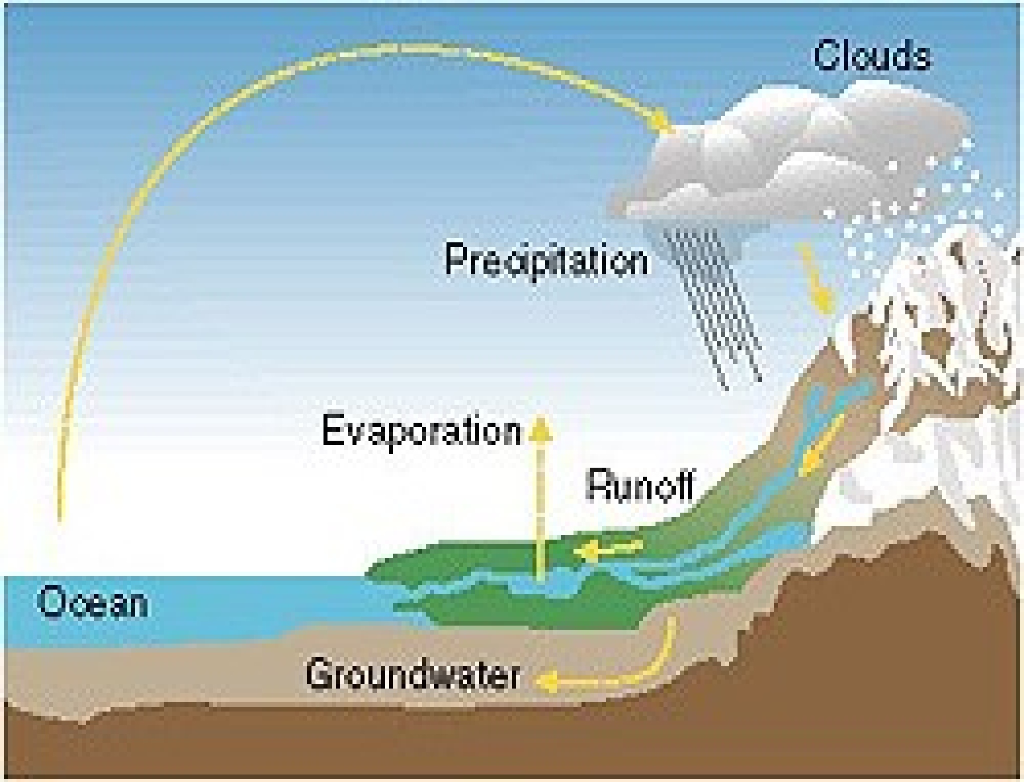
Hydro Power

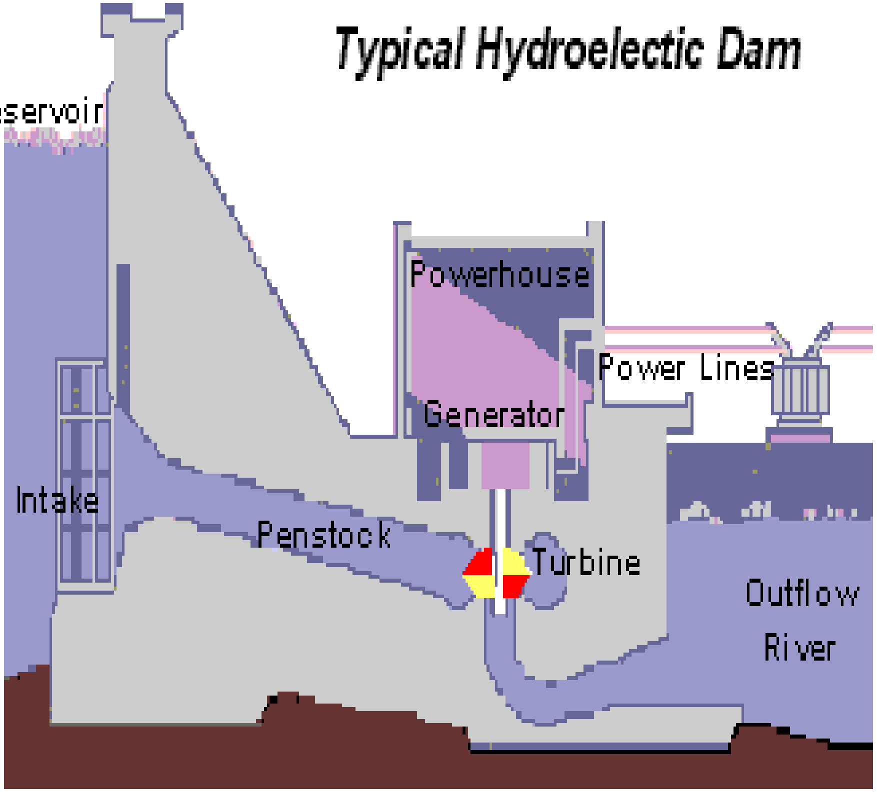
How Hydropower Works!

- Hydrologic cycle



How Hydropower Works! (ctd…)

- Water from the reservoir flows due to gravity to drive the turbine.
- Turbine is connected to a generator.
- Power generated is transmitted over power lines.



Top ten countries (in terms of capacity)

COUNTRY	POWER CAPACITY (GWh)	INSTALLED CAPACITY (GW)
TAJIKISTAN	527000	4000
CANADA	341312	66954
USA	319484	79511
BRAZIL	285603	57517
CHINA	204300	65000
RUSSIA	160500	44000
NORWAY	121824	27528
JAPAN	84500	27229
INDIA	82237	22083
FRANCE	77500	77500

The Indian Scenario

- The potential is about 84000 MW at 60% load factor spread across six major basins in the country.
- Pumped storage sites have been found recently which leads to a further addition of a maximum of 94000 MW.
- Annual yield is assessed to be about 420 billion units per year though with seasonal energy the value crosses600 billion mark.
- The possible installed capacity is around 150000 MW (Based on the report submitted by CEA to the Ministry of Power)

Continued …

- The proportion of hydro power increased from 35% from the first five year plan to 46% in the third five year plan but has since then decreased continuously to 25% in 2001.
- The theoretical potential of small hydro power is 10071 MW.
- Currently about 17% of the potential is being harnessed
- About 6.3% is still under construction.

India's Basin wise potential

Rivers	Potential at 60%LF (MW)	Probable installed capacity (MW)
Indus	19988	33832
Ganga	10715	20711
Central Indian rivers	2740	4152
West flowing	6149	9430
East flowing	9532	14511
Brahmaputra	34920	66065
Total	84044	148701

Region wise status of hydro development

REGION	POTENTIAL ASSESSED (60% LF)	POTENTIAL DEVELOPED (MW)	% DEVELOPED	UNDER DEVELOPMENT
NORTH	30155	4591	15.2	2514
WEST	5679	1858	32.7	1501
SOUTH	10763	5797	53.9	632
EAST	5590	1369	24.5	339
NORTH EAST	31857	389	1.2	310
INDIA	84044	14003	16.7	5294

Major Hydropower generating units

NAME	STATA	CAPACITY (MW)
BHAKRA	PUNJAB	1100
NAGARJUNA	ANDHRA PRADESH	960
KOYNA	MAHARASHTRA	920
DEHAR	HIMACHAL PRADESH	990
SHARAVATHY	KARNATAKA	891
KALINADI	KARNATAKA	810
SRISAILAM	ANDHRA PRADESH	770

Installed Capacity

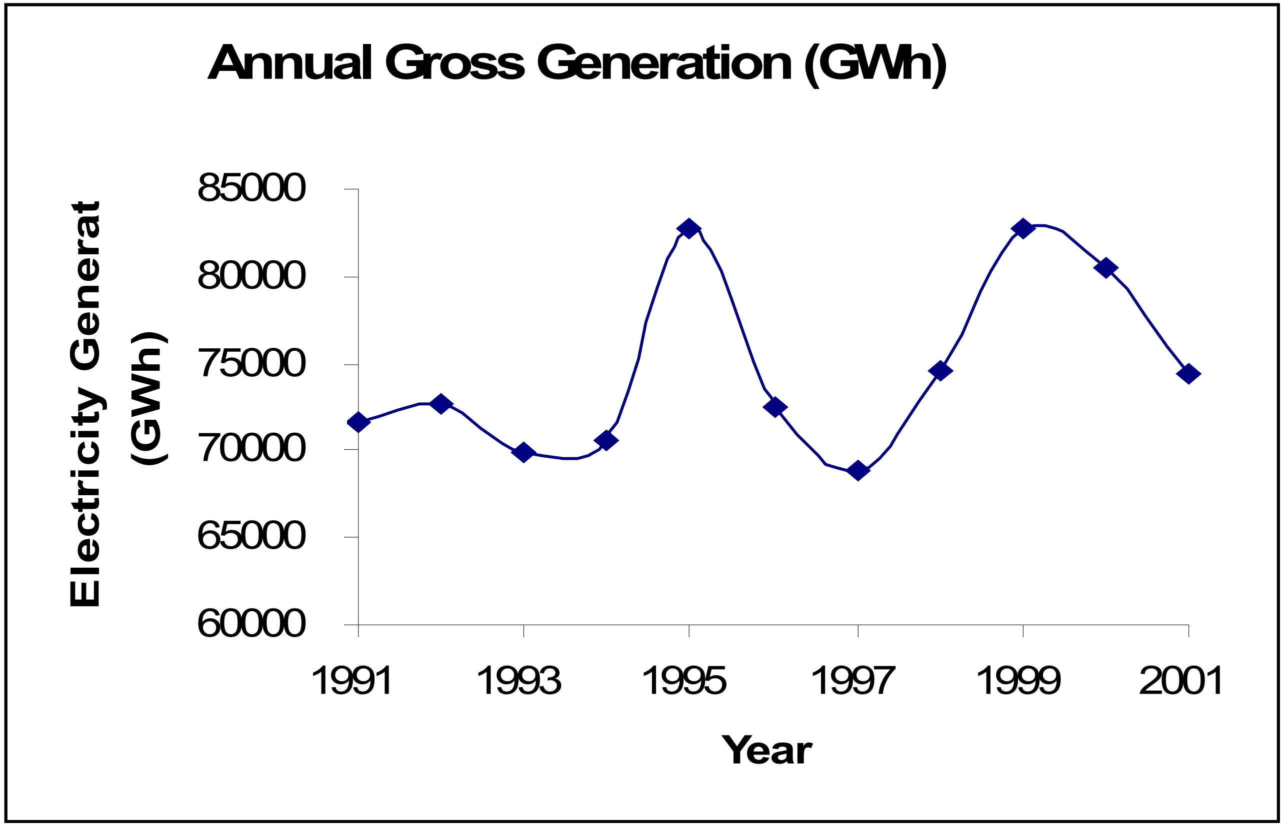
REGION	HYDRO	THERMAL	WIND	NUCLEAR	TOTAL
NORTH	8331.57	17806.99	4.25	1320	27462.81
WEST	4307.13	25653.98	346.59	760	31067.7
SOUTH	9369.64	14116.78	917.53	780	25183.95
EAST	2453.51	13614.58	1.10	0	16069.19
N.EAST	679.93	1122.32	0.16	0	1802.41
INDIA	25141.78	72358.67	1269.63	2860	101630.08

Region wise contribution of Hydropower

REGION	PERCENTAGE
NORTH	30.34
WEST	13.86
SOUTH	37.2
EAST	15.27
NORTH-EAST	37.72
INDIA	24.74

Annual gross generation (GWh)

YEAR	GROSS GENERATION
85/86	51021
90/91	71641
91/92	72757
92/93	69869
93/94	70643
94/95	82712
95/96	72579
96/97	68901
97/98	74582
98/99	82690
99/2000	80533
00/01	74346



Annual Gross Generation (GWh)
Electricity Generat (GWh)
85000
80000
75000
70000
65000
60000
1991
1993
1995
1997
1999
2001
Year

Potential of Small Hydropower

- Total estimated potential of 180000 MW.
- Total potential developed in the late 1990s was about 47000 MW with China contributing as much as one-third total potentials.
- 570 TWh per year from plants less than 2 MW capacity.
- The technical potential of micro, mini and small hydro in India is placed at 6800 MW.

Small Hydro in India

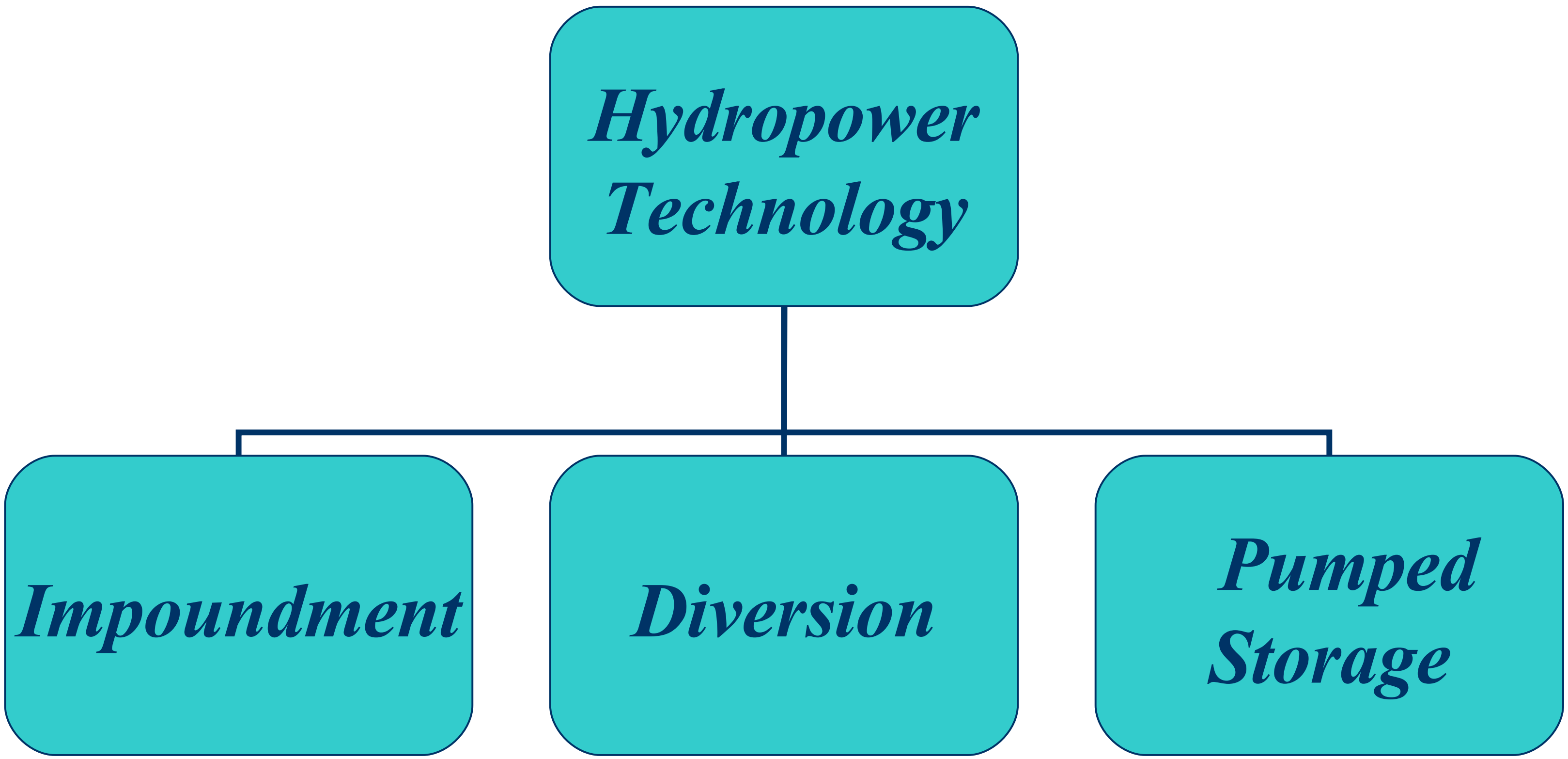
STATE	TOTAL CAPACITY (MW)
ARUNACHAL PRADESH	1059.03
HIMACHAL PRADESH	1624.78
UTTAR PRADESH & UTTARANCHAL	1472.93
JAMMU & KASHMIR	1207.27
KARNATAKA	652.51
MAHARASHTRA	599.47

Sites (up to 3 MW) identified by UNDP

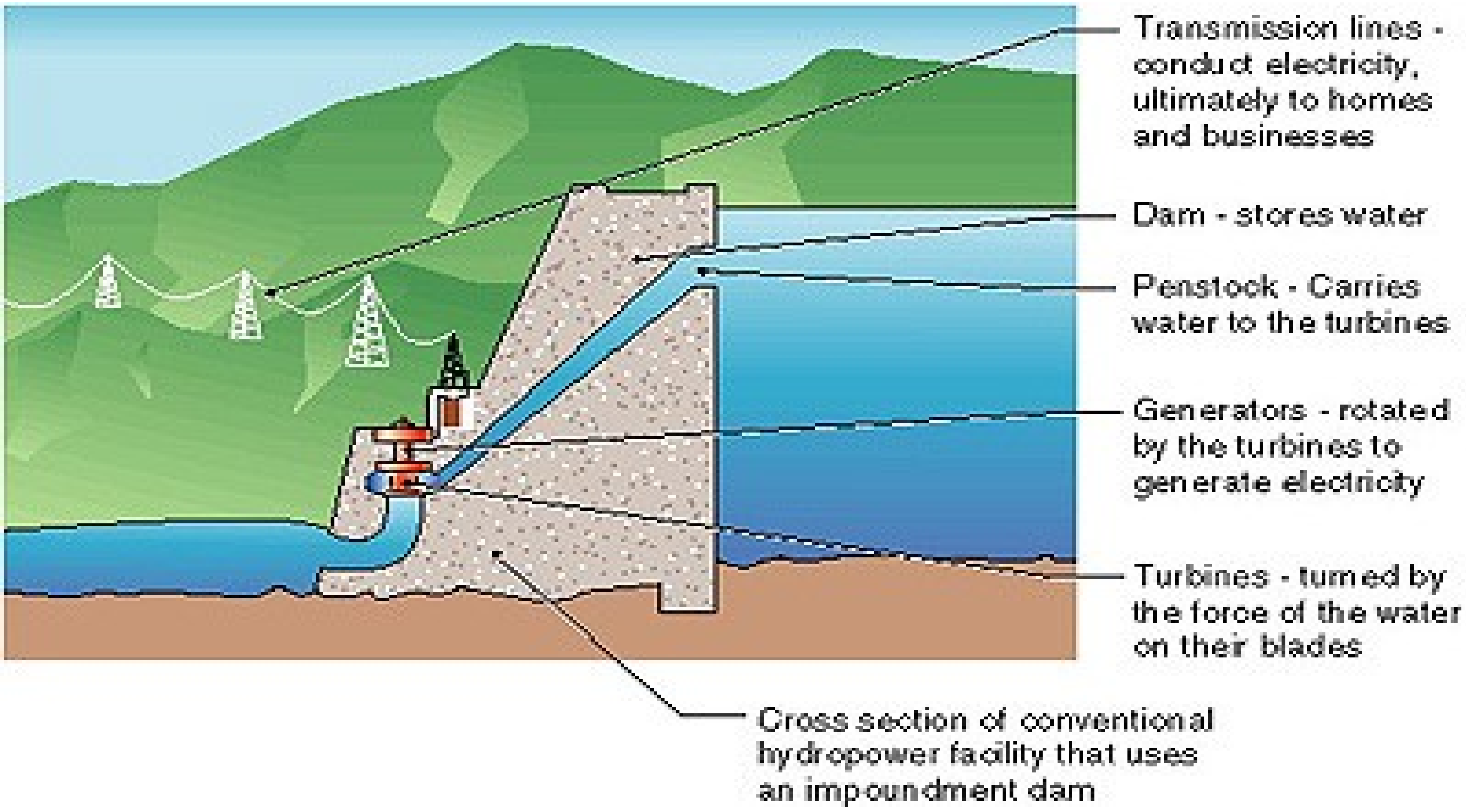
STATE	TOTAL SITES	CAPACITY
NORTH	562	370
EAST	164	175
NORTH EAST	640	465
TOTAL	1366	1010

TECHNOLOGY

Technology


Hydropower Technology
Impoundment
Diversion
Pumped Storage

Impoundment facility

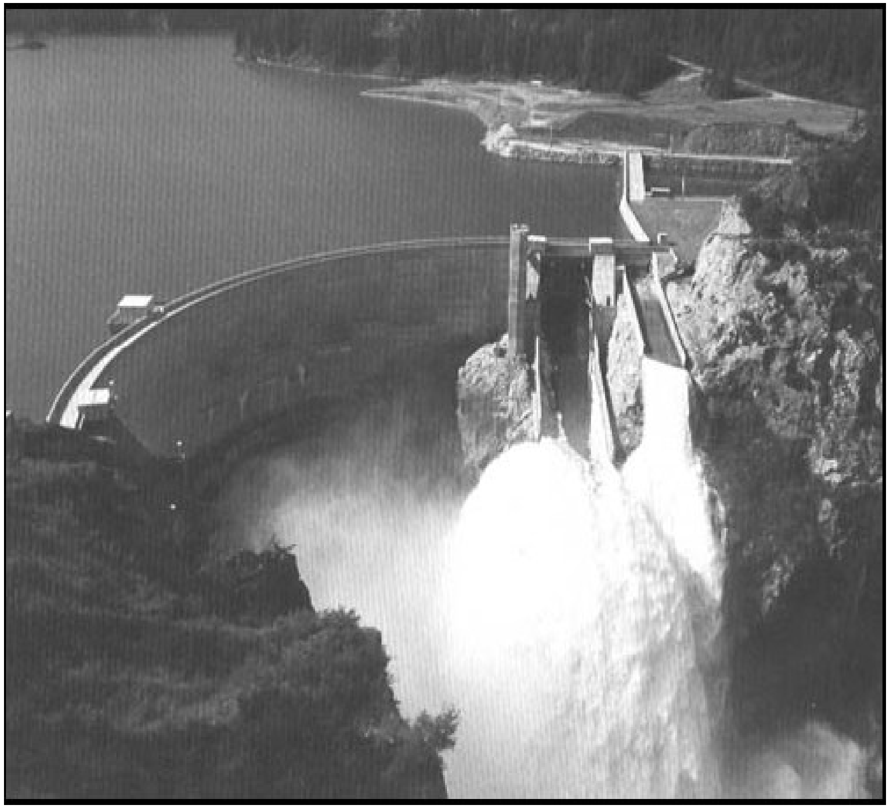


Dam Types

- Arch
- Gravity
- Buttress
- Embankment or Earth

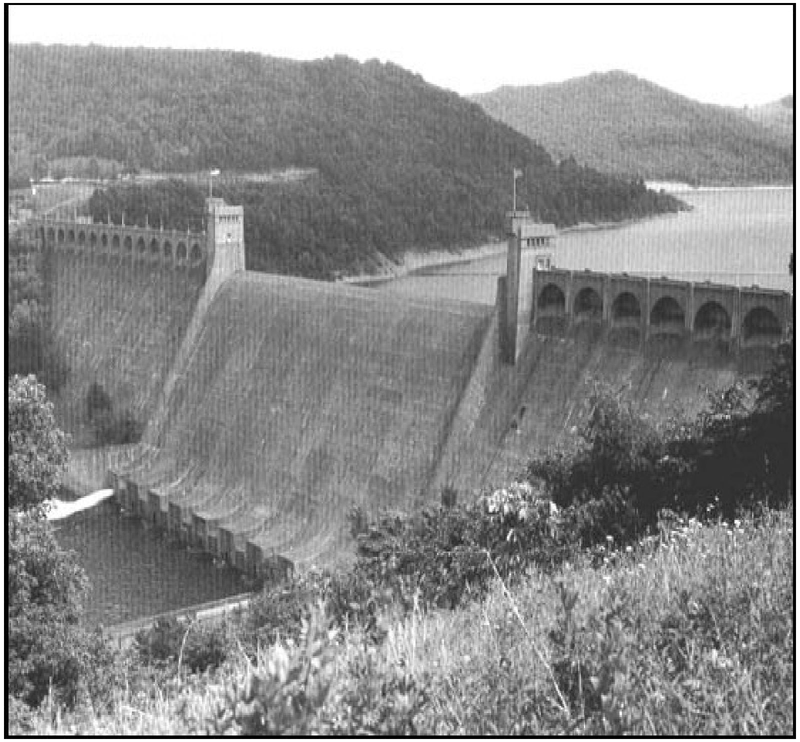
Arch Dams

- Arch shape gives strength
- Less material (cheaper)
- Narrow sites
- Need strong abutments



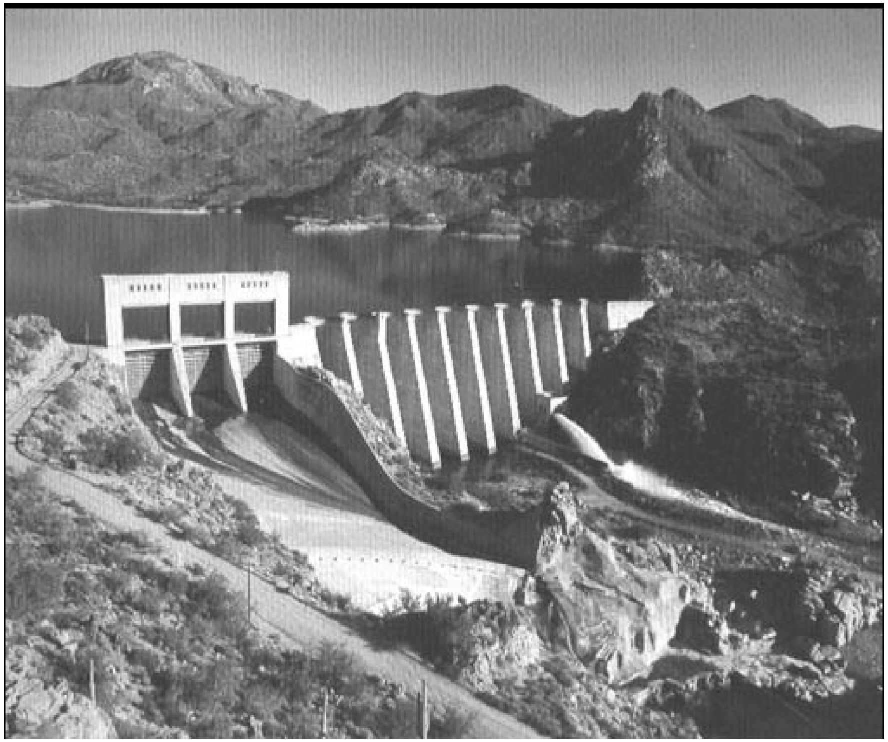
Concrete Gravity Dams

- Weight holds dam in place
- Lots of concrete (expensive)



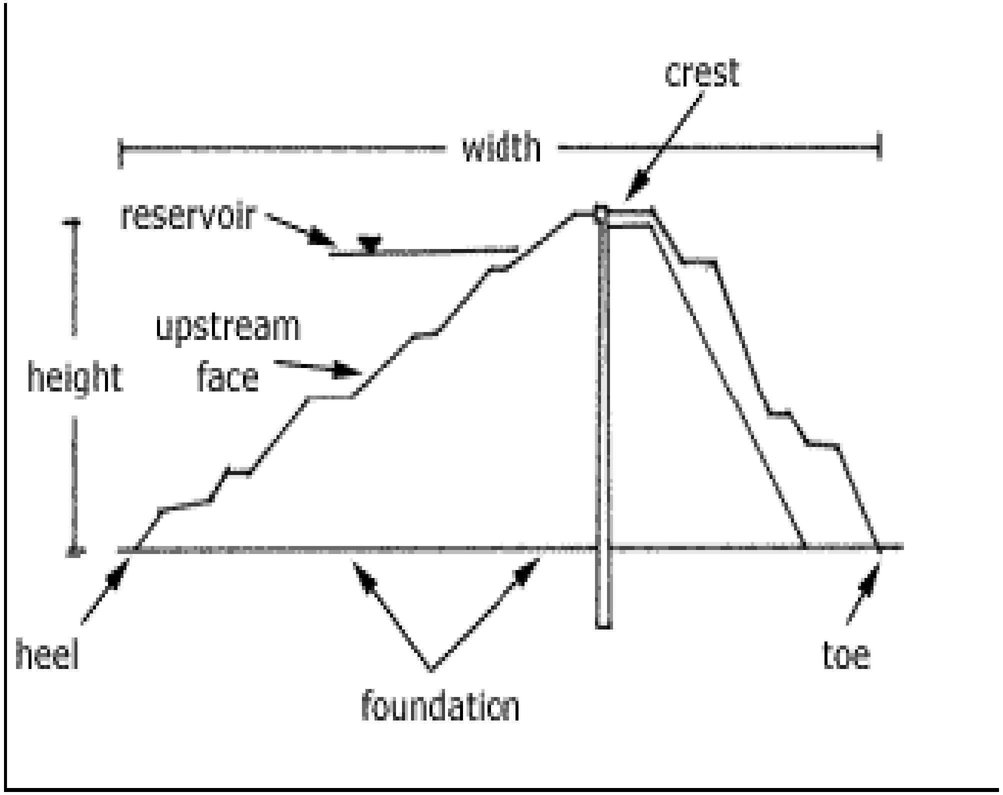
Buttress Dams

- Face is held up by a series of supports
- Flat or curved face

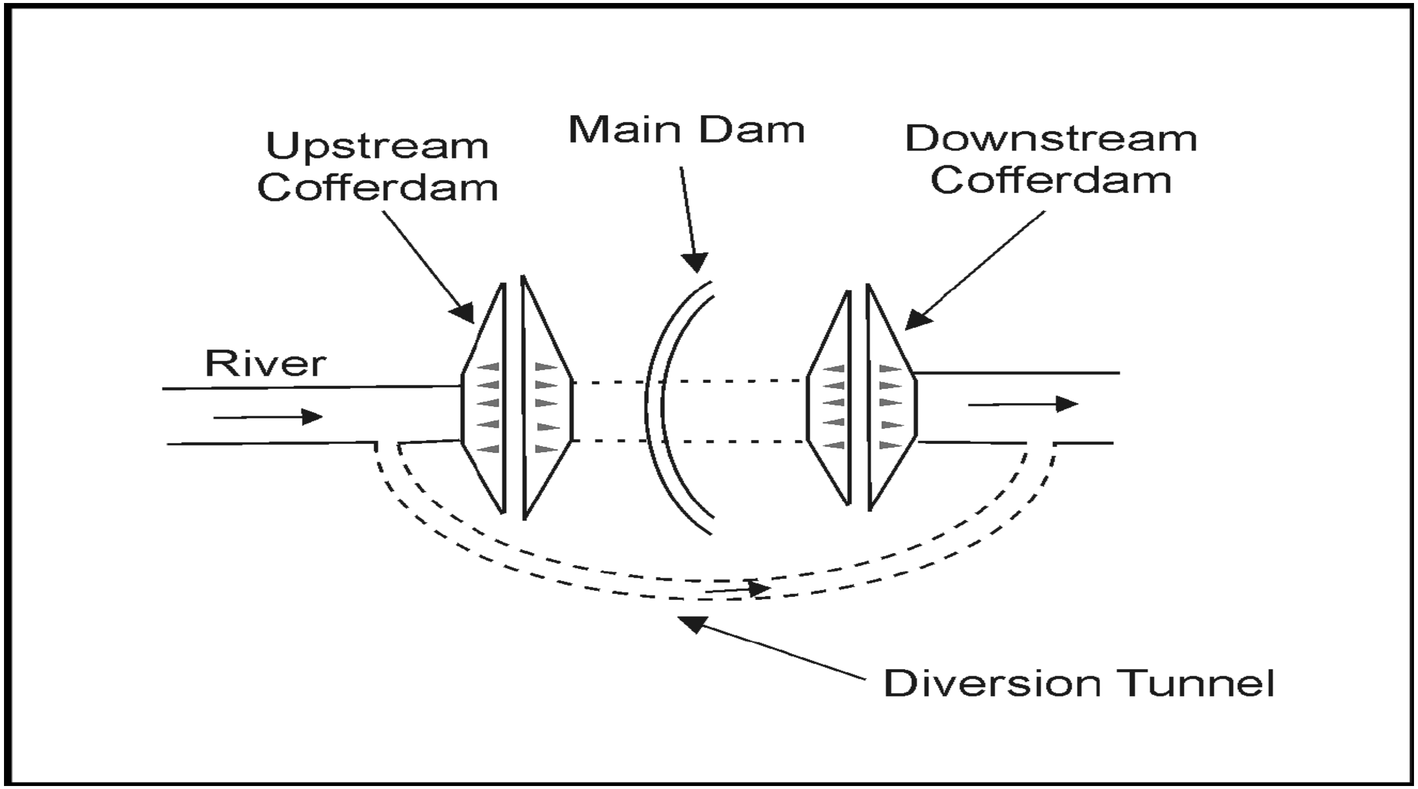


Embankment Dams

- Earth or rock
- Weight resists flow of water



Dams Construction

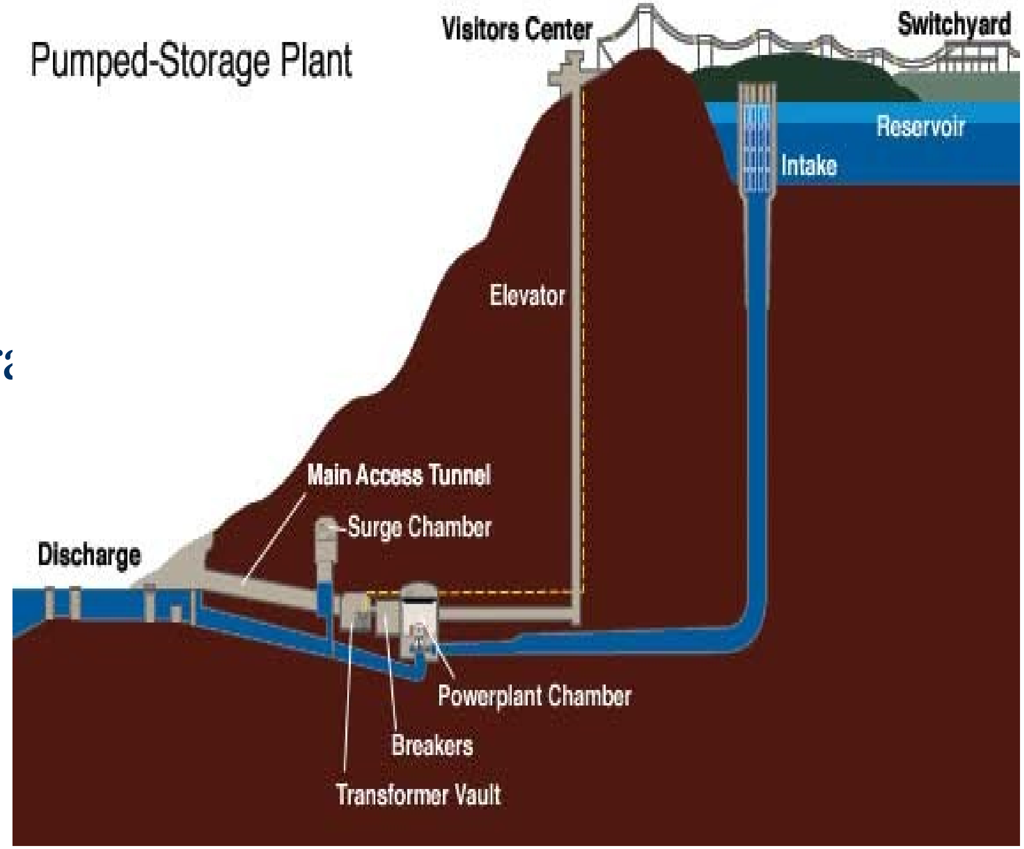


Diversion Facility

- Doesn't require dam
- Facility channels portion of river through canal or penstock

Pumped Storage

- During Storage, water pumped from lower reservoir to higher one.
- Water released back to lower reservoir to genera electricity.



Pumped Storage

- Operation : Two pools of Water
- Upper pool – impoundment
- Lower pool – natural lake, river or storage reservoir
- Advantages :
  - Production of peak power
  - Can be built anywhere with reliable supply of water

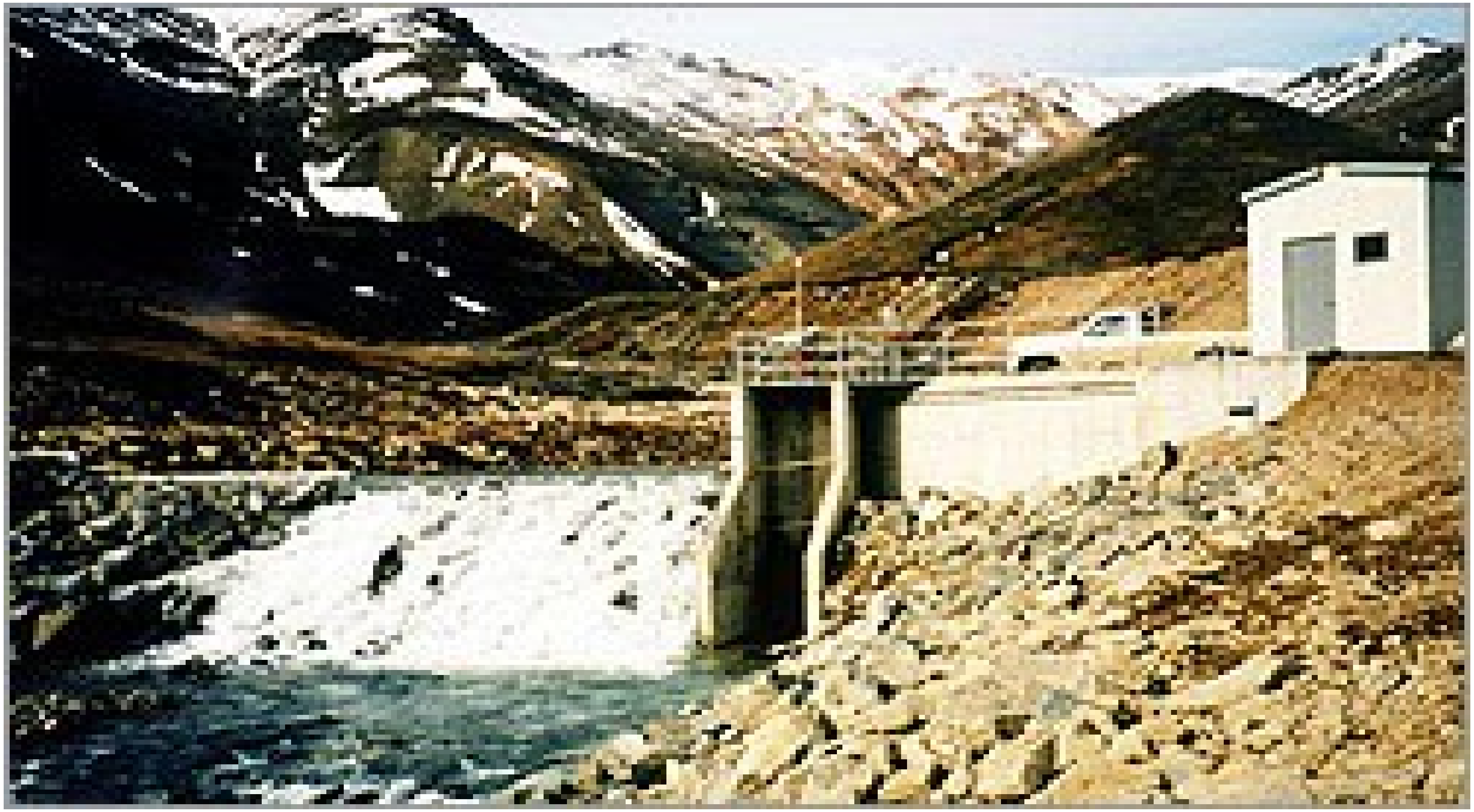
The Raccoon Mountain project

Sizes of Hydropower Plants

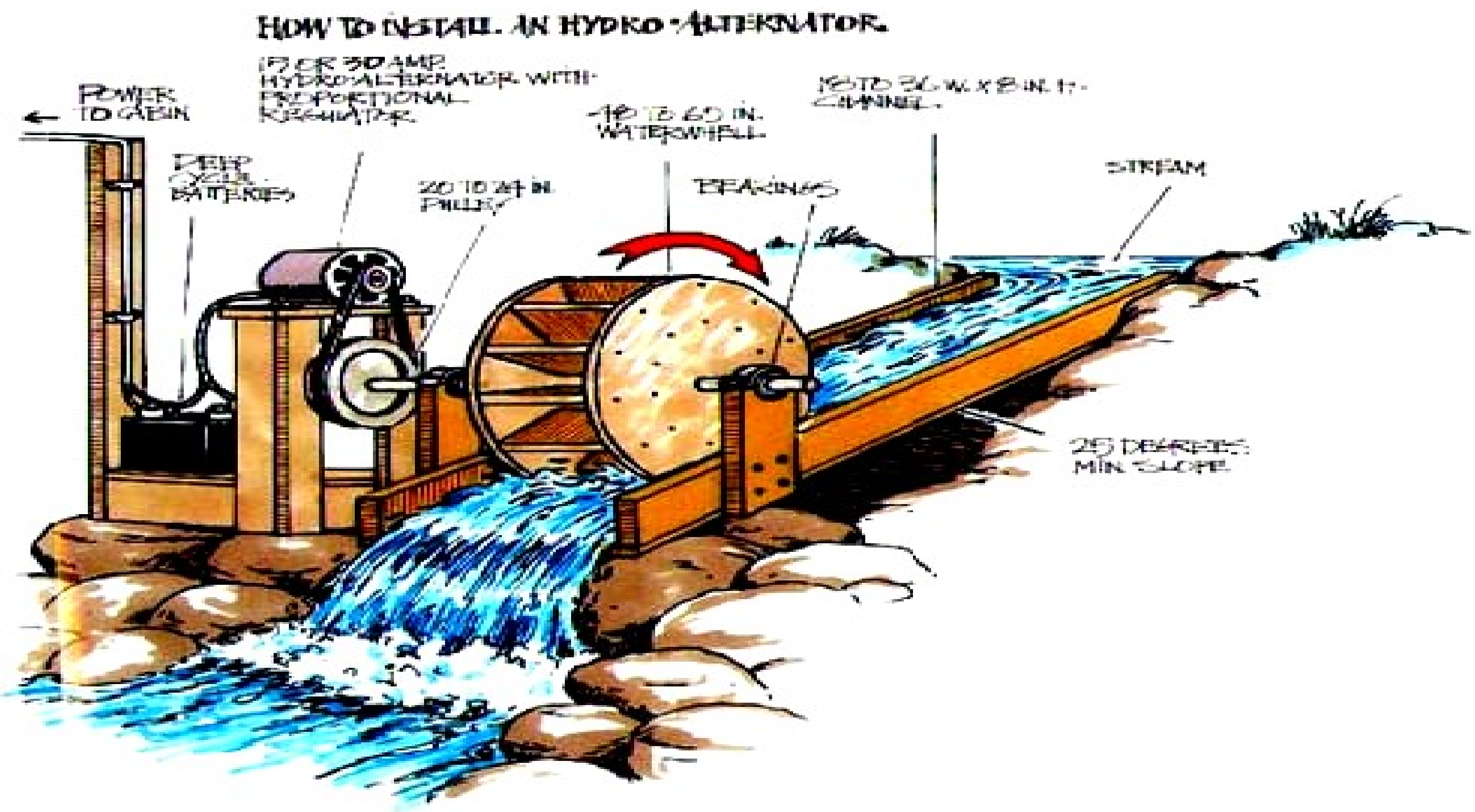
- Definitions may vary.
- Large plants : capacity >30 MW
- Small Plants : capacity b/w 100 kW to 30 MW
- Micro Plants : capacity up to 100 kW

Large Scale Hydropower plant

Small Scale Hydropower Plant



Micro Hydropower Plant



Micro Hydropower Systems

- Many creeks and rivers are permanent, i.e., they never dry up, and these are the most suitable for micro-hydro power production
- Micro hydro turbine could be a waterwheel
- Newer turbines : Pelton wheel (most common)
- Others : Turgo, Crossflow and various axial flow turbines

Generating Technologies

- Types of Hydro Turbines:
  - Impulse turbines
    - Pelton Wheel
    - Cross Flow Turbines
  - Reaction turbines
    - Propeller Turbines : Bulb turbine, Straflo, Tube Turbine,

      Kaplan Turbine
    - Francis Turbines
    - Kinetic Turbines

Impulse Turbines

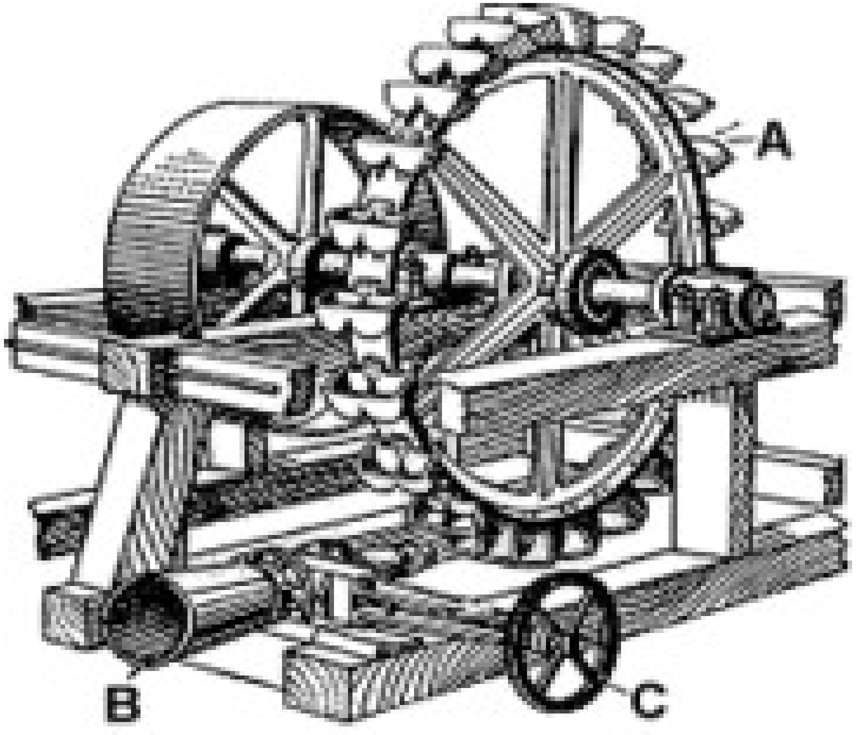
- Uses the velocity of the water to move the runner and discharges to atmospheric pressure.
- The water stream hits each bucket on the runner.
- No suction downside, water flows out through turbine housing after hitting.
- High head, low flow applications.
- Types : Pelton wheel, Cross Flow

Pelton Wheels

- Nozzles direct forceful streams of water against a series of spoon-shaped buckets mounted around the edge of a wheel.
- Each bucket reverses the flow of water and this impulse spins the turbine.

Pelton Wheels (continued…)

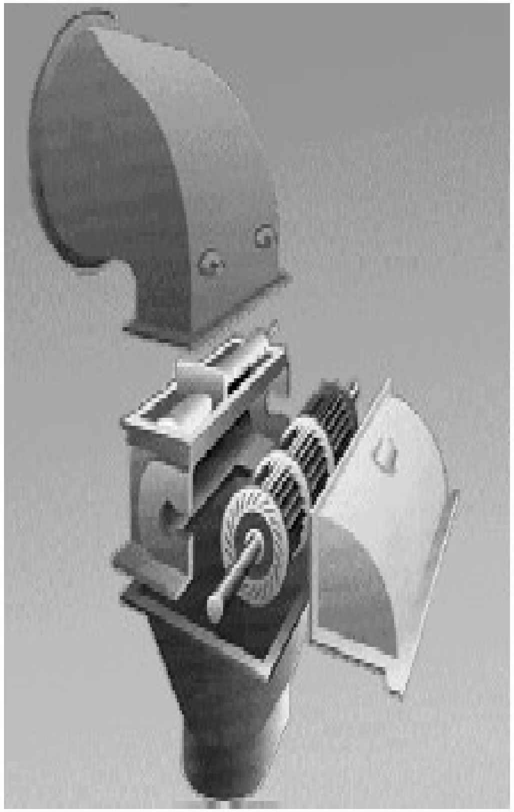
- Suited for high head, low flow sites.
- The largest units can be up to 200 MW.
- Can operate with heads as small as 15 meters and as high as 1,800 meters.

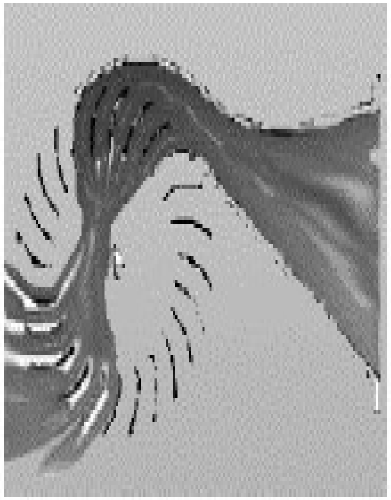


Pelton Wheel, p. 1593.

Cross Flow Turbines

- drum-shaped
- elongated, rectangular-section nozzle directed against curved vanes on a cylindrically shaped runner
- “squirrel cage” blower
- water flows through the blades twice





Cross Flow Turbines (continued…)

- First pass : water flows from the outside of the blades to the inside
- Second pass : from the inside back out
- Larger water flows and lower heads than the Pelton.

Reaction Turbines

- Combined action of pressure and moving water.
- Runner placed directly in the water stream flowing over the blades rather than striking each individually.
- lower head and higher flows than compared with the impulse turbines.

Propeller Hydropower Turbine

- Runner with three to six blades.
- Water contacts all of the blades constantly.
- Through the pipe, the pressure is constant
- Pitch of the blades - fixed or adjustable
- Scroll case, wicket gates, and a draft tube
- Types: Bulb turbine, Straflo, Tube turbine, Kaplan

Bulb Turbine

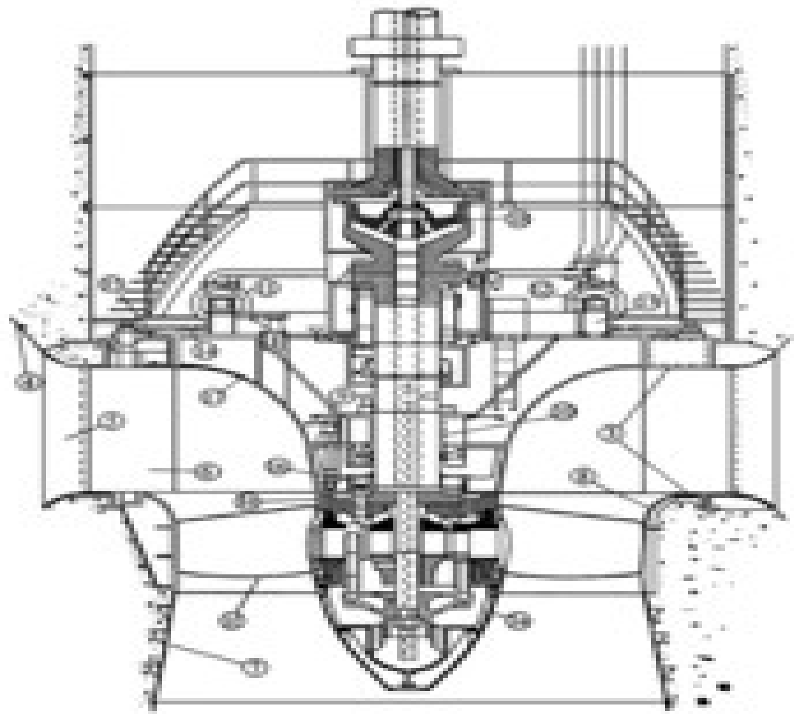
- The turbine and generator are a sealed unit placed directly in the water stream.

Others…

- Straflo : The generator is attached directly to the perimeter of the turbine.
- Tube Turbine : The penstock bends just before or after the runner, allowing a straight line connection to the generator
- Kaplan : Both the blades and the wicket gates are adjustable, allowing for a wider range of operation

Kaplan Turbine

- The inlet is a scroll-shaped tube that wraps around the turbine's wicket gate.
- Water is directed tangentially, through the wicket gate, and spirals on to a propeller shaped runner, causing it to spin.
- The outlet is a specially shaped draft tube that helps decelerate the water and recover kinetic energy.

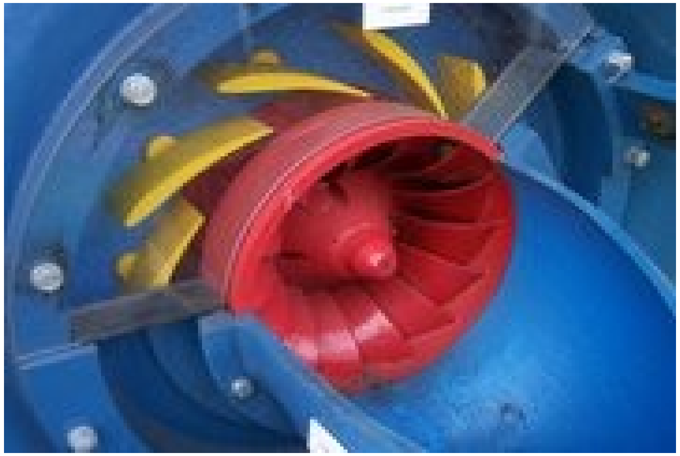


VERTICAL KAPLAN TURBINE

Francis Turbines

- The inlet is spiral shaped.
- Guide vanes direct the water tangentially to the runner.
- This radial flow acts on the runner vanes, causing the runner to spin.
- The guide vanes (or wicket gate) may be adjustable to allow efficient turbine operation for a range of water flow conditions.

Francis Turbines (continued…)



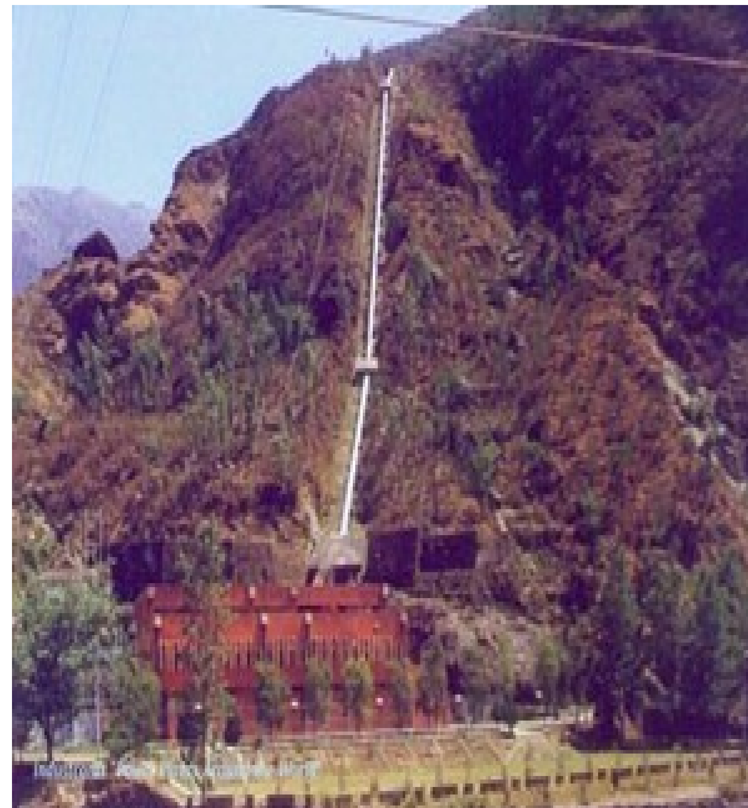
- Best suited for sites with high flows and low to medium head.
- Efficiency of 90%.
- expensive to design, manufacture and install, but operate for decades.

Kinetic Energy Turbines

- Also called free-flow turbines.
- Kinetic energy of flowing water used rather than potential from the head.
- Operate in rivers, man-made channels, tidal waters, or ocean currents.
- Do not require the diversion of water.
- Kinetic systems do not require large civil works.
- Can use existing structures such as bridges, tailraces and channels.

Hydroelectric Power Plants in India

Baspa II



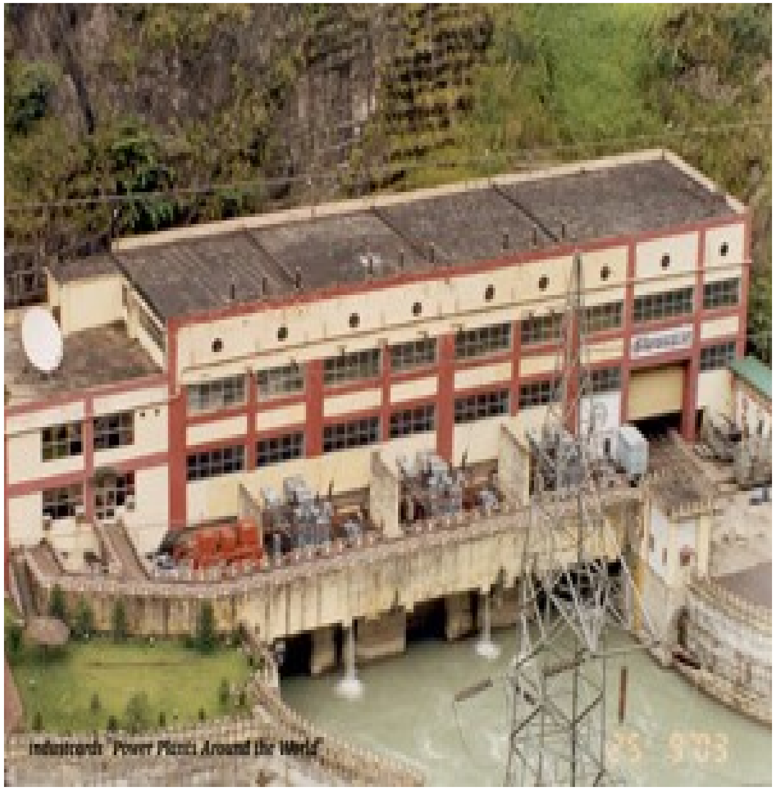
Binwa

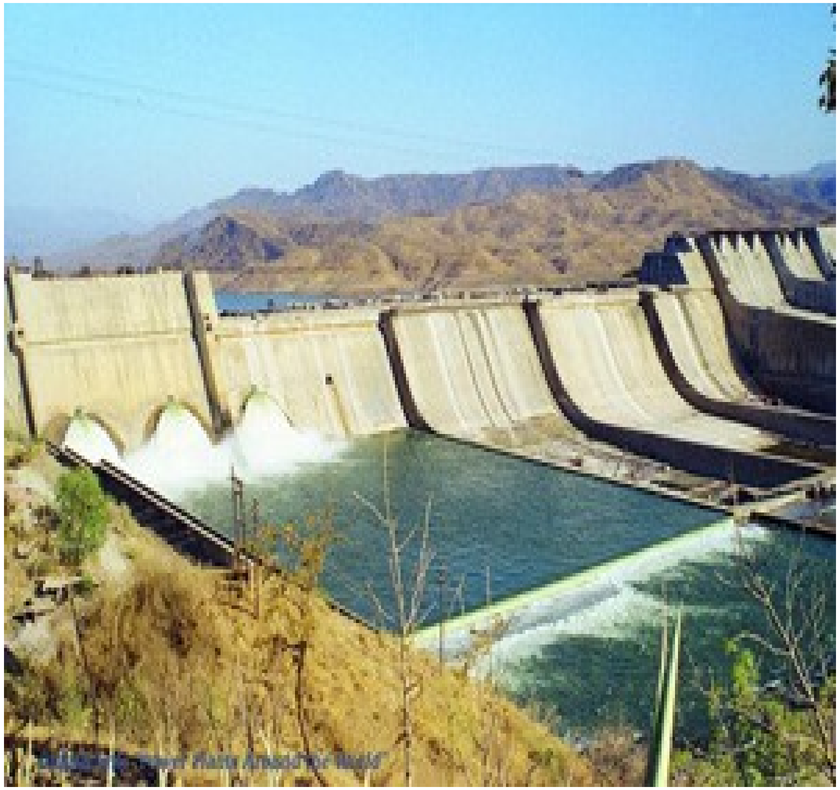
Continued …

Gaj

Nathpa Jakri

Continued…





Rangit ***Sardar Sarovar***

ENVIRONMENTAL IMPACT

Benefits…

- Environmental Benefits of Hydro
  - No operational greenhouse gas emissions
  - Savings (kg of CO_2 per MWh of electricity):
    - Coal 1000 kg
    - Oil 800 kg
    - Gas 400 kg
  - No SO_2 or NOX
- Non-environmental benefits
  - flood control, irrigation, transportation, fisheries and
  - tourism.

Disadvantages

- The loss of land under the reservoir.
- Interference with the transport of sediment by the dam.
- Problems associated with the reservoir.
  - Climatic and seismic effects.
  - Impact on aquatic ecosystems, flora and fauna.

Loss of land

- A large area is taken up in the form of a reservoir in case of large dams.

- This leads to inundation of fertile alluvial rich soil in the flood plains, forests and even mineral deposits and the potential drowning of archeological sites.

- Power per area ratio is evaluated to quantify this impact. Usually ratios lesser than 5 KW per hectare implies that the plant needs more land area than competing renewable resources. However this is only an empirical relation.

Climatic and Seismic effects

- It is believed that large reservoirs induce have the potential to induce earthquakes.
- In tropics, existence of man-made lakes decreases the convective activity and reduces cloud cover. In temperate regions, fog forms over the lake and along the shores when the temperature falls to zero and thus increases humidity in the nearby area.

Some major/minor induced earthquakes

DAM NAME	COUNTRY	HEIGHT (m)	VOLUME OF RESERVOIR (m^3)	MAGNITUDE
KOYNA	INDIA	103	2780	6.5
KREMASTA	GREECE	165	4650	6.3
HSINFENGKIANG	CHINA	105	10500	6.1
BENMORE	NEW ZEALAND	118	2100	5.0
MONTEYNARD	FRANCE	155	240	4.9

Eutrophication

- In tropical regions due to decomposition of the vegetation, there is increased demand for biological oxygen in the reservoir.
- The relatively constant temperatures inhibit the thermally induced mixing that occurs in temperate latitudes.
- In this anaerobic layer, there is formation of methane which is a potential green house gas.
- This water, when released kills the fishes downstream and creates an unattractive odor. The only advantage is that all these activities are not permanent.

Other problems

- Many fishes require flowing water for reproduction and cannot adapt to stagnant resulting in the reduction in its population.
- Heating of the reservoirs may lead to decrease in the dissolved oxygen levels.
- The point of confluence of fresh water with salt water is a breeding ground for several aquatic life forms. The reduction in run-off to the sea results in reduction in their life forms.
- Other water-borne diseases like malaria, river-blindness become prevalent.

Methods to alleviate the negative impact

- Creation of ecological reserves.
- Limiting dam construction to allow substantial free flowing water.
- Building sluice gates and passes that help prevent fishes getting trapped.

Favorable impact

- Enhanced fishing upstream.
- Opportunities for irrigated farming downstream.
- With the flooding of the forest habitat of the Tsetse fly, the vector of this disease, the problem of Sleeping Sickness has been substantially reduced.

Technological advancements

- Technology to mitigate the negative environmental impact.
  - Construction of fish ways for the passage of fish through, over, or around the project works of a hydro power project, such as fish ladders, fish locks, fish lifts and elevators, and similar physical contrivances
  - Building of screens, barriers, and similar devices that operate to guide fish to a fish way

Continued…

- Evaluating a new generation of large turbines
  - Capable of balancing environmental, technical, operational, and cost considerations
- Developing and demonstrating new tools
  - to generate more electricity with less water and greater environmental benefits
  - tools to improve how available water is used within hydropower units, plants, and river systems
- Studying the benefits, costs, and overall effectiveness of environmental mitigation practices

THANK YOU