WATER RESOURCES SYSTEMS, PLANNING AND MANAGEMENT

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Content

- A Water Resources System
- Hydraulic Projects
- Conception, Planning, Design, Construction, Operation
- Water sharing policies
- Case Studies.

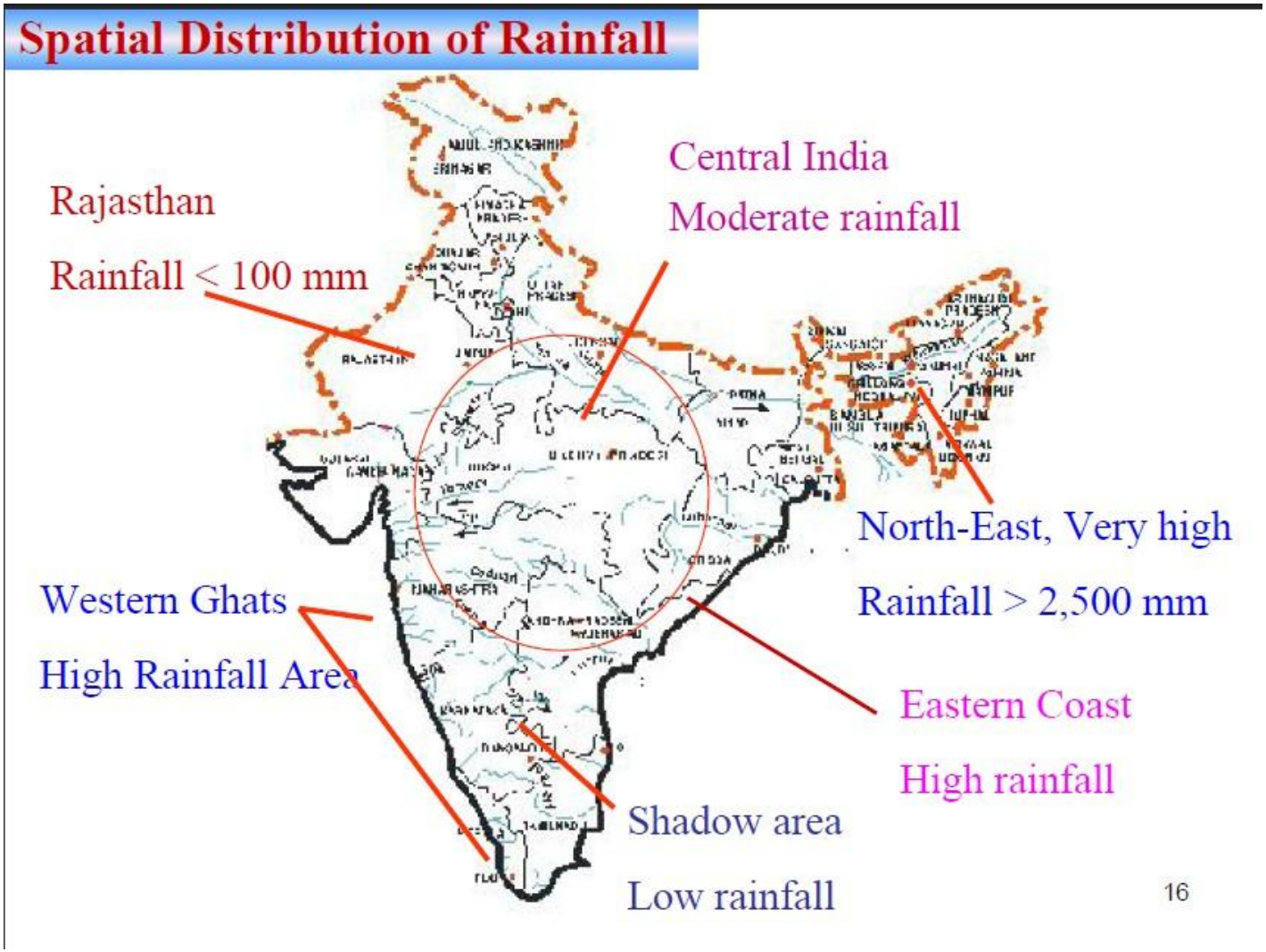
Water Resources System

- Water Resources are special
- Natural states they are beautiful.
- People like to live and vacation near rivers, lakes and coasts.
- Water can erode rock, alter existing landscapes and form new ones.
- All of the food we grow, process and eat requires water.
- Much of our waste is transported and assimilated by water.

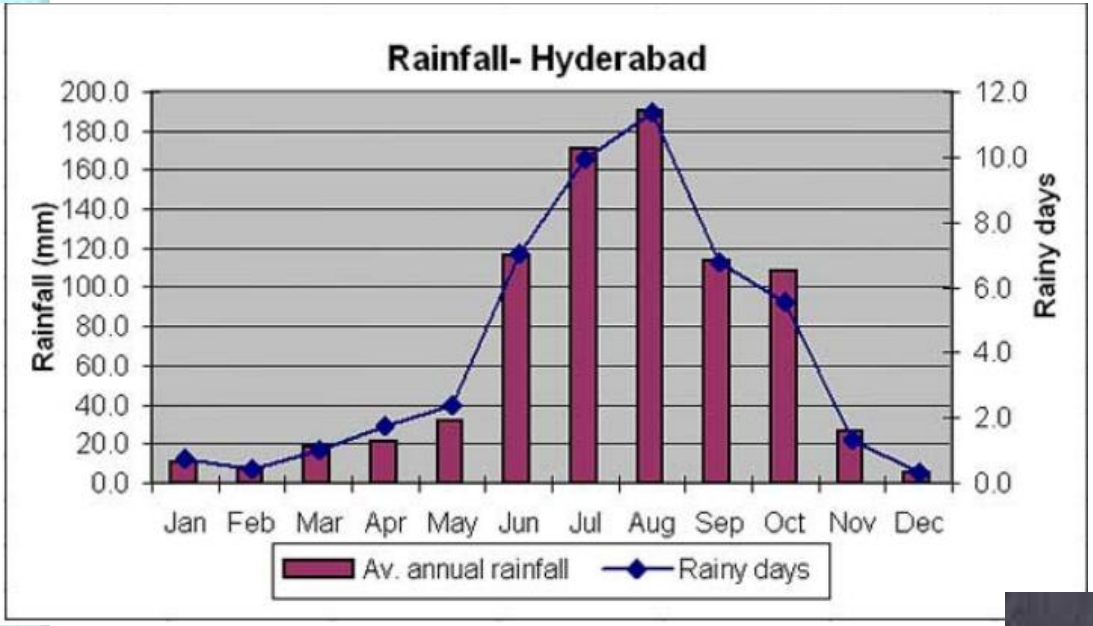
What is the Problem?

- Water is not distributed as we might wish
- There is often too much or too little
- What exists is too polluted or too expensive
- Water situation is likely to further deteriorate as a result of global climate changes

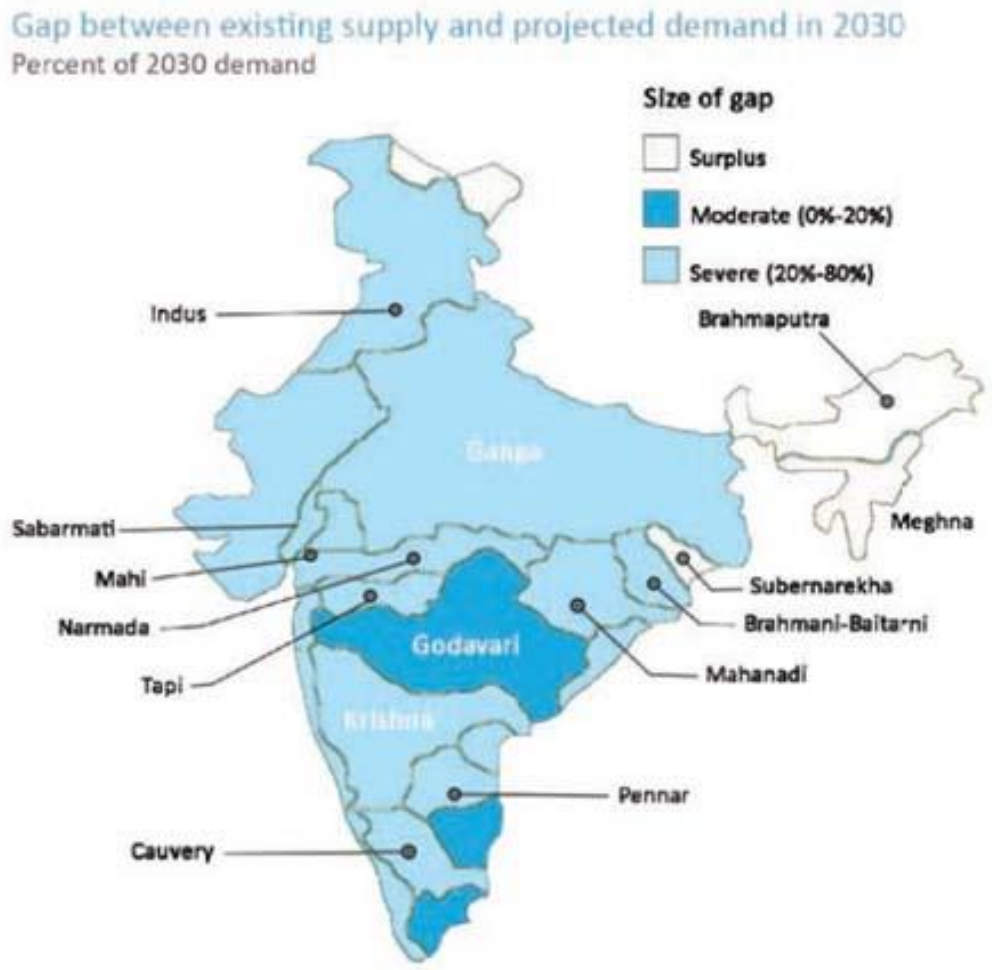
Rainfall - Spatial Variability



Rainfall - Temporal Variability



India's Water Supply and Demand Gap



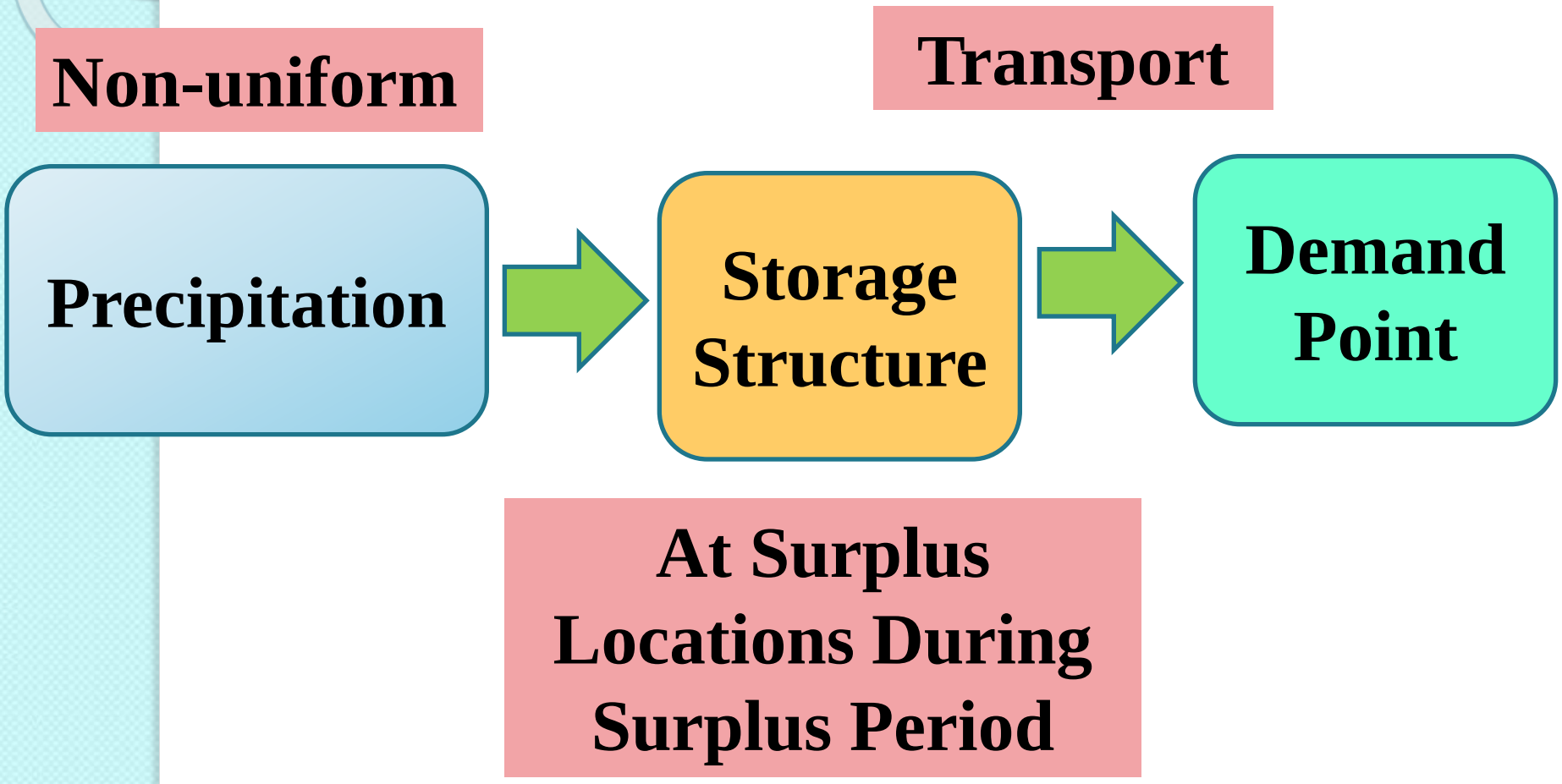
Source: Addams et al. (2009 : 55)

What is the Solution?

The mismatch of supply and demand over time and space has motivated the development of much of the water resources infrastructure that is in place today.

- Hydraulic Projects
- Basin Watershed Management
- Integrated Water Resources Management

Design of Hydraulic Structures

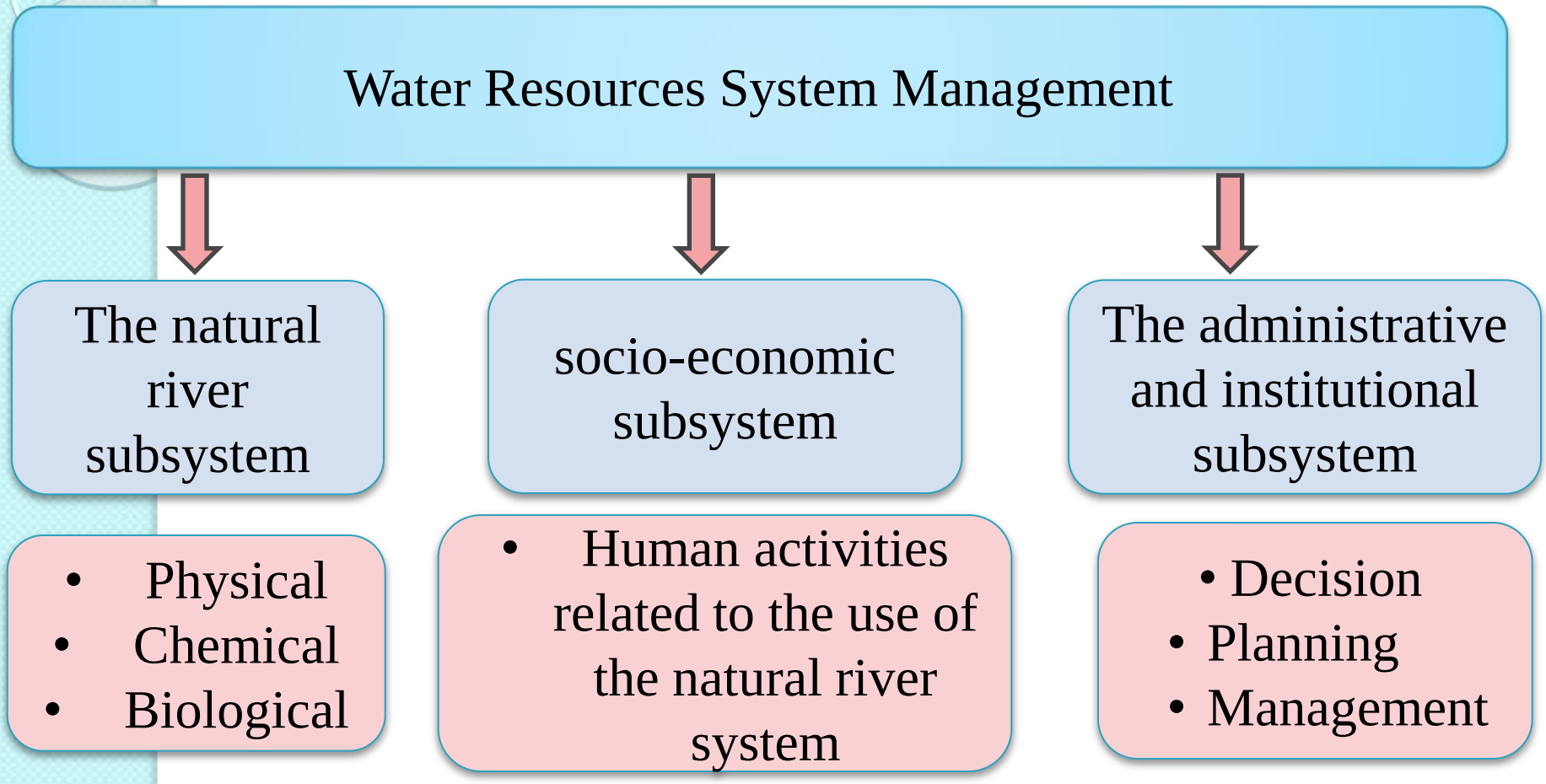


Hydraulic or Water Resources Projects

- Flood control and Famine Reduction
- National economy
- Electric power generation
- Silt mitigation and navigation
- Irrigation and draining
- Fish handling and farming
- Ecologic protection, and recreation

Hydraulic Projects

- A number of hydraulic structures are constructed to form a hydraulic project known as the water resources project.
- The goal of **sustainable water management** is to promote water use in such a way that society's needs are both met to the extent possible now and in the future.
- Managing water resources requires knowledge of the relevant physical sciences and technology.


Water Resources System Management
The natural river subsystem
socio-economic subsystem
The administrative and institutional subsystem
• Physical
• Chemical
• Biological
• Human activities related to the use of the natural river system
• Decision
• Planning
• Management

Regional Water Resources System

- Conception
- Planning
- Design
- Construction
- Operation

Conception of Regional Water Resources System

- How much of water is needed?
- How much water is available?
- How are the requirements will be satisfied by the supplies?
- How is the used up water disposed of?
- What is the source of Water?

Statement of Objectives

- A national Govt. may have a goal of achieving maximum economic and social benefits for the entire nation
- A state Govt. may have a single objective of reducing the flood damage within its boundaries
- The corporations or metropolitan councils or village panchayats need water supply or irrigation facilities

Data Required

- **Physical**: Location, topography, climate
- **Hydrological**: Precipitation, streamflow, sediment etc.
- **Geological**: Soil survey, erosion, ground water, minerals etc.
- **Cartographic**: Maps
- **Ecological**: Vegetation, fish and wild life
- **Economic**: industry, transportation, tourism, markets etc.
- **Legal**: Water rights, land ownership, intrastate and interstate problems, operation rights etc.
- **Public Opinion**
- **Data on Existing Projects**

Projections for planning

- A hydraulic project must be planned to meet present as well as future water requirements
- Projections of future needs compatible to population growth should be made
- Unrealistic higher values of water needs may lead to over design and excessive investments

Site Selection for a Hydraulic Project

- Suitable dam site should exist – A narrow valley opening – shorter length of dam – low cost of the project
- A wide river valley above the dam site – more water storage – adequate reservoir capacity
- Deep reservoir – shallow reservoir has more evaporation, higher land cost, prone to weed growth
- Less marshy land and vegetative growth should be less – Impact on Quality of water
- Impervious rock formation to prevent leakages
- Reservoir banks and hilly abutments should be stable to avoid hill slides or soil movement into the reservoir
- Submerged land cost
- Accessibility

Investigations for a Hydraulic Project

- Geology of the catchment area
- Water tightness of reservoir
- Suitability of foundation for the dam
- Geological features such as faults, fissures and folds etc.
- Location of permeable and soluble rocks
- Ground water contribution in the region
- Location of quarry sites
- Study of runoff pattern
- Study of the worst flood, to determine the spillway capacity and design

Components of Hydraulic Structures

- **Storage:** Dams and Reservoirs
- **Flow Control**: Spillways, Gates, Outlets, Valves etc.
- **Diversion:** Coffer Dams, weirs, Canal Head Works, Intake Works
- **Conveyance:** Open Channel, Pressure Conduits, Pipes, Canals and sewers

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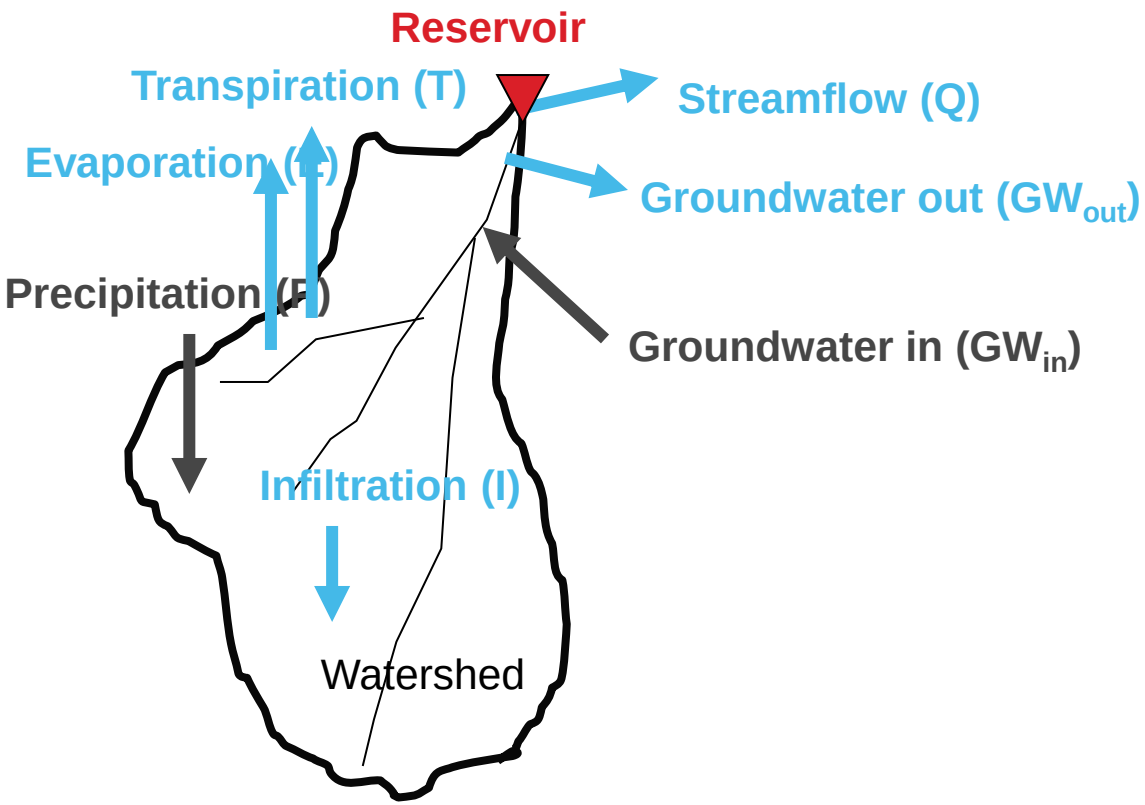
- **Collection:** Drain inlets, Infiltration Galleries, Wells

Water Availability or Inflows to Reservoirs



Physical characteristics affecting Runoff

- **Land use**
- **Vegetation**
- **Soil type**
- **Drainage area**
- **Basin shape**
- **Elevation**
- **Topography**
- **Drainage network patterns**
- **Ponds, lakes, reservoirs etc. in the basin**

Hydro - meteorological factors affecting runoff

- **Rainfall intensity, amount, duration**
- **Distribution of rainfall over the basin**
- **Antecedent moisture content**

Hydrologic Budget (In – Out = ΔStorage)

$$(P + GW_{in}) - (E + T + I + GW_{out} + Q) = \Delta Storage_{reservoir}$$


Upstream
Reservoir
Spillway
Dam body
Downstream

Reservoir

- An area or a water body formed due to construction of a Dam

Benefits

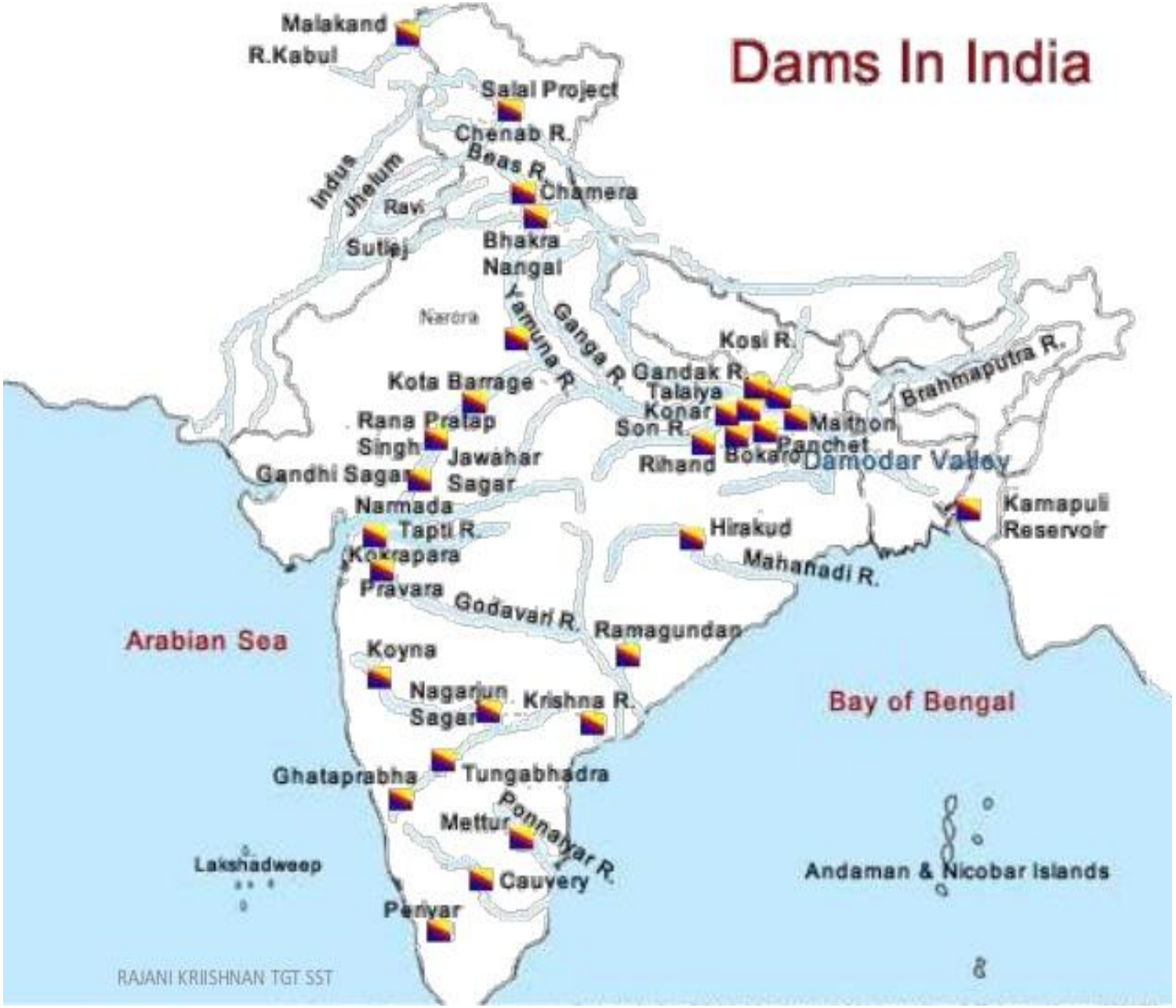
- Protection from flood
- Water Storage
  - Irrigation
  - Hydropower
  - Water supply
  - Navigation
- Improvement in Climate
- Improved water supply and Sanitation

Issues to be Considered

- Submergence of fertile valley lands
- Displacement of Large Population and wild life
- Possible adverse effects on Ecology of the project area

Indian Reservoirs and Dams

- In terms of number of dams, India ranks fourth after China, USA and Russia.
- Currently there are 4710 completed large dams and 390 are under-construction
- Indira Sagar – Narmada River in Madhya Pradesh
- Nagarjuna Sagar – Krishna River in Andhra Pradesh
- Hirakud Reservoir – Mahanadi River
- Gobind Sagar reservoir - Sutlej river, Himachal Pradesh.


Dams In India
Malakand
R.Kabul
Salal Project
Chenab R.
Beas R.
Indus
Jhelum
Ravi
Chamera
Sutlej
Bhakra
Nangal
Narora
Yamuna R.
Ganga R.
Kosi R.
Gandak R.
Brahmaputra R.
Kota Barrage
Talaiya
Konar
Rana Pratap
Singh
Jawahar
Sagar
Gandhi Sagar
Son R.
Rihand
Bokaro
Damodar Valley
Maithon
Panchet
Kamapuli
Reservoir
Hirakud
Mahanadi R.
Narmada
Tapti R.
Koyna
Nagarjun
Sagar
Pravara
Godavari R.
Ramagundam
Krishna R.
Arabian Sea
Bay of Bengal
Ghataprabha
Tungabhadra
Mettur
Ponnaiyar R.
Cauvery
Periyar
Lakshadweep
Andaman & Nicobar Islands
RAJANI KRIISHNAN TGT SST


Bhakranangal
Satluj
Sardar sarovar
Narmada
Tehri dam
Ganga
Hirakud
Mahanadi

Components of Hydraulic Structures

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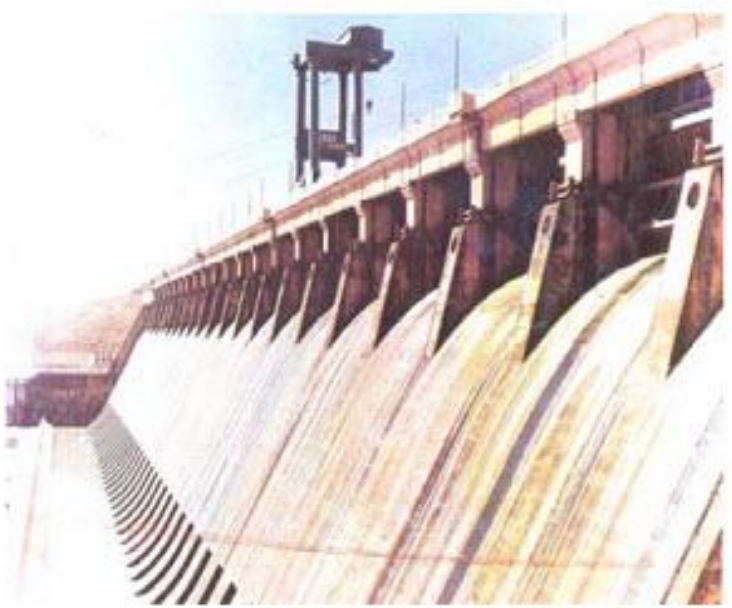
SPILLWAY

- Effectively disposing of the surplus water from upstream to downstream
- Dispose the surplus water and will not let the water rise above the maximum reservoir level, a safety valve for a dam.
- Prevent overtopping and possible failure of the dam
- Structurally and hydraulically adequate to withstand under worst and variable loading conditions.

SPILLWAY IN BHAKRA DAM AND SPILLWAY IN HIRAKUD DAM



TROUGH OR CHUTE SPILLWAY

Tehri dam, India

Components of Hydraulic Structures

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Diversion Head Works

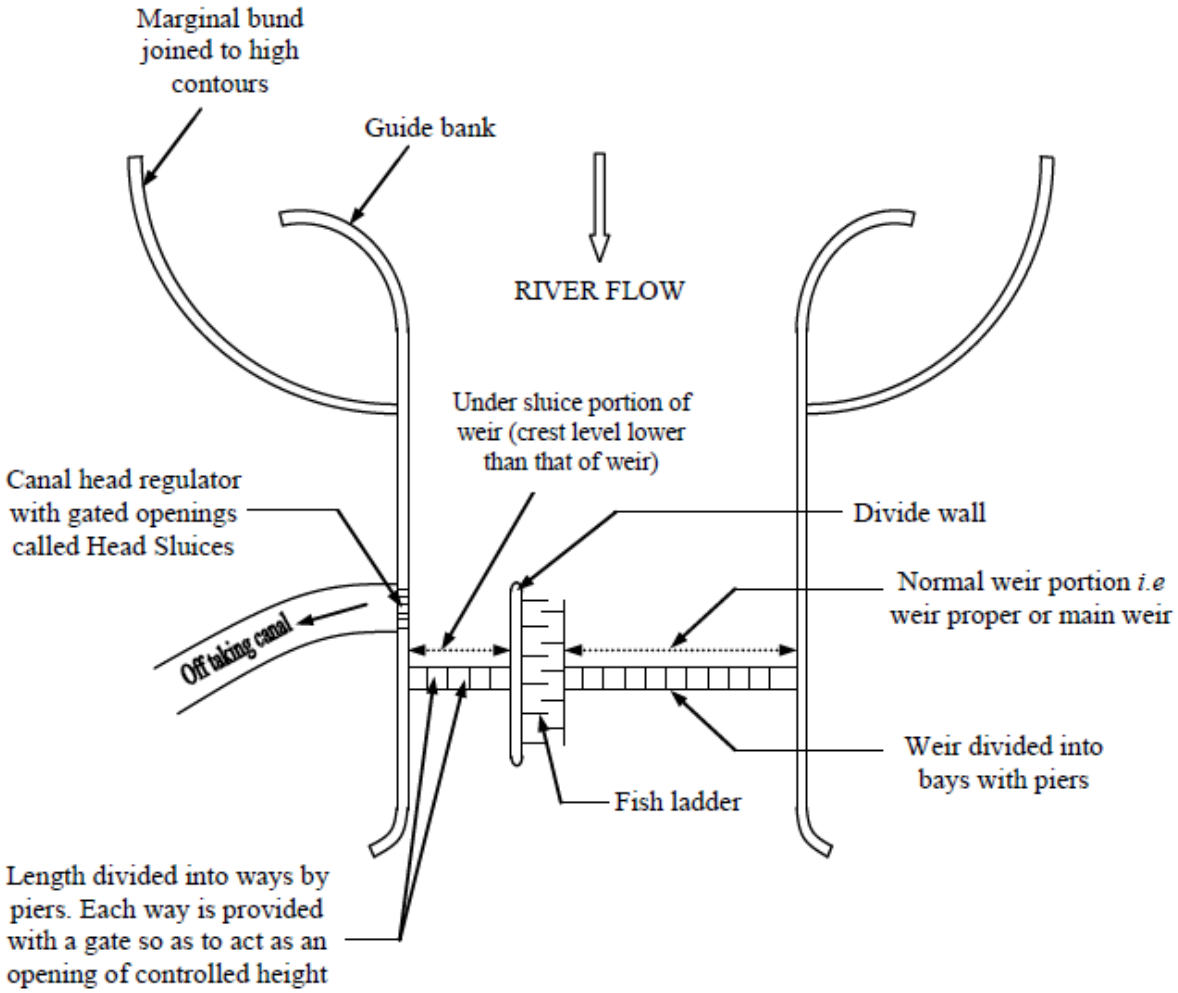

Fig: Typical layout of diversion head-works

Components of Hydraulic Structures

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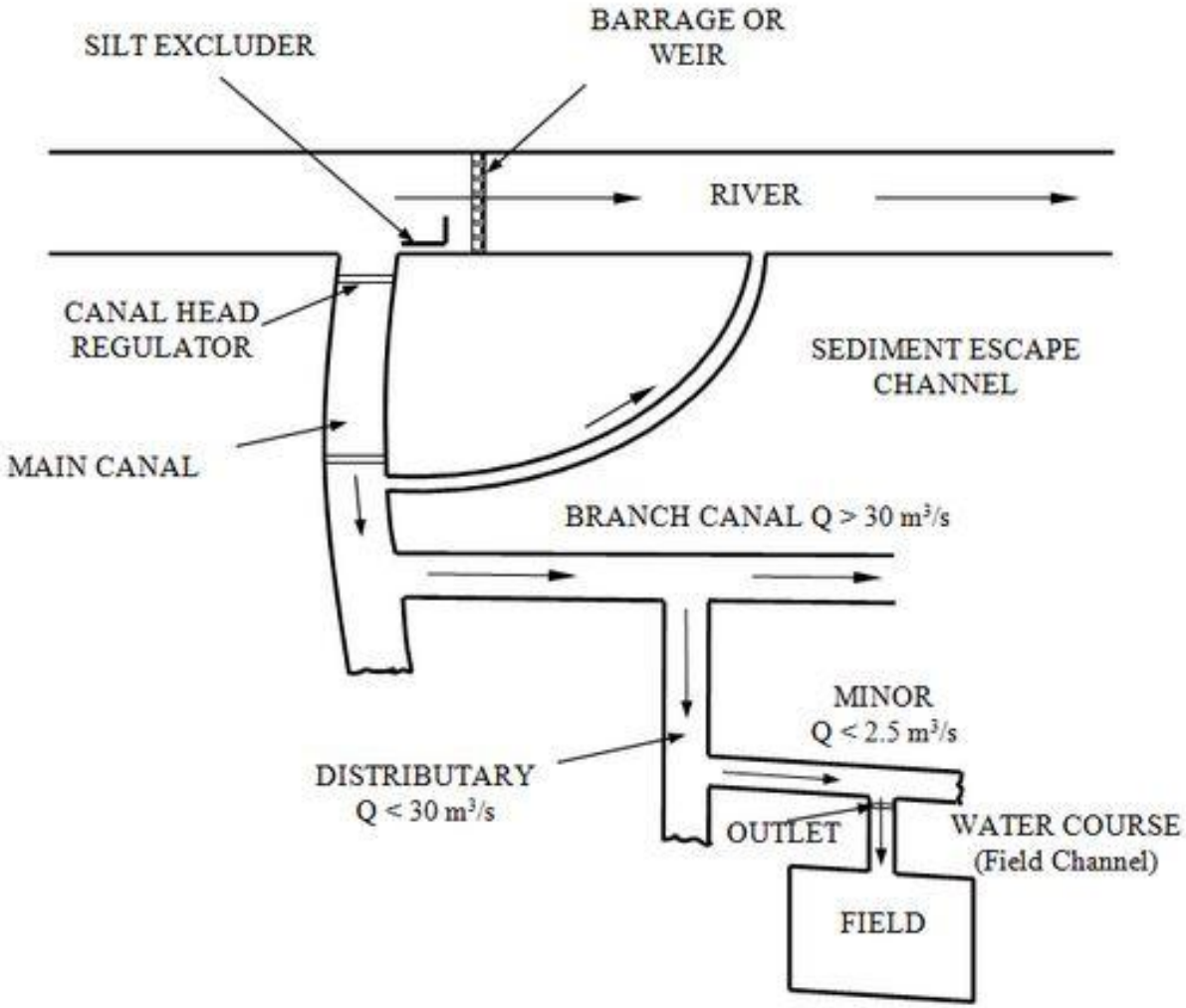
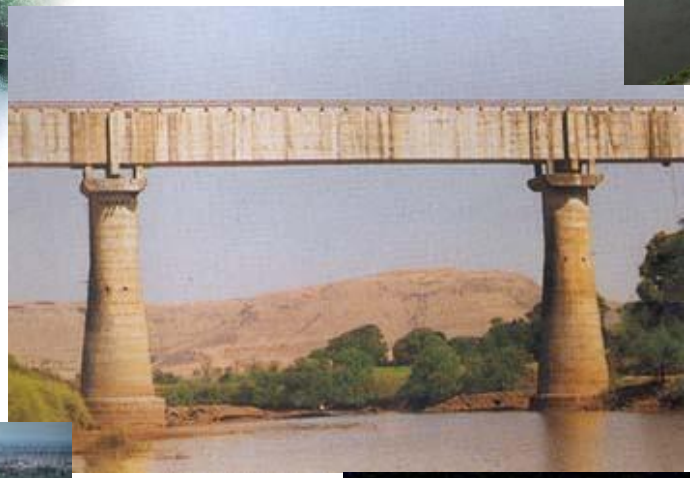
Canals

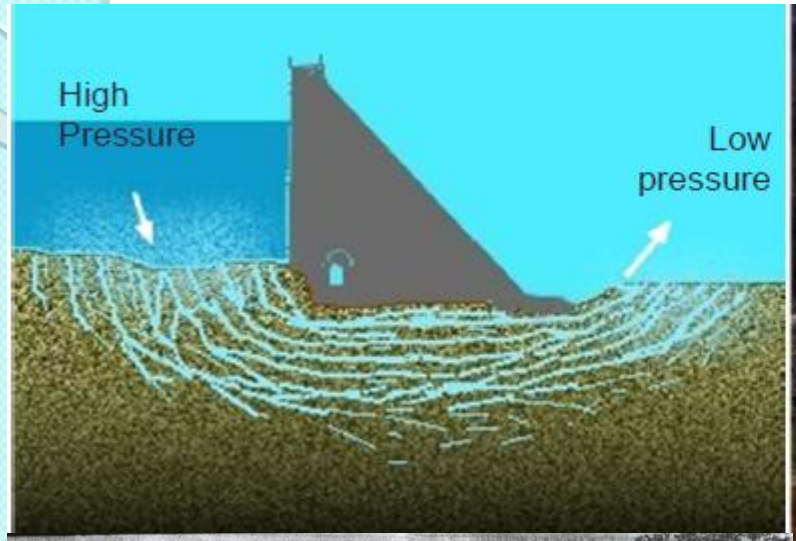
Distribution of Water

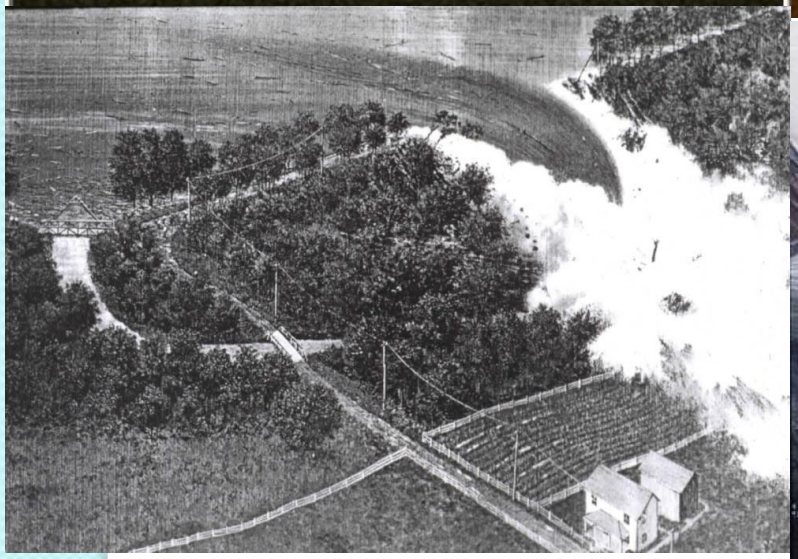


Cross Drainage Works

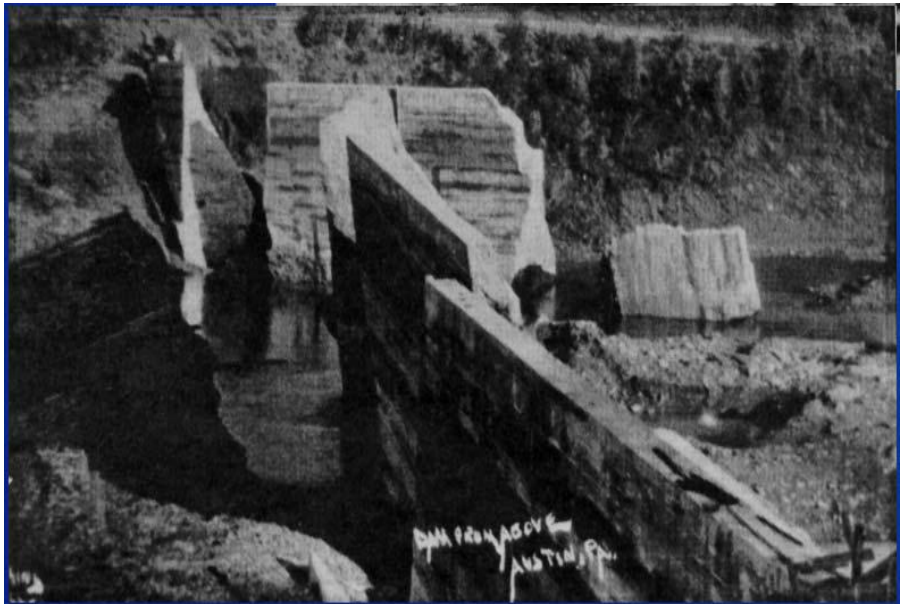


Failures of Hydraulic Projects





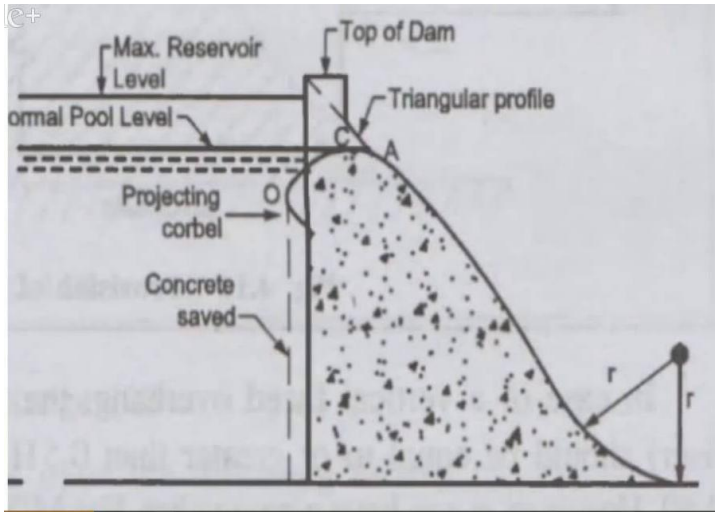
GRAVITY DAM OVERTOPPING



1979 Machchhu dam failure

- Machchu-2 dam, situated on the Machhu river, the town of Morbi in the Rajkot district of Gujarat.
- dam failure is due to flood disaster which occurred on August 11, 1979 in India.
- Estimates of the number of people killed vary greatly ranging from 1800 to **25000** people.
- The spillway capacity provided for **5663 m^3/s** but the actual flow reached is **16307** m^3/s, thrice what the dam was designed for, resulting in its collapse.
- Within 20 minutes the floods of 12 to 30 ft (3.7 to 9.1 m) height inundated the low-lying areas of Morbi industrial town located 5 km below the dam.
- During reconstruction of the dam the capacity of the spillway was increased by 4 times and fixed at about **21,000 m^3/s.**

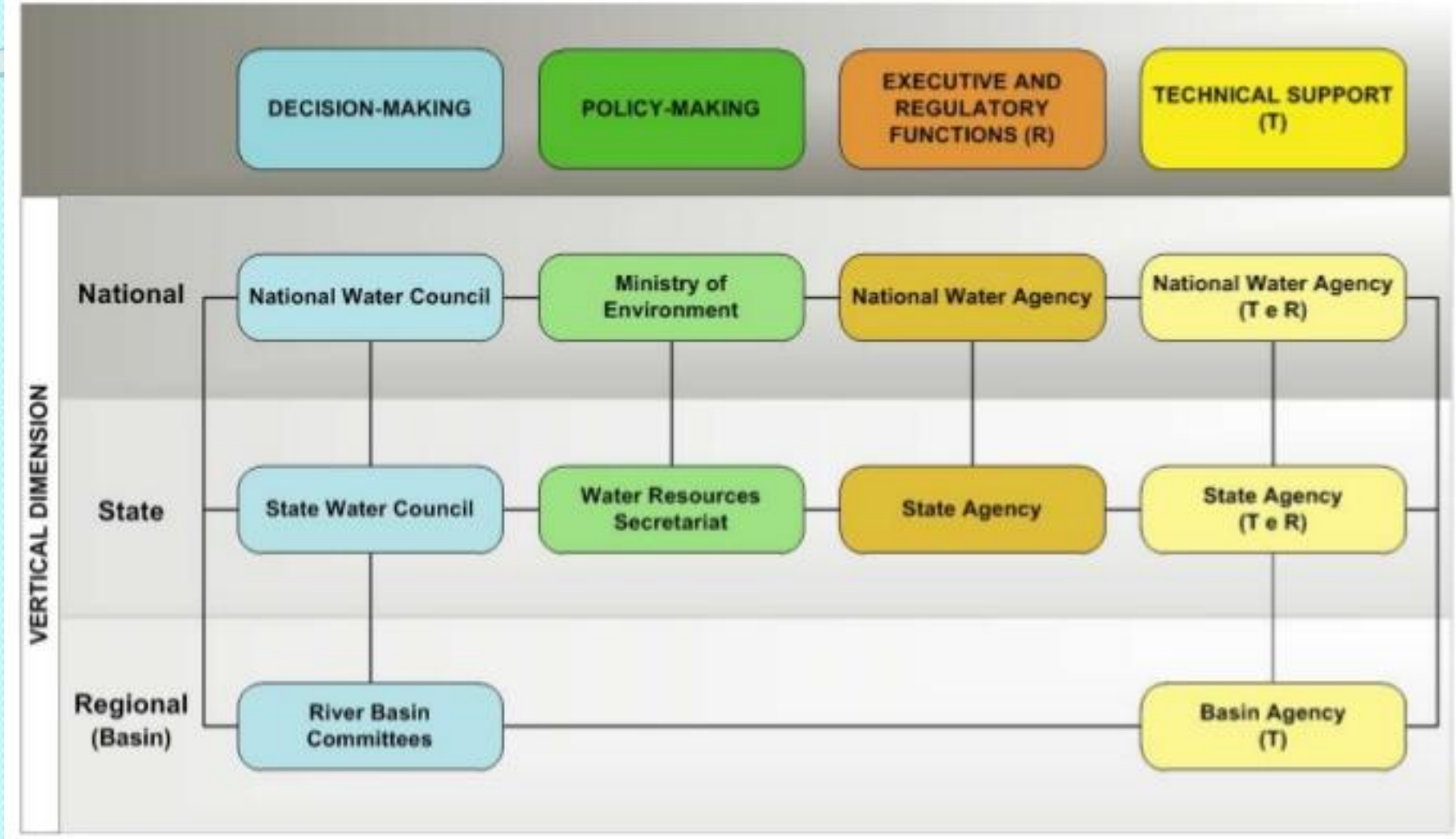
Construction of a Hydraulic Project



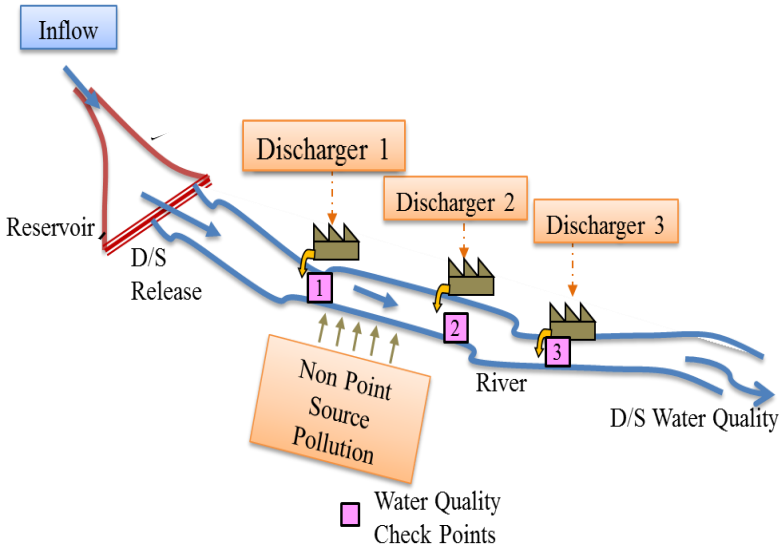
Solar panels are being installed along a 1 kilometre (0.62 mi) pilot project section of the Sanand Branch Canal near Chandrasan village to generate 1 megawatt (1,300 hp) of electricity. The panels are forecast to also reduce evaporation of water from the canal by 9,000,000 litres (2,000,000 imp gal; 2,400,000 US gal) per year

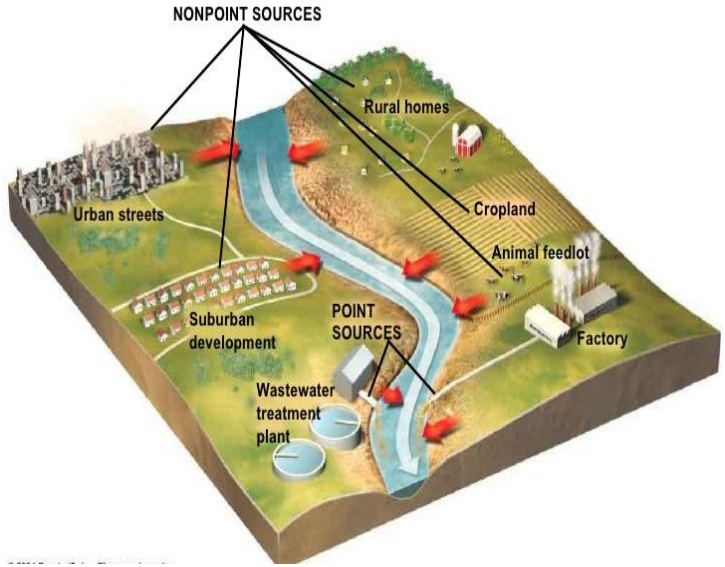
Installed solar panels in covered Narmada Canal

Operation of a Hydraulic Project



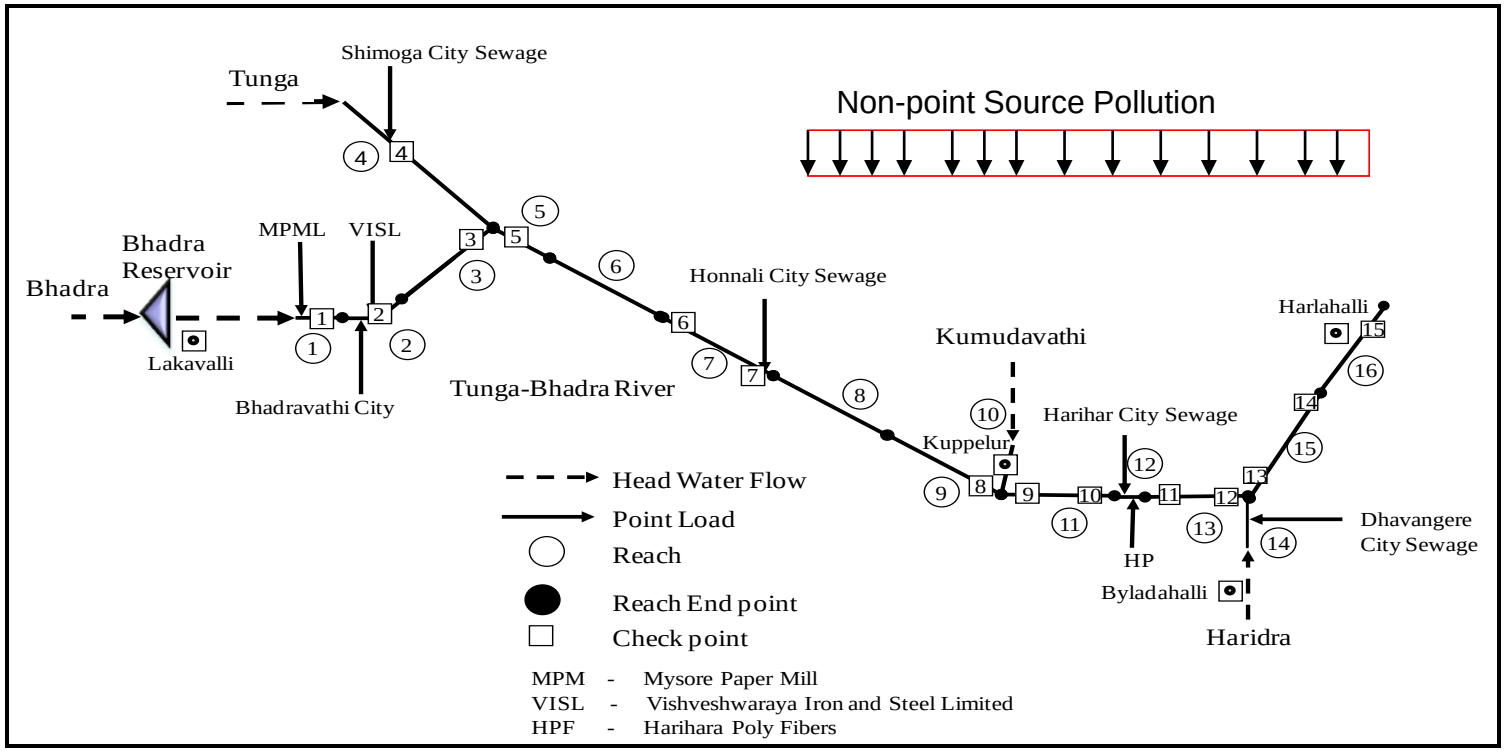
River Water Quality System





- A river system is subjected to a number of pollutants, and these pollutants change the water quality in the river.
- For the estimation of extent of pollution, water quality indicators like DO will be checked at some check points by Pollution Control Agency(PCA), so that DO should be within desirable limit.

Waste Load Allocation Models



•WLA refers to determining the required pollutant treatment levels at a number of point and non point sources to attain a satisfactory water quality response in a receiving water body in an economically efficient manner.

•To arrive at optimal fraction removal levels addressing uncertainty due to randomness, fuzziness and partial ignorance due to missing data or limited data in the input variables.

Major challenges of Agriculture

Climate change - variability - extremes

Soil fertility

Water management

Impact of hazardous pesticides and nitrogen fertilizers

Burning of crop residue

Alkalinity of soils

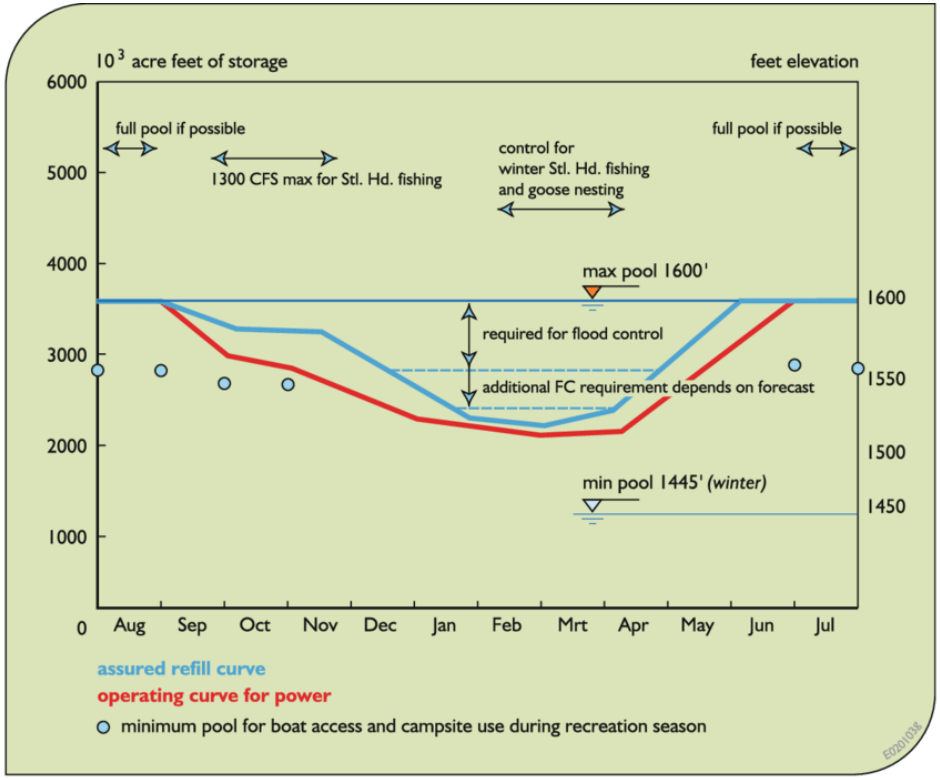
Various problems accompanying urbanization

- Decrease in river flow at ordinary times
- Increase in river runoff at times of rain
- Decline in capacity of stable supply at water supply facilities
- Deterioration of water quality
- Depletion of spring water
- Ground subsidence, etc.

Necessity of sound hydrological cycles

- Securing of safe and tasty water
- Avoidance of urban flood damage
- Maintenance of river flow at ordinary times
- Alleviation of damage by water shortage
- Mitigation of the heat island phenomenon

Reservoir Release Policies



Source: Loucks D.P., van Beek E. (2017) An Introduction to Optimization Models and Methods. In: Water Resource Systems Planning and Management. Springer, Cham, ISBN 978-3-319-44232-7.

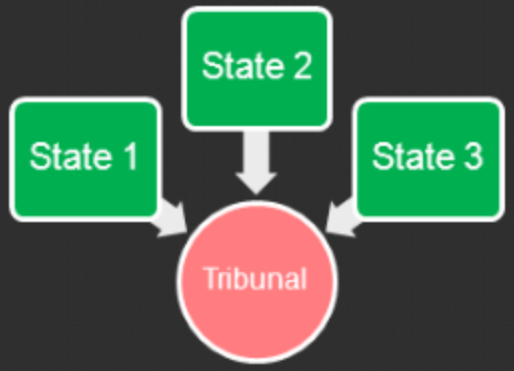
Interstate Water Disputes

- Disputes arising among the states in sharing a river water

- As per the inter-state river water disputes act, 1956 (ISRWD Act, 1956), the water disputes among two or more state Govt. the central govt. receives a request.

Methods of Resolution

Eg. Yamuna River water dispute among Delhi, Haryana and Uttar Pradesh



Eg. The Godavari Water Disputes Tribunal,
Krishna River Water Disputes Tribunal,
The Ravi & Beas Waters Tribunal,
The Narmada Water Disputes Tribunal,
The Kaveri Water Disputes Tribunal.

Approaches of Resolution

Sub-basin Division Approach

- The whole river basin is divided into Sub-basins and thereafter the concerned parties are allocated with the command of Sub-basin lying within their area.

Eg. Indus Water Treaty, 1960 between India and Pakistan. India has rights over three eastern rivers (Ravi, Beas & Satluj) and Pakistan over Western rivers (Chenab, Jhelum and Indus)

Similar, approach was taken in Godavari river dispute among Maharashtra, Karnataka, Andhra Pradesh, Madhya Pradesh and Orissa)

Principle of "Equitable apportionment

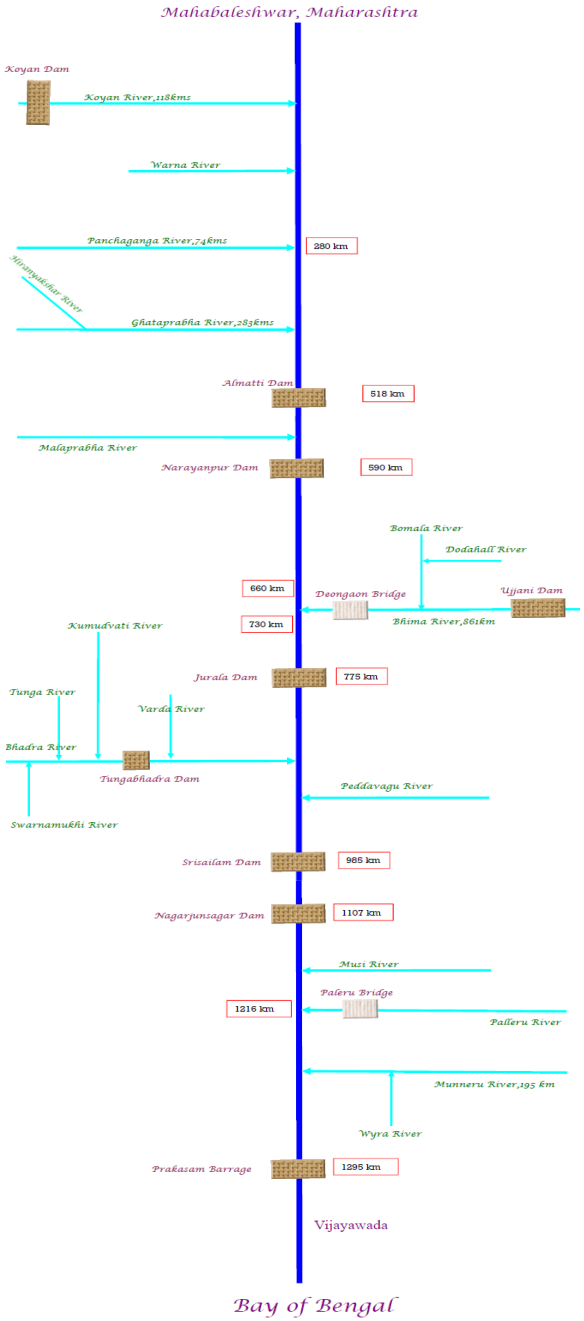
- The proportionate share of states are decided on the basis of their respective property rights, area of drainage, investments, uses and total volume of water in the river.

Eg. The award of Kaveri Water Tribunal :-

State	Allotted water (TMC ft)
Tamil Nadu	419
Karnataka	270
Kerala	30
Puducherri	7
Reserved	10
Sea discharge	4
Total	740

Krishna River Water Allocation

State	TMC
Maharashtra	666
Kamataka	911
Andhra Pradesh	1001


Mahabaleshwar, Maharashtra
Koyan Dam
Koyan River,118kms
Warna River
Panchaganga River,74kms
280 km
Hiranyakeshi River
Ghataprabha River,283kms
Almatti Dam
518 km
Malaprabha River
Narayanpur Dam
590 km
Bomala River
Dodahall River
660 km
Deongaon Bridge
Ujjani Dam
Bhima River,861km
730 km
Kumudvati River
Jurala Dam
775 km
Tunga River
Varda River
Bhadra River
Tungabhadra Dam
Peddavagu River
Swarnamukhi River
Srisailam Dam
985 km
Nagarjunsagar Dam
1107 km
Musi River
Paleru Bridge
1216 km
Palleru River
Munneru River,195 km
Wyra River
Prakasam Barrage
1295 km
Vijayawada
Bay of Bengal

Environmental Factors

- Hydraulic structures alter natural variation in higher and lower discharges.
- May disturb riverine ecological processes such as spawning and migration of fish species
- Estimations of livelihood impacts for different groups of people, such as farmers, fishermen, and reed harvesters. In the
- Inclusion of economic, environmental and social impacts of basin-wide water resources