Dams and Lakes, Problems and Possibilities

Dams generate 20% of the world's electricity. They also provide flood control, supply water to cities and can assist river navigation. Many dams are multipurpose, providing two or more of these benefits. The first written record of a dam is by the Greek historian Herodotus, describing that built across the River Nile in about 2900 BC to protect the city of Memphis from flooding. The Romans also built dams, two of which are still in use today.

Behind dams lie artificial lakes containing accumulated water for their proper functioning. Vast areas of land have disappeared beneath the surface of these newly formed lakes, often passionately opposed by the local population, such land often having been used for agricultural purposes, living areas, burial sites, forests et cetera before the building of the dam. Dams are usually classified according to the materials used to construct them and their basic design.

- earthfill dams have a centre made of clay, and an outside layer of strong, compacted earth. Many dams are made of rock found in local quarries
- concrete gravity dams hold back water with their own weight and construction: the side facing the water is perpendicular while the opposite side gradually slopes downwards
- concrete arch dams use an arch design to hold back the water. They are built within narrow, steep canyons, the side facing the water arching inwards.

Dams also come in sizes: a large dam is defined by the dam industry as one higher than 15 metres. There are more than 40,000 large dams in the world, more than 300 of them defined as 'major dams': giants which meet one of a number of criteria concerning height (at least 150 metres), dam volume and reservoir volume.

Advantages of Dams
Numerous dams have been built and many lakes come into existence over the past fifty years. China is the world's most 'dammed' country, with around 19,000 large dams. The USA comes second, with around 5,500 large dams, followed by the former USSR, Japan and India. Most large dams have been built since 1950, during the post-war development era when large-scale infrastructures were seen as symbols of patriotic pride and technological progress. Large dams have provoked opposition for many social, environmental, economic and safety reasons, the main one being the huge number of people evicted from their land and homes to make way for reservoirs. The livelihoods of people downstream of dams can also be severely affected through the destruction of fisheries, contamination of water supplies and loss of seasonal floods that bring fertile silt and water to agricultural land. Dam reservoirs can also become breeding grounds for waterborne diseases such as malaria, leishmaniasis and schistosomiasis. However, the major problem, and one that is becoming more and more apparent is siltation.

A Massive Problem
Siltation is closely related to deforestation and soil erosion. Deforestation dramatically increases the risk of flooding. Soil erosion deprives an area of nutrition and causes deterioration in the quality of land; but it also silts up dams and lakes, elevates riverbeds and can aggravate flood devastation. With a total of nearly a million dams worldwide (40,000 large and 300 major), and a global area flooded by dams of over 400,000km2, the siltation problem becomes massive! Average annual decreases in dam storage capacity of 1% lead to estimates that between now and ten to fifteen years hence 50% of all dams will become obsolete due to siltation. This is a process whereby fine particles of sand, mud and other material picked up by moving water are deposited to form sediment, and it largely determines the lifetime of any hydropower or water-resource project. The effect actually varies from area to area. Dams in tropical areas are more affected by siltation than are those in temperate zones. Some results of excessive siltation are the following:

- arrested power supply due to clogging of tunnels through which water passes to reach turbines, leading to cessation of power systems
- overtopping, in which siltation-reduced reservoirs overflow, washing away material from the lake and causing extensive damage, including to the dam itself. Overtopping is the primary cause of dam disasters in the world; the number of people killed during the twentieth century being 13,500, excluding China. Those killed in the 1975 break of Banqiao and Shimantan Dams in China totalled 80,000 to 230,000
- induced seismicity, in which weight increase by silt layers add stress to both sub-strata and the power-dam itself. Each year some 32 reservoirs induce earthquakes with a magnitude of 4.0 or more on the Richter scale, and this number is increasing dramatically.

Remedial Action
Decommissioning, or dam removal, has increasingly strong support. Although the design of dams is typically based on a fifty-year economic life, most appropriately designed dams are intended with proper maintenance and periodic repairs to last indefinitely. Without proper operation and maintenance, however, dams may deteriorate and can ultimately create public safety hazards that demand correction. As social values change, some dams come to be considered undesirable from an economic, environmental or other public interest or political point of view. The cost of decommissioning a dam can be very significant, especially the removal and disposal of

contaminated reservoir sediment or replacement of lost hydropower generation.

Reclamation

There is no universal, economically feasible method for reclaiming a silted-up lake. Some dams are fitted out with flushing tunnels, whereby the silt can be washed away. However, these are often placed halfway up the dam, leaving a large portion of silt and an accumulation at the beginning of the lake where silt tends to be deposited due to the sudden drop in water velocity. This may also pose problems for the area downstream from the dam, when suddenly vast amounts of (contaminated) silt come roaring past villages and farmland.

The cost of removing a dam is ten times as high as remedial action (removal: 75 million/dam, dredging: 7.5 million/dam), maintenance and periodic repairs. Still, dredging is often difficult, insufficient and remains expensive. Looking at the type of area where power dams are generally located, in mountainous areas and at high altitudes, two problems present themselves: how to dredge and what to do with the silt.

Dredging/Silt Disposal

Dredging equipment to be deployed depends on location, volume, accessibility, silt-type and budget. Dredged material may contain clays, silts, salts and various hazardous substances such as heavy metals and organic substances. Silt may have to be treated to remove these undesired elements. Treatment technologies are available to destroy, extract, or immobilise sediment contaminants but they are in varying stages of development, with relatively few available full-scale off-the-shelf. Because of the cost, state of development and inability to address the entire suite of contaminants, treatment technologies have to date been used on only a few of the sediment remediation projects around the world.

Since silt consists of soil coming from the hillsides of the upstream watershed area it may be required that it be re-deposited at these locations in a controlled way. Alternatively, another area may be sacrificed for depositing the silt, either permanently or for reuse. It may also be feasible to deposit dredge material downstream for reclamation purposes, soil fertilisation projects or the like.

Survey/Consultation

All phases of a dam rehabilitation project will involve various survey requirements. Prior to each project an in-depth study of the area, including historical data analysis, topographical and hydrographic surveys, seismic analysis, dredging consultations, environmental studies, sediment treatment/handling consultations, dumping areas and sediment logistics, will have to be executed. There are various reasons for this:

- the situation per dam will differ, so solutions will have to be created for each individual situation, taking into account the physical situation of the area, location, height of the terrain, available deposit area, habitation, environment, logistical parameters, available time and, last but not least, budget
- a dam integrity survey will have to be carried out by ROV. Thousands of dams of all types are threatened by structural weaknesses. Visual inspection of the structure is the most direct and reliable method, if necessary supported by other technological means. ROVs are a cost-effective alternative to divers, combined with USBL positioning systems and digital Video recording/processing and GIS integration
- hydrographic and topographical surveys, geophysical and geotechnical investigations will be necessary to provide essential information on silt volume, dredging progress etc. Continuous silt-deposit monitoring during stockpiling and de-watering will also be needed.

In view of the possibilities of induced seismicity and subsequent re-induction of seismicity during dredging operations, seismic activities will also have to be monitored throughout the project. Dam deformation measurements should be done on a regular basis. Dredging and silt-treatment control should be continuously provided and there should be infrastructure consultations and measurements.

With more than twenty thousand large dams to be â€˜treatedâ€™ over the coming ten to fifteen years, there will be a new market opening up for the survey industry. It will require hard work, innovation, creativity and professionalism. Weâ€™re used to thatâ€¦