MAULANA ABUL KALAM AZAD UNIVERSITY OF TECHNOLOGY

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(Formerly known as west Bengal University of Technology)

A STUDY OF MULTIPURPOSE RIVER VALLEY PROJECTS OF INDIA

A project report submitted in partial fulfillment of the requirements for the degree of

BACHELOR OF TECHNOLOGY IN CIVIL ENGINEERING FOR THE ACADEMIC YEAR 2021-22

UNDER THE SUPERVISION OF

MR. SUBHANKAR GIRI

(Assistant Professor)

SUBMITTED BY

DEBARATI SIKDAR	**(ROLL NO- 20601319001)**
PRASENJIT MONDAL	**(ROLL NO - 20601319069)**
SOMNATH MONDAL	**(ROLL NO - 20601319003)**
MOHAMMAD IBRAHIM	**(ROLL NO - 20601318082)**
KAUSTAV MODAK	**(ROLL NO - 20601319080)**
SUDIPTA MANNA	**(ROLL NO - 20601319004)**
SUBHAJIT PANJAL	**(ROLL NO – 20601319005)**

SEACOM ENGINEERING COLLEGE

JALADHULAGORI, HOWRAH-711302

FORWARD

I hereby forward this project work entitled "A Study of Multipurpose River Valley Projects of India" prepared by Debarati Sikdar, Prasenjit Mondal, Somnath Mondal, Mohammad Ibrahim, Koustav Modak, Sudipta Manna, Subhajit Panjal under my guidance and supervision in partial fulfilment of the requirements for the award of Bachelor Of Technology in Civil Engineering.

Date:- _______________

____

Mr. Subhankar Giri

(Asst. Prof. of civil engineering Department)

Project guide

____

Director/ Principal
Seacom Engineering College

____

HOD
DEPARTMENT OF CIVIL ENGINEERING

SEACOM ENGINEERING COLLEGE

CERTIFICATE

This is to certify that the project entitled-"Study of MULTIPURPOSE RIVER VALLEY PROJECT of India " prepared by) **Debarati Sikdar** (roll no-20601319001) ,**Prasenjit Mondal** (roll no-20601319069), **Somnath Mondal** (roll no-20601319003), **Mohammad Ibrahim** (roll no-20601318082), **Kaustav Modak** (roll no- 20601319080), **Sudipta Manna** (roll no- 20601319004 **Subhajit Panjal** (roll no- 2060131905) in partial fulfilment of the requirements for the award of the degree of **BACHELOR OF TECHNOLOGY in CIVIL ENGINEERING** is a *record of research work carried out by them under my guidance. The results embodied in this project have not been submitted to any other institute or university for the award of my degree or diploma. This is an authenticated record of our own work carried out during the period from February 2022 to May 2022(8th Semester) under guidance and supervision.*

Mr. Subhankar Giri

(Asst. Prof. of civil engineering Department)

Project guide

Director/Principal
Seacom Engineering College

HOD
DEPARTMENT OF CIVIL ENGINEERING

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NAME	ROLL NO.	SIGNATURE
1. **Debarati Sikdar**	**20601319001**	
2. **Prasenjit Mondal**	**20601319069**	
3. **Somnath Mondal**	**20601319003**	
4. **Mohammad Ibrahim**	**20601318082**	
5. **Kaustav Modak**	**20601319080**	
6. **Sudipta Manna**	**20601319004**	
7. **Subhajit Panjal**	**20601319005**	

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ABSTRACT

River valley projects involve the construction of a gigantic single dam or series of small dams on a river and on its tributaries. Ever since, dealing with water resources has been one of the primary aims because of which multi-purpose river valley projects have been gaining importance. The purpose of these projects are to fulfil the need of irrigation, flood control and generation of hydroelectricity along with the recreation, fishing and flood control. Such projects include afforestation programmes on barren and wastelands which check soil erosion and conserve water received from rainfall and flowing rivers in the area. Fisheries have been developed in the reservoirs. The bigger size canals are often used for navigation and water gets distributed in the nearby rural settlements and urban centers. These projects encourage growth of industries in the surrounding area. Hence, a multi-purpose project can usher development in the surrounding region. Our country is blessed with lots of rivers and other water bodies.

The river valley projects with many objectives are called multipurpose project. Multipurpose project in the Damodar River played a major role not only as a flood controller but also as a source of canal irrigation. Middle and lower course of the river are the most prominent area where irrigation systems are largely controlled by DVC projects of Damodar River. Several canal systems has also developed after construction of dams in DVC project of Damodar River Valley. The study area falls under the area in between Panchet Dam and Burdwan Town. It is extended up to 23º28' N to 23º41'N latitude and 86 º 44 'E to 87 º 18' E longitudes. Total length of the area is approximately 70 km. the avg. height of this area is 110 m from the sea level. To show the increase of Agricultural Land in downstream section Damodar River Basin, block wise Cropping Intensity distribution has been calculated for showing locational and temporal. In this river valley, the area under Agricultural Land has been drastically increased (15%) from 1990 to 2010 but there are slightly increase in the Built up areas. The western side of the basin have the low cropping intensity in the Burdwan District. Upper reaches are less fertile that is why production is also low and reverse condition are found in the lower reaches of the river basin area. The downstream of the river valley are pure alluvial track of the Ganga River system and this region are more fertile than the upstream region. Whole basin area is bounded with agricultural and industrial activities. Irrigation also can put impetus on the agricultural output of this valley region especially in the downstream areas of the valley. Thus the dams are severally interlinked with the human settlement and landscapes of the Damodar Valley Region.

CHAPTER 1

INTRODUCTION

1.1 Water Resource Projects

Water is a critical natural resource. Without it, life could not exist and people could not survive. For more than 5,000 years, dams have provided people with a reliable source of the water they need to live. Dams have enabled people to collect and store water when it is plentiful and then use it during dry periods. Dams have been essential in establishing and supporting human establishment and farms, as well as providing food through irrigation of cropland. Today, dams and reservoirs also help control flood waters to protect people and property, keep rivers navigable, provide electricity from renewable energy for towns/villages and factories, and provide recreational opportunities such as fishing, water sports, etc. Today dams improve the living conditions of the world's population that continues to grow at a rate of more than 100 million people per year. Yet, about 1.5 billion people still do not have access to a reliable source of suitable drinking water and more than two dozen countries do not have enough water to properly sustain their populations. Today more than one billion people are malnourished or starving. In many countries, increased food production is only possible through improved irrigation, which generally depends on diminishing groundwater resources. Therefore, more dams are needed now and into the foreseeable future to improve the management of existing surface water resources

The availability of energy is essential for the socio-economic development of a region. Today energy is largely supplied by fossil fuels, but these fuels are being depleted and they contribute to air pollution and possibly to climate change. It is clear that we should look for ways to generate electricity without releasing harmful substances in the air. In many countries, hydropower is the only natural energy sources. Hydropower is clean and the production from existing projects can be increased without a harmful impact on the environment. At present, hydropower is the largest renewable source of energy.

In other words, hydropower from dams is one of the key sources for providing energy for expanding development. Dams provide domestic and individual water supply, energy, water for irrigation and industrial use, flood control and recreational opportunities, but there is a cost. Our quest to provide the growing world population with a better life means may change the natural environment if the developmental activities are not carried out in judicious and sustainable manner. People and other forms of life are inevitably affected when dams and reservoirs are built. Developers must avoid or mitigate any environmental and social damage caused by water projects. Historically, the priority was given to meeting people's immediate needs for water and energy. Today, we recognize the importance of the natural environment and the need for long-term protection against pollution.

1.2 Definition of Multipurpose River Valley Projects

The multipurpose river valley project is a river project in which a dam is constructed on the river and stored water is then used in a number of for like irrigation, power generation etc.

Four objectives of multipurpose projects are: —

(i) To check floods by regulating flow of water.

(ii) To generate hydropower for our industries and homes.

(iii) To provide irrigation facilities. This helps in increasing agriculture productivity and bringing more area under cultivation.

(iv) To Check Soil Erosion etc.

1.3 Multipurpose River Valley Projects in India

Some examples of Multipurpose River Valley Projects in India are:

A List of Important River Water Projects in India:

Project	River	Related State
Bansagar Project	Son	Bihar ,Uttar Pradesh, Madhya Pradesh
Bargi Project	Bargi	Madhya Pradesh
Beas Project	Beas	Haryana, Punjab, Rajasthan
Bhadra Project	Bhadra	Karnataka
Bhakhra Nangal Project	Sutlej	Punjab, Himachal Pradesh , Haryana, Rajasthan
Bheema Project	Pawana	Maharashtra
Chambal Project	Chambal	Rajasthan, Madhya Pradesh

Damodar Ghati Project	Damodar	Jharkhand, West Bengal
Dulhasti Project	Chinab	Jammu & Kashmir
Durga Barrage Project	Damodar	West Bengal Jharkhand
Farakka Project	Ganga, Bhagirathi	West Bengal
Gandak Project	Gandaki	Bihar, Uttar Pradesh
Ganga Sagar Project	Chambal	Madhya Pradesh
Ghatprabha Project	Ghatprabha	Karnataka
Girna Project	Girna	Maharashtra
Hansdev Bango Project	Hansdev	Madhya Pradesh
Hidkal Project	Ghatprabha	Karnataka
Hirakud Project	Mahanadi	Orissa
Indira Gandhi Canal Project Jawahar Sagar Project	Satlaj	Rajasthan Punjab
Indira Gandhi Canal Project	Periyar	Haryana Kerala
Indira Gandhi Canal Project	Chambal	Rajasthan
Jayakwadi Project Kakrapara Project Kangsawati Project	Godawari	Maharashtra Gujrat
Jayakwadi Project Kakrapara Project Kangsawati Project	Tapti	Maharashtra Gujrat West Bengal
Kol Dam Project	Kosi	Bihar & Nepal
Koyana Project	Krishna	Karnataka
Krishna Project	Kunda	Tamilnadu
Kunda Project	Ganaga	Uttar Pradesh
Let Bank Ghaghra Canal	Ganaga	Uttar Pradesh
Malprabha Project	Vyas	Odisha Karnataka Himachal Pradesh Uttar Pradesh, Madhya Pradesh
Mandi Project	Betwa	Odisha Karnataka

Matatilla Project	Mayurakshi	West Bengal
Mayurakshi Project	Hasdeo Bango river	Madhya Pradesh Odisha Andhra Pradesh
Minimato Bango Hasdeo Project	Muchkund	Madhya Pradesh Odisha Andhra Pradesh Andhra Pradesh
Narmada Sagar Project	Sutlaj	Himachal Pradesh
Nathpa Jhakri Project	Panam	Gujarat
Panam Project	Panama	Gujarat
Panchet Project Pong Project	Damodar Beas	Punjab
Sharawati Project	Sharda, Gomti	Uttar Pradesh
Sharda Project	Kaveri	Karnataka
Shivsamundram Project	Chinab	Jammu & Kashmir
Sutlaj Project	Tawa	Madhya Pradesh
Tawa Project	Bhagirathi	Uttarakhand
Tehri Dam Project	Barakar	Jharkhand
Tilaiya Project	Chinab	Jammu & Kashmir
Tulbul Project	Tungbhadra	Andhra Pradesh. Karnataka
Tungbhadra Project	Tapti	Gujarat
Ukai Project	Penanga	Maharashtra
Upper Penganga Project	Jhelum	Jammu & Kashmir
Uri Power Project	Vyas	Rajasthan Punjab Haryana

1. 1.4 Importance of Multipurpose River Valley

- **Advantages:**

1. Irrigation Facility:

Extension of irrigation facility is one of the important objectives and advantage of multipurpose projects. These projects can stimulate the agricultural productivity for meeting the growing requirement of food and raw materials required for increasing non- farm activities.

2. Flood Control:

Another important objective of such projects is to control the occurrence of floods creating havocs on the economy.

3. Generating Electricity:

Multi-purpose projects help to generate hydro-electricity on a large scale basis, which is very much important for the development of industry.

4. Navigation:

Such projects can create navigation facility in the country by developing ferrying services for transportation, raise fleet capacity and thereby can reduce the traffic load on rail and road transport.

5. Forests and Fisheries:

These projects can help to raise forestry on the banks of the canals. Moreover, it can also encourage the development of fisheries in the reservoirs.

6. Drinking Water:

Such projects facilitate the development of safe drinking water projects for the adjoining areas.

7. Development of Industry and Employment Generation:

Such projects can create a favourable climate for the development of industry by offering the facilities like cheaper power, better water transport, availability of raw materials at cheaper rates for agro-based industries etc.

Moreover, by developing agriculture, industry and infrastructural services, these projects can generate adequate volume of employment opportunities in the farm and non-farm sector. All these would help to raise the standard of living of the people of those adjoining regions reaping benefits from such projects.

8. Recreation:

Multi-purpose projects can also facilitate to develop recreation facilities in the form of picnic resorts, holiday resorts etc. which are having much commercial viability nowadays.

- **Disadvantages:**

1. Exaggerated Benefits on Irrigation:

It has been argued that irrigation benefits derived out of multi-purpose projects are exaggerated because the actual area irrigated by these projects is much less due to delay in the construction of field channels and water routes. Moreover delay in completion of these projects has resulted in high escalation of its cost.

2. Higher Cost of Hydropower:

Although hydro power is having the advantage of low operating cost, renewable source and eco-friendly but at the same time it is also subjected to long gestation period, delay in commissioning the project resulting escalation of project cost and higher initial cost.

All these have resulted in a comparatively higher unit cost of generation in respect of hydro power.

3. Least Flood Control Benefit:

The multi-purpose projects have also failed to derive maximum benefit in respect of flood control as the embankments, drainage channels and flood protection schemes have failed miserably to achieve results.

4. Adverse Environmental Impact:

Finally, the multi-purpose projects have resulted serious adverse environmental impact in respect of degradation of soil content arising out of waterlogging and soil salinity in its command areas.

5. The multipurpose projects induced earthquake, caused waterborne diseases.

6. Due to anaerobic respirations by the plants submerged, Methane is released causing the water to become poisonous.

CHAPTER 2
LITERATURE REVIEW

SL NO.	AUTHOR NAME	YEAR	WORK DESCRIPTION
1.	Bureau of Statistics and Economics, Government of Orissa	1968	Undertook an agro-economic survey in the villages of Command area of Hirakud Dam to assess the benefits of Hirakud irrigation. The basic objective of the study, as visualized by the economic adviser in his technical note is to cover the entire irrigated area of the Hirakud Dam in order to assess the net effect on the economy as a result of the availability of water in terms of growth of prosperity over a period of time.
2.	Abbasi	1991	Pointing out the overall status of Hirakud Dam as follows. The Hirakud reservoir appears to have catalyzed deforestation in areas surrounding excessive silting which will decrease the life of the dam to 77 years from 111 years. Heavy silting resulted in climatic imbalance, a decrease of rainfall in some areas, increase in humidity, failure in controlling floods the survey highlights
3.	Malik.R	2008	Water is essential for economic production and human well-being. Securing a reliable supply of water for key economic areas is critical to achieving economic growth. Because water is vital to many other sectors such as agriculture, food,hydropower,navigation, transportation, and flood management, management of and investment in water resources often form the basis for broad regional and national development
4.	Bhavana Kasbekar, Aalekh, (Name of Work: Development Administration and Organisational Effectiveness)	2000	Its study gives an idea of structure of IGNP and the functions performed by its various structure. In this study an attempt has been made to analyze the problem faced during implementation of IGNP at various levels, which have caused an extensive delay in its completion. An elaborate description of these problems along with suggestion to overcome them has also been presented in the present research work.
5.	Daniel Klingensmith, Oxford University Press, (Name of Book: One Valley And A Thousand, Dams, Nationalism and Development)	2007	The book shows enormous global investments in dams Dams were essentially political symbol of progress and national empowerment and achievement. This project also shows how Damodar Valley Project was influenced by American River Control Projects. He demonstrates how development policies and actions the construction of dams, power stations and irrigation canals were and are linked to ideological challenges posed by nationalism, liberal colonialism and post war liberal modernism

2.2 Aims & Objectives

As we all know that in tis 20^{th} century, due to global warming and scarcity of unrenewable energy sources is become an essential factor, where Dams have enabled people to collect and store water when it is plentiful and then use it during dry periods. Dams have been essential in establishing and supporting human establishment and farms, as well as providing food through irrigation of cropland. Today, dams and reservoirs also help control flood waters to protect people and property, keep rivers navigable, provide electricity from renewable energy for towns/villages and factories, and provide recreational opportunities such as fishing, water sports, etc . Aim of this study is to give details about several multipurpose projects in India, i.e. its location and brief introduction, working principle and its advantages & disadvantages.

Basic objectives of this multipurpose projects are:—

(i) Working principle of the project & its location.

(ii) Brief introduction of the project.

(iii) To check its advantages & disadvantages.

(iv) To check its future perspective.

CHAPTER 3

DESCRIPTION OF MULTIPURPOSE RIVER VALLEY PROJECTS

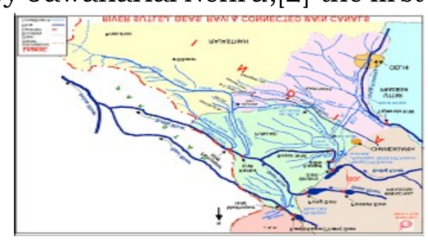
List of Important Multipurpose River Valley Projects:

1. Bhakra Nangal Project –

- **Introduction :** Bhakra Dam is a concrete gravity dam on the Sutlej River in Bhakra Village near Bilaspur in Bilaspur district, Himachal Pradesh in northern India. The dam forms the Gobind Sagar reservoir.

  The dam, located at a gorge near the (now submerged) upstream Bhakra village in Bilaspur district of Himachal Pradesh of height 226 m. The length of the dam (measured from the road above it) is 518.25 m and the width is 9.1 m. Its reservoir known as "Gobind Sagar" stores up to 9.34 billion cubic meters of water. The 90 km long reservoir created by the Bhakra Dam is spread over an area of 168.35 km2. In terms of quantity of water, it is the third largest reservoir in India, the first being Indira Sagar dam in Madhya Pradesh with capacity of 12.22 billion cu m and second Nagarjuna Sagar Dam.

  Described as "New Temple of Resurgent India" by Jawaharlal Nehru,[2] the first prime minister of India, the dam attracts tourists from all over India. Bhakra dam is 15 km from Nangal town, Punjab and 106 km from Bilaspur Nangal Dam is another dam in Punjab downstream of Bhakra Dam. However, sometimes both the dams together are called Bhakra-Nangal Dam though they are two separate dams.



- **History :** The Bhakra-Nangal multipurpose dams were among the earliest river valley development schemes undertaken by India after independence though the project had been conceived long before India became a free nation. The agreement for this project had been signed by the then Punjab Revenue Minister, Sir Chhotu Ram in November 1944 with Raja of Bilaspur and finalised the project plan on 8 January 1945. Preliminary works commenced in 1946. Construction of the dam started in 1948; Jawaharlal Nehru poured the first bucket of concrete into the dry riverbed of the Sutlej on 17 November 1955, as a symbolic initiation of the work. Addressing a gathering there, he said, "This is a gift to the people of India and to the future generations from the workers who built

this dam", calling for "rais[ing] a memorial" at the dam "in honour" of the workers. The dam was completed by the end of 1963. Successive stages were completed by the early 1970s. Initially, the construction of the dam was started by Sir Louis Dane, the Lieutenant Governor of Punjab. But the project got delayed and was restarted soon after independence under the chief architect Rai Bahadur Kunwar Sen Gupta. It was financed entirely by the union government. The Control Board for the project included representatives from union government, and of the governments of Punjab, Patiala and East Punjab States Union, Rajasthan, Bilaspur and Himachal Pradesh. The organisation evolved for the purpose of design and construction was divided into three parts. The Designs Directorate provided the designs and drawings. The Construction and Plant Design Directorate was to look after its execution and installing of the plant, while the Directorate of Inspection and Control ensured that the specifications are accorded to safety requirements were met. In October 1963, at the ceremony to mark the dedication of the Bhakra–Nangal project to the nation, Prime Minister Nehru said, "This dam has been built with the unrelenting toil of man for the benefit of mankind and therefore is worthy of worship. May you call it a Temple or a Gurdwara or a Mosque, it inspires our admiration and reverence". On 22 October 2013, the Government of India approved the release of a commemorative stamp to mark the 50th anniversary of the Bhakra Dam. As how successful India was at that time that it was the only dam in Asia which could produce 1500 MW power. Also, these are multipurpose projects.

- **Features:** The dam, at 741 ft (226 m), is one of the highest gravity dams in the world (compared to USA's largest Oroville Dam at 770 ft). The 166 km2 Gobindsagar Reservoir, named after Guru Gobind Singh, is created by this dam which is the third largest reservoir in India the first being Indira Sagar Dam and second Nagarjuna Sagar Dam. The river Saltuj used to flow through a narrow gorge between two hills, Naina Devi ki dhar and Ramgarh ki dhar, and the site was chosen to dam the river. The large map shows the location of the original Bhakra village that was submerged in the lake formed behind the dam.

Bhakra dam was part of the larger multipurpose Bhakra Nangal Project whose aims were to prevent floods in the Satluj-Beas river valley, to provide irrigation to adjoining states and also to provide hydro-electricity. It also became a tourist spot for the tourists during later years because of its huge size and uniqueness. It also has four spillway gates that are only used when the reservoir exceeds the maximum allowed level. Nangal dam is is a barrage dam that is 10 km downstream of Bhakra dam.

a) **Irrigation:** The dam holds excess waters during the monsoon and provides a regulated release during the year. It also prevents damage due to monsoon floods. The Bhakra Canal fed by this dam provides irrigation to 10 million acres of (40,000 km2) fields in Punjab, Haryana, and Rajasthan

Water flows from Bhakra Dam downstream Nangal dam where it is controlled and released into Nangal Hydel Channel that later becomes Bhakra Main Line after Ganguwal and Kotla power plants. The Bhakra main line is a canal that mostly supplies irrigation water to the state of Haryana.

b) **Electricity Generation:** Bhakra Dam has ten power generators with five on each side. Generators for the left power house were originally supplied by Hitachi, Japan and upgraded to the present capacity by Sumitomo, Hitachi and Andritz. Generators for the right side were originally supplied by Soviet Union and later upgraded to the present capacity by Russia. The two power houses have a total capacity of 1325 MW. The left power house contain 3 x 108 MW and 2 x 126 MW Francis turbines while the right has 5 x 157 MW.

The power generated at Bhakra Dam is distributed among partner states of Himachal Pradesh, Punjab, Haryana , Rajasthan, Chandigarh and Delhi.

Three additional power plants are on the two canals Nangal Hydel Channel and Anandpur Sahib Hydel Channel that originate from Nangal dam. Their generation capacities are: Ganguwal - 77.65 MW, Kotla - 77.65 MW and Anandpur - 134 MW.

c) **Fishing :** The reservoir of the Dam, Gobind Sagar, homes fishes of different species including endangered Mahseer. Commercial fishing by Local fisherman is also common in Gobind Sagar.

d) **Tourism:** Bhakra dam is also a major attraction for tourists. The place is also provided with an opportunity to try water sports at the Gobind Lake, an artificial lake formed on river Sutlej.
Tourist can also experience jungle safari, nearby wildlife sanctuary and visit the temple of Naina Devi.

- **Management :** Bhakra Beas Management Board (BBMB) was constituted in 1966 for the administration, maintenance and operation of Bhakra Nangal Project from 1 October 1967. It manages the operation of both the dams. Its members are appointed by the government of India and by the states of Punjab, Haryana, Rajasthan, Himachal Pradesh, Delhi, and Chandigarh.

Bhakra Management Board was renamed Bhakra Beas Management Board (BBMB) on 15 May 1976 to also manage dams on the river Beas. Since then the Bhakra Beas Management Board is engaged in the regulation of the supply of water and power from Bhakra Nangal Project and Beas Projects to the states of Punjab, Haryana, Rajasthan, Himachal Pradesh, Delhi, and Chandigarh government.

The Bhakra Beas Management Board regulates, operates and manages Bhakra Dam, Dehar Hydroelectric Project, Pong dam, Ganguwal and Kotla power stations.

2. Vyas Project –

- **Introduction :** The Pong Dam, also known as the Beas Dam, is an earth-fill embankment dam on the Beas River in the state of Himachal Pradesh, India, just upstream of Talwara. The purpose of the dam is water storage for irrigation and hydroelectric power generation. As the second phase of the Beas Project, construction on the dam began in 1961 and was completed in 1974. At the time of its completion, the Pong Dam was the tallest of its type in India. The lake created by the dam, Maharana Pratap Sagar, became a renowned bird sanctuary.

- **Background :** The idea for a dam on the Beas at the Pong site was first proposed in 1926 and subsequent surveys of the Indus River and its tributaries were ordered by the Punjab Government in 1927. Interest in the dam declined after the report deemed the project difficult because of flood waters. In 1955, geological and hydrological studies were carried out on the Pong site and an embankment design was recommended. In 1959, extensive studies were carried out and recommended an embankment dam with a gravity section. A final design was issued and construction began in 1961 on the dam which was called Beas Project Unit II - Beas Dam. The Pandoh Dam 140 km (87 mi) upstream being the Beas Project Unit I. It was completed in 1974 and the power station was later commissioned between 1978 and 1983. About 150,000 people were displaced by the dam's large reservoir under a poorly planned and executed relocation program.

- **Design:** The Pong Dam is a 133 m (436 ft) tall and 1,951 m (6,401 ft) long earth-fill embankment dam with a gravel shell. It is 13.72 m (45 ft) wide at its crest and 610 m (2,001 ft) wide at its base. The total volume of the dam is 35,500,000 m^3 (46,432,247 cu yd) and its crest sits at an elevation of 435.86 m (1,430 ft) above sea level. The dam's spillway is located on its southern bank and is a chute-type controlled by six radial gates. Its maximum discharge capacity is 12,375 m^3/s (437,019 cu ft/s). The reservoir created by the dam, Maharana Pratap Sagar, has a gross capacity of 8,570,000,000 m^3 (6,947,812 acre·ft) of which 7,290,000,000 m^3 (5,910,099 acre·ft) is active (live) capacity. The reservoir has a normal elevation of 426.72 m (1,400 ft) and catchment area of 12,560 km^2 (4,849 sq mi). The reservoir reaches from the dam to 41.8 km (26 mi) upstream in length and covers a surface of 260 km^2 (100 sq mi). Located at the base of the dam is its power house. It is supplied with water via three penstocks which each meet a 66 MW Francis turbine-generator located inside the Bhatoli phakorian. The dam's elevation to the power house provides a maximum of 95.1 m (312 ft) in hydraulic head.

3. Hirakud Project –

- **Introduction:** Hirakud Dam is built across the Mahanadi River, about 15 kilometers (9 mi) from Sambalpur in the state of Odisha in India. It is the longest earthen dam in the world. Behind the dam extends a lake, Hirakud Reservoir, 55 km (34 mi) long. It is one of the first major multipurpose river valley projects started after India's independence.

- **Constructions History:** On 15 March 1946, Sir Hawthorne Lewis, the Governor of Odisha, laid the foundation stone of the Hirakud Dam. A project report was submitted to the government in June 1947. Pandit Jawaharlal Nehru laid the first batch of concrete on 12 April 1948.

In 1952, Mazumdar Committee was appointed by the government to oversee the soundness and technical feasibility of the project. The committee has envisaged costs of ₹ 92.80 crore for the project and that the construction of the main dam would be complete by June 1955. It also said that by 1954–55 a total of 1,347,000 acres (545,000 ha) would be irrigated and that 48,000 kW of electric power would be generated. However, the dam was completed in 1953 and was formally inaugurated by Prime Minister Jawaharlal Nehru on 13 January 1957. The total cost of the project was ₹1,000.2 million (equivalent to ₹85 billion or US$1.1 billion in 2020) in 1957. Power generation along with agricultural irrigation started in 1956, achieving full potential in 1966.



- **Structure:** The Hirakud Dam is a composite structure of earth, concrete and masonry. 10 km (6.2 mi) north of Sambalpur, it is the longest major earthen dam in the world, measuring 25.8 km (16.0 mi) including dykes, and stands across the river spandan. The main dam has an overall length of 4.8 km (3.0 mi) spanning between two hills; the Laxmidungri on the left and the Chandili Dunguri on the right. The dam is flanked by 21 km (13 mi) of earthen dykes on both the left and right sides, closing the low saddles beyond the adjoining hills. The dam and dykes together measure 25.8 km (16.0 mi).It also forms the biggest artificial lake in India,[dubious – discuss] with a reservoir holding 743 km2 (287 sq mi) at full capacity, with a shoreline of over 639 km (397 mi). There are two observation towers on the dam one at each side. One is "Gandhi Minar" and the other one is "Jawahar Minar". Both the observation towers present extensive views of the lake.

a) **Power House :** The dam supports two different hydroelectric power houses. Power House I is located at the base (toe) of the main dam section and contains 3 x 37.5 MW Kaplan turbine and 2 x 24 MW Francis turbine generators for an installed capacity of 259.5 MW. Power Station II is located 19 km (12 mi) southeast of the dam 21°21′10″N 83°55′00″E at Chipilima. It contains 3 x 24 MW generators. The entire installed capacity of the dam's power houses is 347.5 MW. Power House I and II were built in three stages. During stage I, four generators were installed at PH I and in stage II, the power channel two and Power House II was constructed. All three generators were installed at PH

II along with two more at PH I by 1963. Between 1982 and 1990, the seventh and final generator was installed at PH I.

- **Purpose:** In the upper drainage basin of the Mahanadi River, centered on the Chhattisgarh Plain, periodic droughts contrast with the situation in the lower delta region where floods may damage crops. The dam was constructed to help alleviate these problems by creating a reservoir and controlling river flow through the drainage system. The dam regulates the flow of the Mahanadi River and produces hydroelectricity through several hydroelectric plants.
  The dam helps control floods in the Mahanadi delta and irrigates 75,000 km2 (19×106 acres) of land. Hydroelectricity is also generated. The Hirakud Dam regulates 83,400 km2 (20.6×106 acres) of Mahanadi's drainage. The reservoir has a storage capacity of 5.818 km3 (1.396 cu mi) with gross of 8.136 km3 (1.952 cu mi).
  It drains an area of 133,090 km2 (32.89×106 acres), more than twice the area of Sri Lanka.
  The project provides 1,556 km2 (384,000 acres) of kharif and 1,084 km2 (268,000 acres) of rabi irrigation in districts of Sambalpur, Bargarh, Bolangir, and Subarnpur. The water released by the power plant irrigates another 4,360 km2 (1.08×106 acres) of CCA in Mahanadi delta. The dam can generate up to 307.5 MW of electrical power through its two power plants at Burla, on the dam's right bank and Chiplima, 22 km (14 mi) downstream from the dam. In addition, the project provides flood protection to 9,500 km2 (2.3×106 acres) of delta area in district of Cuttack and Puri.
  Chiplima has gained prominence as the second hydroelectric project of the Hirakud Dam. A natural fall of 80 to 120 ft (24 to 37 m) in the river Mahanadi is used to generate electricity. The place is mostly inhabited by fishermen, whose deity Ghanteswari is revered in the neighboring area. The state livestock breeding farm and agricultural farm are located here.

a) **Cannel system :** Hirakud Dam has three canals, namely Bargarh Main Canal, Sason Canal and Sambalpur Canal. Bargarh Main canal has a water discharge rate of 4,000 cubic feet per second (110 m3/s).

b) **Industrial Use :** Water from Hirakud Dam at a later stage was allocated to various industries, primarily for mineral processing and coal fired thermal power plants in Jharsuguda and Sambalpur districts.

- **Issues :**

  a) **Situation :** Statistics published by the dam authority show the water holding capacity of the dam has been reduced by 28% due to siltation.

  b) **Water Conflict:** A major conflict for water was reported when over 30,000 farmers gathered around the dam making a human chain, protesting against the allocation of water to the industries and there being no water for the canal system due to a low water level.

  c) **Inter basin water Transfer:** There have been plans for inter-basin water transfer, as per plans of the water resource dept of Odisha as part of India's ambitious Indian Rivers Inter-link.

- **Lost Temples :** These are remnants of temples submerged after the dam was completed in 1957. In the summer season, the receding water of the dam makes the structures become visible. The hidden treasures have finally caught the attention of historians, and steps are being taken to understand the historical significance of these temples, which periodically go under water, only to resurface again. Many temples have been destroyed after 58 years of underwater existence. However, some remain intact.

  Interest in these lost temples has been rekindled after two stones, etched with writing ('Shila Lekha'), were recovered from what is believed to be the Padmaseni temple of submerged Padmapur village. The temples located inside the reservoir area were part of the then Padmapur, one of the oldest and most populous in the region prior to the dam construction. More than 200 temples were submerged by the dam, nearly 150 temples have either perished or are underwater and about 50 are visible during summer. The lost temples present excellent opportunities for scuba diving enthusiasts to explore the underbelly of Hirakud Dam. The temple are visible to visitors on boat only during the summer months of May and June.

- **Cattle Island:** Cattle Island is located in one of the extreme points of Hirakud Reservoir, a natural wonder. Completely inhabited by wild animals, it is without any trace of humans. It is near Kumarbandh village of Belpahar-Banharpali range which is about 90 km (56 mi) from Sambalpur. It can be reached by launch from Hirakud Dam; it is closer by 10 km (6.2 mi) via the river. The island is a submerged hill, and before the construction of Hirakud Dam, it was a developed village. During the resettlement period, villagers left some of their cattle behind; when the dam construction was over, the cattle settled on the hilltop. With the passage of time, the nearby area filled up with the reservoir water, turning the hilltop into an island. Being away from mankind, the cattle are now wild, very swift and not easily caught. Living on a hilltop with dense forest, they are larger than tame cattle, and almost all are white in color. Nearby residents attempt to capture these animals from time to time, but these hunts are rarely successful. Though descended from tame cattle, these animals provide a contrasting picture of this breed of animal returning to life in the wild.

- **Wildlife:** The dam with the channel provides an ideal environment for the wildlife. The Debrigarh wildlife sanctuary is located here. Several species of migratory birds visit the reservoir during winter. Nearly 20-25 species of birds are seen in the reservoir and common among them are common pochard, red-crested pochard, great crested grebe and several others.

  People effected by the Dam construction:

  The main purpose of the Hirakud Dam was to check the massive floods that were affecting a large part of coastal Odisha. But, the construction of the dam greatly affected the natives of the western part of Odisha. Nearly 150,000 people were affected by the Hirakud project and nearly 22,000 families were displaced.

  In the original estimate, an amount of ₹120 million (equivalent to ₹12 billion or US$150 million in 2020) was provided for payment of compensation to the affected people. After revision, the amount was reduced to ₹95 million (equivalent to ₹9.2 billion or US$120 million in 2020) and the total compensation paid to the people was, in reality, only ₹33.2 million (equivalent to ₹3.2 billion or US$42 million in 2020). A large number of families were evacuated from their hearth and homes without compensation from 1956 onwards.

4. Chambal Project: -

- **Introduction:** The Chambal River is a tributary of the Yamuna River in Central and Northern India, and thus forms part of the greater Gangetic drainage system. The river flows north-northeast through Madhya Pradesh, running for a time through Rajasthan then forming the boundary between Rajasthan and Madhya Pradesh before turning southeast to join the Yamuna in Uttar Pradesh state

  It is a legendary river and finds mention in ancient scriptures. The perennial Chambal originates at Janapav, south of Mhow town, near Manpur, Indore, on the south slope of the Vindhya Range in Madhya Pradesh. The Chambal and its tributaries drain the Malwa region of northwestern Madhya Pradesh, while its tributary, the Banas, which rises in the Aravalli Range, drains southeastern Rajasthan. It ends a confluence of five rivers, including the Chambal, Kwari, Yamuna, Sind, Pahuj, at Pachnada near Bhareh in Uttar Pradesh state, at the border of Bhind and Etawah districts.

  The Chambal River is considered pollution free, and hosts a diverse riverine faunal assemblage including 2 species of crocodilians – the mugger and gharial, 8 species of freshwater turtles, smooth-coated otters, gangetic river dolphins, skimmers, black-bellied terns, sarus cranes and black-necked storks, amongst others. Charmanwati' (also spelled Charmanvati) is a river mentioned in the epic Mahabharata. It is believed that the ancient name

of Chambal River was Charmanvati, meaning the river on whose banks leather is dried. In due course of time, this river became famous as the river of 'charman' (skin) and was named as Charmanvati

The Sanskrit epic Mahabharata, refers to the Chambal river as the Charmanyavati: originating in the blood of thousands of animals and cows sacrificed by the Aryan King Rantideva

"So large was the number of animals sacrificed in the Agnihotra of that king that the secretions flowing from his kitchen from the heaps of skins deposited there caused a veritable river which from this circumstance, came to be called the Charmanwati.

- **Origin , Drainage & Mouth** : The 1,024 kilometres (636 mi) long Chambal River originates from the Bhadakla Falls in Janapav Hills on the northern slopes of the Vindhyan escarpment near Mandav,67.5 kilometres (41.9 mi) South-West of Mhow in Indore District, Madhya Pradesh state, at an elevation of about 843 metres (2,766 ft). The river flows first in a northerly direction through Madhya Pradesh (M.P.) for about 376 kilometres (234 mi) and then in a generally north-easterly direction for 249 kilometres (155 mi) through Rajasthan. The Chambal flows for another 216 kilometres (134 mi) between M.P. and Rajasthan and a further 150 kilometres (93 mi) between M.P. and Uttar Pradesh(U.P.). It enters U.P. and flows for about 33 kilometres (21 mi) before joining the Yamuna River in Jalaun District at an elevation of 123 metres (404 ft), to form a part of the greater Gangetic drainage system.

  From its source down to its junction with the Yamuna, the Chambal has a fall of about 747.25 metres (2,451.6 ft). Of this, around 305 metres (1,001 ft) is within the first 26 kilometres (16 mi) reach from its source. It falls for another 195 metres (640 ft) in the next 312 kilometres (194 mi), where it enters the gorge past the Chaurasigarh Fort. During the next 157 kilometres (98 mi) of its run from the Chaurasigarh Fort to Kota city, the bed falls by another 91 metres (299 ft). For the rest of its 529 kilometres (329 mi) run, the river passes through the flat terrain of the Malwa Plateau and later the Gangetic Plain with an average gradient of 0.21 m/km.

  The Chambal is a rainfed catchment with a total drained area up to its confluence with the Yamuna of 144,591 square kilometres (55,827 sq mi). The drainage area resembles a rectangle up to the junction of the Parvathi and Banas Rivers with the Chambal flowing along its major axis. The Chambal Basin lies between latitudes 22° 27' N and 27° 20' N and longitudes 73° 20' E and 79° 15' E. On its south, east and west, the basin is bounded by the Vindhyan mountain ranges and on the north-west by the Aravallis. Below the confluence of the Parvathi and Banas, the catchment becomes narrower and elongated. In this reach, it is bounded by the Aravalli mountain ranges on the North and the Vindhyan hill range on the south.

The Vindhyan scarps, in the northwest, flank the left bank of the Chambal, and subsequently, is mainly drained by it. The Chambal rising within about 16 km of the Narmada river, appears as a consequent on the Mesozoic surface, superimposed on the scarps, and cuts straight through them, with subsequent tributaries on the softer shales. The River Chambal and its tributaries Kali Sindh and Parbati have formed a triangular alluvial basin, about 200–270 metres (660–890 ft) above the narrow trough of the lower Chambal in Kota. It is a typical anterior-drainage pattern river, being much older than the rivers Yamuna and Ganges, into which it eventually flows.

The tributaries of the Chambal include Shipra, Choti Kalisindh, Sivanna, Retam, Ansar, Kalisindh, Banas, Parbati, Seep, Kuwari, Kuno, Alnia, Mej, Chakan, Parwati, Chamla, Gambhir, Lakhunder, Khan, Bangeri, Kedel and Teelar.

According to Crawford (1969), the Chambal River valley is part of the Vindhyan system which consists of massive sandstone, slate and limestone, of perhaps pre-Cambrian age, resting on the surface of older rocks. Hillocks and plateaus represent the major landforms of the Chambal valley. The Chambal basin is characterised by an undulating floodplain, gullies and ravines. The Hadauti plateau in Rajasthan occurs in the upper catchment of the Chambal River to the southeast of the Mewar Plains. It occurs with the Malwa plateau in the east. Physio graphically, it can be divided into Vindhyan scarp land and Deccan Lava (Malwa) plateau. According to Heron (1953), the eastern pedi plain, occurring between the Vindhyan plateau and the Aravalli hill range, contains a thin veneer of Quaternary sediments, reworked soil and river channel fills. At least two erosional surfaces can be recognised within the pediplain are the Tertiary age. The Vindhyan upland, the adjoining Chambal valley and the Indo-Gangetic alluvial tract (older alluvium) are of Pleistocene to Sub-recent age. Badland topography is a characteristic feature of the Chambal valley, whereas kankar has extensively developed in the older alluvium.

- **Vegetation:** The area lies within the semi-arid zone of north-western India at the border of Madhya Pradesh, Rajasthan and Uttar Pradesh States, and the vegetation consists of ravine, thorn forest, a sub-type of the Northern Tropical Forests (Sub-group 6B/C2 of the revised classification of Champion & Seth, 1968). This sub-type typically occurs in less arid areas with 600–700 mm rainfall. Limited examples of Saline/Alkaline Babul Savannah ($5E/8_b$), a type of Northern Tropical Dry Deciduous Forest, also occurs. Evergreen riparian vegetation is completely absent, with only sparse ground-cover along the severely eroded river banks and adjacent ravine lands.

The semiarid tract in Madhya Pradesh is represented by Chambal catchment extending up to Narmda and Betla Rivers. Over 1000 flowering plants have bean reported including Anogeissus latifoia, A. pendula, Tectona grandis, Lannea coromandelica, Diospyros melanoxylon, Sterculia urens, Mitragyna parviflora, Butea monosperma, Emblica officinalls, Boswellia serrata, Bridelia squamosa and Hardwickia binata. Species composition at shrub and ground layer is similar to that of semiarid regions of Gujarat. A few climbers of this area include species of Rhynchosia, Atylosia, Cocculus, Cissampelos, Ipomoea, Pergularia daemia, Pueraria tuberosa and Tinospora cordifolia.

Thorny bushes or small trees commonly found in this area include Capparis deciduas, Capparis sepiaria, Balanites aegyptiaca, Acacia senegal, A. nilotica, A. leucophloea, Prosopis juliflora, Butea monosperma, Maytenus emarginata, Tamarix sp., Salvadora persica, S. oleoides, Crotalaria medicaginea, C. burhia, Clerodendrum phlomidis, Calotropis procera, Xanthium indicum and Leptadenia pyrotechnica associated with climbers such as Maerua oblongifolia, Pergularia daemia, Ceropegia bulbosa, herbs e.g., Argemone mexicana, Farsetia hamiltonii, Tephrosia purpurea, Cleome viscosa, Tribulus terrestris, Glinus lotoides, Sericostoma pauciflorum, Rivea sp., Ipomoea sp., Pedalium murex, Sesamum mulayanum, Lepidagathis sp, Boerhavia diffusa, Chrozophora sp., and grasses like Cyprus sp., Fimbristylis sp., Brachiaria sp., Cenchrus sp., Dichanthium sp., etc.

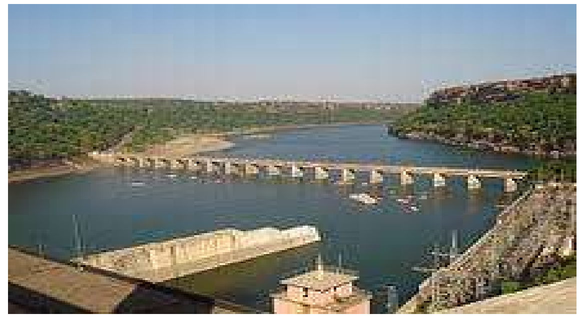
- **National Chambal Sanctuary:** The National Chambal Sanctuary lies between 24°55' to 26°50' N and 75°34' to 79°18'E in Dholpur. It consists of the large arc described by the Chambal between Jawahar Sagar Dam in Rajasthan and the Chambal-Yamuna confluence in Uttar Pradesh. Over this arc, two stretches of the Chambal are protected as the National Chambal Sanctuary status - the upper sector, extending from Jawahar Sagar Dam to Kota Barrage, and the lower sector, extending from Keshoraipatan in Rajasthan to the Chambal-Yamuna confluence in Uttar Pradesh .

  The sanctuary was gazetted 'in order to facilitate the restoration to "ecological health" of a major north Indian river system and provide full protection for the gravely endangered gharial (Gavialis gangeticus).

  Administrative approval of the Government of India for the establishment of the National Chambal Sanctuary was conveyed in Order No. 17-74/77-FRY (WL) dated 30 September 1978. The Sanctuary has sanctuary status declared under Section 18(1) of the Wildlife Protection Act, 1972. Since such a declaration is carried out by individual states for territory falling within their jurisdiction, there are three separate notifications covering the National Chambal Sanctuary - the Madhya Pradesh portion was gazetted in the Government of Madhya Pradesh Notice No. F.15/5/77-10(2) dated 20 December 1978, the Uttar Pradesh portion was gazetted in the Government of Uttar Pradesh Notice No. 7835/XIV-3-103-78 dated 29 January 1979 and the Rajasthan portion was gazetted in the Government of Rajasthan Notice No.F.11(12)Rev.8/78 dated 7 December 1979.

- **Dams on the Cannel:** In a stretch of 96 km, from km 344 to km 440 from its source, the Chambal flows through a deep gorge, while lower down, there are wide plains. The Gandhisagar Dam is located near the center of this reach. As there is a deep gorge immediately upstream of the dam, the reservoir has a large storage capacity despite its comparatively low height.

For the next 48 km, the river flows through the Kundal Plateau, and the Rana Pratap Sagar Dam is constructed at the lower end of this. The topography permits fairly good storage upstream of the dam. Further down, the Jawahar Sagar Dam is located in the middle of the Kota gorge. The Kota Barrage is located near Kota town, where the river emerges from the gorge section into the plateau. The total area draining the Kota Barrage is 27,319 km^2.



The Chambal River is used for hydropower generation at Gandhi Sagar dam, Rana Pratap Sagar dam and Jawahar Sagar Dam and for annual irrigation of 5668.01 square kilometres in the commands of the right main canal and the left main canal of the Kota Barrage.

The Gandhi Sagar dam is the first of the four dams built on the Chambal River, located on the Rajasthan-Madhya Pradesh border. It is a 64 metre high masonry gravity dam, with a live storage capacity of 6,920 MCM (million cubic metres) and a catchment area of 22,584 km^2, of which only 1,537 km^2 is in Rajasthan. The dam was completed in the year 1960. The hydro-power station comprises five generating units of 23 MW capacity each. The water released after power generation is used for irrigation through Kota Barrage.

The Rana Pratap Sagar dam is a dam located 52 km downstream of Gandhi Sagar dam on across the Chambal River near Rawatbhata in Chittorgarh district in Rajasthan. It was completed in the year 1970 and it is the second in the series of Chambal Valley Projects. It is 54 meters high. The power house is located on the left side of the spillway and consists of 4 units of 43 MW each, with firm power generation of 90 MW at 60% load factor. The total catchment area of this dam is 24,864 km^2, of which only 956 km^2 are in Rajasthan. The free catchment area below Gandhi Sagar dam is 2,280 km^2. The live storage capacity is 1,566 MCM.

The Jawahar Sagar Dam is the third dam in the series of Chambal Valley Projects, located 29 km upstream of Kota city and 26 km downstream of Rana Pratap Sagar dam. It is a concrete gravity dam, 45 meter high and 393 m long, generating 60 MW of power with an installed capacity of 3 units of 33 MW. The work was completed in 1972. The total catchment area of the dam is 27,195 km^2, of which only 1,496 km^2 are in Rajasthan. The free catchment area below Rana Pratap Sagar dam is 2,331 km^2.

The Kota Barrage is the fourth in the series of Chambal Valley Projects, located about 0.8 km upstream of Kota City in Rajasthan. Water released after power generation at Gandhi Sagar dam, Rana Pratap Sagar dam and Jawahar Sagar Dams, is diverted by Kota Barrage for irrigation in Rajasthan and in Madhya Pradesh through canals on the left and the right sides of the river. The work on this dam was completed in 1960. The total catchment area of Kota Barrage is 27,332 km^2, of which the free catchment area below Jawahar Sagar Dam is just 137 km^2. The live storage is 99 MCM. It is an earthfill dam with a concrete spillway. The right and left main canals have a headworks discharge capacity of 188 and 42 m^3/s, respectively. The total length of the main canals, branches and distribution system is about 2,342 km, serving an area of 2,290 km^2 of CCA. The Barrage operates 18 gates to control flow of flood and canal water downstream, and serves as bridge between parts of Kota on both side of the river.

- **Mythology:** The ancient name of the Chambal was Charmanvati, meaning the river on whose banks leather is dried. In due course of time, this river became famous as the river of 'charman' (skin) and was named as Charmanvati.

  The epic Sanskrit narrative the Mahabharata, refers to the Chambal river as the Charmanyavati : originating from the blood of thousands of animals sacrificed by the Aryan King Rantideva.

  "So large was the number of animals sacrificed in the Agnihotra of that king that the secretions flowing from his kitchen from the heaps of skins deposited there caused a veritable river which from this circumstance, came to be called the Charmanwati.

  Charmanwati was the southern boundary of Panchala Kingdom. King Drupada ruled the southern Panchalas up to the bank of the Charmanwati river

  According to folklore the Chambal area was part of Shakuni's kingdom and the dice-game played thereabouts. After the attempted disrobing of Draupadi (the daughter of Drupada) she cursed any one who would drink the water of the Charmanwati river. Thus it is believed that due to the curse by Draupadi, have helped the Chambal to survive unpolluted by man, and its many animal inhabitants to thrive relatively untouched. The Chambal remains one of India's most pristine rivers.

5. Tehri Dam Project:

- **Introduction :**

  With a height of 260.5 m (855 ft) Tehri Dam is the tallest dam in India. It is currently ranked No 10 on the List of Tallest Dams in the world. With a total planned installed capacity of 2400 MW, it's the biggest Hydroelectric power plant in India.[1] It is a multi-purpose rock and earth-fill embankment dam on the Bhagirathi River in New Tehri, Tehri Garhwal district in Uttarakhand, India. It is the primary dam of the THDC India Ltd. and the Tehri hydroelectric complex. Phase 1 was completed in 2006. The Tehri Dam withholds a reservoir for irrigation, municipal water supply and the generation of 1,000 megawatts (1,300,000 hp) of hydroelectricity. The dam's 1,000 MW variable-speed pumped-storage scheme is currently under construction with expected commissioning in 2025. This dam project was successfully constructed near Tehri(Uttarakhand) on the meeting place of Bhagirathi and Bhilangana rivers. It is one of the most important hydropower projects of India from which Uttarakhand and Uttar Pradesh are getting benefits.

- **History :** A preliminary investigation for the Tehri Dam Project was completed in 1961 under Jawaharlal Nehru's ministry and its design was completed in 1972 with a 600 MW capacity power plant based on the study. Construction began in 1978 after feasibility studies but was delayed due to financial, environmental and social impacts.

  In 1986, technical and financial assistance was provided by the USSR, but this was interrupted years later with political instability. India was forced to take control of the project and at the first, it was placed under the direction of the Irrigation Department of Uttar Pradesh. However, in 1988 the Tehri Hydro Development Corporation was formed to manage the dam and 75% of the funding would be provided by the federal government, 25% by the state. Uttar Pradesh would finance the entire irrigation portion of the project.

- **Technical Description:** Tehri Dam is a **260.5 m (855 ft)** high rock and earth-fill embankment dam. Its length is 575 m (1,886 ft), crest width 20 m (66 ft), and base width 1,128 m (3,701 ft). The dam creates a reservoir of 4.0 cubic kilometres (3,200,000 acre·ft) with a surface area of 52 km^2 (20 sq mi). The installed hydro capacity is 1,000 MW along with an additional 1,000 MW of pumped storage hydroelectricity. The lower reservoir for the pumped-storage plant is created by the Koteshwar Dam downstream.

  The Tehri Dam and the Tehri Pumped Storage Hydroelectric Power Plant are part of the Tehri Hydropower Complex which also includes the 400 MW Koteshwar Dam. Tehri pumped storage plant (4 X 250 MW) has variable speed features which can optimize the round trip efficiency under varying water levels in its reservoirs.[4] Power is distributed to Uttar Pradesh, Uttarakhand, Punjab, Delhi, Haryana, Jammu and Kashmir, Chandigarh, Rajasthan and Himachal Pradesh . The complex will afford irrigation to an area of 270,000 hectares (670,000 acres), irrigation stabilization to an area of 600,000 hectares (1,500,000 acres), and a supply of 270 million imperial gallons (1.2×10^6 m^3) of drinking water per day to the industrialized areas of Delhi, Uttar Pradesh and Uttarakhand.

- **Environmental Issues:** The Tehri Dam has been the object of protests by environmental organizations and local people of the region. Virendra Dutt Saklani, lawyer and founder of the Anti-Tehri Dam Struggle Committee, was quick to point out the consequences associated to the large project. Environmental activist Sunderlal Bahuguna led the Anti-Tehri Dam movement from 1980s till 2004. The protest was against the displacement of town inhabitants and environmental consequence of the weak ecosystem.

  In addition to the human rights concerns, the project has spurred concerns about the environmental consequences of locating such a large dam in the fragile ecosystem of the Himalayan foothills. There are further concerns regarding the dam's geological stability. The Tehri dam is in the Central Himalayan Seismic Gap, a major geologic fault zone. This region was the site of a 6.8 magnitude earthquake in October 1991, with an epicenter 53 km (33 mi) from the dam. Dam proponents claim that the complex is designed to withstand an earthquake of 8.4 magnitude, but some seismologists say that earthquakes with a magnitude of 8.5 or more could occur in this region. Were such a catastrophe to occur, the potentially resulting dam-break would submerge numerous towns downstream, whose populations total near half a million.

  The relocation of more than 100,000 people from the area has led to protracted legal battles over resettlement rights and, ultimately, resulted in the project's delayed completion.

  Since 2005, filling of the reservoir has led to the reduced flow of Bhagirathi water from the normal 1,000 cu ft/s (28 m^3/s) to a mere 200 cu ft/s (5.7 m^3/s). This reduction has been central to local protest against the dam, since the Bhagirathi is considered part of the sacred Ganges whose waters are crucial to Hindu beliefs. At some points during the year, the tampering with Bhagirathi waters means this tributary stops flowing. This has created resentments among many Hindus, who claim that the sanctity of the Ganges has been compromised for the generation of electricity. The officials say that when the reservoir is filled to its maximum capacity the flow of the river will again become normal. In spite of concerns and protestation, operation of the Tehri Dam continues.

- **NTPC Limited Takeover:** On 21 November 2019, the Government of India approved the take over of Tehri Hyrdo Development Corporation (THDC) by NTPC Limited.

6. Nagarjuna Sagar Project:

- **Introduction:** Nagarjuna Sagar Dam is a masonry dam across the Krishna River at Nagarjuna Sagar which straddles the border between Nalgonda district in Telangana and Palnadu district in Andhra Pradesh. The dam provides irrigation water to the Nalgonda, Suryapet, Krishna, NTR, Bapatla, Eluru, Palnadu, Khammam, West Godavari, Guntur, and Prakasam districts along with electricity generation.

  Constructed between 1955 and 1967, the dam created a water reservoir with gross storage capacity of 11.472 billion cubic metres (405.1×10^9 cu ft). The dam is 490 feet (150 m) tall from its deepest foundation and 0.99 miles (1.6 km) long with 26 flood gates which are 42 feet (13 m) wide and 45 feet (14 m) tall. It is jointly operated by Andhra Pradesh and Telangana

  Nagarjuna Sagar Dam was the earliest in a series of large infrastructure projects termed as "modern temples" initiated for achieving the Green Revolution in India. It is also one of the earliest multi-purpose irrigation and hydroelectric projects in India.

  Nagarjuna Sagar is the biggest masonry Dam in India which is located in **Telangana** state. This dam project was constructed across the **Krishna** river. Telangana and Andhra Pradesh are beneficial states of this project. The general objectives of the are **water reservoir**, irrigation, hydropower, drinking water (especially for Guntur).

- **History:** The Nizam made the British engineers begin the survey work for this dam across the Krishna River in the year 1903.

  The project's construction was officially inaugurated by Prime Minister Jawaharlal Nehru on 10 December 1955 and proceeded for the next twelve years. Raja Vasireddy Ramagopala Krishna Maheswara Prasad, popularly known as late Muktyala Raja, was instrumental in the construction of the Nagarjuna Sagar Dam through active political lobbying and the donation of one hundred and ten million GBP in 1952 and fifty-five thousand acres of land. It was the tallest masonry dam in the world at that time, built entirely with local know-how under the engineering leadership of Kanuri Lakshmana Rao.

  The reservoir water was released into the left and right bank canals by Prime Minister Indira Gandhi on August 4, 1967. Construction of the hydroelectric power plant followed, with power generation increasing between 1978 and 1985 as additional units came into service. In 2015, diamond jubilee celebrations of project's inauguration were held, alluding to the prosperity the dam has ushered into the region.

  The construction of the dam submerged an ancient Buddhist settlement, Nagarjunakonda, which was the capital of the Ikshvaku dynasty in the 1st and 2nd centuries and the successors of the Satavahanas in the Eastern Deccan. Excavations there yielded 30 Buddhist monasteries as well as artwork and inscriptions of historical importance. Prior to the reservoir's flooding, monuments were dug up and relocated. Some were moved to Nagarjunakonda, now an island in the middle of the reservoir. Others were moved to the nearby mainland village of Anupu.

- **Irrigation:** The right canal (Jawahar canal) is 203 km (126 mi) long with maximum 311.5 cumecs capacity and irrigates 1.117 million acres (4,520 km^2) of land in Guntur and Prakasam districts. The left canal (Lalbahadur Shastri canal) is 179 km (111 mi) long with maximum 311.5 cumecs capacity and irrigates 1.008 million acres (4,080 km^2) of land in Nalgonda, Suryapet, Krishna, West Godavari and Khamman districts. The project transformed the economy of above districts. 54 villages (48 in Nalgonda and 6 in Guntur) were submersed in water and 24,000 people were affected. The relocation of the people was completed by 2007.

  Alimineti Madhava Reddy lift irrigation canal draws water from the Nagarjuna Sagar reservoir to irrigate 0.37 million acres (1,500 km^2) of land in Nalgonda district. This lift scheme with pump house located near Puttamgandi village on the left bank of Krishna river also supplies nearly 20 TMC water for the drinking water needs of Hyderabad city. Nearly 80% of the Nagarjuna Sagar water used in Hyderabad city is available for irrigation use in Nalgonda district in the form of regenerated water/treated sewage water. In addition, the high level flood flow canal drawing water from the left side shore of the reservoir also supplies irrigation water in Nalgonda district.

- **Power Generation :** The hydroelectric plant has a power generation capacity of 815.6 MW with 8 units (1x110 MW+7x100.8 MW). First unit was commissioned on 7 March 1978 and 8th unit on 24 December 1985. The right canal plant has a power generation capacity of 90 megawatts (120,000 hp) with 3 units of 30 megawatts (40,000 hp) each. The left canal plant has a power generation capacity of 60 megawatts (80,000 hp) with 2 units of 30 MW each. The tail pond is under advanced stage of construction to put to use the pumped storage features of 7 x 100.8 MW units. And it will be useful for the irrigation. Many times, it happens that power generation from the 150 MW canal based units is not optimised when the Nagarjunasagar reservoir is overflowing on its spillway and very less water is required for irrigation from the canals during the monsoon floods. Power generation from canal based hydro units can be optimised by running these units during the flooding period by releasing the water fully into the canals. The unwanted canal water can be released into the natural stream when it is crossing the major stream.

  Thus run off power can be generated from the water going down unutilised into the river by the canal based power units also.

  The water level in the Nagarjunasagar reservoir shall be maintained above the minimum level required for these units in most of the time by releasing water from the upstream Srisailam reservoir to optimise the power generation from the canal based units during dry season.

- **Tourism :** Nagarjunasagar Dam is one of the popular weekend getaways from Hyderabad. Thousands of tourists visit Nagarjunasagar when the dam gates are open in monsoon season (around September / October). Hotel Vijay Vihar, operated by Telangana Tourism is one of the best places for accommodation in Nagarjunasagar .

  There are several other places around Nagarjunasagar that can be visited as a one- day trip from Hyderabad.

  - Nagarjunakonda in Andhra Pradesh – Has to be reached by a boat from boating point operated by TSTDC or APTDC
  - Anupu in Andhra Pradesh
  - Ethipothala Falls near Macherla in Andhra Pradesh – The water released from the Nagarjuna Sagar right bank canal, the Chandravanka and Suryavanka streams keeps the water fall live or flowing during the rainy season.

- **Environmental Aspect:** The artificial lift irrigation based diversion of the river from its natural delta area into Nalgonda district caused erosion of the fluorine-rich volcanic rocks in Nalgonda and contaminated its groundwater supply. It also caused uncertain flows of water into the Krishna river delta area and a shrinkage of the natural wonder "The Kolleru Lake". The use of erosion resistant canals interfered with the natural silting process of a river to the deltas and created long-term ecological issues to the health of the delta lands. Reduced flows into the sea resulted in land salination and sea encroachment of coastal lands in Diviseema. The diversion of Krishna water for 200 km to Hyderabad resulted in massive evaporation losses especially in summer and reduced the size of Krishna river. Many forest preserves along the natural Krishna flow are now categorized as "completely degraded" forest areas. Krishna river once home to an ecological wonderland of fresh water fish and aquatic population is now completely depopulated. The river stopped being navigable since the year of Nagarjuna sagar construction.

- **Impact on Hyderabad Water Security :** Water planning for Hyderabad city started in 1920 with the tapping of Musi river for 15 Mgd. It progressed to tapping Esi (Himayat Sagar 1927 – 11mgd) and Manjira (1965–1993 – Majira and Singur dams) for another additional 130 Mgd. It took a huge leap during 1995–2004 with the commissioning of Krishna river water project (Phases I – III) at a total cost of over ten thousand crores to supply an additional 190Mgd to Hyderabad from Nagarjuna sagar away from the Krishna Delta and the Kolleru lake. The project incurs an additional evaporation and leakage loss of 64 Mgd. About 30% of the water naturally flowing to Krishna Delta before 1995 is now diverted to Hyderabad.

- **Tapping Dead Storage:** The left and right bank canals sill level is fixed at 490 feet (149 m) MSL to supply irrigation water to two million acres. The unutilized storage capacity is nearly 180 TMC below the canals sill/bed level.[19] Nagarjuna Sagar reservoir also meets the Krishna delta water

requirements to the extent of 80 TMC by letting water down stream into the river. Nearly 1.3 million acres (5,300 km^2) is irrigated under Krishna Delta Canals. There is a possibility to utilize most of this idle dead storage capacity to store the river flood water further and to use as carry over storage. Nearly 150 TMC idle storage up to 380 feet (116 m) MSL, can be used leaving 30 TMC for silt settlement. This is possible by installing Water Powered Pump (WPP) units at the base of the dam. It is technically feasible to generate power by the existing hydro turbines from lower head (75 to 50 meters) at lower frequency and the lower frequency power can be upgraded / converted to normal grid frequency (50 Hz) by installing HVDC converters before feeding power into the grid. The unused converter stations of HVDC Sileru–Barsoor transmission link can be relocated and utilised for this purpose. With minor modifications to the electrical systems of hydro power units, nearly 100 TMC water available in the dead storage of the reservoir can be put to use every year.
The reservoir dead storage water below the 125 m MSL can be released into the downstream river through the existing diversion tunnel which was in use to divert the river flow during the dam construction.

The sill level of the right bank canal power house (3 x 30 MW) is at 479 feet (146 m) MSL. It is possible to draw water from the dead storage by tapping water from the penstocks to feed water to a pump house (3 x 15 MW) located on the left side of the power house. The pump house will have three pump sets each of 5000 cusecs flow capacity to feed into the NS main right bank canal. Power generation from the 90 MW power house is no way affected since its units can only operate when reservoir level is above 540 ft MSL and the pumping units need to operate below the 508 ft MSL to draw water from the dead storage. Thus nearly 50 TMC water can be utilized during the drought years.The power generation units are normally in operation for five months in a year when the water level is above its minimum draw down level at 540 feet (165 m) MSL. During the drought years, the additional water availability is more valuable than the pumping power consumption. The consumed pumping power is compensated fully by the enhanced generation from the 44 MW capacity mini hydel plants located on the downstream canals.

- **Pumped Storage Hydro Power Potential:** Nagarjuna Sagar reservoir, serving as low level reservoir, has potential to install nearly 2,18,000 MW high head pumped storage hydroelectric plants on its right side.

- **Assured water supply to Hyderabad city:** At present nearly one Tmcft per month or 250 million gallons per day or 350 cusecs is supplied to the Hyderabad city from Nagarjuna Sagar (NS) reservoir. The water supply is nearly 50% of the total city water requirement. This water pumping scheme is part of Alimineti Madhava Reddy lift irrigation project with its foreshore pumping station at Puttamgandi which has nearly 2400 cusecs pumping capacity.[24] The water supply to the Hyderabad city is nearly 15% of its total capacity. The approach channel from the reservoir to the Puttamgandi pump house (PH) is located at 16°34′31″N 79°07′51″E where the Bhimanapalli Vagu tributary is joining the Krishna river. The minimum draw down level (MDDL) of the PH is 502 feet (153 m) MSL below which water can not be pumped from NS reservoir.[26] The reliability / dependability of the PH for supplying assured water supply to Hyderabad city, is not adequate due to meagre inflows into the NS reservoir in some years and the need to deplete the NS reservoir water below 502 ft MSL for other purposes. In these circumstances, adequate water is to be stored above the 502 ft MSL to maintain 100% assured water source without depending totally on NS reservoir.

This is possible by constructing a balancing reservoir by separating some area of the NS reservoir with a new dam across the Bhimanapalli Vagu tributary at 16°34′33″N 79°06′53″E just upstream of the Puttamgandi PH approach channel. This new dam with FRL 590 feet (180 m) MSL, would not submerge any additional area other than the area already submerged by the NS reservoir. The water inflows from the Bhimanapalli Vagu tributary joining the NS reservoir are first impounded by the new dam and if found excess over flows into the downstream NS reservoir. This new balancing reservoir's live capacity is nearly 6 Tmcft above the 502 ft MDDL which is equal to six months water supply to the Hyderabad city. This reservoir would have provision to receive water from the Puttamgandi PH when inflows from the Bhimanapalli Vagu tributary is not satisfactory and water is at adequate level in NS reservoir during monsoon months. When water level of NS reservoir goes below the 502 ft MSL, water is fed to the Puttamgandi PH approach channel from the new balancing reservoir for pumping water needs of Hyderabad city. The cost of this new dam project would be nearly 1.5 billion rupees only which will provide 100% assured water supply to the Hyderabad city without depending on the water availability from NS reservoir during the non monsoon months and drought years.

- **Godavari water transfer via Nagarjuna Sagar left canal to Krishna river:** The Nagarjuna Sagar left canal supplies nearly 130 TMC of water for irrigation needs in Telangana and Andhra Pradesh states. This is a contour gravity canal with gradual downward gradient (≃ 1:10,000) along the water flow direction. This canal can be used for transferring nearly 80 TMC Godavari river water into the Nagarjuna Sagar reservoir in addition to supplying the Godavari water under its entire command area. Thus a total of 210 TMC of Godavari water can be used in the Krishna basin of Telangana state from Srisailam and Jurala reservoirs for the new projects with 100% water dependability. Godavari water transferred into the Nagarjuna Sagar reservoir and Krishna main river can also be used for the proposed Palamuru lift irrigation and Nakkalagandi lift irrigation schemes in Telangana.[citation needed]

This is possible by re-engineering of the left canal to reverse its water flow direction from the location (near 17°22′13″N 80°21′43″E) where Godavari water would be pumped into this canal. The canal embankments would be raised to facilitate flow reversing towards Nagarjuna Sagar reservoir and intermediate pumping stations (with low head & high flow concrete volute pumps) would be installed near the Paleru balancing reservoir, Pedda Devulapalli balancing reservoir, left canal head regulator on the rim of Nagarjuna Sagar reservoir and the existing major aqueducts across Halia, Musi and Munneru tributaries. The cost of this canal redesigning and the associated pump houses would be one third of a new scheme to transfer Godavari river water into Nagarjuna Sagar reservoir at its FRL 590 feet (180 m) MSL with least possible total pumping head. The above re-engineering of the canal is similar to modifications carried out to reverse the water flow of ancient Grand canal under Eastern Route project of South to North Water Transfer in China.

7. Kosi Project:

- **Introduction:** Saptakosi High Dam, also called Koshi High Dam, is a multipurpose project proposed to be constructed on the Saptakoshi River of Nepal. The project is primarily aimed to control floods in south-east Nepal and northern Bihar of India, and to generate hydro power.An issue subsequently coming with this project is Nepal's access to sea port via 165 km long navigation canal linking to Calcutta sea port through River Ganges.

  After catastrophe (Koshi changing course breaking the embankments by erosion of embankments Koshi Barrage in 2008 and the 52-year-old barrage's decaying life has given additional pressure to both governments for thinking about its alternative.

  Both governments of India and Nepal have begun studies for the preparation of a detailed project report (DPR) of the Project and Sun Kosi Storage-cum-Diversion Scheme. A Joint Project Office (JPO) was set up in Nepal for investigation of the project in August 2004.

  It is a combined project of India and Nepal, which was constructed across the Kosi river for flood control in North Bihar, Irrigation and Hydropower.

  Kosi is a tributary river of Ganga which is known as the sorrow of Bihar due to changing its route. After this project, Bihar is getting more benefits.

- **Background:** Koshi High Dam is a project that was studied, surveyed and revised by various authorities from centuries. In the history there were many notable heavy floods on Koshi river killing thousands and displacing millions people. To prevent losses first survey was conducted by British India Major J Renal in around 1779. Subsequently James Fargusan studied in 1863 and later A.F. Ceiling Field studied Koshi flood. British authority has reached to a decision of constructing embankments after the devastating flood of 1869-70.

  British made an agreement with Rana rulers of Nepal to construct dam in Sunsari and Saptari districts of Nepal but the project failed after the flood of May 1891. On 27 February 1897 Prime Minister Bir Shamsher Rana approved British India to construct a dam below Barahachhetra. Again in 1944 an American company studied for the British which suggested to construct dam in Churiya range. Following it a commission headed by Rayabahadur Ayodhyanath Khosala studied Koshi on ground in January 1946. He suggested to construct dam 1.6 Kilometer upstream from Barahakshetra area.

After independence India Government formed commission headed by engineer S.P.Prasad which suggested to construct 25.91 meter high dam in Prasad which ended up with Koshi Agreement 25 April 1954 and amended in 1966. Following the agreement India constructed the present Koshi Barrage (completed 24 April 1965).

Construction of Koshi Barrage gave a great relief to people in Bihar for long time but even it couldn't solve the problem. Concept of Saptakoshi High Dam was reinstated after Indian P.M. Atal Bihari Vajpayee introduced Indian Rivers Inter-link project in 2005. Sapta Koshi River is one of the major tributary branch of the Ganges river system that originates from the Himalaya and meets Ganga at Bihar. Koshi causes floods in Nepal and India every year. A big landmass of Bihar is affected by Koshi flood every year. Therefore Koshi is known as 'sorrow of Bihar'

The Koshi Barrage is a sluice across the Koshi river that carries vehicular, bicycle, and pedestrian traffic between Saptari district and Sunsari district of Nepal. It is near the international border with India. It was built between 1958 and 1962 and has 56 gates. It was constructed after the Koshi Agreement was signed between the Government of Nepal and India on April 25, 1954.The barrage was designed and built by Joseph and Company Limited, India. The Koshi Tappu Wildlife Reserve is roughly 3–4 miles north of the barrage.

- **Flood:** Due to this barrage, every year several areas of Terai are affected due to the flood and blockage of this barrage. This affects mostly the Koshi region of Bihar (Supaul, Saharsa, Madhepura and Purnia). The Kosi River is known as the "Sorrow of Bihar" as the annual floods affect about 21,000 km2 (8,100 sq mi) of fertile agricultural lands thereby disturbing the rural economy. The Koshi has in an average water flow (discharge) of 2,166 m3/s (76,500 cu ft/s).August 2008, the eastern embankments of the Koshi Barrage collapsed, several miles north of the Nepal-India border. The resulting flood wiped out miles of fertile farmland in Nepal, covering it with a thick layer of river sand, and affected 53,800 Nepalese. It left 3 million people homeless in Bihar, India.
- **Tourism:** This river the home for Gangetic Dolphin and other different species of fresh water fishes. Siberian birds can be seen there easily during the month of August-October. People usually visit there to have the varieties of fish dishes in the nearby riverside restaurants and see the scenic view from the barrage. The sunrise and the sunset view literally catch people' eyes there. Rowing or a motor boat is available there for extra adventure which carries people to the is lets.

8. Tungabhadra Project :

- **Introduction:** The Tungabhadra Dam, also known as Pampa Sagar, is constructed across the Tungabhadra River, The dam is in Hosapete, Vijayanagara district of Karnataka. It is a multipurpose dam serving irrigation, electricity generation, flood control, etc. This is a joint project of erstwhile Hyderabad state and erstwhile Madras Presidency when the construction was started; later it became a joint project of Karnataka and Andhra Pradesh after its completion in 1953. The main architect of the dam was Vepa Krishnamurthy, ISE, Engineer-in-Chief, Hyderabad State, after Police Action, an engineer from Madras PWD. There is a dispute between Andhra Pradesh, Telangana and Karnataka for the water of Tungabhadra reservoir. He argued for the stability and longevity of the Dam, built of Surki Mortar viz a combination of mud and limestone. Apart from Mullaperiyar Dam, it's the only non-cement dam in the country and has withstood the test of time for over 70 years, and may well cross many more decades. He envisioned it as being built with a large contingent of manual labour, as best suited to Indian labour availability and employment. The main contractor for the dam was Venkat Reddy Mulamalla, from Konour village, Mahabubnagar, Hyderabad state.

  It was constructed across the Tungabhadra river (tributary river of Krishna) in 1953. Under this project Tungabhadra dam was built at Hospet city of Karnataka.

  It is a combined enterprise of Andhra Pradesh and Karnataka states which is used for Irrigation, Water reservoir, and Hydropower. The 8-megawatt Hydropower plant has been established in Hampiunder this project

- **History :** The famine region of Rayalseema, comprising the districts of Bellary, Anantapur, Kurnool and Cuddapah attracted the attention of the British Engineers as early as 1860. To relieve the intensity of in these districts, proposals were made in 1860 to utilize the waters of Tungabhadra through a storage reservoir and a system of canals to provide irrigation for the lands.

  Sir Arthur Cotton originally conceived the Tungabhadra Project in the year 1860. The proposals were further modified and developed subsequently evolving it into a joint scheme with Hyderabad. N. Paramseswaran Pillai accordingly revised the Scheme in 1933. Several agreements were concluded in the past for harvesting and imposing certain restrictions on utilizing the Tungabhadra waters. Protracted negotiations and investigations lasted for about eighty years. The Government of Madras in 1940 ordered for a detailed investigation of the scheme. Based on the agreements concluded and examination of a number of alternatives by L. Venkata Krishna Iyer, the then Superintending Engineer, Bellary, and F. M. Dowley, Chief Engineer, Irrigation, further detailed investigations if of the project was done by M. S. Thirumale Iyengar on the Madras side in the year 1942. The Agreement between Madras and Hyderabad of June 1944 enabled the Madras and Hyderabad Governments finally to start the construction of the Tungabhadra project.

The Tungabhadra Project was formally inaugurated by laying foundation stone on 28 February 1945 by "Prince of Berar" on the left side and by Sir Arthur Hope, Governor of Madras on right side. However, much headway could not be made up to January 1949. Difference of opinion in certain technical matters and settled political situation in Hyderabad were the reasons for the slow progress. The Madras and the Hyderabad engineers were sharply divided on:

1. Nature of mortar to be used in the construction of the dam
2. Design of spillway
3. Design of over flow and non-overflow sections of the dam and
4. Contraction joints

These differences were referred to a Board of Engineers under the Chairmanship of M. Visveswaraya, a Statesman-cum-Engineer.

- **Dam construction:** Excavation in the riverbed was started in 1947 and masonry construction on 15 April 1949. With help of a cofferdam constructed earlier, foundation excavation was continued during flood season also. The river bed portion was tackled during the summer of 1950 (1949–50). Masonry in the riverbed blocks was started in the year 1951. Thereafter there was vigorous progress in works. By October 1953 the structures were completed substantially enabling the storage of water in the reservoir up to +1613.00 ft. Acquisition of lands and villages and rehabilitation of persons displaced from the water spread area up to 1630 ft contour were completed by September, 1953 in all respects. About 90 villages and 54,452 people were effected. The balance of the works namely the spillway, bridge road on the top of the dam, construction of utility tower, manufacture of crest grates for storing water up to 1633 level were completed in all respects by the end of June 1958. The cost of dam and appurtenant works was Rs. 16.96 crores. The water was led down into the canal on 1 July 1953 to derive partial benefits.

➢ Timeline of the construction of the dam:

Foundation excavation	Completed by June 1952
Masonry	Completed by October 1953
Drilling and Grouting	Completed by August 1955
Crest Gates, embedded part	Completed by February 1955
Spillway shutters	Completed by June 1955
Operation bridges	Completed by February 1956
Counterweight erection	Completed by January 195
Hoists	Completed by January 1957
Gate House	Completed by June 1957
Utility Tower	Completed by June 1958

Power Canal works started in June 1954 and were completed by May 1957.

The project submitted by M. S. Tirumale Iyengar in 1942 for Low Level Canal was accepted by Government of Madras with certain modifications fixing sill level at RL 1550 ft. The Low Level Canal excavation was completed by 1953 up to Mile 173. The balance portion of canal from Mile 173 to 203 that had to be excavated by the GOAP was completed by the end of March 1957.

As major portion of the construction of the dam was over by the middle of 1953, the reservoir circle was entrusted with the construction of canal works in 1956. In 1958 water was let out up to and inclusive of distributory 42 to serve an area of about 1.80 lakh acres.

By 1952, when project sanctioned by both the Government's for constituting Tungabhadra Reservoir and the canals reached advance and decisive stage of construction, the Government of Madras in GO 382 dated 30-1-1952 ordered investigation of the High Level Canal. On 15-11-1952 detailed estimates were got prepared up to Mile 79/2 covering the reach just before Chinna-Hagari and by 1954 the investigation of the remaining portion of canal from Mile 79/2 to Mile116/0 was completed and project report submitted to Government of India for approval. The proposals were further reviewed and a final project report to the Planning Commission costing Rs.21.90 crores for head discharge of 4000 cusecs for clearance. The CWC advised the participating states to execute the project in two stages. The 1st stage contemplated an unlined canal with a head discharge of 2300 cusecs and the 2nd stage a lined canal with 4000 cusecs head discharge.

The 1st stage scheme was inaugurated by the Governor of Andhra Pradesh on 2 October 1956 under the presidency of the Chief Minister of Mysore. The 1st stage work was almost completed by June 1966 at a cost of Rs. 920 lakhs and canal commissioned by releasing water for Irrigation on 27 July 1966. The 2nd stage works were approved by the Board in June 1967 for Rs.385 lakhs. The works were completed by June 1970 at an estimated cost of Rs.487 lakhs.

The Tungabhadra Hydro Electric Scheme was undertaken in the composite Madras State in the post war period under the first five-year plan in the year 1950. The work on the project was taken up in the year 1951 but no appreciable progress was achieved till the end of the year 1953. During 1957 two units of 9 MW each at Dam Power House were installed and in 1958 two units of 9MW each were installed at Hampi Power House. Thus the first stage of the scheme was completed in 1958 and the second stage under this scheme was taken up in the year 1959. The plant erection was started in the Dam Power House in Nov.1962 and in the Hampi Power House in February `1963. Under stage II the units 3 and 4 of both, Dam Power House and Hampi Power House started functioning by June 1964.

On left side the powerhouse is designed to accommodate 4 units of 9MW each. The stage I power generation commissioned during 1960-61.

- **Agreements for harnessing Tungabhadra waters:** Issue of sharing of waters of river Tungabhadra has its genesis in 1861 when Kurnool-Cuddapah Canal (KC Canal) was proposed by the then Government of Madras. Despite agreement on construction of KC Canal project, there was no general agreement on sharing of Tungabhadra waters between Government of Madras and Government of Mysore. In 1930, Government of Madras proposed a joint project on the Tungabhadra. Subsequently, a number of conferences between the Governments of Madras, Mysore, Hyderabad and Bombay took place, but all were inconclusive. In 1936, there was an agreement between Governments of Madras and Mysore, followed up by an agreement between Governments of Madras and Hyderabad in 1938. However, due to some differences in interpretation of the agreement between Governments of Madras and Hyderabad no substantial progress was made in implementation of the project. It was in a conference between the Governments of Madras and Hyderabad held on 26 June 1944, that a final decision was arrived at on the allocation of waters as well as on taking up the project jointly and sharing the cost equally between the two States.

- **Tungabhadra River:** The river Tungabhadra derives its name from two streams viz., the Tunga, about 147 km (91.6 miles) long and the Bhadra, about 178 km (110.9 miles) long which rise in the Western Ghats. The river after the confluence of the two streams near Shimoga, runs for about 531 km (330 miles) till it joins the river Krishna at Sangamaleshwaram in Andhra Pradesh. It runs for 382 km (237 miles) in Karnataka, forms the boundary between Karnataka and Andhra Pradesh for 58 km (36 miles) and further runs for the next 91 km (57 miles) in Andhra Pradesh. The total catchment area of the river is 69,552 km^2 (26,856 Sq miles) up to its confluence with Krishna and it is 28,177 km^2 (10,880 Sq miles) up to Tungabhadra Dam. It is influenced chiefly by the South-West monsoon. It is a perennial river but the summer flows dwindle to as low as 2.83 to 1.42 cumec (100 to 50 cusec).

- **Technical details:** The dam creates the biggest reservoir on the Tungabhadra River with 101 tmcft of gross storage capacity at full reservoir level (FRL) 498 m MSL, and a water spread area of 378 square kilometres. The dam is 49.39 meters high above its deepest foundation.The left canals emanating from the reservoir supplies water for irrigation entirely in Karnataka state. Two right bank canals are constructed — one at low level and the other at high level serving irrigation in Karnataka and Rayalaseema region of Andhra Pradesh. Hydropower units are installed on canal drops. The reservoir water is used to supply water to downstream barrages Rajolibanda and Sunkesula located on the Tungabhadra River. The identified water use from the project is 220 tmcft by the Krishna Water Disputes Tribunal. Karnataka and Andhra Pradesh got 151 tmcft and 79 tmcft water use entitlement respectively.

- **Future potential:** On the right side of the dam, tall Sanduru hill ranges extending up to 800 m MSL are close to the periphery of the Tungabhadra reservoir. These hill ranges form the Sanduru valley located above 600 m MSL. This reservoir is an ideal place to install pumped storage hydropower plants and lift irrigation projects. A moderate high level storage reservoir of capacity 20 tmcft at FRL 620 m MSL, can be constructed by damming the Sanduru valley. This reservoir will serve as upper pond and existing Tungabhadra reservoir as tail pond for installing pumped-storage hydroelectricity units. The water pumped during the monsoon months into the upper pond can be diverted by gravity to irrigate an extensive area in the uplands up to 600 m MSL in Rayalaseema and Karnataka. This water can be pumped further to meet the drinking water requirements of Bengaluru city.

  However, the available water resources at Tungabhadra dam are over-used, and water shortages are frequent. Water availability in the reservoir could be augmented by transferring water from the Krishna River, if a link canal were constructed from the Almatti reservoir to the Tungabhadra reservoir.Envisaging small balancing reservoirs where this link canal is intercepting the tributaries of Tungabhadra River would facilitate water diversion to Tungabhadra reservoir for augmenting further water availability. Once the Almatti reservoir FRL is raised to 524 m MSL, this canals full supply level (FSL) can also be increased to 516 m MSL from 510 m MSL to reduce its construction cost and serve more area for irrigation in Karnataka

Nearly 180 tmcft out of 230 tmcft water presently supplied from Tungabhadra reservoir to various canals can be replaced by reliable Krishna river water from the Narayanpur reservoir.These are water supply to mid and lower reaches of Tungabhadra left bank canal, water assistance to Rajolibanda canal, water assistance to KC canal and mid and lower reaches of Tungabhadra right bank low level canal. This is achieved with a 20 km long tunnel from Narayanpur reservoir to the Maski nala reservoir / tank situated at 475 m MSL for drawing nearly 250 tmcft Krishna river water.From this tank, north canal would supply Krishna river water by gravity flow to the lower reaches of Tungabhadra left bank canal in addition to bringing substantial uplands under irrigation in Karnataka and Telangana. From this tank, south canal would supply Krishna river water by gravity flow to the middle portion of Tungabhadra left bank canal in addition to bringing substantial uplands under irrigation in Karnataka and also connected to the Tungabhadra right bank low level canal at 425 m MSL near 15°22′09″N 76°32′55″E through a 1.5 km long aqueduct over Tungabhadra main river. Water is also released from the Maski nala in to downstream Tungabhadra main river to meet continuous water needs of downstream Rajolibanda canal and KC canal. 180 tmcft water in addition to the water diverted from the Almatti reservoir to Tunghbadra reservoir can be utilised for uplands irrigation in Tungabhadra basin and Rayalaseema region of Andhra Pradesh. When these joint projects of Karnataka and Andhra Pradesh are constructed, nearly 400 tmcft water additionally will be available for irrigation and drinking purposes in the high drought risk uplands of Rayalaseema and Karnataka.

9. Thein Dam Project :

- **Introduction:** The Ranjit Sagar Dam, also known as the Thein Dam, is part of a hydroelectric project constructed by the Punjab Irrigation Department on the Ravi River on the border of Union Territory, Jammu and Kashmir and state Punjab. It is located upstream of the Madhopur Barrage at Madhopur. A large portion, up to 60%, of the reservoir falls within Jammu and Kashmir. The dam is around and equidistant 30 km from both Pathankot in the state of Punjab and Kathua in Jammu and Kashmir. The project is used for both irrigation and power generation. The project is the largest hydroelectric dam in Punjab with a capacity of 600 megawatts. Also, the dam is amongst the highest earth-fill dams in India and has the largest diameter penstock pipes in the country. The township where the site is located is called Shah pur Kandi Township. Feasibility studies for the project began in 1953 and geotechnical studies continued until 1980. Construction began in 1981, the generators were commissioned in 2000 and the project complete in March 2001.

There have been several issues and claims between the governments of Jammu and Kashmir and of Punjab over the usage of water, electricity, employment, compensation to the locals and land acquisition. On 12 May 2017 Government of Jammu and Kashmir raised these issues in the Northern Zonal Council Meeting held in Chandigarh; following which the Ministry of Home Affairs, GOI mandated the construction of barrages that will allow both states equal rights over the dam. The proposed barrages will help Jammu and Kashmir irrigate Samba and Kathua districts. The Government of Punjab had also agreed to share electricity produced through the project but previous claims of Jammu and Kashmir remained unsettled and a resolution is pending. In 2017, the Government of Jammu and Kashmir claimed 8000 crores from fhs Government of Punjab as losses.

- **History:** Studies that examined the feasibility of the project construction, and whether the dam would be a success began in 1953 and continued till 1980 when it was concluded that construction of the dam would be a success and would benefit all those involved. The construction of the dam was steeped in controversy, as all dam constructions are. The construction of the dam would cause unimaginable losses to the locals due to land acquisition by the government. The governments of Punjab and Jammu and Kashmir also had to fight over their respective claims over the Ravi river, which ran through both the states and had to be divided equally.

The issue was resolved when the Government of India decided to construct a barrage that would allow both states to enjoy equal rights over the dam and the electricity generated from it. Barrages would help Jammu and Kashmir irrigate the districts of Samba and Kathua. The Government of Punjab also agreed to share the electricity produced by the Ranjit Sagar Dam.

Despite all the issues, the dam was finally constructed and remains one of the most beautiful dams in the country as of today.

Another fascinating thing about the dam is that recently, a Water Sports Academy was announced in Basohli, which is about 56 km from Pathankot. This Academy is set to be the first of its kind in North India and will encourage water sports like swimming, rowing, water polo, synchronized swimming, etc. For this purpose, advisors to the Jammu and Kashmir Governor, namely Mr. K Vijay Kumar, Mr. K K Sharma, and Mr. K Skandan paid a visit to the Ranjit Sagar Dam to inspect and analyze the quality of the tourist facilities at the dam and check on the progress of construction of this Water Sports Academy, for which 3 crore rupees have been earmarked. Construction of this Academy would substantially increase tourism and the economy of the area, as well as bring a lot of recognition to young and budding water sport athletes who do not have the proper facilities to train as water sports in India are highly underrated.

Last year, the water levels in the Ranjit Sagar dam touched 520.43 meters on the 29th of August, which is much higher than that of last year. This is all thanks to the efforts of the PSPCI and the Irrigation Dept of the Government of Punjab.

An official of the Ranjit Sagar Dam has said that the water level of the Dam on the 7th of April this year, 2019 was 495.65 Meters. The Governments of all the nearby states which make use of the dam and its facilities are dedicated to ensuring that the dam is used to its full capacity and that the water and the hydroelectricity generated from the dam be used to the maximum.

- **Tourism:** The Ranjit Sagar Dam is located in a very serene and idyllic location. It is at a drive-able distance from Pathankot and the drive is also very scenic and enjoyable. To be able to enter the dam, visitors will need a permission note from the authorities.

  This note can be obtained at the Juigal barrier which is about 15 kilometers from the Ranjit Sagar Dam. The officers at this barrier will be able to give you a permission slip. To get this permission slip, you will need to present a valid, government-issued identity proof. Upon receiving this slip you can proceed on to the dam. Many tourists are unaware of this fact and waste many hours going back and forth from the barrier to the entrance. Hopefully, this tip will save you a lot of time.

  A few tourist dedicated cottages are surrounding the dam where the tourists can stay after paying a certain amount. The booking and payment for these cottages can only be done at the entrance to the dam. The cottages offer a serene, calm stay for tourists and everyone who visits the dam must spend a day at these cottages. However, there are only a limited number of cottages and they are given out on a first come first serve basis. If you want a cottage you must get there early and book one before the rush comes in.

Tourists will also be allowed to enter the building where the electricity is generated and get a view of how things work on the inside and learn about dams in the process. If one visits the place in the monsoon seasons, you can see the lake brimming with water, which is a very beautiful sight. One must not miss the opportunity of seeing the entire lake and even touching the clear, cool water. The staff is very helpful and will explain everything so articulately that your vacation will become educational as well!

One can also see the newly constructed wire bridge, the second of its kind in our country. The views from the bridge as well as the pictures taken are very aesthetic and visually pleasing. The dam is the perfect spot for people of all ages, old, young, middle-aged and teenagers to come and have a pleasant experience.

Another highlight is the flora and fauna that grows in the vicinity of the dam. One will see a lot of migratory birds visit, depending on which time of the year you visit. Several animals like foxes, wild rabbits, hares and birds can be spotted in the area. Shops and small dhabas selling warm food and souvenirs can be found near the dam which makes it a perfect tourist destination. During public holidays and festivals, the dam becomes highly crowded which makes it difficult to enjoy its scenic beauty and thus it is recommended that you visit the dam during the weekends or weekdays.

It is best to visit the dam during August or September when the lake is full and the scenery is at its best. During the summer, the lake is dry and the scenery is not as appealing. The best time of day to visit is during mid-day, as one can get a quick lunch from the dhabas nearby and enjoy the warm sun and the pleasant breeze. The climate in the area is always pleasant which makes the experience so much more enjoyable for everyone.

- **Things to Do In the Area:** The dam is situated near Pathankot, on the border between Jammu, Kashmir and Punjab – three states that enjoy heavy tourist traffic. Thus, the tourist attractions in the area are immense and are listed down below. Do make sure to visit all the attractions and have a marvelous holiday in the lap of nature. You can visit the Kathgarh Temple, Mukteshwar Temple, Shahpurkandi Fort, Kali Mata ka Mandir, Nagini Temple, Laxmi Narayan Mandir, Novelty Mall, Ashapurni Mandir and the Hydraulic Research Station.

- This holiday would not only be enjoyable for you but also educational and would offer quality bonding time with your family and friends. If you like learning and also enjoying nature, then this is the place for you. The dam is the perfect spot not only for families but also for couples, friends and simply to enjoy a picnic spot and take some photos. The upcoming Water Sports Academy also adds appeal to the spot, making it one of the lesser-known and highly underrated tourist spots in India.

10. Farakka Project:

- **Introduction:** Farakka Barrage is a barrage across the Ganga river located in Murshidabad district in the Indian state of West Bengal, roughly 18 kilometres (11 mi) from the border with Bangladesh near Shibganj. Farakka Barrage Township is located in Farakka (community development block) in Murshidabad district. Construction of the Farakka barrage started in 1962, was completed in 1970 at a cost of $208 million. Operations began on 21 April 1975. The barrage is about 2,304 metres (7,559 ft) long. The Feeder Canal (Farakka) from the barrage to the Bhagirathi-Hooghly River is about 42 km (26 mi) long.
  Farakka Barrage Project with its headquarter at Farakka in Murshidabad district of West Bengal is a subordinate office under the Department of Water Resources, River Development & Ganga Rejuvenation, Ministry of Jal Shakti. The Farakka Barrage Project Authority was set up in 1961 with the mandate to execute and thereafter operate and maintain the Farakka Barrage Project Complex. The project construction commenced in 1961 and the project was commissioned and dedicated to the Nation in May 1975.
  The Farakka Barrage Project was designed to serve the need of preservation and maintenance of the Kolkata Port by improving the regime and navigability of the Bhagirathi-Hoogly river system. In addition to this, now the project has been serving other purposes such as water supply to power plants of NTPC Ltd, Farakka (2100MW) and WBPDC Sagardighi (1600MW); provides rail-cum-road communication link between North-Eastern Region and Eastern part of the country;

regulation of water to Bangladesh as per Indo-Bangladesh Treaty-1996 on sharing of Ganga Water at Farakka; fresh water supply to Kolkata city and en-route cities, etc.

The Farakka Barrage Project organization has been assigned the work for operation and maintenance of the following principal components of the Project:

(i) Farakka Barrage: The main barrage has a length of 2,245 m with 109 Gates having 18.30 m span. The design discharge of the barrage is 76,500 cumecs across the mighty Ganga river at Farakka in Murshidabad. Gates numbered 1 to 24 are under sluice gates with a height of 7.93 m and gates numbered 25 to 109 are spillway gates with a height of 6.40 m. And protection works of barrage in the upstream and the downstream of the barrage near to the gates.

(ii) Head Regulator: At the upstream of the barrage on its right bank, the head regulator was constructed with 11 gates of 12.19 m span. The head regulator controls the diversion of 40,000 cusecs of Ganga water into the Feeder Canal.

(iii) Feeder Canal: The length of the Feeder canal is 38.38 km which originates in the upstream of the barrage to carry a discharge of 40,000 cusecs into the river Bhagirathi-Hooghly mainly for the preservation of Kolkata Port. The Bhagirathi Ganga waterway is the National Waterway No.1 for the inland transport facilities from Allahabad to Kolkata operated by IWAI. The Feeder canal has several cross-drainage structures for irrigation, communication, and removal of drainage congestion. It has around 17 jetties for ferry service, 2 road cum rail bridges, 2 road bridges, 3 inlets, 1 syphon and 2 drainage regulators.

(iv) Navigational Lock at Farakka: In order to facilitate the navigation vessel from Ganga to Bhagirathi via Feeder canal, a navigational lock is provided having a width 25.15 m and length 180.7 m along with two giant gates of dimensions 25.15 m x 12.6 m on the upstream and 25.15 m x 10.52 m in the downstream. Floating caisson type emergency gates are provided to carry the repair works and other facilities such as jetties, shelter basin, gauges, ladders hooks, floating mooring bitts, fixtures, fenders, bollards etc. have also been provided to aid the navigation smoothly. The navigational lock has been now transferred to IWAI in the year 2018 for their operational requirement.

(v) Jangipur Barrage: It has been constructed across the river Bhagirathi near its off take from the river Ganga. The main function of Jangipur barrage is to regulate the flow of Ganga water into the Bhagirathi and vice versa. It has 15 gates of 12.20 m span. A navigational lock on bypass channel alongside of Jangipur barrage was also constructed.

(vi) Guide Bunds and Afflux Bunds: In order to maintain the safety of the barrages, four guide bunds are provided along both the banks at Farakka and Jangipur. The Left Afflux Bund (LAB) with inspection road is 34 km long along with several regulators across rivers at Pagla, Tutianala, Nimjala, Bhagirathi and Kalindri. The Right Afflux Bund (RAB) is 10 km long. The Left bank protection works on the upstream of the barrage is carried out for the protection of riverbanks and thickly populated villages close to the embankment.

(vii) Township: A large township is maintained by the Farakka Barrage Project which consists of residential and non-residential buildings at Farakka and two other townships at Jangipur and Khejuriaghat.

(viii) School & Hospital: A higher secondary school and hospital with bed capacity of 40 is maintained by the Farakka Barrage Project for the welfare and health care of employees including CISF Personnel working for the scheme.

(ix) Ferry Services: At various locations of Feeder Canal, ferry services are provided for communication of villagers residing on both sides of canal banks.

(x) Anti-erosion Works: Protection works against bank/bed erosion of river Ganga is being executed along the bank of river Ganga up to 12.5 km upstream and 6.9 km downstream of the Farakka Barrage. Anti-erosion works are also executed along the feeder canal.

(xi) Maintenance of Road Bridge: The renovation and maintenance of PSC Road Bridge includes replacement of damaged portion of super structure and sub structure, bearings, surfacing, road marking, bridge lighting, etc.

(xii) Other Hydraulic Structures: The organization also looks after other appurtenant structures such as Pagla regulator, Bhagirathi regulator, Kalindi regulator, Maha Pagla regulator, Bansloi regulator, Bagmari syphon, etc.

- **Purpose:** The barrage was constructed by Hindustan Construction Company. Out of 109 gates, 108 are over the river and the 109th one over the low-lying land in Malda, as a precaution. The Barrage serves water to the Farakka Super Thermal Power Station. There are also sixty small canals which can divert some water to other destinations for drinking purposes etc.

  The purpose of the barrage is to divert 1,800 cubic metres per second (64,000 cu ft/s) of water from the Ganges to the Hooghly River for flushing out sediment deposition from Kolkata harbour without the need of regular mechanical dredging. After commissioning the project, it was found that the diverted water flow from the Farakka barrage was not adequate to flush the sediment from the river satisfactorily. In addition, there are regular land/bank collapses in to the Ganga river due to the high level back waters of the Farakka barrage. Substantial high land is already converted into low level river bed causing displacement of huge populations. The water diverted from the Farakka barrage is less than 10% of Ganga river water available at Farakka.

- **Farakka Water Sharing Treaty:** As per the treaty between India and Bangladesh, signed in 1996, for sharing of the Ganges water at Farakka, the division is as follows:

Availability at Farakka	Share of India	Share of Bangladesh
70,000 cusecs or less	50%	50%
70,000 – 75,000 cusecs	Balance of the flow	35,000 cusecs
75,000 cusecs or more	40,000 cusecs	Balance of the flow

- **Impact:** The Ganges is one of the major rivers of the world. It rises at an elevation of about 4,356 metres (14,291 ft) in Gangotri on the southern slope of the Himalayan range. About 70% of the total population of Bangladesh and about 50% of the Indian population live in the Ganges basin; 43% of the total irrigated area in India is also in the Ganges basin and there are about 100 urban settlements with a total population of about 120 million on its banks. As a result, Bangladesh and India have had many debates about how the Farakka Barrage cuts off Bangladesh's water supply and how to share the water. Right from the beginning, this created a concern for Bangladesh as it constitutes the low-lying part of the Gangetic valley. After the completion of the barrage at the end of 1975, it was agreed to run it with specified discharges for a period of 41 days from 21 April to 31 May during the remaining period of the dry season of 1975 under an accord announced as a joint press release on 18 April 1975. But after the assassination of Sheikh Mujibur Rahman on 15 August 1975, relations between the two countries became greatly strained and India continued to withdraw water even after the agreed period. The diversions led to a crisis situation in Bangladesh in the dry season of 1976. In 1977, Bangladesh went to the United Nations and lodged a formal protest against India with the General Assembly of The United Nations, which adopted a consensus statement on 26 November 1976. Talks between the two countries were resumed in December 1976. No consensus was reached.

  Twenty years later, in 1996, a 30-year agreement was signed. It did not contain any guarantee clause for unconditional minimum amounts of water to be supplied to Bangladesh or India, nor could the future hydrological parameters taken into account as is always the case when water resources are planned on historic data series. As a result, the agreement is sometimes perceived to be failed by some sections in Bangladesh to provide the expected result. Constant monitoring of the implementation of negotiations in lean season continue to the present today. In Bangladesh, it is perceived that the diversion has raised salinity levels, contaminated fisheries, hindered navigation, and posed a threat to water quality and public health. Lower levels of soil moisture along with increased salinity have also led to desertification. However, this barrage still has significant effect on the mutual relation of these two neighboring countries.

Farakka barrage has been criticized for the floods in Bihar as it is causing excessive siltation in the Ganga.

11. Damodar Valley Project :

- **Introduction:** Damodar Valley Corporation (DVC) is a government-owned power generator which operates in the Damodar River area of West Bengal and Jharkhand states of India. The statutory corporation operates both thermal power stations and hydel power stations under the ownership of Ministry of Power, Government of India. DVC is headquartered in the Kolkata city of West Bengal, India.
- **History :** The valley of the Damodar River was flood prone and the devastating flood of 1943, lead to the formation of the high-powered "Damodar Flood Enquiry Committee" by the government of Bengal. The committee recommended the formation of a body similar to the Tennessee Valley Authority of the United States. Subsequently, W.L. Voorduin, a senior engineer of TVA, was appointed to study the problem. He suggested the multi-purpose development of the valley as a whole in 1944. Damodar Valley Corporation was set up in 1948 as "the first multipurpose river valley project of independent India."

  DVC was formed with the central government and the governments of Bihar (later Jharkhand) and West Bengal participating in it. The main aims of the corporation were flood control, irrigation, generation and transmission of electricity, and year-round navigation. The corporation was also expected to provide indirect support for the over-all development of the region. However, while Voorduin had proposed the construction of eight dams, DVC built only four.

  Mr. Voorduin's "Preliminary Memorandum" suggested a multipurpose development plan designed for achieving flood control, irrigation, power generation and navigation in the Damodar Valley. Four consultants appointed by the Government of India examined it. They also approved the main technical features of Voorduin's scheme and recommended early initiation of construction beginning with Tilaiya to be followed by Maithon.

By April 1947, full agreement was practically reached between the three Governments of Central, West Bengal and Bihar on the implementation of the scheme and in March 1948, the Damodar Valley Corporation Act (Act No. XIV of 1948) was passed by the Central Legislature, requiring the three Governments, The Central Government and the State Governments of West Bengal and Bihar to participate jointly for the purpose of building the Damodar Valley Corporation. The Corporation came into existence on 7 July 1948 as the first multipurpose river valley project of independent India.
The first dam was built across the Barakar River at Tilaiya and inaugurated in 1953. The second dam, Konar Dam, across the Konar River was inaugurated in 1955. The third dam across the Barakar River at Maithon was inaugurated in 1957. The fourth dam across the Damodar at Panchet was inaugurated in 1959. Durgapur Barrage was built in 1955, with a 136.8 kilometres (85.0 mi) long left bank main canal and a 88.5 kilometres (55.0 mi) long right bank main canal.
Command area: 24,235 km2 spread across the Damodar basin. Jharkhand: 2 districts fully (Dhanbad and Bokaro) and parts of 9 districts (Hazaribagh, Koderma, Chatra, Ramgarh, Palamau, Ranchi, Lohardaga, Giridih, and Dumka) West Bengal: 6 districts (Purba Bardhhaman, Paschim Bardhhaman, Hooghly, Howrah, Bankura and Purulia).

- **Water Management :** DVC has a network of four dams - Tilaiya and Maithon on Barakar River, Panchet on Damodar river and Konar on Konar river. Besides, Durgapur barrage and the canal network, handed over to the Government of West Bengal in 1964, remained a part of the total system of water management. DVC dams are capable of moderating floods of 6.51 lac cusec to 2.5 lac cusecs.
  Four multipurpose dams were constructed during the period 1948 to 1959:
    - Tilaiya Dam (1953)
    - Konar Dam (1955)
    - Maithon Dam (1957)
    - Panchet Dam (1959)

  Flood reserve capacity of 1,292 mcm has been provided in 4 reservoirs, which can moderate a peak flood of 18,395 cumecs to a safe carrying capacity of 7,076 cumecs. 419 mcm of water is stored in the 4 DVC reservoirs to supply 680 cusecs of water to eet industrial, municipal and domestic requirements in West Bengal & Jharkhand. The Durgapur barrage on river Damodar was constructed in 1955 for the supply of irrigation water to the districts of Burdwan, Bankura & Hooghly.
  Irrigation Command Area (Gross): 569,000 hectares (5,690 km2)
  Irrigation Potential Created: 364,000 hectares (3,640 km2)
  Canals: 2,494 km (1,550 mi)
  30,000 hectares (300 km2) of land in the upper valley is being irrigated,

every year by lift irrigation with the water available from 16,000 (approx) check dams constructed by DVC.

12. Rihand Dam:

- **Introduction**: Rihand Dam also known as Govind Ballabh Pant Sagar, is the largest dam of India by volume. The reservoir of Rihand Dam is called Govind Ballabh Pant Sagar and is India's largest artificial lake. Rihand Dam is a concrete gravity dam located at Pipri in Sonbhadra District in Uttar Pradesh, India. Its reservoir area is on the border of Madhya Pradesh and Uttar Pradesh. It is located on the Rihand River, a tributary of the Son River. The catchment area of this dam extends over Uttar Pradesh, Madhya Pradesh & Chhattisgarh whereas it supplies irrigation water in Bihar located downstream of the river.

- **Specification:** Govind Ballabh Pant Sagar is the largest man made lake in India. Rihand dam is a concrete gravity dam with a length of 934.45 m. The maximum height of the dam is 91.46 m and was constructed during period from 1954–62. The dam consists of 61 independent blocks and ground joints. The powerhouse is situated at the toe of the dam, with installed capacity of 300 MW (6 units of 50 MW each). The Intake Structure is situated between blocks no. 28 and 33. The Dam is in distress condition. It is proposed to carry out the rehabilitation works in the dam and the powerhouse.The F.R.L. of the dam is 268.22 ft (81.75 m) and it impounds 8.6 Million Acre feet of water. The construction of the dam resulted in forced relocation of nearly 100,000 people Many super thermal power stations are located in the catchment area of the dam. These are Singrauli, Vindyachal, Rihand, Anpara & Sasan super thermal power stations and Renukoot thermal station. The high alkalinity run off water from the ash dumps (some are located in the reservoir area) of these coal-fired power stations ultimately collects in this reservoir enhancing its water alkalinity and pH range. Using high alkalinity water for irrigation converts the agriculture fields in to fallow Alkali soils.

- **Dam and Development:** As the first Prime Minister of India, Jawaharlal Nehru was determined to make India economically self-reliant and self-sufficient in its food production. Nehru waged an aggressive dam building campaign, drastically expanding infrastructure left by the British Raj, who "had put down 75,000 miles of irrigation canals to water the subcontinent's most valuable farmland." Nehru believed dams held the key for growth and the achievement of his economic goals for India. At the opening of the Bhakra Dam in 1963, he referred to the dam as "the temple of a free India, at which I worship. "The taming of rivers throughout India marked the dawn of a new, independent and most importantly free India that would finally be able to make use of its resources on its terms, enriching its people in the process. To this day, India continues to build dams throughout to achieve these ambitious economic goals

- **Background:** Before the dam was built, Renukoot, the town in which it was built, was a primarily agrarian locale. The region lacked basic modern features such as adequate transportation and roads, and electricity, but the prospect of arable land provided a boon for local villages to farm and sustain themselves. Authorities recognized the potential for growth in the region, as Sonbhadra was home to vast natural resources including coal, forests with various types of trees such as sal, bamboo, khair, and salal. Building a dam to harness the power of the Rihand would represent a first step in developing the region and bringing industry to it.
  British colonial authorities were interested in building a dam on the Rihand River as early as 1940.The construction of a dam had the potential to improve irrigation in the region, as well, and held the promise of generating hydro-electric power. In 1952, the Independent Indian government sanctioned survey work; construction began in 1954 and was completed in 1962.

- **Social Impact:** The construction of the Rihand Dam has catalyzed the transformation of the Singrauli region from an agrarian society into an industrial one. Greenpeace found "the social and demographic profile of the area has undergone a significant transformation with the massive industrial changes to the landscape." This influx of industry, primarily energy and manufacturing interests, has allowed the region to grow and power the growing Indian economy. Despite this growth, serious questions over the nature of these development projects remain, as tens of thousands of locals were forced to relocate for the construction of the Rihand Dam, and tens of millions throughout India as a consequence of the construction of dams throughout the country. Critics allege that growth takes priority over human welfare, with safety precautions in work environments severely lacking and little care taken to protect the environment. Despite being built 60 years ago, these impacts are longstanding.
- **Economic Impact:** In terms of achieving economic growth and development for Indian authorities and business interests, the Rihand Dam has been an unmitigated success. The construction of the dam allowed for the Singrauli region to expand rapidly in the ensuing years, with various industries

emerging in the region. Local industries produce a wide range of goods, such as commercial vehicles, mining equipment, locomotives, telecommunication cables, and power generation equipment. To facilitate this growth, the Indian government subsequently purchased thousands of acres of land in neighboring villages and throughout the district of Madhya Pradesh to sell to industrialists. These plants required tens of thousands of workers to operate them, creating opportunities for Indians to earn better wages. Singh points out firms did not hire the locals displaced by the dam. Instead, the government and companies chose to hire laborers from other regions within India.

As these other industries arose, coal remained the driving force behind the expansion of the Singrauli economy. With nine billion tons of coal reserves, Singrauli has long been viewed as "India's energy capital;" its vast coal reserves, discovered in 1840, have long attracted mining companies and state planners sought to harvest this resource to power the industry that eventually came to dominate the area. Coal mining increased precipitously in the decades after the construction of Rihand; By 1980, production totaled around six million tons and at the time Singh wrote his article, was expected to reach 30 million tons by 1995 and eventually eclipse 75 million tons amounting to more than half of India's entire production of coal in 1983.

- **Environmental Impact:** As the Indian government's primary concern has been to foster growth, it has often chosen the most expedient route to achieve its goals, at the expense of the environment. The construction of the Rihand Dam was only the beginning of industrialization in the Singrauli region. As state and private entities have continued to develop the region, pollution has increased, threatening the environment and wellbeing of residents, while taking valuable farmland. Pollution from industry has harmed the health of local residents, as well. Fluoride contamination in the dam's reservoir water pollutes groundwater, consequently affecting drinking water and agriculture. Researchers estimate that more than 60 million people from 17 states deal with the effects of dental, skeletal, or non-skeletal fluorosis, a chronic condition caused by excessive intake of fluorine compounds, marked by mottling of the teeth and, if severe, calcification of the ligaments. While some fluoride contamination may be caused by natural processes, human activities such as coal and mineral mining and the operation of thermal power plants have led to increased pollution. Coupled with increased demands for water, more residents are consequently forced to drink this contaminated water.

  Despite the ramifications of this industry, the Indian government has often willfully ignored the consequences. On January 13, 2010, the Ministry of Environment and Forests halted all mining in the region until environmental concerns were addressed. Indian officials from the Central Pollution Control Board and researchers from the Indian Institute of Technology found the area to be "critically polluted," but mining was allowed to continue in July 2011. This tension between immediate growth and environmental safeguards continues, as Indian authorities continue to push for more money (energy production and economic growth), ignoring the concerns of local governments and the lives of these people.
- **Forced Relocation :** The most significant consequence of the construction of the Rihand Dam has been the internal displacement of local tribes. Development projects throughout India have led to the forced migration of tens of millions with India, creating a phenomenon that Indian environmental activist Parshuram Ray dubs "Development Induced Displacement." After

British colonial rule, the Indian government ambitiously sought to develop their newly independent country. The state facilitated the construction of dams, mega dams, mines, factories, and irrigation projects. Despite governments making promises to these groups, little action has been taken to alleviate their suffering. Researchers estimate the number of displaced persons for dam projects across India to top 50 million and believe official statistics often understate the true level of destruction that these projects bring to mask their true cost. Despite this forced relocation across India being rather commonplace, the government is most likely violating its own constitution, which guarantees its citizens a right to life. But there is little political will to address or contest this, and authorities have no impetus to change their practices.

By 1960, the dam was nearing completion and almost ready to be put into use. 108 villages containing 50,000 people were immediately put at risk, but the government provided no assistance to assist their relocation. Instead, in May–June 1961, 20,000 locals went to protest the lack of government action to protect their welfare. Instead of acknowledging the protestors' concerns, the local Deputy Commissioner instead sent two thousand policemen to force the protestors home and ordered the dam gates to be closed, forcing people from their homes with only 24 hours of notice. The same villagers were then forced to relocate in 1965 when coal mines opened, again in 1980 when the National Thermal Power Corporation broke ground on a thermal power project, and once more in 2009, when the Essar Power MP broke ground on a new plant. Despite being displaced as many as five times, families forced out by the construction of Rihand never found a new permanent home.

Enduring such upheavals caused psychic harm in addition to the precipitous drop in living standards. Parshuram Ray goes into further detail when discussing the traumas caused by displacement:

The long drawn out, dehumanising [sic], disempowering and painful process of displacement has led to widespread traumatic psychological and socio-cultural consequences. It causes dismantling of production systems, desecration of ancestral sacred zones or graves and temples, scattering of kinship groups and family systems, disorganization of informal social networks that provide mutual support, weakening of self-management and social control and disruption of trade and market links etc… Essentially, the very cultural identity of the displaced community and individual is subjected to massive onslaught leading to very severe physiological stress and psychological trauma.

Despite these very real traumas, the national government has failed to alleviate suffering in any meaningful way. Planners are not pressured by governments to plan for these consequences. The disruption in communities that these projects cause also quash potential political unrest or protest, as people can no longer rely on their destroyed networks.

Within these forced displacements, gender and economic issues bring more hardship. Indian law provides no relief to displaced women and women do not enjoy the same economic protections and freedoms that men do. Women are consequently forced to rely on male members of the household, as they are not entitled to any benefits the government offers. For tribes that have only lived off the land, shifting to a market economy is also a massive shock because they have never engaged in such a system.

The constant and forced resettlement, in addition to being cruel and callous, threatens gains from these projects such as the Rihand Dam. The intergenerational traumas wound those forced to leave, but also disrupt stable villages and economies, ultimately dooming millions of future Indians to poverty.

- **The Push for Sustainable Growth :** The construction of the Rihand Dam falls into a larger paradigm, as its construction has arguably propagated more problems than it has benefits. Writing in 2003, reporter Diane Raines Ward found:
A 1995 Indian Environment Ministry report revealed that 87 percent of India's river-valley projects did not meet required safeguards. Recent reports show that larger dam reservoirs are silting up at rates far higher than assumed when the projects were built, that the life span of major Indian dams is likely to be only two-thirds of their projected life, and that every dam built in India during the last 15 years has violated various environmental regulations — from siltation and soil erosion, to the neglect of health, seismological, forest, wildlife, human, and clean water issues.
As the world's largest democracy and second most populous country, Indian leaders must balance the goals of economic development with democratic ideals and the overall welfare of its people. While economic growth is attractive, it alone cannot increase the welfare of Indian people and growth pursued in this matter will not only not bring about long term growth, but it will kill people in the process and make India uninhabitable. Amartya Sen and Jean Drèze discuss these tensions, acknowledging "issues of economic development in India have to be seen in the larger context of the demands of democracy and social justice." They push back against India's preoccupation with simply increasing its GDP per capita, as such a metric is limited in scope and fails to capture what is being done with that increase in wealth, who is benefitting from it, and whether people's lives are materially improving. They write:
Those who dream about India becoming an economic superpower, even with its huge proportion of undernourished children, lack of systematic health care, extremely deficient school education, and half the homes without toilets (forcing half of all Indians to practise open defecation), have to reconsider not only the reach of their understanding of the mutual relationship between growth and development, but also their appreciation of the demands of social justice, which is integrally linked with the expansion of human freedoms.
Sen and Drèze push for sustainable growth; growth that is environmentally sustainable but socially sustainable so that the gains are not zero sum. Instead, sustainable growth maximizes the number of individuals who benefit, while minimizing the hardship and complications that arise from economic expansion. The construction of the Rihand Dam and the destruction it caused in the lives of hundreds of thousands exemplify the need for such an approach. This is achievable, but requires patience and a commitment to working within this framework. NGOs working with villages and small towns to bring back water collection methods speak to the efficacy of such an approach, showing mega-projects are not the only solution. Local level provisions like these can often solve the problem more effectively, as locals are more privy to their own needs and how their immediate area operates.
By 2019, various Indian companies such as the Shapoorji Pallonji Group and ReNew Power had won the rights to invest ₹7.5 billion ($106 million) to build solar panels with a capacity of 150MW on the Rihand Dam.A project like this shows not only how sustainable policies and projects are possible, but

existing infrastructure can be used in new and different ways to yield more benefit.

13. Koyna Project:

- **Introduction**: The Koyna Hydroelectric Project is the largest hydroelectric power plant in India, just after Tehri Dam Project. It is a complex project with four dams including the largest dam on the Koyna River, Maharashtra hence the name Koyna Hydroelectric Project. The project site is in Satara district. The Koyana Dam situated near Koyananagar village. On river Koyana.
- **Purpose:** The main purpose of the dam is hydroelectricity with some irrigation in neighboring areas. Today the Koyna Hydroelectric Project is the largest completed hydroelectric power plant in India] having a total installed capacity of 1,960 MW. Due to its electricity generating potential Koyna river is considered as the 'life line of Maharashtra'.

  The spillway of the dam is located at the center. It has 6 radial gates. The dam plays a vital role of flood controlling in monsoon season. The catchment area dams the Koyna river and forms the Shivasagar Lake which is approximately 50 km (31 mi) in length. It is one of the largest civil engineering projects commissioned after Indian independence. The Koyna hydro-electric project is run by the Maharashtra State Electricity Board.

  The dam has withstood many earthquakes in the recent past, including the devastating 1967 Koynanagar earthquake, resulting in the dam developing some cracks. After the disaster grouting of the cracks was done. Also internal holes were drilled to relieve the hydrostatic pressures in the body of the dam. Indian scientific establishment has formulated an ambitious project to drill a deep borehole in the region and intensely study the earthquake activity. This would help in better understanding and possible forecast of earthquakes. The proposal is to drill up to 7 km and study the physical, geological and chemical processes and properties of the reservoir triggered earthquake zone in real time. It would be an international project to be led by Indian scientists.

  In 1973 the non-overflow portion of the dam was strengthened, followed by strengthening the spillway section in 2006. Now the dam is expected to be safe against any future earthquake, including ones with a higher intensity than that of 1967.

  The total capacity of the project is 1,960 MW. The project consists of four stages of power generation. All the generators are located in underground powerhouses excavated deep inside the mountains of the Western Ghats. A dam foot powerhouse also contributes to the electricity generation. Due to the project's electricity generating potential the Koyna River is considered as the life line of Maharashtra.

The project takes advantage of the height of Western Ghats. Thus a very large hydraulic head is available over a very short distance.

The project is composed of four dams with the major contributors being the Koyna Dam and Kolkewadi Dam. The water from Shivasagar reservoir was formed by the Koyna Dam and is used in the 1st, 2nd and 4th stages. This water is drawn from head race tunnels situated below the reservoir. Then it travels through vertical pressure shafts to the underground powerhouses. The discharged water from these stages is collected and stored in Kolkewadi Dam situated near village of Alore. The water is drawn from the penstocks of Kolkewadi Dam to an underground power station in the 3rd stage and then discharged to the Arabian Sea.

The electricity generated in all the stages is delivered to the main electrical grid. The project is run by the Maharashtra State Electricity Board

- **Stage I and II**: The first stage of the project was approved in late 1953 and construction began in early 1954. Initially a two-stage construction was conceived. But the total generation capacity of the two stages was too large for load forecasts of that time. So a time lag of more than 10 years was proposed between the two stages. Within two years thereafter, it came to be noticed that the 10 years time tag between these two stages will not be affordable and to cope up with the power requirements, the two stages should be merged and both the stages should be constructed simultaneously. Hence, it was accepted that the two stages have to be executed as one.

  The 1st and 2nd stages share same powerhouse with total eight Pelton turbine units. Each of the two stages has four turbines having capacity of 65 MW each for 1st stage and 75 MW each for 2nd stage. The water from Shivasagar reservoir is taken through an intake structure known as Navja tower near village of Navja into the head race tunnel. Then it travels towards the surge tank. It is further divided into four pressure shafts which run vertically downward delivering water to the turbines. Then the water is discharged into the tail race tunnel.

  A dam foot powerhouse was also constructed which is used to generate electricity by the water which is discharged from the Koyna Dam for irrigation purpose. It has two Francis turbine units of 20 MW each. This powerhouse is run according to the irrigation requirements of the downstream areas.

  The combined installed capacity of the two stages and the dam foot powerhouse is 600 MW.

- **Stage III :** Initially a weir was proposed to divert the water coming out of tail race tunnel of Stage I and II. But it was later observed that the water still had a hydraulic head of about 120 m which could be used. To use this head, the Kolkewadi Dam was constructed at this location. It forms a balancing reservoir and maintains the head. This dam impounds the tail race water from Stage I and II. This water is drawn through penstocks and electricity is generated by four Francis turbine units with a capacity of 80 MW each.
  The tail race water from these stages then flows through a channel and joins the Arabian Sea near Chiplun. The installed generating capacity of this stage is 320 MW.
- **Stage IV :** Later in the 1980s, the electricity demand of the Maharashtra increased tremendously resulting in inadequate power supply. The Planning Commission accorded approval to Stage IV with installation capacity of 4 × 250 MW. Thus, one more stage called Stage IV was added to power system of Stages I and II, thus converting the Koyna Power Station into a peaking power station complex with load factor of about 18.7%. This scheme also draws water from the existing Shivasagar reservoir same as Stages I and II.
  A nonconventional intake system was created by piercing the lake from the bottom by blasting the rock plug using dynamite. This double lake tapping process was the first of its kind in Asia.
  The water in head race tunnel is directly drawn from the reservoir and delivered to the head surge tank. Then four pressure shafts take the water downward vertically. The four huge Francis turbine units of 250 MW each generate electricity and tail race water is taken into the Kolkewadi Dam reservoir through tail race tunnel. A revolutionary gas insulated switchgear system is used in the underground powerhouse of this stage.
  The installed capacity of this stage alone is 1000 Mw. This stage is mostly used to cater for the peak hour demands of the electric grid.

14. INDIRA GANDHI PROJECT :

- **Introduction:** The Indira Gandhi Canal (originally, Rajasthan Canal) is the longest canal in India. It starts at the Harike Barrage near Harike, a few kilometers downriver from the confluence of the Satluj and Beas rivers in Punjab state, and ends in irrigation facilities in the Thar Desert in the northwest of Rajasthan state. Previously known as the Rajasthan Canal, it was renamed the Indira Gandhi Canal on 2 November 1984 following the assassination of Prime Minister Indira Gandhi.

- **Purpose:** The canal consists of the Rajasthan feeder canal with the first 167 kilometres (104 mi) in Punjab and Haryana state and a further 37 kilometres (23 mi) in Rajasthan. This is followed by the 445 kilometres (277 mi) of the Rajasthan main canal, which is entirely within Rajasthan. The canal enters Haryana from Punjab near Lohgarh and runs through the western part of the Sirsa district before entering Rajasthan near Kharakhera village in the Tibbi tehsil of the Hanumangarh district.

  It traverses seven districts of Rajasthan: Barmer, Bikaner, Churu, Hanumangarh, Jaisalmer, Jodhpur, and Sriganganagar. The main canal is 445 km (277 mi) long, which is 1458 RD (reduced distance). From 1458 RD, a 96 km (60 mi) long branch starts, known as the Sagar Mal Gopa Branch or the SMGS. From the end point of SMGS, another 92-kilometer-long sub-branch starts, the last of the Baba Ramdev sub-branch. It ends near Gunjangarh village in Jaisalmer district.

The idea of bringing the waters from the Himalayan Rivers flowing through Punjab and into Pakistan was conceived by hydraulic engineer Kanwar Sain in the late 1940s. Sain estimated that 2,000,000 ha (20,000 km2) of desert land in Bikaner and the northwest corner of Jaisalmer could be irrigated by the stored waters of Punjab rivers. In 1960, the Indus Water Treaty was signed between India and Pakistan, which gave India the right to use the water from three rivers: the Satluj, Beas and Ravi. The proposed Rajasthan Canal envisioned use of 7,600,000 acre-feet (9.4×109 m3) of water.

The initial plan was to build the canal in two stages. Stage I consisted of a 204 km (127 mi) feeder canal from Harike barrage, Firozpur, Punjab to Masitawali (Hanumangarh) with the main canal of 189 km (117 mi) from Masitawali (Hanumangarh) to Pugal, (Bikaner) in Rajasthan. Stage I also included constructing a distributary canal system of about 2,950 km (1,830 mi) in length. Stage II involved constructing a 256 km (159 mi) long main canal from Pugal (Bikaner) to Mohangarh (Jaisalmer) along with a distributary canal network of 3,600 km (2,200 mi). The main

canal was planned to be 140 ft (43 m) wide at the top and 116 ft (35 m) wide at the bottom with a water depth of 21 ft (6.4 m). It was scheduled to be completed by 1971.

The canal faced severe financial constraints, neglect and corruption.[2] In 1970 the plan was revised and it was decided that the entire canal would be lined with concrete tiles. Five more lift schemes were added and the flow command of Stage II was increased by 100,000 ha (1,000 km^2). With increased requirements, the total length of main, feeder and distribution canals was about 9,245 km (5,745 mi). Stage I was completed in 1983 around 20 years behind the completion schedule.

After the construction of the Indira Gandhi Canal, irrigation facilities were available over an area of 6,770 km^2 (1,670,000 acres) in Jaisalmer district and 37 km^2 (9,100 acres) in Barmer district. Irrigation had already been provided in an area of 3,670 km^2 (910,000 acres) in Jaisalmer district. Mustard, cotton, and wheat now grow in this semi-arid northwestern region, replacing the soil there previously. However, many dispute the success of this canal in arid regions and question whether it has achieved its goals.

- **Background:**
  - Kanwar Sain conceived it in 1948, and it was first broadcast on March 31, 1958.
  - The canal begins from the Harike Barrage in Punjab and goes about 40 kilometers in the Thar Desert (Marusthali) of Rajasthan, parallel to the Pakistan border.
  - The system's overall projected length is 9,060 kilometers, and it will serve the irrigation needs of a total culturable command area of 19.63 million hectares.
  - The flow system was supposed to irrigate around 70% of the total

command area, while the lift system was supposed to irrigate the rest.
- There are two stages to the construction process:

- **STAGE – I:**

- The command area of Stage-I lies in Ganganagar, Hanumangarh, and the **northern part of the Bikaner districts**.
- It's a gently undulating topography, and its culturable command area is 5.53 lakh hectares.

- **STAGE – II :**

- Stage II's command area spans the districts of Bikaner, Jaisalmer, Barmer, Jodhpur, Nagaur, and Churu, encompassing 14.10 lakh hectares.
- It consists of **desert territory** scattered with shifting dunes, with summer temperatures reaching 50 degrees Celsius.
- The water is hoisted in the lift canal to make it flow against the land's slope.
- The Indira Gandhi Canal system's lift canals all originate on the left bank of the main canal, while the flow canals all originate on the right side.

15. PRAMBIKULAM DAM :

- **Introduction:** Parambikulam Dam is an embankment dam on the Parambikulam River, Parambikulam located in the Palakkad district in the Western Ghats of Kerala, India, ranks number one in India as well as in the top ten embankment dams in the world in volume in the year 2000.
  This Dam was built at the time of Kamarajar. This is one of the Major irrigation schemes were planned in Kamaraj's period . The other projects are Lower Bhavani, Krishnagiri, Mani Muthuar, Cauvery delta, Aarani River, Vaigai Dam, Amravathi, Sathanur, Pullambadi, and Neyaru Dams. The dam is operated and maintained by Tamil Nadu but the ownership rests with Kerala,Per the agreement with Tamil Nadu, Kerala was supposed to receive 7.25 TMC feet of water per year from the Parambikulam-Aliyar Project of which the Parambikulam Dam is a part. In 2004, Kerala did not receive any water after February 10, resulting in the drying up of paddy in thousands of acres in Chittur taluk.Since this agreement has still not been met as of July 2006, Kerala Water Resources Minister has called for a review of the project agreement.
  On 17 October 2012, Kerala and Tamil Nadu reached an accord on Parambikulam-Aliyar water.
- **Background:** Parambikulam Dam is designed as an embankment dam on the Parambikulam River, included in the Palakkad district in the Western Ghats of Kerala, India. The dam is located near Udumalaipettai city in Kerala. Parambikulam Dam is known as one of the finest dams in India as well as one of the best embankment dams in the world in volume capacity as recorded in the year 2000.

Kerala was supposed to receive 7.25 TMC feet of water per year from the Parambikulam Aliyar Project, according to the state agreement with Tamil Nadu. The Parambikulam Dam is a part of Parambikulam Aliyar Project. In 2004, Kerala did not receive any water until February. Thus paddy in thousands of acres in Chittur taluk dried. The agreement of Parambikulam Aliyar Project started officially since July 2006; Kerala Water Resources Minister has called for a review of the project agreement for better execution.


Parambikulam Dam

The original Indian design provided for a 130-metre-high dam up to an elevation of 1627 ft above sea level, a 40 ft gated spillway at the top (between elevations 1560–1600 ft) and six under-sluices at elevation 1365 ft.[3] The under-sluices would have enabled the 'drawdown flushing' of sediments.[note 4] However, at Pakistan's insistence, the under-sluices were permanently plugged with concrete, and the gates were reduced from 40 ft to 30 ft. This meant that the only live storage is between elevations 1570–1600 ft, and the storage below that level has gotten silted up, forming an elevated river bed. The level of the bed now varies between 477 m (1,565 ft) and 484 m (1,588 ft).

16. BANSAGAR PROJECT :

- **Introduction:** Bansagar or Ban Sagar Dam is a multipurpose river Valley Project on Sone River situated in the Ganges Basin in Madhya Pradesh, India with both irrigation and 435 MW of hydroelectric power generation.
  Bansagar or Ban Sagar Dam is a multipurpose river Valley Project on Sone River situated in the Ganges Basin in Madhya Pradesh, India with both irrigation and *435 MW* of hydroelectric power generation.

The Bansagar Dam across the Sone River was constructed near the Deolond village in the Shahdol district. It is surrounded by Satna, Katni, and Rewa districts. The project was called "Bansagar" after Bana Bhatt, the renowned Sanskrit scholar of the 7th century, who is believed to have hailed from this region in India. Bansagar Dam is located at Latitude 24-11-30 N and Longitude 81-17-15 E.

The project was initially called the "Dimba Project" in 1956 by the Central Water Commission, New Delhi to be constructed on the Sone River at the confluence of the Sone and Banas Rivers near Shikarganj town 30 km down river from the present site. Later it was shifted to the present site at Deolond. There was an agreement in 1973 between the State Governments of Madhya Pradesh, Uttar Pradesh and Bihar for the construction of the dam, in which the states shared the expenditure in the ratio of 2:1:1. The 4 million-acre-feet of water is also shared by the states in the same ratio. The construction work was started in 1978 at original approved cost of Rs. 91.31 crores. The final estimated cost in 1998 was Rs. 1054.96 crores.

Pandit Ram Kishore Shukla following Motilal Vora leading to their motorcade succeeding an inspection of Bansagar The Bansagar Dam across the Sone

River was constructed near the Deolond village in the Shahdol district. It is surrounded by Satna, Katni, and Rewa districts. The project was called "Bansagar" after Bana Bhatt, the renowned Sanskrit scholar of the 7th century, who is believed to have hailed from this region in India. Bansagar Dam is located at Latitude 24-11-30 N and Longitude 81-17-15 E.Dam in Madhya Pradesh in 1985.jpg|200px|thumb|right|Pandit Ram Kishore Shukla following Motilal Vora leading to their motocade succeeding an inspection of Bansagar Dam in Madhya Pradesh in 1985]]

17. KANSHABATI PROJECTS :

- **Introduction**: Kangsabati River (also variously known as the Kasai and Cossye) rises from the Chota Nagpur plateau in the state of West Bengal, India and passes through the districts of Purulia, Bankura, Paschim Medinipur and Purba Medinipur in West Bengal before draining in the Bay of Bengal.

  he river's headwaters are on the Chota Nagpur Plateau in Purulia district, near the city of Jhalda, where the smaller rivers Saharjhor and Girgiri join together. From there, it passes through Bankura district, passing the towns of Purulia, Khatra and Ranibandh. At Binpur it is joined by the Bhairabbanki, and at Keshpur the river splits into two.

  The northern branch flows through the Daspur area, where it is known as the Palarpai. This branch eventually flows into the Rupnarayan River. The other branch, still called the Kangsabati, flows in a south-easterly direction. Eventually, it meets the Keleghai River, and the junction of the two forms the Haldi River, which flows into the Bay of Bengal at Haldia.

  In 1956, the Indian government launched the Kangsabati Irrigation Project (also called the Kangsabati Reservoir Project) to provide water for the irrigation of Bankura, Hooghly, and Midnapore districts (the last now partitioned into Paschim Medinipur and Purba Medinipur districts). To facilitate this, Mukutmanipur Dam was constructed at the border of Purulia and Bankura districts near Mukutmanipur, creating a large reservoir. It is an earthen gravity dam with a concrete saddle spillway, standing 38 metres (125 ft) high and 10,098 m (33,130 ft) long. Prior to this project, an anicut dam built on the Kangsabati River near Midnapore in 1784 was the sole irrigational structure on the river. As of August 2008, the dam provided water to just under 3,500 square kilometres (1,400 sq mi) of land.

  Kangsabati Reservoir Project was started in the year 1956-57. Till date an irrigation potential of 3,48,477 ha. has been created in the districts of Bankura, Midnapore and Hooghly through this Project.

With bank assistance and under Accelerated Irrigation Benefit Programme, the Government has undertaken large extension and improvement programme of the main canals. The project though originally planned for Kharif and limited Rabi, at present the irrigation water is provided for Boro cultivation also to an area of 27,944 ha.

18. MAYURAKHI PROJECTS:

- **Introduction:** Mayurakshi River is a major river in Jharkhand and West Bengal, India, with a long history of devastating floods. It has its source on Trikut Hills, about 16 kilometres from Deoghar in Jharkhand. Mayurakshi Reservoir Project was taken up for execution in 1951. This Project has been completed in all respects in the year 1985. The irrigation potential created through completion of this project comes to 2,50,860 ha. in the districts of Birbhum, Murshidabad and Burdwan. Irrigation water is also supplied to the state of Jharkhand from this reservoir to an area of about 6,000 ha. This Project is adjudged to be one of the best performing irrigation projects in India. The project was planned originally for giving water to Kharif and Boro seasons. At present with favourable rainfall we provide irrigation to Boro crops for an area of 20,000 ha (approx.). The industrial requirement of Bakreshwar Thermal Power project is also now made from this project. Though there is no provision for flood control yet with advanced planning it was possible to reduce peak flood of year 2000 by 30%.

19. Madhya Ganga project:

- **Introduction:** The Ganges Canal or Ganga Canal is a canal system that irrigates the Doab region between the Ganges River and the Yamuna River in India.
  The canal is primarily an irrigation canal, although parts of it were also used for navigation, primarily for its construction materials. Separate navigation channels with lock gates were provided on this system for boats to negotiate falls. Originally constructed from 1842 to 1854, for an original head discharge of 6000 ft^3/s, the Upper Ganges Canal has since been enlarged gradually for the present head discharge of 10,500 ft^3/s (295 m^3/s). The system consists of main canal of 272 miles and about 4000 miles long distribution channels. The canal system irrigates nearly 9,000 km^2 of fertile agricultural land in ten districts of Uttar Pradesh and Uttarakhand. Today the canal is the source of agricultural prosperity in much of these states, and the irrigation departments of these states actively maintain the canal against a fee system charged from users.
  There are some small hydroelectric plants on the canal capable of generating about 33MW if running at full capacity these are at Nirgajini, Chitaura, Salawa, Bhola, Jani, Jauli and Dasna.
  The canal is administratively divided into the Upper Ganges Canal from Haridwar to Aligarh, with some branches, and the Lower Ganges Canal which constitutes several branches below Aligarh.
- **Upper Ganges Canal:** The Upper Ganges canal is the original Ganges Canal, which starts at the Bhimgoda Barrage near Har ki Pauri at Haridwar, traverses Roorkee, Purquazi, Sardhana (Meerut district), Muradnagar, Dasna, Bulandshahr, Khurja, Harduaganj and continues to Nanau (near Akrabad) in

Aligarh district, where it bifurcates into the Kanpur branch and Etawah branch

- **Lower Ganges Canal:** A channel from Chaudhary Charan Singh Ganga barrage at Narora (Bulandshahr district) intersects the canal system 48 km downstream from Nanau (Aligarh district), and continues past the Sengar River and Sersa River, past Shikohabad in Firozabad District to become the Bhognipur branch which was opened in 1880. This branch, starting at village Jera in Mainpuri district, runs for 166 km to reach Kanpur. At kilometre 64 the Balrai escape carries excess water through a 6.4 km. channel through the ravines to discharge into the Yamuna. This branch has 386 km. of distributary channels.
  The Bhognipur branch, together with the Kanpur and Etawah branches, is known as the Lower Ganges Canal. The old channels of the old Kanpur and Etawah branches between Nanau and the point of intersection by the channel from Narora, are known as "stumps", and are utilized only when the supply of water in the lower Ganges system runs low.[3] The main branch of the river passes Kanpur (behind IIT Kanpur campus) before breaking into several branches. A branch of it terminates Kanpur Jal Sansthan which comes from behind J. K. Temple.

20. Salal project:

- **Introduction:** Salal Dam, also known as Salal Hydroelectric Power Station, is a run-of-the-river hydropower project on the Chenab River in the Reasi district of the Jammu and Kashmir.It was the first hydropower project built by India in Jammu and Kashmir under the Indus Water Treaty regime. After having reached a bilateral agreement with Pakistan in 1978, with significant concessions made to Pakistan in the design of the dam, reducing its height, eliminating operating pool, and plugging the under-sluices meant for sediment management, India completed the project in 1987. The concessions made in the interest of bilateralism damaged the long-term sustainability of the dam, which silted up in five years. It currently runs at 57% capacity factor. Its long-term future is uncertain.

  The project is located on the Chenab River near the Salal village in the Reasi District, a few kilometres south of Matlot where the river turns to a southerly course. Pakistan's Marala Headworks is 72 km (45 mi) downstream, from where the Marala–Ravi Link Canal and the Upper Chenab Canal carry water to various parts of Pakistani Punjab.

  The Salal project was conceived in 1920. Feasibility studies on the project commenced in 1961 by the Government of Jammu and Kashmir and a project design was readied by 1968. Construction was started in 1970 by the Central Hydroelectric Project Control Board (under the Government of India's Ministry of Irrigation and Power). The design of the project contained a two-stage powerhouse generating 690 MW power making use of the head created by the dam.

Under the Indus Waters Treaty of 1960, the Chenab River is allocated to Pakistan for exploitation (one of the 'Western Rivers' – Indus, Jhelum and Chenab). India has rights to use the river for "non-consumptive" uses such as power generation. India is obliged under the treaty to inform Pakistan of its intent to build a project six months prior to construction and take into account any concerns raised by the latter.

Since Pakistan lost the three eastern rivers to India by the treaty, its dependence on the Chenab river increased. It viewed the Salal project with great concern. Even limited storage in a relatively low dam upstream was viewed as a flood risk, even a threat, whereby India could flood Pakistan's farm lands by a sudden release of water. Equally, India could hold back water in its reservoir starving them of water. Zulfiqar Ali Bhutto, foreign minister and later

prime minister, argued that the dam could be used strategically as an instrument of war to bog down Pakistan's armour. After the two wars of 1965 and 1971, all such theories were easily believable.
During the negotiations, Pakistan raised technical objections to the design and capacity of the dam. It argued that the 40-foot gates on the spillways gave the dam more storage than allowed by the treaty. It also argued that the under-sluices included for sediment clearing were not permitted under the treaty. Indians argued that the flood risk that Pakistanis expressed was unreasonable. Any intention on India's part to flood Pakistan would involve causing much more damage to its own territory.In the face of Pakistan's unwillingness to relent, the Indian negotiators wanted to take it to arbitration by a neutral expert, as provided for in the treaty.
However, after signing the 1972 Simla Agreement with Pakistan, India wanted to steer the relations towards bilateralism. Its foreign policy establishment ruled out going to a neutral expert. In further bilateral talks in October 1976, India made significant concessions in the dam's height and other issues. An agreement was reached in 1977, but deferred till after the elections in Pakistan. Soon afterwards, change of government occurred in both India and Pakistan, but the understanding survived.[note 3]
A formal agreement was signed in Delhi on 12 April 1978 by Indian foreign minister Atal Bihari Vajpayee and Pakistan's foreign secretary Agha Shahi.The height of spillway gates was reduced from 40 ft to 30 ft. The under-sluices designed for sediment management were permanently plugged. The agreement was hailed as a triumph of bilateralism, facilitating an atmosphere of trust and confidence between the two countries.But the agreement also seriously damaged the sustainability of the dam and the Indian engineers viewed it as too high a price to pay for bilateralism

After signing the agreement in 1978, the construction of the project was entrusted to National Hydroelectric Power Corporation (NHPC) on an agency basis. NHPC was incorporated by the Government of India in 1975, with an authorised capital of Rs. 200 crore. The Salal project was its first project.

The Stage-I of the powerhouse was commissioned in 1987; Stage-II between 1993 and 1995. The final commissioning of the project took place in 1996. After completion, the Salal project was transferred to NHPC on an ownership basis. The Government of Jammu and Kashmir is said to have had a Memorandum of Understanding with the Government of India to receive the project at a depreciated cost However, according to the National Conference party, the coalition government in power at 1985, run by the Ghulam Mohammad Shah-wing of the National Conference and the Indian National Congress, surrendered the state's rights over the project.
The state of Jammu and Kashmir receives 12.5 percent of the energy generated from the project. The rest is transmitted to the Northern Grid where it is distributed to the states of Punjab, Haryana, Delhi, Himachal Pradesh, Rajasthan, and Uttar Pradesh. Jammu and Kashmir also purchases additional power at regular prices.

- **Technical parameters:** The original Indian design provided for a 130-metre-high dam up to an elevation of 1627 ft above sea level, a 40 ft gated spillway at the top (between elevations 1560–1600 ft) and six under-sluices at elevation 1365 ft.[3] The under-sluices would have enabled the 'drawdown flushing' of sediments.[note 4] However, at Pakistan's insistence, the under-sluices were permanently plugged with concrete, and the gates were reduced from 40 ft to 30 ft. This meant that the only live storage is between elevations 1570–1600 ft, and the storage below that level has gotten silted up, forming an elevated river bed. The level of the bed now varies between 477 m (1,565 ft) and 484 m (1,588 ft)

Other Most Important Projects In India

River Projects	River	Beneficiaries States	Objective
Mayurakshi Project	Mayurakshi	West Bengal	Irrigation and Hydropower
Matatila Project	Betva	Uttar Pradesh, Madhya Pradesh	Irrigation and Hydropower
Koyna Project	Koyna	Maharashtra	Hydropower
Salal Project	Chenab	Jammu Kashmir	Hydropower
Ghataprabha Project	Ghataprabha	Karnataka	Irrigation and Hydropower
Ramganga Project	Ramganga	Uttarakhand, Uttar Pradesh	Irrigation and Hydropower
Ukai Project	Tapti	Gujarat	Irrigation and Hydropower
Nafta-Jhakri Project	Satluj	Himachal Pradesh, Haryana, Punjab	Hydropower
Rihand Project	Rihand	Uttar Pradesh	Irrigation Hydropower
Idukki Project	Periyar	Kerala	Hydropower

Machkund Project	Machkund	Andhra Pradesh Orissa	Irrigation Hydropower
Nizam Sagar	Manjara	Andhra Pradesh	Hydropower
Mettur dam Project	Kaveri	Tamilnadu	Hydropower
Mahatma Gandhi (Jog) Project	Sharavati	Karnataka	Hydropower
Loktak Project	Manipur	Manipur	Hydropower

CHAPTER 4

CONCLUSION

Multi-purpose dams, if well planned and managed, provide an important option to meeting some of today's major development challenges. By providing clean and reliable energy, storage volume to improve drinking water supply or agricultural food production, and enhanced flood control, they contribute to energy, water and food security -- and to human security in general. In vulnerable regions, multi-purpose dams can also be an appropriate response to the impacts of climate change. Yet, as many new multi-purpose projects are expected to be realized in the future, the sustainability of large dams and reservoirs will remain a key issue.

Dr. B.B. Vora has rightly observed, **"The future of major and medium irrigation is dim and the country has neither the resources nor the time for creating additional gross potential of some 26 million hectares of irrigation through this route. Hence minor irrigation, particularly through the use of ground water, must be the mainstay for all future places."** Management of big dams is also being done at exorbitant financial and ecological costs.

But the management of minor projects has resulted in maximum use of water resources and better control.

Rapid growth of industrialization and urbanization and rising standards of living has exposed water resources to various forms of degradation. Creating water storage would go a long way in leading to river rejuvenation by augmentation of e-flows especially during lean season by considered dam operation strategies. It can be seen from the above case study of Dibang Multipurpose project that velocity/flow fluctuation in the downstream of dam is insignificant due to peaking operation. This could be achieved by proper planning of dam operation strategies. In a long-term perspective, green growth is growth without unsustainable deterioration of the environment or growth with 'modest' negative impact on the environment in the short term and hydropower growth comes under this green growth category.

Any development big or small, has some impact on the environment. A crucial decision concerns the desired condition or level at which the eco- system of the region is to be maintained. Sustainability concept suggests that we need to maintain the eco-systems so that they yield the greatest benefit to the present generations, while retaining the ability to meet the needs and aspirations of future generations. There is a need to accelerate the development of new water storage projects for multiple purposes. Reservoir regulation must be optimised to store more flood waters while considering the requirements of upstream and downstream areas.
 Storage projects are also needed for creation of water security which can be put to multiple use. Hydropower could be one of the incidental benefits for these storages.

Thus, in recent times, basic questions have been raised from various organisations about the standing conventional emphasis and grounds on the multi-purpose river valley projects. It is time to re-evaluate the irrigation policy of the country in a judicious manner and to formulate the policy with new directives and emphasis.