ASFPM Working Group on Dams
Issue 5: Environmental Issues Related To Dams

a. How do dams affect wetlands, riparian habitats and other sensitive areas?

Note: The combination of dam types, operating systems, and the contexts where they are built, yields a multitude of conditions & impacts that are site specific and very variable.

1. Disruption of Sediment Processes: Dams have a significant impact on the disruption of natural sediment transport processes in rivers. Sediment transport in the river is blocked by the dam and sediment builds up within the reservoir behind the dam, while creating sediment starved conditions below the dam that lead to channel bed degradation, channel narrowing and bank erosion. This disruption of sediment processes often disconnects a river from its natural floodplain downstream or submerges riverine floodplains upstream of a dam. These impacts are compounded by multiple dams along a river. The decrease in sediment supply downstream means that natural processes like deposition of sediment on floodplains, creation of deltas, and creation of coastal beaches are all negatively impacted by dams. In some cases this leads to river systems that are no longer naturally self-sustaining.

2. Changes to Channel, Floodplain and Coastal Delta Morphology:

- **Impacts of Dams on Channels:** As stated previously sediment starved conditions below a dam can lead to channel bed degradation, channel narrowing and bank erosion, while upstream reaches of the channel are submerged by the reservoir. The river channel aggrades significantly at the furthest upstream location in the reservoir and these impacts can extend upstream beyond the reservoir as well. The changes in channel bed elevation change the interaction between the river and its floodplain.

- **Impacts of Dams on Floodplains:** Damming a river can alter the character of floodplains as the reduction in high-magnitude flows reduces the number of occasions and extension of floodplain inundation. In this sense the river becomes divorced from it floodplain. Effects on floodplain ecosystems are specifically critical as they often are matured systems with a large biological diversity and complicated food web structures that are difficult to restore once lost (if at all). In some circumstances the depletion of fine suspended solids reduces the rate of overbank accretion so that new floodplains take longer to form and soils remain infertile. In other circumstances channel bank erosion results in loss of floodplains. However, in some places the reduction in the frequency of flood flows and the provision of stable low flows may encourage vegetation encroachment which will tend to stabilize new deposits, trap further sediments and reduce floodplain erosion. (WCD Report)

- **Impacts of Dams on Costal Deltas:** In contrast to the impact on river and floodplain morphology, where aggradation may occur, impounding rivers invariably results in increased degradation of at least part of coastal deltas, as a consequence of the reduction in sediment input. (WCD Report)

- **Examples of Changes to Channel, Floodplain and Coastal Delta Morphology**:

Sediment Exchange between Floodplains and River Channels

Dunne et al (1999) presented results of the most comprehensive sediment budget ever constructed for a large floodplain river system (Dunne et al, 1998). Dividing the main stem Amazon river into ten reaches, each about 200 km in length, Dunne et al measured the sediment fluxes between the river and floodplain and downstream along the river. Sediment enters each reach by in-channel suspended load and bedload transport, from local tributaries and by bank erosion. Sediment leaves the reach by deposition on bars, diffuse overbank flow, by flow into floodplain channels leading to lakes and other off-channel waterbodies, and by in-channel transport. They found that the magnitude of annual sediment exchange between the river and floodplain typically exceeds the magnitude of downstream annual sediment flux, often by a factor of nearly two. This result shows that sediment supply in the channel can be dominated by interaction with the floodplain. It also suggests that the floodplain is closely coupled to the channel system and thus is vulnerable to even subtle changes in channel sediment transport capacity and supply caused by construction of dams upstream. For example, reduction in sediment supply from upstream could lead to channel bed erosion and deepening of the channel cross-section, which in turn would reduce the frequency and duration of overbank flooding and limit sediment flux to the floodplain. Floodplain ecosystems would then experience a reduction in the supply of vital nutrients carried by fine-grained suspended sediments. This process has been documented by Ligon et al (1995) on the Oconee River in the southern United States.

Smith & Sidorchuk (1999) looked at the Ob, Yenisey and other large Siberian rivers that drain into the Arctic Ocean. In these rivers, the timing of the annual ice break-up strongly influences the duration and extent of floodplain inundation, and thus the rate of sediment delivery to the floodplain. Compared with river water entering the floodplain, the water that drains from the floodplain wetlands system has a much lower suspended sediment concentration and an elevated organic carbon content, factors that are important for the coastal ecosystems of the arctic ocean. Rosales et al (1999) studied the influence of river confluences on floodplain ecosystem diversity in two large tributaries of the Orinoco River in Venezuela. They found a maximum in species diversity near tributary junctions that they attribute in part to more active, and more temporally variable, sediment exchange between channel and floodplain. Junctions are more dynamic because of differences in flood timing, flood magnitude, sediment load and sediment grain size between the main stem and tributary channels.

Source WCD Report

3. Impacts on Water Quantity & Flow Characteristics: Dams often alter the natural distribution and timing of streamflow. By altering the pattern of downstream flow (i.e. intensity, timing and frequency), they change sediment and nutrient regimes and alter water temperature and chemistry. Terrestrial ecosystems in reservoir areas are replaced by lacustrine, littoral and sublittoral habitats and pelagic mass-water circulations replace riverine flow patterns. (WCD report) The impacts of dams also include the effects of water diversion on riverine systems, which can vary significantly depending on the dam in question. The altered pattern and quantities of downstream flow can also disrupt critical river channel-floodplain interactions downstream. Inn addition water quality is often reduced within the reservoir and those reduced water quality conditions are then released downstream.

4. Disruption of Nutrient Cycling: (Paragraph needed)

5. Impacts on Water Temperature: Reservoirs behind dams alter the temperature regimes in river systems both within the upstream reservoir and then downstream of the dam as the water is released. The reservoirs change a once swifter flowing river condition with diverse patterns of circulation into a slow moving and often stratified water body. Shallow impoundments can often significantly increase the temperature of the river both upstream and downstream of the dam. Highly stratified reservoirs can release water with increased water temperatures when releasing flows from a surface release, or can release water with decreased temperatures when releasing water from a low level outlet; either way the natural temperature regime of the river is modified and native aquatic organisms must either adapt, perish, or relocate.

6. Reduction of Natural Attenuation: Most dams are not flood control dams and have little to no ability to attenuate floods. Dams that do not attenuate floods actually have the opposite effect on flooding, they increase flooding, both upstream of the dam where water surface elevations are raised due to the impoundment, and downstream by eliminating the ability of the river and floodplain to attenuate floods (in the area that the impoundment inundates). Some dams also create significant downcutting of the channel downstream of the dam, disconnecting the river from its natural floodplain and again decreasing natural attenuation of flood flows.

7. Impacts on Riparian Habitat: Dams block not only sediment but debris and nutrients as well. Excluding these critical building blocks of riverine habitat from reaching downstream locations, while upstream riverine habitat is submerged by the reservoir itself. Dams are often built in high gradient reaches of the river, prime spawning habitat for many cold water fish species. In addition to many high gradient riffles and rapids, many waterfalls have been submerged under dams and their impoundments.

8. Impact on Natural "Flushing" Function of Rivers: Dams alter flow patterns, reduce flood pulses and change the river ability to transport sediment and debris. This limits the rivers ability to "flush" out the river and form the river channel and floodplain. These cyclical "flushing" events help ensure diversity of species and complexity of habitat.

9. Impacts on Riparian, Delta & Coastal Vegetation: (Paragraph needed)

10. Impact on Diversity: An increased number of invasive species are often found in the reservoirs created by dams, while native species are often displaced, decreased in abundance or in some cases eradicated. Storage reservoirs flood terrestrial ecosystems, killing terrestrial plants and displacing animals. As many species prefer valley bottoms, large scale impoundment may eliminate unique wildlife habitats and extinguish entire populations of endangered species (Nilsson and Dynesius, 1994). Loss of some ecosystems may benefit some species (e.g. waterfowl and fish that favor deep water), but others may suffer significant loss of population, or even extinction. (WCD report) While a number of species may benefit from the creation of open water habitat, there are a larger number of species that depend on marshes, floodplains, and riverine habitats that are negatively impacted by dams. (WCD report)

11. Fragment Riverine Systems: Dams of all sizes fragment riverine corridors. Both the river channel itself and the river's floodplain are fragmented by the many barriers along them (i.e. dams, road crossings, and levees). These impacts can be significant for many aquatic species and may also impact terrestrial wildlife passage. Open riverine corridors play a significant role in the ability of many species to migrate either due to life cycle requirements, habitat disturbances or changing climate. In the USA it is close to impossible to find river systems that are not fragmented by numerous man-made barriers.

12. Potential for Catastrophic Breach: Unlike the controlled removal of a dam, uncontrolled breaches of dams can have catastrophic effects on downstream ecosystems, the river channel and the floodplain, as well as damage downstream property and put human life at risk. In addition since many dams have deposits of sediment behind them of unknown quality, there is also the risk of devastating contamination of downstream systems if a dam with contaminated sediment were to fail.

13. Cumulative Impacts of Multiple Dams or of Multiple Types of Impacts: The environmental impacts can be cumulative when multiple dams are on a river. In addition, since there are a wide variety of environmental impacts relating to dams, multiple types of impacts can combine to have a greater cumulative impact on the river system, even when only one dam is being analyzed.

- **Examples of Cumulative Impacts of Dams:**

Cumulative Impact Analysis

Cumulative impact analysis is an essential tool for understanding and predicting the impacts of dams on large river basins. Unfortunately, little scholarly research been devoted to developing a theoretical framework or practical methodologies for cumulative impact analysis. Cumulative impacts have been defined in two different and useful ways. First, the indirect impacts which result from interaction of direct impacts, originating with a single intervention in the river system, can be considered cumulative impacts. For example, the reduction in sediment flux downstream of a dam could lead to channel bed coarsening, while flow regulation by the same dam could result in the elimination of infrequent large discharge events and lead to channel narrowing due to vegetation encroachment. The combined effect of these two impacts may be sufficient to eliminate the spawning habitat for an endangered fish species, although either impact taken alone may not have had any major effect. A second type of cumulative impact results from the additive effects of multiple interventions in different places within the river system. For example, cold water releases from a high dam combined with a large reduction in suspended sediment flux downstream of a large volume storage dam on the same river, may result in water too nutrient poor and cold to allow the spring bloom of algae, which form the base of the aquatic food chain. The effects of either dam, taken individually, may not produce this result.

The cumulative impacts illustrated above result from the existence of thresholds and feedbacks within river systems. Anticipating cumulative impacts involves more than the summing of individual impacts. The relevant thresholds need to be identified and the state of the system relative to those thresholds needs to be assessed. Cumulative impact analysis is difficult because it requires cross-disciplinary interaction among experts who are usually trained in reductionist approaches to science. Cumulative impacts are particularly important to assess in large rivers when a large number of dams may be built within a single basin.

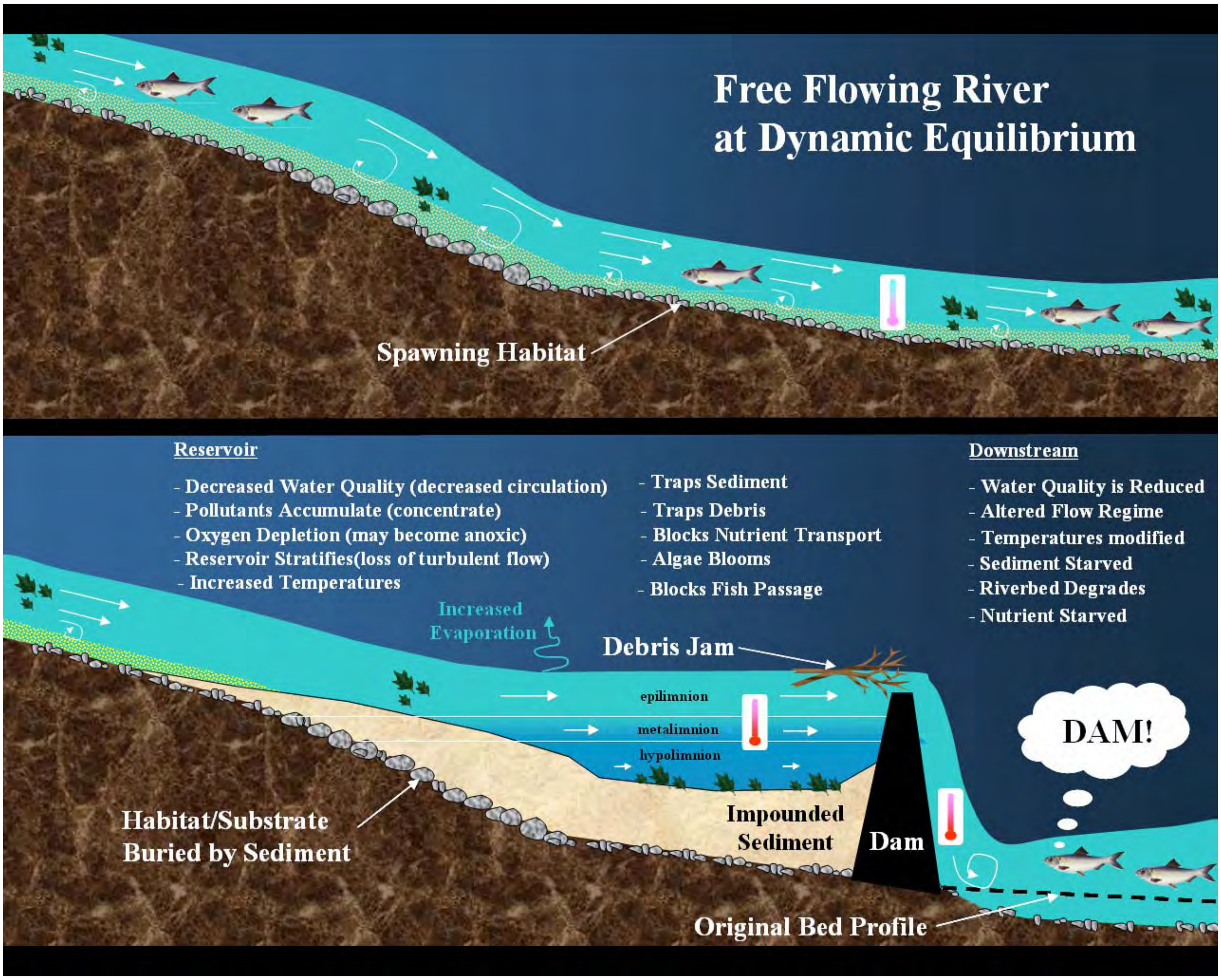
14. Construction & Maintenance Impacts: When a dam is built or repaired that construction project alone can have an impact on the river system and watershed in which the dam is located. These impacts can come from the construction of access roads, increased turbidity while the work is under way, impacts of temporary water diversions to control water during construction, etc.

15. Increase Development of Land in Flood Prone Areas: Dams increased public confidence that they are safe from all flooding, this often promotes increased development in flood prone areas, similar to when levees are constructed. The lack of publicly available and easily accessible information regarding dam condition, dam breach inundation zones and the location of dams leads to a disconnect between local planning and dam safety. The most common problem associated with this disconnect is “hazard creep”, which describes when the hazard classification of a dam is unknowingly increased because of development downstream of a dam.

> Large dams protect from regular annual floods but often fail to hold back floods of longer return periods. Dams lead people to believe that floods are controlled and so lead to increased development of floodplains. Then when a large flood does come, damage caused is often greater than it would have been without the dam. If a dam fails the consequences can be devastating. Thus dams reduce, in a very tangible way, the security of people living downstream.
>
> Source: WCD Report

<u>Grouping Environmental Impacts of dams by Order (Source: WCD Report)</u>

Downstream	First-Order Impact	Daily, Seasonal and Annual Flows
		Water Quality
		Reduced Sediment Flows
		Changes to Channel, Floodplain and Coastal Delta Morphology
		Groundwater in riparian zone
		Water temperature – thermal pollution
		Ice formation
	Second-Order Impact	Plankton and Periphyton
		Growth of Aquatic Macrophytes
		Riparian Vegetation
		Carbon flows and cycle distortions
	Third-Order Impact	Invertebrates, Fish, Birds and Mammals
		Estuarine Impacts
		Marine Impacts



Summary of the Environmental Impacts of Dams of Rivers
(Source: Laura Wildman – American Rivers)

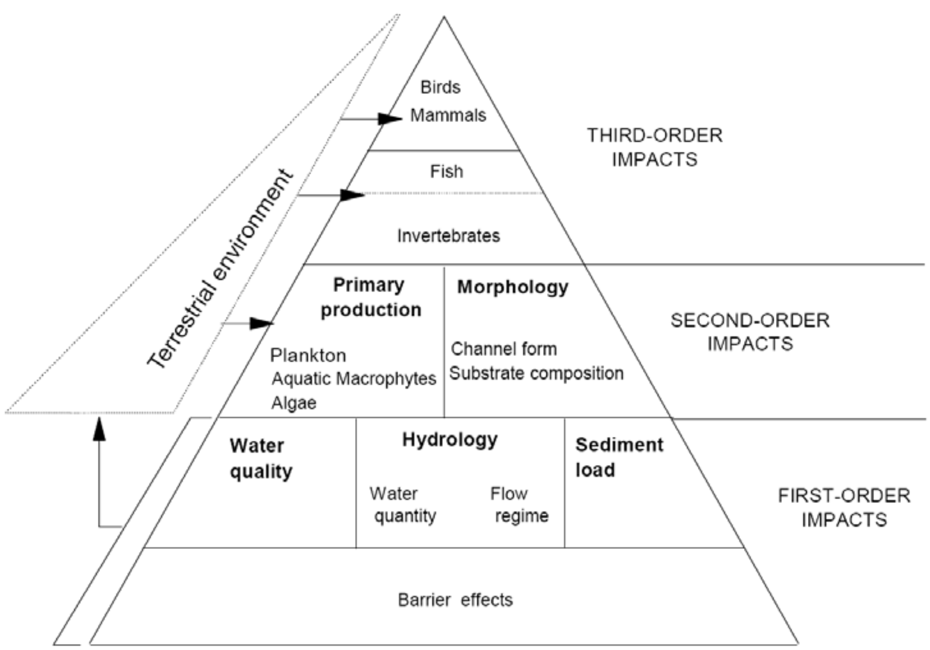


Table 3.4: A framework for assessing the impact of dams on river ecosystems(modified from Petts, 1984).

Summary of the Environmental Impacts of Dams (Source: WCD Report)

A. Impacts on the Natural Environment

1. Negative environmental effects due to construction activities (S1);
2. Loss of wildlands, wetlands and wildlife habitat, extinction of plant and animal life (S15, B50); threats to endangered species (U);
3. Effects of stopping the flow of nutrients downstream (U, B50);
4. Reduced biological activity downstream (B50) (In arid areas often an increase in quantity of flora and fauna (B50);
5. Reduction in downstream flooding may result in less natural submergence for flood-recession agriculture, reduction in groundwater recharge and reduction in removal of parasites by natural flooding (B50);
6. Impacts on quantity of water needed for maintaining downstream ecology (B35);
7. Anaerobic decomposition of vegetation and production of greenhouse gasses (high cost of cleaning up);
8. Environmental degradation from increased pressure on land such as irrigated agriculture, industries and municipalities (S23);
9. Dams form obstacles to passage of trees, floating debris, ice and ships (B35);
10. Waterloss due to evaporation;
11. Induced seismicity;
12. Changed morphological character of rivers (flow volume, surface area and water levels) (B50);
13. Rivers may dry up (B35).

A* Flora

1. In severely cold climates, impact is limited to direct inundation and nearby changes in groundwater levels (B50);
2. Aquatic weeds (floating and submerged) may proliferate, especially in tropical areas: Water hyacinth and water lettuce (B35);
3. Prolific vegetation impedes navigation and fishing, and affects hydraulic structures (B50);
4. Tourism may adversely affect flora and fauna and also create social problems (B50).

A** Fauna

1. Accommodation of amphibians, riparian fauna and birds to a new environment (B35);
2. Migration of animals to new areas, where new equilibrium may favour some species over others (B50).

A** Aquatic Fauna

1. Blocking fish migration (S14, B35);
2. Disruption of riverine fisheries due to changes in patterns, duration, velocity and volume of flow (S14, U, B35);
3. Introduction of new species of fish in the reservoirs (B35);
4. Inappropriate reservoir operation with large variations in water levels could threaten fish by drying up shallow-breeding and flood-producing areas (B50);
5. Destruction of spawning beds in shallow areas at the margins of reservoirs due to enhanced turbidity as a result of land erosion caused by wave action.

E. Sedimentation of Reservoirs

1. Sedimentation of reservoirs causes loss of storage capacity (S8) (often not in severe winter climates, except in the Himalayas) (B50);
2. Formation of sediment deposits at reservoir entrance creates backwater effect, flooding and water-logging upstream (S9);
3. Capture of nutrients causes deficiencies downstream;
4. Scouring of river bed below dam due to lower sediment content of released water (S10) Also less soil replacement;
5. Poor land use practices in catchment areas (such as deforestation and incautious agricultural development (B35), and inflow of untreated industrial effluents and municipal wastes (B50);
6. Release of captured sediments (e.g. heavy metals).

F. Downstream Hydrology

1. Change of riverflow patterns;
2. Oxygen deficiency, changes in water temperature and pH;
3. Salination and saltwater encroachment;
4. Changes in tidal prism in estuaries resulting from increased siltation;
5. Changes in water quality.

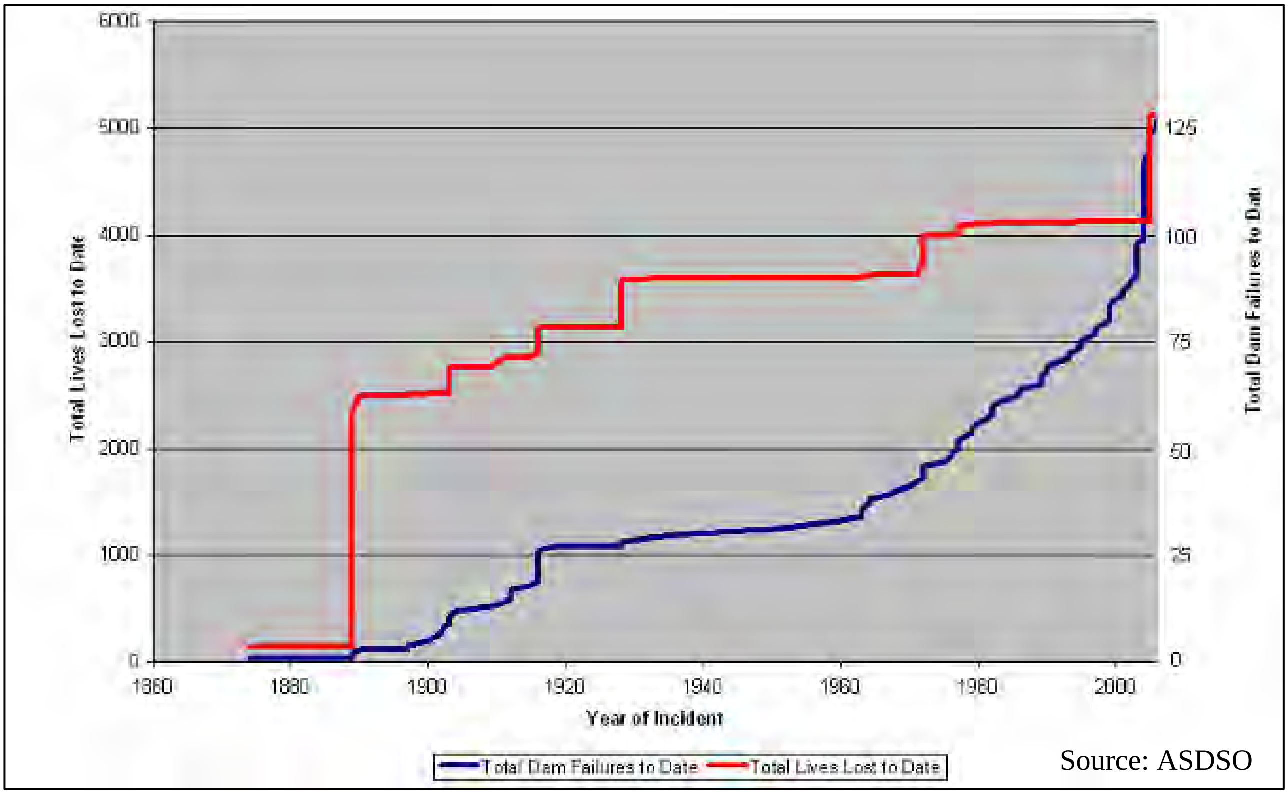
G. Water Quality

1. Changes to water quality and limnology (S14) due to inflow of saline water (B35, 37) (retention time is important);
2. Effects of changes in groundwater levels, higher around the reservoir and lower downstream (U, B35). These may also affect ground water quality;
3. Proliferation of aquatic weeds in reservoir and downstream, causing clogging and impairing navigation, recreation, fisheries and irrigation (S6);
4. Deterioration of water quality in the reservoir due to rotting of submerged vegetation and hydrogen sulphide (B50) (Normally not in areas with a severe winter climate (B50) (S7);
5. Water quality deterioration is due to lack of dissolved oxygen near the bottom of reservoirs (B50). This is toxic to fish and can lead to death of aquatic life (B35). It is also corrosive to turbines;
6. Snagging of fishing nets due to submerged vegetation in reservoir;
7. Deoxygenation (especially at lower levels in the reservoir) due to submergence of forests and other vegetation with a high content of degradable matter (B50);
8. Fish may die downstream from nitrogen and oxygen supersaturation (B35);
9. Thermal stratification in deep reservoirs (due to heating and cooling of the surface layer (B50) may result in low temperature water released through low level outlet works. This is detrimental to fish, and affects home and industrial water supplies and cooling ponds (B35);
10. Eutrophication results from sediment inflow enriched with nutrients (B35);
11. Pollution of reservoirs by humans and animals (B35) (industrial affluents, mercury release from the soil and raising or contaminating watertables);
12. Macrophytes cause high water losses due to evaporation and depletion of oxygen and creates difficulties for fishing (B50);
13. Agriculture on marginal lands near the water level (e.g. islands), may introduce pesticide, rendering fish inedible (B50);
14. Evaporation in arid areas increased salinity, chlorides, carbonates and sulphates (B50);

b. How much of a threat do dams pose to water and sewage treatment plants, chemical plants and storage facilities, etc.? Is this a question on the condition of dams?

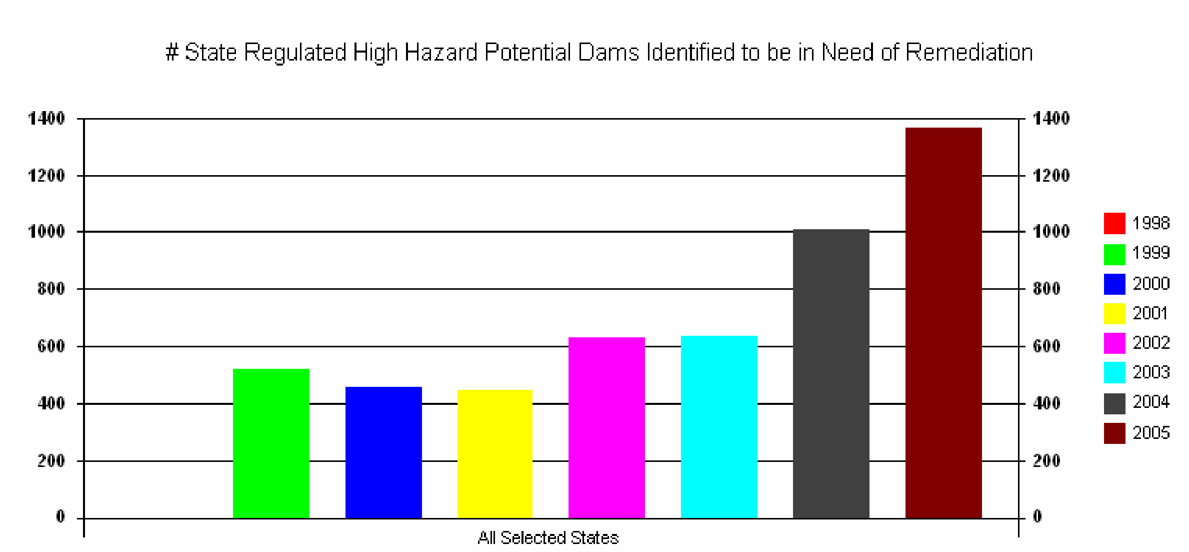
I could see adding points such as the following (with data to back this up)

- Thousands of dams are beyond their usable life expectancy
- The frequency of dam failures/breaches is steadily on the rise



Source: ASDSO

- The number of high hazard dams in need of repair is steadily on the rise



Data source: Michael Grounds ASDOS 2006 presentation on Dams Safety Performance Measures and NID

- Old dams are increasingly posing a threat to public safety (life, property & the environment) These threats include the threat of failure and the potential for loss of life through the attractive nuisance aspects of dams (i.e. deaths due to boating, swimming, climbing or playing near a dam)

- Old dams are increasingly expensive to maintain and are placing an economic burden on our communities and country.

- Many people live unaware that they are within the breach inundation zone of a dam. Community planning efforts are also often unaware of issues relating to dams, their condition, their location, and their area of potential impact, therefore many local planning decisions are made that further increase the threat to the general public.

- There are almost no state regulations that require the notification of a property owner when they buy a piece of property with a dam on it (and therefore dam owner responsibilities associated with ownership transfer) or buy a property within a dam breach inundation zone, even if the dam in question is in poor condition and needs repair.

- There are exiting dams and dams recently built with unrealistic warning period for evacuation of the population at risk. (i.e. Sundial Mine Waste Dam in WV – with a 3 minutes to evacuate window for the Elementary School, located 400yds downstream, before water is 6 ft and the Creekside Dam in OR, built in 2005, which has a 5min warning

Some References on The Environmental Impacts Of Dams:

- World Commission on Dams Report. Dams and Development: A New Framework for Decision Making, Cape Town, 2000 (and the expanded environmental appendix for this report which I have attached to the e-mail) http://www.dams.org/report/contents.htm (see Chapter 3)
- Exploring Dam Removal – A Decision Making Guide (explains some of the ecological issues associated with dams and dam removal)
- The Ecology of Dam Removal – A Summary of Benefits and Impacts (this goes into the ecological impacts of dams and dam removal)
- http://dameffects.org/ (this is a nice animated gif showing some of the impacts of dams. You have to move the mouse around the page to get to the additional pop-up information with more detail.
- Ecological Impacts of Glen Canyon Dam http://www2.kenyon.edu/projects/Dams/gbe03hol.html
- Ecological Impacts of Dams, Water Diversions and River Management on Floodplains Wetlands in Australia http://cat.inist.fr/?aModele=afficheN&cpsidt=792463
- International Development Studies Network – Environmental Impacts of Dams http://www.idsnet.org/Resources/Dams/Development/impact-enviro.html
- Analyzing the Impacts of dams on Riparian Ecosystems: A Review of research Strategies and Their Relevance to the Snake River http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2233706
- Dams and Rivers: Primer on the Downstream Effects of Dams – Collier, Webb & Schmidt

We could definitely add more good references

Table 5.1: Distillation of arguments used by proponents and opponents of large dams

Source: WCD Report

Proponents	Opponents
Through provision of reliable water supplies, production of energy and creation of recreational opportunities, dams have improved the economic and social well-being of many millions of people.	Through inundation of huge tracts of inhabited land and destruction of the natural services provided by downstream ecosystems, dams have destroyed the livelihoods and reduced the well-being of many millions of people. The social and economic benefits promised for large dams have in many cases not been realised.
Dams are the most important means of making surface water available at the place and time of demand. Although there are non-structural alternatives (eg demand management), more dams will be needed in the future to manage the world's limited water resources.	Dams are only one way of providing water when required. Other options such as demand management, rainfall harvesting and the tapping and recharging of groundwater or desalination of seawater could reduce our dependence on the construction of dams.
Dams create new habitat through the creation of reservoirs, which, although detrimental to some species, provides opportunities for others.	Through creation of reservoirs, dams have flooded and so destroyed many pristine biotopes, with consequent negative impacts on biodiversity. Dams transform "healthy" river ecosystems into impoverished reservoirs.
Downstream from dams, the destruction of ecosystems resulting from the disruption of the natural flow regime can be mitigated by release of compensation flows that simulate both the high and the low discharges of the natural flow regime.	Downstream from dams, disruption of natural flow, sediment and energy dynamics destroys the integrity of many ecosystems. Although it is possible to mitigate against some of the negative effects, it is impossible to undo all the damage.
Large dams provide flood protection, and so increase the security of many millions of people who live downstream from them.	Large dams protect from regular annual floods but often fail to hold back floods of longer return periods. Dams lead people to believe that floods are controlled and so lead to increased development of floodplains. Then when a large flood does come, damage caused is often greater than it would have been without the dam. If a dam fails the consequences can be devastating. Thus dams reduce, in a very tangible way, the security of people living downstream.
The health risks associated with dams and associated projects were not appreciated in the past. We now understand the risks and so can mitigate against the causes. Furthermore dams, by increasing economic status, can provide the impetus for improved health care.	Many large dams and the projects associated with them (eg irrigation schemes) create health risks for many people who live in their vicinity. The health risks associated with the workforce bringing in disease during dam construction are an additional hazard.
Hydropower represents a "clean" sustainable energy source. Many of the alternatives to hydropower (eg nuclear and coal fired power stations) create greater environmental and social-economic problems.	Hydropower is not a "clean" energy. By altering chemical and thermal regimes, reservoirs effectively pollute rivers and destroy downstream ecosystems. Furthermore, reservoirs may contribute to greenhouse gases (i.e. decomposition of submerged vegetation releases carbon dioxide and methane). Modern technologies (eg solar power) provide new opportunities that enable us to reduce our dependence on large dams.
Over the last 20 years, environmental issues have come to the fore, but people (especially in the developed world) are not prepared to make the changes to their life styles that doing away with large dams would entail.	Over the last 20 years societal values have changed (especially in the developed world). Environmental damage is no longer accepted as an inevitable consequence of human development. Indeed, it is now recognised that continued environmental degradation is non-sustainable.
Overall: In the past mistakes have been made. We now have a greater understanding of the negative ecological, socio-economic and health consequences of large dams, and to a large extent these can be mitigated against. The scope for reducing any detrimental impacts on the environment through alternative solutions, project modifications in response to particular needs, or mitigating measures should be thoroughly investigated, evaluated and implemented (ICOLD, 1997). The benefits of dams outweigh the costs. In many cases the alternatives are associated with far greater costs. The negative impacts of large dams on the environment are sometimes overstated. Dams can sometimes enhance environmental conditions. Dams are now an essential part of the basis for human survival. More dams will be needed in future. The future for large dams should be bright.	**Overall:** Large dams should be a last resort after "less damaging and costly alternatives for flood management, transportation, water supply, irrigation and power supply are exhausted" (IRN, 1994). In the past, dams have not lived up to the promises made for them. The ecological, socio-economic and health costs associated with their construction are now recognised. In many cases these costs outweigh the benefits. The price paid is too high. Alternatives to large dams exist. The era of large dams should be brought to an end.