Chapter 3

Drainage

THE DRAINAGE SYSTEM

The drainage system is an integrated system of tributaries and a trunk stream which collect and funnel surface water to the sea, lake or some other body of water. The total area that contributes water to a single drainage system is known as a drainage basin. This is a basic spatial geomorphic unit of a river system, distinguished from a neighbouring basin by ridges and highlands that form divides. Thus, river basins are natural units of land. They are regarded as the fundamental geomorphic as well as hydrological units for a systematic study of the river basins, mainly due to the following three reasons:

(i) They can be placed in an orderly hierarchy,

(ii) They are areal units whose geomorphological and hydroloical characteristics can be measured quantitatively, and

(iii) They can be treated as working systems with energy inputs of climatological variables like temperature and rainfall and output of river discharge as runoff.

The Committee on Runoff of the American Geophysical Union treats the micro-unit within a river basin as the *watershed,* while the sum of all the micro, meso and macro tributaries of a river is known as a *river basin.*

DRAINAGE PATTERN

A geometric arrangement of streams in a region; determined by slope, differing rock resistance to weathering and erosion, climate, hydrologic variability, and structural controls of the landscape is known as a drainage pattern. In other words, drainage pattern refers to a design which a river and its tributaries form together, from its source to its mouth. The factors controlling the pattern of drainage in a region include the topography, slope, structural control, nature of rocks, tectonic activities, supply of water, and above all, the geological history of that region. In India, the following types of drainage patterns are found:

1. The Antecedent or Inconsequent Drainage

The rivers that existed before the upheaval of the Himalayas and cut their courses southward by making gorges in the mountains are known as the antecedent rivers. The Indus, Satluj, Ganga, Sarju (Kali), Arun (a tributary of Kosi), Tista and Brahmaputra are some of the important antecedent rivers, originating from beyond the Greater Himalayas.

2. Consequent Rivers

The rivers which follow the general direction of slope are known as the consequent rivers. Most of the rivers of peninsular India are consequent rivers. For example, rivers like Godavari, Krishna and Kaveri, descending from the Western Ghats and flowing into the Bay of Bengal, are some of the consequent rivers of Peninsular India (**Fig. 3.1**).

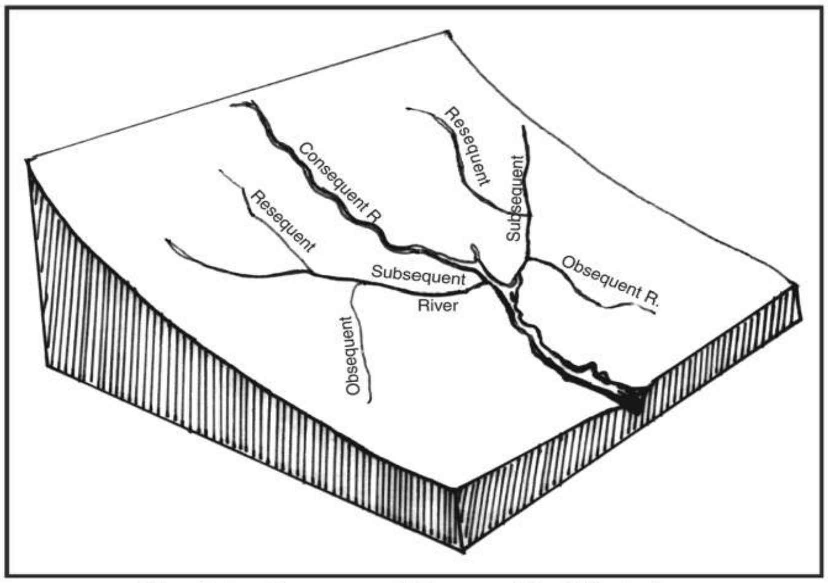


Fig. 3.1 Consequent River and its Tributaries

3. Subsequent Rivers

A tributary stream that is eroded along an underlying belt of non-resistant rock after the main drainage pattern (consequent river) has been established is known as a subsequent river. Due to the northward slope of the Peninsula towards the Great Plains, the rivers originating from the Vindhyan and the Satpura ranges flow northward into the Ganga system. The Chambal, Sind, Ken, Betwa, Tons and Son meet the Yamuna and the Ganga at right angles. They are the subsequent drainage of the Ganga drainage system.

4. Superimposed, Epigenetic (Discordant) or Superinduced Drainage

It is formed when a stream with a course originally established on a cover of rock now removed by erosion, so that the stream or drainage system is independent of the newly exposed rocks and structures. In other words, it is a drainage pattern which exhibits discordance with the underlying rock structure because it originally developed on a cover of rocks that has now disappeared due to denudation. Consequently, river directions relate to the former cover rocks and, as the latter were being eroded, the rivers have been able to retain their courses unaffected by the newly exposed structures. The stream pattern is thus superposed on, or placed on, ridges or structural features that were previously buried. The Damodar, the Subarnarekha, the Chambal, the Banas and the rivers flowing at the Rewa Plateau present some good examples of superimposed drainage.

5. Dendritic Drainage

A term used for drainage which is branching, ramifying or dichotomising, thereby giving the appearance of a tree. Thus, a dendritic pattern develops in a terrain which has uniform lithology, and where faulting and jointing are insignificant; e.g., massive crystalline rocks or thick plains consisting of clays. Most of the rivers of the Indo-Gangetic Plains are of dendritic type. The term dendritic, coined by I.C. Russel (1898), is used to denote the most common type of drainage pattern and is a distinctive feature of the regions having horizontally bedded sedimentary rocks or massive igneous rocks (**Fig. 3.2-A**).

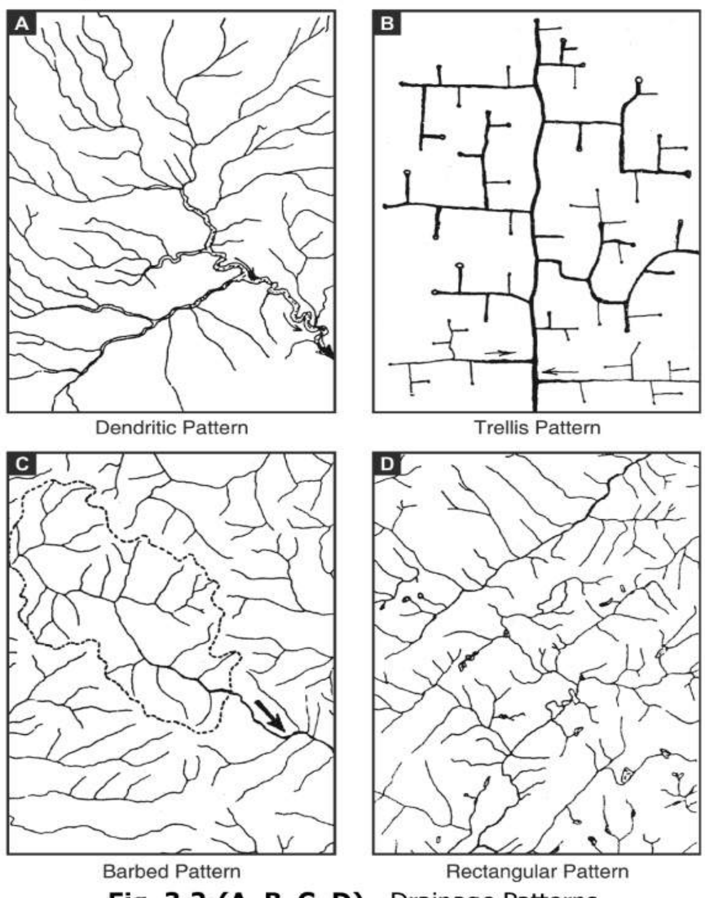


Fig. 3.2-(A, B, C, D) Drainage Patterns

6. Trellis Drainage

Trellis is a rectangular pattern formed where two sets of structural controls occurs at right angles. In a trellis pattern, the river forms a net like system and the tributaries flow roughly parallel to each other. The old folded mountains of the Singhbhum (Chotanagpur Plateau) have a drainage of trellis pattern **(Fig. 3.2-B)**.

7. Barbed Pattern

A pattern of drainage in which the confluence of a tributary with the main river is characterised by a discordant junction—as if the tributary intends to flow upstream and not downstream. This pattern is the result of capture of the main river which completely reverses its direction of flow, while the tributaries continue to point in the direction of former flow. The Arun River (Nepal), a tributary of the Kosi is an interesting example of barbed drainage pattern **(Fig. 3.2-C)**.

8. Rectangular Drainage

The drainage pattern marked by right-angled bends and right-angled junctions between tributaries and the main stream is known as rectangular drainage. It differs from the trellis pattern in so far as it is more irregular and its tributary streams are neither as long, nor parallel as in trellis drainage. A typical example of this drainage pattern is found is the Vindhyan Mountains of India **(Fig. 3.2-D)**.

9. Radial Pattern

It is a pattern characterised by outflowing rivers, away from a central point, analogous with the spokes of a wheel. It tends to develop on the flanks of a dome or a volcanic cone. A good example of a radial drainage pattern is provided by the rivers originating from the Amarkantak mountain. Rivers like Narmada, Son and Mahanadi originating from Amarkantak Hills flow in different directions and are good examples of radial pattern. Radial drainage patterns are also found in the Girnar Hills (Kathiwar, Gujarat), and Mikir Hills of Assam **(Fig. 3.3-A)**.

10. Annular Pattern

In this drainage pattern, the subsequent streams follow curving or arcuate courses prior to joining the consequent stream. This results from a partial adaptation to an underground circular structure; a dome like igneous intrusion (batholith). The subsequent streams find it easier to erode the concentric, less resistant strata. This is not a very common drainage pattern in India. Some examples of this are however found in Pithoragarh (Uttarakhand), Nilgiri Hills in Tamil Nadu and Kerala **(Fig. 3.3-B)**.

11. Parallel Drainage

The drainage pattern in which the rivers flow almost parallel to each other is known as parallel drainage. The small and swift rivers originating in the Western Ghats and discharging their water into the Arabian Sea provide a good example of parallel drainage pattern in India **(Fig. 3.3-C)**.

12. Deranged Pattern

This is an uncoordinated pattern of drainage characteristic of a region recently vacated by an ice-sheet. This is probably due to the irregularities produced by glacially deposited materials, e.g., Kame and

Kettle, and by the fact that there has been insufficient time for the drainage to become adjusted to the structures of the solid rock underlying the glacial drift. The picture is one of numerous water courses, lakes and marshes; some inter-connected and some in local drainage basins of their own. This type of drainage is found in the glaciated valleys of Karakoram (**Fig. 3.3-D**).

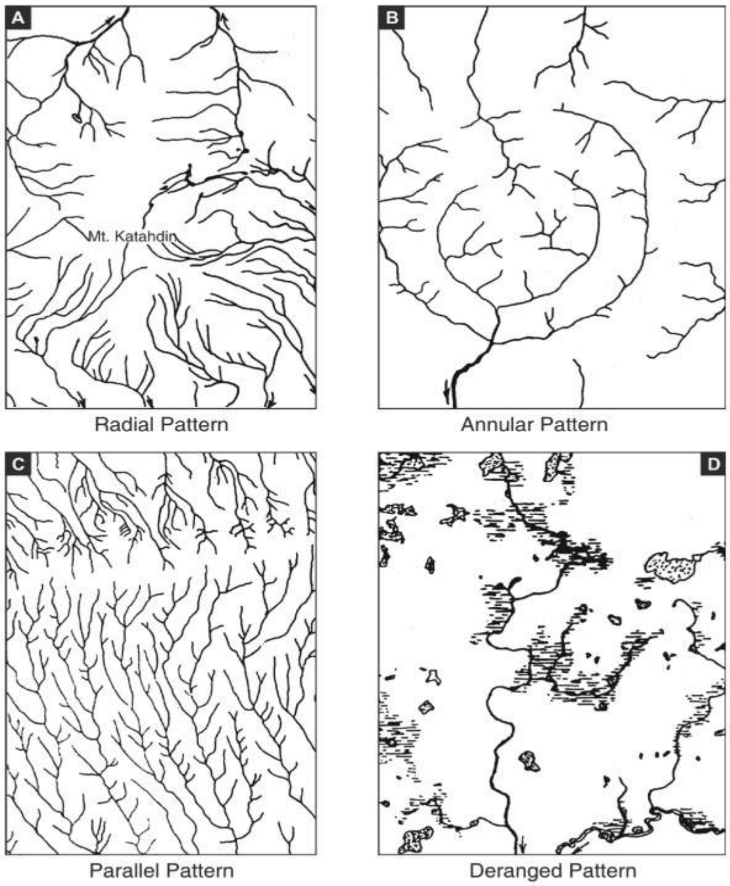


Fig. 3.3-(A, B, C, D) Drainage Patterns

RIVER BASINS OF INDIA

Rivers with their tributaries are the main channels of drainage of the land surface; they are at the same time also the chief agents of land-erosion, and the main lines for transport waste-products of the land to the sea. The area drained by the main river including all its tributaries is known as its drainage basin. On the basis of the area drained, the river basins of India have been classified into three categories: (i) river basins with catchment area of more than 20,000 sq km known as large river basins; (ii) river basins having a catchment area between 2000 to 20,000 sq km known as the medium basins, and (iii) the rivers having a catchment area less than 2000 sq km known as minor river basins. India has one hundred and thirteen river basins, of which 14 are large, 44 medium and 55 minor river basins. The major river basins of India in descending order of area are: the Ganga, Indus, Godavari, Krishna, Brahmaputra, Luni, Mahanadi, Narmada, Kaveri, Tapi, Pennar, Brahmani, Mahi, Sabarmati, Barak, and Subarnarekha. The major river basins form about 84 per cent of the total drainage area of the country (**Fig. 3.4**).

The three major river systems (Ganga, Indus, and Brahmaputra) are international rivers. The Indus and some of its important tributaries traverse Tibet (China), India, and Pakistan, while the

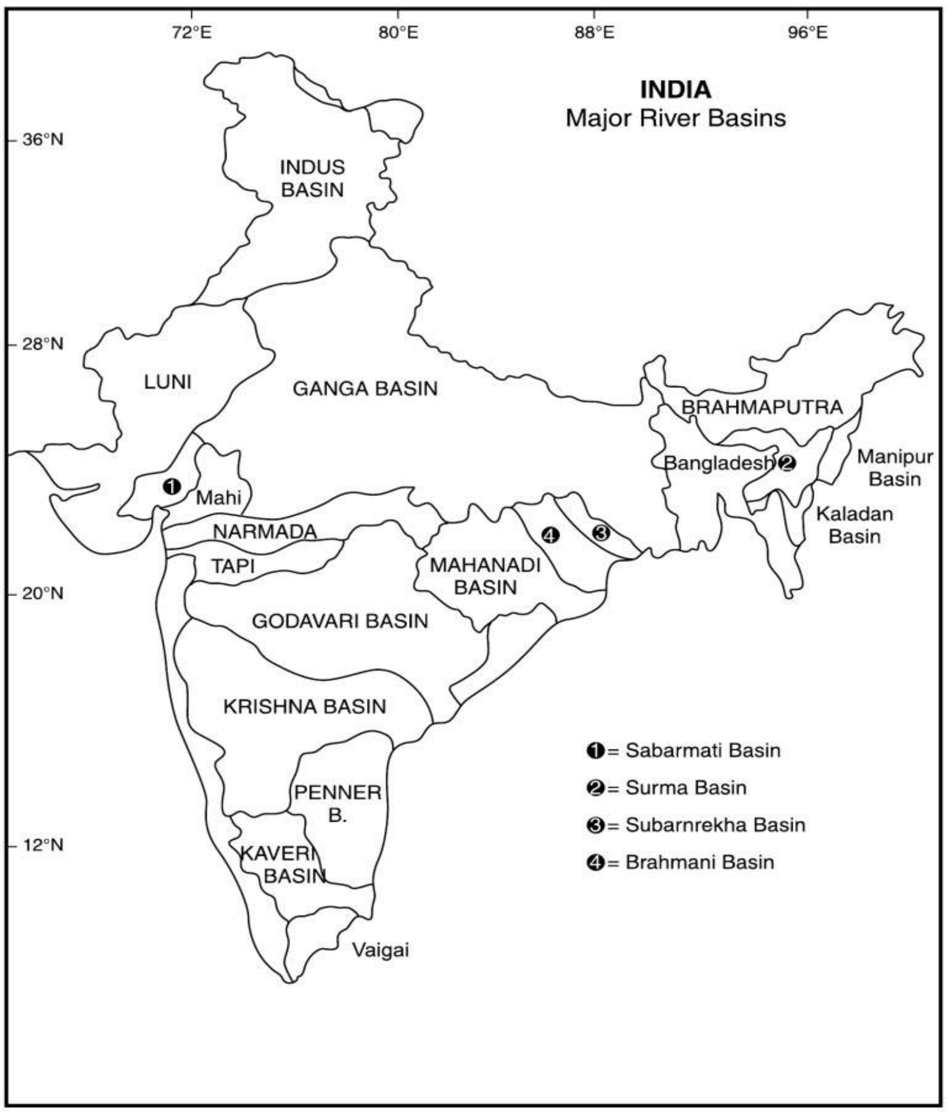


Fig. 3.4 Major River Basins

Ganga and Brahmaputra, and their tributaries cross Tibet, Nepal, Bhutan, and Bangladesh. The main river basins, their basin area, and annual discharge has been shown in Table 3.1.

On the basis of mode of origin, the drainage of India may be divided into (i) Himalayan or the Extra-Peninsular Drainage, and (ii) the Peninsular Drainage.

There is no clearcut line of demarcation between these two drainage systems, as many of the Peninsular rivers like the Chambal, Betwa, Sind, Ken, and Son are much older in age and origin than the Himalayan rivers.

Table 3.1 *Major Rivers of India and their Surface Flow*

River Basin	*Basin Area**	*Percentage area*	*Annual Discharge (M^3/km^2)*	*%*
Ganga	861,404	26.2	468,700	25.2
Indus	321,284	9.8	79,500	4.3
Godavari	312,812	9.5	118,000	6.4
Krishna	258,948	7.9	62,800	3.4
Brahmaputra	258,008	7.8	627,000	33.8
Mahanadi	141,589	4.3	66,640	3.6
Narmada	98,795	3.0	54,600	2.9
Kaveri	87,900	2.7	20,950	1.1
Tapi	65,150	2.0	17,982	0.9
Pennar	55,213	1.7	3,238	0.2
Brahmani	39,033	1.2	18310	1.0
Mahi	34,481	1.0	11,800	0.6
Subarnarekha	19,296	0.6	7,940	0.4
Sabarmati	21,895	0.7	3,800	0.2
Medium and Minor Rivers	711,833	23.6	—	16.0
Total (India)	328,76,97	100.00	1,561,170	100.00

*Area means basin area in India.
Source: S.P. Das Gupta, 1989.

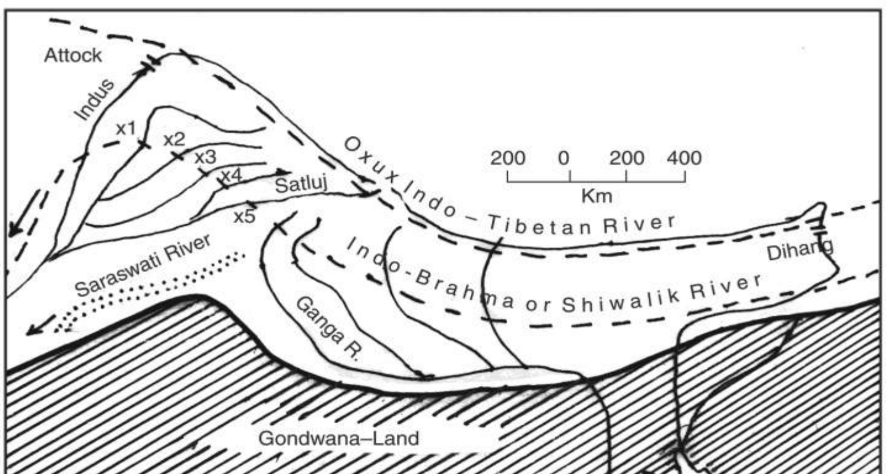
The Himalayan Drainage

The Himalayan drainage system comprises all the international rivers of India, i.e, the Indus, the Ganga, and the Brahmaputra. Most of these rivers and their major tributaries are perennial in character, obtaining their water from the glaciers and rains. These rivers are in their youthful stage carving out a number of erosional landforms like waterfalls, cataracts, rapids, gorges, steep slopes, and river terraces. The Himalayan rivers are not only eroding agents, but are also depositing agents in the plains and deltas. The great Himalayan rivers (Indus, Satluj, Ganga, Kali, Karnali, Gandak, Kosi, Tista and Brahmaputra) are older than the Greater Himalayas. They are antecedent, and drain not only the southern slopes of the Himalayas but to a large extent, the northern Tibetan slopes as well. The Himalayan courses of these rivers are highly tortuous, but in plains they display a strong meandering tendency and shift their courses frequently. The river regimes, although perennial, exhibit wide seasonal fluctuations; causing devastating floods during rainy season but shrinking to the bottom of the valley with a number of shoals during the dry season. These rivers continue to cause intensive erosion and transport heavy loads of sand and silt annually. Several of the Himalayan rivers are older to the Himalayas. Such rivers are known as the antecedent rivers. The Himalayan rivers have great socio-economic and cultural importance in the life of the Indian people. The water of the Himalayan rivers is utilised for irrigation, industries, hydel-power generation, navigation and domestic purposes. Moreover, the big rivers are navigable in the plain areas of their courses.

Evolution of the Himalayan Rivers

The geologists and geomorphologists are not unanimous about the origin of the Himalayan rivers. The Himalayan rivers have a long geological history. The major rivers of the Himalayas like Indus, Brahmaputra, Satluj, Ganga (Alaknanda and Bhagirathi), Gandak, Kali, Kosi, Tista, Manas, etc. originate on the southern slopes of the Tibetan Highlands. Rivers like Indus, Satluj and Brahmaputra first flowed parallel to the main axis of the moutain in longitudinal troughs, then they take sudden bends towards the south, carving out deep gorges across the mountain ranges to reach the northern plains of India. Such deep gorges created by the Indus, Satluj, Alaknanda, Sarju (Kali), Gandak, Kosi, Tista and Brahmaputra suggest that they are older than the Himalayan mountains, and are antecedent in character.

E. H. Pascoe (1919) and G.E. Pilgrim (1919) attempted to give a tangible explanation to the problem of the Himalayan drainage. According to them, the Tibetan Plateau was drained to the west by the mighty Tsangpo-Indus-Oxus combine with the Tibetan river merging into Oxus Lake before the upheaval of the Himalayas **(Fig. 3.5).** Similarly, another big river called the Indo-Brahma River (Pascoe, 1919) or the Shiwalik River (Pilgrim, 1919) traversed the entire longitudinal extent of the Himalaya from Assam to Punjab from north-east to empty into the Gulf of Sindh, near lower Punjab, during the Miocene Period **(Fig. 3.5).** The former (Tsangpo-Indus-Oxus) was disrupted by the headward erosion of its left hand tributaries, i.e. the Proto-Sind, the Proto-Satluj, the Proto-Brahmaputra, and later was captured by the present lower Irradwady-Chindwin, the lower Brahmaputra, the lower Satluj, and the lower Indus which are the probable remnants of the Shiwalik River.



Capture of Tibetan River Indus at Attock and Brahmaputra at Dihang X_1-X_5: successive captures of Indo-Brahma or Shiwalik Rivers by the rivers of Punjab.

Fig. 3.5 Evolution of Himalayan Drainage

Later the mighty Shiwalik river was dismembered into three main systems: (i) the Indus and its tributaries in the western part, (ii) the Ganga and its Himalayan tributaries in the central part, and (iii) the Brahmaputra in Assam and its Himalayan tributaries in the eastern part (**Fig. 3.5**). The dismemberment is attributed to the Pleistocene upheaval in the Western Himalayas including the uplift of the Potwar Plateau (the Delhi Ridge) which acted as a water divide between the Indus and the Ganga systems. Similarly, the down thrusting of the Malda-Gap area between Rajmahal Hills and the Meghalaya Plateau during the mid-Pleistocence period (about 5 lakh years ago) caused the Ganga and the Brahmaputra systems to flow towards the Bay of Bengal. These developments brought a reversal in the direction of flow in the middle section of the severed stream, i.e. the Ganga of today, resulting in its taking a southerly course and eventually annexing the Yamuna and its tributaries. Earlier, the Yamuna had a south-westerly course and was a tributary of the Indus. This entire event was completed by the late Pleistocene period leading to the evolution of the present drainage systems of northern India.

Pascoe's and Pilgrim's concepts about the origin of the Himalayan drainage systems have been criticised on the following grounds:

(i) It is not necessary to postulate a stream of the size of Shiwalik River flowing all along the longitudinal extent of the Himalayas to explain the occurrence of the Shiwalik alluvial deposits and the boulder beds. They might represent a succession of alluvial fans deposited by rivers descending from the Himalayas, which have coalesced over time. Leading geologists, M.S. Krishnan and N.K.N. Iyangar (1940) found it difficult to accept the existence of such a mighty river on geological as well as physiographic grounds.

(ii) The evidence furnished by the depositional history of the Ganga Delta does not fit well with the theory. In fact, the alluvium should have been laid down over a much longer period of time than that suggested in the concept.

(iii) The evidence of the Tipam sandstones of Assam, which were deposited in an estuary situated too close to the source of the Indo-Brahma River, also cast doubts over the acceptance of the theory.

Professor Enayat Ahmad (1965–71) has given his own interpretation of evolution of the Himalayan drainage. He opined that the Tethys remained as a basin of sedimentation from the Cambrian to the Eocene Periods, but the major portion of the Himalayan region was occupied by Gondwana Landmass. During the Himalayan upheaval in the Oligocene period, part of the Tethysian geosyncline and probably, part of the Gondwana Land, were uplifted. Most probably, this marked the initiation of the Himalayan drainage. The Tethys Sea was raised into a landmass with a median mass of the high Tibetan Plateau in the centre and the two bordering ranges namely, the Kun-Lun in the north and the Himadari in the south. The drainage started from the southern edge of the median mass and flowed south towards the foredeep. As the formation of east-west ranges created east-west valleys, the rivers partly flowed along these valleys. This is indicated by the upper course of several rivers such as the Indus, the Shyok, the Satluj, the Ganga, the Brahmaputra, the Arun (Kosi), etc. Since the whole of the Tethys was not fully raised to become land surface, there existed patches of sea along the margins and drainage lines were not fully defined.

The second Himalayan upheaval during the mid-Miocene period increased the altitude of the medium mass and the bordering ranges. The remnant sea was raised to form the landmass. The rise in land resulted in greater and more invigorated drainage. Alongwith these changes, the region to the south of the first Himalayan range was raised as the Lesser Himalayan range. Earlier, streams on the southern margin of the Tibetan Plateau cut down deep valleys to maintain their courses. Along the southern slopes of the Lesser Himalayas, a number of consequent streams also merged which drained into the southern foredeep.

The third Himalayan upheaval during the Pleistocene perioid resulted into the folding of the Shiwalik foredeep into hill ranges. Also, the height of earlier ranges and the Tibetan Plateau were raised. The rise in the Tibetan Plateau blocked the streams that had gone northward into the Tibetan Sea. These streams were diverted east and west, which probably led to the formation of the Trans-Himalayan master stream. This master stream was broken into two (the Proto-Indus and the Proto-Brahmaputra) by the formation of the Kailash Range. The uplift of the Shiwalik range gave rise to the last set of consequents, originating on the crest of the range, into older streams.

THE MULTIPLE RIVER THEORY

An alternative explanation regarding the evolution of the Himalayan drainage has been offered by the Multiple River Theory. The protagonists of this theory find it difficult to accept the existence of a large river like the Indo-Brahma or Shiwalik on geological and physiographic grounds.

This theory postulates that the Eocene Sea (Tethys Sea) extended from Sindh (Pakistan), Rajasthan, Jammu, and Punjab to Lansdown and Nainital (Uttarakhand). The existence of such a sea is evidenced by the presence of shallow water facies indicative of coast near Lansdown (Garhwal, Uttarakhand). This limit also coincides with the eastern continuation of one of the ridges of the Aravalli Ranges which presumably acted as a barrier. At the same time, another ridge extended from the Rajmahal Hills to the Meghalaya or Shillong Plateau (Rajmahal-Garo Gap) which is now occupied by the Ganga Brahmaputra basin. The sea was broken by the first upheaval of the Himalayas to form an isolated basin in which sediments were deposited. In the next upheaval, a pronounced foredeep all along the southern border of the Himalayas was formed. This foredeep contained numerous lagoons into which flowed streams from the Peninsular area and the newly uplifted Himalayas. These streams brought down sediments which later came to be known as the Shiwalik deposits. The outlet of this foredeep was through the Rajmahal-Garo-Gap in the Bay of Bengal in the east and the Arabian Sea in the west. Later on, the lagoons got dried up and numerous transverse streams flowing from the Himalayan region formed what is now known the Himalayan drainage.

RIVER SYSTEMS OF THE HIMALAYAN DRAINAGE

The rivers originating from the Himalayan and Trans-Himalayan regions consist of three river systems, namely: (i) the Indus System, (ii) the Ganga System, and (iii) the Brahmaputra System (**Fig. 3.6**).

1. The Indus (Sindhu)

The Indus is one of the most important drainage systems of the subcontinent of India. It has a length of 2880 km, of which 709 km lies in India. The catchment area of the Indus is about 1,165,000 sq km, out of which about 321,284 sq km is in India.

The Indus is the westernmost river system in the Subcontinent. Jhelum, Chenab, Ravi, Beas, and Satluj are its main tributaries. The Indus originates from the Bokhar Chu (glacier) in northern slopes of Mt. Kailash (6714 m). It drains the largest number of glaciers and mountain slopes of the Karakoram,

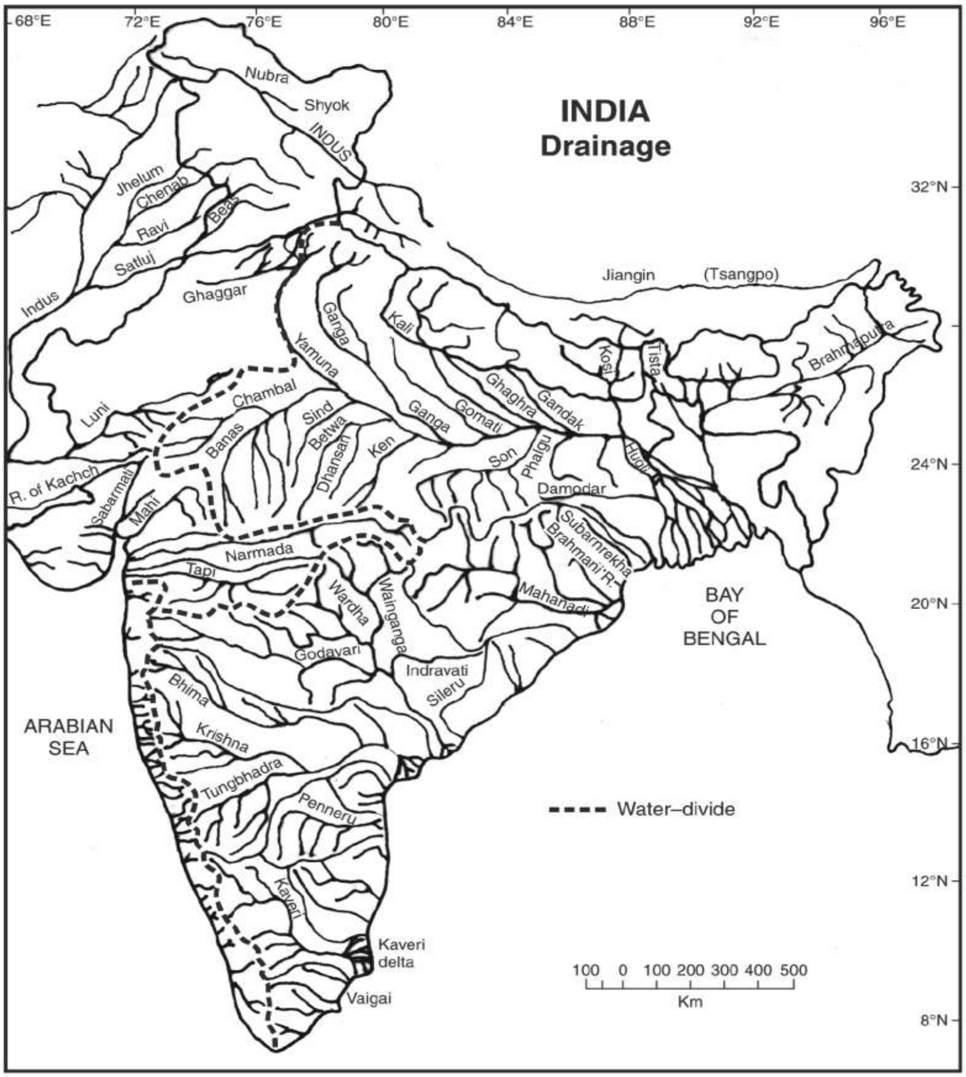


Fig. 3.6 River Systems of India

Ladakh, Zaskar, and Himalayan Ranges. Originating from the Kailash Mountain, it flows in a constricted valley north-westwards through Tibet (China), where it is called as Singi Khamban or Lion's mouth. In Ladakh, it follows a long, nearly straight course between the Ladakh Range and the Zaskar Range. In the first 480 kilometres, it flows along the northern flank of the Zaskar Range over a flat country at heights over 3200 metres where it receives river Zaskar below Leh. Suru and Dras are the other left bank tributaries which join the Indus near Kargil. Moving north-westward, the Indus is joined by the Shyok-Nubra tributaries. These tributaries arise from the Siachin Glacier (Karakoram Range). At Skardu, at a little distance below the Shyok, the Shigar river, which drains the northern slopes of

Mt. K^2, meets river Indus. In this region, River Indus is more wide than in Ladakh. The transverse glaciers and landslides periodically dam the river. The Gilgit is another important tributary which comes from the west to join Indus. Downwards, the Indus crosses the Central Himalayan Range through a huge synclinal gorge. The Indus makes saveral deep gorges. The deepest of all is at Gilgit, which is 5200 m in height above the level of the water at its bed. The river passes by the Nanga-Parbat and turns south-west to enter Pakistan.

The Jhelum (Vitasta)

The Jhelum rises from a spring at **Verinag** in the south-eastern part of the Vale of Kashmir. It flows north-westward for about 110 kilometres where it enters the Wular Lake. Further downstream from Baramula, it enters a gorge, 2130 metres deep, and moves towards Muzaffarabad (Pakistan). It joins the Chenab at Trimmu. Its gradient is gentle in the entire Vale of Kashmir and it is thus navigable between Anantnag and Baramulla. It is the most important river of Kashmir.

The Chenab (Asikni)

It flows in India for about 1180 km draining 26,755 sq km of area in India. The river Chenab is known as Chandra-Bhaga in Himachal Pradesh. The Chandra and Bhaga, the two main upper tributaries of the river, originate on either side of the Bara-Lacha Pass (4843 metres) in the Lahul District of Himachal Pradesh. Of these streams, Chandra originates from the glacier, while the Bhaga is precipitous downward, they make a confluence at Tandi. After uniting, the Chenab flows between the Pir-Panjal and the Greater Himalayas. Near Kishtwar, it makes a hair pin bend and flows across the Pir-Panjal at Riasi to enter into Pakistan. The important hydel projects installed across the Chenab are Salal, Baghliar and Dulhasti. The construction of the Baghliar Project in Doda District, financed by the World Bank, has been approved in Feb. 2007. The total dam height of the Baghliar Project will be 144.5 m. This project will cost Rs. 4500 crore and will produce 450 MW of power. The much delayed project (delayed by 15 years) promises to bring enough power to the state of Jammu and Kashmir.

The Ravi (Parushni or Iravati)

It flows for about 725 km and drains 5957 sq km area in India.The Ravi rises near the Rohtang Pass in Kullu, very close to the source of the Beas river. It drains the western slope of Pir-Panjal and the northern slope of Dhauladhar Range. Below the Chamba Town, it turns to the south-west, cuts a gorge in Dhaula Dhar Range and enters the plain of Punjab. In Punjab plains, it runs along the Indo-Pak boundary, along Gurdaspur and Amritsar districts, before entering into Pakistan.

The Beas (Vipasa or Argikiya)

The river Beas has its source at Beas Kund near the southern face of the Rohtang Pass in Kullu (4000 m), where it runs for a few kilometers and then cuts through the Dhauladhar Range in a deep gorge near Koti and Larji. Then it flows from north to south along Manali and Kullu towns, where the river has a transverse valley popularly known as Kullu Valley. Further down, it flows through Kangra Valley and then turns to the west to enter the Punjab Plain. It finally passes through Kapurthala and Amritsar and joins the Satluj near Harike (within India) after flowing for a total distance of 465 km.

The Satluj (Satadru or Satudri)

The Satluj river rises from the Rakas Lake (Rakas-Tal) which is situated at an altitutude of about 4600 metres near the Mansarovar Lake in Tibet (China). This is an antecedent river, called Langechen Khambab in Tibet. It makes gorges through the Zaskar and the Greater Himalayan Ranges. At the pass of Shipki La (4300 m), it enters Himachal Pradesh where it cuts through the Zaskar Range. From here the river flows westward and passes Kalpa, and then crosses Dhaula Dhar Range near Rampur through a narrow gorge. It passes through the Shiwalik, and at the gorge near Bhakra village, the Bhakra Dam has been constructed across the river. Below the Bhakra Dam, the river comes to the Punjab Plain at Rupar. From Rupar, Satluj River flows westward, and at Harike in the southwest corner of Kapurthala, it meets the Beas. After the confluence, the combined river enters Pakistan. In India, the length of its course is 1050 km, draining an area of about 28,090 sq km.

Ghaggar (the legendary Saraswati)

This is an inland drainage which rises in the talus fan of the Shiwaliks of Sirmur near Ambala (Haryana). After entering the plains, it disappears, but reappears at Karnal District (**Fig. 3.8**). Further on, the stream is called Hakra which gets lost near Hanumangarh in Bikaner. The considerably large size of this river bed, 5 to 8 kilometres wide, with the loamy soil in the river bed, led to the belief that in old times the Satluj flowed south through this Ghaggar-Harka river instead of flowing southwestward (in the form of a much bigger river known as river Saraswati in Vedic literature, probably 5000 BC or earlier). This river is traced further on as Eastern Nara which is, at present, an old channel of the Indus in Sind (Pakistan), and flows into the Rann of Kachch which was described as a ***deep fairly gulf*** at that time. At present, the entire area is practically a desert, and the Ghaggar-Hakra are practically ephemeral streams coming into flow only during the season of general rains.

2. The Ganga Basin (length 2510 km; area 861,404 sq km)

The Ganga basin is the largest river basin in India. It drains about one-fourth of the total area of the country. It is an international river as it passes through Bangladesh before merging into the Bay of Bengal (**Fig. 3.7**).

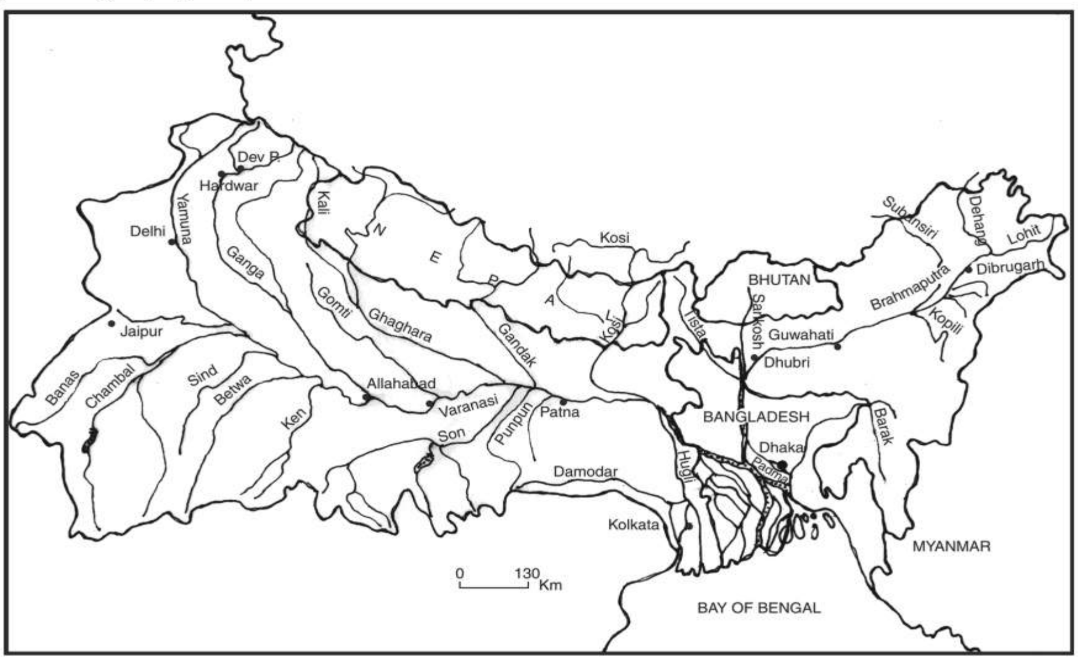


Fig. 3.7 Ganga–Brahmaputra Basins

The Ganga is the most important river of India. In the opinion of Nehru, "From her source to the sea, from old times to new, the Ganga is the story of India's Civilisation." In fact, the Ganga is virtually synonymous with Indian Civilisation. Beyond water's material uses, which are critical to life and development, Ganga water is associated with fertility, purity, and spiritual nourishment of the people.

The Ganga rises from the Gomukh Glacier (about 7000 m) near Mana Pass in Uttar Kashi District of Uttarakhand. This river is known as Bhagirathi, which cuts through the Greater Himalayas and the Lesser Himalayas in narrow gorges. At Devprayag, the Bhagirathi river meets Alaknanda river which has its source (7800 m) in the Satopanth Glacier to the north of Badrinath near Niti Pass. After the confluence of the Bhagirathi and Alaknanda at Devprayag, the river is called Ganga. Passing by Rishikesh, the Ganga debouches into the plains at Hardwar. From Hardwar, it turns towards the south-east upto Mirzapur in the Upper Gangetic Plains, and further down eastwards, in Bihar in the Middle Gangetic Plains. Near the Rajmahal Hills, it turns to the southeast below Farakka Barrage in Malda District of West Bengal. After the barrage, the river splits into two branches

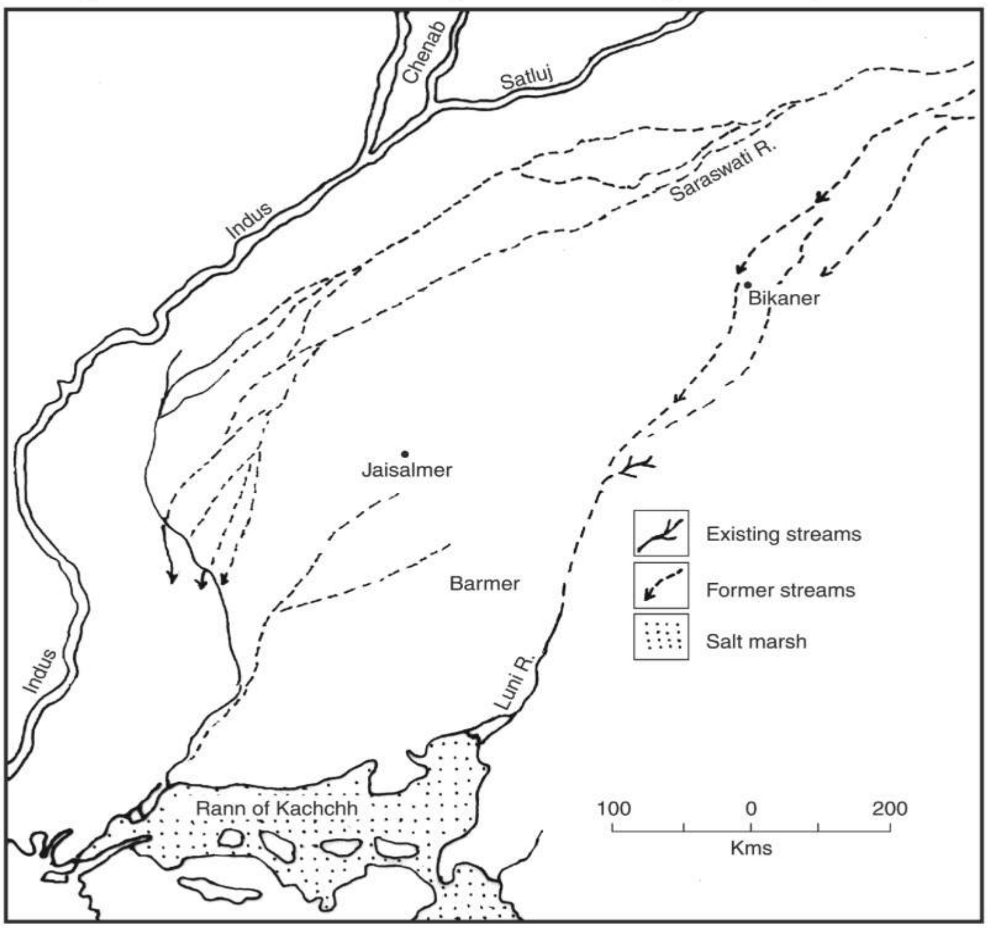


Fig. 3.8 Ghaggar

namely, the Bhagirathi-Hugli and the Padma. The Hugli flows through Kolkata, while the Padma enters Bangladesh. At present, the Hugli is the westernmost distributary in the Bengal delta. The Hugli is a tidal river on which the Kolkata port is situated. Further 121 km downstream, the Hugli river merges into the Bay of Bengal. The Bengal delta is the result of the filling-up of geological sag formed between the Rajmahal Hills and the Chotanagpur Plateau on the west, and the Plateau of Meghalaya in the east. This delta, known as the Sundarban Delta, stretches in West Bengal and Bangladesh. The Sundarban Delta is the result of the depositional action of the Ganga-Brahmaputra and the Meghna rivers.

This most important and sacred river of India is highly polluted and dying. Pollution, over-extraction of water, emaciated tributaries and climatic changes are killing the mighty river, on whose fertile plains live one in twelve people of the earth. The Ganga basin makes up almost a third of India's land area and its rich soil is home to millions of people.

However, indiscriminate extraction of water with modern tube-wells from the rivers as well as its basin, coupled with the damming of its tributaries for irrigation, have seriously reduced its flow. Climatic change has added to the threat. According to the WWF Programme Director, Sejal Worah: "Glaciers account for 30 to 40 per cent of water in the Ganga and this goes up to 70–80 per cent in the case of Indus. Studies are required to gauge the impact of melting glaciers on the flow."

Apart from humans, many other kinds of lives are in danger due to Ganga's degeneration. The river is home to more than 140 fish species, 90 amphibian species, and the endangered Ganga river dolphin. The Ganga is, of course, sacred to the people of India, besides having spawned many great cities on its banks. The maintenance of this sacred river is imperative from socio-cultural and ecological point of view.

The Yamuna River (length 1380 km.)

This is the longest and the western-most tributary of the Ganga. Its source lies in the Yamunotri Glacier on the western slopes of Banderpunch (6316 m). Downwards, it is joined by Tons river behind the Mussoorie Range (Uttarakhand). From the Mussoorie Range, it debouches into the plains where it flows in a broad curve. Making a boundary between Haryana and Uttar Pradesh, it passes Delhi, Mathura, Agra and flows southward until it joins the Ganga at Allahabad. The important tributaries of the Yamuna are mostly the right bank tributaries, originating from the Aravallis (Rajasthan), Vindhyan Range, and the Malwa Plateau of Madhya Pradesh. The Chambal, Sind, Betwa, Ken and Tons are the main righthand tributaries of the Yamuna River.

It is believed that during the Vedic period, the River Yamuna might have flowed towards south and southwest through Bikaner in Rajasthan, and shared its water with the legendary River Saraswati.

The Chambal (length 960 km)

The Chambal River rises near Mhow Cantt.—south-west of Indore in Malwa Plateau from the Vindhyan Range—and flows towards the north in a gorge upto the city of Kota. Below Kota, it turns to the north-east, and after passing Bundi, Sawai-Madhopur and Dholpur, it finally joins the Yamuna about 40 km to the west of Etawah. The Banas River, rising from the Aravalli Range is its main left bank tributary. Kali Sind and Parbati originating from the Malwa Plateau are the right bank tributaries of Chambal. The Chambal River is famous for its extensive ravines which it has carved all along in the Lower Chambal Valley. The ravines of the Chambal Basin are attributed to a slight uplift during the recent geological times, and they merge into the Yamuna alluvial plain where the landscape is extensively etched out by other tributaries of the Yamuna to the east and west of Chambal. Multipurpose projects have been constructed across the river. The main dams across the river are Gandhi Sagar, Rana Pratap Sagar (Rawatbhata) and Jawahar Sagar.

Chambal Ravines

A maze of ravines, valleys and saw-toothed ridges dissect the plateau. These ravines are found in Rajasthan, Madhya Pradesh and Uttar Pradesh in the lower course of the Chambal River. Infested with dacoits, the ravines are being reclaimed for agriculture, pastures, and social forestry.

The Ramganga

This is a comparatively small river which rises in the Kumaun Himalayas. The river is deflected to the south-west by the Shiwalik, which it cuts through, before emerging at the Ganga Plain in Najibabad. It joins the River Ganga in Hardoi district opposite to Kannauj.

The Sharda

This river rises from the Milam Glacier in the Nepal Himalayas where it is known as the Goriganga. It is known by various names, such as the Kali, when it turns along the Indo-Nepal border, and the Chauka, before it joins the right bank of Ghagra near Barabanki.

The Karnali

The Karnali is known as Kauriala in the Nepal Himalayas and as Ghagra in the Ganga Plain. The Karnali is an antecedent river originating from the Gurla Mandhata Peak (7720 m) of the Nepal Himalayas. Before making a gorge in the Greater Himalayas, the Karnali river traverses a 160 km long tract in the Trans-Himalayan region. This river cuts through the Mahabharata Range in the western part of Nepal through a deep gorge. In the Plains, it is joined by the Sharda river and acquires the name Ghagra meaning ***rattling*** or ***lahnga.*** Passing through Ayodhya and Faizabad towns, it joins River Ganga at Chapra near Ballia town. Ghagra is a large river with its vagaries of shifting course.

River Gandak

Draining the Central parts of Nepal, Gandak River rises in the Nepal Himalayas between Dhaulagiri and Mt. Everest. It enters the Great Plains of India in Champaran District of Bihar, and turning south-east, it joins the Ganga River at Sonpur opposite the city of Patna. This river also changes its course frequently.

The Kosi

The Kosi is also an antecedent river. It is often referred to as the '***Sorrow of Bihar***'. Arun is its main stream which originates from the northern slopes of Mt. Everest in Tibet (China). After piercing the Greater Himalayas in Nepal, it is joined by the Sun-Kosi from the west and the Tamur-Kosi from the east. Both these rivers run for a fairly long distance parallel to, and north of, the Mahabharata Range and join River Arun to form the *Sapt-Kosi.* This river cuts across the Mahabharata Range and the Shiwalik Hills, and emerges into the Bihar Plains near Chatra in Saharsa District. In Bihar Plains, it splits into numerous capricious channels. It is known that about 200 years ago, the Kosi used to flow by the side of Purnea town, but now by its westward migration it is about 160 km to the west of Purnea. In July, 2008, the Kosi River shifted its course towards east by more than 100 km. The devastating flood was declared as a national calamity. The Kosi river joins the Ganga River 30 km west of Manihari. It has however, been tamed since 1962 by the construction of embankments on its two banks.

The Tista

This is the westernmost right bank tributary of the Brahmaputra. Rising from Kanchenjunga, it is a wild mountain torrent in the Darjeeling Hills with a number of tributaries like the Rangpo, Rangit, and Sevak. Situated on its bank, the Jalpaiguri town, was completely swept away in the flood of 1968. At present, river Tista joins the Brahmaputra river in Bangladesh. It shifted its course substantially in the flash flood of 1787, prior to which it used to make a confluence with the Ganga.

The Mahananda River

This river rises in the Darjeeling Hills of West Bengal. Near Siliguri, it merges into the ***duars*** (Bhabhar) of West Bengal. Making sharp curves, it joins the Ganga river. This is the last north bank tributary of the Ganga.

Ken-River

Originating for the Malwa Plateau, Ken passes through Panna District (M.P), where it makes a gorge at Gangau. It joins the Yamuna river in Banda District of U.P. Sonar and Beawar are its main tributaries.

The Son (length 780 km, basin: 54,000 sq km)

This is a large south bank tributary of the Ganga River. It originates from the Amarkantak Plateau not far from the source of Narmada. It leaves the plateau in a series of waterfalls and meets the Kaimur Range which turns its course towards the north-east and allows it to follow a strike valley. Below Garwa, it enters the Ganga Plain, where it widens upto about 5 kilometres, and finally flows into the Ganga at Bankipora near Aara to the west of Patna. During the rainy season, the river often flows in spate with an annual peak discharge of about 750,000 cusecs in the rainy season, while in the dry season it has little water.

The Damodar River

The Damodar drains the eastern parts of the Chotanagpur Plateau. This river runs from west to east and, in the narrow bottleneck at Asansol, it emerges on the deltaic plains of Bengal. Barakar is the largest feeder of the Damodar river which meets the main river above Asansol. Below Bardhaman (Burdwan), the river makes a right-angled bend and meets the Hughli river at Falta to the north of Kolkata.

3. The Brahmaputra River

Originating from the glaciers lying to the east of the Mansarovar Lake, at an elevation of 5150 m, the Brahmaputra is known as the Tsangpo in Tibet. It pierces the Greater Himalayas (7755 m) near Namcha Barwa. It passes the Dihang-Gorge in Arunachal Pradesh. At Sadiya, the river comes down to 135 m above sea level.

In India, the river is known as Brahmaputra. The river flows to the west in Assam upto Dhubri (28 m), and further below, it takes a sharp southward bend to enter into Bangladesh.

The catchment area of the Brahmaputra receives heavy rainfall. Consequently, it has numerous tributaries on both of its banks in the 750 kilometre long Assam Valley. Most of the tributaries are large and pour large quantity of water and sediment into the Brahmaputra River. During the rainy season, the river oscillates from one bank to other for a width of 10 kilometres (on an average), and being turbulent with heavy loads of silt, the channel is heavily braided. There is a constant silt movement resulting in the instability of river regime, channel shifting and formation of sandy shoals. *Majuli,* the largest river island in Asia, lies in this river which is bounded by the Lakhimpur District in the north and the Jorhat District in the south. The Brahmaputra river basin is notorious for flooding and river bank erosion. The floods affect on average, an area of 100,000 hectares annually. The peak annual discharge at Pandu, near Guwahati, is more than 2.5 million cusecs (650,000 cumecs), while the low discharge is 120,000 cusecs (4210 cumecs). Below Pasighat, the river draws a number of tributaries such as Subansiri, Bhareli, Manas, Sankos, Tista and Raidak on its right bank, while the Dihang, Lohit, and Burhi Dihang are from the east, and Dhansiri, Kalang and Kapili are the left bank tributaries of the Brahmaputra.

Rangit River

Originating from Sikkim, Rangit river has a large number of rapids. This river is well known all over the world for rafting sports. Its banks provide good camping grounds.

The Sankosh

This is the main river of Bhutan. It meets Brahmaputra River below Dhubri.

The Manas

It is an antecedent river. Rising from Tibet, it pierces the Greater Himalayas in a gorge with river bed at 3000 metres. It collects a number of tributaries in the Lesser Himalayas and debouches into the plains to join the river Brahmaputra.

The Subansiri

This is a large tributary of the Brahmaputra River. It has a long course in the Himalayas and, after leaving the mountains, it has a long 160 km course in the Upper Assam Plain before joining the Brahmaputra. It separates the Miri Hills from the Abor Hills.

The Dhansiri

This river rises from the Naga Hills and after flowing for about 300 km through Nagaon, it joins the Brahmaputra River.

The Manipur River

It rises from the northern part of Manipur and flows southwards. On passing through Imphal, this river drains the Loktak Lake and joins the Chindwin Valley, a tributary of the River Irrawaddy in Myanmar (Burma).

Kaldan River

This river drains the southern parts of Manipur and Mizoram where it flows southward to the Bay of Bengal.

Barak River

This river rises from Mt. Japov (Nagaland), flows southwards in Manipur and makes a hair pin bend. Several of its affluents, which drain the northern part of Mizoram, combine together to flow past Silchar in the Cachar District. The Barak basin has Mawsynram and Cherrapunji which receive the highest rainfall in the world. Consequently, the Barak river discharges heavy quantity of water. It flows to Bangladesh where it is called as Surma. The Barak river meets the Padma at Chandpur below Dacca, after which the combined river of Surma (Barak) and Padma is known as Meghna.

MAIN RIVERS OF PENINSULAR INDIA

The main rivers of peninsular India have been described in the following section and shown in **Fig. 3.9**.

Luni River

The Luni River rises near Ajmer in the Aravalli Range and receives a few streams like the Bandi, Sukri and the Jawai only on its left bank. The streams which drain the western flank of the Aravalli Range south of Ajmer are seasonal. The Luni turns brackish below Balotra and loses itself southwestwards into the Rann of Kachchh.

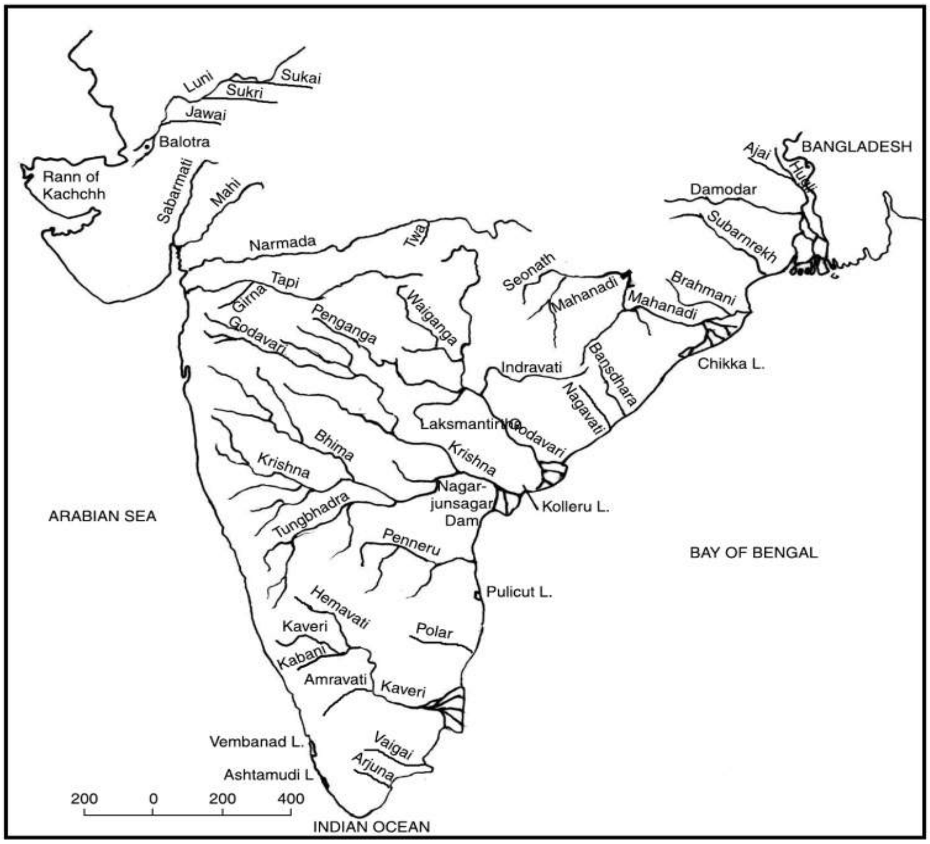


Fig. 3.9 Major Rivers of Peninsular India

Sabarmati

This river drains the southern slope of the Aravalli Range. It has a narrow long basin with an area of 21,700 sq km. Sabarmati receives its tributaries on its eastern flank and follows a nealy north-south course before merging into the Gulf of Khambat.

Mahi

The Mahi has its source in the Vindyan Hills of Madhya Pradesh. It flows southwest through the Banswara and Anand districts and finally, making an estuary, merges into the Gulf of Khambat.

Most of the rivers draining the west-facing scarp of the Western Ghats, particularly in the Konkan coastal belt, are short and swift-flowing over a humid tropical landscape at 100 to 280 metres above sea level along narrow to broad V-shaped valleys. These small streams have great erosive capacity. They display a parallel pattern of drainage, characterised by sharp bends, and fall into the Arabian Sea through estuaries. Some of the important streams draining the western slopes of the Western Ghats are Ulhas, Savitri, Vashist, Netravati, Periyar and Pambiyar. Some of these streams make waterfalls and rapids when they descend their steep gorges.

Sharavati

Sharavati rises in Shimoga district in Karnataka and creates the Garsopa Falls, the most spectacular waterfalls in India, commonly known as Jog Falls (271 m). The only break in the unbroken watershed of the Western Ghats face is the 13 km wide Palakkad Gap also known as Pal-Ghat. The river Ponnani flowing westward through this gap appears to be a misfit river.

Narmada (length 1300 km, drainage basin 98,800 sq km)

The Narmada River rises from the plateau of Amarkantak of the Maikal Hills of Chhattisgarh. Moving north-westward, it passes through a complex course near Jabalpur, through some impressive marble gorges, the most spectular being Dhunwadhar Waterfalls (10m high) near Jabalpur. Moving westward from Jabalpur, it flows through a rift valley between the Vindhyan and the Satpura ranges. It has rich alluvial deposits in its valley. Finally, it widens below Bharuch and makes a 27 km wide estuary to enter the Gulf of Khambat (Arabian Sea).

Tapi

Having a length of 700 km and a basin area of 66,900 sq km, the river Tapi rises from the Satpura Range and flows westward almost parallel to Satpura. At Khandwa-Burhanpur Gap, the Narmada and Tapi come close to each other. Below Jalgaon , the river, like the Narmada, flows in a rift valley but in a much constricted form between the Satpura Range to the north and the Ajanta Range to the south. Below the city of Surat, it makes an estuary and merges into the Gulf of Khambat.

EASTERLY RIVERS OF THE PENINSULAR REGION

There are a number of rivers originating from the Chotanagpur Plateau and merging into the Bay of Bengal, of which the Brahmani is the most important.

Subernrekha (length 400 km, basin 28,000 sq km)

The Subernrekha rises a little to the southwest of Ranchi where it has a number of waterfalls. In a general easterly direction, it passes through Jamshedpur and flows to the Bay of Bengal near Balasore. Its drainage basin is shared by the states of Jharkhand, Odisha and West Bengal.

The Brahmani (length 420 km)

The Brahmani river is formed by the confluence of the Koel and Sankh rivers. They join together at Rourkela and drain the western parts of the Garhjat Hills. Flowing through Bonai, Talcher and

Balsore districts, it merges into the Bay of Bengal above the Paradwip-port. With the Baitarani river to its north, a delta complex forms below Bhadrak.

The Mahanadi (length 885 km, basin 141,600 sq km)

The Mahanadi is the most important river of Odisha as well as that of Chhattisgarh. This river rises in the Chhattisgarh basin, draining the western and eastern parts of Raipur. In the initial stage, it flows towards the north-east, and after receiving a number of streams such as Seonath and Sandur on both its flanks at heights between 200 m and 700 m, the combined water gets a natural exit towards the east through a gorge which has been impounded to create the Hirakud Dam. A little below the dam at Sambalpur, the river turns eastward and flows through the Eastern Ghats entering the Bay of Bengal through several distributaries in its delta. Cuttack city is located at the apex of the Mahanadi delta.

The Godavari (length 1465 km, basin 312,800 sq km)

Godavari is the largest river of peninsular India. It rises in the Western Ghats from a spring below Nasik, drains eastern and southeastern Maharashtra, Bastar plateau (Chhattisgarh), and Telengana and Andhra regions of Andhra Pradesh. It receives a large number of tributaries, particularly on its left bank, such as Purna, Maner, Penganga, Pranhita (the combined Wardha and Wainganga), Indravati, Tal and Sabri. The Manjira is the only important right bank tributary. The Indravati and Sabri are the two streams which rise on the western slopes of the Eastern Ghats, but they flow east and southeastwards respectively. Below the confluence with Indravati, it flows in a picturesque gorge through the Eastern Ghats. Below Rajamundry, it has constructed a large symmetrical delta and reaches the Bay of Bengal by its three main ditributaries. The delta of Godavari is characterised by a number of palaeo-channels and mangroves associated with lagoons. The Kolleru Lake, lying to the southeast of Kakinada, is one such inland lagoon.

The Krishna (length 1290 km, basin 259,000 sq km)

The river of Krishna has its origin near Mahabaleshwar in the vertical faces of the Western Ghats. A number of minor streams like Koyna and Ghataparbha join the Krishna river to give a subdendritic pattern. The Bhima in the north and the Tungbhadra in the south are the other important tributaries of the Krishna river. Downwards passing through the quartzite scarps, the Krishna has been dammed to form the Nagarjun-Sagar Reservoir. Further east, beyond the gorge in the Srisailam Hills below Vijaiwada, it has built its fertile bird-foot delta (Mississippi-type).

The Pennar

The Pennar river rises in the Kolar District of the South Mysore Plateau. Its main tributaries are Chitravati and Papaghni. It flows through a gorge of Cuddapah quartzite and enters the Bay of Bengal in the form of an estuary.

The Kaveri (length 765 km, basin 87,900 sq km)

The Kaveri is a sacred river like the Ganga. Hence, it is called the Ganga of South India. It rises from the southern part of Mysore Plateau as a rocky mountain stream forming rapids, cataracts and waterfalls. Its drainage basin receives rainfall during the summer monsoon as well as during the retreating and winter monsoon. Only 20 km above Mysore, it has been dammed to form the

Krishnasagar Reservoir. It passes through the islands of Srinagapatnam and Sivasamudram. The channel around the Sivasamudram makes a succession of rapids which were harnessed to develop hydel-power in 1902. Below the island, Kaveri River plunges through a succession of beautiful gorges with hair pin bends. This scenic landscape, known as the Hagenakal Fall, may be taken as the end of the plateau course of the river. There is however, another narrow gorge in the Nilgiri Hills to the east of Dodabetta Peak (2636 m) which is drained by the Bhavani and its tributary, the Moyar, which provides the site for the Mettur Dam. Draining the Coimbatore basin, the Kaveri enters the plains after its confluence with the Bhavani. A few kilometers above Tiruchirappalli, the river fans out forming a quadrant-delta in Thajavur District of Tamil Nadu.

Amravathi River

Amravathi river is a tributary of the Kaveri river in Coimbatore District of Tamil Nadu. Having its origin at the Kerala-Tamil Nadu border, it is 175 km in length. It joins with the Kaveri in Karur District. It irrigates over 60,000 acres of land in Coimbatore. Due to the heavy industrialisation in its basin, the river is highly polluted.

The Tambraparni

This is a river of Tiruneveli District. It rises on the slopes of the Palni Hills of the Western Ghats and passes Madurai to flow into the Gulf of Mannar through the Ramanathapuram Peninsula.

RIVER REGIMES

The pattern of the seasonal flow of water in a river is called its regime. The main difference in the flow pattern of the Himalayan and the Peninsular rivers is caused by the differences in climate. The Himalayan rivers are perennial and their regimes are dependent on the pattern of water supply both from snow-melt and rainfall. Their regimes are monsoonal as well as glacial. The regime of most of the peninsular rivers, on the other hand, are only monsoonal as they are controlled by rainfall alone. Even regimes of different peninsular rivers are not the same because of the differences in the seasonal distribution of rainfall in various parts of the plateau **(Fig. 3.10)**

The discharge is the volume of water flowing in a river measured over time. It is measured either in cusecs (cubic feet per second) or cumecs (cubic metres per second). The Ganga has its minimum flow during the period of January to June. The maximum flow of water in the Ganga occurs either in July or August. After September, there is a steady fall in the flow of Ganga. The river thus has a typical monsoonal regime. There are striking differences in the river regimes in the eastern and western parts of the Ganga basin. The Ganga maintains a sizable flow in the early parts of summer before the monsoon rains begin. This is largely due to the water supply from the Himalayan snow-melt. The discharge data, however, do not include the volume of water diverted for irrigational purposes at different points before the Farakka Barrage (Malda, West Bengal). The mean maximum discharge of the Ganga at Farakka is about 55,000 cusecs, while the mean minimum is only 1300 cusecs.

The two peninsular rivers display an interesting difference in their regime as compared to the Himalayan rivers. The Narmada has a very low volume of discharge from January to July. It suddenly rises in August when the maximum discharge is attained. The fall in October is as spectacular as the rise in August. The Godavari flows at a low level until May. It has the minimum discharge in

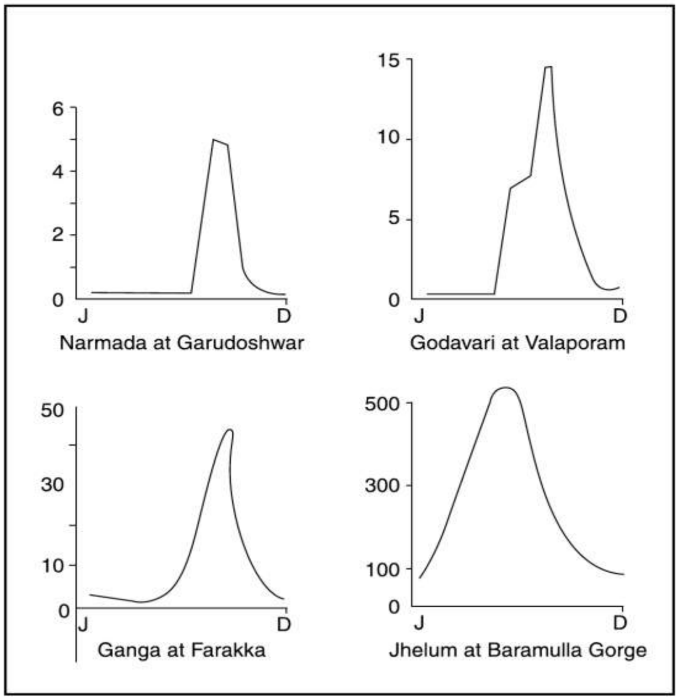


Fig. 3.10 River Regimes

May and the maximum in July–August. After August there is a sharp fall in water flow, although the volume of flow in October and November is higher than that in any of the months from January to May. The mean maximum discharge of Godavari at Valaporam is 3200 cusecs. These figures give an idea of the regime of the river. The flow of water in the Narmada, as recorded at Gurudeshwar, shows that the maximum flow is of the order of 2300 cusecs, while minimum flow is only 15 cusecs.

The data on water discharge in different rivers in different parts of the year have important implications to their utilization by states. It is on this count that inter-state disputes arise.

Table 3.2 *Major Rivers of Peninsular India*

River	*Source*	*Length in km*	*Main tributaries*
1. Godavari	Trimbak Plateau Near Nasik (Maharashtra)	1465	Manjra, Penganga, Wardha Wainganga, Indravati, Sabari, Pranhita
2. Krishna	Near Mahabaleshwar (Maharashtra)	1400	Koyna, Ghataprabha, Malprabha, Bhima, Tungbhadra, Musi, Muneru
3. Narmada	Amarkantak	1310	Hiran, Orsang, Barna, Kolar, Burhnar, Tawa, Kundi

(*Contd.*)

(*Contd.*)

4. Mahanadi	Dandakaranya Plateau near Raipur	857	Ib, Mand, Hasdeo, Seonath, Ong, Jonk, Tel
5. Kaveri	Taal Kaveri	800	Herangi, Hemavati, Lokpavni, Shimsa, Arkavati, Kabani,Bhavani, Amravathi
6. Tapi	Multai in Betul Distt. (M.P.)	730	Purna, Betul, Patki, Ganjal, Dhatranj, Bokad, Amravati

Comparison of the Peninsular and the Extra-Peninsular Rivers

Peninsular Rivers	*Extra-Peninsular Rivers*
1. The rivers of Peninsular India are much older. Some of them are as old as the Pre-Cambrian Period.	1. The rivers of the Extra-Peninsular India are much younger, excepting a few antecedent rivers like Indus, Satluj, Ganga, Brahmaputra, etc.
2. They are mostly consequent or rejuvenated rivers.	2. Many of them like Indus, Satluj, Kali, Kosi, Brahmaputra, Tista are inconsequent rivers.
3. These rivers, except Godavari, have relatively small basins.	3. These rivers generally have large basins.
4. The channels of these rivers are broad.	4. The channels of these rivers in the upper courses form gorges waterfalls, and rapids.
5. There is hardly any vertical erosion.	5. Both vertical and lateral erosions are significant.
6. These are slow moving.	6. These are both swift and have sluggish movements.
7. These have low carrying capacity.	7. They transport huge quantities of sediments.
8. These are mainly depositional agents.	8. These are active erosional and depositional agents.
9. They make shallow meanders.	9. In the plains, they make numerous sharp meanders and ox-bow lakes.
10. These are generally not navigable.	10. Most of them are navigable in the plains.
11. These are mostly seasonal.	11. These are perennial.
12. Most of them originate from the Western Ghats and plateaux.	12. Most of them originate from the Himalayan Glaciers.
13. Most of them are in the senile stage.	13. Most of them are in the late youth stage.
14. There is no river capturing.	14. River capturing is a common phenomenon.
15. These rivers have been harnessed for the generation of hydel-power, e.g. Hirakund, Koyna, Nagarjunasagar.	15. There are numerous multipurpose projects on these rivers, e.g. Bhakra, Tehri, Salal, etc.
16. These rivers make deltas (Godavari, Krishna, Kaveri) and estuaries like Narmada and Tapi.	16. These rivers make only deltas. The Sundarban Delta is the largest in the world.
17. Their channels are near the base level.	17. These rivers are in the ending part of youth stage. In their mountainous course they do river capturing.

SHIFTING COURSES OF THE RIVERS

An interesting phenomenon of most of the Extra-Peninsular rivers and that of the Peninsular have shifting courses, especially in their lower reaches. In the upper reaches, the Himalayan rivers have the tendencies of river capturing. River capturing is mainly caused by the headward erosion of the river. In the plain areas, generally, the rivers form meanders in their courses. During floods, due to increased quantity of water, the streams try to straigthen their courses. Earth movements do have their role in affecting these processes. Some of the important river captures are as under:

The ancient Saraswati River, which provided an abode for early Aryan settlers, presents a typical example of shifting courses and river capturing. Descending from the Himalayan ranges, its initial course during the pre-historic period was passing near Churu (about 2000 to 3000 BC), and the Luni river was one of its tributaries. It gradually shifted towards west till it joined the Satluj near Ahmadpur. Later on, the water of its upper course was captured by a tributary of the Ganga River as a result of which its lower course became dry. This gave birth to Yamuna River, an important tributary of the Ganga System. Even today the dry valley of the Saraswati River is found in Rajasthan area in the form of Ghaggar valley. Similar shifting has also been observed in the rivers of the Punjab during the historical past. The records of the third century BC show that the Indus flowed more than 130 km east of its present course, through the now practically dry beds of the deserted channel, to the Rann of Kachchh which was then a gulf of the Arabian Sea. Later on, it gradually shifted towards the west and occupied its present position. During the reign of Akbar the Great, the Chenab and Jhelum rivers joined the Indus near Uch (Pakistan), but their present confluence lies near Mithankot about 100 km downstream of the old place of confluence. Similarly, Multan was formerly located along the Ravi River, but today it is situated about 60 km south of its confluence with the Chenab. About 250 years ago the Beas river changed its old course, traces of which are still found between Montgomery and Multan, and joined the Satluj river near Sultanpur. In the early part of the Christian Era the Satluj had more easterly course and independently discharged its water into the Arabian Sea.

About 250 years ago, the Brahmaputra flowing through Mymensingh was discharging its waters into the Meghna River. In due course of time, it straightened its course and joined the Ganga (Padma) River forming a new stream called Jamuna in Rangpur and Jamalpur districts of Banglasesh. A feeble channel of the Brahmaputra is still flowing along the same old course and retains the old name. This change in the course was associated with 30 m rise in Madhopur forest area between 1720–1830 AD Even the entry of the Brahmaputra to the plains of Assam is also the outcome of the process of river capturing. According to geologists, during early days, the Tsangpo river of Tibet taking an easterly course used to join the Irrawaddy River (Myanmar) through the Chindwin, which was then a large river, transporting huge quantity of water. Later on, a small river flowing along the southern slopes of the Himalayas through its headward erosion captured the water of the Tsangpo River and, thus, helped in the evolution of the stream of Brahmaputra.

Similarly, Kapili, a tributary of the Brahmaputra, has captured the waters of the Meghna river of Bangladesh. In old days, the Meghna originated from the Brail Ranges (between Meghalaya and Manipur) and flowing southward, emptied its waters in the eastern part of the Bay of Bengal. But Kapili, through headward erosion, captured its northern course. The Lumding-Halflong Pass is an evidence of this abandoned valley. In a similar way, the Dhansiri River capturing the water of a tributary, Kapili River has helped in the formation of a new river called Jumuna (Assam).

There can be numerous causes responsible for the shifting of river courses. These include the shifting gentle slope of the Great Plains of India, meandering courses of the rivers, straightening of the river courses during floods, upliftment of the Potwar Plateau (Delhi-Sirhind Plateau), downwarping of the Malda Gap, rise in the Madhopur forest area and uplift of the Barind area.

TYPES OF LAKES

A lake is a natural depression filled with water. In this period of population explosion and scarcity of water, lakes are an important source of water supply to humanity. They also help in the prevention of sudden floods and droughts. The lakes of India have different origins. Some of the important lakes of India have been described briefly in the following section**:**

1. The Tectonic Lakes

These are formed due to the fractures and faults in the earth's crust. Most of the lakes in the hilly areas of Kashmir and Kumaun belong to this type of lakes. The Tso Moriri, and Pangong Tso (Ladakh) are some of the examples of such lakes.

2. The Crater Lakes

Crater lakes are formed when the craters and calderas are filled with water. They are very few in number in India. The Lonar Lake of Buldhana (Maharashtra) is one of the examples of crater lakes.

3. Glacial Lakes (Tarns)

These lakes are the result of glacial erosion. *Tarn* is a small mountain lake, especially one that collects in a cirque basin behind rises of rock material. Most of the glacial lakes in India are small in size. The Gangabal lake of Kashmir, located in the Greater Himalayas of Kashmir, is one such examples. Glacial lakes are also found in Ladakh (J&K), Himachal Pradesh and Kumaun region of Uttarakhand.

4. Fluvial Lakes

Rivers form different types of lakes through their erosional and depositional work. In general, rivers are the destroyers of lakes. In fact, lakes are often obliterated due to filling of sediments and headward erosion by rivers. Fluvially originated lakes are generally temporary and are soon obliterated. Fluviaslly originated lakes include plunge-pool lakes (in front of a waterfall), ox-bow-lakes, alluvial fan lakes, delta lakes, flood plain lakes and raft-dammed lakes. All these lakes may be observed in the upper, middle and lower courses of the Ganga and the Brahmaputra rivers. Lakes formed to the meandering of rivers in the plains of gentle gradient are known as alluvial lakes. The ox-bow lakes found in the Middle and Lower Ganga Plains are some such examples.

5. Aeolian Lakes

These are small temporary hollows or depressions lying on the wind blown sand surface. Western Rajasthan has several lakes of this type. The desert lakes generally have a larger proportion of salt content and are often been called salt lakes. The Dhands of western Rajasthan are some of such examples.

6. Dissolution Lakes

These lakes are formed due to a depression of the surface by underground dissolution of soluble rocks like limestone and gypsum. Such lakes are found in and around Cherrapunji, Shillong (Meghalaya), Bhimtal (Kumaun), and Garhwal (Uttarakhand).

7. Lagoons

These are formed by deposition of sandbars along the sea coast. The Lake Chilka of Odisha; Pulicat (Andhra Pradesh); Vembanad, Asthamudi, and Kayals of Kerala are some of the examples of lagoons.

8. Landslide Lakes

These lakes are produced by landslides and rock-falls causing obstruction in the course of streams. The Gohna Lake of Garhwal was formed due to a huge landslip across a tributary of the Ganga.

MAIN LAKES OF INDIA

Ashtamudi Lake (Astamudi Kayal)

It is a lagoon in the Kollam district of Kerala. Ashtamudi means 'eight branches'. In fact, this is a lake with multiple branches. It has been registered as a wetland of international importance under the Ramsar Convention.

Bhimtal

Situated near the town of Bhimtal in Kumaun Divison of Uttarakhand, it is a fascinating lake with an island in the centre. The Bhimtal town, though ancient, was never prominent because of the greater popularity of Nainital. At present, it attracts a large number of the domestic and international tourists.

Bhoj Wetland

Located in the city of Bhopal (capital of Madhya Pradesh), it consists of two lakes, namely the Upper Lake and the Lower Lake. Being in the vicinity of the capital city, it is one of the highly polluted lakes of India.

Chandra Tal

It is a high altitude lake in Lahaul and Spiti district of Himachal Pradesh. It is about 4300 m above sea level. The Kunzam Pass, which connects Lahaul and Spiti, is only about 6 km from this lake.

Chembarambakkam Lake

It is located in the Chengalpattu district of Tamil Nadu, about 40 km south of Chennai. The Adyar River originates from this lake. A part of the water supply of the Chennai metropolis is drawn from this lake.

Chilka Lake (Chilika Lake)

Situated in the state of Odisha, it is a brackish water coastal lake. It is the largest coastal lake in India. The lake was formed due to the silting action of the Mahanadi River which drains into the northern end of the lake. The area of the lake varies from 1175 sq km in the monsoon season to 900 sq km in the dry season.

Dal Lake

Dal is a famous lake in Srinagar. Stretching over an area of 18 sq km, it is divided by causeways into four basins; namely, Gagribal, Lokut Dal, Bod Dal and Nagin. It is well known for approximately five hundred houseboats. Apart from houseboats, the lake provides a good opportunity to the tourists for canoeing, water-surfing and kayaking. Being highly polluted, the lake is shrinking at a faster pace. The lake has some interesting flora like lotus flowers and water lilies and water-chestnut.

Dhebar Lake (Jaisamand)

Situated in the state of Rajasthan, about 45 km to the east of Udaipur, it is the largest artificial lake of India. It stretches over an area of about 87 sq km. It was built in the 17^{th} century when Rana Jai Singh of Udaipur built a marble dam across the Gomati River. This lake has three islands; the Jaisamand Resort is located on the biggest island.

Himayat Sagar

Located at a distance of 20 km from the city of Hyderabad, it was named after the youngest son of the seventh Nizam, Himayat Ali Khan. It is an artificial lake constructed across the Musi river in 1927.

Hussain Sagar

Hussain Sagar is in the city of Hyderabad. It was built across a tributary of the Musi River by Hussain Shah Wali in 1562. Its water is supplied to the city of Hyderabad.

Kaliveli Lake

It is a coastal lake in the district of Viluppuram in Tamil Nadu. It lies about 10 km to the north of Pondicherry. The lake is one of the largest wetlands in the peninsular India. It is being encroached by agricultural fields. Its area is shrinking fast.

Khajjiar Lake

Located in the Chamba district of Himachal Pradesh, it is only 24 kms from the important hill station of Dalhousie. Surrounded by the giant deodar trees, it presents a panoramic view for the tourists.

Khecheopalri Lake

It lies in West Sikkim. It is considered a holy lake, both by the Buddhists and the Hindus. The lake is surrounded by thick forests of bamboo. The placid waters of the lake are visited by many pilgrims and tourists.

Kolleru Lake

Situated in Andhra Pradesh, it is the largest fresh water lake of India. It is located between the deltas of the Krishna and Godavari rivers in the Krishna and Godavari districts. The lake serves as a natural flood-balancing reservoir for the two rivers. The lake was an important habitat for an estimated 20 million residents and migratory birds Grey or Spot-billed pelicans. Rich in flora and fauna, it attracts birds from Siberia and eastern Europe between the months of October and March.

The lake was notified as a wildlife sanctuary in 1999 under India's Wild Life Protection Act. It was declared a wetland of international importance in 2002 under Ramsar convention. Increasing pollution has reduced the bio-diversity in the lake.

Loktak Lake

It is the largest fresh water lake in north-east India. It is also called the only 'Floating Islands Lake' in the world due to the floating Phundis (floating islands) on it. It was designated a wetland of inter- national importance under Ramsar Convention in 1990. It serves as a source of water for hydro-power generation, irrigation and drinking. The lake is also a source of livelihood for the rural fishermen who live in the surrounding areas and on Phundis (floating islands), which are actually heterogeneous mass of vegetation, soil and organic matter.

Nako Lake

Situated in the district of Kinnaur (Himachal Pradesh), it is a high altitude lake. This lake is surrounded by willow and poplar trees. Near the lake there are four Buddhist temples. It is considered a sacred lake.

Osman Sagar

It is an artificial lake in Hyderabad. It was created by damming the Musi River in 1920 by the last Nizam of Hyderabad (Osman Ali Khan) for providing a drinking water source to Hyderabad. A guest house called 'Sagar Mahal' overlooking the lake, now a heritage building, was the summer resort of the erstwhile Nizam.

Pongong Tso

Situated in Ladakh, this lake lies at a distance of five hours from the city of Leh. The road traverses the third highest pass in the world; the Changla Pass. A special permit is required to visit the lake. For security reasons, no boating is allowed. There is a small hotel and campsite, and houses with primitive guestrooms in the village.

Pulicat Lake

It is the second largest brackish water lake on the Coromandal Coast. It lies on the border of Andhra Pradesh and Tamil Nadu. The barrier island of Sriharikota separates the lake from the Bay of Bengal. The lake is 60 km long and varies 0.5 to 18 km in width. It is the habitat of numerous local and migratory birds. Nearly 15,000 flamingos visit the lake every year, along with pelicans, kingfishers, herons, painted storks, spoonbills and ducks.

Pushkar Lake

Situated in the district of Ajmer, it is an artificial lake. The lake was created in the 12^{th} century when a dam was built across the headwaters of the Luni River. Thousands of pilgrims come to bathe in the waters of the lake during the festival of Kartika Poornima in November.

Renuka Lake

Situated in the Siarmaur District of Himachal Pradesh, this lake has been named after the goddess Renuka. A Lion Safari and a zoo are major attractions at Renuka. It is a site for the annual fair in the month of November.

Roopkund

Situated in Uttarakhand, it is a lake around which 600 skeletons were found at the edge of the lake. The location is uninhabited and is located at an altitude of about 5030 m. The skeletons were discovered in 1942. Radio-carbon dating suggest that these people died in an epidemic.

Sambhar Lake

Situated about 70 km to the west of Jaipur city, it is the largest salt lake of India. On the eastern end, the lake is divided by a 5 km long dam made of stones. To the east of the dam are salt evaporation ponds where salt is being produced for more than a thousand years. The water depth varies from a few cm during the dry season to about 3 m after the monsoon rains. Sambhar has been designated a Ramsar site (recognised wetland) of international importance. Thousands of Siberian birds reach the lake during the winter season.

Sasthamkotta Lake

It is a large fresh water lake in Kerala state. It is located near Sasthamkotta in Kollam District, about 30 km from Kollam. It is a great attraction for the tourists.

Satta or Sat Tal

It is the calm, quiet group of seven lakes near Bhimtal town of the Kumaun Division of Uttarakhand. These lakes are situated at an altitude of 1370 m above mean sea level. These lakes are a paradise for migratory birds.

Suraj Tal

Located below the summit of the Baralacha Pass, it is a high altitude lake, 4980 m above sea level. This lake is the source of the Bhaga River, one of the main branches of the Chenab River.

Tawa Reservoir

Located in Hoshingabad on the River Narmada (M.P.), it was created as a result of the Tawa Dam. It forms the western boundary of Satpura National Park and Bori Wild Life Sanctuary.

Tsongmo Lake

Situated in the state of Sikkim, about 40 km away from Gangtok, it is a glaciated tarn lake. It is oval shaped. Being situated at an altitude of about 3780 m, it remains frozen during the winter season. It is a sacred lake for the Buddhists and the Hindus.

Veeranam Lake

It is located in Cuddalore District of Tamil Nadu, about 235 km from Chennai. It is one of the water reservoirs from where water is supplied to Chennai.

Vembanad Lake (Vembanad Kayal or Vembanad Kol)

Covering an area of about 200 sq km, it is the largest lake in Kerala. The lake lies at sea level, and is separated from the Arabian Sea by a narrow barrier island. Several rivers flow into the lake including the Pamba and Periyar. The lake surrounds the islands of Pallipuram and Perumbalam.

Veeranpuzha Lake

Located in Kochi, it is the northern extension of Vembanad Lake. It attracts a large number of tourists from different parts of the country and abroad.

Vembanattu Lake

About 16 km from Kottayam is a vast network of rivers and canals forming Vembanattu Lake. An enchanting picnic spot and a fast developing back water tourism spot providing boating, fishing and sightseeing experiences that are truly exhilarating. Kumarakom Bird sanctuary is on the banks of Vembanattu Lake.

Wular Lake

Situated in the Valley of Kashmir between Sopore and Bandipore, it is the largest fresh water lake in India. The lake was formed as a result of tectonic activity during the Pleistocene Period. Depending on the season, the size of the lake varies between 30 and 250 kilometres. The River Jhelum feeds the lake, which acts as a natural reservoir. The Tulbul Project is a 'navigation lock-cum-control structure' at the mouth of the Wular lake. It envisages regulated water release from the natural storage in the lake to maintain a minimum draught of 4.5 feet in the river up to Baramulla during the lean winter months.

WATER RESOURCES OF INDIA

Water is a primary natural resource, a basic human need and a precious national asset. Water is critical to our daily lives and a principal compound in nature. A human can survive 50 to 60 days without food, but only 2 or 3 days without water. The water we use must be adequate in quantity as well as quality for its many tasks—everything from personal hygiene to vast national water projects. Water indeed occupies that place between land and sky, mediating energy and shaping both, the lithosphere and atmosphere. The significane of water is increasing with the tremendous increase in population. We need water for drinking, personal hygiene, domestic consumption, irrigation, industrial purposes, generation of hydel-power, transport and recreation.

The average annual water availability of the country is assessed at 1869 billion cubic metres (BCM). Of this, total utilisable water resource is assessed at 1123 BCM; surface water 690 BCM and ground water 433 BCM. The per capita availability of water at the national level has been reduced from about 5177 cubic metres in 1951 to the estimated level of cubic metres in 2012 with variation in water availability in different river basins.

There are two main sources of water, i.e. (i) the surface water, and (ii) the underground water. According to Prof. K.L. Rao (1975), the total quantity of water annually carried by the rivers of the country is about 1,645,000 million cu m. The utilisation of water as estimated by Rao is given in **Table 3.3.**

Table 3.3 *India's Water Utilisation by 2000 (in thousand million cubic metres)*

Sector	*per cent use*	*water used*	*water consumed*	*water reused*
1. Agriculture				
(a) Irrigation	77.0	860	774	86
(b) Livestock	1.0	9	9	—
2. Power	13.0	150	5	145
3. Industries	3.0	35	10	25
4. Municipal/Rural (domestic consumption)	6.0	62	31	31

Source: Rao, K.L. (1975)***: India's Water Wealth.***

It may be noted from Table 3.3 that about 77 per cent of the available water is used for irrigation purposes, 13 per cent for power generation, 3 per cent for industries and the remaining 6 per cent for domestic consumption.

According to one estimate the total ground water reserve up to a depth of 300 m is about 3700 mham, almost ten times of the annual rainfall. In terms of exploitation of ground water potential, Punjab comes on top (about 94%) followed by Haryana (84%), Tamil Nadu (61%), Rajasthan (51%), Gujarat (42%), Uttar Pradesh (38%), Maharashtra (31%), West Bengal (25%), and Andhra Pradesh (24%). States like Assam, Odisha, Madhya Pradesh, and Bihar have not been able to utilise even 20 per cent of their total ground water potential.

The main problems associated with the utilisation of water are: (a) high fluctuations in the regimes of rivers, (b) uneven spatial distribution of precipitation, (c) wastage of water during floods, (d) unscientific utilisation of water, (e) pollution of rivers, and (f) dispute on water distribution among the states.

India's rivers are highly polluted. The rapid growth of population, agricultural modernization, industrialization and urbanization have reduced the per capita availability of water. The pollution of rivers, lakes and ponds have aggrevated the situations.

Water Harvesting in India

Water is a prime national resource, a basic human need and a precious asset. The U.N. report published in 2003 at the time of the Third World Water Forum in Kyoto says that water reserves are drying up fast, and booming population, and global warming will combine to cut the average person's supply by a third by 2020. The report also ranked 122 countries on the quality of their water provision. India was placed at the bottom of the list.

The agricultural output depends on monsoon as nearly 60 per cent of the area sown is dependent on rainfall. In the areas of rain-fed agriculture, watershed harvesting has great economic and ecological significance. The greater parts of Rajasthan, Gujarat, parts of Haryana, Punjab and Uttar Pradesh, western Madhya Pradesh, eastern Maharashtra, northern Andhra Pradesh, western Karnataka, parts of Tamil Nadu, Odisha, Jharkhand, and Chhattisgarh frequently suffer from droughts. These regions face two critical issues:

(i) They have severe droughts in summer with an acute scarcity of water and a declining water-table, resulting in the loss of crop productivity for major and minor crops.

(ii) Heavy and intensive rainfall and surface run-off leads to soil erosion and sedimentation in the lower courses of the rivers, resulting in the formation of ravines and gulleys across the region.

These are the areas which are economically poor, struggling around the vicious cycle of underdevelopment. These areas require appraisal of land and soil resources based on micro watersheds (within an area of 10 to 1000 hectares), and macro watersheds (area over 1000 hectares) to draw plans for *in-situ* water harvesting and conservation through conjunctive uses, and thus monitor the development mode in a harmonised manner. The entire watershed management involves innovation in group decisions followed by action involving joint decisions. Thus, starting with a watershed (which is a manageable hydrological unit) as a land unit, it takes up water as the most important resource for development. It aims at containing the deterioration of land and its approach to development is not confined just to agricultural land alone, but covers the watershed area, starting from the highest point of the area to the outlet or the natural drainage line. This involves the implementation of ameliorative measures for barren hill slopes, marginal lands, agricultural lands, gullies and ravines.

Optimal sustainable development can occur only with the maintenance of quality and efficient use of the country's water resources to match the growing demands on this precious natural resource with the active involvement of all in order to achieve accelerated, equitable economic development of the country.

It is rightly said that water resources hold the key to the socio-economic development of any country, and India is not an exception to this. It is a fact that water, a fragile and finite resource, is fast becoming scarce day by day. A recent study by the world bank indicates that per capita availability of water in India, which was to the order of 5000 cubic metres per year at the time of independence, has drastically come down to 2000 cubic metre per year at present. The average annual rainfall of 110 cm in the country, though fairly high, is marked by wide variations, both spatial and temporal. About 67 per cent of the water resources are reported to be available in the Indo-Gangetic alluvial basins covering 33 per cent of the geographical area of the country, as against 33 per cent of the potential in the hard rock regions, occupying 67 per cent of the geographical area. Looking at the existing scenario of water availability in the country, there is an urgent need for propagating water harvestring and transforming it into a mass movement. With regard to the water resource, the main challenges that need to be addressed are:

(a) ground water depletion, (b) water quality deterioration, (c) low water use efficiency, (d) expensive new water resources, (e) resource degradation, (f) development of new water resources (g) reformed price incentives, (h) appropriate technology, (i) tradable water rights, and (j) international cooperation.

Rain-water Harvesting

Rainwater is biologically pure, soft in nature and free from organic matter. Rainwater harvesting is an effective technique of conserving water by guiding the rainwater that falls on rooftops to storage tanks or underground pumps for future usage. Groundwater recharging, on the other hand, is undertaken by guiding water through pipes to wells, bore wells or recharge pits to ensure recharging water in the underground aquifers, for later use, whenever the need arises. Tamil Nadu is the first and only state in India which has made roof-top rain-water harvesting structure compulsory to all the houses across the state. There are legal provisions to punish the defaulters.

The collection of water from a catchment surface is referred to as rainwater harvesting. Water harvesting also includes activities aimed at harvesting surface and groundwater and other techniques aimed at conservation and efficient utilisation of limited water endowment. In general, water harvesting is the activity of direct collection of rainwater. The collected water can be stored for direct use or can be used to recharge the groundwater.

The quantum of harvested rainwater depends on:

1. Frequency, duration and intensity of rainfall.
2. Nature of catchment.
3. Run-off characteristics.

Merits of Rainwater Harvesting

Following are the main advantages of rainwater harvesting:

1. Improves soil moisture.
2. Increases groundwater level.
3. Improves the quality of water.
4. Allows drought-proofing.
5. Prevents flooding of storm water drains.
6. Saves energy required to lift water.
7. Reduces flooding of roads.
8. Reduces soil erosion.
9. An ideal solution to water problem in areas having inadequate water resources.

Rainwater Harvesting Practices

There are two main practices of rainwater harvesting:

1. Storage of rainwater on surface for future use. It is a traditional practice and structures used are underground tanks, ponds, check-dams, weirs, etc.
2. Recharge of groundwater. It is a new concept of rainwater harvesting and the structures generally used are:
   - (a) **Pits-recharge**: Pits are constructed for recharging the shallow aquifers.
   - (b) **Trenches**: These are constructed when the permeable strata is available at shallow depths.
   - (c) **Dug wells**: Drainpipes carry the water to a filtration tank from which it flows into the dug well. Rainwater that is collected on rooftop of buildings is also diverted to the dug wells.
   - (d) **Hand pumps**: The existing hand pump may be used for recharging the shallow/deep aquifers, if the availability of water is limited.
   - (e) **Recharge well**: Recharge wells are generally constructed for recharging the deeper aquifers and water is guided through filter media to avoid choking of recharged well.
   - (f) **Recharge shafts**: For recharging the shallow aquifers which are located below clayey surface, recharge shafts are used.
   - (g) **Lateral shafts**: Lateral shafts with bore wells for recharging the upper as well as deeper aquifers.
   - (h) **Spreading techniques**: When permeable strata from top is available, then water spreading technique is used. Water is spread in streams/*nalas* by making check-dams, cement plugs or percolation ponds.

Government Strategy

The total renewable water resources of India are estimated at about 1900 sq km per annum. It is predicted that by 2025 large parts of India will join countries or regions having absolute water scarcity. Groundwater has emerged as the prime source of drinking and irrigation. About 92 per cent of present groundwater withdrawl is being used for irrigation purpose, thus contributing largely in food security of the country.

The following steps have been taken by the government to implement the water harvesting programme:

1. Since sustainability of drinking water-source is of paramount importance for smooth functioning of rural water supply, 25 per cent out of 20 per cent of the allocation under Accelerated Rural Water Supply Programme (ARWSP) has been earmarked exclusively for water harvesting schemes to make implementation of such schemes mandatory.
2. Similarly, 25 per cent out of the allocation under Prime Minister's *Gramodaya Yojana* has also been earmarked for funding schemes under submission on sustainability.
3. MPs are requested to utilise Local Area Development Fund in their respective constituencies to take up water harvesting schemes.
4. Preparation of pilot projects on water harvesting in selected states have already been undertaken.
5. Further, preparation of user-friendly atlas type of document on traditional water-harvesting structures in various parts of the country has been initiated for popularising the concept of water harvesting amongst all concerned, including the community.

By adopting watershed as a unit, different location-specific measures are adopted and executed carefully in each of the topo-sequences according to capability. Considering the fact that the rainfed area in India is about 60 per cent of the country's net sown area, and the vast area should not suffer from neglect and poverty, investment in watershed management for water-scarce regions (receiving rainfall below 75 cm) of India is an appropriate development intervention which warrants top priority from the point of social justice and containing the widening spatial imbalance between irrigated wet farming and dryland farming systems.

In brief, watershed development approach being an intensive one, appears to be infinitely expensive in a relative sense over the seed and fertilizer approach, but economic evaluation conducted at the *Central Soil and Water Conservation Research Institute* at Dehra Dun shows that this is not so. On the other hand, the realisation that a crop-based approach, or an approach which treats the country as a single unit, would not address the major issue for agricultural development in different location-specific conditions, watershed management (or alternative drainage, flood control and conjunctive uses of water of different sources, or again, a more appropriate management of hill and forest-based agriculture) are alternative regimes, each having a different investment and policy support strategy.

There are a number of successful watershed management experiences like *Sukhomajri*, near Kalka and *Pani-Panchayats* (water collectives) at Ralegaon in Maharashtra, where the basic problems of food and fuelwood requirements of poor rural communities have been largely solved by water harvesting.

It is being suggested that in many rural or agricultural situations in our country, we require community participation interfaced with institutional support at the level of, say, 'watershed' land and water managements in difficult ecological regimes to develop the slender resource base of the areas. The replication of successes like *Sukhomajri* would be for the better.

Studies to develop a baseline data for better understanding of the existing and emerging situations need to be undertaken. Recycling of water and water conservation will be a critical component of our daily lives in the new millennium. As far as possible, the technologies should be indigenously developed so as to make them socially acceptable and economically viable.

THE INTER-STATE WATER DISPUTES

Water being the most precious resource is required for domestic, irrigation and industrial purposes. River is more than an amenity, it is a treasure. It offers a necessity of life that must be rationed among those who have power over it. Most of the Indian rivers traverse more than one state. Each of the states of a river basin tries to obtain the maximum quantity of water. This has resulted in many water disputes in the country. In the Indian Constitution (1950), water is a state subject. Consequently, the state governments virtually exercise full control on planning, development, regulation, distribution and control of water flowing through their territories. Under Article 262 of the Indian Constitution, the Parliament is empowered to provide the adjudication or control of water on any interstate river. Most of the rivers of India travese several states. Under the Water Dispute Act, 1956 a tribunal of three sitting judges of the Supreme Court has to be constituted by the Central Government for the settlement of an interstate water dispute when a request is received from a state government. According to the Interstate Water Dispute Act, 1968, the Central Government has also been given the responsibility of regulation and development of interstate rivers and river valleys to the extent to which such regulation and development under the control of the Union is declared by the Parliament, by law, to be expedient in public interest. Some of the important interstate water disputes in India are as under:

1. The Kaveri water dispute between Karnataka, Kerala, and Tamil Nadu.
2. The Krishna water dispute between Maharashtra, Karnataka, and Andhra Pradesh.
3. The Tungbhadra water dispute between Andhra Pradesh and Karnataka.
4. The Godavari water dispute between Andhra Pradesh, Madhya Pradesh, Maharashtra, and Odisha.
5. The Narmada water dispute between Gujarat, Madhya Pradesh, Maharashtra, and Rajasthan.
6. The Ravi, Beas and Satluj water dispute between Punjab, Haryana, Rajasthan, Delhi, and Jammu and Kashmir.
7. The Yamuna River water dispute between Uttar Pradesh, Haryana, Himachal Pradesh, Punjab, Rajasthan, Madhya Pradesh, and Delhi.

Many of these water disputes have been settled on the basis of equitable apportionment which is the universally accepted principle. However, there are some interstate water disputes whose final solution, acceptable to all parties, has not yet been worked out. The Kaveri water dispute has been resolved by the Supreme Court in February, 2007, but the government and people of Karnataka are not satisfied with the decision of the court. The Ravi and Beas water dispute is still a bone of contention between Punjab and Haryana governments.

In developing countries like India, the interstate water dispute must be resolved quickly so that water resources could be utilised and harnessed properly for economic development. One of the measures could be to declare all the major rivers as national property, and national schemes under Central assistance should be launched for the development of total command area of the concerned states. Establishment of separate corporations on the pattern of the Damodar Valley Corporation may be immensely useful in this direction.

INTERNATIONAL AGREEMENTS FOR SURFACE WATER RESOURCES

Several of the Indian rivers flow through Tibet (China), Pakistan, Bangladesh, Bhutan, Nepal, and Myanmar. India has many international agreements with these neighbouring countries regarding the sharing of international river waters.

The Indus Water Treaty

This treaty was signed between India and Pakistan on September 19, 1960, regarding the sharing of water of the Indus and its tributaries. It was reached through the arbitration of the International Bank for Reconstruction and Developemnt which has set up a permanent Indus Commission to look after disagreement arising between India and Pakistan. Under this agreement, India has been given exclusive rights to use the waters of the three eastern rivers (Ravi, Beas and Satluj), leaving out the remaining three (Chenab, Jhelum, and Indus) to Pakistan, which will also take into account the water needs of the Indian state of Jammu and Kashmir. The agreement between India and Pakistan of the Salal, Baghliar and Dulhasti projects (Chenab River) are an excellent example of co-operation between the two countries.

Similarly, a thirty-year agreement was also reached between India and Bangladesh on December 12, 1996, for the sharing of Ganga waters. Under the agreement, India and Bangladesh would share alternately for 10 days each, 35,000 cusecs of water during the lean season (1^{st} March to 10^{th} May) to fulfill their water needs. A similar agreement has been concluded between India and Nepal for sharing river waters. Moreover, India is helping Nepal in executing many river valley projects. The Mahakali Project is the outcome of one such Indo-Nepal joint ventures. Mutual agreement has also been reached between India and Bhutan for harnessing the waters of the international rivers affecting these countries. The king of Bhutan has agreed to join a sub-regional plan for sharing river waters and power with India and Bangladesh. Bhutan is willing to divert 12,000 cusecs of water from the Sankosh River to Tista and from Tista to Farakka Barrage to be shared by India and Bangladesh. The plan also envisages India purchasing 4000 megawatt of hydel power from Bhutan to strengthen its National Power Grid and to meet the power needs of the north-eastern region.

NATIONAL WATER GRID

The distribution of rainfall in India is highly unequal and seasonal. The rivers having their origin in the Himalayas are perennial, while those of Peninsular India are generally seasonal. During the months of general rains, much of the water is wasted during floods and flows down to the sea, but in the dry months of the year there is scarcity of water. Consequently, there are droughts and famines in one part of the country and floods in the other regions. The problems of droughts and floods can be minimised through the inter-basin linkages or through national water grid, under which, water from one river basin can be transferred to another basin for optimum and judicious utilisation. The salient features of the National Water Grid are as follows:

1. The Ganga-Kaveri Link Canal passing through the basins of Son, Narmada, Tapi, Godavari, Krishna, Penner, and Kaveri.
2. The Brahmaputra-Ganga Link Canal passing through Bangladesh.
3. The Narmada Canal passing through Gujarat and Rajasthan.
4. The Canal from Chambal to Central Rajasthan.
5. The Link Canals between the rivers of the Western Ghats towards the east.

1. The Ganga–Kaveri Link Canal

At the request of the Government of India, a UNO team prepared a project report on the Ganga-Kaveri Link Canal (**Fig. 3.11**). The main objectives of the project are to safeguard against the recurring floods in the Ganga Basin and to assure more water to the comparatively less rainfall receiving areas of central India. Under this project, the Ganga is to be linked with Kaveri by a man-made canal; 2636 km or 1650 miles long. This canal was proposed not only to provide drinking water to its command area, but also to provide water for irrigation and sanitation. In addition to these, the canal is supposed to help in the generation of hydel-power, navigation, flood control, tourism promotion, and recreation. The Ganga-Kaveri Link Canal is thus, a multi-purpose project of immense size. If completed, the country will no longer have to depend so much on monsoon, the vagaries of which are well known.

The scheme proposes to draw 1700 cumecs (60,000 cusecs) of water from the Ganga, constructing a barrage near Patna, and lift its water by large pumps to a point near the boundary of the basins of Ganga and the Narmada from where it will be possible to distribute the water by

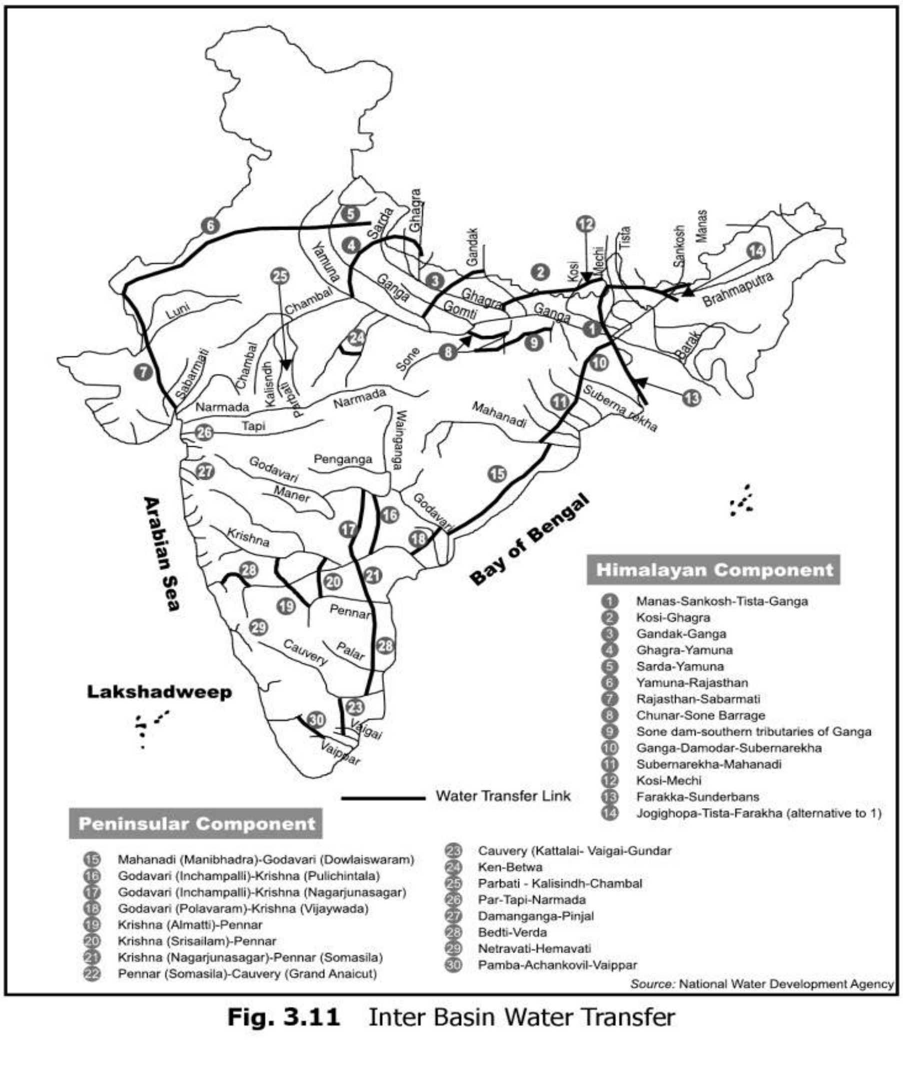


Fig. 3.11 Inter Basin Water Transfer

gravity via dug-up canals or through existing rivers to the west or south. The flood waters of the Narmada (flowing into the Arabian Sea) and the Godavari (flowing into the Bay of Bengal) could also be used profitably by a separate water grid. Water for the inter-basin transfer would be derived from the Ganga only during the four months of the rainy season (July to October) when the flow exceeds on an average by 2850 cumecs (100,000 cusecs).

The length of the Ganga-Kaveri Link Canal will be between 2400–3200 km, depending upon the actual alignment finally chosen, with smaller secondary branches connecting areas chronically prone to droughts. It is also proposed to supply the Ganga water to Bihar, Uttar Pradesh, Jharkhand, Chhattisgarh, Madhya Pradesh, and Rajasthan by pumping additional water during the lean water season. Similarly, 1410 cumecs (50,000 cusecs) of water pumped for 150 days or more, depending upon the surplus waters in the Ganga, would be diverted during the high flow period only, and would be transferred outside the basin to meet partially the water demand of the chronically drought prone areas of Rajasthan, Gujarat, Madhya Pradesh, Chhattisgarh, Maharashtra, Andhra Pradesh, Karnataka, and Tamil Nadu.

A site near Patna having an elevation of about 46 metres above sea level will be the starting point which would collect the surplus water from the Ganga. From here, the water would be pumped into a series of reservoirs between the watersheds of the Narmada and Son, involving a pumping lift of 335 to 400 m. From this elevation (Bagri Reservoir on the Narmada 423 m above sea level), a lined aquaduct will convey the water to the south utilising the natural water resources of the Wainganga, Pranhita, and Godavari, and crossing the Krishna and the Penner to Kaveri, upstream of the Upper Anicut.

Storage would be provided enroute, especially on the ridge regions to conserve the water for the dry season. These storages would be located inside valleys, which do not have sufficient catchment area of their own to provide adequate run-off which would be utilised during the dry season. On the way, water would also be released into the basins of the Narmada and the Tapi rivers which flows westward into the Arabian Sea, and the Godavari, the Krishna, the Penner, the Kaveri which flow eastward into the Bay of Bengal. From the selected points on the Son River itself, water pumped separately for the basin will be diverted to the drought prone areas in the Ganga basin.

The project involves huge expenditure, massive survey operations and strong administrative decisions. Since it will take a decade or more to complete the project which has several administrative and socio-ecological constraints, the government has not yet taken any decision to execute the project.

2. The Brahmaputra–Ganga Link Canal

The Brahmaputra is a mighty river which carries a discharge of 3500 to 5000 cumecs even during the dry season. Much of this water is beyond the requirement limit of the basin and is wasted. On the other hand, there is a scarcity of water in the lower Ganga basin, especially during the dry months. Hence, the diversion of excess water from the Brahmaputra to the Ganga may meet this water deficit, which shall help in the economic development of the region.

The Brahmaputra-Ganga Link Canal Project involves the construction of a diversion barrage at Dhubri (Lower Assam), and a 320 km long feeder canal linking the Dhubri Barrage to the Farakka Barrage. A portion of this feeder canal will lie in Bangladesh for which an interenational agreement between India and Bangladesh has to be signed. This canal will provide irrigatioin water to Bangladesh also. The canal may augment the flow of water in the Padma River (Ganga in Bangladesh) during the lean months of the year. Besides, the link canal would provide cheap inland navigation facility to both the countries. Due to lack of concurrence from Bangladesh and involvement of huge financial expenditure, the scheme has not yet been started.

3. The Narmada Link Canal to Gujarat and Rajasthan

Under the Sardar Sarovar Project, there is a proposal to build a terminal storage dam across the Narmada River near Navagam, and a diversion canal linking the place to regions of Kachchh (Gujarat) and western Rajasthan. This link canal will be of immense help to the drought prone areas of Gujarat and western Rajasthan.

4. The Chambal Link Canal

A canal of about 500 km connecting the Chambal River with the Indira Gandhi Canal has also been proposed. The canal would provide water to the central parts of Rajasthan. It will involve a lift of 200 to 250 m. Moreover, Chambal-Parbati, Betwa-Ken, Ghagra-Yamuna, Gandak-Ganga, Mechi-Kosi-Ganga, Par-Tapi-Narmada, Mahanadi-Godavari are also under consideration (**Fig. 3.11**)

5. Links between the Rivers of the Western Ghats to the East

The rivers of the Western Ghats carry enormous quantity of water during the rainy season. Due to steep gradient and the narrow coastal plains much of the water goes to the Arabian Sea as waste. This water may be diverted to the rain-shadow areas of the Western Ghats through the diversion canals where it can be utilised for irrigation. The Periyar Diversion Scheme, constructed several years ago, is such a type of model scheme where the surplus water of the west-flowing Periyar river has been collected in a barrage and diverted through a tunnel across the Sayadri, so as to meet the water needs of the drought prone areas of Tamil Nadu in the east. Other projects of western Ghats include: Damanganga with Pinjal, Bedti with Varda, Netravati with Hemavati and Pamba with Vaippar (**Fig. 3.11**). Similar schemes may also be executed in case of other rivers of the Western Ghats.

GROUND WATER RESOURCES OF INDIA

India is rich in underground water. Its spatial distribution, however, is most uneven. For example, the average annual rainfall in India is about 110 cm. While Mawsynram and Cherrapunji receive more than 1000 cm rainfall annually, the average annual rainfall in Ganganagar is only about 20 cm.

The underground water resource is a function of geological structure, topography, slope, precipitation, runoff, soils and hydrological conditions of a region. In the opinion of Prof. R.L. Singh (1971), India may be divided into eight ground water provinces (**Fig. 3.12**). A brief account of these provinces has been given in the following section:

1. The Pre-Cambrian Crystalline Province

The Pre-cambrian province stretches over about 50 per cent of the total area of the country, especially over Peninsular India. It sprawls over Tamil Nadu, Karnataka, Andhra Pradesh, Maharashtra, Chhattisgarh, Chotanagpur Plateau and Aravallis. This province is generally poor in under-ground water resource.

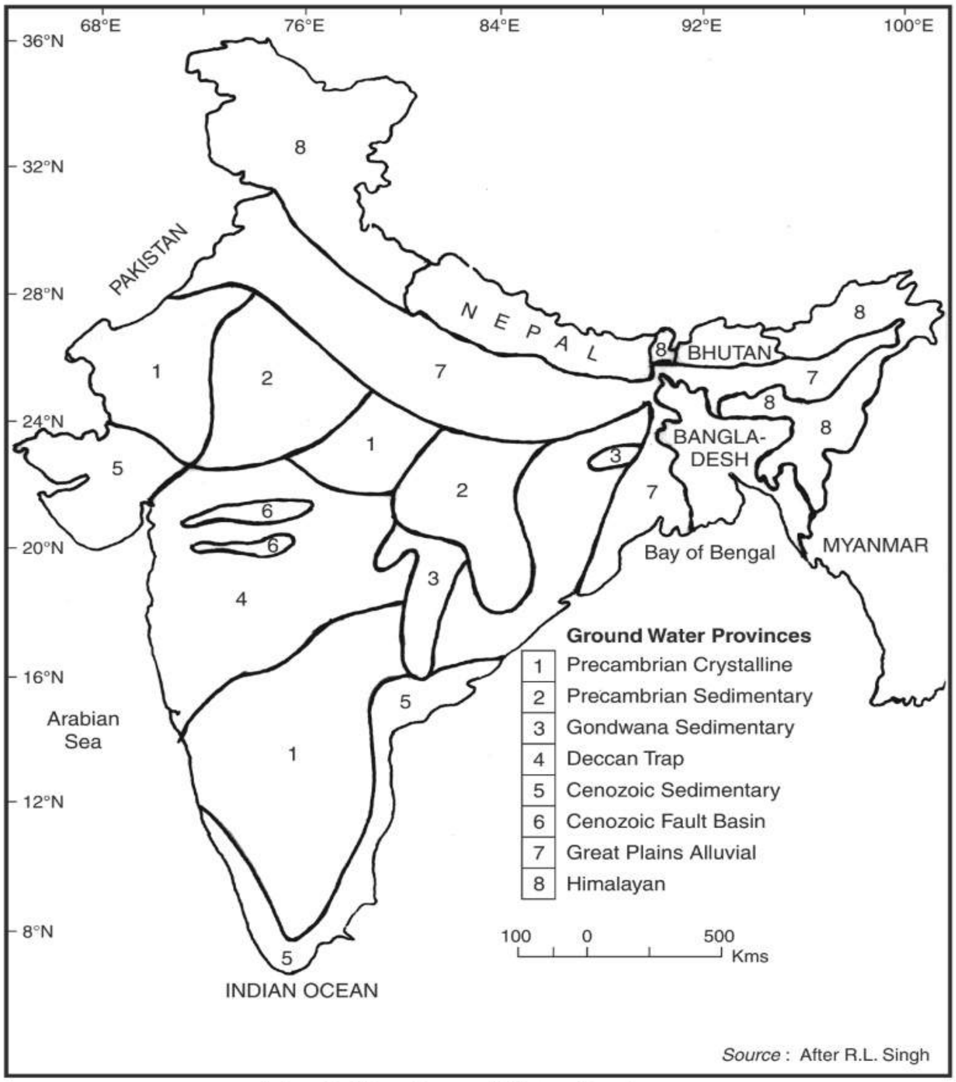


Fig. 3.12 Ground Water Provinces

2. Pre-Cambrian Sedimentary Rocks Province

The Archaean, Dharwar, Cuddappah and Vindhyan formations are included in this province. These regions are also not rich in ground-water resource.

3. The Gondwana Sedimentary Province

Stretching over the Godavari basin, this province is fairly rich in underground water resource.

4. The Deccan Trap Province

Stretching over the states of Mahrashtra, parts of Gujarat, Madhya Pradesh, Chhattisgarh, Andhra Pradesh and Karnataka, this province is also deficient in underground water resource. In fact, the Deccan Trap is a deep lava formation of the Cretaceous Period in which the seepage of water is possible only through the cracks and fissures. The limited under-ground water is however, of immense help for the irrigation of cereal crops, orchards, sugarcane, vegetables, flowers, and grasses.

5. The Cenozoic Sedimentary Province

This province includes the coastal areas of Andhra Pradesh, Tamil Nadu, Kerala, and Gujarat. The sandstones of the Tertiary Period in these regions are rich in the underground water resource.

6. The Cenozoic Fault Basin

The rift valleys of the Narmada and Tapi rivers are included in this province, which are quite rich in underground water.

7. The Ganga Brahmaputra Alluvial Province

Sprawling over Punjab, Haryana, Uttarakhand, Uttar Pradesh, Bihar, West Bengal, Assam and parts of Rajasthan, this province has the richest underground water resource. About 44 per cent of the Indian underground water resource is found in this province. Thousands of tube-wells have been installed in the Northern Plains of India to utilise this resource for irrigation, domestic, and industrial purposes.

8. The Himalayan Province

This is complex structural, physiographic and geographical region of India. In general, it is deficient in underground water except the intermontane valleys, like the Dun, Kashmir, Kangra, Kullu, and Manali valleys. There are numerous springs in this region.

THE NATIONAL WATER POLICY

The government of India designed the National Water Policy for the optimum and judicious utilisation, management and conservation of water resources in the country. The main features of the policy are given in the following paras:

According to one estimate, out of the total precipitation of about 400 million hectare metres in the country, only 178 million hectare metres is the available surface water. Out of this, about 50 per cent can be put to beneficial use because of topographical and other features. Moreover, there is a ground water potential of about 42 million hectare metres. The distribution of water resource as stated above is highly uneven in terms of both space and time. Precipitation over the greater part of the country is seasonal, mainly concentrated to three or four months of the rainy season. It varies from about 20 cm in Ganganagar (western Rajasthan) to over 1000 cm at Mawsynram (Meghalaya). Hence, there is a water surplus in one part of the country and water deficit in another part. The National Water Policy proposes to evolve a national water grid for the proper management and utilisation of the water of the country. The main objective of the policy is to provide water from the surplus areas to the deficit areas. The national water policy proposes to initiate investigation for a national plan for inter-basin transfer for water from the water surplus areas to the water deficit areas. Its aims are enumerated below:

1. Water is a primary natural resource, a basic human need and a precious national asset. Hence, the planning and development of water resources need to be governed by national perspective.
2. The National Water Policy aims at planning the surface water resources of the country on the basis of hydrological units such as drainage basin as a whole for a sub-basin. This will ensure an optimum utilisation of the water resources of the country.
3. There is an increasing demand of water for irrigation, industries and domestic uses. The national water policy aims at taking suitable measures for proper management and conservation of water resources of the country, minimising losses at the storage and diversion points in the distribution system.
4. The policy aims to reduce water pollution and to improve the quality of water of the rivers. There is an emphasis on the recycling of water also.
5. It proposes an adequate maintenance of canals and distribution systems by making adequate financial allocations for maintenance of canals and their distributaries.
6. It suggests a detailed survey for the preparation of new projects on priority basis for tribal areas, drought prone areas as well as for the economically weaker sections of society.
7. The policy lays emphasis on the supply of good quality drinking water to rural areas besides meeting the needs of the urban areas.
8. It proposes a proper survey of the underground water resources and how to utilise them judiciously. The conservation and recharging of ground water is also a priority of the national water policy.
9. The policy also focuses attention on devising suitable strategies for such problems as waterlogging, salinisation, degradation of fertile arable lands, deteriorating water quality, over exploitation of ground water resources, and uprooting of families due to development projects.
10. The policy also aims at reducing the runoff, soil erosion and silting of river beds.

MAIN WATERFALLS OF INDIA

Agaya Gangai Waterfall

Located in the Kolli Hills (Eastern Ghats, Tamil Nadu). It provides serene solitude, and is a great attraction in the Tamil Nadu tourism. The approach is, however, tortuous.

Ayyanar Waterfall

It is situated in the Virudhunagar District of Tamil Nadu in the Western Ghats. It gets water mainly during the retreating monsoon rain. The water from the falls is mainly used for drinking purposes by the people of Rajapalayam. It is a famous tourist spot for the people of neighbouring districts.

Barakana Falls

Situated in the Shimoga District of Karnataka, Barakana is one of the highest water falls of the country. Currently, Barkamna Falls are the prime source of one of the hydro-electric projects of Karnataka.

Dudhsagar (Goa)

Dudhsagar (The Sea of Milk) is a tiered water fall located in the upper reaches of Mandovi River in the state of Goa. It is a great attraction for the national and international tourists.

Duduma Waterfall (158 m)

Situated about 92 km from Koraput, it lies on the Machhkund River in Odisha. A large hydro-electric project has been constructed at this waterfall. Machhkund is an important place for pilgrimage.

Gokak Falls (53 m)

They are located in the upper reaches of the Ghataprabha (a tributary of the Krishna) in Belgaum District of Karnataka. The waterfall is about six km. away from Gokak, a nearby town. It resembles to Niagra Falls. It is a great attraction for the domestic and international tourists.

Jog Falls (253 m)

Located on the Sharavathi River in the Shimoga District of Karnataka, they are the highest untiered waterfalls in India. Jog falls is one of the major attractions in Karnataka tourism. It is also called by alternative names of Gerusoppe Falls, Gersoppa Falls and Jogada Gundi.

Kiliyur Falls

Kiliyur are the waterfalls in the Servary Hill of Eastern Ghats (Tamil Nadu). Having an elevation of about 100 m, it is a great attraction in the tourism of Tamil Nadu.

Kurtalam Falls

Situated in the Tirunelveli District, Tamil Nadu, the Kurtalam waterfalls is a great attraction for the domestic and international tourists.

Lodh Waterfalls (also known as Buddha Ghagh Falls)

The Lodh Waterfalls are located on the Budh River about 40 km from Ranchi (Jharkhand). The falls, named Gautam Budha, also have a Buddha Temple there.

Shivasamudram Waterfall

Shivasamudram Falls formerly known as the Cauvery Falls are the second highest waterfall in India. It is located 80 km from Mysore and 120 km from Bangalore. It is a major attraction in Karnataka tourism.

Siruvani Waterfall

It is situated at the Siruvani River at a distance of about 40 km from Coimbatore in the Western Ghats. It is one of the main water sources of Coimbatore city. The panoramic view of the dam and the falls is enchanting.

Thalaiyar Waterfall (Rattail)

Also known as Rat-tail, it is located near Kodaikanal in Tamil Nadu. With an elevation of 297 m, it is the highest waterfall in Tamil Nadu State. The waterfall is, however, not connected by road and the approach is tiresome.

Vattaparai Waterfall

Located at the Pazhayar River in the Kanyakumari District of Tamil Nadu, it is a great attraction for tourists. The surrounding area is proposed to be developed into a Wildlife Sanctuary.

Vazhachal Waterfall

Located in the Thrissur District of Kerala, these are one of the best waterfalls in India. They are a great attraction for the domestic and international tourists.

Some of the other important Waterfalls in India

Chhattisgarh

Teerathgarh.

Madhya Pradesh

Dhunwadhar (Narmada River, near Jabalpur).

Himachal Pradesh

Bundla and *Palani* falls.

Jharkhand

Ghaghri, Hundru and *Johna* falls.

Karnataka

Abbey Falls, Arisina Gundi Falls, Hebbe Falls, Irupu Falls, Kalhatti Falls, Keppa Falls, Koosalli Falls, Kudumari Falls Kunchikal Falls, Magod Falls, Mekedaatu Falls, Muthyala Falls, Sathodi Falls, Simsa Falls, Chunchi Falls, Unchalli Falls.

Kerala

Athirappilly Falls, Meenmutty Falls, Palaruvi Falls, Soochipara Falls, Thusharagiri Falls.

Maharashtra

Chchai Falls, Gatha Falls, Keoti Falls, Rajat Pratap Falls (M.P.), Kune Falls, Marleshwar Falls, Pandavgat Fall.

Meghalaya

Beodon Falls, Bishopfalls, Elephant Falls (Shillong Peak), Kynrem Falls (308 m), Langshiang Falls (341 m), Margaret Falls, Nohkalikai Falls (338 m), Spread Eagle Falls, Sweet Falls (97 m).

Mizoram

Vantawng Falls.

Odisha

Joranda Falls (151 m), Khandadhar Falls near Buguda (246 m).

Tamil Nadu

Aintharuvi (five-falls), Beman Falls (Palani Hills), Bear Shola Falls (Kotagiri), Chitraruvi Falls (Small falls), Courtallam Falls, Elk Falls (in Palni Hills National Park),

Fairy Falls (5 km from Kodaikanal), Glen Falls in Palani Hills National Park), Hogenakal Falls (20 m).

Kalikesam Falls (in Kanyakumari District), Koraiyar Falls (in Panchaimalai near Arumbavur), Kovai Kutaralam Falls (at Siruvani 37 km from Coimbatore), Kumbakkarai Falls (in the foothills 8 km from Periyakulam), Kuthiraiyar Falls (167 m).

Mangalam Aruvi Falls (in Pachaimalai), Mayil Utha Falls, Monkey Falls (near Coimbatore), Mutyalamaduvu Waterfalls, Neptune Falls (in Palani National Park).

Palaruvi Waterfalls, Pambar Falls (4 km from Kodaikanal), Pazhathotta Aruvi Falls (Fruit Garden Falls or Orchid Falls), Pazhaya Courtallam Falls (Old Falls), Peraruvi Waterfalls (Main Falls), Periyar Falls, Pudur Megan Falls, Puli Aruvi (Tiger Falls), Puthu Aruvi (New Falls- Milk Falls), Pyakara Falls (Nilgiri).

Sengupathi Falls, Shenbaga Devi Falls, Thenaruvi Falls (Honey Falls), Shimsha Falls, Silver Cascade (8 km from Kodaikanal), Skamba Waterfalls (8 km from Kodaikanal), Snake Falls (in Palani Hills Nationalpark), Suruli Waterfalls (123 km from Madurai).

Thakkam Thootam Falls (near Palani), Tirparappu Waterfalls (in Kanyakumari District), Thirumoorthy Falls (about 20 km from Udumalpet), Thoovannam Falls or Dhuvanam Falls (near Amaravathinagar).

Vaideki Falls (about 30 km from Coimbatore).

REFERENCES

Chatterjee, S.P. “India, in World Atlas of Agriculture.” Asia and Oceania Volumes, *International Association of Agricultural Economists*, Novava (1973) : 186–200.

Chatterjee, S.P. “Physiography.” *Gazetteer of India,* Chapter I (1975).

Chhibber, H.L.. “The Drainage Pattern Observed in India and Adjacent Countries.” *National Geographical Journal of India,* Vol. 2 (1) (1948): 2–5.

Christopherson, R.W. *Elemental Geosystems—A Foundation in Physical Geography.* New Jersey: Prentice Hall, Englewood Cliff, 1995.

Das Gupta, S.P., ed. “India’s Water Resource Potential.” *Man and Ecology,* School of Fundamental Research, Calcutta (1989).

Government of India, *India—2012*, Publication Division, Ministry of Information and Broadcasting.

Hamblin, W.K., and Christiansen E.H. *Earth’s Dynamic Systems.* NJ: Prentice Hall, Englewood Cliff, 1995.

Husain, M. *Fundamentals of Physical Geography.* Jaipur: Rawat Publications, 2005.

Law, B.C. *Mountains and Rivers of India.* 21st International Geographical Congress Publication, Calcutta, (1968).

Singh, R.L. *India—A Regional Geography.* Varanasi: NGSI, 1971.

Susan, M. *Oxford Dictionary of Geography.* Indian Edition, Oxford University Press. 1997.