NEXT IAS

INDIAN GEOGRAPHY & DISASTER MANAGEMENT

CIVIL SERVICES
EXAMINATION 2027

Published by

MADE EASY PUBLICATIONS

MADE EASY Publications Pvt. Ltd.
Corporate Office: 44-A/4, Kalu Sarai
(Near Hauz Khas Metro Station), New Delhi-110016
Contact: 011-45124660, 8860378007
E-mail: infomep@madeeasy.in
Visit us at: www.madeeasypublications.org

Indian Geography & Disaster Management

© Copyright, by MADE EASY Publications Pvt. Ltd.
All rights are reserved. No part of this publication may be reproduced, stored in or introduced into a retrieval system, or transmitted in any form or by any means (electronic, mechanical, photo-copying, recording or otherwise), without the prior written permission of the above mentioned publisher of this book.

First Edition: 2017
Second Edition: 2018
Third Edition: 2019
Revised & Updated: 2020
Fourth Edition: 2021
Fifth Edition: 2022
Sixth Edition: 2023
Seventh Edition: Nov. 2023
Eighth Edition: 2025

Ninth Edition: 2026

Contents

Indian Geography & Disaster Management

PART–I: INDIAN GEOGRAPHY

PART–II: DISASTER MANAGEMENT

Chapter – 17

Introduction to Disaster Management.....313

Chapter – 18

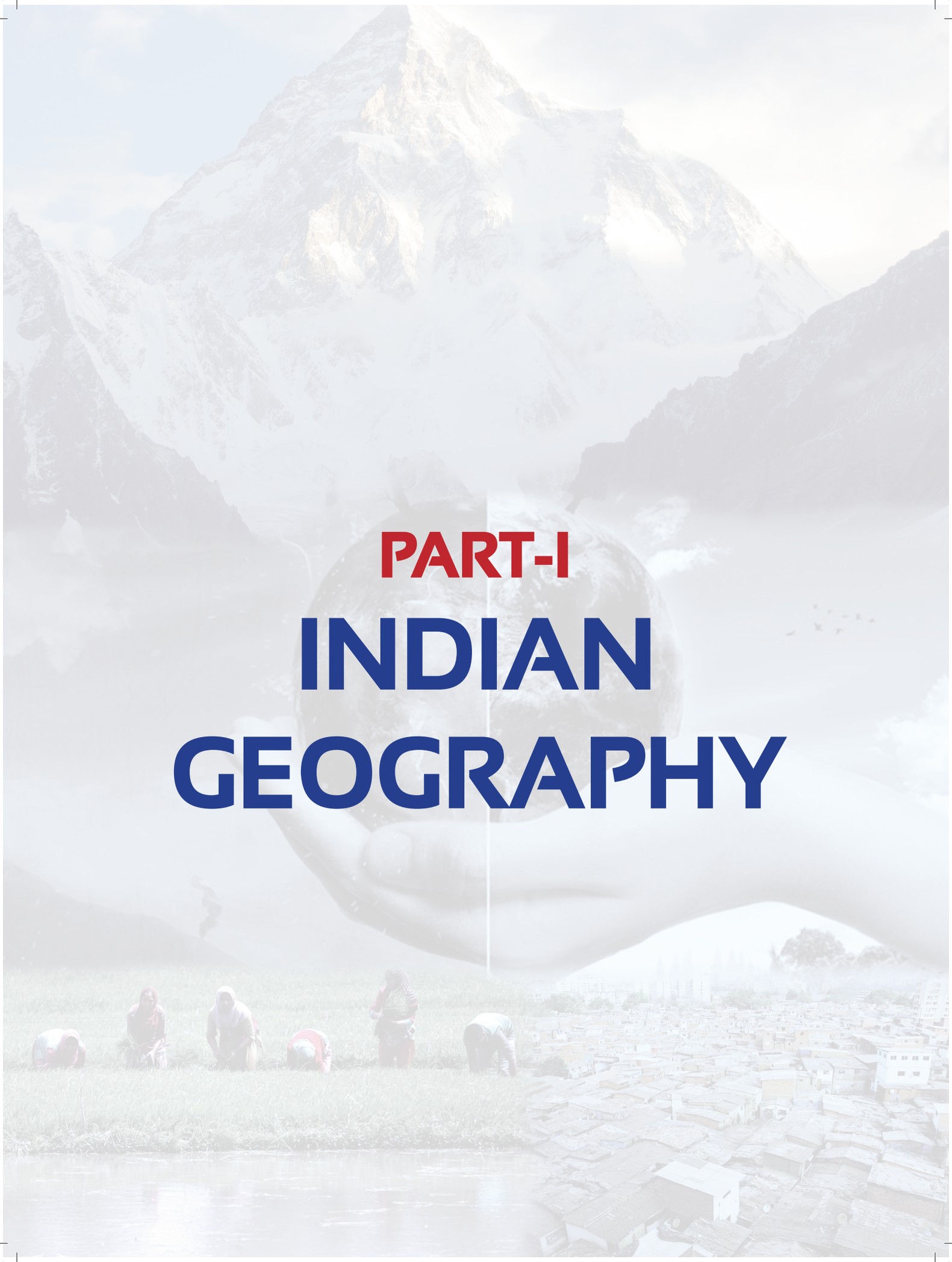
Disaster Management In India.....317

Chapter – 19

Vulnerability Profile of India.....330

Chapter – 20

International Cooperation and Current Developments.....372



PART-I

INDIAN GEOGRAPHY

4 CHAPTER

DRAINAGE SYSTEM

4.1 Introduction

Drainage can be defined as the naturally occurring flow of water in well defined channels formed by streams and rivers that carry the surface water to sea, lake or water body. A network of such channels is known as a ***drainage system.***

Whenever a river and its tributaries act like a drainage system for a specified area, then this area is called as ***drainage basin***. A drainage system can be defined as the pattern formed by the rivers, streams and lakes in a particular drainage basin.

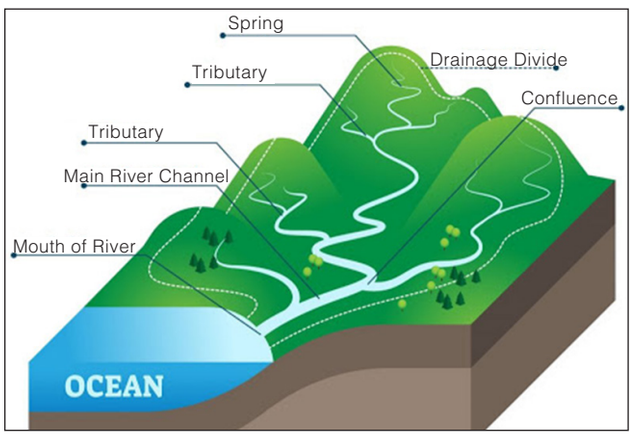


Fig. 4.1: River Drainage System

When we go through map of India or world, it will indicate many elevated areas such as a mountain, plateaus or other uplands. At various stages of time, these elevated areas act as a boundary, which separates the drainage basin of one river from other, and it is called as the ***water divide***.

The boundary line separating one drainage basin from the other is known as the ***watershed***.

The catchment of large rivers are called ***river basins*** while those of small rivulets and rills are often referred to ***watersheds***.

4.2 Types of Drainage Systems

There are following two major types of drainage systems:

Sequent Drainage Systems

Sequent streams generally follow the regional or general slope. It has the following four categories of Drainage System.

- **Consequent Streams (Dip Stream):** When a river originates from a particular region and it follows the initial and developed course of the slope according to their general formation, then it is called as Consequent streams. It generally follows the regional slope in its course of drainage. Prominent rivers of Peninsular India are Consequent streams rivers. E.g. Krishna, Godavari and Cauvery follow the path of Western Ghat to Bay of Bengal.
- **Subsequent Streams:** The is a master stream which generate first, then other streams are flowing in the axis of the ridge and strike the beds of a river called as subsequent streams. They almost join each other at right angle. E.g. Tributary of Ganga at Dehradun valley.
- **Obsequent Streams:** If the streams are flowing in the opposite direction of the main consequents (stream), then it is called as obsequent streams. They follow the regional slope. E.g. The Mahabharata range of Himalaya has several obsequent streams.
- **Resequent Streams:** If the streams of drainage system follows the direction of the main consequents, then it is called as resequent streams. They are originated after the origination of the main stream.

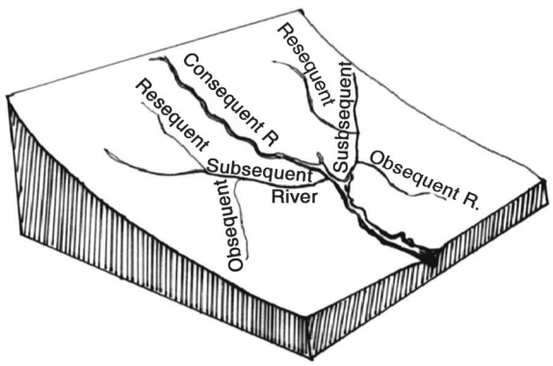


Fig. 4.2: Sequent Drainage System

Insequent Drainage Systems

Insequent streams do not follow the regional slope. They can be divided in following two types:

- **Antecedent Drainage System:** This drainage system originates before upliftment of the formations e.g. mountain, land surface, plateau etc., they flow across the upliftment of the formation by down cutting the valley in their course. They also form gorge in their path. E.g. Indus, Sutlej, Ganga, Saryu across the Himalaya etc. are prominent antecedent rivers.

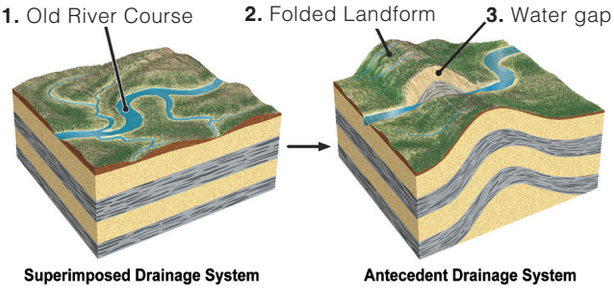


Fig. 4.3: Insequent Drainage System

- **Superimposed Drainage System:** The Rivers which do not follow their regional slope or courses. When the nature of the valleys and the flow course of resultant drainage on the upper geological formation and structure is superimposed on the lower geological formation of entirely different characteristics then it is called as superimposed drainage system. E.g. Son River flowing across the Khainjua ridge etc.

4.3 Drainage Pattern

Drainage pattern are defined to be generalized movement of active channels in accordance to prevailing relief and structure. Prominent type of drainage patterns results as a consequence of different activities of drainage system, due to various natural phenomenon e.g. shaping of rock-systems, climatic conditions, slope etc.

Types of Drainage Patterns

The streams within a drainage basin form certain patterns, depending on the slope of land, underlying formations as well as the climatic conditions of the area. There are mainly six different types of Drainage Patterns:

- **Dendritic Drainage Pattern:** The drainage pattern that represents the combination of broader valleys involving a dense network of tributaries which project to be the example of *radiating branches of trees* is called Dendritic Pattern. This pattern develops where the river channel follows the slope of the terrain. E.g. The Ganga river system, The Godavari river system, the Krishna river system etc.
- **Parallel Drainage Pattern:** It comprises numerous rivers which are parallel to each other and follow the regional slope. It is due to the steeper slopes, the rivers become so swift that they travel in straight course and thus become parallel to each other. River Narmada and river Tapi are considered as prominent examples.
- **Trellis Drainage Pattern:** Several streams developed on both the flanks of the ridges and join the longitudinal synclinal streams at the right angle. This pattern also resembles the rectangular pattern, however the streams are closely spaced in trellised pattern as compared to the rectangular pattern. It involves alternating outcrops of soft and hard rocks. Soft rocks get eroded with time, eventually leading trellis pattern. The extra-peninsular river system represents this pattern and the most developed example is the Ganga river system.
- **Radial Drainage Pattern:** It forms the drainage pattern that involves the channel of different systems. It represents centrifugal flow (flow radially outward and downward from a central topographic high). E.g. Amarkantak (Narmada, Son, Hasdeo).
- **Rectangular Drainage Pattern:** This pattern is considered to be specific type of Trellis pattern where tributaries merge with main river almost at right angle (90 degree). It is indicative of streams following prominent fault or joint that breaks the rock into rectangular block. E.g. The Brahmani and Mahanadi river system.
- **Deranged Drainage Pattern:** It is a drainage system where there is no coherent pattern to the rivers and lakes. It happens in areas where there has been much geological disruption. E.g. It is found in the glaciated valleys of Karakoram.

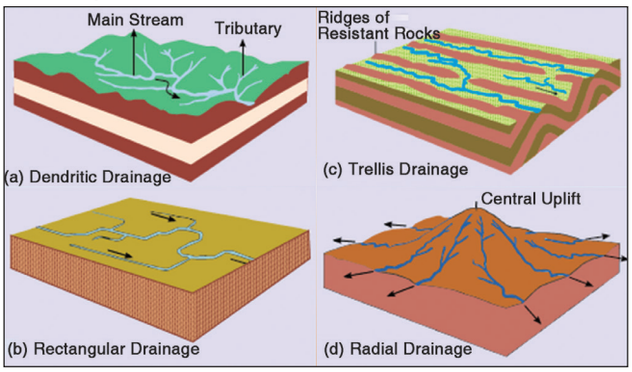


Fig. 4.4: Various Drainage Patterns

4.4 Indian Drainage System

Most of the rivers discharge their waters into the Bay of Bengal. Some of the rivers flow through the western part of the country and merges into the Arabian Sea. Also, the northern parts of the Aravalli range, some parts of Ladakh, and arid regions of the Thar Desert have inland drainage. All the major rivers of India originate from one of the three main watersheds- The Himalayas and the Karakoram range, the Chotanagpur plateau and Vindhyas and Satpura range and the Western Ghats.

Drainage Systems Based on Origin

- **The Himalayan Rivers (Perennial rivers):** Indus, Ganga, Brahmaputra, and their tributaries.
- **The Peninsular Rivers (Non-Perennial rivers):** Mahanadi, Godavari, Krishna, Cauvery, Narmada, and Tapi and their tributaries.

Drainage Systems Based on the Type of Drainage

The river systems of India can be classified into four groups viz. Himalayan rivers, Deccan rivers, and Coastal rivers that drain into the sea and rivers of the inland drainage basin. Streams like the Sambhar in western Rajasthan are mainly seasonal in character, draining into the inland basins and salt lakes. In the Rann of Kutch, the only river that flows through the salt desert is the Luni.

Drainage Systems Based on Orientation to the Sea

Bay Of Bengal Drainage	Arabian Sea Drainage
Rivers that drain into Bay of Bengal.	Rivers that drain into Arabian sea.
East flowing rivers.	West flowing rivers.
Nearly 77 percent of the drainage area of the country is oriented towards the Bay of Bengal.	Nearly 23 percent of the drainage area of the country is oriented towards the Arabian sea.
The Ganga, the Brahmaputra, the Mahanadi, the Godavari, the Krishna, the Cauvery, the Penneru, the Penneiyar, the Vaigai, etc.	The Indus, the Narmada, the Tapi, the Sabarmati, the Mahi and the large number of swift flowing western coast rivers descending from the Sahyadris.

Fig. 4.5: Major Rivers of India

Himalayan Drainage System

Himalayan River System mainly comprises the Indus, the Ganga, and the Brahmaputra river basins. These rivers are fed both by *melting of snow and precipitation.* Therefore, rivers of this system are perennial. These passes through the giant gorges carved out by the erosional activities carried on simultaneously with the uplift of the Himalayas. Besides deep gorges, these rivers also form U-shaped valleys, V-shaped valleys, rapids and waterfalls in their mountainous course. In plains, they form *depositional features* like flat valleys, meanders, ox-bow lakes, flood plains, braided channels, and deltas near the river mouth. In the Himalayan regions, the course of these rivers is highly tortuous, but over the plains they display a strong *meandering tendency and shift their courses* frequently. For instance, Kosi - known as the *'sorrow of Bihar'*. The course of the Kosi is unstable in nature and likely to heavy wear and tear which ultimately increase sediment load in the flow of the river. So, due to this increase of sediments, Kosi frequently changes its course.

Evolution of The Himalayan Drainage

There are difference of opinion about the evolution of the Himalayan rivers. However, geologists believe that a mighty river called Shiwalik or Indo-Brahma traversed the entire longitudinal extent of the Himalaya from Assam to Punjab and onwards to Sindh, and finally discharged into the Gulf of Sindh near lower Punjab during the Miocene period some 5-24 million years ago.

The remarkable continuity of the Shiwalik and its lacustrine origin and alluvial deposits consisting of sands, silt, clay, boulders and conglomerates support this viewpoint.

It is opined that in due course of time Indo–Brahma river was dismembered into three main drainage systems:

- The Indus and its five tributaries in the western part.

- The Ganga and its Himalayan tributaries in the central part.
- The Brahmaputra in Assam and its Himalayan tributaries in the eastern part.

The dismemberment was probably due to the Pleistocene upheaval in the western Himalayas, including the uplift of the Potwar Plateau (Delhi Ridge), which acted as the water divide between the Indus and Ganga drainage systems. Likewise, the down thrusting of the Malda gap area between the Rajmahal hills and the Meghalaya plateau during the mid-Pleistocene period, diverted the Ganga and the Brahmaputra systems to flow towards the Bay of Bengal.

Major Himalayan drainage systems are the Indus, the Ganga and the Brahmaputra river.

Indus River System

It originates from a glacier near *Bokhar Chu* in the Tibetan region in the Kailash Mountain range near the Mansarovar Lake. The river flows northwest and enters in Ladakh region in India from a place called *Demchok*. After entering India, Indus river flows in between Karakoram and Ladakh range.

In Tibet it is known as '*Singi Khamban* or the *Lion's Mouth*'.

It is joined by the Zaskar River at Leh and is then joined by the Shyok river. The Gilgit, Gartang, Dras, Shiger, Hunza are the other Himalayan tributaries of the Indus.

The accumulated waters of the five eastern tributaries—the Jhelum, the Chenab, the Ravi, the Beas, and the Satluj. In Sindh Province river accumulates a lot of sediments and forms the Indus river delta before draining into the Arabian sea near Karachi. The blind *Indus River Dolphin*, a sub-species of dolphin, is found only in the Indus River.

The Indus flows in India only through the Leh district in the Union Territory of Ladakh.

Tributaries of Indus

Fig. 4.6: Indus River System

Left-bank Tributaries: Zaskar river, Suru river, Soan river, Jhelum River, Chenab River, Ravi River, Beas river, Satluj river, Panjnad river.

Right-bank Tributaries: Shyok River, Gilgit river, Hunza river, Swat river, Kunnar river, Kurram river, Gomal River, Tochi river and Kabul river.

- **Shyok River:** It rises from the Karakoram Range and flows through the Northern Ladakh region. It originates from the *Rimo Glacier* and the river widens at the confluence with the *Nubra River.* Shyok River marks the south-eastern fringe of the Karakoram ranges by forming a V-shaped bend around it.
- **Nubra River:** It is the main tributary of the Shyok River. It originates from the *Nubra Glacier* and the river meanders towards the southeast to join the Shyok River downstream of Shyok Valley at the base of the Ladakh range.
- **Zanskar River:** It is one of the important left bank tributaries of the Indus. Human settlements are sparse.
- **Chenab River:** The Chenab originates near the Bara Lacha Pass in the Lahul-Spiti part of the Zaskar Range. Chenab river is formed by the confluence of the Chandra and Bhaga rivers at Tandi located in the upper Himalayas in the Lahul and Spiti District of Himachal Pradesh. In its upper reaches, it is also known as the *Chandrabhaga*. It flows through the Jammu region of J&K to the plains of Punjab in Pakistan.
- **Jhelum River:** It is a tributary of the Chenab River. The river Jhelum rises from a spring at *Verinag* situated at the foot of the Pir Panjal in the south eastern part of the valley of Kashmir in India. There the Kishenganga (Neelum) River, the largest tributary of Jhelum, joins it. The Chenab merges with the Sutlej to form the Panjnad River system which joins the Indus River at Mithankot and it ends in a confluence with the Chenab in Pakistan.
- **Ravi River:** The Ravi River originates from Dhauladhar range of the Himalayas in the Chamba district of HP. Ravi has its source in *Kullu hills* near the *Rohtang Pass* in Himachal Pradesh. The major multipurpose project built on the river is the *Ranjit Sagar Dam*. Chamba town is situated on the right bank of the river.
- **Sutlej River:** It is an antecedent river and the sometimes known as the *Red River*. It rises from beyond the Indian borders in the southern slopes of the Kailash Mountain near Mansarover Lake from *Rakas Lake.* In Tibet known as Langchen Khambab. It enters Himachal Pradesh at *Shipki La* and flows in the South-westerly direction through Kinnaur, Shimla, Kullu, Solan, Mandi, and Bilaspur districts.

  It leaves HP to enter the plains of Punjab at Bhakra, where the *world's highest gravity dam- Bhakra Nangal Dam,* has been constructed on this river. It is mainly used for power generation and many large canals draw water from it. Across the river, there are many Hydroelectric and irrigation projects such as the *Kol Dam, Nathpa Jhakri project.*
- **Beas River:** It is an important river of the Indus River System, emerges from *Rohtang pass* in Himachal Pradesh. The river before entering Pakistan merges with the Sutlej River at *Hari-Ke-Pattan in Punjab.* The city of *Manali* situated on the right bank of the River Beas.

INDUS WATERS TREATY, 1960

The Indus river system comprises of main Indus River with Jhelum, Chenab, Ravi, Beas, and Sutlej. The basin is mainly shared by India and Pakistan with a small share for China and Afghanistan. Under the treaty signed between India and Pakistan in 1960, all the waters of ***three Eastern Rivers, namely Ravi, Sutlej, and Beas were allocated to India*** for exclusive use. While, the waters of ***Western rivers like Indus, Jhelum, and Chenab were allocated to Pakistan*** except for specified domestic, non-consumptive, and agricultural use permitted to India as provided in the Treaty. India has also been given the right to generate Hydroelectricity through the run of the river (RoR) projects on the Western Rivers which, subject to specific criteria for design and operation is unrestricted.

Present Developments to Utilize the Waters of the Eastern Rivers:

India has constructed the following dams such as ***Bhakra Dam on Satluj, Pong and Pandoh Dam on Beas and Thein (Ranjit Sagar) on Ravi.*** Other works like Beas-Sutlej Link, Madhopur-Beas Link, Indira Gandhi Nahar Project, etc has helped India to utilize nearly the entire share (95 %) of the waters of Eastern rivers.

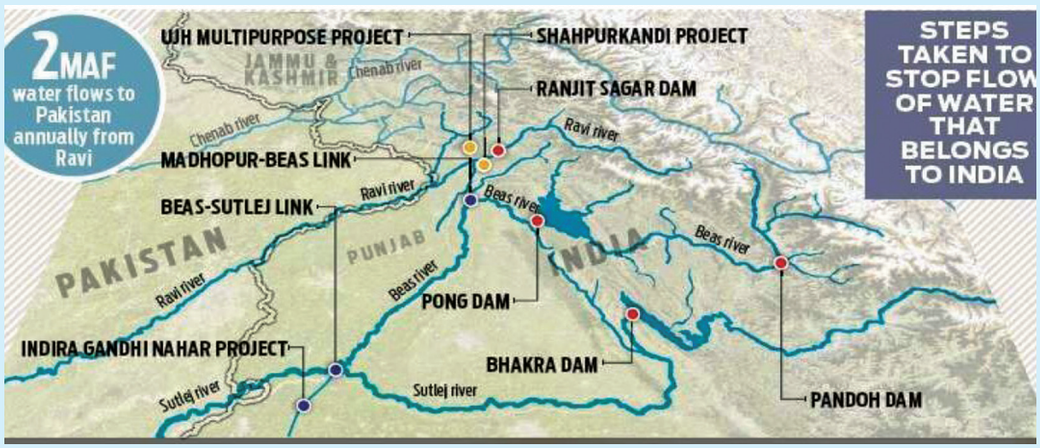
However, about 2 Million Acre Feet (MAF) of water annually from Ravi is reported to be still flowing unutilized to Pakistan below Madhopur. To stop the flow of these waters that belong to India for its utilization in India, the following steps have been taken:

Shahpurkandi Project: This project will help in utilizing the waters coming out from the powerhouse of Thein dam for irrigation and power generation in J&K and Punjab. The construction work is being undertaken by the Govt of Punjab under the monitoring of the Govt of India.

Construction of Ujh Multipurpose Project: This project will create storage of water on river Ujh, a tributary of Ravi for irrigation and power generation in India. This project is a National Project whose completion period will be 6 years from the beginning of the implementation.

The 2nd Ravi Beas Link Below Ujh: This project is being planned to tap excess water flowing down to Pakistan through river Ravi, even after construction of Thein Dam, by constructing a barrage across river Ravi for diverting water through a tunnel link to Beas basin. Govt. of India declared this project as National Project.

Since the nullification of ARTICLE 370 of Indian consitution and creation of Union Terrirories of Ladakh and Jammu Kashmir, India has cleared few hydropower projects in the Ladakh union territory which includes: Durbuk Shyok (19 MW) Nimu Chilling (24 MW), Shankoo (18.5 MW), Rongdo (12 MW), Mangdum Sangra (19 MW), Kargil Hunderman (25 MW) and Tamasha (12 MW) for UT of Ladakh while Ratan Nag (10.5 MW) for J&K.



Ganga River System

The holy river Ganga is a major river of the Indian subcontinent rising in the Himalaya mountains and flowing about 2,525 km generally eastward through a vast plain to the Bay of Bengal. Flowing through a vast length, it crosses five states of India namely Uttarakhand, Uttar Pradesh, Bihar, Jharkhand and West Bengal. It has catchment area of 8,61,404 sq. km (26.4%) of India. Major tributaries of River Ganga are Yamuna, Ramganga, Gomti, Ghaghara, Gandak, Damodar and Kosi etc.

Flowing through major cities/towns like Srinagar, Rishikesh, Haridwar, Roorkee (in Uttarakhand), Bijnor, Narora, Kannauj, Kanpur, Allahabad, Varanasi, Mirzapur (in Uttar Pradesh), Patna, Bhagalpur (in Bihar) and Beharampore, Serampore, Howrah and Kolkata (in West Bengal). Finally, it drains into the Bay of Bengal. The Ganga river basin is one of the most populated river basins in the world and is home to half the population of India. The basin provides over one-third of the available surface water in India and contributes to more than half the national water use.The Ganga also serves as one of India's holiest rivers whose cultural and spiritual significance transcends the boundaries of the basin.

Course of Ganga

The Bhagirathi, considered to be source stream of Ganga, emanates from Gangotri Glacier at Gaumukh at

an elevation of 3, 892 m (12,770 feet). Many small streams comprise the headwaters of Ganga. The important among these are Alaknanda, Dhauliganga, Pindar, Mandakini and Bhilangana. At Devprayag, where Alaknanda joins Bhagirathi, the river acquires the name Ganga. At Haridwar, Ganga opens to the Gangetic Plains, where a barrage diverts a large quantity of its waters into the Upper Ganga Canal, to provide water for irrigation. At Bijnore, another barrage diverts water into the Madhya Ganga Canal but only during monsoon months. At Narora, there is further diversion of water into the Lower Ganga Canal.

Further down, River Ramganga joins Ganga near Kannauj, adding additional water to the river. Yamuna confluences Ganga at the Sangam in Prayagraj (Allahabad), making a major contribution to the river flow. Beyond Prayagraj, Ganga is joined by several tributaries, most of which are from the north and a few from the south.The Farakka barrage in West Bengal regulates the flow of the river, diverting some of the water into a feeder canal linking Hooghly to keep it relatively silt-free. Downstream of this barrage, River Ganga splits, into two, Bhagirathi (Hooghly) on the right and Padma on the left. Bhagirathi (Hooghly) meets the Bay of Bengal about 150 km downstream of Kolkata. Padma enters Bangladesh and meets river Brahmputra and Meghna before finally joining the Bay of Bengal.

Panch Prayag

The five places of confluence of Ganga rivers system (Prayag) as shown below.

Place of Confluence	River System
Devprayag	Bhagirathi and Alaknanda
Rudraprayag	Mandakini and Alaknanda
Nandaprayag	Nandakini and Alaknanda
Karnaprayag	Pindar and Alaknanda
Vishnuprayag	Dhauliganga and Alaknanda

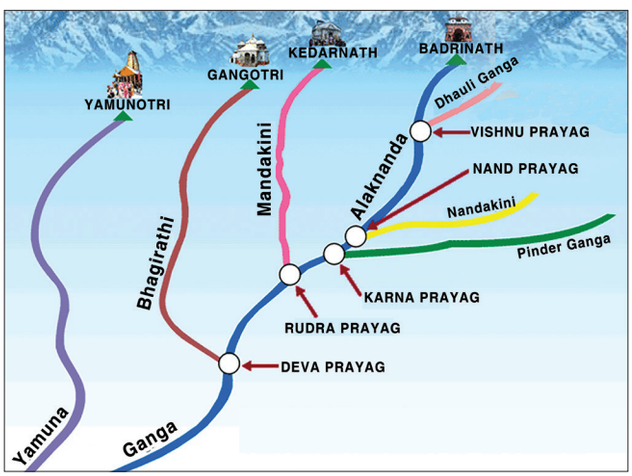


Fig. 4.7: Confluence of Ganga River

Tributaries of Ganga River

- **Alaknanda:** It is one of the headstreams of the Ganga. It rises at the confluence and feet of the *Satopanth and Bhagirath glaciers* in Uttarakhand. It meets the Bhagirathi River at Devprayag after which it is called as the Ganga.

  Its main tributaries are the Mandakini, Nandakini, and Pindar rivers. The Hindu pilgrimage center of Badrinath and the natural spring Tapt Kund lie along the banks of the Alaknanda River. At its origin, *Lake Satopanth* is a triangular lake and named after the Hindu trinity Lord Brahma, Lord Vishnu, and Lord Shiva.

- **Bhagirathi:** It is one of the two most important headstreams of the Ganga which meets the Alaknanda at Devprayag to form the Ganga. It rises *at the foot of Gangotri Glacier, at Gaumukh*, at the base of Chaukhamba peak in the Uttarkashi district of Uttarakhand. The upper catchment of the river is glaciated. It cuts spectacular gorges in its middle course where it cuts through granites and crystalline rocks of the central Himalaya.

- **Dhauliganga:** It originates from *Vasudhara Tal*, perhaps the largest glacial lake in Uttarakhand.

  Dhauliganga is one of the important tributaries of Alaknanda, the other being the Nandakini, Pindar, Mandakini and Bhagirathi. Dhauliganga is joined by the Rishiganga river at Raini.

  It merges with the Alaknanda at Vishnuprayag. There it loses its identity and the Alaknanda flows southwest through Nandaprayag, Karnaprayag until it meets the Mandakini river, which coming from the north at Rudraprayag. After subsuming Mandakini, the Alaknanda carries on past Srinagar, before joining the Ganga at Devprayag.

  Alaknanda then disappears and the mighty Ganga carries on its journey first flowing south then west through important pilgrimage centres such as *Rishikesh* and finally descending into the Indo-Gangetic plains at *Haridwar*.

  Tapovan Vishnugad Hydropower Project being constructed on the Dhauliganga.

- **Rishiganga River:** It springs from the *Uttari Nanda Devi Glacier on the Nanda Devi Mountain*. It is also fed from the Dakshini Nanda Devi Glacier. It flows through the *Nanda Devi National Park* and merges into the Dhauliganga River near the village Raini.

- **Ramganga:** Ramganga River originates in the southern slopes of *Dudhatoli Hill* in the Chamoli district of Uttarakhand. It is fed by springs emanating from the reservoirs of underground water. the *prominent geomorphic features* found in its tract across the lower Himalayan hills are *incised meanders, paired and unpaired terraces, interlocking spurs, waterfalls, rock benches, cliffs, and towering ridges.* It also flows through the dun valley of *Corbett National Park*. There is a dam built across the Ramganga at Kalagarh. It finally meets the Ganga near Kannauj. Bareilly city is situated on its banks.

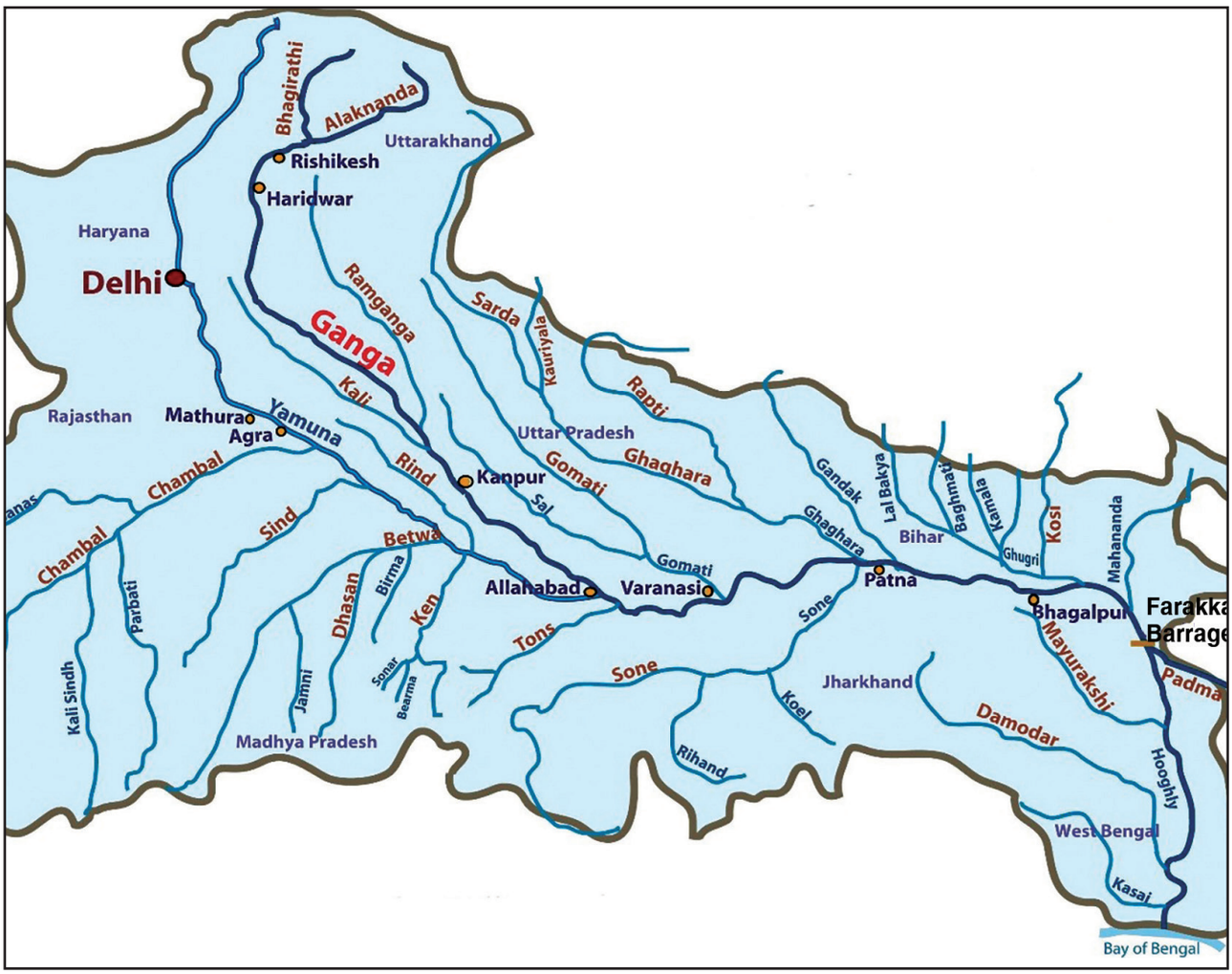


Fig. 4.9: Ganga River Drainage

- **Gomti:** It originates from *Gomat Taal* which formally is known as *Fulhaar Jheel*, near Madho Tanda, Pilibhit in UP. It meets the Ganges River in Ghazipur. At the Sangam of Gomti and Ganga, the *famous Markandey Mahadeo temple* is situated. The most important tributary is the Sai River, which joins near Jaunpur. The cities of Lucknow, Lakhimpur Kheri, Sultanpur and Jaunpur are located on the banks of Gomti.
- **Ghaghara:** The Ghaghara originates in the *glaciers of Mapchachungo*. It also known as *Karnali or Kaurial*. It is a trans-boundary perennial river originating from the Tibetan plateau near Lake Mansarovar. It cuts through the Himalayas in Nepal and is joined by the Sharda River at Brahmaghat in India. It is a major left-bank tributary of the Ganga and joins it at Chhapra in Bihar. Rapti, Chhoti Gandak, Sharda, and Saryu are the major tributaries of this river.
- **Sharda:** The Sharda river rises in the *Milam glacier* in the Nepal Himalayas where it is known as the *Goriganga*. The Sharda originates from the Greater Himalayas at Kalapaani in the Pithoragarh District of Uttarakhand this river is also known as **Kali** River. Kalapaani is situated on the *route of Kailash Manasarovar Yatra* The river flows in a gorge section in the upper region. The Mahakali after it descends into the plains into India is known as Sarda, which meets the Ghaghara.
- **Sarayu:** It is a river that flows through UP and Uttrakhand. Sarayu is a river that originates at a ridge lies in south of Nanda Kot mountain in Bageshwar district in Uttarakhand. This river is of ancient significance, finding mentions in Vedas and Ramayana. It is a left-bank tributary of River Sharda.
- **Rapti:** The Rapti rises south of western Dhaulagiri Himalaya and the Mahabharat Range in Nepal. The mainstream of this river rises as a spring in the southern slopes of the lower Himalayas. The river is essentially fed by underground water. It has the tendency of recurrent floods that led to its nickname Gorakhpur's Sorrow.
- **Gandak:** It is formed by the union of the Kali and Trisuli rivers, which rises in the Great Himalayan Range in Nepal. From this junction to the Indian border, the river is called the *Narayani*. It enters the Ganga river opposite of Patna in a place called Sonepur. The middle and the lower courses of the river flows through the V-shaped valleys, incised meanders, and have paired and unpaired terraces on either side.

- **Kosi:** It also known as *Saptakoshi* for its 7 Himalayan tributaries. it is an antecedent transboundary river flowing through Nepal and India. This river is one of the largest tributaries of the Ganga and joins it at Kursela in Kathiar district. The highest peak in the world, Mt. Everest and the Kanchenjunga are in the Kosi catchment. Its unstable nature has been attributed to the heavy silt it carries during the monsoon season, Due to this, it is also termed as *The Sorrow of Bihar.*
- **Son:** The Son river originates near *Amarkantak* in MP, just east of the headwater of the Narmada River, and flows north-northwest through MP. The Son parallels the Kaimur hills, flowing east-northeast through UP, Jharkhand, and Bihar states to join the Ganga just above Patna.

  The Tributaries of Son River are:

  Right: Gopat river, Rihand River, Kanhar River, North Koel River.

  Left: Ghaggar River, Johila River, Chhoti Mahanadi River.
- **Rihand:** The Rihand rises from Matiranga Hills in the region southwest of the Mainpat plateau, in Chhattisgarh. The Rihand Dam was constructed across the Rihand River, the reservoir impounded behind the dam is called *Govind Ballabh Pant Sagar*.
- **North Koel:** The river rises on the Ranchi plateau and enters Palamau division near Rud. The North Koel, along with its tributaries, meanders through the northern part of *Betla National Park.*

GANGA–BRAHMAPUTRA DELTA

Before entering the Bay of Bengal, the Ganga, along with the Brahmaputra, forms the largest delta of the world between the Bhagirathi, Hugli and the Padma or Meghna. The coastline of the delta is a highly indented area. The delta is made of a web of distributaries and islands and is covered by dense forests called the mangroves. A major part of the delta is a low-lying swamp that is flooded by marine water during high tide.

NAMAMI GANGE PROGRAMME

'**Namami Gange Programme**', is an Integrated Conservation Mission, approved as 'Flagship Programme' by the Union Government in June 2014 with budget outlay of Rs.20,000 Crore to accomplish the twin objectives of effective abatement of pollution, conservation and rejuvenation of National River Ganga.

Key Pillars:

- Sewage Treatment Infrastructure
- River Front Development
- River Surface Cleaning
- Biodiversity
- Afforestation
- Public Awareness
- Industrial Effluent Monitoring
- Ganga Gram

Its implementation has been divided into Entry-Level Activities (for immediate visible impact), Medium-Term Activities (to be implemented within 5 years of time frame) and Long-Term Activities (to be implemented within 10 years).

The key achievements under Namami Gange programme are:

- **Creating Sewerage Treatment Capacity:** 70 sewage management projects are under implementation and 73 sewage projects have been completed in the states of Uttarakhand, Uttar Pradesh, Bihar, Jharkhand, West Bengal, Delhi, Himachal Pradesh, Haryana, and Rajasthan.
- **Creating River-Front Development:** 63 Ghats/Crematoria projects for construction, modernization, and renovation of 262 Ghats/Crematoria and Kunds/Ponds have been initiated.
- **River Surface Cleaning:** River surface cleaning for collection of floating solid waste from the surface of the Ghats and River and its disposal are afoot and pushed into service at 11 locations.
- **Bio-Diversity Conservation:** One of NMCG's long-term visions for Ganga rejuvenation is to restore viable populations of all endemic and endangered biodiversity of the river, so that they occupy their full historical range and fulfil their role in maintaining the integrity of the Ganga river ecosystems.
- **Afforestation:** One of the major components of Ganga rejuvenation is 'forestry interventions' to enhance the productivity and diversity of the forests in head water areas and all along the river and its tributaries.
- **Public Awareness:** A series of activities such as events, workshops, seminars and conferences and numerous IEC activities were organized to make a strong pitch for public outreach and community participation in the programme. Various awareness activities such as TV/Radio, print media advertisements, advertorials, featured articles and advertorials were published. Gange Theme song was released widely and played on digital media to enhance the visibility of the programme. NMCG ensured presence at Social Media platforms like Facebook, Twitter, You Tube etc.
- **Industrial Effluent Monitoring:** The number of Grossly Polluting Industries (GPIs) in April, 2019 are 1072. Regulation and enforcement through regular and surprise inspections of GPIs is carried out for compliance verification against stipulated environmental norms.
- **Ganga Gram:** Ministry of Drinking Water and Sanitation (MoDWS) identified 1674 Gram Panchayats situated on the bank of River Ganga in 5 State (Uttarakhand,Uttar Pradesh,Bihar,Jharkhand,West Bengal).

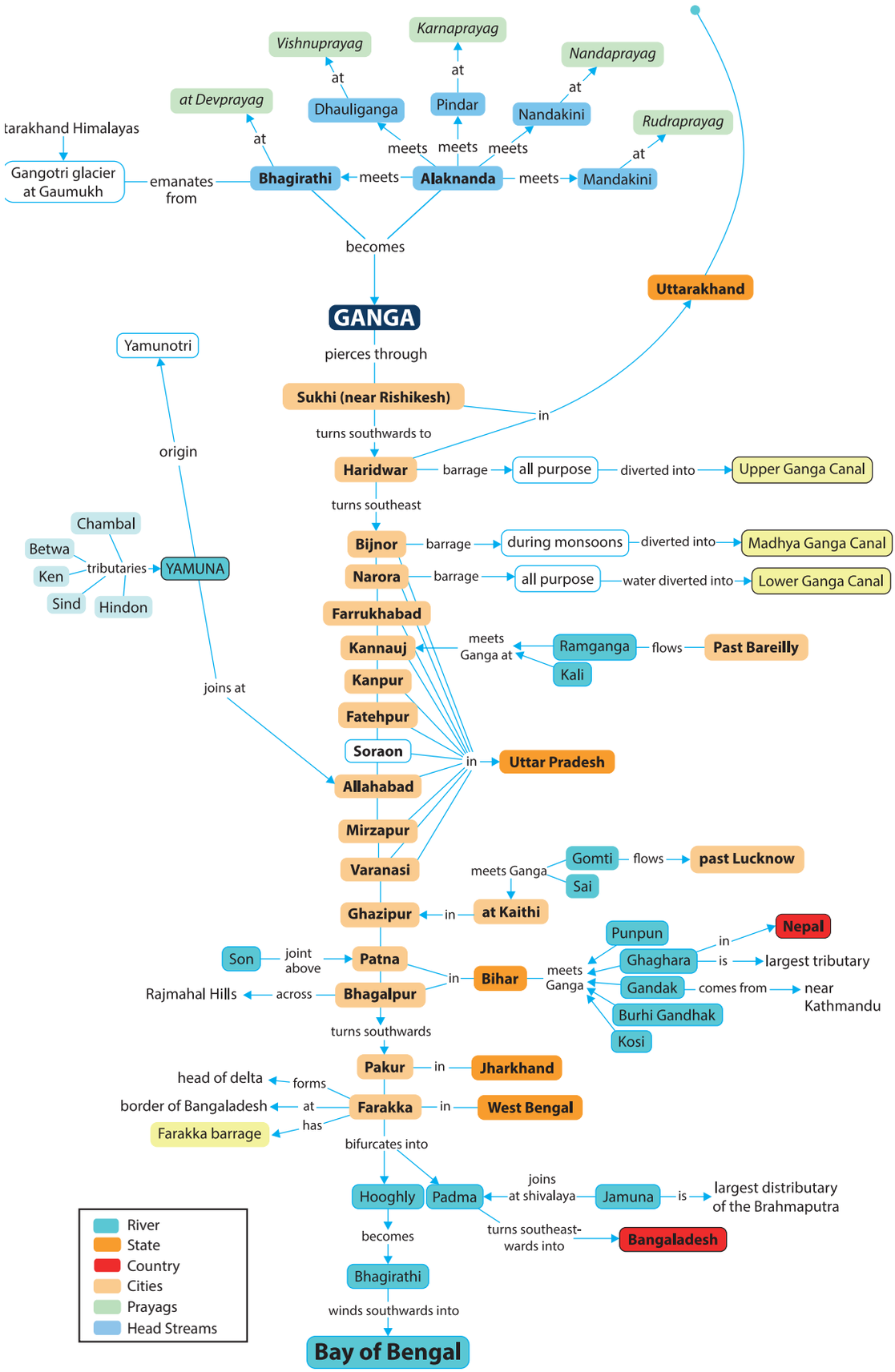


Fig. 4.8: Schematic Diagram of Ganga River Course

National Mission for Clean Ganga, endeavors to deploy best available knowledge and resources across the world for Ganga rejuvenation. Clean Ganga has been a perennial attraction for many international countries that have expertise in river rejuvenation. Countries such as Australia, United Kingdom, Germany, Finland, Israel etc. have shown interest in collaborating with India for Ganga rejuvenation.

Yamuna River System

It originates from the **Yamunotri Glacier** near Bandarpoonch peak in the Mussoorie range of the lower Himalayas. It flows along states of Uttarakhand, Himachal Pradesh, Haryana and enters Delhi and merges with the Ganga near Triveni Sangam, Allahabad (Prayagraj). It the largest tributary of the Ganga in the northern plains. Its main affluent in the upper reaches is the Tons which also rises from the Bandarpoonch glacier. The cities of Bhagpat, Delhi, Noida, Mathura, Agra, Firozabad, Etawah, Hamirpur, and Prayagraj (Allahabad) lie on its banks.

Tributaries of Yamuna

- **Tons River:** The Tons is the longest and biggest tributary of the Yamuna River and it flows through Garhwal, the western part of the Himalayan state of Uttarakhand. The river originates at an elevation of 3900 m and joins the Yamuna below Kalsi near Dehradun, Uttarakhand. It is one of the most major perennial Indian Himalayan rivers. It is the biggest tributaries of the Yamuna.
- **Giri River:** The river Giri is an important tributary of the Yamuna River. It is the main source of water in the South-Eastern Himachal Pradesh. The Giri is famous in the Jubbal, Rohru hills that rise from Kupar peak.
- **Hindon River:** Hindon River is an important tributary of the Yamuna River and originates from upper shivalik (lower himalayas). In fact, this river is sandwich between two major rivers i.e. Ganga on the left and Yamuna on the right.

Fig. 4.10: Tributaries and Drainage Basin of Yamuna

- **Chambal River:** Chambal River is also known as Charmanwati or Charmawati. The Chambal river originates from Janapao Hilis on the southern slope of the Vindhya range, in Madhya Pradesh. The river flows much below its banks due to severe erosion because of poor rainfall and numerous deep ravines have been formed in the Chambal Valley, giving rise to *badland topography.*

Dams on the Chambal

There are four major dams on Chambal river located from south to north

- Gandhi Sagar Dam
- Rana Pratap Sagar Dam
- Jawahar Sagar Dam
- The Kota Barrage

Water released after power generation at Gandhi Sagar dam, Rana Pratap Sagar dam and Jawahar Sagar Dams, is diverted by Kota Barrage for irrigation in Rajasthan and in Madhya Pradesh through canals. Keoladeo National Park is supplied with water from Chambal river irrigation project.

- **Banas River:** It is also known as *'Van Ki Asha'(Hope of forest).* It originates in the Aravalli Range in Rajsamand District of Rajasthan.
- **Kali Sindh:** Flows in the Malwa region of Madhya Pradesh, that joins the Chambal River near Sawai Madhopur in Rajasthan.
- **Sindh:** The Sindh originates on the Malwa Plateau in Vidisha district, flows north-northeast through the districts of Guna, Ashoknagar, Shivpuri, Datia, Gwalior, and Bhind in Madhya Pradesh. It join the Yamuna River in Etawah District (UP) and flows through Madhya Pradesh and Uttar Pradesh.
- **Betwa:** Also known as *Vetravati*, it rises in the Vindhya Range north of Hoshangabad in Madhya Pradesh. The confluence of the Betwa and the Yamuna Rivers takes place in the Hamirpur town in Uttar Pradesh.
- **Ken River:** The Ken River originates from the slopes of Kaimur Range in Jabalpur district in Madhya Pradesh. It merges with the Yamuna near Fatehpur in UP. The Ken valley separates the Rewa Plateau from the Satna Plateau. The Ken River passes through *Panna National Park*.

Ken Betwa Interlinking Project

This project involves transfer of water from the Ken to the Betwa River through the construction of Daudhan Dam and a canal linking the two rivers, the Lower Orr Project, Kotha Barrage -and Bina Complex Multipurpose Project. The project will provide an annual irrigation of 10.62 lakh ha, drinking water supply to a population of about 62 lakhs and also generate 103 MW of hydropower and 27 MW solar power. The Project is proposed to be implemented in 8 years with state of the art technology.

The Project will be of immense benefit to the water starved Bundelkhand region, spread across the states of MP and UP. This project will provide enormous benefits to the districts of Panna, Tikamgarh, Chhatarpur, Sagar, Damoh, Datia, Vidisha, Shivpuri and Raisen of Madhya Pradesh and Banda, Mahoba, Jhansi & Lalitpur of Uttar Pradesh.

The project is expected to boost socio-economic prosperity in the backward Bundelkhand region on account of increased agricultural activities and employment generation. It would also help in arresting distress migration from this region.

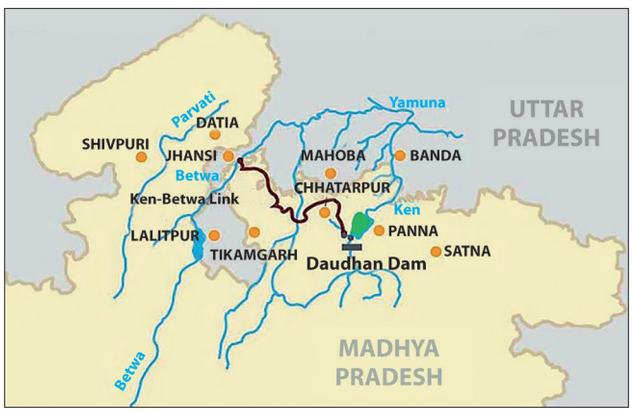


Fig. 4.11: Ken-Betua Interlinking Project

Important Cities Through which Yamuna Passes

State	Uttarakhand, Himachal Pradesh, Uttar Pradesh, Haryana, Delhi
Cities	Delhi, Noida, Mathura, Agra, Firozabad, Etawah, Kalpi, Hamirpur and Prayagraj (Allahabad) lie on its banks.

Brahmaputra River System

The Brahmaputra (meaning the Son of Brahma) rises in the Chemayungdung glacier in southwestern Tibet. Its source is very close to the sources of Indus and Satluj. Inspite of the exceptionally high altitude, the Tsangpo has a gentle slope. The river is sluggish and has a wide navigable channel for about 640 km.

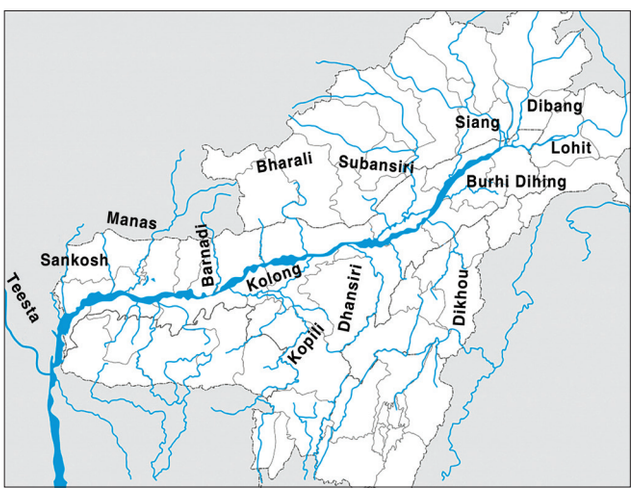


Fig. 4.12: Brahmaputra River Drainage

It flows as the Yarlung Tsangpo River across southern Tibet to break through the Himalayas in great gorges and into Arunachal Pradesh where it is known as ***Dihang.*** Just west of the town of Sadiya, the Dihang turns to the southwest and is joined by two mountain streams, the Lohit and the Dibang. Below the confluence, the river is known as the ***Brahmaputra.*** It flows through Bangladesh as the ***Jamuna*** where it merges with the Ganga to form a vast delta, the Sunderbans.

The biggest and the smallest river islands of the world, ***Majuli, and Umananda*** respectively, are in the Brahamputra river in the state of Assam. Dibrugarh, Pasighat, Neamati, Tezpur, and Guwahati are the important urban centers on the river.

Different Names of Brahmaputra River

Region	Name
Tibet	Tsangpo (meaning 'The Purifier')
China	Yarlung Zangbo Jiangin
Assam Valley	Dihang or Siang, South of Sadiya: Brahmaputra
Bangladesh	Jamuna River
	Padma River: Combined Waters of Ganga and Brahmaputra
	Meghana: From the confluence of Padma and Meghna

Major Tributaries of the Brahmaputra River

Left: Lhasa river, Nyang river, Parlung Zangbo, Lohit river, Dhanashri river, kolong river.

Right: Kameng river, Manas river, Beki river, Raidak river, Jaldhaka river, Teesta river, Subansiri river.

- **Subansiri River:** Subansiri River is also called as *Gold River* as it is famous for its gold dust. It flows through the Lower Subansiri District in Arunachal Pradesh. Subansiri, a swift river offers excellent kayaking opportunities.
- **Kameng River:** Kameng River in the eastern Himalayan mountains originates in the Tawang district. It flows through West Kameng District, Arunachal Pradesh, and Sonitpur District of Assam. The *Pakhui Wildlife Sanctuary* and the *Kaziranga National Park* are located near the Kameng River.
- **Manas River:** Manas River is a transboundary river in the Himalayan foothills between southern Bhutan and India. It flows through Bhutan and then through Assam before it joins the mighty Brahmaputra River at Jogighopa. The river valley has two major reserve forest areas, namely the *Royal Manas National Park in Bhutan and the contiguous Manas Wildlife Sanctuary.*
- **Sankosh River:** It rises in northern Bhutan and empties into the Brahmaputra in the state of Assam. The upper catchment of the river is glaciated. The middle and the lower courses flow along V-shaped valleys that have

been carved by running water. The entire catchment of the river is covered with forests.

- **Tista River:** The river originates from Tso Lhamo lake in North Sikkim in the Himalayas. Rangeet river is the major tributary of the Teesta river which joins it at a place known as *Tribeni.*
- **Dibang River:** The river Dibang is originating from the snow-covered southern flank of the Himalayas close to the Tibet border. It emerges from the hills to enter the plain area near Nizamghat in the Lower Dibang Valley district of Arunachal Pradesh. The *Mishmi hills* are found along the upper course of the Dibang River.
- **Lohit River:** The River Lohit originates in eastern Tibet. The river flows through the Mishmi hills to meet the Siang at the head of Brahmaputra valley. The valley of Lohit is thickly forested, covered with alpine and sub-tropical vegetation A large variety of medicinal plants are also found here.
- **Kopili River:** It is an interstate river in Northeast India that flows through the states of Meghalaya and Assam and is the largest south bank tributary of the Brahmaputra in Assam. *Carissa Kopilii* (Plant Species) is distributed sparsely along the Kopili riverbed. The plant is threatened by a Hydroelectric project on the river and water turned acidic because of coal mining in Meghalaya upstream.

Cities on Brahmaputra

The cities situated on the banks of river Brahamaputra are given below.

Major River Valley Projects/Dams/Barrages Associated with the Brahmaputra River System:

States	Hydel Power Projects
Arunachal Pradesh	Tawang, Subansiri, Ranganadi, Paki, Papumpap, Dhinkrong, Upper Lohit, Damway, Kameng.
Sikkim	Rangit Hydel Power Project, Tista Hydel Power Project.
Assam	Kopili Hydel Power Project
Meghalaya	New Umtru Hydel Power Project
Nagaland	Doyang Hydel Power Project
Manipur	Loktak Hydel Power Project Tipaimukh Hydel Power Project
Mizoram	Tuibai Hydel Power Project, Tuirial Hydel Power Project, Dhaleshwari Hydel Power Project

Peninsular River System

Indian peninsula is traversed by a number of rivers, which are much older than the Himalayan Rivers. These rivers are in their mature stage and have reached the base level of their erosion characterized by broad, shallow and largely graded valleys.

The Western Ghats acts as the water divide between the major Peninsular rivers, discharging their water in the Bay of Bengal, and small rivulets joining the Arabian Sea. Almost the entire peninsula represents older formation showing features of the mature drainage.

Due to low gradients and large deltas on their mouth, there is reduction in their velocity and load carrying capacity in their courses. Most of the major Peninsular rivers except Narmada and Tapi flow from west to east and pouring in to Bay of Bengal.

Evolution of Peninsular Drainage

The evolution of present Peninsular drainage systems seems to have been shaped by the following three factors:

- **Subsidence of the Western Flank** of the Peninsula leading to its submergence below the sea during the early tertiary period which disturbed the symmetrical plan of the river on either side of the original watershed.
- **Upheaval of the Himalayas** when the northern flank of the Peninsular block was subjected to subsidence and the consequent trough faulting.
- **Slight Tilting of the Peninsular Block** from north-west to south-eastern direction gave orientation to the entire drainage system of the peninsular India towards the Bay of Bengal during the same period.

East Flowing Rivers

Mahanadi River system

The Mahanadi basin extends over states of Chhattisgarh and Odisha and comparatively smaller portions of Jharkhand, Maharashtra, and Madhya Pradesh. It is bounded by the Central India hills on the north, by the Eastern Ghats on the south and east, and by the Maikala range on the west. It has its source in the northern foothills of Dandakaranya in Raipur District of Chhattisgarh at an elevation of 442 m.

The Mahanadi is one of the major peninsular rivers, in water potential and flood producing capacity, it ranks second to the Godavari. Other small streams between the Mahanadi and the Rushikulya draining directly into the Chilka Lake also forms the part of the basin. The major part of the basin is covered with agricultural land accounting to 54.27% of the total area.

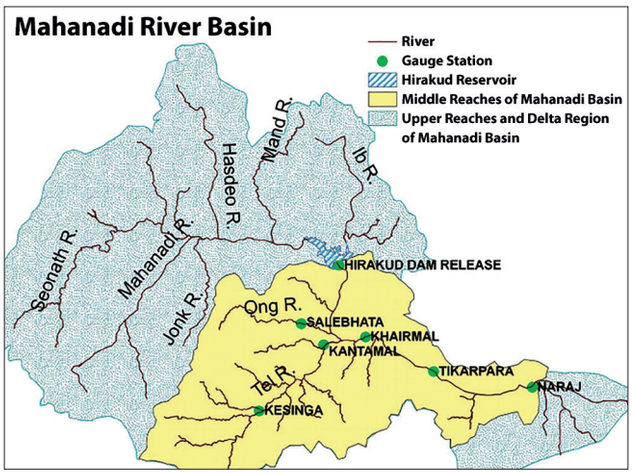


Fig. 4.13: Mahanadi River Drainage

It is one of the most-active silt-depositing streams in the Indian subcontinent. After receiving the Seonath River, it turns east and enters Odisha state. At Sambalpur, the Hirakud Dam (one of the largest dams in India) on the river has formed a man-made lake 35 miles (55 km) long. It enters the Odisha plains near Cuttack and enters the Bay of Bengal at *False Point* by several channels. Puri, at one of its mouths, is a famous pilgrimage site.

Tributaries of Mahanadi River

Its upper course lies in the saucer-shaped basin called the '*Chhattisgarh Plain*'. This basin is surrounded by hills on the north, west, and south as a result of which a large number of tributaries join the main river from these sides.

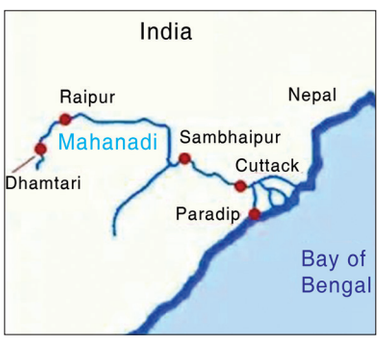
Left Bank Tributaries: The Seonath, the Hasdeo, the Mand, and the Ib.

Right Bank Tributaries: The Ong, the Tel and the Jonk.

- **Seonath:** It originates from Panabaras Hill (625 m) and flows towards the north-east. The river feeds the inhabitants and industries of Durg District.
- **Hasdeo:** The River originates from Chhattisgarh. The river flows towards the south of Chhattisgarh, through Bilaspur and Korba Districts. Along the river lie rocks and hilly areas, thin forest areas.
- **Ib:** It is a left-bank tributary of Mahanadi River, Originates in hills in Raigarh district of Chhattisgarh.

Cities on Mahanadi

The cities situated on the banks of river Mahanadi are given below.



Projects on Mahanadi River

- **The Hirakund Dam:** It is one of the first major multipurpose river valley projects started after India's independence. The dam aims at controlling floods in the Mahanadi basin, providing water for irrigation and municipal water supply. The dam is located near Sambalpur in the state of Odisha.
- **The Gangrel Dam:** It is also known by the name of R.S. Sagar Dam. The dam is built across the Mahanadi river in Dhamtari district in the state of Chhattisgarh.
- **The Dudhwa Dam:** The dam is constructed across the Mahanadi river in Dhamtari district in the state of Chhattisgarh.

Industry in Mahanadi River Basin

Three important urban centres in the basin are Raipur, Durg and Cuttack. Mahanadi basin, because of its rich mineral resource and adequate power resource, has a favorable industrial climate. The Important industries presently existing in the basin are the Iron and Steel plant at Bhilai, aluminium factories at Hirakud and Korba, paper mill near Cuttack and cement factory at Sundargarh.

Other industries based primarily on agricultural produce are sugar and textile mills. Mining of coal, iron and manganese are other industrial activities.

Godavari River System

The Godavari river is the largest river in Peninsular India. It is known as the *Dakshin Ganga* or *Vridha Ganga* (old Ganga) because of its age, size, and length. It is navigable in the delta region. It originate from a place called *Trimbak* located in the Western Ghats in Nashik district in the state of Maharashtra. It drains into the Bay of Bengal before *forming a large delta below Rajahmundry.*

The Godavari basin extends over states of Maharashtra, Andhra Pradesh, Chhattisgarh, and Odisha in addition to smaller parts in Madhya Pradesh, Karnataka, and the Union Territory of Puducherry (Yanam).

The basin is bounded by Satmala hills, the Ajanta range, and the Mahadeo hills on the north, by the Eastern Ghats on the south and the east, and by the Western Ghats on the west.

Rajahmundry is the largest city on the banks of Godavari. The Sri Ram Sagar project which was constructed on this river (1964-69) serves the irrigation needs of Adilabad, Nizamabad, Karimnagar and Warangal districts.

Fig. 4.14: Godavari River Drainage

Cities on Godavari

The cities situated on the banks of river Godavari are given below.

Tributaries of Godavari River

Left Bank Tributaries: Dharna, Penganga, Wainganga, Wardha, Pranahita (conveying the combined waters of Penganga, the Wardha and Wainganga), Pench, Kanhan, Sabari, Indravati etc.

Right Bank Tributaries: Pravara, Mula, Manjra, Peddavagu, Maner etc.

Below Rajahmundry, the river divides itself into two main streams, the *Gautami Godavari* on the east and the *Vashishta Godavari* on the west, and forms a large delta before it pours into the Bay of Bengal. The delta of the Godavari is of lobate type with a round bulge and many distributaries.

- **Manjra:** It is a right-bank tributary of the river Godavari. It originates in the *Balaghat range*, near Ahmednagar. Manjra River flows through the Latur District of Maharashtra and the Bidar District of Karnataka before entering Medak District in Andhra Pradesh.

  Nizam Sagar dam was constructed across the Manjra River between Achampeta and Banjapalle villages of the Niamabad district in Andhra Pradesh.
- **Painganga:** It originates in the *Ajanta ranges* in the Aurangabad district in Maharashtra. It then flows through Buldhana and Washim districts. It then flows along the state border between Maharashtra and AP.
- **Wardha:** It is one of the biggest rivers in the Vidarbha region of Maharashtra. It originates in *Satpura Range* near Multai in Betul District of Madhya Pradesh and then enters into Maharastra. It joins Wainganga and together they are called Pranhita, which ultimately flows into the Godavari River.
- **Wainganga:** It literally means *the arrow of water*. It originates from *Mahadeo Hills* of the Satpura Range of Madhya Pradesh and flows south through Madhya Pradesh and Maharashtra. After joining the Wardha, the united stream, known as the Pranahitha, ultimately falls into the river Godavari. It drains the Chandrapur. Gadchiroli, Bhandara, Gondia, and Nagpur districts of Maharashtra.

Projects on Godavari River

Important projects completed are Srirama Sagar, Godavari barrage, Upper Penganga, Jaikwadi, Upper Wainganga, Upper Indravati, Upper Wardha. Among the on-going projects, the prominent ones are Pranhita-Chevalla and Polavaram.

Floods and Droughts in Godavari Basin

Godavari basin faces flooding problems in its lower regions. The coastal areas are cyclone-prone. The delta areas face drainage congestion due to flat topography. A large portion of Maharashtra falling (Marathwada) in the basin is drought-prone.

Godavari and Cauvery River Interlinking Project

The project envisages the diversion of 247 thousand million cubic feet (tmcft) of unutilized water in the Indravati sub-basin of the Godavari basin to meet the requirements between the Godavari and the Cauvery rivers. Water will be diverted from the Godavari River to Nagarjuna Sagar dam (through lifting) and further south to meet the demands of Krishna, Pennar, and Cauvery basins.

The Godavari – Cauvery link comprises three components namely, the Godavari (Inchampalli/Janampet) – Krishna (Nagarjunasagar), the Krishna (Nagarjunasagar) – Pennar (Somasila) and the Pennar (Somasila)–Cauvery (Grand Anicut).

The project will provide irrigation facilities to Prakasam, Nellore, Krishna, Guntur, and Chittoor districts of Andhra Pradesh.

Krishna River System

The Krishna is the second-largest east-flowing river of the Peninsular India. Krishna river rises at *Mahabaleshwar* near the Jor village in the extreme north of Satara district. Ecologically, this is one of the *disastrous rivers* in the world, as it causes heavy soil erosion during the monsoon season. It is bounded by the Balaghat range on the north, by the Eastern Ghats on the south and the east, and by the Western Ghats on the west. The total length of the river from origin to its outfall into the Bay of Bengal is 1,400 km. The major part of the basin is covered with agricultural land accounting to 75.86% of the total area. The Krishna forms a large delta with a shoreline of about 120 km.

Almatti Dam, Srisailam Dam, Nagarjuna Sagar Dam, and Prakasham Barrage are some of the major dams constructed on the river. Because it is fed by seasonal monsoon rains, the river's flow undergoes great fluctuation during the year, limiting its usefulness for irrigation. Satara, Karad, Sangli, Bagalkot, Srisailam, Amaravati, and Vijayawada are some of the important urban and tourist centers on the bank of the river.

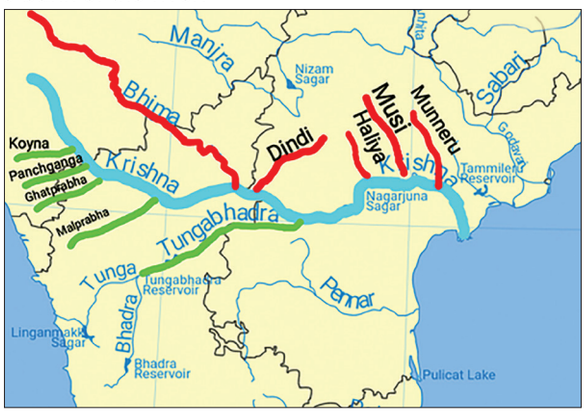


Fig. 4.15: Krishna River Drainage

Cities on Krishna

The cities situated on the banks of river Krishna are given below.

Tributaries of Krishna River

Right Bank: Venna, Koyna, Panchganga, Dudhganga, Ghataprabha, Malaprabha and Tungabhadra are the major right-bank tributaries

Left Bank: Bhima, Dindi, Peddavagu, Halia, Musi, Paleru, and Munneru are the major left-bank tributaries

- **Bhima:** It originates in *Bhimashankar hills* near Karjat on the western side of Western Ghats (known as Sahyadri), in Maharashtra. Bhima flows southeast through Maharashtra, Karnataka and Andhra Pradesh.
- **Musi:** It originates in *Anantagiri Hills* near Vikarabad, Rangareddi district, 90km west of Hyderabad In 1920, the *Osmansagar reservoir* was constructed across the river at Gandipet village. Another important dams i.e. *Himayat Sagar, Hussain Sagar Lake* are built on the tributary of the River Musi. Together, they act as a source of water for Hyderabad.

  Musi River is also the bowl for water festivals such as boating races, decorated boating contest, and river swimming tournament.
- **Koyna:** It rises in *Mahabaleshwar,* Satara district of Maharashtra and is a tributary of the Krishna River. Unlike most of the other rivers in Maharashtra which flow East-West direction, the Koyna River flows in a North-South direction.

  The Koyna River is famous for the *Koyna Dam* which is the largest Hydroelectric project in Maharashtra. This dam was perhaps the main cause of the devastating Earthquake (6.4 on Richter scale) in 1967 that killed 150 people. The reservoir – Shivasagar Lake, is a huge lake of 50 km in length.
- **Panchaganga:** The Panchganga river flows through the borders of Kolhapur. The Panchganga is formed by four streams: the Kasari, the Kumbhi, the Tulsi, and the Bhogawati.
- **Dudhganga:** It is a right-bank tributary of the river Krishna. It is an important river of the Kolhapur district. The *Kallammawadi Dam* has been built on the Dudhganga River in collaboration with the Karnataka State.
- **Ghatprabha:** Ghataprahha river originates in the Western Ghats and flows eastward across Karnataka and Maharashtra states before its confluence with the Krishna River at Almatti.

  There is *Gokak waterfall* on the river in Belgaum. Also, the Ghataprabha Project (Hydroelectric and irrigational dam) is across the river.
- **Malaprabha:** Malaprabha originates in Kanakumbi of Belgaum District in Karnataka, at an altitude of 792 m in the Sahyadris. The *Navilatirtha Dam* is constructed near Munavalli in Belgaum District. Its reservoir is called *Renukasagara.*

  Famous temples of *Aihole Pattadakal* and *Badami* are located on the Banks of this river. These are listed as *World Heritage sites by UNESCO.*
- **Tungabhadra:** The Tungabhadra is formed by the unification of the Tunga and the Bhadra originating from Gangamula in the Central Sahyadri. At Wazirabad, it receives its last important tributary, the Musi, on whose banks the city of *Hyderabad* is located.

  The ancient name of the river was Pampa. The wedge of land that lies north of the Tungabhadra River, between the Tungabhadra and the Krishna, is known as the *Raichur Doab*. Harihar, Hospet. Hampi, Mantralayam, and Kurnool are the major urban centers on the river.

Resources in Krishna Basin

The basin has rich mineral deposits and there is good potential for industrial development. Iron and steel, cement, sugarcane, vegetable oil extraction, and rice milling are important industrial activities in the basin.

Drought and Floods in Krishna Basin

Some parts of the basin, especially the Rayalaseema area of Andhra Pradesh, Bellary, Raichur, Dharwar, Chitradurga, Belgaum, Bijapur districts of Karnataka and Pune, Sholapur, Osmanabad, and Ahmedanagar districts of Maharashtra are drought-prone.

The delta area of the basin is subject to flooding. It has been observed that the river bed in the delta area is continuously raised due to silt deposition resulting in reduction in the carrying capacity of the channel. The coastal cyclonic rainfall of high intensity and short duration makes the flood problem worse.

PROJECTS ON KRISHNA RIVER	
Tungabhadra Project	The project aims at producing hydro-electricity, providing irrigation water and municipal water supply, and controlling floods in the region. Under this project, a dam has been constructed across the Tungabhadra river near Hospet in the state of Karnataka.

PROJECTS ON KRISHNA RIVER	
Srisailam Project	Under the project, a large dam has been constructed across the Krishna river in Kurnool district in the state of Andhra Pradesh. It has created a reservoir named as Srisailam Sagar or Neelam Sanjjeva Reddy Sagar.
Nagarjuna Sagar Dam	The construction of the dam started in 1950, being one of the earliest large infrastructure projects of India, aimed at bringing the Green Revolution. The dam has been constructed across the Krishna river straddling the borders of the Nalgonda and Guntur districts.
Prakasam Barrage	The Prakasam Barrage was conceptualized by Major Cotton of the East India Company. It is constructed across the Krishna river near Vijayawada in the state of Andhra Pradesh.
Ghatprabha Project	The project has been executed across the Ghatprabha river near Chandgad in Kolhapur district in the state of Maharashtra in the Krishna river basin.
Bhima Project	The project has been executed across the Bhima river in the Solapur district in the state of Maharashtra in the Krishna river basin.

Cauvery River

The Cauvery River (Kaveri) is designated as the *'Dakshin Bharat ki Ganga'* or *'the Ganga of the South'*. It originates at *Talakaveri on the Brahmagiri* range near to Kodagu (Coorg) district of Karnataka.

It flows in south-easterly direction through the states of Karnataka and Tamil Nadu and descends to Eastern Ghats with a series of great falls.

Before emptying into the Bay of Bengal, the river breaks into a large number of distributaries forming a wide delta called the *garden of southern India.* The Cauvery basin extends over states of Tamil Nadu, Karnataka, Kerala, and Union Territory of Puducherry. It is bounded by the Western Ghats on the west, by the Eastern Ghats on the east and the south, and by the ridges separating it from the Krishna basin and Pennar basin on the north.

The *Nilgiris,* an offshore of Western ghats, extend Eastwards to the Eastern ghats and divide the basin into two natural and political regions i.e., Karnataka plateau in the North and the Tamil Nadu plateau in the South.

The delta area is the most fertile tract in the basin. The principal soil types found in the basin are black soils, red soils, laterites, alluvial soils, forest soils, and mixed soils. Red soils occupy large areas in the basin. Alluvial soils are found in the delta areas.

The basin in Karnataka receives rainfall mainly from the S-W Monsoon and partially from N-E Monsoon. The basin in Tamil Nadu receives good flows from the North-East Monsoon. Its upper catchment area receives rainfall during summer by the south-west monsoon and the lower catchment area during the winter season by the retreating north-east monsoon.

Therefore, it is almost a perennial river with comparatively fewer fluctuations in flow and is very useful for irrigation and Hydroelectric power generation. The falls supply Hydroelectric power to Mysore, Bengaluru, and the Kolar Gold Fields.

Also the Cauvery is one of the best regulated rivers and around 92 to 95% of its irrigation and power production potential already stand harnessed.

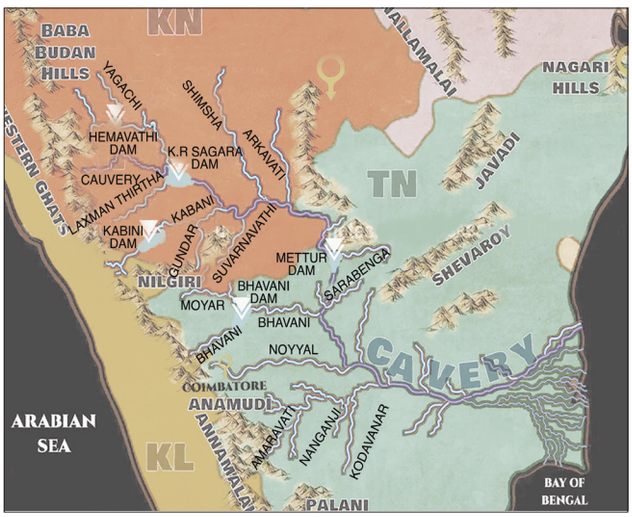


Fig. 4.16: Cauvery River Drainage

Tributaries of the Cauvery River

Left Bank: the Harangi, the Hemavati, the Shimsha, and the Arkavati.

Right Bank: Lakshmantirtha, Kabbani, Suvarnavati, Bhavani, Noyil and Amaravati.

The river descends from the South Karnataka Plateau to the Tamil Nadu Plains through the *Sivasamudram waterfalls* (101 m high). The falls at this point is utilized for power generation by the power station at Shivanasamudram.

The two branches of the river join after the fall and flow through a wide gorge which is known as *'Mekedatu'* (Goats leap) and continues its journey to form the boundary between Karnataka and the Tamil Nadu States. At *Hogennekkal Falls,* it takes a Southerly direction and enters the Mettur Reservoir.

A tributary called *Bhavani* joins Cauvery on the Right bank below Mettur Reservoir. Thereafter it enters the plains of Tamil Nadu. Two more tributaries Noyil and Amaravathi join on the right bank and here the river widens with a sandy bed and flows as *'Akhanda Cauvery'*. After flowing for about 16 Kms, the two branches join again to form '*Srirangam Island*'.

On the Cauvery branch lies the *"Grand Anicut"* said to have been constructed by a *Chola King* in 1st Century A.D.

- **Hemavati:** It is an important tributary of the Kaveri River, rises from the Western Ghats near Ballalarayana Durga in the Chikmagalur District of Karnataka and flows through Chikkamagaluru, Hassan District, and Mysore district before joining the Kaveri near Krishnarajasagara.
- **Kabini:** Kabini originates from Pakramthalam hills in Wayanad District of Kerala from the confluence of the Panamaram river and Mananthavady river.

  The backwaters of the Kabini reservoir are very rich in wildlife especially in summer when the water level recedes to form rich grassy meadows.
- **Noyyal River:** It rises from the Vellingiri hills in the Western Ghats in Tamil Nadu and drains into the Kaveri river. Noyyal joins with river Cauvery at Kodumudi in Erode District.
- **Amaravati:** It is also known as Pournami in the Kerala and Tamil Nadu border at the bottom of Manjampatti Valley between the *Annamalai Hills* and the *Palani hills in Indira Gandhi Wildlife Sanctuary and National Park.* It descends in a northerly direction through Amaravati Reservoir and Amaravati Dam at Amaravatinagar.

  The Amaravati River and its basin, are heavily used for industrial processing water and waste disposal and as a result, are severely polluted due to a large amount of textile dyeing and bleaching units.

Projects on Cauvery River

During the pre-plan period many projects were completed in this basin which included Krishnarajasagar in Karnataka, Mettur dam and Cauvery delta system in Tamil Nadu. Lower Bhavani, Hemavati, Harangi, Kabini are important projects.

CAUVERY WATER DISPUTE

Issue:

- It involves three states and one union territory (Tamil Nadu, Kerala, Karnataka and Puducherry).
- The origins of the conflict may be traced back to two arbitration agreements signed between the then-Madras presidency and Mysore in 1892 and 1924.
- It established the premise that any building project, like a reservoir on the Cauvery River, must be approved by the lower riparian state.

Dispute:

- The river Cauvery originates in *Karnataka's Kodagu district*, flows into Tamil Nadu and reaches the Bay of Bengal.
- **1892:** The dispute started between the Madras Presidency (under British rule) and the Princely state of Mysore. Madras disagrees with the Mysore administration's proposal to build irrigation systems, arguing that it would impede water flow into Tamil Nadu.
- **1924:** The dispute comes close to being resolved when *Mysore and Madras* reached on an agreement under which Mysore is allowed to build a dam at Kannambadi village.

  The agreement is to be valid for 50 years and reviewed thereafter. Based on this agreement, *Karnataka builds the Krishnaraja Sagar dam*.
- **1974:** The 1924 water-sharing agreement between the then Madras Presidency and Princely State of Mysore (now Tamil Nadu and Karnataka) lapses after the expiration of its term of 50 years.
- **1990:** Cauvery Water Disputes Tribunal was set up to adjudicate upon the water dispute regarding the Inter-State river Cauvery and the river valley thereof among the States of Karnataka, Kerala, Tamil Nadu and Union territory of Puducherry.
- **2007:** The tribunal declared its final award, in which it said Tamil Nadu should receive 419 tmcft (thousand million cubic feet) of water more than double the amount mentioned in the interim order of 1991.
- **2016:** The Tamil Nadu government said that there was a deficit of 50.0052 tmcft of water released from Karnataka. The Karnataka government said it wouldn't be able to release any more Cauvery water due to low rainfall.

  Tamil Nadu then sought the Supreme Court's intervention.
- **2017:** The SC ordered the Karnataka government to release 15,000 cusecs of water a day for 10 days, to Tamil Nadu. This led to widespread protests and bandhs in Karnataka.

  After several modifications of the order, the Karnataka government has been directed by SC to release 2,000 cusecs of water per day to Tamil Nadu till further orders.
- **2018:** The apex court gave its final verdict saying that Karnataka will get an additional 14.75 TMC of the river water and Tamil Nadu will get 177.25 instead of 192 TMC water.

The court considered the water scarcity in Bengaluru while delivering the final judgment and also said no deviance shall be shown by any state to the order.

The Centre was also ordered to notify the Cauvery Management Scheme. To give effect to the judgement, the central government published the *'Cauvery Water Management Scheme' in June 2018, forming the 'Cauvery Water Management Authority' and the 'Cauvery Water Regulation Committee'.*

Inter-State River Disputes

The major inter-state river disputes which remain in news are given below.

RIVER	STATES
Ravi and Beas	Punjab, Haryana, Rajasthan
Narmada	Madhya Pradesh, Gujarat, Maharashtra, Rajasthan
Krishna	Maharashtra, Andhra Pradesh, Karnataka, Telangana
Vamsadhara	Andhra Pradesh & Odisha
Cauvery	Kerala, Karnataka, Tamil Nadu, and Puducherry
Godavari	Maharashtra, Andhra Pradesh, Karnataka, Madhya Pradesh, Odisha
Mahanadi	Chhattisgarh, Odisha
Periyar	Tamil Nadu, Kerala
Mahadayi	Goa, Maharashtra, Karnataka

West Flowing Rivers of Peninsular India

India is a geographical paradise with a multitude of rivers flowing across the country. While most of the rivers in the country are east flowing in nature, i.e. they join the Bay Of Bengal, there are a few rivers that defy the odds and are west flowing, These west-flowing rivers ultimately end up in the Arabian Sea.

The two major west-flowing rivers are the Narmada and the Tapi. This exceptional behavior is because these rivers didn't form valleys and instead they flow through faults (linear rift, rift valley, trough) created due to the bending of the northern peninsula during the formation process of the Himalayas.

These faults run parallel to the Vindhyas and the Satpuras. The **Sabarmati, Mahi, and Luni** are other rivers of Peninsular India which flow westwards. Hundreds of small streams originating in the Western Ghats flow swiftly westwards and join the Arabian Sea.

It is interesting to note that the *Peninsular rivers which falls into the Arabian Sea. They do not form deltas, but only estuaries*. This is due to the fact that the west-flowing rivers, especially the Narmada and the Tapi flow through hard rocks and hence do not carry any good amount of silt. Moreover, the tributaries of these rivers are very small and hence they don't contribute any silt. Hence these rivers are not able to form distributaries or a delta before they enter the sea.

A few rivers in Rajasthan do not drain into the sea. They drain into salt lakes and get lost in the sand with no outlet to the sea. Besides these, there are the Desert Rivers which flow for some distance and are lost in the desert. These are Luni and others such as, Machhu, Rupen, Saraswati, Banas, and Ghaggar.

Fig. 4.17: Westward flowing river in India

ESTUARY

An estuary is a partially enclosed body of water along the coast where freshwater from rivers and streams meets and mixes with saltwater from the ocean. (Primary productivity in estuaries is very high. Fishing is a dominant occupation around estuaries. Most of the estuaries are good bird sanctuaries). Estuaries and the lands surrounding them are places of transition from land to sea and freshwater to saltwater.

Although influenced by the tides, they are protected from the full force of ocean waves, winds, and storms by such landforms as barrier islands or peninsulas. Estuarine environments are among the most productive on Earth, creating more organic matter each year than comparably-sized areas of forest, grassland, or agricultural land. The tidal, sheltered waters of estuaries also support unique communities of plants and animals especially adapted for life at the margin of the sea.

Estuaries have important ***commercial value*** and their resources provide economic benefits for tourism, fisheries, and recreational activities. The protected coastal waters of estuaries also support important public infrastructure, serving as harbors and ports vital for shipping and transportation.

Estuaries also perform other valuable services. Water draining from uplands carries sediments, nutrients, and other pollutants to estuaries.

As the water flows through wetlands such as swamps and salt marshes, much of the sediments and pollutants are filtered out. Saltmarsh grasses and other estuarine plants also help prevent erosion and stabilize shorelines Mangroves.

Narmada River

Narmada is the largest west flowing rivers of the peninsular India. Narmada flows westwards through a rift valley between the Vindhyan Range on the north and the Satpura Range on the south.

It rises from the *Maikala range near Amarkantak* in Madhya Pradesh. Narmada basin extends over states of Madhya Pradesh, Gujarat, Maharashtra, and Chhattisgarh.

It is bounded by the Vindhyas on the north, Maikala range on the east, Satpuras on the south, and by the Arabian Sea on the west. The hilly regions are in the upper part of the basin, whereas lower-middle reaches are broad and fertile areas well suited for cultivation.

Jabalpur is the only important urban center in the basin. The river slopes down near Jabalpur where it cascades (a small waterfall, especially one in a series) 15 m into a gorge to form the *Dhuan Dhar (Cloud of Mist) falls*. Since the gorge is composed of marble, it is popularly known as the Marble Rocks.

Near the place called Maheshwar, the river again descends from another small fall of 8 m, known as the *Sahasradhara Falls*. There are several islands in the estuary of the Narmada of which *Aliabet* is the largest. The Narmada is navigable up to 112 km from its mouth.

Tributaries of Narmada River

Right Bank Tributaries: The Barna, Hiran river, Tendoni river, Choral river, Kolar river, Man river, Uri river, Hatni river, Orsang river

Left Bank Tributaries: Burhner river, Banjar river, Sher river, Shakkar river, Dudhi river, Tawa river, Ganjal river, Chhota Tawa river, Kaveri river, Kundi river, Goi river, Karjan river.

The major Hydro Power projects in the Narmada basin are *Indira Sagar, Sardar Sarovar, Omkareshwar, Bargi & Maheshwar.*

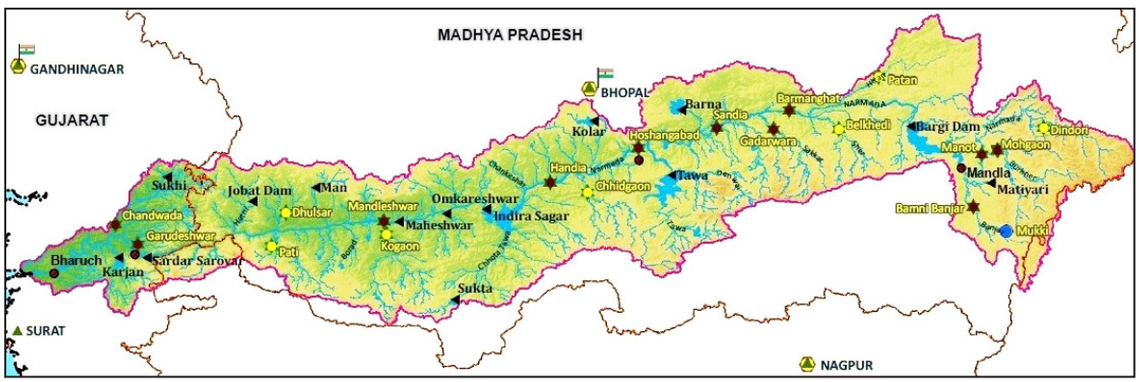


Fig. 4.18: Narmada River Drainage

Tapti River (Tapi)

It is the second-largest west flowing river of Peninsular India and is known as '*the twin*' or '*the handmaid' of the Narmada*. It originates near *Multai reserve forest* in Madhya Pradesh. It drained into the Arabian Sea through the *Gulf of Cambay.*

The Tapti River along with its tributaries flows over the plains of Vidharbha and Khandesh and a small area in Madhya Pradesh.

The hilly region of the basin is well forested while the plains are broad and fertile i.e. suitable for cultivation.

There are two well-defined physical regions, in the basin, viz hilly region and plains; the hilly regions comprising Satpura, Satmalas, Mahadeo, Ajanta, and Gawilgarh hills are well forested.

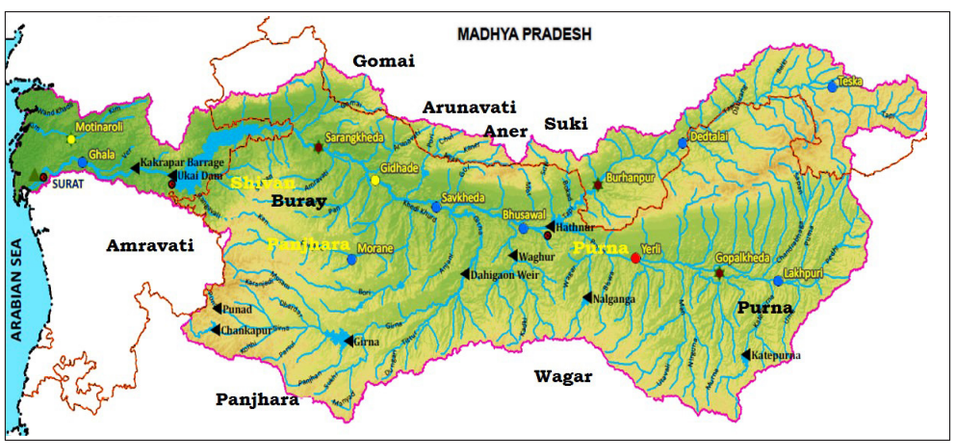


Fig. 4.19: Tapi River Drainage

Tributaries of Tapti River

Right Bank: The Suki, the Gomai, the Arunavati and the Aner.

Left Bank: The Vaghur, the Amravati, the Buray, the Panjhra, the Bori, the Girna, the Purna, the Mona and the Sipna.

Projects on Tapti River

Hathnur Dam of Upper Tapi Project (Maharashtra), Kakrapar weir and Ukai Dam of Ukai Project (Gujarat), Girna Dam and Dahigam Weir of Girna Project (Maharashtra)

Industry in the Tapti Basin

Important industries in the basin are textile factories in Surat and paper print factory at Nepanagar.

Sabarmati River

The Sabarmati is the name given to the combined streams of the Sabar and Hathmati. The Sabarmati basin extends over the states of Rajasthan and Gujarat. The basin is bounded by Aravalli hills on the north and north-east, by Rann of Kutch on the west, and by the Gulf of Khambhat on the south.

Sabarmati originates from *Aravalli hills* near village Tepur, in the Udaipur district of Rajasthan. The major part of the basin is covered with agriculture accounting to 74.68% of the total area. Rainfall varies from a meager few mm in Saurashtra to over 1000 mm in the southern part.

Projects: Sabarmati reservoir (Dharoi), Hathmati reservoir, and Meshwo reservoir project.

Mahi River

It originates from the *northern slopes of Vindhyas* in the Dhar district of Madhya Pradesh. It drains into the Arabian Sea through the *Gulf of Khambhat*.

The Mahi basin extends over states of Madhya Pradesh, Rajasthan, and Gujarat. The major part of the basin is covered with agricultural land, about 63.63% of the total area. It is one of the major inter-state west flowing rivers of India.

The important Hydro Power stations are located in Mahi basin are Mahi Bajaj Sagar dam, Kadana dam, and Wanakbori dam (Weir). The city of Vadodara lies in the Mahi basin.

Luni River

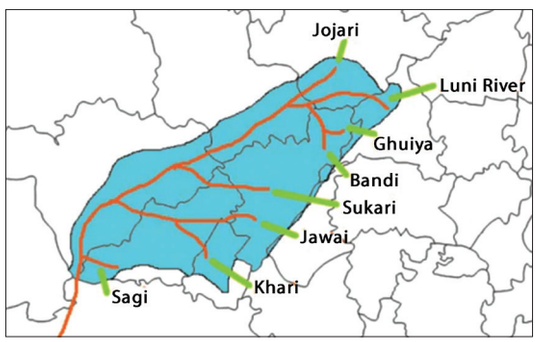


Fig. 4.19: Luni River Drainage

The Luni or the Salt River is named so because its water is brackish. Luni is the only river basin of some significance in Western Rajasthan, which forms the bulk of the arid zone. Luni originates from the western slopes of the Aravalli ranges near Ajmer and flows in the southwest direction and it finally drains into the Rann of Kutch (it gets lost in the marsh).

Sharavati River

It originates and flows entirely within the state of Karnataka. The *Jog or Gersoppa Falls* (289 m) made by the Sharavati river is the most famous waterfall of India.

Mahadayi River

Fig. 4.20: Mahadayi River Course

Mahadayi or Mhadei, the west-flowing river, originates in *Bhimgad Wildlife Sanctuary* (Western Ghats), Belagavi district of Karnataka. It is a rain-fed river also called as Mandovi in Goa. It is joined by a number of streams to form the Mandovi which is one of two major rivers (the other one is the Zuari river) that flows through Goa.

MAHADAYI / MANDOVI RIVER DISPUTE

The dispute over Mahadayi river is between Goa and Karnataka. It started in the 1980s and grew stronger in the subsequent decades.

Karnataka move to design a number of dams, canals and barrages to route the Mahadayi river water to the Malaprabha basin.

The state claimed that channeling the river water into the Malaprabha basin, a tributary of the Krishna, would meet the requirements of water-scarce districts of baalkot, Gadag, Dharwad and Belagavi.

An Inter-state Water Disputes Tribunal has allotted 13.42 thousand million cubic feet of water (TMC) to Karnataka and 1.33 TMC to Maharashtra. Both Karnataka and Goa have contested the order and the matter is now pending in apex court.

Ghaggar River

The Ghaggar is the most important river of inland drainage. It is a seasonal stream which rises on the lower

slopes of the Himalayas and forms the boundary between Haryana and Punjab.

It gets lost in the dry sands of Rajasthan near Hanumangarh. Earlier, this river was an affluent of the Indus, the dry bed of the old channel is still traceable. Its main tributaries are the Tangri, the Markanda, the Saraswati and the Chaitanya.

4.5 River Regimes

The pattern of flow of water in a river channel over a year is known as its regime. Usually, fluctuations in the water flow of a river occurs due to various factors such as melting, precipitation, formation of rocks or other relief-changes etc. resulting in different river regimes. For example, the regimes of Himalayan rivers are different from peninsular rivers.

The Himalayan rivers are perennial as they are fed by both rainfall and glaciers and said to be of glacial regime whereas the Peninsular rivers are fed only by the rainfall thus subjected to fluctuations in the water flow depending on the amount of rainfall and said to be of monsoonal regime.

The rivers with the monsoonal regime have minimum water flow in the month of January to May and maximum water flow in the monsoon season i.e., June to September. For example, the Narmada river has a very low volume of discharge from January to July but it suddenly rises in August when the maximum flow is attained. The fall in October is as spectacular as the rise in August.

DIFFERENCE BETWEEN THE HIMALAYAN AND THE PENINSULAR RIVER SYSTEM

Features	The Himalayan River System	The Peninsular River System
Origin	These rivers originate from the lofty Himalayan ranges and are named as the Himalayan rivers.	These rivers originate in the hills of Peninsular Plateau and are named as Peninsular rivers.
Catchment area	These rivers have large basins and catchment areas. The total basin area of the Indus, the Ganga and the Brahmaputra are 11.78,8.61 and 5.8 lakh square kilometres respectively.	These rivers have comparatively small basins and catchment areas. The Godavari has the largest basin area of 3.12 lakh square kilometres.
Valleys	The Himalayan rivers flow through deep V-shaped valleys called gorges. These gorges have been carved out by down cutting carried on side by side with the uplift of the Himalayas.	The Peninsular rivers flow in comparatively shallow valleys. These are more or less completely graded Valleys. The rivers have little erosional activity to perform.
Drainage Type	These are examples of antecedent drainage.	These are examples of consequent drainage.
Water Flow	The Himalayan rivers are perennial in nature, i.e., water flows throughout the year in these rivers. These rivers receive water both from the monsoons and snow-melt. The perennial nature of these rivers makes them useful for irrigation.	The Peninsular rivers receive water only from rainfall and water flows in these rivers in rainy season only. Therefore, these rivers are seasonal or non- perennial. As such these rivers are much less useful for irrigation.
Stage	These rivers flow across the young fold mountains and are still in a youthful stage.	These rivers have been flowing in one of the oldest plateaus of the world and have reached maturity.
Meanders	When they enter the plains, there is a sudden reduction in the speed of flow of water. Under these circumstances, these rivers form meanders and often shift their beds.	The hard rock surface and non-alluvial character of the plateau permits little scope for the formation of meanders. As such, the rivers of the Peninsular Plateau follow more or less straight courses.
Deltas and Estuaries	The Himalayan rivers form big deltas at their mouths. Ganga-Brahmaputra delta is the large est in the world.	Some of the Peninsular rivers, such as the Narmada and the Tapti form estuaries. Other rivers such as the Mahanadi, the Godavari, the Krishna and the Cauvery form deltas. Several small streams originating from the Western Ghats and flowing towards the west enter the Arabian Sea without forming any delta.