Water Power Development

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What is Hydropower?

- Hydropower(from hydro meaning water) or water power is energy that comes from the force of moving water.
- The fall and movement of water is part of a contentious natural cycle known as the water cycle.
- Hydropower is free and renewable source of energy because the water on the earth is continuously replenished by precipitation.
- Compared with the fossil fuels, hydropower is environment friendly as it emits no carbon dioxide and little pollution.
- However, it causes displacement of people, endangered habitats and causes siltation of rivers.

History :

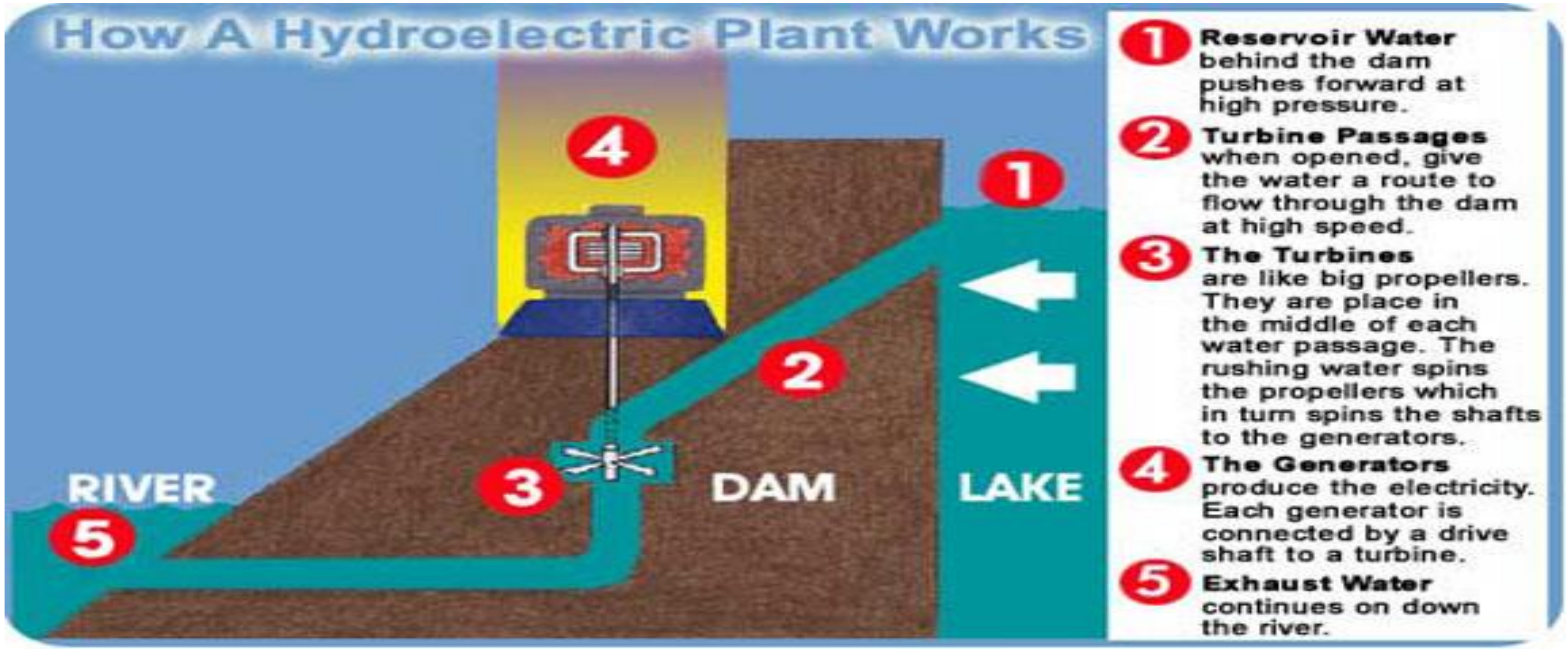
- The Greeks used water wheels to grind wheat into flour more than 2000 years ago.
- In the early 1800s, American and European factories used the water wheel to power machines.
- In the 19th century, the force of falling water was used to generate electricity.
- The first hydroelectric power plant was built at Niagara Falls in 1879.
- Hydropower is the cheapest way to generate electricity today.

https://www.youtube.com/watch?v=9ZY_5RhSCgo&pp=ygUVaGlzdG9yeSBvZiBoeWRyb3Bvd2Vy

- Five countries –Canada, U.S.A, Brazil, China and Russia – account for more than half the world’s hydropower generation.
- Norway produces more than 99% of its electricity from hydroplant, while 75% of electricity generated in New Zealand is from hydropower.

- It utilizes the potential energy of water at a high level for generation of electrical energy.
- These plants are generally located in hilly areas where dams can easily be built.
- From the dam water is led to a water turbine.

- The figure below shows a cross sectional view of a Hydroelectric power plant
- https://www.youtube.com/watch?v=Qk2op7ErigU



http://www.talgov.com/you/electric/corn.cfm

Dams and Storage Reservoirs

- A typical hydropower plant is a system with the three parts .
- A dam across the river that can be opened or closed to control water flow.
- A reservoir(artificial lake) where water can be stored and
- A power plant where the electricity produced.
- https://www.youtube.com/watch?v=3ixtdPORwsw

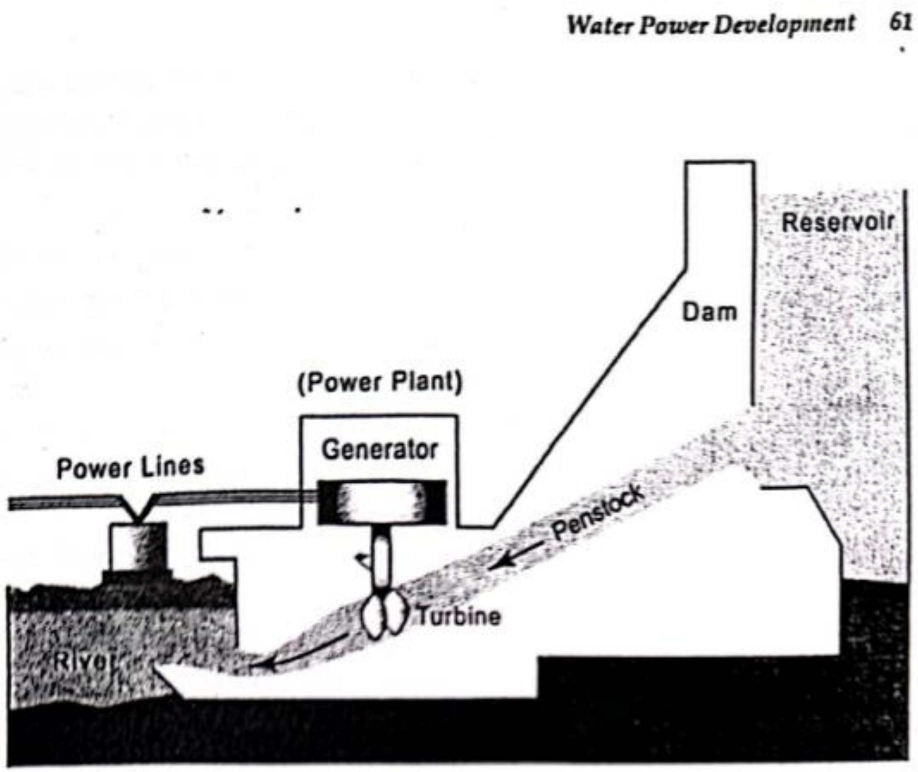


Fig. 6.1 A Typical Hydro Plant

- In order to generate electricity, a dam opens its gates to allow water from the reservoir above to flow down through large tubes called penstocks.
- At the bottom of the penstocks, the fast moving water spins the blades of the turbines.
- The Turbine are connected to generators to produce electricity.
- The electricity is then transported through huge transmission cable to the

central distribution company, Some modem large scale hydroelectric plants use pumped storage systems.

- The International Commission on Large Dams (ICOLD) defines any dam with **a height of 15 meters** or more as **a large dam.**
- If dams are between **5 and 15 meters high** and have a reservoir volume of more than **three million cubic meters,** they are also classified as **large dam.**
- The two main categories of large dams are reservoir type **storage projects a**nd **run-of-river dams** that often have no storage reservoir and may have limited daily pondage.
- Reservoir projects impound water behind the dam for seasonal,annual, and in some cases, multi-annual storage and regulation of the river.
- Run-of-river dams (weirs and barrages, and diversion dams) create 2 hydraulic head in the river to divert some portion of the river flows to 2 power station.

- Historical records show that the use of dams for **irrigation and water supply** became widespread about two to three thousand years ago.
- The first use of dams for hydroelectric generation was around 1890. By 1900, several hundred large dams had been built in different pants of the world. In fact,the last century saw a rapid increase in large dam construction.
- By **1949,about 5,000 large dams** had been built worldwide, three-quarters of them in the industrialized world; and around the end of the 20th century, there were 45,000 large dams in over 140 countries.

- The top five dam-building countries account for nearly 80 percent of all large dams in the world.
- China alone has built over 22,000 large dams(recent data- 98,000), or clase 10 half the world's total number, although before 1949, it had only 22 large dams.
- Other top dam-building countries include the United States with around 6,400 large dams(recent data-91,720); India with over 4,000(recent data-5,202); and Spain and Japan with between 1,000 and 1,200 large dams.
- Approximately, two-thirds of the world’s existing large dams are in developing countries.

- Dams have been promoted as an important means of meeting perceived needs for water and energy services and as long term strategic investments with the ability to deliver multiple benefits.
- America’s pioneering giant, multipurpose dams in the early 20™ century received instant attention throughout the world. The result was a dam-building boom of epic proportions on virtually every major river of the planet.

Multiple Benefits and Multipurpose Use of Dams

- Hydropower is the most **environment-friendly energy source.** It prevents the burning of 22 billion gallons of oil or 120 million tons of coal each year. Hydropower is also the most efficient way to generate electricity. Modem hydro turbines can convert as much as 90 percent of the available energy into electricity, while the best fossil fuel plants are only about 50 percent efficient.
- A major advantage of hydroelectricity is **elimination of the cost of fuel.** The cost of operating a hydropower plant is almost immune to increases in the cost of fossil fuels like coal, oil or natural gas.
- Hydroelectric plants tend to have **longer economic lives** than fuel-fired generation, with some plants now in service having been built about 50 years ago, including the Kaptai hydroelectric plant in Rangamati.

- **Maintenance and operating labor costs** in the hydroelectric plants are relatively lower than coal or oil-fired plants since the plants are usually automated and need fewer personnel on site during normal operation.
- Hydropower is the world's **leading source of renewable energy**, provided by falling water. It provides more than 97 percent of all electricity generated by renewable source (other sources being solar, geothermal, wind, and biomass).

- Hydropower's fuel supply (running water) is clean and is renewed annually by snow and rainfall. Hydropower is credited as the **cleanest source of energy** because it does not emit any carbon dioxide, or cause air pollution, and does not leave behind any waste product.
- However, the installation of hydro plants requires **significant financial investments** with a gestation period ranging from five to ten years.
- Several rigorous **social and environmental impact** studies are also mandatory prior to the start of implementation phase.
- Owing to the high costs involved in commissioning a hydropower plant through building dam and storage reservoir, it is a common practice that most hydropower plants are usually built as **multipurpose projects** — serving a variety of uses (irrigation, flood control, domestic and industrial water supply, fisheries expansion,navigation improvement, river flow augmentation, and recreation/tourism), although, in some cases, dams are also built for single purpose (irrigation, water supply, flood control, or hydroelectricity) use.

- Large dams and storage reservoirs have been promoted as an important means of meeting perceived needs for water and energy services, and as **long term strategic investment for multiple benefits.**
- **Regional development, employment generation and creating an industrial base** with export potentials are most often cited as additional considerations for building large dams. Water-rich countries such as Canada, Norway, Brazil and parts of Russia have built large dams for hydropower generation wherever physically suitable sites were available (WCD 2000).

- At present, the world's large dams regulate, **store and divert water** from rivers for agricultural production (providing irrigation), meeting industrial and urban water supply needs, electricity generation, flood control in the wet season, and dry season flow augmentation in the rivers.
- Besides, the reservoirs of large dams often provide facilities to improve **river transportation.** The reservoirs are also being used for recreation and tourism as well as aquaculture as in the case of **Kaptai lake** (the reservoir for the Kaptai hydroelectric plant).

Dam for irrigation use

- Irrigation is the single largest consumptive use of freshwater in the world today, and it is linked to food production and food security.
- Half of the world's large dams have been built primarily for irrigation, and about 40 percent of irrigated lands worldwide are dependent on dams. Discounting conjunctive use of groundwater and surface water, dams are estimated to contribute to nearly 12 to 16 percent of world food production (WCD 2000).
- **The scale and significance of large dams for irrigation vary significantly from country to country in terms of the percentage of agricultural land irrigated**, and the proportion of irrigation water supplied from large dams. China, India, the United States and Pakistan jointly account for more than 50 percent of the world’s toe irrigated area.

- Dams supply water for almost 100 percent of irrigated production in Egypt — mostly from the Aswan High Dam on the Nile river -
- while in Bangladesh, dams provide only one percent of irrigation water.
- (Nonetheless, 66 percent of the net sown area in Bangladesh is irrigated, mostly from groundwater).
- In the two countries with the largest irrigated areas — China and India — official statistics indicate large dams supplying approximately 30 to 35 percent of irrigation water.

Dams for electricity generation:

- **Electricity generation is an important** reason for building large dams in many countries, either as the primary purpose, or as an additional function where a dam is built for other purposes.
- Over the last two decades, global electricity production from hydro plants has more than doubled. At the global scale, current levels of hydropower generation offset 4.4 million barrels of oil-equivalent (thermal electricity generation) a day, approximately six percent of the world’s oil production (WCD 2000).
- About a third of the countries in the world currently rely on hydropower for more than half of their electricity needs, and it is worthwhile to repeat that about **99 percent of electricity in Norway is produced from hydro plants.**

- In Bangladesh, the lone hydroelectric plant at Kaptai on the Karnaphuli river in the southeastern part of the country (with installed capacity of **230 MW)** produces only six percent of the country's total electricity output. It is believed that an additional production of 100 MW is possible at Kaptai without raising the height of the existing dam and submerging new lands, and this expansion opportunity might be examined by the government.
- The Kaptai hydro plant was completed in 1962, located 65 km upstream of Chittagong.
- The dam is **671 meters long and 46 meters high,** with the crest level being 36 meters above mean sea level. The generation of electricity is the main purpose of the Kaptai dam, while other uses include fisheries, recreation/tourism, flood control, and navigation improvement. Himalayan countries of Nepal and Bhutan, and both of them have huge hydropower potentials, which constitute their largest source of wealth

Dams for urban and industrial use.

- Globally, urban water **consumption accounts for seven** percent of total freshwater withdrawals from rivers, and 22 percent from lakes
- Many storage reservoirs are built to provide a dependable supply of water to meet growing urban and industrial needs, especially in arid and semi-arid regions.
- **About 12 percent of the large dams in the world are designated as water supply dams for urban centers and industries, and 60 percent of them are in North America and Europe.**
- However, the extent to which urban centers rely on dams and reservoirs for their water supply varies greatly even within countries, since, in many cases, some towns and industries in certain parts of the country may get their water supply from groundwater sources or even from distant rivers, while other parts are supplied from reservoirs where facilities for storage exist.

Dams for flood control and flow augmentation

- By storing water in a reservoir, dams perform a flood management function through preventing downstream inundation during the wet season. A**bout 13 percent of all large dams in the world — in more than 75 countries — have a flood control purpose.**
- The proposed Sapta Koshi High Dam in eastern Nepal is 2 multipurpose project, which is expected to minimize and control floods in southern Nepal and northern India, in addition to generating electricity.

- Although dams have historically been extensively used as a **defense against floods**, some groups are critical about their efficacy and dependability because of poor reservoir operation in some instances, **changed downstream sedimentation pattern, and concern for dam break or failure.**
- A **collateral function of dams and reservoirs is augmentation** of flow in rivers during the dry season through release of stored water from the reservoirs. In other words, the stored water in the reservoirs **perform dual functions** of **preventing inundation in downstream sections of a river basin in the wet season, and enhance the flow of the river in the dry season to meet the water demand for the downstream population.**
- For example, the option for augmenting dry season flows in the Ganges lies in storing the surplus water through constructing large reservoirs on the Ganges tributaries flowing through Nepal. The terrain of the northern and middle belts of Nepal offer excellent sites for storage reservoirs, which could perform such multiple functions as electricity generation, irrigation expansion, flood attenuation, and dry season flow augmentation (Ahmad ed.2004).

Regional Profile of Purpose

- Asia as a region, and particularly **China and India,** is one of the most active in the world in terms of the number of dams in operation, under construction and ‘planned. Most large dams in Asia were built for irrigation, followed by hydropower, flood control and water supply functions .
- A quarter of them, usually large, are multipurpose. Nevertheless, there are large differences across Asia in the purpose and type of dams.
- The primary purposes of dams built today include irrigation in India and Turkey; flood control and hydropower in China; flood management and hydro- pumped storage in Japan; and irrigation and hydropower in Iran (WCD 2000). **China, India, Turkey, Japan and Iran are among the most active Asian dam building countries.**
- The overall rate of large dam building peaked in Asia in the 1970s and 1980s at over 200 dams per year. The pace of construction slowed in the 1990s (excluding China), reflecting a variety of trends, including a focus on improving existing surface irrigation infrastructure, although focus on electricity generation continued in China and India.

- Around the end of the last century, there were more than 4,000 large dams in Europe, with Spain being the leader, followed by France, Italy and the United Kingdom.
- From the data it was evident that hydropower, followed by irrigation and water supply, has been the main purposes of dams in Europe.
- There is marked contrast in reservoir use and importance across Europe, reflecting varied topography, rainfall and national policies — particularly on hydropower.

Social and Environmental Concerns

- While large dams have contributed to significant economic development in the 20™ century, they have also **faced criticisms** for some of their adverse social and environmental impacts.
- A major disadvantage of planning to build large dams is **involuntary population displacement** from the place where the reservoirs are going to be planned.
- The flooding of several hundreds or even thousands of square kilometers will generale large numbers of people needing resettlement.

- **In February 2008,** it was estimated that between 40 and 80 million people worldwide had been physically displaced as a result of dam construction (Wikipedia 2008). Many of them have not been satisfactorily resettled or received adequate compensation,
- The guiding philosophy behind involuntary resettlement for displaced communities is that t**hey should be better off in their new locations than they were in the past,** and that the population displaced by a project should receive benefits from it.
- Involuntary resettlement, therefore, should form an **integral part of project design.** The adversely affected population includes not only the directly displaced families, but also the host communities where families are resettled, and the riverine communities — especially those downstream of dams.

- **Resettlement** efforts are often hampered by **rapid construction schedules** that allow little time for preparation, by speculators who try to profit **unethically from compensation schemes,** by **mismanagement and corruption in compensation payments,** and **by lack of suitable land for resettlement** (in densely populated small countries like Bangladesh).
- **Compensation payments** also face snag when the project area is communally owned (as in lands **inhabited by traditional**, tribal or indigenous communities) and the displaced families lack written proof or documents of land ownership.
- The scale and range of social issues encountered in the river basins altered by large dam construction **vary from region to region,** and they also depend to a great extent on the overall population density in the river basin.

- **The Three Gorges Dam (2 km long) on the Yangtze river in China** -the world's largest hydroelectric dam and reservoir - aimed to produce 10 percent of China's electricity, reduce floods and siltation, provide irrigation and navigation benefits, but would also displace about 1.9 million people.
- **The Narmada Dam in western India** (a collection of dozens of large, medium and small dams to provide, irrigation, water supply, electricity and flood control benefits) is believed to cause displacement of about half a million people.
- **A related problem to population displacement is agricultural land loss due to submergence of farmlands by the reservoir.**
- Since most large dams are located or built in mountainous topography, cultivated lands in such environment are lesser than densely populated lowlands or floodplains. Hence, it is often argued that agricultural land loss due to reservoir construction is not extremely high.

- Nonetheless, reservoir sites in mountain areas are, in many cases, inhabited by communities who have practiced traditional farming for several generations, and for them, an **involuntary displacement is a traumatic experience,** which includes difficulty in adapting to new ways of agricultural life in-new sites as well as non-availability of suitable farmlands in alternate sites.
- Additionally, **historically and culturally important sites** can be flooded and lost, as what happened in the **Aswan Dam**, which submerged many archaeologically vital Nubian temples and monuments under the reservoir (Lake Nasser) — many of them were meticulously disaggregated and relocated on higher lands.
- **The Aswan Dam was built in the 1960s to provide irrigation, generate electricity, control floods and improve navigation. Likewise, the construction of the Kaptai Dam in Rangamati (Bangladesh), built in the early 1960s, displaced hundreds of tribal communities practicing jhum or slashes and burn farming, who were encouraged to move to new sites and engage in sedentary farming.**

- Large dams are also considered a **threat to forest wealth in watersheds,** causing a progressive biodiversity loss through **fragmentation, alteration and degradation of terrestrial and aquatic ecosystems** with a range of effects varying in duration, scale and degree of reversibility.
- Mountain slopes and valleys covered with **vegetation are usually inundated** as the reservoirs fill up with water, and valuable species of trees are thus destroyed along with significant loss of wildlife habitat in some cases.

- Ecosystems transformations occur not only in the upper, lower and mid-reaches of watersheds, they also impact on river estuaries, which are normally complex ecosystems. **Large dams and reservoirs can be disruptive to surrounding aquatic ecosystems — both upstream and downstream of the dam site.**
- Among the many issues at stake are **morphological changes at the river mouth, salt intrusion, loss of wetlands, and destruction of mangroves.**
- **Siltation of the reservoir** often results from poor basin management or, in some cases, unwise location of the dam.
- **Flow regulation** by the dam can upset the natural pattern of floods, and low flows can impact negatively the downstream population.
- The loss of silt below the dam can also lead to serious channel scouring, bank and coastal erosion. It is reported that the construction’ of the Aswan Dam in Egypt has produced such adverse impacts as erosion of the river delta, reduced detritus affecting marine organisms and fisheries in the Nile mouth, and loss of fertile silt deposition in the downstream sections of the dam.

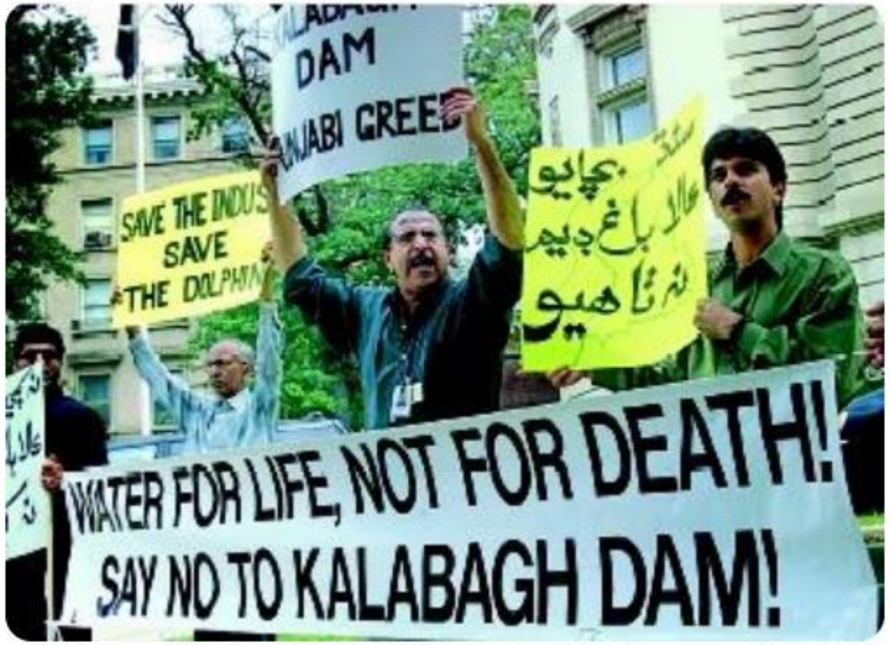
- Risk of dam failure, while rare - due to **seismic activity** or any other stress - is a matter of concern in both developed and developing countries.
- Sometimes cracks might develop in dams due to engineering faults leading to catastrophic failure and hundreds of thousands of people might be washed away and/or made homeless.
- Reinforced concrete dams might sometimes show cracks in seismically active zones if any earthquake occurs with Richter scale around 8.
- The upper catchments of the Indus-Ganges-Brahmaputra basins fall within seismic zones of the Himalayas, yet many large dams have been constructed in this dynamic tectonic region, which have not failed.

- On the- other hand, in recent years, proposed dams in **earthquake prone zones** have faced stiff opposition at the planning stage — as in the case of the Tehri Dam in northern India. Several experts on dam building of international repute have argued that safe high dams can be constructed at suitable sites provided due allowance is made for the seismic factors in designing the' various structures (Verghese 1999).
- Large dams themselves might cause seismic disturbance due to the weight of water in the reservoir (known as reservoir induced seismicity), stressing rocks and opening faults in the dam,
- However, experience indicates that larger magnitude earthquakes cannot be caused by impoundment of water as the stresses caused by reservoir impoundment are much smaller than stresses released by earthquakes of magnitude 5 in the Richter scale (Verghese 1999).
- Despite the fact that many large and high dams have stood for years and others have also been built in complex terrains, the probability of dam failure remains, and thus, **dam safety must always be a prime concern.**
- In the meantime, **dam building technology has greatly advanced,** and with adequate care in design and planning along with the state-of-the-art research and rigorous monitoring, large dams can be built with acceptable guarantee of safety even in vulnerable areas.

The Dams Debate

- Dam building has a long history.
- Conflicts and controversies over dam building too, have a long history, although it is only in recent years that they have gained wider attention. Conflicts over water and dams are probably 2 ancient as dam building itself. People affected or threatened by dams have fiercely protested and resisted dam construction throughout the last century.
- **When dam building activities accelerated after the 1950s, opposition to dams became more widespread, vocal and organized. Conservationists led the first significant campaigns against large dams.**

- Over the past 35 years, the alliance of activist groups (environmental and human rights groups) with NGOs and affected groups' associations has resulted in more vigorous and coordinated opposition to dams worldwide.
- **By the late 1980s,** environmentalists and sociologists began to play a more important role in the planning process, and by the mid-1990s, the involvement of affected communities and NGOs in the process became more significant (Goodland 2000, quoted in WCD 2000).



Protestors in front of the Pakistan embassy in Washington, D.C. in 2000 wave placards against the proposed Kalabagh Dam on the Indus River. Their concerns included the displacement of people, environmental impacts, and the ultimate distribution of water. The Pakistani government was compelled to cancel its construction plans because of these stakeholder conflicts.

WCD:

- Global controversies against dam building gave birth to the **World Commission on Dams (WCD) in February 1998.** The WCD was headed by the then Minister of Water Affairs of South Africa; the Commission's 12 international members were chosen to reflect regional diversity and expertise.
- The objectives of the Commission were to -
- (a) review the **development effectiveness** of large dams and **assess alternatives**, and
- (b) develop **internationally acceptable criteria,** guidelines and standards for the planning, design, construction and operation of dams. Although differences existed among the commissioners about dams, the WCD produced a sort of consensus document as its Report in 2000.
- The Commission identified five core values for decision making in water development projects; these are **(a) equity, (b) efficiency, (c) participatory decision making, (d) sustainability,and (e) accountability.**

- The arguments of dam critics and dam proponents are very wide and varied.
- The WCD Report summarized some of them as follows (WCD 2000). **The dam critics or opponents point to:**
- the need for **sustainable and alternatives to dams;**
- the imperative for **improved transparency, accountability and public participation** in the planning of water development projects;
- the importance of prior **project approval by potentially affected groups**,
- the need for protecting and promoting the **rights of potentially affected people;** and
- the necessity **of reparation measures to address the legacy of unfulfilled commitments and unresolved problems.**

- On the other hand, **the dam proponents underline:**
- the **evolution and changes** in practices over time;
- the **recognized need for social and environmental concerns** to be elevated to the same level as safety concerns;
- the importance of **ensuring that affected people are better off** as a result of dam development, and considering them as shareholders partners, and therefore, project beneficiaries;
- the imperative of **participatory decision making;**
- the need to promote the **principles of equity, efficiency and economic viability; and**
- the importance of **balancing the need for development with the requirement of ensuring environmental sustainability.**
- It is obvious that there are many areas of potential convergence of views among the dam opponents and dam proponents, especially regarding what needs to be done in the future. **All seem to agree on the need:**
- to take **environmental and social costs of dams more seriously;**
- for more **systematic consultation with affected people;**
- to ensure that **affected people are better off as a result of the dam development;** and to ensure that the costs and benefits of dams are shared more equitably.