To Dam or Not to Dam:
Purposes and Impacts of Dams on Society

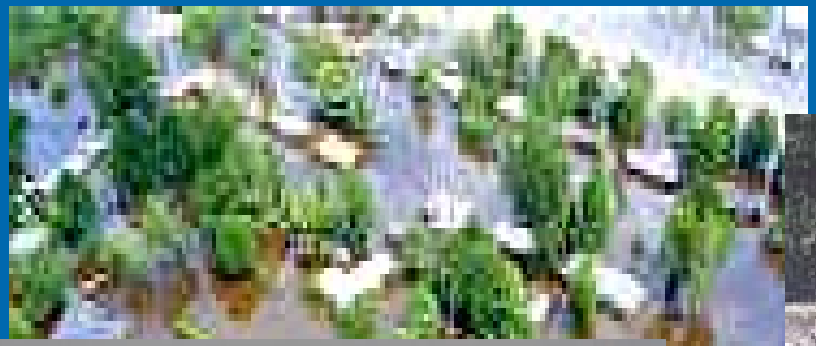
What is the function of a Dam/Reservoir?

Reservoirs provide a means of regulating downstream surface water flows over space and time by altering the natural spatial and temporal distributions of streamflows

Why Build Dams?

To improve the quality of human life by providing….

Reservoirs provide…



naviga

recreation

hydropower

water quality

riparian habitat

cv

Although people starting building dams thousands of years ago, technology for large dams didn't evolve until the 19th century

Today….

- 60% of the world's rivers are dammed
- There are ~ 45,000 large dams (>15m high) and over 1500 under construction
- There are ~ 800,000 smaller dams
- Volume: 10,000 km^3 (5x vol of all river water)

Have Dams Achieved their purpose?

- Dams have saved countless millions of lives from floods
- 30%-40% of 271 million hectares of irrigated lands worldwide rely on dams
- Dams contribute water to 12-16% of the world's food production
- India has been self-sufficient in food production since 1974 due to irrigation from reservoirs

Have Dams Achieved their purpose?

Hydropower provides 19% of world's electric supply (low greenhouse gas emissions)

- 13% in US (92,000 MW= 500 barrels oil or 150 coal plants; prevents 200 million tons of CO2; 85-90% efficient compared to 50% for gas turbines)
- 99% in Norway
- 75% in New Zealand
- 70% in Latin America

US Society on Large Dams – Benefits of Dams to Sociey

www.ussdams.org/benefits.html

- Nagarjunasagar Dam in India transforms regional economy
- Austin saved from serious flooding
- Kilbourn Dam provides access to Wisconsin attraction, the Upper Dells
- Oroville Dam Prevents More Than One Billion in Flood Damages
- New Big Cherry Dam helps communities weather drought
- Ware Shoals Hydroelectric Project contributes to South Carolina economy
- Susquehanna Dams limit sediment deposits in the Chesapeake Bay
- Pink salmon runs have increased since construction of Culmback Dam
- Two hydropower dams are nearly invisible to fish Kaneohe
- Summersville Dam releases provide world class whitewater

But there are serious objections to dams and problems to overcome

- Large populations need to be resettled
- Economic benefits are often not achieved
- Dams harm the environment
- Water is lost through evaporation and seepage
- Dams fill with sediment and change the geomorphology of the river
- Dams have a life that ends… then what?
- Dams can be unsafe; have killed thousands

Displacing populations

Estimate: 40-80M displaced by dams.

(10M reported in China; 1.5M for Three Gorges)

Usually poor/indigenous people who leave behind productive farms and ancestral homes. They rarely receive benefits of the project.

Results in conflicts, social problems, cultural loss, economic disaster

Economic Benefits considered in justifying the project are often not realized

- Hydropower is exported or goes to cities to benefit wealthier populations
- Anticipated water supplies not met
- Irrigation becomes less efficient as supplies increase
- Projects are expensive (almost always underestimated) and drain the resources of a country

Environmental Issues

Dams change the chemical, physical and bilogical processes of river ecosystems. They alter free-flowing systems by reducing river levels and downstream ecosystems, blocking the flow of nutrients, changing water temperature and oxygen levels, and impeding or preventing fish and wildlife migration.

Environmental effects of dams

- Cuts off water from floodplains and wetlands that are habitats to fish, birds and other species.
- Cuts off migration of fish, even with fish ladders
- Interrupt natural high-low flow patterns that many species need for normal reproduction cycles
- Cuts off sediment flow to d.s. habitats; clear water further scours in-place sediments
- Reduces fresh water supplies to estuaries and costal areas, often destroying fish industries
- Promotes reproduction of mosquitos and other disease-producing organisms.

Environmental effects of dams

- Reservoirs trap nutrient-ladened sediments which accelerates cycle of eutrophication (O^2 depletion); lower layers of water often lack DO.
- Methane production due to decaying biomass is high in tropical reservoirs; this greenhouse gas is worse than CO^2 and counters the greenhouse gas savings of hydropower.
- Releases from lower levels of reservoir alter temperature and DO levels of river (affect water's ability capacity to process waste)
- Construction of dams and associated transmission lines and roads often destroy pristine wilderness

Water Lost to Evaporation and Seepage

- Large reservoirs, especially in arid regions, can lose significant water to evaporation.
- Reservoirs in porous formations can lose significant volume to seepage.

FACT: The Colorado River loses 20% of its total flow to evaporation and seepage

Lake Powell alone loses 1MAF per year

Lake Powell in 1999 (top) and in 2003 after record-breaking drought

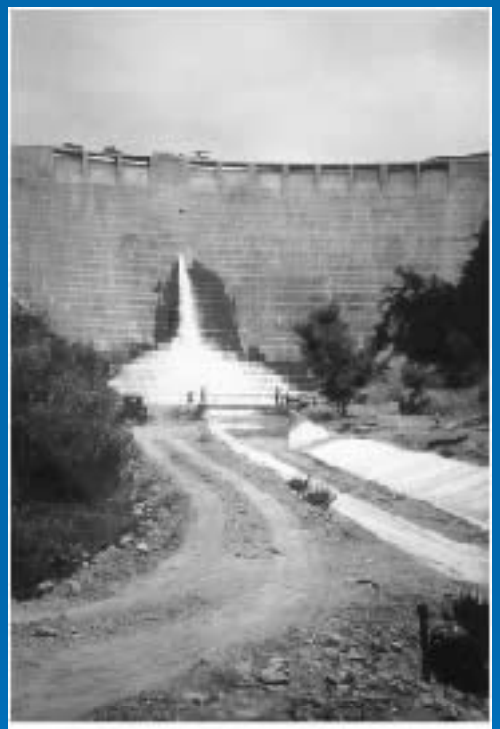
Sediments fill up dams

- Sediment retention can interfere with dam operations and shorten intended lifespans.
- In US each year about 2km^3 of reservoir storage capacity is lost from sediment retention (at a cost of about $820million)
- Management of sediments adds to cost of operations

Dams can be unsafe: causes of failure

- Overtopping caused by floods that exceed the capacity of the dam.
- Deliberate acts of sabotage.
- Structural failure of materials used in dam construction.
- Movement and/or failure of the foundation supporting the dam.
- Settlement and cracking of concrete or embankment dams.
- Piping and internal erosion of soil in embankment dams.
- Inadequate maintenance and upkeep.

Dam failures have killed thousands and cost billions



Close-up of St. Francis Dam, Los Angeles County, before failure in 1928. Source: http://santaclaritamagazine.com/Pages/0304/images/image53.jpg; accessed June 25, 2006.

Dam Rehabilitation Needed

- The Association of State Dam Safety Officials estimates that $36.2 billion is needed to rehabilitate dams across the nation, based on the current national inventory of non-federally owned dams. The estimate does not include costs for administration of a funding program, nor does it take into account the fact that the number of high hazard potential dams is increasing.
- It is estimated that $10.1 billion is needed to address the most critical* dams that pose a direct risk to human life should they fail.
- Needed repairs to publicly owned dams are estimated at $5.9 billion.

A Critical Look at Dams

- Opposition to dams is widespread world-wide, lead mainly by environmental interestes and groups representing displaced populations
- 1997-2000 World Committee on Dams undertook and evaluation of benefits, dis-benefits, problems and issues of large dams.
- Final report of WCD points out problems with planning and decision processes that result in ineffective and flawed projects

Where does this leave us?

- A billion people world wide do not have clean drinking water
- Most new agricultural development needs irrigation
- 2 billion people have no electicity
- The developing world is intent on continuing to build large dams

As engineers, we want to be aware of all the issues and to be prepared to perform thorough technical analysis and sound designs.

Objectives of this class

- Understand the role of dams in society
- Knowledge of many of the technical issues associated with dam planning and design
- Overview of technical approaches to dam planning and design
- See many examples of actual dams (planned and/or built)