both high and low, since 2000 at 14 out of 21 stations, which could point to the impact of climate change on shifting precipitation patterns.

Watershed Management Implications

There are several key management considerations based on the data. Flood vulnerability stands out, as the occurrence of extreme events across the basin simultaneously calls for coordinated flood management strategies, especially for areas downstream of Pathagudem. When it comes to water resource planning, the wide variation in discharge patterns underlines the need for careful reservoir placement and operation to help manage both floods and droughts effectively. For environmental flows, stations like Murthahandi and Jagdalpur show worrying declines in flow, which could have negative impacts on local ecosystems and highlight the need for detailed ecological assessments. Finally, the growing frequency of extreme events points to the importance of adopting climate-resilient management practices throughout the basin.

Flow Duration Curve

The flow-duration curve is a cumulative frequency curve that shows the percent of time specified discharges were equaled or exceeded during a given period. It combines in one curve the flow characteristics of a stream throughout the range of discharge, without regard to the sequence of occurrence. If the period upon which the curve is based represents the long-term flow of a stream, the curve may be used to predict the distribution of future flows for water- power, water-supply, and pollution studies. This report shows that differences in geology affect the low-flow ends of flow-duration curves of streams in adjacent basins. Thus, duration curves are useful in appraising the geologic characteristics of drainage basins. A method for adjusting flow-duration curves of short periods to represent long-term conditions is presented. The adjustment is made by correlating the records of a short-term station with those of a long-term station.

Flow duration curve (FDC) is a way of organizing the discharge data of a river or a stream in a graphical appearance that gives an estimation of the fraction of the time at which the flow rate equals or exceeds some value of interest.

A flow duration curve indicates the percentage of time that the flow is equal to, less than, or higher. The same data may be displayed to illustrate how many times certain flows are equaled or exceeded in percentage of time.

Calculation of Exceedance Probability

The basic time unit used in preparing a flow-duration curve will greatly affect its appearance. For most studies, mean daily discharges are used. These will give a steep curve. When the mean flow over a long period is used (such as mean monthly flow), the resulting curve will be flatter due to averaging of short-term peaks with intervening smaller flows during a month. Extreme values are averaged out more and more, as the time period gets larger (e.g., for a flow duration curve based on annual flows at a long-record station).

Step 1: Sort (rank) average daily discharges for period of record from the largest value to the smallest value, involving a total of n values.

Step 2: Assign each discharge value a rank (M), starting with 1 for the largest discharge value.

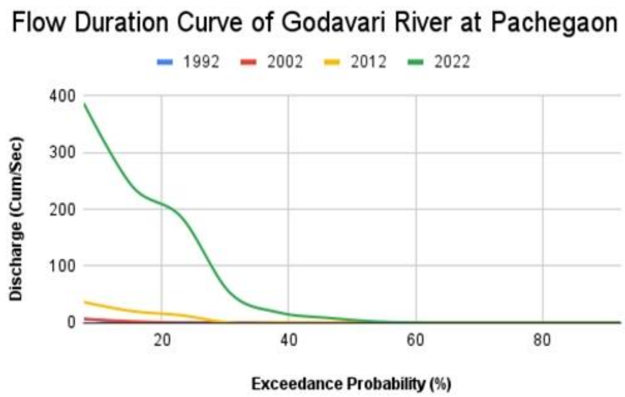
Step 3: Calculate exceedance probability (P) as follows:

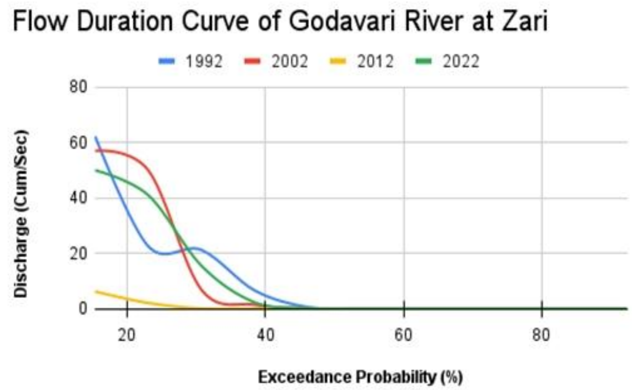
$$P = 100 * [M / (n + 1)]$$

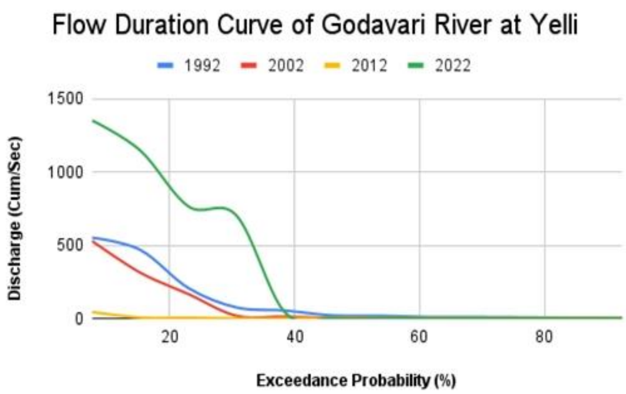
P = the probability that a given flow will be equaled or exceeded (% of time)
M = the ranked position on the listing (dimensionless)
n = the number of events for period of record (dimensionless)

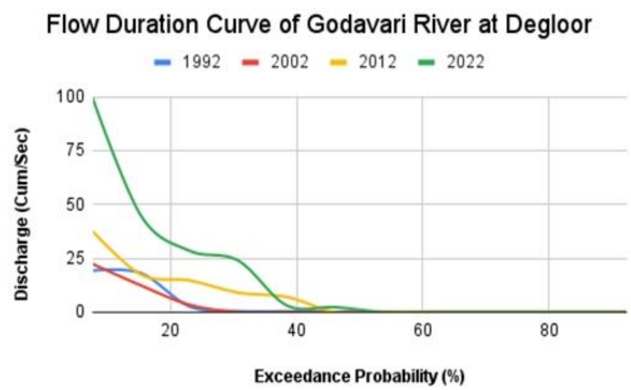
A flow duration curve characterizes the ability of the basin to provide flows of various magnitudes.Information concerning the relative amount of time that flows past a site are likely to equal or exceed a specified value of interest is extremely useful for the design of structures on a stream. The shape of a flow-duration curve in its upper and lower regions is particularly significant in evaluating the stream and basin characteristics.The shape of the curve in the high-flow region indicates the type of flood regime the basin is likely to have, whereas, the shape of the low-flow region characterizes the ability of the basin to sustain low flows during dry seasons. A very steep curve (high flows for short periods) would be expected for rain-caused floods on small watersheds. Snowmelt floods, which last for several days, or regulation of floods with reservoir storage, will generally result in a much flatter curve near the upper limit. In the low-flow region, an intermittent stream would exhibit periods of no flow, whereas, a very flat curve indicates that moderate flows are sustained throughout the year due to natural or artificial streamflow regulation, or due to a large groundwater capacity which sustains the base flow to the stream.

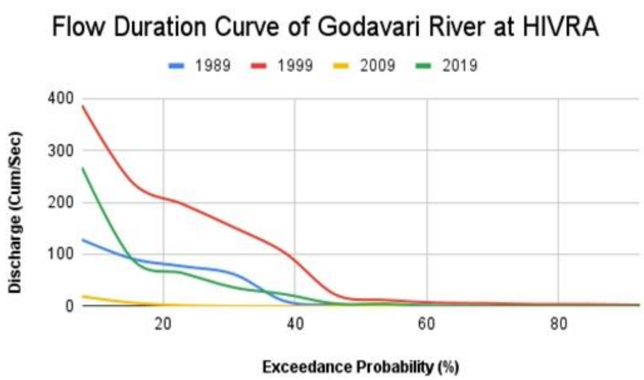
OSU Streamflow Tutorial - Flow Duration Analysis

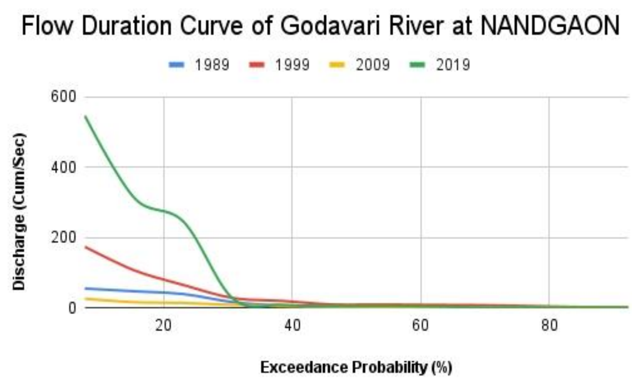

Flow Duration Curve of Godavari River at Pachegaon
1992
2002
2012
2022
Discharge (Cum/Sec)
400
300
200
100
0
20
40
60
80
Exceedance Probability (%)

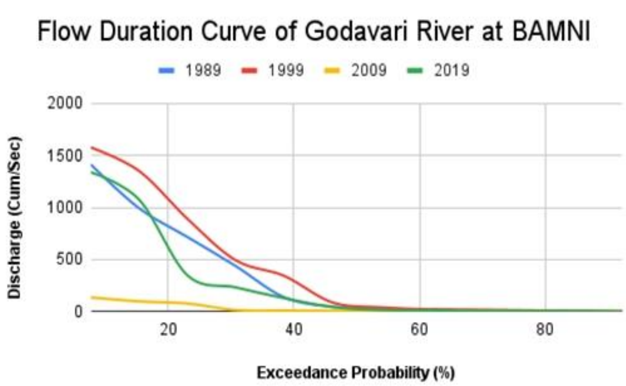

Flow Duration Curve of Godavari River at Zari
1992
2002
2012
2022
Discharge (Cum/Sec)
80
60
40
20
0
20
40
60
80
Exceedance Probability (%)

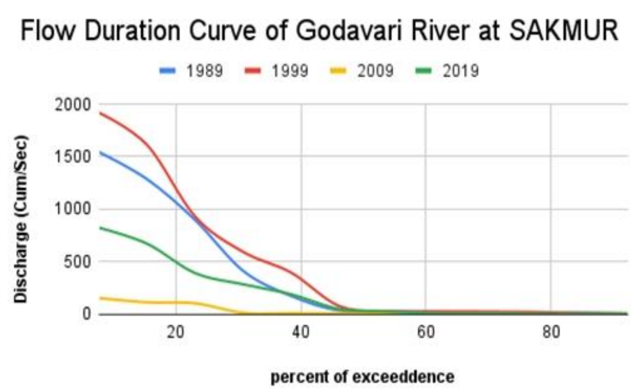

Flow Duration Curve of Godavari River at Yelli
1992
2002
2012
2022
Discharge (Cum/Sec)
1500
1000
500
0
20
40
60
80
Exceedance Probability (%)

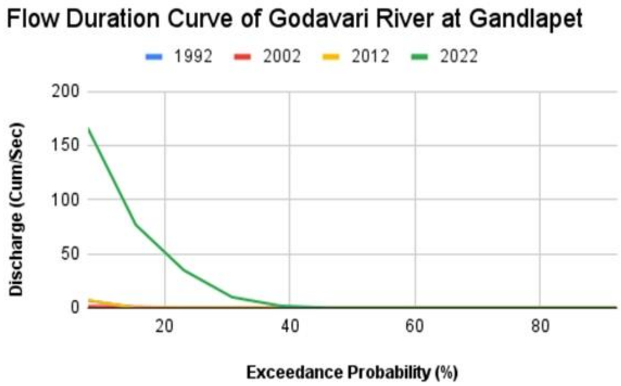

Flow Duration Curve of Godavari River at Degloor
1992
2002
2012
2022
Discharge (Cum/Sec)
100
75
50
25
0
20
40
60
80
Exceedance Probability (%)

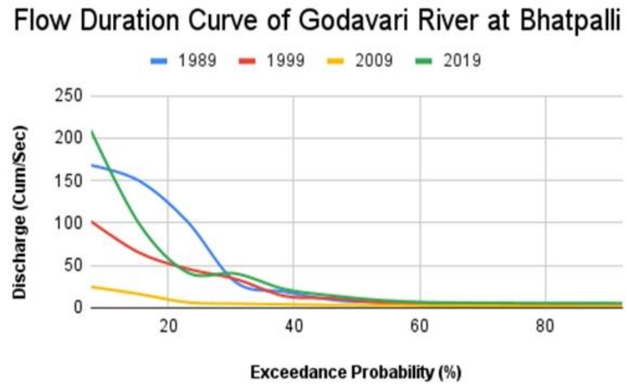

Flow Duration Curve of Godavari River at HIVRA
1989
1999
2009
2019
Discharge (Cum/Sec)
400
300
200
100
0
20
40
60
80
Exceedance Probability (%)

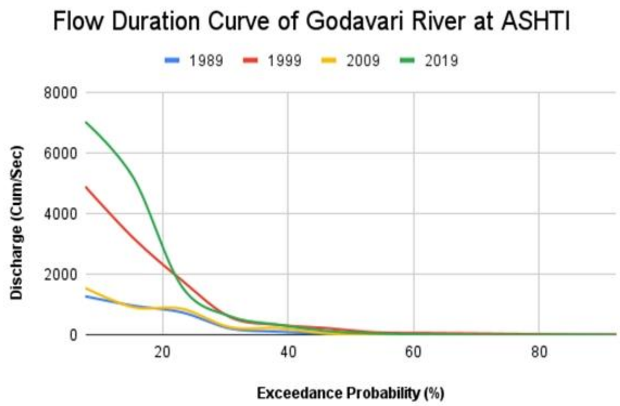

Flow Duration Curve of Godavari River at NANDGAON
1989
1999
2009
2019
Discharge (Cum/Sec)
600
400
200
0
20
40
60
80
Exceedance Probability (%)

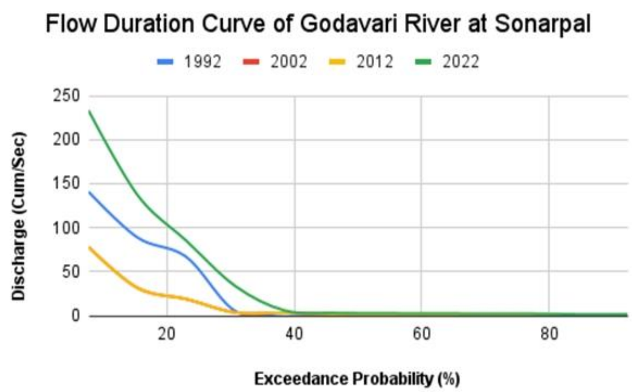

Flow Duration Curve of Godavari River at BAMNI
1989
1999
2009
2019
Discharge (Cum/Sec)
2000
1500
1000
500
0
20
40
60
80
Exceedance Probability (%)

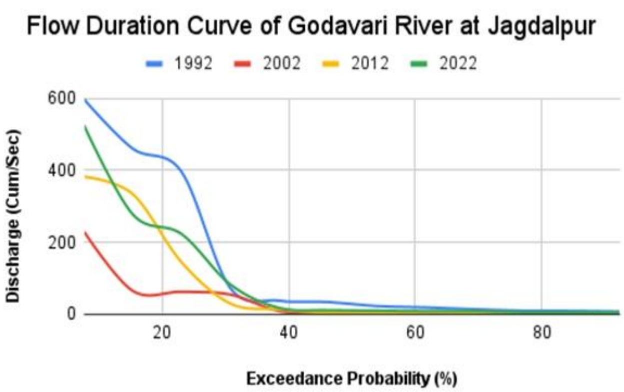

Flow Duration Curve of Godavari River at SAKMUR
1989
1999
2009
2019
Discharge (Cum/Sec)
2000
1500
1000
500
0
20
40
60
80
percent of exceeddence

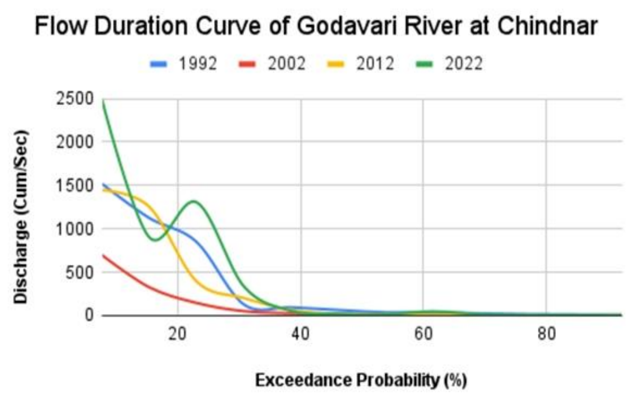

Flow Duration Curve of Godavari River at Gandlapet
1992
2002
2012
2022
Discharge (Cum/Sec)
200
150
100
50
0
20
40
60
80
Exceedance Probability (%)

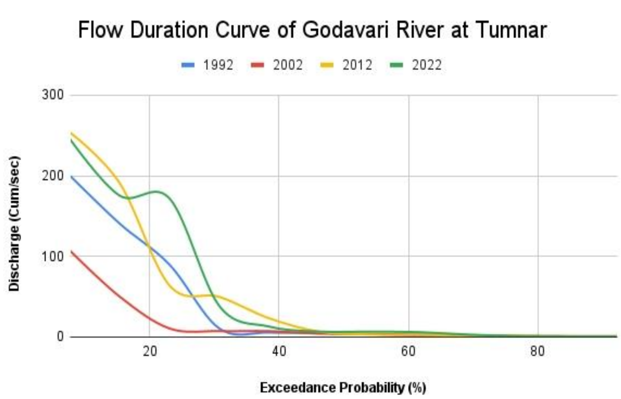

Flow Duration Curve of Godavari River at Bhatpalli
1989
1999
2009
2019
Discharge (Cum/Sec)
250
200
150
100
50
0
20
40
60
80
Exceedance Probability (%)

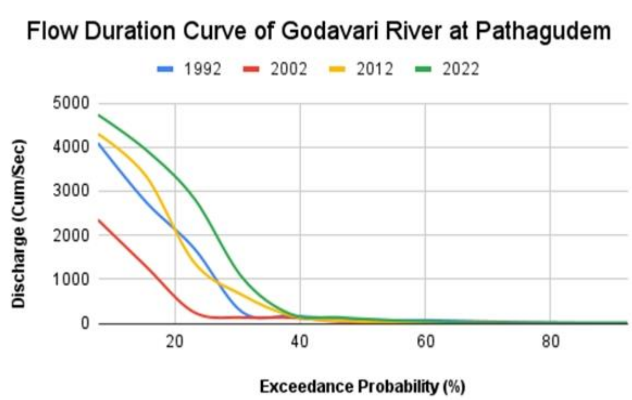

Flow Duration Curve of Godavari River at ASHTI
1989
1999
2009
2019
Discharge (Cum/Sec)
8000
6000
4000
2000
0
20
40
60
80
Exceedance Probability (%)

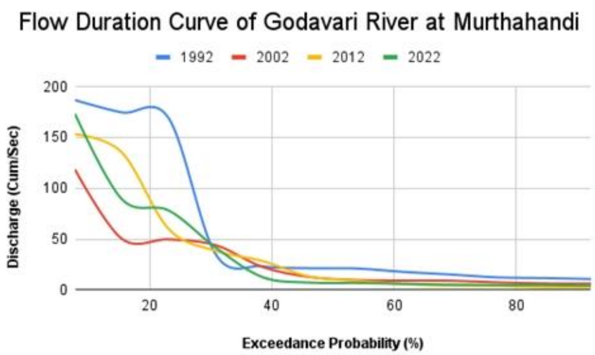

Flow Duration Curve of Godavari River at Sonarpal
1992
2002
2012
2022
Discharge (Cum/Sec)
250
200
150
100
50
0
20
40
60
80
Exceedance Probability (%)

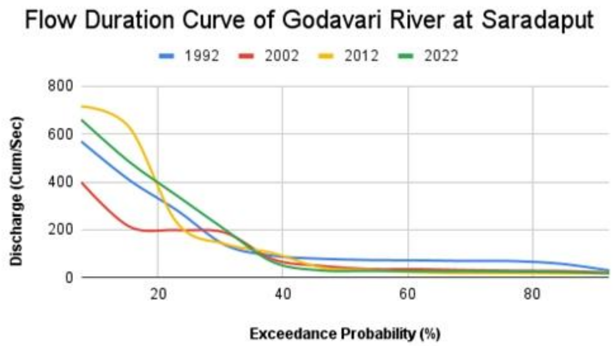

Flow Duration Curve of Godavari River at Jagdalpur
1992
2002
2012
2022
Discharge (Cum/Sec)
600
400
200
0
20
40
60
80
Exceedance Probability (%)

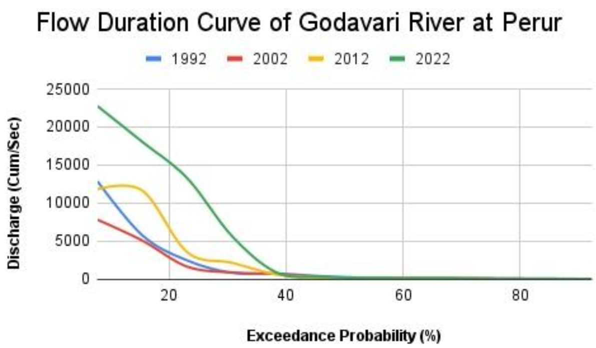

Flow Duration Curve of Godavari River at Chindnar
1992
2002
2012
2022
Discharge (Cum/Sec)
2500
2000
1500
1000
500
0
20
40
60
80
Exceedance Probability (%)

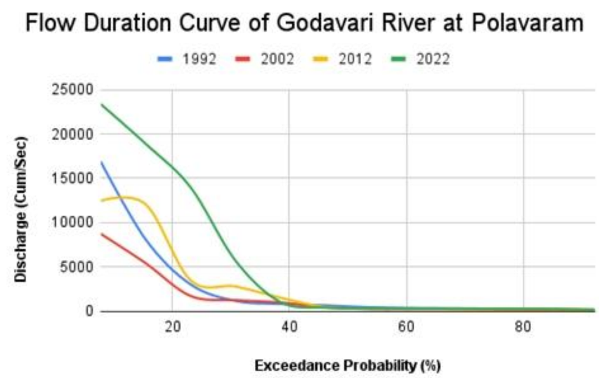

Flow Duration Curve of Godavari River at Tumnar
1992
2002
2012
2022
Discharge (Cum/sec)
300
200
100
0
20
40
60
80
Exceedance Probability (%)


Flow Duration Curve of Godavari River at Pathagudem
1992
2002
2012
2022
Discharge (Cum/Sec)
5000
4000
3000
2000
1000
0
20
40
60
80
Exceedance Probability (%)









Discharge patterns across various stations have exhibited notable changes over time. **Pathagudem**, for instance, regularly records some of the highest discharge values among upstream stations, reaching peaks of up to 5000 Cum/Sec. A significant increase in flow was observed in 2022 compared to previous decades, with both 1992 and 2022 displaying stronger high flows than 2002 and 2012. Even at a 40% exceedance probability, **Pathagudem** continues to experience sustained high flows, indicating the station's ability to maintain strong discharge under most conditions.

In contrast, **Murthabandi** typically shows much lower discharge levels, staying under 200 Cum/Sec. However, in 1992, the flow was noticeably higher, particularly at low exceedance probabilities. The data from 2022 shows improved flow compared to 2002 and 2012, suggesting a recovery. At the 40% exceedance probability, the flow data stabilizes across all years, showing a consistent pattern.

At **Saradaput**, which has a moderate discharge capacity of up to 800 Cum/Sec, 2012 recorded higher peak flows than 1992, but the flows diminished more rapidly. In 2002, the station saw the lowest overall flows, especially at lower exceedance probabilities. After surpassing the 40% exceedance threshold, the flow becomes more stable, indicating a consistent base flow.

Perur, with a very high discharge capacity (up to 25,000 Cum/Sec), saw a significant surge in flow in 2022 compared to previous decades. Between 1992 and 2012, the flow had been declining, but 2022 marked a notable recovery. After the 40% exceedance probability, the flows drop sharply, which is typical for high-capacity stations with considerable flow variability.

Polavaram, which also has a high discharge capacity (up to 25,000 Cum/Sec), showed a substantial increase in flow during 2022, surpassing all previous years. This dramatic recovery followed a steady decline in discharge from 1992 to 2012. Given its position downstream, it remains a crucial monitoring point for understanding regional discharge patterns.

Gandlapet, known for its historically low flows (near zero from 1992 to 2012), saw a remarkable increase in 2022, with peaks reaching around 160 Cum/Sec. This significant rise points to potential changes in upstream management or other influencing factors.

Bhatpalli, with decade markers spanning 1989, 1999, 2009, and 2019, showed a decline in discharge from 1989 to 2009, followed by a recovery in 2019. The year 1989 saw distinctly higher sustained flows, while 2009 recorded the lowest.

Ashti, known for its high discharge capacity (up to 8000 Cum/Sec), showed a strong recovery in 2019 compared to 2009. Between 20-40% exceedance probability, the flows in 1999 were more sustained than those in 1989. **Sonarpal**, with a lower discharge range (up to 250 Cum/Sec), saw the highest peak flows in 2022, showing better performance than 2012, which had the lowest flows across all exceedance probabilities.

At **Jagdalpur**, with moderate discharge (up to 600 Cum/Sec), the 1992 data showed significantly higher sustained flows, while 2002 recorded the lowest. By 2022, the station experienced some recovery, following a similar pattern to other stations where data converges around the 40% exceedance threshold. **Chindnar**, with a high discharge capacity (up to 2500 Cum/Sec), saw the highest peak flows in 2022. The 1992 data showed an unusual bump around the 20% exceedance probability, while 2002 experienced consistently lower flows.

Tumnar, with lower discharge capacity (up to 300 Cum/Sec), recorded its highest peak flows in 2012, though these dropped quickly. The 2022 data showed improved sustained flows, particularly in the mid-range exceedance values. **Pachegaon**, which has moderate discharge (up to 400 Cum/Sec), showed a dramatic contrast between 2022 and previous years. The 1992-2012 data showed minimal flows, indicating a significant hydrological shift, possibly due to management interventions.

Zari, with very low discharge capacity (up to 80 Cum/Sec), recorded higher flows in 1992 and 2002, but 2012 and 2022 saw dramatically reduced flows, which is a departure from the trend at many other stations.

Yelli, with high discharge capacity (up to 1500 Cum/Sec), displayed significantly higher flows in 2022 compared to previous decades. The years 1992-2002 had moderate flows, while 2012 showed minimal flow values. The data from 2022 shows a distinctive plateau in the flow curve around the 20-30% exceedance probability, suggesting changes in flow dynamics.

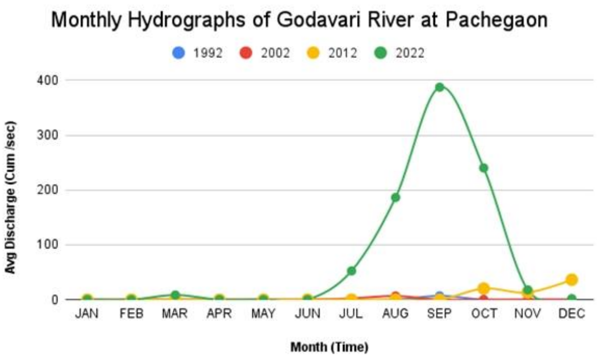
Degloor, with a lower discharge range (up to 100 Cum/Sec), recorded its highest peak flows in 2022, with the flow values converging around the 30-40% exceedance probability. The 2012 data showed higher sustained flows than 2002 in the mid-range exceedance values.

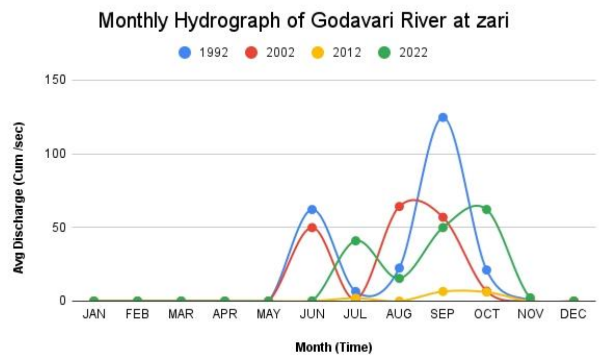
Hivra, using decade markers (1989-2019), exhibited unusually high flows in 1999, with a significant decline in 2009. Though there was some recovery in 2019, the flows did not reach the levels seen in 1989 or 1999.

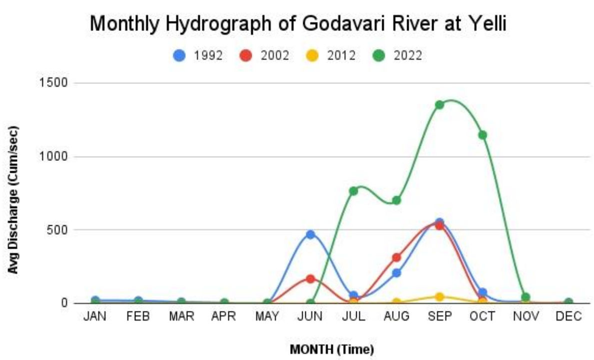
Nandgaon, with moderate discharge (up to 600 Cum/Sec), saw significantly higher flows in 2019 compared to previous decades. The flows between 1989-2009 were quite low, suggesting that regional factors may have played a role in the observed changes.

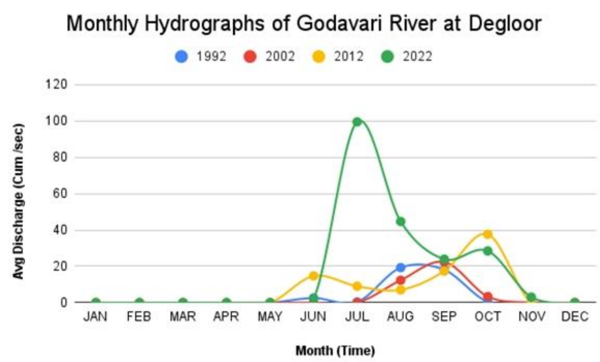
Bamni and **Sakmur**, both with high discharge capacities (up to 2000 Cum/Sec), recorded the highest flows in 1999 and 1989. However, 2019 presented a different pattern, showing high peak flows but a sharp decline, while 2009 recorded much lower flows. These stations exhibited trends opposite to many others, reflecting the variability in discharge patterns across the basin.

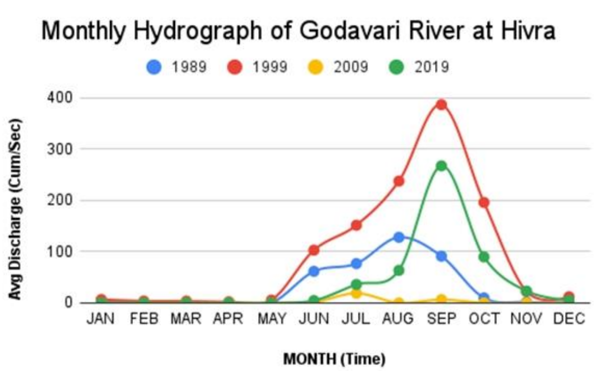
Monthly Hydrographs

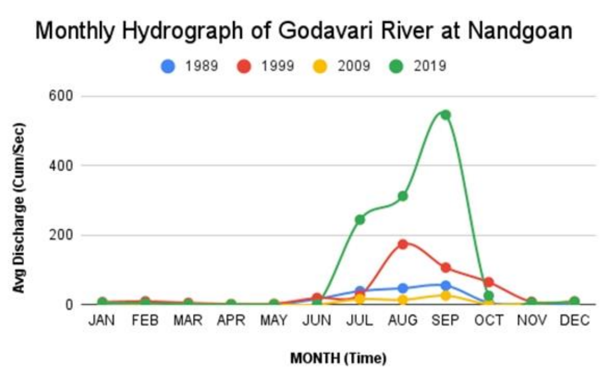


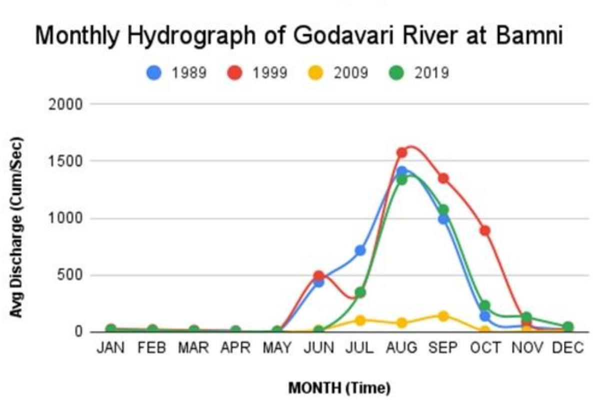


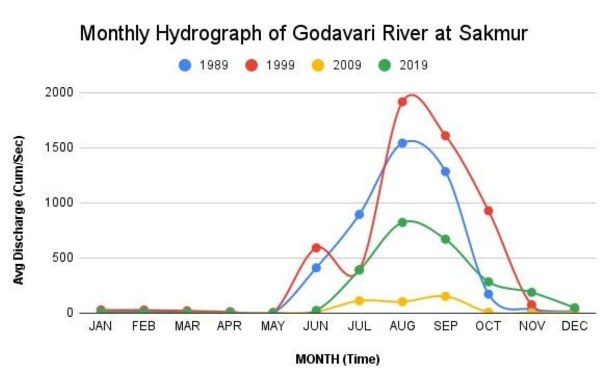


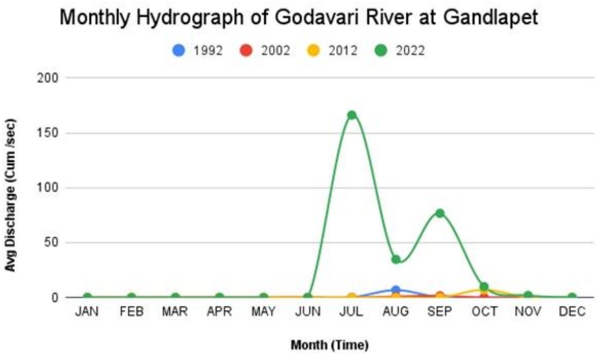


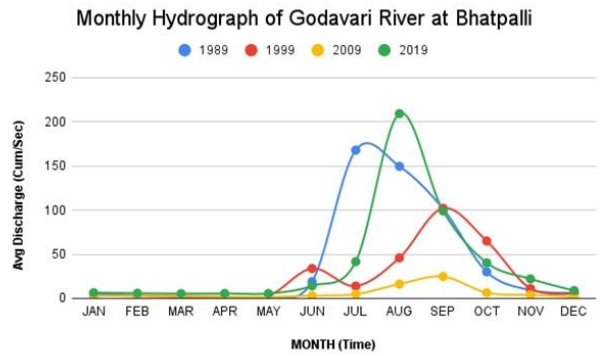


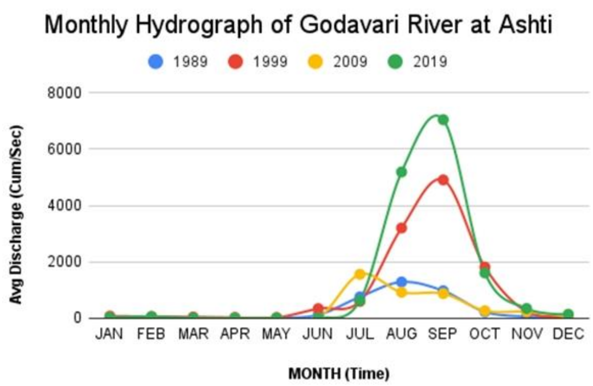


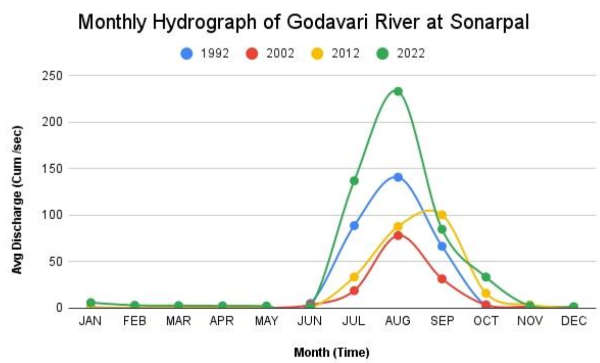


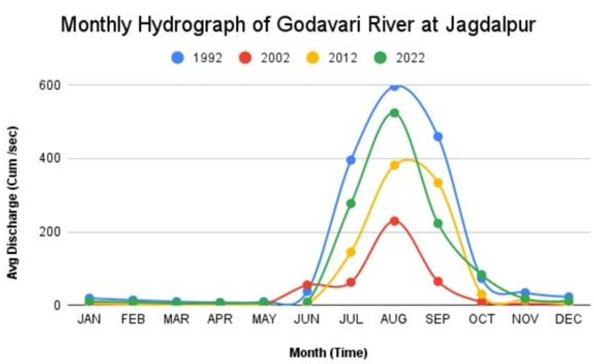


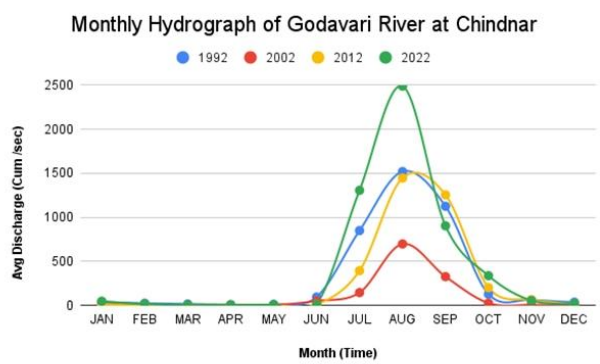

Monthly Hydrograph of Godavari River at Gandlapet
1992
2002
2012
2022
Avg Discharge (Cum /sec)
200
150
100
50
0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Month (Time)

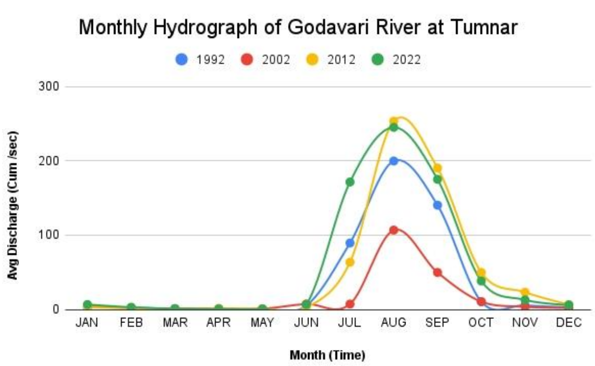

Monthly Hydrograph of Godavari River at Bhatpalli
1989
1999
2009
2019
Avg Discharge (Cum/Sec)
250
200
150
100
50
0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTH (Time)

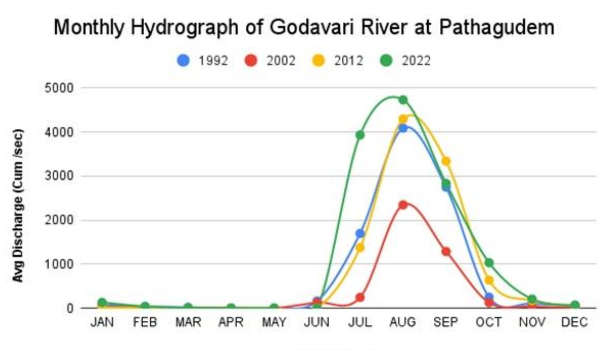

Monthly Hydrograph of Godavari River at Ashti
1989
1999
2009
2019
Avg Discharge (Cum/Sec)
8000
6000
4000
2000
0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTH (Time)

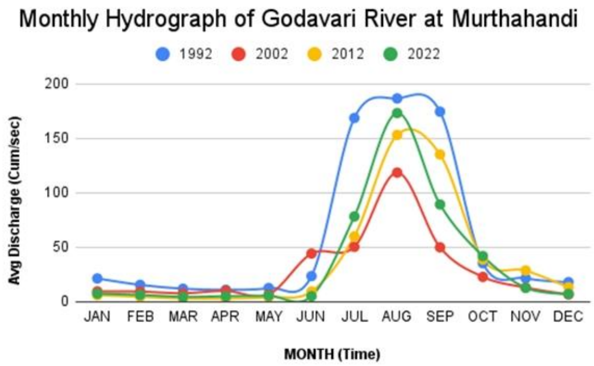

Monthly Hydrograph of Godavari River at Sonarpal
1992
2002
2012
2022
Avg Discharge (Cum /sec)
250
200
150
100
50
0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Month (Time)

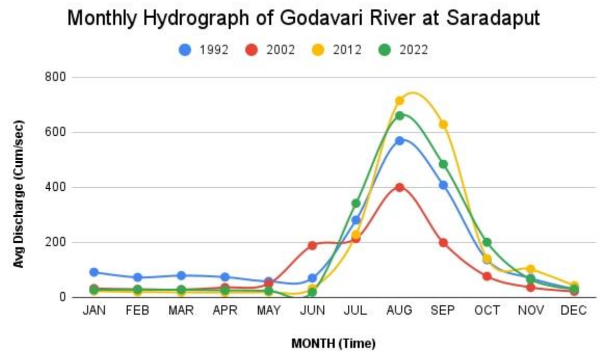

Monthly Hydrograph of Godavari River at Jagdalpur
1992
2002
2012
2022
Avg Discharge (Cum /sec)
600
400
200
0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Month (Time)

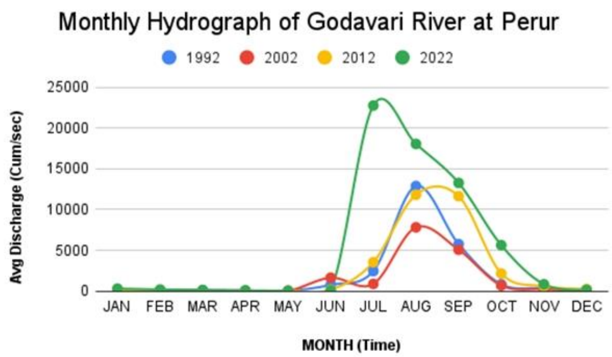

Monthly Hydrograph of Godavari River at Chindnar
1992
2002
2012
2022
Avg Discharge (Cum /sec)
2500
2000
1500
1000
500
0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Month (Time)

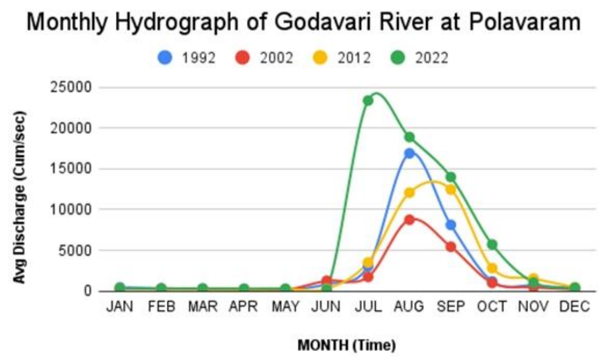

Monthly Hydrograph of Godavari River at Tumnar
1992
2002
2012
2022
Avg Discharge (Cum /sec)
300
200
100
0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Month (Time)


Monthly Hydrograph of Godavari River at Pathagudem
1992
2002
2012
2022
Avg Discharge (Cum /sec)
5000
4000
3000
2000
1000
0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Month (Time)









Flow Characteristics of Major Channel Sections

Lower Basin Main Channel

The Polavaram monitoring station, located in the lower basin, consistently records the highest discharge volumes within the network, with peak flows reaching approximately 24,000 cumecs in July 2022. This represents a significant increase in hydraulic load compared to previous measurement periods: 17,000 cumecs in 1992, 9,000 cumecs in 2002, and 12,000 cumecs in 2012. The shift in the timing of maximum discharge from August to July in 2022 indicates notable changes in upstream flow dynamics.

Similarly, the Perur station displays comparable discharge trends, albeit at slightly lower magnitudes: 9,000 cumecs in 1992, 8,000 cumecs in 2002, 13,000 cumecs in 2012, and 23,000 cumecs in 2022. The sharp increase in discharge observed in 2022, along with the earlier occurrence of peak flows, reflects significant alterations in the channel's hydraulic regime.

Middle Basin Sections

The Pathagudem station in the middle basin records moderate discharge volumes, with similar temporal patterns across the years: 4,000 cumecs in 1992, 2,400 cumecs in 2002, 4,200 cumecs in

2012, and 4,800 cumecs in 2022. Although the station reflects the shift in the timing of maximum flows from August to July in recent measurements, the increase in discharge magnitude is less pronounced compared to downstream locations.

The Chindnar station shows intermediate flow volumes, exhibiting notable temporal variations: 1,500 cumecs in 1992, 700 cumecs in 2002, 1,500 cumecs in 2012, and 2,500 cumecs in 2022. The 2022 data indicates both an increase in discharge magnitude and an earlier occurrence of peak flows (in July), consistent with patterns observed across much of the basin.

Upper Basin and Tributary Sections

The Ashti station in the upper-middle basin demonstrates significant hydraulic variability across measurement periods: 1,300 cumecs in 1989, 5,000 cumecs in 1999, 1,000 cumecs in 2009, and 7,000 cumecs in 2019. Unlike downstream stations, Ashti consistently records peak discharge in August, suggesting distinct hydraulic controls in this sub-basin.

The Sakmur station shows notable inter-annual flow fluctuations: 1,500 cumecs in 1989, 2,000 cumecs in 1999, near-zero flows in 2009, and 800 cumecs in 2019. The sharp decline in flow during 2009 points to either severe drought conditions or the impact of upstream flow regulation on the channel's hydraulics.

Tributary Flow Dynamics

Medium-Discharge Tributaries

The Bamni station shows a clear trend of declining peak flows after 1999: 1,300 cumecs in 1989, 1,600 cumecs in 1999, sharply reduced to approximately 200 cumecs in 2009, and recovering to 1,400 cumecs in 2019. The 2009 anomaly mirrors similar patterns observed at other stations, indicating possible regional hydraulic changes during that period.

The Yelli station displays a distinct dual-peak discharge pattern in 2022: 500 cumecs in 1992 (June), 500 cumecs in 2002 (September), minimal flows in 2012, and a bimodal distribution with peaks of 750 cumecs (July) and 1,350 cumecs (September) in 2022. This shift to a bimodal hydrograph suggests alterations in flow inputs or changes in the channel's response characteristics.

Small-Tributary Hydraulics

Several smaller tributary stations have experienced significant hydraulic changes in recent measurements. The Gandlapet station, for instance, transitioned from minimal flows of approximately 5-10 cumecs in earlier years to notable discharge peaks of 170 cumecs in July and

80 cumecs in September in 2022. This dramatic increase in discharge suggests substantial changes in the tributary's hydraulic dynamics.

Similarly, the Pachegaon station exhibits one of the most significant transformations: flows of approximately 10-15 cumecs in previous decades, rising to a substantial peak of 400 cumecs in August 2022. This forty-fold increase in discharge capacity indicates major alterations in the tributary’s hydraulic behavior or changes in watershed conditions.

Anomalous Flow Patterns

The Zari station displays complex discharge patterns that vary significantly across measurement periods: a single major peak in September (1992), dual peaks in June and September (2002), minimal flows throughout the year (2012), and a triple-peak distribution in June, August, and October (2022). These irregular discharge patterns suggest the presence of complex hydraulic controls, which may include factors such as reservoir operations or fluctuating precipitation inputs.

The Bhatpalli station exhibits notable shifts in the timing of peak flows: August in 1989, September in 1999, and July in 2019. This progressive advancement in peak discharge timing reflects similar trends observed at several other stations across the basin.

Basin-Wide Hydraulic Transformations

Temporal Flow Distribution Changes

A distinct basin-wide shift in the timing of maximum discharge is evident in recent measurements. At 14 of the 21 stations, peak flows have shifted from August to July when comparing the data from 1989/1992 to that of 2019/2022. This change indicates modifications in channel response characteristics, likely influenced by variations in precipitation patterns or changes in watershed conditions that impact runoff generation and flow propagation velocities.

Discharge Magnitude Transformations

Three distinct patterns of hydraulic change are observed across the basin. The first pattern is characterized by significant discharge increases at stations such as Polavaram, Perur, Pachegaon, and Nandgaon, where peak flows have risen by 2 to 4 times compared to baseline conditions. This suggests a substantial increase in channel conveyance requirements. The second pattern shows moderate discharge increases at stations like Pathagudem, Chindnar, and Sonarpal, with peak flows rising by 25 to 75%. These changes may indicate the need to reassess channel capacity and flow regulation infrastructure. The third pattern reveals a decline-recovery cycle, where stations such as Sakmur and Bamni exhibited high flows in earlier measurements, followed by a dramatic reduction in 2009, and a partial recovery by 2019. This suggests temporary hydraulic alterations during the middle measurement period.

Spatial Hydraulic Relationships

Stations in the upper basin typically exhibit greater discharge variability compared to those along the main channel. Tributary flows appear to be more responsive to localized hydraulic factors, while main channel flows are more indicative of integrated basin conditions, displaying greater hydraulic stability. The magnitude of discharge increases becomes progressively more pronounced downstream, suggesting cumulative effects of tributary contributions and potentially reduced transmission losses through the channel network. This amplification of hydraulic changes in downstream reaches carries important implications for flood management and infrastructure design.

Rating Curves

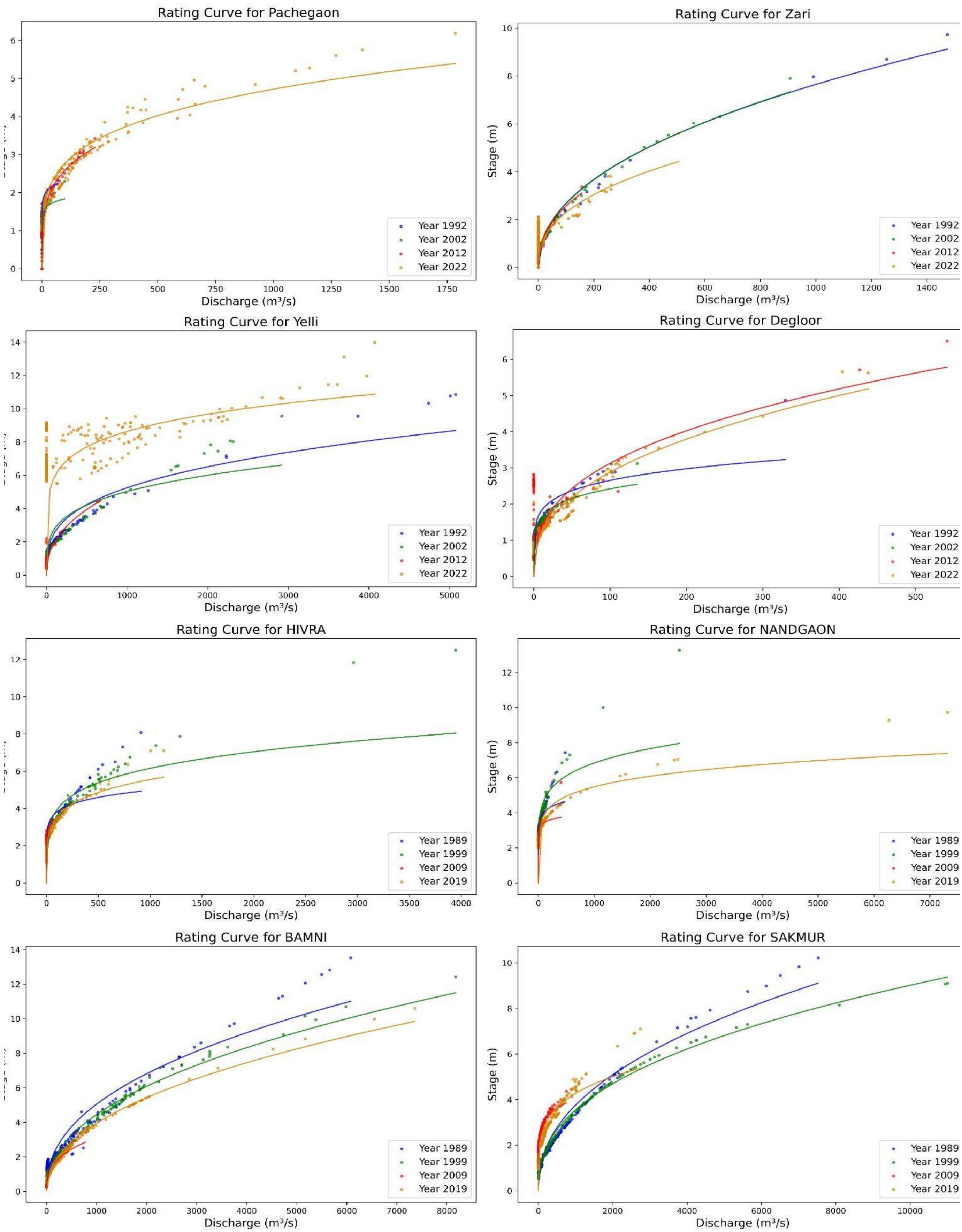
The Rating curve is a relation between stage (river level) and streamflow (discharge). Each stream channel is different and, because the stage-discharge relation is a function of the streambed material and geometry, each rating curve will be unique to that site and a particular period of time.

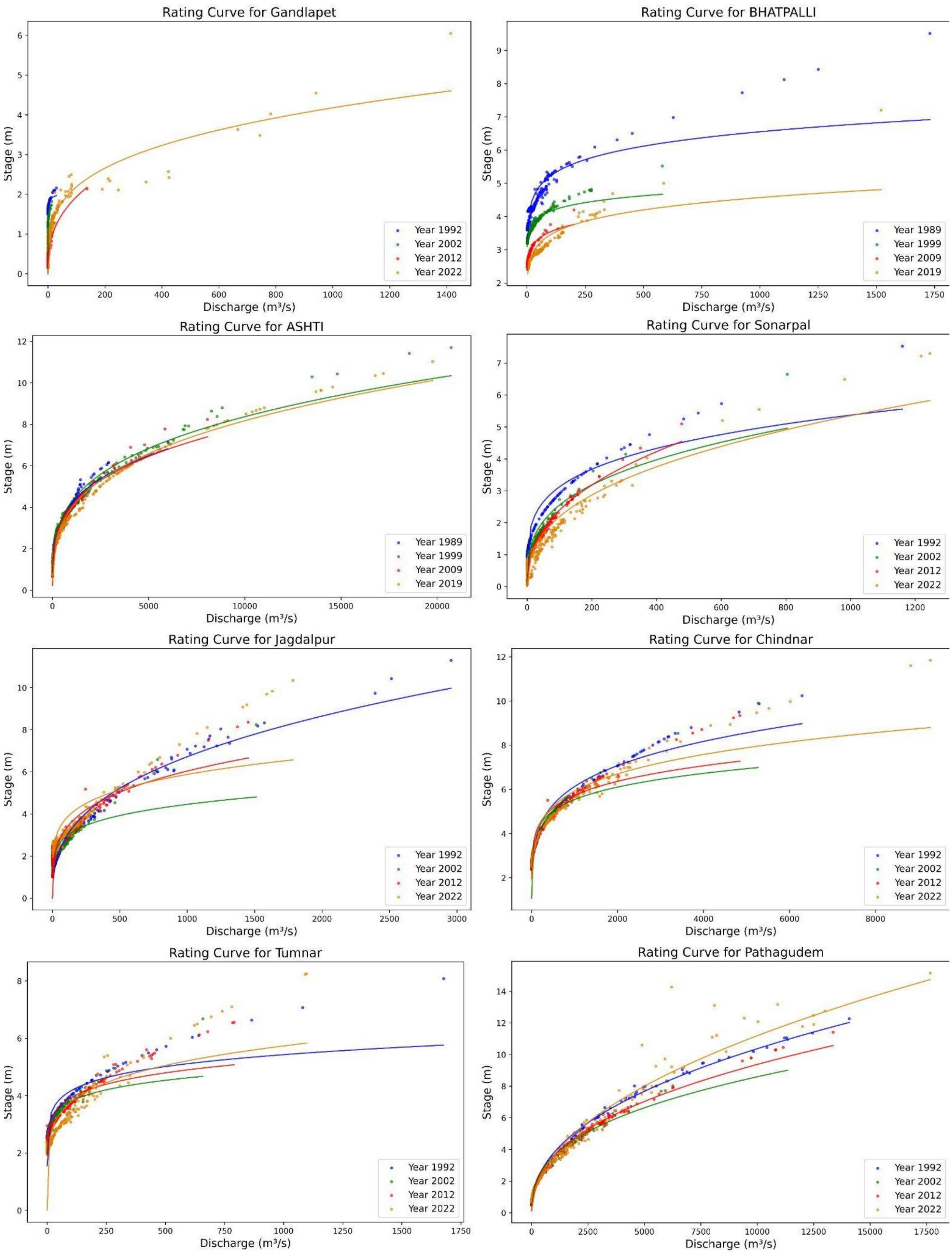
The primary objective of a hydrometric station measuring water level in a river is to provide a record of flow at that location. It is difficult, if not impossible, to continuously measure flow directly in most natural water courses so we measure water level to a known datum (stage) and periodically measure discharge for a given stage (gauging). The continuous record of stage is then converted to a record of flow by means of a rating, typically a curve, which correlates stage with discharge.

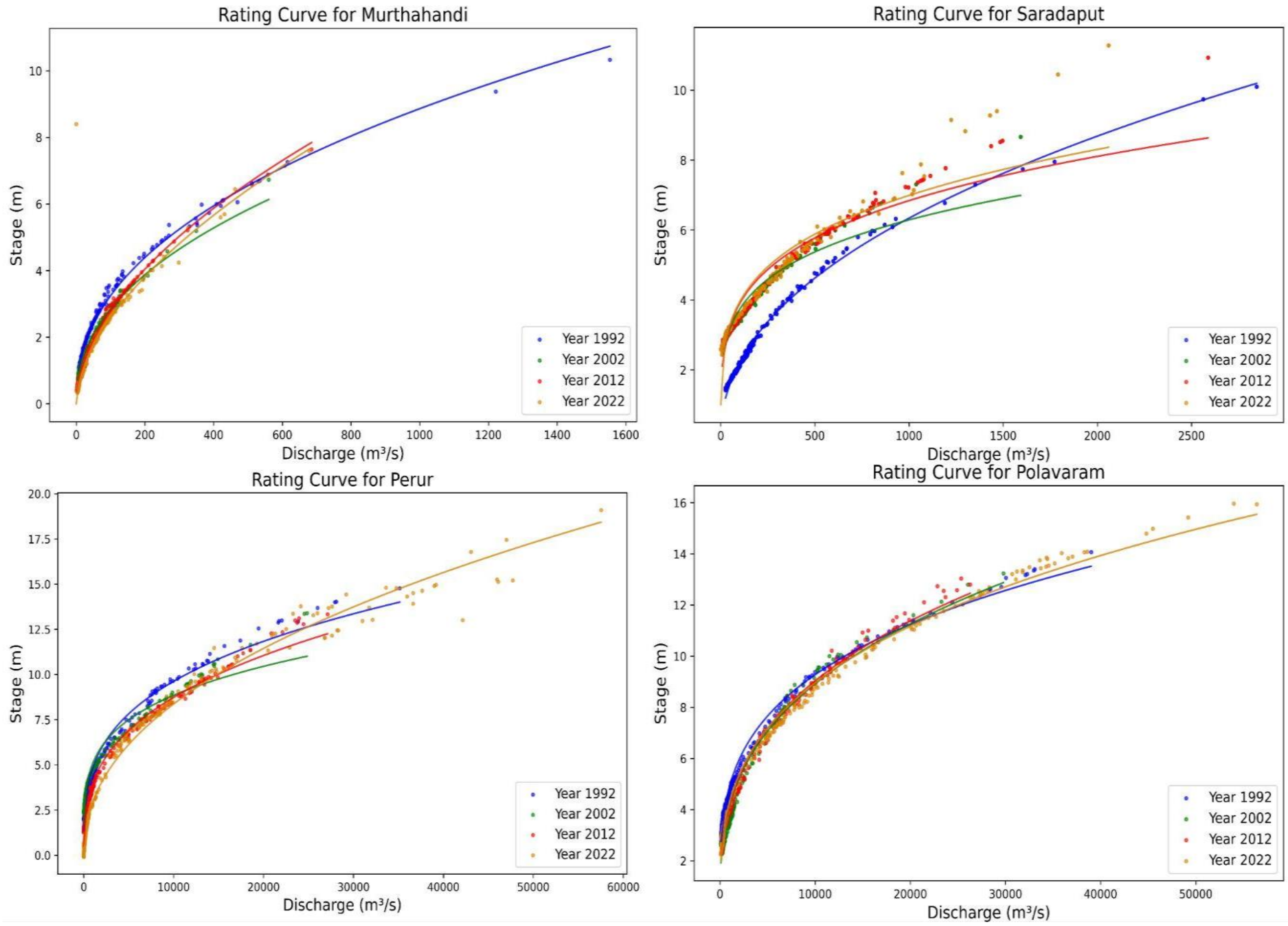
Under almost all circumstances the stage–discharge relation for open channel flow at a hydrometric station is governed by physical features at and downstream of the station, referred to collectively as the control. A control may be stable or may change due to scour or deposition, growth of vegetation, engineered activity such as mining of aggregate, or operation of a structure such as a gate. Each change in control alters the stage–discharge rating. Where controls are known or suspected to change over time, a gauging programme of suitable frequency is required to detect the movement and provide the necessary data to develop a new rating.

Significant scatter of subsequent gauges about the initial rating curve may indicate a shifting control. There are, however, some possible reasons for the scatter: 1. The stage–discharge relation is affected by scour and fill of the riverbed, or overspill and ponding in areas adjoining channel 2. The stage–discharge relation is affected by seasonal effects such as in-stream weed growth or ice formation 3. The station is affected by variable control such as backwater or a leaking control structure 4. the stage–discharge relation is affected by unsteady.(Rating curves)

Some measurements indicate a temporary change in the rating, often due to a change in the streambed (for example, erosion or deposition) or growth of riparian vegetation. Such changes are called shifts; they may indicate a short- or long-term change in the rating for the gauge. In normal usage, the measured shifts (or corrections) are applied mathematically to a defined rating.


Rating Curve for Pachegaon
Discharge (m³/s)
Year 1992
Year 2002
Year 2012
Year 2022
Rating Curve for Zari
Stage (m)
Discharge (m³/s)
Year 1992
Year 2002
Year 2012
Year 2022
Rating Curve for Yelli
Discharge (m³/s)
Year 1992
Year 2002
Year 2012
Year 2022
Rating Curve for Degloor
Stage (m)
Discharge (m³/s)
Year 1992
Year 2002
Year 2012
Year 2022
Rating Curve for HIVRA
Discharge (m³/s)
Year 1989
Year 1999
Year 2009
Year 2019
Rating Curve for NANDGAON
Stage (m)
Discharge (m³/s)
Year 1989
Year 1999
Year 2009
Year 2019
Rating Curve for BAMNI
Discharge (m³/s)
Year 1989
Year 1999
Year 2009
Year 2019
Rating Curve for SAKMUR
Stage (m)
Discharge (m³/s)
Year 1989
Year 1999
Year 2009
Year 2019


Rating Curve for Gandlapet
Stage (m)
Discharge (m³/s)
Year 1992
Year 2002
Year 2012
Year 2022
Rating Curve for BHATPALLI
Stage (m)
Discharge (m³/s)
Year 1989
Year 1999
Year 2009
Year 2019
Rating Curve for ASHTI
Stage (m)
Discharge (m³/s)
Year 1989
Year 1999
Year 2009
Year 2019
Rating Curve for Sonarpal
Stage (m)
Discharge (m³/s)
Year 1992
Year 2002
Year 2012
Year 2022
Rating Curve for Jagdalpur
Stage (m)
Discharge (m³/s)
Year 1992
Year 2002
Year 2012
Year 2022
Rating Curve for Chindnar
Stage (m)
Discharge (m³/s)
Year 1992
Year 2002
Year 2012
Year 2022
Rating Curve for Tumnar
Stage (m)
Discharge (m³/s)
Year 1992
Year 2002
Year 2012
Year 2022
Rating Curve for Pathagudem
Stage (m)
Discharge (m³/s)
Year 1992
Year 2002
Year 2012
Year 2022



Discharge and Stage Classification

The Godavari River Basin exhibits a diverse hydraulic environment, with significant variations in discharge capacity and stage heights across its 20 monitoring stations. These variations provide a deeper understanding of the river's behavior, which can be categorized into different hydraulic zones based on discharge and stage characteristics.

High Discharge and Stage Stations

Perur Station is one of the most hydraulically significant locations in the basin. The station is capable of handling discharge volumes up to 60,000 m^3/s and stage heights reaching 20 meters. The relationship between discharge and stage at this site is highly nonlinear, suggesting complex channel geometry with substantial variations in width and depth. The stage-discharge curve reflects the dynamic nature of this station's hydraulic performance.

Polavaram Station is another important location, with discharge values approaching 50,000 m^3/s and stage heights reaching up to 16 meters. The station's hydraulic profile is indicative of a large river segment, where a wide channel and varying flow conditions influence the stage-discharge relationship. The rating curve here exhibits a nonlinear pattern, which suggests the presence of complex flow dynamics.

Moderate to High Discharge Stations

Bamni and Ashti Stations lie in the intermediate range of hydraulic behavior. Bamni experiences discharge up to 12,000 m^3/s, with stage heights varying from 0 to 16 meters, while Ashti handles discharges up to 20,000 m^3/s with stage heights around 12 meters. These stations present rating curves with noticeable curvature, reflecting varied hydraulic resistance and flow interactions that arise due to the influence of the channel's morphology.

Chindnar and Jagdalpur Stations also show complex hydraulic behavior. Chindnar has discharge capacities up to 8,000 m^3/s and stage heights that reach 12 meters, while Jagdalpur experiences discharge of 3,000 m^3/s with stage variations up to 10 meters. The stage-discharge relationships at these stations indicate the presence of significant variations in channel geometry, as well as localized flow resistance mechanisms.

Low to Moderate Discharge Stations

Degloor and Nandgaon Stations represent more constrained hydraulic conditions. At Degloor, discharge reaches a maximum of 500 m^3/s with stage heights around 6 meters, while Nandgaon shows similar characteristics. These stations are likely situated in narrow, more confined sections of the river, where the stage-discharge relationship is almost linear, reflecting consistent hydraulic conditions and limited flow variability.

Stations like Gandlapet, Sonarpal, and Tumnar exhibit lower discharge capacities, ranging from 1,200 to 1,750 m^3/s, with stage heights varying between 5 and 8 meters. The stage-discharge curves for these stations display a more gradual increase, indicating relatively stable channel conditions with less variability in hydraulic behavior.

Stage-Discharge Relationship Analysis

The analysis of stage-discharge relationships across the Godavari River Basin reveals critical insights into how the river's flow responds to changes in discharge. In high-discharge stations like Perur and Polavaram, stage height increases rapidly at lower discharge levels but becomes more gradual as discharge rises. This suggests that at higher flows, the channel may widen, reducing the sensitivity of the stage to further increases in discharge.

In intermediate discharge stations such as Bamni and Ashti, the relationship between discharge and stage is more complex, with the stage height becoming more sensitive to changes in discharge. This reflects the influence of varying channel morphology and increased hydraulic resistance.

At low discharge stations like Degloor and Nandgaon, the stage-discharge relationships are nearly linear, with stage increasing in proportion to discharge. This linear behavior is indicative of stable and less variable channel conditions, where flow resistance remains relatively constant.

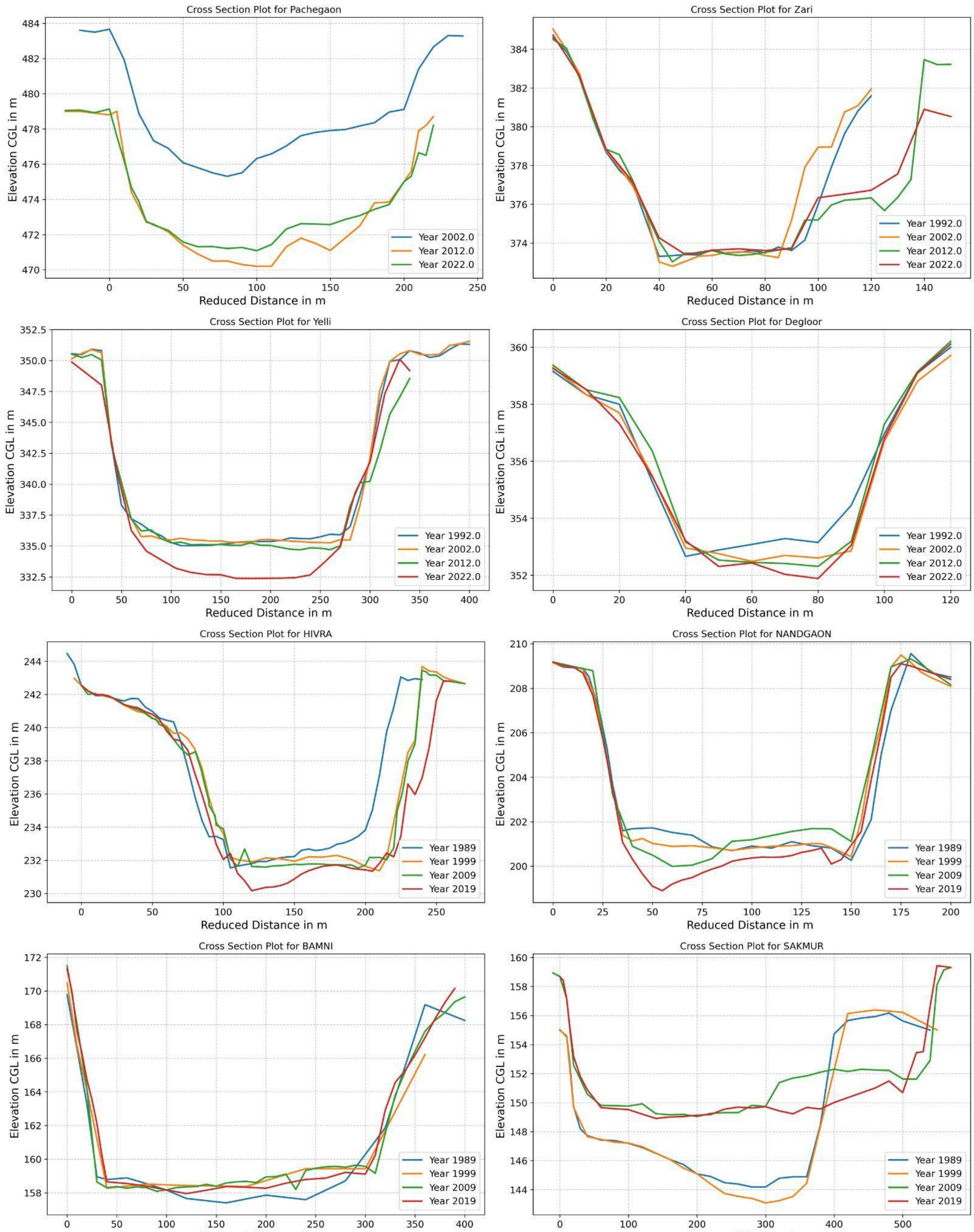
Temporal Hydraulic Evolution

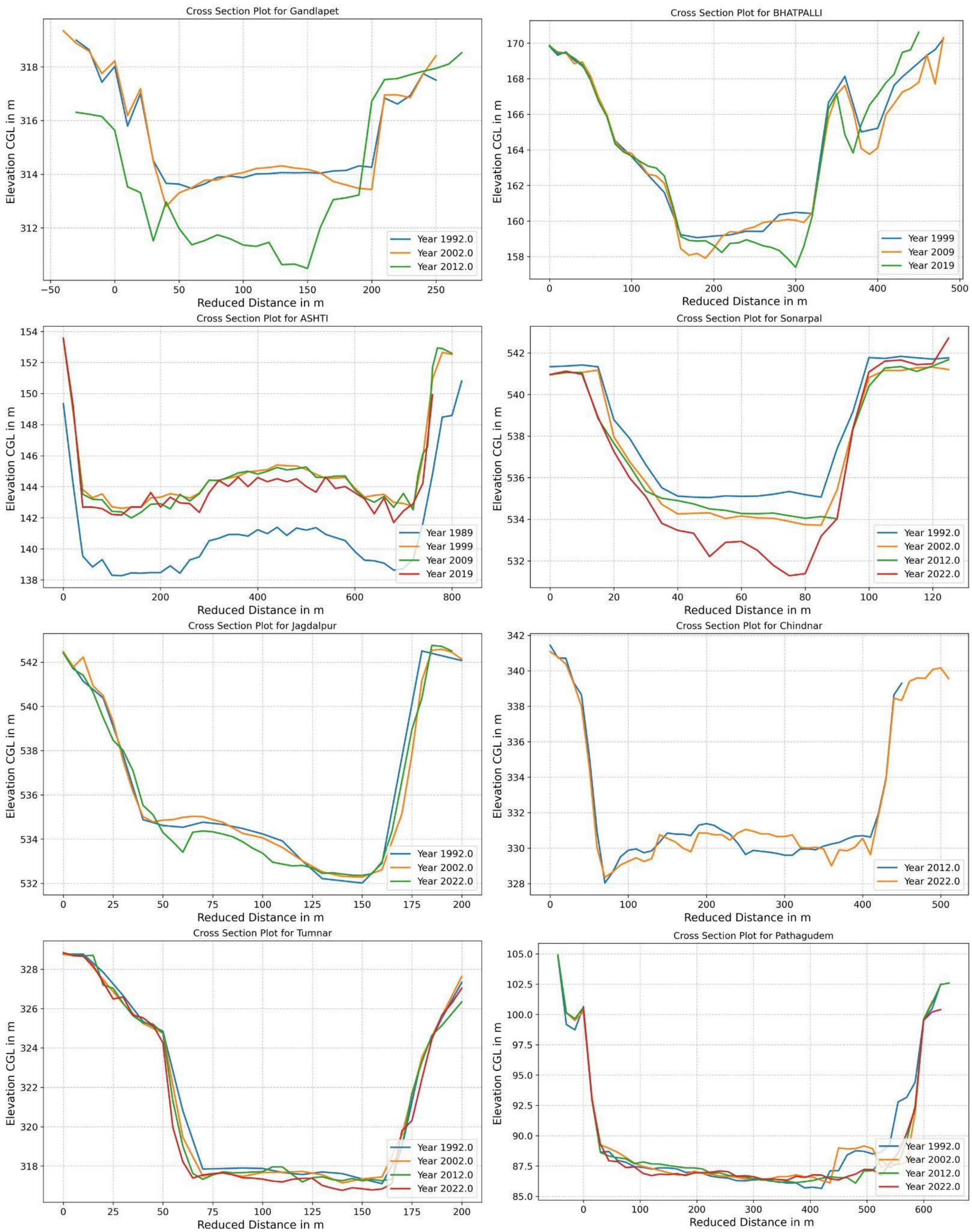
A comparison of rating curves from 1992 to 2022 reveals gradual changes in the hydraulic behavior at several stations. These changes could be due to natural processes such as sediment deposition and erosion, along with possible impacts from climate variations. These findings suggest that river systems are not static and that their hydraulic characteristics evolve over time, warranting continuous monitoring to track these transformations.

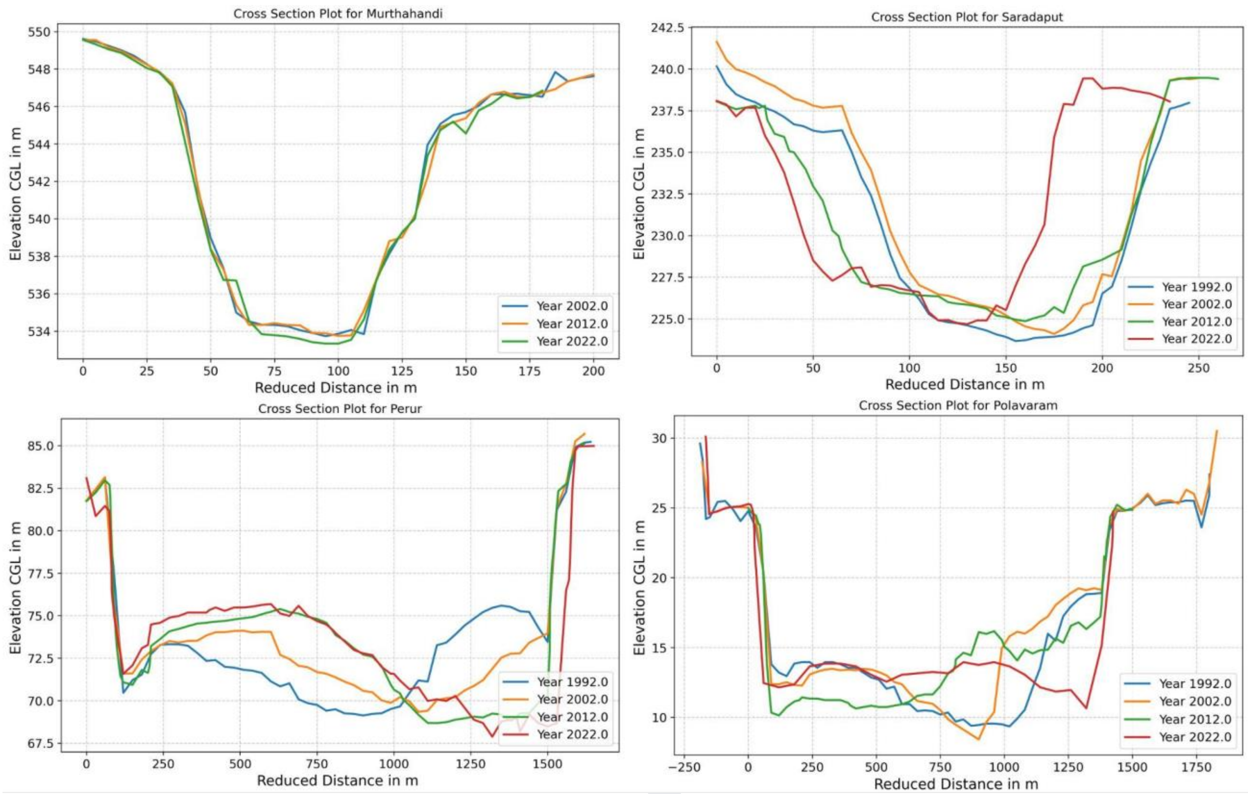
The hydraulic diversity within the Godavari River Basin highlights the varying flow characteristics and complex interactions between discharge and stage at different locations. From the expansive high-discharge environments at Perur and Polavaram to the more confined channels at Degloor and Nandgaon.

Cross Section of River Godavari

River cross-section surveys are invaluable for understanding and managing riverine environments effectively. They provide essential data on the shape, depth, and profile of riverbeds, which are crucial for flood risk management, hydraulic modelling, and the design of flood defences


Cross Section Plot for Pachegaon
Elevation CGL in m
Reduced Distance in m
Year 2002.0
Year 2012.0
Year 2022.0
Cross Section Plot for Zari
Elevation CGL in m
Reduced Distance in m
Year 1992.0
Year 2002.0
Year 2012.0
Year 2022.0
Cross Section Plot for Yelli
Elevation CGL in m
Reduced Distance in m
Year 1992.0
Year 2002.0
Year 2012.0
Year 2022.0
Cross Section Plot for Degloor
Elevation CGL in m
Reduced Distance in m
Year 1992.0
Year 2002.0
Year 2012.0
Year 2022.0
Cross Section Plot for HIVRA
Elevation CGL in m
Reduced Distance in m
Year 1989
Year 1999
Year 2009
Year 2019
Cross Section Plot for NANDGAON
Elevation CGL in m
Reduced Distance in m
Year 1989
Year 1999
Year 2009
Year 2019
Cross Section Plot for BAMNI
Elevation CGL in m
Reduced Distance in m
Year 1989
Year 1999
Year 2009
Year 2019
Cross Section Plot for SAKMUR
Elevation CGL in m
Reduced Distance in m
Year 1989
Year 1999
Year 2009
Year 2019


Cross Section Plot for Gandlapet
Elevation CGL in m
Reduced Distance in m
Year 1992.0
Year 2002.0
Year 2012.0
Cross Section Plot for BHATPALLI
Elevation CGL in m
Reduced Distance in m
Year 1999
Year 2009
Year 2019
Cross Section Plot for ASHTI
Elevation CGL in m
Reduced Distance in m
Year 1989
Year 1999
Year 2009
Year 2019
Cross Section Plot for Sonarpal
Elevation CGL in m
Reduced Distance in m
Year 1992.0
Year 2002.0
Year 2012.0
Year 2022.0
Cross Section Plot for Jagdalpur
Elevation CGL in m
Reduced Distance in m
Year 1992.0
Year 2002.0
Year 2022.0
Cross Section Plot for Chindnar
Elevation CGL in m
Reduced Distance in m
Year 2012.0
Year 2022.0
Cross Section Plot for Tumnar
Elevation CGL in m
Reduced Distance in m
Year 1992.0
Year 2002.0
Year 2012.0
Year 2022.0
Cross Section Plot for Pathagudem
Elevation CGL in m
Reduced Distance in m
Year 1992.0
Year 2002.0
Year 2012.0
Year 2022.0



Erosion and Sedimentation Dynamics in the Godavari River Basin

Spatiotemporal Patterns of Channel Bed Processes

Upper Basin Dynamics

The upper reaches of the Godavari basin display distinct erosional patterns. At Pachegaon, channel incision has progressed significantly, with around 7 meters of bed degradation recorded between 2002 and 2022. A consistent incision rate of approximately 35 cm per year suggests that sediment transport capacity has exceeded sediment supply, likely influenced by upstream dams that trap sediment while releasing erosive flows.

At Zari, the erosion-deposition dynamics are more intricate. While the central channel shows moderate incision (about 1-2 meters between 1992 and 2022), the right bank (120-140m distance) has experienced significant sediment deposition in the 2012 and 2022 surveys. This suggests active lateral processes, such as point bar development or bank failure, with flow deflection or secondary circulation patterns influencing sediment transport.

Gandlapet displays notable bed level fluctuations, particularly in the central channel (50-100m), where deepening (approximately 3.5 meters) occurred between 1992 and 2012. The adjacent sections show sediment accumulation, which indicates that focused flow energy has deepened the thalweg, while lower-velocity areas facilitate deposition, indicative of supply-limited conditions.

Middle Basin Sedimentation-Erosion Balance

At Yelli, the 1992, 2002, and 2012 profiles suggest a stable equilibrium, with bed elevations consistently around 335-336m. However, the 2022 profile shows a sudden deepening to approximately 332m, signaling intensified erosion. This abrupt change may result from extreme hydrological events or alterations in the sediment-flow regime, suggesting a potential threshold response.

At HIVRA, progressive incision in the central channel (approximately 2 meters from 1989 to 2019) is accompanied by marginal sedimentation, particularly between 200-240m. This suggests dynamic channel adjustments, with both vertical and lateral processes influencing sediment redistribution.

Degloor has shown consistent erosion over the observed period, with bed elevations progressively lowering across the entire channel width in successive profiles (1992, 2002, 2012, 2022). This pattern reflects a sustained sediment deficit, with minimal lateral deposition, indicating that this reach primarily functions as a sediment transfer zone.

Lower Basin Depositional Features

The BAMNI cross-section demonstrates relative bed elevation stability across all surveys (1989-2019), with a consistent low point around 158m. However, significant sediment deposition was observed along the right bank (300-375m distance) in 1999, followed by modest erosion in subsequent surveys. This fluctuation suggests episodic bank accretion and erosion, likely influenced by flood events.

At SAKMUR, channel shifting is evident, with the 1989 profile showing a wide, shallow channel compared to later surveys, which show progressive deepening and a more defined channel form. The 1999 survey indicates significant deposition (2-3 meters), followed by erosion in subsequent years, which may reflect channel avulsion processes and cut-and-fill sequences.

Perur shows evidence of progressive channel migration, with the deepest section (1000-1100m) progressively filling between 1992 and 2022, while deepening occurs between 700-900m. This lateral shift indicates active meandering, with cut-bank erosion and point-bar deposition dominating sediment redistribution.

Remarkable Stability Zones

A few locations exhibit exceptional stability over the 30-year observation period. Murthahandi, for example, shows almost identical bed elevations across all surveys (2002, 2012, 2022), with variations limited to 10-20 cm. This stability suggests strong geological controls, such as bedrock or armored conditions, which constrain both erosional and depositional processes.

Similarly, Tumnar shows minimal changes in bed elevation in the central channel (1992-2022), with only slight adjustments observed at the bank margins. This stability may be due to local factors such as channel gradient, width constraints, or substrate conditions that regulate sediment transport capacity.

Cross-Sectional Form Evolution and Channel Morphodynamics

Transformation of Channel Geometry

Examination of cross-sectional geometry reveals significant changes in channel form. At Pachegaon, the 2002 profile shows a broadly U-shaped cross-section, with a relatively flat central bed. By 2022, the channel has transformed into a V-shaped form with a distinct thalweg and steeper banks. This shift indicates a concentration of flow paths, potentially increasing shear stress and accelerating erosion.

At Bathpalli, the active channel width narrowed between 1999 and 2019, from 220m to 180m, alongside deepening and steepening of the banks. This constriction may reduce flood conveyance capacity and increase downstream flood risk due to the decreased channel storage volume.

At Zari, significant asymmetric modifications occurred between 1992 and 2022. The thalweg shifted laterally by about 15m, and the right bank exhibited substantial elevation changes, fluctuating by up to 3 meters. This suggests that preferential flow routing, possibly influenced by upstream curvature or local bank resistance variations, has altered sediment transport dynamics.

Bedform Signatures and Substrate Evolution

Some cross-sections display changes in bedforms, indicative of substrate evolution. At NANDGAON, the 1989 profile showed regularly spaced undulations, which were progressively smoothed in later surveys. This suggests a transition from a dune-ripple dominated bed to a plane-bed configuration, which affects flow resistance and sediment transport.

At Sonarpal, bedrock control emerged progressively, with the 1992 profile showing a smooth concave bed. By 2022, angular irregularities and stepped features were exposed, particularly between 60-80m, indicating that overlying alluvial materials were eroded, revealing resistant lithological units.

At Saradaput, the formation and gradual filling of a scour hole (125-175m distance) was observed. The 1992 profile shows a uniform bed, while the 2002 profile reveals a 2m depression that partially fills by 2012, leading to complex topography by 2022. This scour-fill sequence likely reflects adjustments following extreme events, followed by recovery toward equilibrium conditions.

Bank Retreat and Failure Mechanisms

Bank profiles reveal distinct failure mechanisms at different sites. At Jagdalpur, the left bank (0-25m distance) exhibited stepped retreat, with approximately 5m of horizontal displacement between 1992 and 2022. The steep profile suggests cohesive bank materials failed through rotational slumping rather than gradual erosion.

In contrast, the right bank at Pathagudem (500-600m distance) showed gradual modification, with the development of a concave profile and reduced slope angle. This is indicative of progressive fluvial entrainment of less cohesive materials, which may influence riparian vegetation and bank stabilization strategies.

At BAMNI, the right bank (350-400m distance) showed multi-stage failure processes, with initial steepening followed by upper bank retreat and eventual profile adjustment. This sequence is characteristic of cohesive riverbanks undergoing undercutting, mass failure, and relaxation over time.

Cross-Sectional Area Dynamics

Quantitative analysis of cross-sectional area changes provides insight into channel capacity evolution. At Pachegaon, despite significant bed degradation, the total cross-sectional area has increased only marginally (about 5%) between 2002 and 2022, suggesting that the channel width has been constrained by resistant bank materials, maintaining flow conveyance capacity.

Perur shows a decrease in cross-sectional area (approximately 8%) from 1992 to 2022, despite deepening of the channel. Sediment deposition along the margins (250-500m and 1000-1250m) compensates for the central incision, resulting in a narrower, deeper channel form. This redistribution affects flow velocity profiles and sediment transport capacity.

At Gandlapet, the cross-sectional area has decreased by approximately 15% from 1992 to 2012, primarily due to deposition along the left bank (0-50m), which could lead to flow constriction and increased upstream backwater effects during high-discharge events.

Implications of Cross-Sectional Changes

These cross-sectional modifications have profound implications for reach-scale river dynamics. The prevalent pattern of deepening without corresponding widening suggests that while the channel can convey moderate flows efficiently, it may have reduced capacity for overbank storage during extreme events. This may result in higher flow velocities and more pronounced flood pulses downstream.

Asymmetric cross-sections observed at several stations (e.g., Zari, HIVRA, Gandlapet) indicate the development of stronger secondary circulation patterns, enhancing flow complexity and habitat diversity, but also concentrating erosive forces, particularly at vulnerable bank locations.

Sites exhibiting channel narrowing (e.g., Bathpalli, Gandlapet) may be experiencing sediment continuity issues, as the reduction in channel width can increase stream power during moderate flows, which could exceed upstream sediment supply and lead to ongoing erosion.

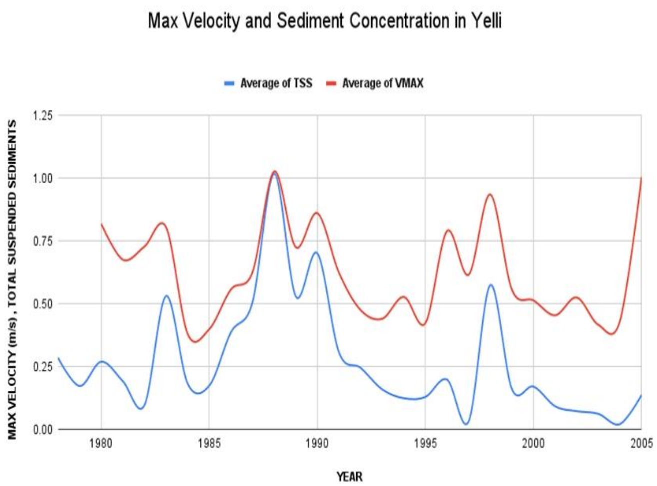
Anthropogenic Influences on Sediment Dynamics

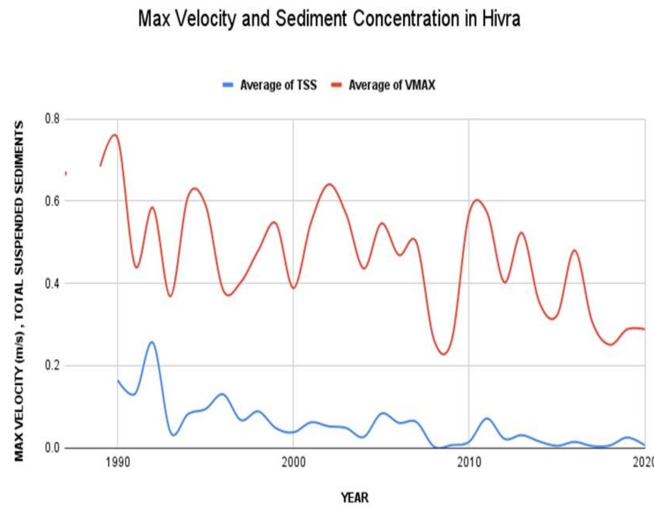
Some cross-sections exhibit adjustment patterns likely influenced by anthropogenic activities. The Ashti profile, for example, shows an abrupt elevation increase (approximately 4 meters) between 1989 and 1999, followed by relative stability. This pattern suggests potential structural interventions, such as the installation of grade control structures or weirs.

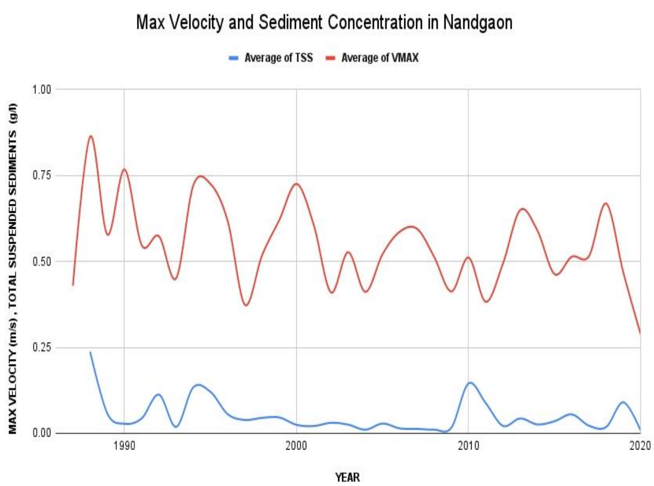
Similarly, the Chindnar profile shows an unusually uniform bed between 2012 and 2022, contrasting with a more irregular 1992 profile. This could indicate channel dredging or regularization activities aimed at controlling channel morphology.

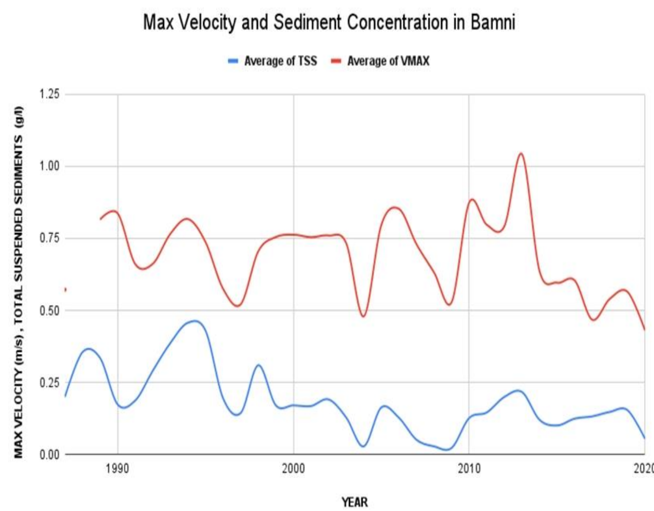
At Polavaram, the pronounced depression (750-850m) observed in the 2022 profile suggests the impact of sand mining, with persistent negative relief features potentially indicative of extraction activities.

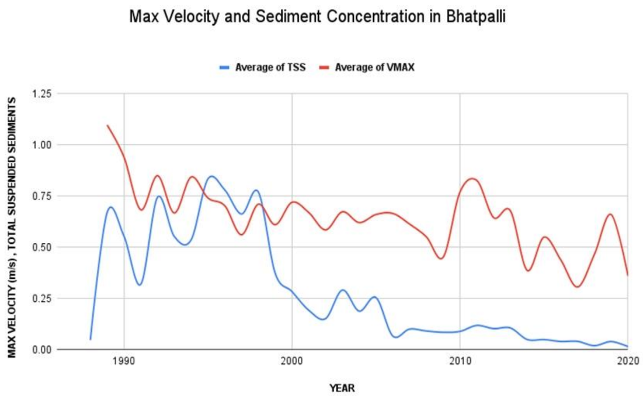
Total Sediment Solids Concentration And max Velocity Relations

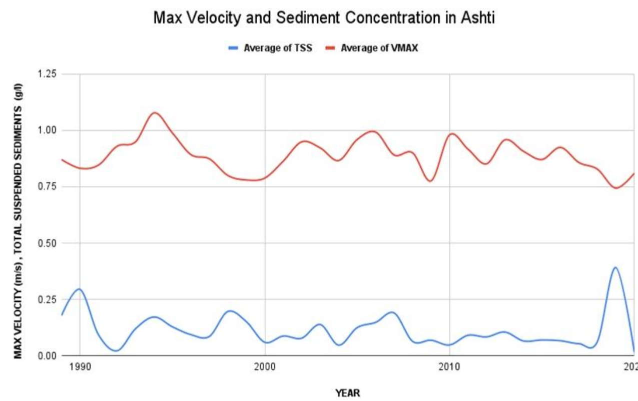

Max Velocity and Sediment Concentration in Yelli
Average of TSS
Average of VMAX
MAX VELOCITY (m/s) , TOTAL SUSPENDED SEDIMENTS
1.25
1.00
0.75
0.50
0.25
0.00
1980
1985
1990
1995
2000
2005
YEAR

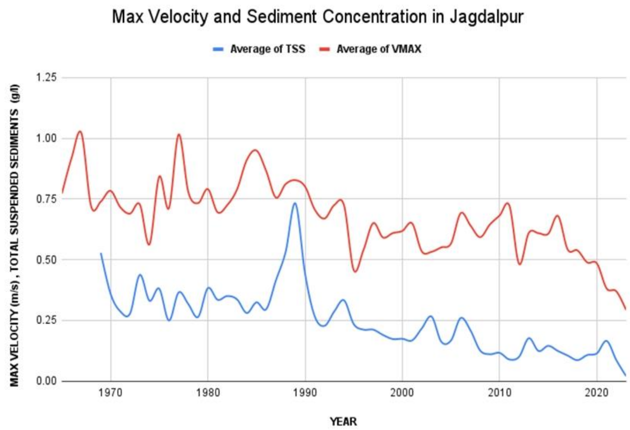

Max Velocity and Sediment Concentration in Hivra
Average of TSS
Average of VMAX
MAX VELOCITY (m/s) , TOTAL SUSPENDED SEDIMENTS
0.8
0.6
0.4
0.2
0.0
1990
2000
2010
2020
YEAR

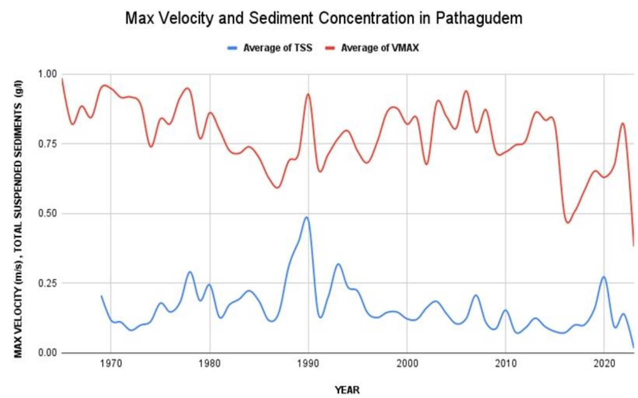

Max Velocity and Sediment Concentration in Nandgaon
Average of TSS
Average of VMAX
MAX VELOCITY (m/s) , TOTAL SUSPENDED SEDIMENTS (g/l)
1.00
0.75
0.50
0.25
0.00
1990
2000
2010
2020
YEAR

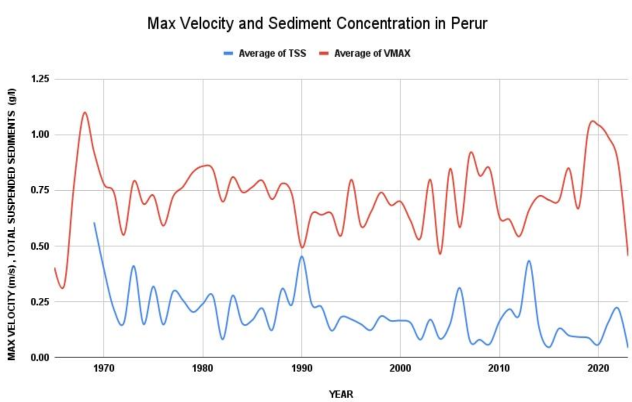

Max Velocity and Sediment Concentration in Bamni
Average of TSS
Average of VMAX
MAX VELOCITY (m/s) , TOTAL SUSPENDED SEDIMENTS (g/l)
1.25
1.00
0.75
0.50
0.25
0.00
1990
2000
2010
2020
YEAR

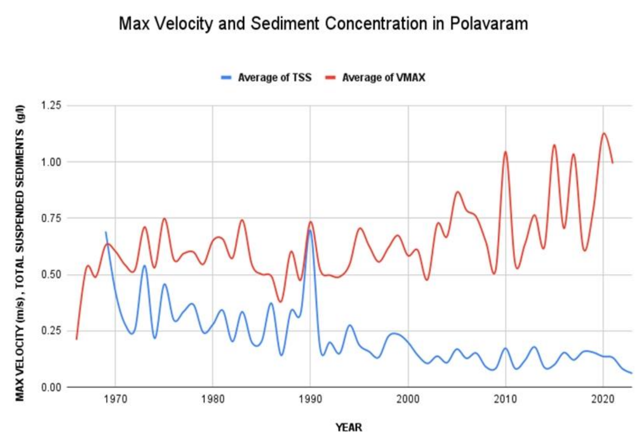












The Godavari River Basin is a complex hydraulic system, where each monitoring station offers unique insights into sediment transport and water flow dynamics. A closer examination of the hydraulic data reveals considerable variability across the basin, challenging the use of simple models to explain river behavior and highlighting the range of hydraulic processes that shape the river system.

The stations at Bhatpalli and Jagdalpur. Both locations saw significant changes in the early 1990s, but their responses to shifts in flow conditions were quite different. At Bhatpalli, there is a clear relationship between water velocity and sediment concentration as the water velocity increases, sediment load rises in a nearly synchronous pattern. However, at Jagdalpur, the relationship is more complex. Fluctuations in water velocity do not consistently match changes in sediment concentration, pointing to other local hydraulic factors that might influence sediment transport separately from the velocity of the water.

The Ashti and Hivra stations are notably stable within the basin. At these locations, sediment concentrations remain consistently low, and water velocity maintains a steady rate over time. These sites provide valuable insights into environments with stable hydraulic conditions, showing regions that are less affected by the fluctuating changes seen elsewhere in the basin.

Further complexity is seen at the Pathagudem and Peru stations. While both stations exhibit similar velocity patterns, their sediment transport behaviors differ significantly. Pathagudem shows a relatively steady sediment concentration, while Peru experiences intermittent spikes in sediment levels that coincide with increases in water velocity. This suggests that even neighboring stations can display different sediment transport dynamics, likely due to local variations in hydraulic conditions or channel characteristics.

The Polavaram and Yelli stations illustrate additional shifts in hydraulic conditions. Polavaram has shown increasing variability in data since 2020, pointing to changes in flow patterns or adjustments in the upstream catchment area that may affect sediment transport. In contrast, Yelli displays more dramatic fluctuations, with significant peaks in sediment concentration during the mid-1980s and a sharp rise in water velocity around 2005. These stations appear to reflect substantial changes in the hydraulic environment, possibly linked to shifts in the landscape or upstream processes.

At the Nandgaon and Bamni stations, there is another contrast in hydraulic conditions. Both locations maintain low sediment concentrations, but their water velocity patterns are different. Nandgaon shows more significant fluctuations in velocity, while Bamni maintains a more consistent rate, suggesting variations in local hydraulic conditions, such as channel morphology or flow resistance.

The differences between high-variability stations like Jagdalpur and the more stable environments at Ashti are particularly striking. This contrast highlights the difference between a dynamic river system, where sediment transport is heavily influenced by fluctuating hydraulic conditions, and a more stable, low-velocity system where sediment movement is minimal and steady.

Ultimately, the data reveals the hydraulic diversity within the Godavari River Basin. Each station reflects different hydraulic influences from water velocity and channel characteristics to upstream changes and local sediment conditions. These differences highlight the challenges of creating a one-size-fits-all model for sediment transport in the basin, as each area shows unique hydraulic dynamics shaped by natural processes and human impacts.

The Godavari River Basin should not be treated as a uniform system with predictable hydraulic behavior. Instead, it is a diverse network of river sections, each with its own set of conditions that influence sediment transport and water flow. Understanding these complexities is key to developing more accurate, localized models for managing sediment transport and water resources in the region.

Sitewise Monsoon, Non-Monsoon & Annual Flow of Water (2010–2011 to 2019–2020) – Unit: MCM

This dataset covers water flow measurements from 31 monitoring sites in the Godavari River basin over a decade. It includes data for monsoon, non-monsoon, and annual flows, showing how water distribution changes with seasons.

Monsoon flows are the largest contributor to the annual water budget across all sites. Many locations show little to no flow during the non-monsoon period, highlighting the region's dependence on seasonal rainfall. This makes the area vulnerable to droughts when rainfall is below average.

Major water contributors include Bhadrachalam, Polavaram, and Perur at Godavari, with annual flows often exceeding 100,000 MCM. Tributaries like the Indravathi and Sabari rivers also play a key role in maintaining water balance.

There's significant year-to-year variation. For instance, 2013–14 saw high flows at many sites, while 2015–16 and 2017–18 experienced lower flows. This variability makes water management challenging, especially for planning during droughts or floods.

Drought conditions are evident, with several sites recording zero flow during the non-monsoon season in multiple years. Locations like Degloor at Lendi, Dhalegaon at Godavari, and Zari at Dudha show complete channel drying during dry periods.

Flow consistency differs across sites. Some maintain steady patterns, while others show extreme fluctuations. These differences are influenced by factors such as local rainfall, catchment characteristics, and human activities like dam operations.

The reliance on monsoon rainfall also varies. Some sites get over 95% of their annual flow from monsoon rains, while others have significant base flows during dry periods, likely due to groundwater contributions or controlled reservoir releases.

Site-wise Maximum & Minimum Observed Water Level and Discharge in River Basins (up to 2019–20) – Unit: MCM

This dataset includes water level and discharge measurements from 56 monitoring sites across different river basins, covering data up to 2019–20. It shows the highest and lowest water levels along with discharge values, helping to understand how rivers behave in different seasons and conditions.

The highest water levels vary widely, from 861.32 meters at Kunturla to just 6.06 meters at Valamuru. This range reflects differences in the landscape and river flow patterns across the basin. Most of the highest water levels happened during the monsoon season, especially between July and October, with August being the peak month. This clearly shows how much the monsoon rains affect river flows.

Discharge levels also change dramatically. The highest discharge was recorded at Polavaram with 87,250 cumecs and at Perur with 62,889 cumecs. On the other hand, many sites recorded zero discharge during dry periods, especially in the non-monsoon season. This shows how these rivers can shift from flooding to completely drying up depending on the season.

A striking observation is that about 60% of the sites recorded zero discharge at some point, meaning the rivers dried up completely during certain times of the year. This was most common from January to June, before the monsoon rains, indicating severe water shortages in many areas.

The data covers a wide range of years, with some sites having records dating back to the 1960s and others starting more recently. This helps track changes in river behavior over time, which is important for understanding the effects of climate change and shifting weather patterns.

Annual Dependable Flow of Water by Site and River Basin (1990–91 to 2019–20)

This dataset provides important information about water availability at 32 monitoring sites across different river basins over the last 30 years, from 1990–91 to 2019–20. It shows the dependable flow of water at different reliability levels, from 10% to 90%, measured in Million Cubic Meters (MCM).

Dependable flow refers to the amount of water that can be expected to be available with a certain level of confidence. For example, a 90% dependable flow means this amount of water would be available in 9 out of 10 years. This helps in planning how water is used, especially during dry periods.

The biggest water flows are found at key sites along the Godavari River. For example, Polavaram and Bhadrachalam record impressive flow volumes, with 50% dependable flows of 80,753 MCM and 64,054 MCM, respectively. These sites collect water from large upstream areas, making them crucial for the basin.

Water availability drops significantly as the reliability percentage increases. At Perur station, the 10% dependable flow (available during very wet years) is 110,906 MCM, but the 90%

dependable flow (available even in dry years) drops to 33,564 MCM. This shows how much water can vary from year to year, depending on rainfall.

Smaller sites often have very low dependable flows, especially at higher reliability levels. Sites like Gandlapet at Peddavagu and Dhalegaon at Godavari show zero flow at 90% dependability, meaning the rivers dry up completely during droughts. This is a big concern for drinking water, farming, and maintaining the environment.

There's also a big difference in how steady the water flows are at different sites. Some places, like Murthahandi at Journala, have fairly stable flows, possibly because of groundwater support or controlled releases from upstream dams. On the other hand, sites like Yelli at Godavari show huge changes, with the 10% dependable flow at 10,710 MCM dropping to just 149 MCM at 90% dependability. This shows how unpredictable water availability can be in dry years.

Overall, this dataset is very useful for planning water use, managing droughts, building infrastructure, and protecting the environment. It helps decision-makers allocate water wisely, especially during times of scarcity, and identifies areas that are most at risk from changing climate conditions.

Time Series of Sediment Load by Site in River Basin (2019–2020)

This dataset tracks sediment movement across twelve monitoring sites in the river basin from 2010–2011 to 2019–2020. It shows that sediment loads vary widely between different sites. For example, Indravati at Jagadalpur consistently carries the heaviest sediment load, averaging over 47 million metric tonnes each year. In contrast, places like Godavari at Dhalegaon often show little to no sediment flow in several years.

Sediment transport is strongly influenced by the seasons. During the monsoon, over 99% of the annual sediment load is carried by the rivers. This happens because heavy rains create strong river currents that wash away soil and debris from the land into the rivers.

There's also a lot of variation from year to year. For instance, Paddavagu at Bhatpalli had an extraordinary surge in sediment in 2013–2014, with 266.6 million metric tonnes—more than six times the usual amount. On the other hand, Pranhita at Tekra completely stopped showing measurable sediment flow from 2015 onwards. This could be due to changes in the river's path, reduced water flow, or human activities upstream affecting sediment movement.

Some sites show a steady decline in sediment over the years, while others have fluctuating patterns without a clear trend. Interestingly, sites within the same sub-basin often show similar changes, suggesting that major weather events or shifts in the river system can affect multiple areas at once.

This sediment data is important for understanding how rivers erode land, how their channels change over time, and how these changes might affect water infrastructure. The wide variations in sediment load across different sites and years show the need for targeted management strategies to handle sediment in each part of the river basin.

TABLE 01: Sitewise Monsoon, Non-Monsoon & Annual Flow of Water from 2010-2011 to 2019-2020 (Unit: MCM)

Sitewise Monsoon, Non-Monsoon & Annual flow of water from 2010-2011 to 2019-2020												Unit: MCM
S. No.	**Site Name**	**Season**	**2010-11**	**2011-12**	**2012-13**	**2013-14**	**2014-15**	**2015-16**	**2016-17**	**2017-18**	**2018-19**	**2019-20**
1	Ambabal at Narangi	Monsoon	1107	478	587	809	940	523	1114	647	587	946
		Non-Monsoon	35	165	0	0	0	0	62	0	0	0
		Annual	1142	642	587	809	940	523	1176	647	587	946
2	Betmogrra at Maner	Monsoon	211	228	9	148	30	0	178	4	91	385
		Non-Monsoon	25	8	0	10	0	0	0	0	0	2
		Annual	236	236	9	158	30	0	178	4	91	386
3	Bhadrachalam	Monsoon	103332	45598	70766	136197	47130	40924	78950	33213	63090	103312

	at Godavari	Non-Monsoon	4849	1908	4339	6595	2725	1592	1881	887	964	1102
		Annual	108181	47506	75105	142791	49856	42517	80830	34100	64054	104415
4	Cherribeda at Bardha	Monsoon	805	306	621	939	1457	889	1919	415	565	1079
		Non-Monsoon	37	11	15	33	33	15	12	7	8	25
		Annual	842	317	636	972	1490	903	1931	422	573	1104
5	Chindnar at Indravathi	Monsoon	11505	4640	8746	9955	10587	7519	11549	7056	7142	14172
		Non-Monsoon	582	135	257	638	340	187	143	152	100	262
		Annual	12087	4775	9003	10593	10927	7707	11691	7207	7242	14435
6	Degloor at Lendi	Monsoon	254	221	227	263	42	0	759	46	11	120
		Non-Monsoon	43	0	0	20	0	0	0	0	0	0
		Annual	297	221	227	283	42	0	759	46	11	120

7	Dhalegaon at	Monsoon	408	193	0	0	0	0	694	0	0	1958
	Godavari	Non-Monsoon	0	0	0	0	0	0	0	0	0	0
		Annual	408	193	0	0	0	0	694	0	0	1958
8	G.R.Bridge at Godavari	Monsoon	698	498	231	717	220	0	949	341	93	1538
		Non-Monsoon	0	0	0	55	0	0	0	0	0	0
		Annual	698	498	231	773	220	0	949	341	93	1538
9	Gandlapet at Peddavagu	Monsoon	63	62	19	355	3	0	12	0	3	36
		Non-Monsoon	0	0	0	26	0	0	0	0	0	0
		Annual	63	62	19	381	3	0	12	0	3	36
10	Jagdalpur at Indravathi	Monsoon	2629	1160	2365	2691	2448	2217	2202	2235	2149	3633
		Non-Monsoon	211	49	40	78	34	0	0	0	0	132

		Annual	2841	1210	2405	2769	2482	2217	2202	2235	2149	3765
11	Kiwaibalenga at Bawardhi	Monsoon	1286	468	798	1248	341	274	552	628	647	1170
		Non-Monsoon	40	6	8	27	12	5	3	4	4	9
		Annual	1326	474	806	1275	353	279	555	632	651	1179
12	Konta at Sabari	Monsoon	14707	7442	13296	16960	15322	13155	11097	12647	18105	20228
		Non-Monsoon	4761	2274	4385	4598	4198	3533	3222	2784	2807	3711
		Annual	19468	9716	17680	21557	19520	16688	14319	15431	20913	23939
13	Kosagumda at Bhaskal	Monsoon	1232	646	889	1020	1209	815	853	1036	694	1190
		Non-Monsoon	100	16	38	63	53	28	14	13	19	24
		Annual	1332	662	927	1083	1262	843	867	1049	712	1214
14	Mancherial at	Monsoon	9100	2381	1825	6670	767	873	7855	183	2050	2561

	Godavari	Non-Monsoon	667	266	398	820	250	251	226	48	22	0
		Annual	9767	2647	2224	7489	1017	1124	8081	232	2071	2561
15	Murthahandi at Journala	Monsoon	1260	781	1048	1342	1193	811	1048	1113	1287	1848
		Non-Monsoon	384	120	231	247	195	143	75	93	87	152
		Annual	1645	900	1279	1589	1388	955	1123	1206	1374	2000
16	Nowrangpur at Indravathi	Monsoon	1006	484	854	1214	1218	731	699	761	1810	1753
		Non-Monsoon	220	46	64	144	94	69	48	62	70	94
		Annual	1225	531	917	1358	1312	800	746	824	1880	1847
17	Pachegaon at Pravara	Monsoon	178	380	54	161	69	0	523	496	122	849
		Non-Monsoon	43	0	131	98	195	135	8	5	0	0
		Annual	222	380	185	259	265	135	531	502	122	849

18	Pathagudem at Indravthi	Monsoon	29689	13336	25587	38360	23315	18168	10195	13343	21976	37683
		Non-Monsoon	1482	323	742	1634	1016	413	334	238	293	800
		Annual	31172	13658	26329	39994	24331	18582	10529	13581	22268	38483
19	Perur at Godavari	Monsoon	94978	50737	77426	143249	51030	41435	82394	28196	63173	94703
		Non-Monsoon	5251	1836	3164	5847	2416	1149	1425	556	619	750
		Annual	100229	52573	80590	149096	53445	42584	83820	28752	63791	95454
20	Polavaram at Godavari	Monsoon	107288	50647	82244	138191	52145	48424	81829	40342	76622	112965
		Non-Monsoon	9883	5171	9455	11682	6192	4366	4390	3349	4010	4145
		Annual	117171	55818	91698	149873	58338	52791	86219	43691	80632	117111
21	Kopergaon at Godavari	Monsoon	-	-	-	-	1150	350	1851	1832	865	4090
		Non-Monsoon	-	-	-	-	0	167	0	0	0	0

		Annual	-	-	-	-	1150	516	1851	1832	865	4090
22	Potteru (Seasonal) at Potteru vagu	Monsoon	1577	1311	1178	2000	1863	1340	1204	1890	2419	2564
		Non-Monsoon	151	69	118	251	149	87				
		Annual	1728	1380	1297	2251	2011	1427	1204	1890	2419	2564
23	Purna at Purna	Monsoon	1436	344	243	1303	116	67	659	185	245	328
		Non-Monsoon	130	12	0	17	0	0	4	24	0	0
		Annual	1565	357	243	1321	116	67	663	209	245	328
24	Saigaon at Manjera	Monsoon	2282	587	56	171	9	0	2281	221	22	3
		Non-Monsoon	102	0	0	0	0	0	0	0	0	0
		Annual	2384	587	56	171	9	0	2281	221	22	3
25	Sangam at	Monsoon	415	143	225	196	146	244	273	202	242	256

	Murredu	Non-Monsoon	82	8	58	59	17	14	7	4	14	10
		Annual	496	151	283	255	163	258	279	206	256	266
26	Saradaput at Sabari	Monsoon	4374	2841	4616	5837	4508	3444	4497	3908	5959	7066
		Non-Monsoon	1174	445	962	1132	895	739	502	449	635	855
		Annual	5548	3286	5577	6970	5403	4183	4999	4358	6594	7921
27	Somanpally (Seasonal) at Maner	Monsoon	1905	306	1060	2450	290	267	967	219	784	1204
		Non-Monsoon	115	8	31	142	12	2			1	16
		Annual	2020	314	1091	2591	302	269	967	219	785	992
28	Sonarpal at Markandi	Monsoon	948	342	627	737	604	570	1071	663	401	39
		Non-Monsoon	50	2	10	33	8	4	0	0	6	1030
		Annual	998	344	637	769	612	574	1071	663	407	266

29	Tumnar at Dantewara	Monsoon	1758	685	1482	1551	783	1021	1321	1078	1443	2114
		Non-Monsoon	119	50	102	177	118	36	26	33	44	69
		Annual	1877	735	1585	1728	901	1058	1347	1111	1487	2182
30	Yelli at Godaavari	Monsoon	4949	1383	145	2610	82	0	4604	1186	1238	3482
		Non-Monsoon	36	0	0	5	0	0	0	0	0	0
		Annual	4985	1383	145	2615	82	0	4604	1186	1238	3482
31	Zari at Dudha	Monsoon	618	192	39	321	43	1	841	166	36	126
		Non-Monsoon	1	0	0	0	0	0	26	0	0	0
		Annual	618	192	39	321	43	1	867	166	36	126

TABLE 02: Site wise Maximum & Minimum Observed Water level and Discharge in River Basins till 2019-20

Site wise Maximum & Minimum Observed Water level and Discharge in River Basins till 2019-20	Unit: MCM

Sl. No.	Site Name	Maximum Water Level			Minimum Water Level			Maximum Observed discharge		Minimum Observed discharge		Refrence Period
		Water level (m)	**Date**	**Discharge (Cumecs)**	**Water level (m)**	**Date**	**Discharge (Cumecs)**	**Discharge (Cumecs)**	**Date**	**Discharge (Cumecs)**	**Date**	**Unit : MCM**
1	Somanpally (seasonal)	127.344	24/Jul/1989	3360	118.34	11/Jun/1967	0.068	3360	24/Jul/1989	0.068	11/Jun/1967	2019-20
2	Keolari	440.5	21/Jul/1994	5500	425.82	23/Mar/2019	0	5500	21/Jul/1994	0	23/Mar/2019	2019-20
3	Kumhari	304.335	18/Aug/2002	16747	290.08	28/May/2017	0.255	16747	18/Aug/2002	0.255	28/May/2017	2019-20
4	Nowrangpur	560.636	29/Jul/1969	2164	550.03	18/Apr/2016	1.249	2164	29/Jul/1969	0	18/Apr/2016	2019-20
5	Kosagumda	555.87	06/Aug/2010	1692	547.79	23/Apr/2016	0	1692	06/Aug/2010	0	25/Mar/2015	2019-20
6	Rajegaon	284.26	23/Jul/2014	9682	0	15/Jul/1986	0	9682	23/Jul/2014	0	15/Jul/1986	2019-20
7	Murthahandi	545.09	06/Aug/2010	1882	533.75	13/Jun/2016	0	1882	06/Aug/2010	0	13/Jun/2016	2019-20
8	Jagdalpur	544.551	15/Aug/1986	3109	533.44	26/Mar/1999	0.265	3109	15/Aug/1986	0	26/Mar/1999	2019-20
9	Kopergaon gauge	495.6	03/Aug/2016	5362	485.5	21/Jan/2015	0	5362	03/Aug/2016	0	21/Jan/2015	2019-20

	,Rainfal,W/L											
10	Ramakona	349.5	30/Jul/1991	3560	336.70	30/May/2013	0.067	3560	30/Jul/1991	0.067	30/May/2013	2019-20
11	Sonarpal	542.57	04/Jul/2006	1509	534.21	16/Mar/2002	0	1509	04/Jul/2006	0	16/Mar/2002	2019-20
12	Pachegaon (Terminal site on River Pravara)	481.45	12/Oct/1990	1234	475.5	25/Jan/2007	0	1234	12/Oct/1990	0	25/Jan/2007	2019-20
13	Satrapur	277.61	06/Sep/1994	14161	263.59	26/Apr/2019	0	14161	06/Sep/1994	0	26/Apr/2019	2019-20
14	Ambabal	542.45	05/Jul/2006	2243	534.54	23/May/2002	0	2243	05/Jul/2006	0	23/May/2002	2019-20
15	Kiwaibalenga	571.79	06/Aug/2010	1408	563.80	18/Feb/2012	0	1408	06/Aug/2010	0	18/Feb/2012	2019-20
16	Cherribeda	573.9	04/Jul/2006	2485	565.07	20/051997	0	2485	04/Jul/2006	0	20/051997	2019-20
17	Dhalegaon	399.855	13/Aug/2006	7652	386.575	25/Jan/2015	0	7652	13/Aug/2006	0	25/Jan/2015	2019-20
18	Ashti	155.1	13/Jul/1994	27874	138.16	14/Jun/1983	1.08	27874	13/Jul/1994	1.08	14/Jun/1983	2019-20
19	Chindnar	340.1	05/Jul/2006	13351	327.69	13/May/1976	9.758	13351	05/Jul/2006	9.758	13/May/1976	2019-20
20	G.r.bridge	378.37	14/Aug/2006	6222	364.5	13/Jun/2007	0	6222	14/Aug/2006	0	13/Jun/2007	2019-20

21	Hivra	246.31	07/Sep/1994	6862	0	21/Apr/2004	0	6862	07/Sep/1994	0	21/Apr/2004	2019-20
22	Tumnar	325.977	14/Jun/2004	3584	317.08	14/052019	0.071	3584	14/Jun/2004	0.071	14/052019	2019-20
23	Nandgaon	212.55	13/Jul/1994	3205	0	09/May/1989	0	3205	13/Jul/1994	0	09/May/1989	2019-20
24	Zari	385.71	27/Jul/2005	2471	373	17/Jan/2015	0	2471	27/Jul/2005	0	17/Jan/2015	2019-20
25	Pathagudem	103.5	05/Aug/2006	35392	86.13	15/May/1994	1.963	35392	05/Aug/2006	1.963	15/May/1994	2019-20
26	Perur	87.42	15/Aug/1986	62889	68.49	13/Jun/1966	14.2	62889	15/Aug/1986	14.2	13/Jun/1966	2019-20
27	Purna (Terminal Site on River Purna)	371.80	27/Jul/2005	10811	358.02	25/Jan/2010	0	10811	27/Jul/2005	0	25/Jan/2010	2019-20
28	Nanded	349.675	26/Sep/2016	3709	340.95	01/Jun/2017	0	3709	26/Sep/2016	0	01/Jun/2017	2019-20
29	P.G. Bridge	217.92	07/Aug/2006	13881	197.22	10/Jun/1965	0	13881	07/Aug/2006	0	10/Jun/1965	2019-20
30	Yelli	354.2	07/Aug/2006	12535	334.3	21/Jan/2015	0	12535	07/Aug/2006	0	21/Jan/2015	2019-20
31	Bhadrachalam	50.14	08/Aug/2010	51444	32.77	02/May/2010	0.346	51444	21/Aug/2006	40300	02/May/2010	2019-20

32	Bamni (balharsha)	176.32	15/Aug/1986	21400	158.01	17/May/1989	1.9	21400	15/Aug/1986	1.9	17/May/1989	2019-20
33	Saigaon	554.253	07/Oct/1983	3395	542.773	19/Dec/2008	0	3395	07/Oct/1983	0	19/Dec/2008	2019-20
34	Sakmur/sirpur	161.95	08/Aug/2006	14335	145.49	30/May/2005	0	14335	08/Aug/2006	0	30/May/2005	2019-20
35	Salebardi	233.52	15/Sep/2005	3017	0	15/Mar/1990	0	3017	15/Sep/2005	0	15/Mar/1990	2019-20
36	Sangam	58.25	21/Sep/2015	970.6	51.00	25/Feb/2015	0	970.6	21/092015	0	25/Feb/2015	2019-20
37	Degloor	363.85	24/Aug/2000	2732.23	352	10/Jan/2016	0	2732.23	24/Aug/2000	0	10/Jan/2016	2019-20
38	Wairagarh	215.905	07/Aug/2007	2732	210.32	04/Apr/1998	0	2732	07/Aug/2007	0	04/Apr/1998	2019-20
39	Betmogrra	362.24	02/Oct/2016	3814	247.5	25/Jan/2015	0	3814	02/Oct/2016	0	25/Jan/2015	2019-20
40	Potteru (seasonal)	131.99	04/Aug/2006	3331	121.48	02/Jun/1997	0.013	3331	04/Aug/2006	0.013	35583	2019-20
41	Rajoli	239.615	14/Aug/1986	1830	0	08/Mar/2004	0	1830	14/Aug/1986	0	08/Mar/2004	2019-20
42	Konta	49.91	17/Aug/1986	20187	30.70	15/May/1967	23.81	20187	17/Aug/1986	23.81	15/May/1967	2019-20
43	Bhatpalli	168.5	02/Oct/1988	3750	158.45	19/May/1996	0.75	3750	02/Oct/1988	0.75	19/May/1996	2019-20

44	Saradaput	239.53	04/Aug/2006	6480	224.67	25/May/1975	6.164	6480	04/Aug/2006	6.164	25/May/1975	2019-20
45	Tekra	112.40	09/Sep/1994	35750	96.00	26/Jun/2005	1.095	35750	09/Sep/1994	1.095	26/Jun/2005	2019-20
46	Gandlapet (Terminal Site on River Peddavagu)	317.9	30/Aug/1990	1656	-	-	-	1656	30/Aug/1990	-	-	2019-20
47	Mancherial	137.386	20/Oct/1995	31820	124.7866	01/Apr/2010	0	31820	20/Oct/1995	0	01/Apr/2010	2019-20
48	Kanergaon	473.22	24/Jul/2013	1398	465.12	11/Nov/2014	0	1398	24/Jul/2013	0	11/Nov/2014	2019-20
49	Mangrul	289.89	19/Jul/2000	1039	181.40	31/May/1996	0.075	1039	19/Jul/2000	0.075	31/May/1996	2019-20
50	Polavaram	28.02	16/Aug/1986	87250	12.21	01/Jun/1973	77.53	87250	16/Aug/1986	77.53	01/Jun/1973	2019-20
51	Pratapur	525.64	23/Aug/2018	177.1	-	-	-	177.1	23/Aug/2018	-	-	2019-20
52	Ankushapur	100.26	12/Aug/2018	288.1	-	-	-	288.1	12/Aug/2018	-	-	
53	Kunturla	861.32	20/072018	326.7	857.45	20/Apr/2016	1.613	326.7	20/072018	1.613	20/Apr/2016	
54	Garmillapalli	101.68	12/Aug/2018	193.9	-	-	-	193.9	12/08/20118	-	-	

55	Valamuru	6.06	20/Aug/2018	466.9	1.93	10/Jun/2018	0.392					
56	Allamvari	97.24	21/Aug/2018	634	92.69	16/Apr/2019	0.296					

TABLE 03: Annual Dependable Flow of Water by Site and River Basin for the Last 30 Years (1990-91 to 2019-20)

Annual dependable flow of water by site and river basin for the last 30 Years (1990-91 to 2019-20)													Unit: MCM
Sl. No.	**Site Name**	**Period**	**Dependable flow**										
			10%	**20%**	**25%**	**30%**	**40%**	**50%**	**60%**	**70%**	**75%**	**80%**	**90%**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**	**(13)**	**(14)**
1	Ambabal At Narangi	06/1990 To 05/2020 (Last 30 years data)	1349.45	1146.20	1113.18	985.54	800.74	748.28	643.09	584.10	549.35	524.89	458.95
2	Betmogra At Maner		434.20	350.72	247.60	236.24	217.36	157.93	74.56	32.91	27.16	14.07	1.70
3	Bhadrachalam At		128947.13	104680.18	92317.66	79685.29	74055.96	64053.82	49576.21	47836.14	45011.26	40833.18	29273.56

	Godavari												
4	Cherribeda At Bardha		1353.12	1103.87	973.46	961.99	842.06	620.79	523.93	383.18	371.67	316.69	241.54
5	Chindnar At Indravathi		14410.52	11763.85	11126.62	10606.14	9252.22	8605.45	7660.76	6984.11	6531.06	5986.91	4590.45
6	Degloor At Lendi		671.68	453.70	391.00	340.17	246.68	176.96	108.51	75.39	63.68	48.97	22.18
7	Dhalegaon At Godavari		3595.20	2182.28	1757.46	990.99	718.87	366.66	224.96	144.36	106.09	11.77	0.00
8	G.R.Bridge At Godavari		4503.41	2404.94	1598.26	1092.12	966.10	735.53	509.96	351.33	228.35	186.22	94.85
9	Gandlapet At Peddavagu		365.96	188.51	117.41	81.30	55.09	29.30	14.59	3.07	2.88	1.42	0.00
10	Jagdalpur At Indravathi		4705.53	3743.18	3562.52	3214.82	2914.46	2550.83	2386.17	2206.84	2120.27	1900.92	1337.42

11	Kiwaibalenga At Bawardhi		1295.56	1104.50	806.36	682.42	601.31	474.15	308.35	2.91	2.00	1.10	0.51
12	Konta At Sabari		23023.66	20635.28	19521.14	19039.44	17106.21	15387.02	14413.14	13900.63	13251.31	13043.40	9764.89
13	Kopergaon		Sufficient data not available										
14	Kosagumda At Bhaskal		1314.48	1218.99	1205.10	1130.61	1049.22	896.75	750.39	717.38	698.06	661.61	376.54
15	Mancherial At Godavari		14734.39	9702.57	8421.74	7428.96	5695.44	3624.81	2602.45	2258.74	1939.01	1207.37	519.63
16	Murthahandi At Journala		2114.30	1878.81	1810.65	1742.37	1564.28	1384.34	1332.20	1207.99	1116.34	1010.74	905.84
17	Nanded		Sufficient data not available										
18	Nowrangpur At Indravathi		3983.49	3064.93	2381.31	2016.36	1780.93	1509.17	1259.79	851.70	794.32	776.11	689.91

19	Pachegaon At Pravara		1244.14	915.67	768.44	552.57	366.76	287.22	215.54	125.76	105.28	55.89	18.54
20	Pathagudem At Indravathi	06/1990 To 05/2020 (Last 30 years data)	39842.76	34021.50	31252.09	26640.75	24372.91	21548.43	18652.23	17311.21	16314.56	15167.60	11499.33
21	Perur At Godavari		110906.14	93190.85	83899.55	78335.73	65503.66	64387.62	57063.45	44309.20	42492.76	41321.30	33564.46
22	Polavaram At Godavari		146479.06	115009.16	98580.62	93200.06	86116.38	80753.13	72801.85	58421.54	57707.75	53395.98	47620.16
23	Potteru (Seasonal) At Potteru Vagu		3033.78	2509.12	2449.73	2385.59	2103.63	1934.94	1854.11	1746.78	1427.42	1363.46	1138.74
24	Purna At Purna		4063.16	1802.94	1604.08	1363.32	987.20	471.23	348.77	284.11	244.38	230.42	176.84
25	Saigaon At Ari		2374.11	1429.59	926.42	759.63	440.31	277.94	168.15	44.52	26.82	22.12	9.70
26	Sangam At Murredu		436.94	365.27	346.06	315.83	279.15	262.25	254.58	203.03	172.46	151.42	105.88

27	Saradaput At Sabari		7889.19	6894.70	6376.47	6119.24	5588.43	5382.76	4715.76	4189.32	4112.17	3837.64	3207.00
28	Somanpally (Seasonal) At Manner		2077.94	1917.21	1666.47	1263.97	1073.58	785.62	718.71	490.53	311.08	282.10	223.65
29	Sonarpal At Markandi		1070.70	998.10	876.70	802.76	769.50	659.71	628.99	573.18	515.83	406.97	353.11
30	Tumnar At Dantewara		2013.65	1794.97	1716.62	1592.22	1346.67	1264.89	1126.20	901.19	868.60	792.91	571.14
31	Yelli At Godavari		10710.04	4813.42	4655.06	3702.68	2910.94	2522.09	1657.81	1300.44	1225.25	886.17	149.37
32	Zari At Dudhna		856.95	619.21	514.51	460.54	334.70	221.69	149.33	123.84	97.04	50.48	35.88

TABLE 04:Time Series of Sediment Load by Site in River Basin during 2019-2020

Time series of Sediment load by site in River Basin during 2019-2020 Unit: Million Metric Tonnes

SNo	Year	Monsoon	Non-Monsoon	Annual	SNo	Year	Monsoon	Non-Monsoon	Annual
	Indravati at Jagadalpur					**Wainganga at Ashti**			
1	2010-2011	76.467	0.135	76.602	1	2010-2011	7.885	0.074	7.959
2	2011-2012	18.025	0.110	18.135	2	2011-2012	3.473	0.034	3.507
3	2012-2013	37.552	0.096	37.648	3	2012-2013	4.583	0.068	4.651
4	2013-2014	86.219	0.055	86.274	4	2013-2014	13.398	0.054	13.453
5	2014-2015	32.118	0.023	32.141	5	2014-2015	2.575	0.009	2.584
6	2015-2016	28.123	0.033	28.156	6	2015-2016	3.628	0.002	3.631
7	2016-2017	47.261	0.072	47.333	7	2016-2017	4.201	0.020	4.221
8	2017-2018	18.466	0.027	18.493	8	2017-2018	0.360	0.007	0.367
9	2018-2019	61.743	0.119	61.862	9	2018-2019	7.664	0.011	7.675
10	2019-2020	66.224	0.113	66.336	10	2019-2020	8.598	0.023	8.621

	Pranhita at Tekra					**Wardha at Hivra**			
1	2010-2011	24.421	0.423	24.844	1	2010-2011	0.287	0.010	0.297
2	2011-2012	2.149	0.174	2.323	2	2011-2012	0.060	0.066	0.126
3	2012-2013	4.135	0.126	4.261	3	2012-2013	0.116	0.012	0.128
4	2013-2014	7.705	0.417	8.122	4	2013-2014	0.298	0.009	0.307
5	2014-2015	7.183	0.414	7.597	5	2014-2015	0.079	0.003	0.082
6	2015-2016	0.000	0.000	0.000	6	2015-2016	0.091	0.002	0.093
7	2016-2017	0.000	0.000	0.000	7	2016-2017	0.129	0.007	0.136
8	2017-2018	0.000	0.000	0.000	8	2017-2018	0.014	0.005	0.019
9	2018-2019	0.000	0.000	0.000	9	2018-2019	0.058	0.001	0.059
10	2019-2020	0.000	0.000	0.000	10	2019-2020	0.101	0.002	0.103
	Paddavagu at Bhatpalli					**Godavari at Mancherial**			
1	2010-2011	74.426	0.205	74.631	1	2010-2011	1.584	0.005	1.589

2	2011-2012	59.054	0.008	59.062	2	2011-2012	0.301	0.001	0.302
3	2012-2013	59.332	0.059	59.391	3	2012-2013	0.213	0.002	0.215
4	2013-2014	266.352	0.252	266.604	4	2013-2014	0.969	0.006	0.975
5	2014-2015	40.661	0.021	40.682	5	2014-2015	0.090	0.001	0.091
6	2015-2016	7.733	0.003	7.736	6	2015-2016	0.062	0.003	0.065
7	2016-2017	41.970	0.106	42.076	7	2016-2017	2.115	0.017	2.132
8	2017-2018	5.371	0.014	5.386	8	2017-2018	0.009	0.002	0.011
9	2018-2019	17.754	0.038	17.792	9	2018-2019	0.803	0.000	0.803
10	2019-2020	22.123	0.016	22.139	10	2019-2020	0.357	0.000	0.357
	Wardha at Bamni					**Manijira at Saigaon**			
1	2010-2011	15.620	0.008	15.628	1	2010-2011	1.399	0.005	1.404
2	2011-2012	7.144	0.000	7.144	2	2011-2012	0.219	0.000	0.219

3	2012-2013	12.298	0.000	12.298	3	2012-2013	0.859	0.000	0.859
4	2013-2014	16.971	0.000	16.971	4	2013-2014	0.049	0.000	0.049
5	2014-2015	11.035	0.002	11.037	5	2014-2015	0.003	0.000	0.003
6	2015-2016	6.162	0.000	6.162	6	2015-2016	0.000	0.000	0.000
7	2016-2017	7.445	0.012	7.457	7	2016-2017	0.000	0.000	0.000
8	2017-2018	4.976	0.012	4.988	8	2017-2018	0.000	0.000	0.000
9	2018-2019	7.800	0.003	7.803	9	2018-2019	0.000	0.000	0.000
10	2019-2020	21.870	0.035	21.905	10	2019-2020	0.000	0.000	0.000
	Penganga at PG Bridge					**Godavari at Dhalegaon**			
1	2010-2011	1.425	0.000	1.425	1	2010-2011	0.400	0.000	0.400
2	2011-2012	0.605	0.000	0.605	2	2011-2012	0.034	0.000	0.034
3	2012-2013	1.703	0.000	1.703	3	2012-2013	0.000	0.000	0.000

4	2013-2014	2.903	0.000	2.903	4	2013-2014	0.000	0.000	0.000
5	2014-2015	1.696	0.000	1.696	5	2014-2015	0.000	0.000	0.000
6	2015-2016	5.683	0.000	5.683	6	2015-2016	0.000	0.000	0.000
7	2016-2017	1.321	0.000	1.321	7	2016-2017	0.258	0.000	0.258
8	2017-2018	0.924	0.000	0.924	8	2017-2018	0.000	0.000	0.000
9	2018-2019	0.967	0.000	0.967	9	2018-2019	0.000	0.000	0.000
10	2019-2020	3.134	0.003	3.137	10	2019-2020	0.000	0.000	0.000
	Wardha at Nandgaon					**Wardha at Sakmur**			
1	2010-2011	20.410	0.045	20.455	1	2010-2011	0.000	0.000	0.000
2	2011-2012	31.397	0.002	31.399	2	2011-2012	0.000	0.000	0.000
3	2012-2013	34.260	0.007	34.267	3	2012-2013	0.000	0.000	0.000
4	2013-2014	76.578	0.031	76.609	4	2013-2014	0.000	0.000	0.000

5	2014-2015	6.599	0.007	6.606	5	2014-2015	1.131	0.001	1.132
6	2015-2016	10.931	0.002	10.933	6	2015-2016	2.616	0.000	2.616
7	2016-2017	4.058	0.007	4.065	7	2016-2017	0.505	0.001	0.506
8	2017-2018	0.923	0.003	0.926	8	2017-2018	0.095	0.001	0.096
9	2018-2019	1.912	0.009	1.921	9	2018-2019	0.356	0.001	0.357
10	2019-2020	0.001	0.000	0.001	10	2019-2020	0.286	0.016	0.302

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