Before the Deluge

Coping with Floods in a Changing Climate

An IRN Report

Welcome to International Rivers Network's second annual "Dams, Rivers and People" report. Each year we focus on a key issue affecting the world's rivers and the people who depend upon them. We also summarize key dam-related developments in the previous year and predict where the hotspots will be for the coming year. This year's theme is floods and flood management.

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Cover Photo: *Flood refugees in Mozambique struggle through high waters to reach a rescue helicopter during the February 2000 floods. Photo: Karel Prinsloo/AP Images*

Back Cover Photo: *Trudging through the waters of a flooded New Orleans after the levees broke, 2005. Photo by FEMA/IllinoisPhoto.com*

INTRODUCTION AND KEY MESSAGES

Floods are the most destructive, most frequent and most costly natural disasters on earth. While harmful floods have happened throughout human history, flood damages have soared in recent decades, despite the expenditure of hundreds of billions of dollars on flood control structures. This is partly because global warming is causing more severe storms, and partly because of growing populations and economic activity on floodplains. It is also because flood control technologies and approaches often prove counterproductive. Improving our ability to cope with floods under the current, and future, climates requires adopting a more sophisticated set of techniques – the "soft path" of flood risk management, which aims to understand, adapt to and work with the forces of nature.

There are three main reasons why conventional "hard path" flood-control – based on dams and levees (embankments) – is not working. First, no complex engineering system can be totally fail-proof. Second, they have too often been based on an incomplete understanding of the workings of rivers and coasts. Third, they encourage the intensive development of flood-prone areas while discouraging investments in other flood-proofing measures and in preparations for flood evacuations. While hard flood control can prevent most "normal" floods, in the long run it tends to increase damage from severe floods. It also causes major harm to riverine ecosystems.

Dams and levees set off profound changes in the ways in which water and sediment flow through watersheds. This can increase flood damage for reasons such as:

- reduced channel capacities, because of sediment deposition on river beds;
- faster-flowing floodwaters due to straightening (and thus shortening) and narrowing of rivers;
- loss of sediment flows, leading to subsidence of deltas and coastal erosion.

The breaching of levees and dams (and the careless manage-ment of dam releases) cause extremely destructive floods because they tend to happen without warning and create fast-moving flood waves.

Climate change is expected to dramatically increase the size and frequency of floods. Structural flood control is based on the assumption of a static climate. In this fictitious world, engineers can calculate the probability of a flood of any given size occurring in any year. Dams and levees are designed to withstand a particular "return flood." But in the real, warming world, it is impossible to calculate meaningfully the size of any given return flood. The inflexibility of hard flood control is a major weakness not only because climate is changing, but also because the timing and size of floods change over time due to urbanization and other land-use alterations as well as natural geomorphological processes.

Flood risk management is flexible, in that it seeks to reduce damage from any size of flood, and adaptive in that it seeks to respond to the hydrological changes caused by changing land use and river morphology. Flood risk management assumes that floods will happen and that we need to learn to live with them as best we can, reducing their speed, size and duration where possible; getting out of their destructive path, and doing our best to protect our most valuable assets. It assumes that all flood protection infrastructure can fail and that this failure must be planned for. It is also based on an understanding that floods are not inherently bad – and indeed that floods are essential for the health of riverine ecosystems.

Key elements of flood management in a changing climate include:

1. Slow the flood: Strategies to reduce the speed and size of floods include moving embankments back from rivers and restoring wetlands, floodplains and meanders, and slowing down urban run-off. These measures also have major ecological, aesthetic and recreational benefits.

2. Improve emergency procedures: Possibly the most important measures in terms of saving lives are to improve flood forecasting, warning and evacuation procedures. It is also vital to prepare strategies in advance to help households and communities recover from the impacts of floods.

3. Move out of harm's way: A vital part of reducing damage, especially in less densely populated areas such as the US, is to discourage people from living in the areas most vulnerable to floods. Floodplain management includes planning regulations to discourage new floodplain development, and financial incentives for people living in the riskiest areas to move to higher ground.

4. Protect the most vulnerable buildings and areas: Flood risk management includes structural measures such as flood-proofing of individual buildings (for example, by raising them on stilts or mounds) and communities (e.g., building flood shelters and flood-protected water sources), the building of floodplain storage and bypass systems (areas of sparsely or undeveloped land which can be used to divert or store high floods), and the judicious use of well-maintained embankments for vulnerable urban areas.

5. Improve dam management: In many countries, dams worsen flood damages when they overtop, collapse or are poorly operated (as when reservoirs are kept full in order to maximize power generation, leaving little room for flood storage). Operating rules for dams should be developed with opportunity for public input, published, and stringently enforced. A safety assessment of existing dams is another critical issue; plans for removing unsafe dams should be prioritized. ■

Before the Deluge

Coping with Floods in a Changing Climate

by Patrick McCully
Executive Director, International Rivers Network

The levee breaks that devastated New Orleans after Hurricane Katrina was just the latest sign that conventional flood-control measures too often do not control floods. These systems are failing around the world for three main reasons: because no complex engineering system can be totally fail-proof, because too often they are based on an incomplete understanding of the workings of rivers and coasts, and because they encourage the rapid development of flood-prone areas. Reducing long-term flood vulnerability requires embracing the "soft path" of flood-risk management, which aims to understand, adapt to, and work with the forces of nature. The growing size and frequency of floods due to global warming make the need for better protection from flood damage an urgent necessity.

On the evening of Sunday, August 28, 2005, a solemn New Orleans Mayor Ray Nagin issued the first-ever mandatory evacuation order for the residents of his city. "We're facing the storm most of us have feared," said Nagin. "This is very serious. This is going to be an unprecedented event." The day before, Hurricane Katrina had intensified over the Gulf of Mexico to one of the strongest hurricanes ever measured, with top winds of 269 kilometers per hour. The storm appeared to be aimed straight at New Orleans.

Katrina made landfall early Monday morning about 80 kilometers from New Orleans. To many it seemed that the city had dodged the bullet of a direct hit from a major hurricane. "Escaping Feared Knockout Punch, Barely, New Orleans Is One Lucky Big Mess," *The New York Times* proclaimed on Tuesday.

Few people would now describe New Orleans' Katrina experience as "lucky." The storm is believed to have killed more than 1,200 people in New Orleans and the adjoining parishes. Four-fifths of the city was flooded, with some parts under more than six meters of water. The area suffered an estimated $28 billion in direct damage to its housing and other infrastructure.[1] Eighteen months after the storm, much of the city's housing still lies in ruins, many schools and clinics remain closed, and fewer than half of the former residents of Orleans parish have returned.[2]

Yet, despite the terrible losses, *The New York Times* was right: the city did escape the feared "knockout punch." What felled New Orleans was not the windstorm that pummeled much of the Gulf coast, but the failure of the city's flood protection infrastructure to perform as designed.[3]

New Orleans sits, encircled by floodwalls, in a bowl-shaped depression wedged between one of the world's mightiest rivers and a lake connected by a short strait through a spit of marshlands to the Gulf of Mexico. The 300-year history of the efforts to protect New Orleans from Mississippi floods and Lake Pontchartrain storm-surges serves as a cautionary tale of the dangers of trusting flood control structures to stop destructive floods.

> **"I don't think that anyone anticipated the breach of the levees."**
>
> President George W. Bush on the flooding of New Orleans, September 1, 2005

The US Army Corps of Engineers' hurricane-protection system, started 40 years ago and still unfinished, was supposedly designed to withstand a Category 3 storm – yet Katrina when it hit New Orleans was at most of this strength, and possibly weaker. A 6,000-page Corps of Engineers investigation admitted that their network of floodwalls was a system "in name only" and accepted responsibility for the failures, acknowledging that engineering error had played a major role in the flooding.[4] Nicholas Pinter, a geology professor at Southern Illinois University, describes the flooding of New Orleans as "a levee disaster: the result of a flood-protection system built too low and protecting low-lying areas considered uninhabitable through most of the city's history."[5] ("Levees" is the name given to flood embankments and walls in the US – the origin of the word coming from the earthen flood defenses built by the French founders of New Orleans.)

The levees failed because they were poorly designed and built, and because New Orleans and the Mississippi Delta are sinking. Like all deltas, that of the Mississippi was built up by countless millennia of floods spreading their load of sediments out over the landscape, through a network of distributaries that fan out from the mainstream of the river. A portion of those sediments that are carried out the mouths of rivers are subsequently washed back to help build up barrier islands and beaches. Stop the regular floods, and the land starts to compact and sink and get eaten away at the edges by the erosive power of the sea. The spread of levees up and down the Mississippi and the blocking of the many distribu-

Neighborhoods flooded by Hurricane Katrina and levee breaks are patrolled by rescue crews. Photo: Jocelyn Augustino/FEMA

taries now keeps sediments within the Mississippi's main channel, before shooting them out to sea, beyond the reach of coastal currents.

Dams also play a part in the drama of New Orleans' flood vulnerability, because the huge reservoirs on the upper Missouri trap about half of the sediment which once flowed out of the Mississippi.[6]

The Mississippi Delta stopped growing around 1900 and has been steadily sinking and shrinking ever since. Since the 1930s more than 4,900 square kilometers of Louisiana's coastal wetlands – almost twice the area of Luxembourg – have been devoured by the waves of the Gulf of Mexico.[7] The US Geological Service calculates the current rate of loss as around two soccer pitch's worth of wetlands every hour.[8] On a map, the areas along the Louisiana coast look more like watery lacework than landscape.

The loss of coastal wetlands causes massive damage to local ecosystems and economies. Because wetlands and offshore barrier islands can significantly reduce the power and height of storm surges, their loss also increases the hurricane-vulnerability of coastal communities.

New Orleans' self-defeating cycle – flooding followed by new investments in flood control, followed by the development of supposedly flood-protected areas, which then experience disastrous floods, which leads to more flood-control projects, which induce more development, which leads to more damage the next time floods hit – is unfortunately far from unique. Around the world, flood damages have soared while expenditures on flood-engineering projects have steadily increased. While many factors besides levees and dams – not least of which is global warming – are contributing to increasing the severity and frequency of floods, it is indisputable that the proponents of flood control have failed to deliver on their expensive promise of reducing flood damage.

THE FAILED PROMISE OF FLOOD CONTROL

Oh cryin' won't help you, prayin' won't do no good
When the levee breaks, mama, you got to lose.

From "When the Levee Breaks," blues song by Kansas Joe McCoy and Memphis Minnie, written after the Great Mississippi Flood of 1927

According to research by Munich Reinsurance Company, from the 1950s to the 1970s, seven to nine "major floods" occurred around the world each year. In the 1980s the number leaped to 20, and then to 34 in the 1990s. The rapid rise in the number of floods was accompanied by an increase in their severity. The exponential rise in flood disasters in Europe in recent decades is even more striking. In Switzerland, flood losses have quadrupled over the past 35 years, despite a major increase in flood control investments.[9] India built some 16,800 km of embankments between 1954 and 1998, with at best no decrease in the area affected by floods (and a clear increase in the number of people affected and number of deaths).[10] The length of embankments in the Indian state of Bihar increased by 22 times between 1952 and 1998 – while its flood-prone area almost tripled.[11] The average annual damage (inflation-adjusted) caused by floods in Bihar almost quadrupled between the 1950s and 1970s.[12]

Since the 1920s the US government has spent more than $123 billion on flood control schemes, mainly dams and levees. Yet over the same period the average inflation-adjusted cost of flood damage every year has tripled to $6 billion (without taking into account the estimated Katrina property damage of at least $100 billion and perhaps twice that).[13]

The Corps of Engineers claims that its reservoirs and levees prevent more than $19 billion in flood damages each year.[14] Yet much of this supposed avoided damage is to infrastructure that would not have been placed in areas at risk had the dams and levees not been built (and, as is explained below, many floods would have been slower and lower and thus less potentially damaging had the Corps' projects not been built).[15]

Conventional structural flood control systems fail partly because no complex engineering system is able to be totally fail-proof, and partly because they are too often based on a badly incomplete understanding of the hydrological and geomorphological realities of rivers and coasts. They also fail because they encourage the rapid development of areas that will, almost inevitably, eventually be flooded.

The very concept of "hard" flood control is based on the idea that nature can be confronted, constrained and made to do humanity's bidding. Hard flood control advocates believe that wild rivers should – and can – be tamed by trapping them behind reservoirs and then gradually releasing their waters into engineered channels below. But experience shows that such measures both cause great harm to riverine ecosystems, and, in the long run, only tend to increase vulnerability to severe floods.

The very concept of "hard" flood control is based on the idea that nature can be confronted, constrained and made to do humanity's bidding.

Reducing long-term flood vulnerability requires a more sophisticated set of techniques – the "soft path" of flood-risk management, which aims to understand, adapt to and work with the forces of nature. Flood risk managers understand that floods take many different forms – flash floods on urban creeks, slow-rising floods on major rivers, cyclonic storm surges, dam- and levee-break floods, tsunamis, *bishyaris* (the breaking of natural dams caused by landslides), and glacial lake outbreak floods (GLOFs) are just a few of the many types. Such a diversity of floods – and the diversity of the socio-economic and cultural contexts of the people affected by them – requires a wide diversity of hazard reduction responses.

Flood-risk management assumes that floods will happen and that we need to learn to live with them as best we can, reducing their speed, size and duration where possible, getting out of their destructive path, and doing our best to protect our most valuable assets. It also assumes that all flood-protection infrastructure can fail and that this failure must be planned for. Importantly, it is also based on an understanding that floods are not inherently bad – and indeed that floods are essential ecosystem processes.

Advocates of flood-risk management stress the vital nature of non-structural measures, in particular better flood warning and evacuation procedures, and zoning regulations that discourage further development of the most vulnerable areas. Important structural flood management measures include the flood-proofing of individual structures (for example, by raising them) and communities (e.g., building flood shelters and flood-protected water sources), the building of floodplain storage and bypass systems (areas of sparsely or undeveloped land which can be used to divert or store high floods), and the judicious use of well-maintained embankments where these are the only viable option, such as for vulnerable urban areas.

Flood-risk management also involves measures to reduce the speed and size of floods, including moving embankments back from rivers, restoring wetlands, re-meandering channelized rivers, and slowing down urban run-off.

Contractionists and Expansionists

Disputes between flood "controllers" and "managers" have a long pedigree. In China, arguments between Confucian "contractionists" – who believed that rivers should be constricted between high river-side embankments – and Taoist "expansionists" – who argued for low embankments to be built back from the river to allow floodwaters to spread out – date back more than 20 centuries.[16] The contractionists largely won the river management argument in China, and one must wonder whether the country would have suffered so many catastrophic floods had this not been the case (the two deadliest natural disasters in history are the Yellow River floods of 1887 and 1931, which together killed as many as six million people). Outside of China, the contractionist approach has also dominated efforts to deal with floods (with scattered examples where expansionists had brief periods of influence).[17] However, in recent decades, and especially in the US and Europe since the massive floods on the Mississippi in 1993 and the Rhine in 1994, the "expansionist" managers have been increasingly in the ascendant.

While flood-risk management has now reached the status of "conventional wisdom" among most contemporary analysts on floods, the old habits of engineers, politicians and institutions die hard. And various engineering and construction industry groups have a strong motivation to ensure that the old habits remain. The Corps of Engineers is in some places (such as the Kissimmee River in Florida and Sun Valley and Napa in California) undoing some of its past errors and trying new management techniques.[18] Yet elsewhere in the US the Corps – encouraged by its Congressional allies who relish bringing federal dollars back to their home districts via big water projects – continues to pour billions of dollars into old-style dam expansion, dredging, pumping and levee raising.

The activities of the Corps of Engineers – not just on flood control but also its related dredging, draining, channelization and hydropower projects – have long been the focus of a flood of criticism from community activists, academics, journalists, auditors, and some politicians. President Franklin D. Roosevelt's interior secretary blasted the "reckless and wastrel behavior" of the "insubordinate and self-seeking" Corps.[19] In 1974, the then Governor of Georgia, Jimmy Carter, berated the Corps for their "false justifications" and "grossly distorted" analyses of costs and benefits of their proposed dams.[20]

In 2000, the *Washington Post* devoted a major series of articles to the dysfunctional and dishonest activities of the Corps. Six years later its author, Michael Grunwald, wrote a post-Katrina opinion piece in the *Post* lamenting that despite all the criticism and exposés, the Corps continues to inflate benefits, low-ball costs, misrepresent environmental impacts, and otherwise justify projects "that keep its employees busy and its congressional patrons happy." [21]

Yet the Corps' sullied reputation in the US has not stopped the agency's concept of flood control from being promoted as a model for the rest of the world. A Corps of Engineers official is one of the office holders on the board of the influential Global Water Partnership, and Corps generals and civilian employees are regular presenters at major international water conferences. The World Bank's position paper for the World Water Forum in Mexico in 2006 not only applauds the economic benefits of the Corps' flood control efforts, but lauds the performance of their infrastructure during the 2004 hurricanes in Florida – while, astonishingly, not even mentioning the devastating failure of one of their grandest schemes, the hurricane protection "system" around New Orleans.[22]

Perhaps partly because there are no agencies with the clout of the World Bank or the Corps to promote internationally the soft path of flood management, in much of the world the old flood-control mentality still appears to dominate among government planners and politicians. The standard response to a flood disaster in many parts of the world is to call for more levees and dams – regardless of any role that these technologies may have played in failing to prevent, or actually worsening, the latest disaster.

The call for new flood control infrastructure has even grown louder recently. Praise of hard flood control in the US and Europe is included within an influential advocacy campaign by World Bank water sector staff to push big dams and other water mega-projects as essential for developing countries to reduce poverty. The World Bank and various dam-industry associations also stress that more dams and levees will be essential to assist societies to adapt to climate change. This message is repeated at numerous (often World Bank-sponsored) international conferences, and in World Bank research and policy papers.

The Wrong Model for a Changing Climate

That climate change will worsen flooding there is little doubt. The UN estimates that climate change, coupled with population growth, deforestation and other forms of land degradation, will mean that two billion people will live in the path of a potential damaging flood by 2050, twice the current number.[23] Rising sea levels (coupled with sinking deltas and eroding coasts) will obviously exacerbate coastal floods and the damage from hurricane- and typhoon-driven storm surges. The already observed increase in the intensity and frequency of severe wind- and rain-storms is expected to accelerate. Melting glaciers and more precipitation falling in mountains as rain rather than snow will likely worsen floods in the huge areas through which snow and ice-fed rivers flow.[24]

The age-old debate between management and control is thus now as important as it has ever been. While the flood controllers see climate change as supporting their agenda, a much better case can be made that the risk management approach is essential if we are to lessen the sting of the super-floods that will inevitably happen. Most importantly, flood control has failed under historical and present climates. This is reason enough not to accept it as a solution to adapting to future climates.

Engineers design dams and their spillways to cope with the extreme floods that they predict using past records of streamflow and precipitation. But the assumption that we live in a stable climate no longer holds.

Structural flood control can only cope with floods up to a certain magnitude. When the design flood (the maximum flood they are built to withstand) of a levee or dam is exceeded it will almost certainly fail. Unlike flood control, flood-risk management is flexible, in that it seeks to reduce damage to any size of flood; and adaptive, in that it seeks to respond to the hydrological changes caused by changing land use and river morphology.

"It is necessary," says Colin Green of The Flood Hazard Research Centre at England's Middlesex University, "to plan how to respond before, during and after all floods rather than simply construct an engineering solution that protects up to some design standard flood." Flood management must allow for what to do when one or more elements of the adopted strategy fails. "We should seek 'forgiving systems' those that fail gracefully," says Green.

"Soft" flood risk management measures – including reversing some of the damage done to rivers and watershed ecosystems by "hard" flood control – will form an important part of adaptation. These are usually "no regrets" measures in that they would produce sizeable benefits in terms of reducing flood damage and restoring ecosystems even without any further climate change.

Effective adaptation will require increasing the resilience of households, villages, cities, countries and regions to cope with climate shocks. Just as poor people and poor countries now suffer the most by far in natural disasters, so it is the poor who are most vulnerable to climate change (while, cruelly, being the least responsible for causing it). Actions that reduce poverty are thus a key part of adaptation, including adaptation to worsening floods.

FATAL ATTRACTION: LEVEE LOVE & RESERVOIR ROMANCE

"Nature … is always right and the errors are always those of man."

Johann Wolfgang von Goethe

Geographer Graham Tobin of the University of Minnesota describes the history of flood control in the US as an "undying affair with levees."[25] More than 40,000 km of levees separate rivers in the US from their floodplains. It is easy to see why levees have been so attractive. They are in most cases relatively cheap and easy to build. It seems logical that a high barrier along a river will keep its floodwaters in place, and indeed for the majority of time a levee may do a perfectly good job of keeping the areas behind it dry. Levees are therefore often politically popular. But in the long-term a flood protection system that relies on extensive use of levees will, for a number of reasons, almost certainly fail to prevent destructive floods.

First, levees break. For example, around one-third of all flood disasters in the US are caused by levee failures.[26] As a US National Academy of Sciences panel concluded in 1982,

Levees can fail for many reasons. Above: An unexpected levee break in California's central valley in 2004 caused $90 million in damages; exact cause is unknown but poor maintenance may have been an issue. (Photo: Calif. Dept. of Water) Below: A massive slope failure in Louisiana in 1983.

"it is short-sighted and foolish to regard even the most reliable levee system as fail-safe."[27] Levees fail because of poor design, substandard construction, poor maintenance, or the reduction of their channel capacity because of sedimentation of the riverbed. Sometimes they are deliberately breached to lessen pressure on levees on the opposite bank or downstream, or, as is often the case in Bihar, to reduce the damage endured by people living within the embankments.

Levees also fail because their "design flood" is exceeded. This is an inherent limitation with "hard" flood control infrastructure: planners must make what is ultimately an arbitrary decision for the maximum flood they will protect against. Any flood larger than this, which may be rare but is eventually likely to happen, will likely overwhelm the levee. Theoretically, levees could be built to withstand the "Probable Maximum Flood," the most severe flood that hydrologists consider possible in a particular location (sometimes correlated with a 10,000-year flood). But economic and technical realities mean that levees are built for design floods that are not extremely unlikely.

In the US, levees are often built to a 100-year flood specification. This is a flood that has a 1-in-100 chance of occurring in any given year. So if a town has just been hit by a 100-year flood it does not mean that it will be 99 years before such a misfortunate overtakes it again. It means that the next year, and for every subsequent year, there is a 1-in-a-100 chance that a flood of at least this magnitude will strike.[28]

In most parts of the world, streamflow records are not long enough to accurately estimate the 100-year flood. Even if they were, urbanization and other land use changes in watersheds (including the channelization of rivers, deforestation, subsidence and other factors) are likely to mean that what is considered the 100-year flood may in fact have a much higher annual probability. Furthermore, all these statistical calculations are based on the now obsolete assumption of a static climate.

The consequences of a levee failure can be severe, usually causing much worse flooding than if no levee had been built. Levee-break floods are unpredictable, sudden and powerful. Such floods leave little or no time for evacuation, and can cause major damage to infrastructure and wash away even large buildings.[29] Levee-break (or the rarer dam-break) floods can erode large volumes of floodplain soils while harming other areas through depositing their loads of heavy sediments. ("Natural" floods tend to carry finer, nutrient-rich sediments that benefit the flooded land.)

As long as levees do their job and hold a river "in place," they prevent river-borne sediments being spread out across floodplains. Instead, some of the sediments settle out on the bed of the river, gradually increasing its height. This then requires the levees to be raised. On the outside of the levee the land is deprived of sediments and often, especially on the peaty soils common in deltas, suffers from subsidence.

Over time the riverbed rises and the floodplain sinks so that the riverbed of a sediment-rich river can become "suspended" or higher than the surrounding countryside. China's Yellow River is the best-known example of a suspended river. It is in places as high as 20 meters above the surrounding land – the height of a six-storey building. The Indian state of West Bengal gave its candid assessment to the central government's National Flood Commission that "where river water carries a heavy silt charge [a] vicious race starts . . . between the rise of the river bed and raising of the embankments in which the latter has not even a remote chance to win."[31]

When a levee on a suspended river is breached, the resulting flood may be catastrophic. This is not just because it may be exceptionally fast and powerful, but also because the water will be unable to drain back into the river and so may pool for many weeks or months after the initial flood.

While a well-built and maintained levee can protect the areas behind it from floods smaller than its design flood, it may do so only at the cost of magnifying flood damage in unprotected areas. As a rising river flows into an embanked section its flow is immediately constricted, causing localized flooding upstream. As high water flows between the levees, it becomes deeper and faster and gains more erosive power. The water then exits the leveed stretch of river with more destructive potential than had the levees not been built.[32] Analyses show that upstream levees raised peak flows past St. Louis at the heart of the Mississippi basin by nearly a meter during the giant floods of 1993. Had it not been for the extensive breaching and overtopping of levees allowing water to inundate the floodplain upstream, the river would have been another half a meter higher.[33]

The densely populated plains of Bihar are crossed by numerous broad, meandering, braiding, constantly shifting rivers that flow down from the Himalayas to the Ganges. Their high sediment loads and dynamic nature mean they are particularly

NOTABLE DAM-INDUCED FLOODS

Italy, October 1963: The Vaiont Dam, one of the world's tallest, set off earthquakes as soon as its reservoir began to fill. One tremor set off landslides that plunged into the reservoir, creating a huge wave that overtopped the dam by 110 meters. About two minutes later, the town of Longarone was leveled and almost all its 2,000 inhabitants killed.

China, August 1975: As many as 230,000 people died in a domino-effect collapse of dams on the Huai River - some 85,000 in the flood waves and the rest from resulting epidemics and famine. The disaster began with the failure of the Banqiao Dam in a typhoon, which resulted in the collapse of as many as 62 smaller dams downstream.

Pakistan, September 1992: Operators of the Mangla Dam opened its spillway gates without warning. A wall of water, described by eyewitnesses as seven meters high, rushed into villages and army garrisons below the dam, killing over 500 people and washing away entire settlements. Fourteen years later a government commission stated that officials could have averted the tragedy if they had released water more slowly, and called on the government to provide compensation to families of the victims. The government refused.

Canada, July 1996: Flooding in the Saguenay Valley in Quebec killed seven people and forced the evacuation of nearly 16,000. The Can$1.5 billion worth of damages made it the most costly flood in Canadian history. A government commission found that the floods were worsened by the improper operation and failure of dams and embankments. Five of seven small dams on the Chicoutimi and aux Sables rivers were breached.

Nigeria, September/October 1999: Operators of the Kainji, Jebba and Shiroro dams opened their gates causing severe flooding along the Niger and Kaduna rivers. Reports cite as many as 1,000 dead and 300,000 people affected.

Nigeria, August/September 2001: Large areas in northern Nigeria were devastated after the sudden release of water from the Tiga and Challawa dams, leaving 200 killed and 82,000 affected.

Uzbekistan/Kyryzstan, February 2002: Sudden releases from the Toktogul Dam on the Syr Darya (Jaxartes) River in Kyrgyzstan reportedly caused $700 million in damages to downstream Uzbekistan.

A dam in Quebec's Saguenay Valley fails, 1996

Mexico, August 2002: Two dam breaks on the same day, one in the state of San Luís Potosí and the other in neighboring Zacatecas, displaced more than 3,000 and left 21 dead.

Cameroon/Nigeria, September 2003: High releases from Lagdo Dam in Cameroon caused severe flooding along the Benue River in Nigeria, killing 28 and washing away more than 200 houses.

China, May 2004: Eighteen were killed when heavy rains broke the temporary cofferdam at the construction site of the Dalongtan Dam on the Qingjiang River in Hubei Province.

Brazil, June 2004: The two-year-old Camará Dam in the state of Paraíba ruptured and flooded the towns of Alagoa Grande and Mulungu. Five killed and 800 families made homeless.

Pakistan, February 2005: Five dams burst after torrential rains. The biggest – the 35-meter Shadikor Dam – killed at least 80, injured many more and left 4,000 families homeless. The Shadikor Dam was only two years old.

India, April 2005: At least 62 people were killed in a dam-created flash flood on the Narmada River in Madhya Pradesh state. The river banks were crowded with Hindu pilgrims. The tragedy occurred after the gates of the Indira Sagar Dam, about 100 kilometers upstream, were opened without warning.

Afghanistan, March 2005: Heavy rains burst the Band-e Sultan Dam, killing six and flooding thousands of hectares of land.

India, March 2006: At least 39 people walking across the Sind River in Madhya Pradesh during a religious ceremony were washed away by sudden releases from the Manikheda Dam.

unsuited to straight-jacketing by embankments, yet are lined by one of the world's most extensive levee networks. The levees are regularly breached, causing suffering to hundreds of thousands, sometimes millions of people.[34]

The levee breaches actually reduce the suffering of the two million people who have been left living *inside* the levees, and are at the mercy of the highly destructive intra-levee floods.[35] Since large-scale levee building began in the 1950s, promises to resettle and compensate these "embankment victims" have repeatedly been broken.[36] Not surprisingly, many of the breaks in the embankments are believed to be deliberately caused by those trapped within them – thus creating more flood victims outside them (and causing violent disputes between the two groups).[37]

Because communities living downstream of a newly built set of levees will start to experience worse floods, they will frequently demand protection themselves. Thus a vicious cycle of levees requiring more levees is set in motion. A similar pattern happens on tributaries. The rise of the bed of the mainstream causes flooding around the mouth of the tributaries, and creates political pressure for these stretches of river to be embanked. And so, at great cost, the levees spread like a cancer throughout the basin, offering a sense of false security to those living behind them, and increasing the flood damage suffered by those living in "unprotected" areas.

Another consequence of proliferating levees is a huge increase in the costs of monitoring and maintaining them. Where levees cause the riverbed to rise or the floodplain to subside, they must be constantly raised. As they grow (and as they age) their maintenance costs soar. Except for soon after major floods, allocating adequate funds for levee up-keep is often not a political priority, and so the levees steadily deteriorate.

Along with the spread of levees often come efforts to "improve" the shape of the river so as to make it hold more water, run faster, and shorten its route to the sea. The Mississippi has lost more than 300 kilometers of its original length due to the cutting-off of its meander bends, the Rhine 80 kilometers.[38] The straightening and embanking of the Rhine has narrowed its width in places from a 12-kilometer bed of wildlife-rich interweaving braided watercourses, islands, backwaters and meanders, to a 250 meter-wide channel.[39]

Such "improvements" have not only devastated riverine habitats but also magnified the destructiveness of floods downstream. A straighter, shorter, narrower river with less vegetation along its banks is a steeper, faster-flowing river, often with less capacity to hold high flows. The time it takes for floods on the Upper Rhine to speed from Basel on the Swiss border to Karlsruhe, Germany, has been cut in half. This acceleration increases the destructive potential of floods and reduces the time for evacuations. It has also worsened flooding by synchronizing the cresting of the mainstream of the Rhine with peak flows from major tributaries.[40]

In urban areas, rivers are often dredged to increase their capacity, and may be cleared of vegetation and lined with concrete or rocks to stabilize their banks, and to increase the speed of flood flows. These alterations can prove self-defeating (as well as destroying the ecological and aesthetic value of the river). Normal flows will slow down in the expanded channel and deposit more of their sediment load, eventually returning the channel to its original capacity and flow regime. The *reductio ad absurdum* of "river improvement" is the Los Angeles River, which is now encased in a barren cement floodway for all but 10 kilometers of its 80 kilometer length.[41]

Dams: The Ultimate Blunt Instrument

Jeffrey Mount, a geologist at the University of California at Davis and one of the foremost authorities on rivers and floods in the US, describes dams as "the ultimate blunt instrument" for controlling floods.[42] Dams share many of the features of embankments when it comes to reducing flood damage. They have prevented countless potential floods around the world (while also stopping the ecological benefits of "normal" floods). At the same time they have created floods and magnified the severity of floods that would have happened anyway. By promising protection from floods, they have encouraged development downstream, and so increased the potential for harm when a flood does happen.

As with embankments, the data are not available for an overall global accounting of whether the net impact of dams has been to reduce or increase flood damage. But it is clear that dams can cause extensive flood damage and that the hundreds of billions of dollars spent on dams have failed to prevent the ongoing rise in flood damages. (It is also clear that dams have permanently flooded huge areas – estimates of global reservoir area range upward of 260,000 square kilometers, slightly larger than the size of the United Kingdom).[43]

Even for an individual dam it can be very difficult to be certain about its net impact on flood damages. Reasons include the effect of inducing development downstream, changes in erosion and sedimentation patterns, the difficulty of separating out the impact of a dam (or dams) from the impact of other watershed changes such as deforestation, urban sprawl and drainage-blocking roads and railways, and, importantly, the difficulty in getting dam operators to release reliable in-flow and discharge data.

There a number of reasons why dams create and exacerbate floods:

Operational issues: A dam can reduce flood peaks downstream if its reservoir has the capacity to absorb a significant proportion of the floodwaters flowing into it. This water can then be released gradually over weeks or months. The huge reservoirs on the Upper Missouri are calculated to have reduced the peak of the 1993 Great Mississippi Flood at St. Louis by around 1.5 meters, saving many levees and floodwalls from overtopping and significantly reducing flood losses.[44]

Extreme river-engineering: The Los Angeles River has been reduced to a concrete channel.

For a dam to effectively function in this way, however, requires its operators to keep the reservoir low until the major flood occurs, and to be confident that the in-flows will not exceed the dam's capacity to discharge them safely. Many thousands of lives have been lost because dam operators have guessed wrongly as to in-flow rates and have had to abruptly open their gates – or face their dam overtopping, which could lead to a catastrophic dam collapse.

One reason for operational failures is that dam operators may not have access to accurate real-time streamflow and rainfall data, or to reliable storm forecasts. Another is that dam operators receive no income for avoided floods, unlike revenues that can be earned for storing and releasing water for irrigation and, in particular, power generation. The pattern of reservoir releases may also be set by whichever particular group of beneficiaries has the most political clout. As an internal World Bank report concluded: "Dam and reservoir operation is not dictated by optimization rules but by the struggles of interest groups."[45] So the reservoirs of multipurpose dams are often filled early during the wet season to guarantee that they will have sufficient water for dry season hydropower and irrigation. In these cases when a large flood arrives at the end of the wet season, there is little or no flood-cushioning capacity available.

Dam breaks: Colin Green of the Flood Hazard Research Centre explains: "Dams and dikes have the common disadvantage of discontinuity: the transition time from 'safe' to 'failure' can be very short, and the time available to carry out warning and evacuation correspondingly limited."[46] Author Jacques Leslie puts the issue more graphically: "Dams are loaded weapons aimed down rivers."[47] Dam-break floods are particularly disastrous because of their speed, size and (usually) unexpectedness.

Large dams have in general a good safety record, especially those built according to modern engineering standards. However while the risk of any given large dam breaking is very low, the consequences of such a break when it does happen can be catastrophic, killing thousands, even hundreds of thousands (in the case of a 1975 multiple-dam break in China). On the other hand, the safety record is poor for older dams and smaller ones not built under proper engineering supervision which often receive no or inadequate monitoring and maintenance.

In 2005, just two powerful storms in the northeastern US overtopped or breached more than 400 small dams.[48] The American Society of Civil Engineers classifies more than 3,500 US dams, most of them small, as capable of causing death in the event of failure and requiring repairs. The total investment to bring US dams into safety compliance or remove those that are no longer needed tops $30 billion, according to the Association of State Dam Safety Officials.[49]

Chinese officials declared in 1998 that thousands of the country's dams were "time bombs." More than one-third of the country's 85,000 dams are estimated to be old, poorly built and in need of urgent repairs.[50]

Geomorphology and diminishing capacity: It is not just carelessly built, poorly operated and badly maintained dams that can increase flood damage. Because of its disruption of sediment erosion and deposition patterns, even a "properly working" dam can increase floods all the way from the upper end of its reservoir to coasts near the river mouth, perhaps many hundreds of kilometers downstream. All reservoirs trap riverborne sediments, often capturing nearly all of the sediments that are flushed into them. In doing so they raise the bed of the river as it enters the reservoir, creating a "backwater effect" which increases waterlogging and flooding upstream. India's Sardar Sarovar Reservoir is expected to cause the Narmada River to rise more than 3.5 meters behind the reservoir zone, putting at least an additional 20 villages at risk of being inundated by what was calculated as the 100-year flood.[51]

Over time, the accretion of sediments depletes the storage capacity of a reservoir and thus its long-term ability to hold back floods. This is particularly dangerous because – at least for those dams that do not regularly cause "operational floods" – downstream areas will develop during the early years of a reservoir's life-span in the expectation that all floods will be controlled. The operation of many of the dams built in the 20th century will be seriously compromised by sedimentation in the 21st. Some types of reservoirs can be operated to flush out sediments during flood periods. But if the purpose of a reservoir is to trap floods then it will unavoidably also trap the flood's sediments (the great majority of annual sediment loads are carried during major floods).

Downstream, the impact of a dam on the dynamics of sediment transport can increase floods through several mechanisms. One is the coastal erosion caused by sediment starvation as described above for Louisiana. Delta areas are particularly badly impacted by the loss of sediments. The deltas of the Yellow, Indus, Nile, Yangtze, Ebro (Spain) and Sacramento-San Joaquin (California) are among those suffering major erosion and land subsidence, and thus higher risks of both river floods and storm surges, due to dam construction and water diversions upstream.[52]

While loss of sediment increases flood risk near the mouth of a river, elsewhere a dam may cause flooding by causing too much sediment to build up. Because it has left its sediment load behind in the reservoir, water flowing out from a dam is usually clear, with a high erosive potential. This water will pick up sediment from the bed and banks of the river immediately below the dam and deposit them downstream. But where moderate flood flows have been eliminated from the river, it will not have the force to carry these sediments away. The sediments can then raise the riverbed, reducing its capacity to carry large flood flows when these do occur.

The Elephant Butte Dam in New Mexico was built to hold and divert almost the entire average annual flow of the Rio Grande. Since its completion in 1916 (appropriately at a town named Truth or Consequences), 250 kilometers of the Rio Grande downstream has gradually lost its original channel which has become choked with sediment, most of it washed down from tributaries and some stripped from the riverbed immediately below the dam. "The river's all choked up," says one local farmer, "ain't good for nothing."[53]

One consequence of the choked-up river is that relatively small flows caused major damage to the border town of El Paso in 1942 and 1987.[54] The reduced capacity of the Rio Grande also helped worsen the floods caused by extremely heavy rains in El Paso in August 2006, which caused $100 million in damage.[55] In February 2007 the Federal Emergency Management Agency announced that because of the sediment build-up and the poor state of the city's levees, much of El Paso would be re-designated as lying within the 100-year floodplain.[56]

Restoration of 180 acres of wetlands along a major tributary to the Neuse River in North Carolina is helping restore this watershed's ability to perform natural functions like flood control and water purification. The North Carolina company Restoration Systems backfilled over three miles of drainage canals, removed earthen levees, and planted 50,000 trees. Animals have returned in droves. Photo: Restoration Systems

LIVING WITH THE FLOOD

Flooding should not automatically be assumed to be a problem to be solved. "Normal" floods are essential to the maintenance of riverine and floodplain ecosystems. Many species depend on seasonal pulses of nutrients or water to give the signals to start reproduction, hatching, migration or other important lifecycle stages. Annual floods replenish wetlands not only with water but also with nutrients. Annual floods on tropical rivers are estimated to produce fish yields a hundred times higher than in rivers without floodplains.[57] These ecological benefits translate directly into benefits for humans: productive fisheries, nutrient-enriched croplands, floodplain forests and wetlands with plentiful game.

The Bengali language arose in the huge floodplain where three of the world's largest rivers – the Meghna, Brahmaputra and Ganges – meet and fan out to the sea. Bengali distinguishes between abnormally severe floods, termed *bonna*, and the more frequent rainy season floods, or *barsha*, which Bangladeshi villagers do not consider a threat "but rather a necessity for survival."[58]

Flood-risk management allows, where possible, the good *barsha* floods to occur. In its concern for maintaining the ecological values of rivers, flood management also assists in another important aspect of climate adaptation, which is to try to allow natural ecosystems to adapt.[59] Enabling ecosystems to adapt to global warming requires preserving or restoring as best as possible a diversity of habitats which animals and plants will be able to move to when their old habitat can no longer support them.

The soft path of flood management includes a diverse range of practices and technologies, some of which are described below. Flood management can be technically complex, but it is often the institutional and governance questions which are the most difficult to solve, especially where these involve reshaping existing relationships between political and economic interests.

Be Prepared: Preparing for floods means improving flood forecasting and preparing strategies for flood warnings, evacuation, transport during floods, and post-flood recovery. These strategies require increasing the capacity of individuals, households and communities to cope with flooding. Coping capacity can be increased through public information campaigns and training exercises. Involving communities in decisions on flood risk mitigation planning can improve the effectiveness and public acceptability of the decisions, and improve the coping capacity of the communities.[60]

Slowing the Flood: High-volume, fast-moving floods are the ones that flood managers fear most. They give little time to issue warnings and organize evacuations, and have the most destructive force. Flood hazard management seeks to slow down and reduce the size of floods. It also seeks to divert as much water as possible away from developed areas, and to improve drainage in flood-prone areas, partly as a flood-prevention measure, and partly to reduce the amount of time that buildings and crops are inundated when floods do occur.

While flood control has often focused on trying to stop any land flooding (other than that under reservoirs), floodplain management seeks to allow the flooding of vulnerable land of low economic (but often high natural) value. This can reduce flood peaks – and flood damage – in more developed areas. Moving levees back from rivers, restoring meanders, letting floodplain wetlands play their natural role of providing flood storage, and creating flood detention basins alongside rivers all help to mitigate downstream flood speed and scale. Unlike reservoirs, flood detention basins can be used for farming (or in urban areas, for sports fields or parks) outside of major floods.[61]

Flood by-pass channels have long been used as a way of diverting floods around urban areas (one was built around Tokyo in 1621).[62] The 47-kilometer Red River Floodway around Winnipeg in Canada has been used more than 20 times in the 40 years since it was completed. The $63 million spent on building the floodway – reportedly the world's largest earth-moving project at the time of its construction – is estimated to have saved more than $8 billion in flood damage.[63]

De-Paving Cities: Urban development adds to flood risk by covering huge areas with impermeable streets, parking lots and roofs. Rain quickly runs off these surfaces and into sewers and storm drains. While on undeveloped land typically only a fifth or less of rainfall runs directly into streams and rivers, city drains can speed over four-fifths of rainfall into local water-courses. If the drains are blocked or inadequate, serious local flooding can result; if the drains work efficiently they can cause flash floods below where the water is discharged. The inadequate capacity of Mumbai's century-old drains, and their blockage by garbage, particularly plastic bags, contributed to the terrible destructiveness of the July 2005 floods which killed 1,100 people in India's commercial capital.[64]

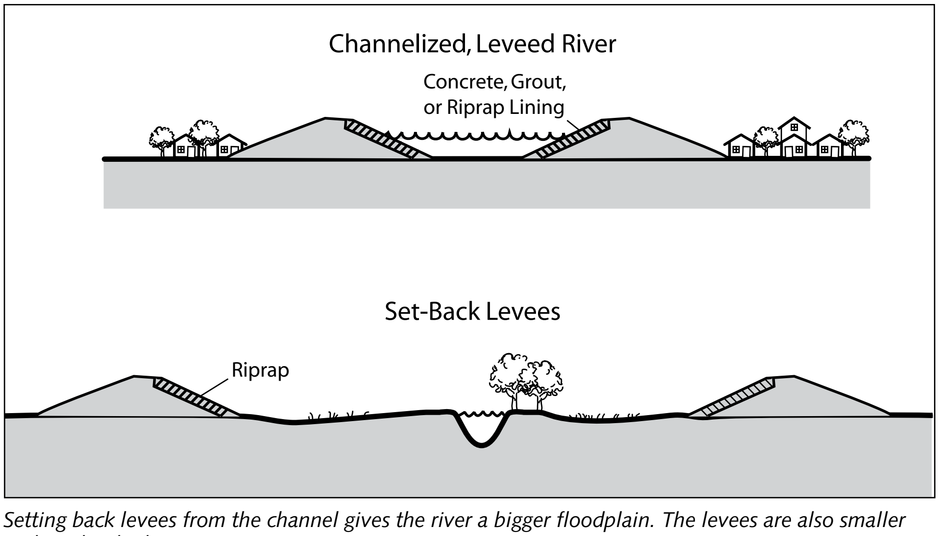
Numerous techniques are available to limit the volume and speed of urban run-off, including new permeable materials which can be used on roads, car parks and playgrounds; strips of shrubs and trees alongside streets and sidewalks; and grassed depressions ("swales") which catch run-off and allow it to infiltrate into the ground. Many US cities have programs that encourage owners of buildings to convert their downspouts so that they discharge water over lawns or other non-paved areas rather than down sewers, or collect the runoff in rainbarrels. Downspout diversions have reduced sewer flows by up to 62% during rainstorms.[65] These techniques not only reduce flood risks but also replenish groundwater and reduce pollution into rivers and bays from urban run-off. Seattle's new City Hall diverts rainfall on its roof into a 1,000 cubic-meter cistern in its basement. The water is used for toilet flushing and on-site irrigation. The system reduces stormwater runoff from the building by up to 75% (and reduces indoor potable water use by 30%).[66]

Out of harm's way: One important way to reduce damage is to dissuade people from living on the most vulnerable parts of floodplains (although this may have little relevance in densely populated floodplain areas such as Bihar or Bangladesh). Floodplain management includes planning regulations to discourage new floodplain development and financial incentives for people living in the riskiest areas to move to higher ground.

In the wake of the Great Mississippi Flood of 1993, a federal government task force recommended that the optimum strategy for limiting flood damage was to restrain development on floodplains. Since 1993 the government has bought out some 7,700 riverside properties in the two worst affected states, Illinois and Missouri.[67] Unfortunately, this common-sense response to the 1993 flood has not been sustained, and the flood controllers and floodplain developers appear to have once again got the upper hand along at least parts of the Mississippi. By 2005 more than 28,000 new homes had been built on land flooded in 1993, most of them supposedly protected by new and enlarged levees.[68]

Under a law passed in 1995, local communities in France are supposed to draw up "Plans for the Prevention of Flood Risk" to restrain development on floodplains. Unfortunately progress has been slow and by 2004 only a third of the 10,000 *communes* at risk had prepared their plans.[69] Planning codes in general are widely flouted in many countries, and zoning decisions often subject to corruption. Trying to impose floodplain management is particularly difficult in developing countries where large numbers of people live in informal settlements – often in extremely flood-prone areas. Colin Green from Middlesex University is sadly correct when he says that "land use control is most likely to be effective when it is least needed: it will fail where the development pressures are great."[70] Still, planning controls are a vital part of the flood manager's toolkit.

Of course a huge amount of infrastructure is going to remain on floodplains in harm's way. Embankments that protect urban areas will have to be maintained and strengthened. Isolated buildings can be flood-proofed through structural measures such as raising houses on stilts (as along the Russian River in California and in many traditional architectural styles in flood- and tsunami-prone regions) or on small mounds



Setting back levees from the channel gives the river a bigger floodplain. The levees are also smaller and tend to be less expensive.

(as in Manitoba, Canada). Buildings can also be surrounded by small ring-dykes.[71]

In Bihar, *pakka* houses built of brick and cement survive floods much better than the majority of houses that are built of mud and other local materials. The importance of a *pakka* house is not just that the house itself can withstand swirling flood waters, but that if it has a sturdy, flat roof, this can serve as a place of refuge and storage during a flood. Another flood-proofing measure used in Bihar is to build houses, and sometimes whole villages, on mounds. Raising the height of hand pumps is also vital to ensure access to drinking water during floods.[72] Earth mounds used to be built in the Dutch province of Zeeland as refuges in the event of embankment failures.[73]

A Better Way

Despite setbacks and the lobbying efforts of construction and engineering interests, there is a trend in many places toward flood management superseding flood control. One optimistic case from the last decade of the 20th century is Bangladesh's Flood Action Plan. In its original form, this World Bank-coordinated project was a classic "hard" flood control scheme involving several thousand kilometers of embankments. But public criticism of its high cost, displacement of millions of people, damage to vital fisheries and disregard for the beneficial impacts of monsoon floods on rural livelihoods forced a thorough rethink of the plan. The plan ended up not recommending any large-scale construction projects, and morphed into a process that emphasized flood management based on public participation and recognition of the environmental benefits of "normal" flooding.[74]

Another remarkable change in attitudes around flood protection occurred in the Netherlands during the 1990s. The Dutch owe their country's existence to many centuries of efforts to drain their land, dike back the sea, and embank their rivers. Yet after the country suffered a near-disaster in 1995 when a quarter of a million people had to be evacuated as the Meuse and the distributaries of the Rhine almost burst their banks, the country's water managers realized that the old attitude of trying to engineer floods out of existence could no longer be trusted to work. A national policy was released two years later called "Room for the River," under which raising dikes is no longer the starting point for dealing with floods, but used only as a last resort. According to W. van Leussen of the Department of Public Works and Water Management: "The preferred solution is now the restoration of natural processes, and especially opportunities to create more space for the river. This means that the floodplains should only be used for necessary river-related activities, while measures should be taken to give the river more room to expand."[75]

Hurricane Katrina has, not surprisingly, sparked much debate over how to best protect New Orleans. One positive outcome of this debate may be significant investments in efforts to reverse the loss of coastal wetlands. The Corps of Engineers is committed to completing its Category 3 protection system for the city. Meanwhile many New Orleanians are, for good reason, dismissive of only receiving Category 3 protection and are pushing for protection from a Category 5 storm, which estimates say would cost around $32 billion and take decades to build.[76] Yet the key economic reason for the existence of New Orleans, its major deep-water port, may not survive for many decades. The port depends on the Mississippi to keep it supplied with water and reasonably free of sediment. But at a time of the river's choosing, the Mississippi will for geomorphological reasons shift course upstream of New Orleans and take a shorter, steeper route to the sea, most likely down the Atchafalaya River.

Richard E. Sparks, director of research at the National Great Rivers Research and Education Center in Illinois, argues that working with the forces of nature rather than against them implies building over a period of decades a new port and city of New Orleans on higher ground near the mouth of the Atchafalaya. The natural process of sediment deposition around the "lobe" where the Atchafalaya meets the Gulf would be encouraged, offering protection against subsidence and storm-surges. The higher parts of "Old" New Orleans would remain as a cultural treasure and a tourist and convention city, but the lowest-lying sections would be converted to natural areas and parks.[77]

Such a grand vision has precious little chance of being implemented in a deliberate fashion. Yet without a radically new approach, the inconvenient truths of geology, hydrology, climate change, and the inherent limitations of hard flood control (and of institutions and political structures) mean that the chances of New Orleans suffering another Katrina-like disaster in the coming decades are uncomfortably high.

New Orleans is far from the only place where a radical rethinking of how we cope with floods is essential. Thankfully, we already know many of the technologies and approaches that can help us live better with floods, even the super-floods that are now our fate in our warming world. The main challenge now is to generate the political will to entrench and expand good flood management and relegate hard flood control to the minor role it deserves. ■

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A Dam-Made Disaster

How Large Dams and Embankments Have Worsened India's Floods

by Himanshu Thakkar
Coordinator, South Asia Network on Dams, Rivers & People

India has seen its flood damages increase at the same time that the total area supposedly protected by flood-control engineering projects has grown. In too many cases, structural measures have worsened flooding. Yet the state and national governments in India are pushing for more, not less of the same structural solutions. Civil society is pushing back, with ideas for more sensible flood-management measures.

India's monsoons are legendary. Very heavy rains can come in concentrated periods, making the runoff particularly hard to manage with traditional engineered solutions. This has not prevented the Indian government from trying to use big dams, embankments, floodwalls and the like to control floodwaters. When these efforts fail, they can fail catastrophically. This is a story of one of those failures.

Near the end of July 2006, the annual 3-4 month long monsoon had been pummeling the South Gujarat region for about a month. The first seasonal increase in the water level at the huge Ukai Dam was noticed on July 2. The dam, located about 80 km upstream from the city of Surat, was designed with adequate storage capacity (7.092 billion cubic meters when it was completed in 1972) and a comfortable flood cushion (1.332 billion cubic meters, or almost 20% of the reservoir, was intended to remain unfilled until the end of monsoon). Residents of Surat – a thriving city known for diamonds, silk textiles and interesting cuisine – should have had little to fear.

But just a week into August, the most disastrous flood in the city's history hit like a runaway train. By the evening of August 8, the dam was releasing over twice the amount of water that the river downstream could carry. That carrying capacity is further reduced on high tide days, as was the case on that fateful August day. High releases continued for over four days. By the time the floods subsided, at least 120 people were dead, hundreds of others missing, over 4,000 cattle dead and more missing, and economic losses estimated by the Gujarat Chambers of Commerce at US$49 billion.

The New York Times reported: "With water brimming well past the permitted levels at the 350-foot Ukai Dam, according to official records, and the skies showing no sign of relief, the engineers apparently threw open the reservoir's 21 sluice gates. Water then did what water does. It surged downriver, swallowing this city of three million people like a hungry beast. The diamond lanes of India became a warren of muck and ruin."

As revealed by analysis undertaken by my organization, South Asia Network on Dams, Rivers & People,the Ukai flood disaster was entirely avoidable, and entirely due to the mismanagement of Ukai Dam by its operators.[1]

> **"With water brimming well past the permitted levels at the Ukai Dam, and the skies showing no sign of relief, the engineers apparently threw open the reservoir's sluice gates. Water then did what water does. It surged downriver, swallowing this city of three million people like a hungry beast."**
>
> The New York Times

What went wrong?

The dam's mismanagement was as wide as it was deep. First, its operators allowed the reservoir to fill past the allotted "flood storage" point, then waited too long to begin releasing water. Second, critical information on the carrying capacity of the Tapi River did not seem to be part of the equation of the dam's water releases. And third, siltation in the reservoir had reduced the dam's storage capacity. Add to this dangerous mix the fact that 21% of the live storage capacity of the reservoir was full even before the monsoon started.[2]

When we compared the Ukai reservoir levels just before the monsoon to previous years, we found that they were at their highest levels in four years. In the days before the flood, dam managers knew that especially high rains had hit the basin in recent days. They could have restored an adequate flood cushion by beginning much higher water releases on August 1. Yet releases even just two days before the flood were shockingly low. On top of all this, the authorities knew the flood cushion had shrunk from siltation, and had recommended a review of its operation. This likely would have resulted in an even greater flood cushion requirement. This was not done.

The Ukai Dam story was repeated in many river basins across India in 2006, including the Mahi, Sabarmati, Chambal, Narmada, Krishna, Godavari and Mahanadi basins. Everywhere, sudden high releases of water from dams (many of them having high pre-monsoon storages) were the prime reason for most of the flood damages in these basins. And in most cases, the floods occurred less than half way through the monsoon.

The floods of 2006 were in no way unique. There have been many other instances where dams have led to flood disasters,

The dam failure that flooded Surat killed 120 people, thousands of animals, and resulted in billions of dollars in damage.

including the Bhakra, Hirakud, Tawa-Bargi, and Damodar dams, to name a few. Over the years, India has seen its flood damages increase, at the same time that the total area supposedly protected by flood-control engineering projects has grown. It is noteworthy that most of these high flood events occurred after the flood control projects were in place.

A number of factors are contributing to this alarming trend. Some of the main issues are discussed below.

Lack of Operating Rules

It is often claimed by the government that India's more than 4,000 large dams reduce flooding, yet far too often the results have been increased flood damages, usually because of mismanagement. The operation of dams for flood protection is not carefully regulated. A report by the Government of India's National Commission on Floods (NCF) noted in 1980: "Most of the reservoirs completed in the country do not have any specific operation schedules for moderation of floods." In the Ganga basin, the Kangsabati Dam is supposed to reserve more than a quarter of its reservoir for flood storage, yet the report says, "The Kangsabati reservoir has no operation rules drawn up so far, nor have the moderation benefits been evaluated." The report also criticizes management of dams on the Damodar River and others.

A similar case can be made about the other major flood protection measure widely adopted by India, namely embankments (also known as levees). Embankments can offer partial protection for limited periods, but when they do break – and they certainly do – the damage is much larger, the floods more sudden, of greater intensity and longer duration. There is the additional problem of people who live within the embankments, which number in the millions in India. These people face the prospects of floods almost every year, and since they have not been provided any proper rehabilitation, they have no option but to stay within the embankments to cultivate their land, mostly in post-monsoon months.

Changing the character of floods

Flood protection measures in one area can increase the problem in another area. The Government of India's National Commission on Floods notes: "Local or narrow functional approaches often conflict with the interests of the basin or the region or the nation as a whole. For example, construction of embankments in certain areas can lead to increase in flood levels upstream and downstream." Embankments are basically flood transfer mechanisms: they quickly transfer the floods from a given area to downstream areas. The floods resulting when embankments are breached are very different than a natural flood. Embankment floods are sudden, have greater destructive power, often bring a huge quantity of sand, and remain for longer periods than would be the case without the embankments. Large-scale breaches in embankments have been common in some of the more flood-prone states.

The NCF reports that there has been no credible assessment of the performance of the embankments on any river. The commission notes, "The annual benefits from embankments were, therefore, by and large, a matter of overall opinion of some individual, with no supporting data. We were, therefore, reluctant to draw any conclusion from the trend of such opinions."

R. Rangachari, the former second-most senior official in India's Water Resources Ministry, has noted: "There are many

"MAD RIVER" FLOOD CONTROL DAM WILL MAKE BAD SITUATION WORSE

The Government of India approved the Pagladiya Multipurpose Project in Assam in 2001, citing flood control as a major benefit. The dam is being built on the Pagladiya River, a tributary of the Brahmaputra. This "multipurpose dam" is meant to establish "flood control" over 40,000 hectares, and irrigate 54,000 hectares. In 2001, the project was expected to cost US$123 million. Today, its estimated cost has more than doubled, to $257 million.

The Pagladiya project came in for sharp criticism last year in the Parliamentary Standing Committee on Agriculture. Praful Bidwai, who served on an Environment Ministry "Expert Committee" on river valley projects in 1996-98, states: "Pagladiya literally means 'mad river' because it changes its course wildly, drastically and suddenly. This is the result largely of seismic factors that cause mountainous masses of earth to shift position, creating landslides, huge silt flows and floods. The effect is compounded by deforestation and other man-made factors. A minority within the committee, including me, opposed the project because no dam could possibly address the root cause of the floods or the river's shifting of its bed by kilometers at a time. A three-km-long dam would be useless, for instance, on a river that changes course by 30 km in 4 years! The project, we argued, is doubly irrational because in the name of 'irrigation', it would create waterlogging in places." Despite the criticism, the dam was approved under pressure from the Government and irrigation lobbies. The dam is now under construction.

The report of the Parliamentary agriculture committee notes the large amount of sand the river carries "gets deposited on the bed, raising its level. As a result, it easily breaches the banks, causing catastrophic damage. In 2004 too, [the] Pagladiya changed its course and converged with another river." According to the Pagladiya Dam Project Affected Area Agitation Committee, a local community group, the project will result in the loss of ancestral homes of 33 villages, in order to benefit 37 villages further south. Several other groups have held demonstrations seeking a halt to the dam as it may create a serious flood problem in tribal-dominated areas. The groups stress that small check dams in the tributaries in Nalbari district would be a better option, and would also help with irrigation.

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problems associated with embankments. Unfortunately there are few scientific evaluations of their actual performance under different types of rivers in representative regions." Similarly, while dams may or may not moderate floods in the downstream areas, they certainly lead to submergence in the immediate upstream areas. The backwaters behind dams affect additional areas in the flood season. Similarly, a flood caused by the opening of a dam's spillway gates is very different in character than a naturally occurring flood. The dam-related flood generally comes fast, without warning and hence is more destructive.

Floodplains mismanagement

The UN University study of trends of floods in Bangladesh notes: "In the discussions about the history and causes of floods, there is more and more evidence that human influences within lowlands significantly contribute to the increasing dimension of flooding and flood damage. The construction of lateral river embankments or the cutting off of feeder channels isolate the large river systems from open water bodies and swamps that were natural storage areas for surplus water but are gradually being converted into agricultural land. According to Khan et al. (1994), in the Ganga-Brahmaputra floodplain alone approximately 2.1 million hectares of wetlands have been lost to flood control, drainage and irrigation development."[3]

The Way Forward

A comprehensive flood-management program should revolve around improving flood-coping mechanisms and flood-preparedness. Some key areas that must be addressed in India include sustaining and improving natural systems' ability to absorb floodwaters; improving dam management, and instituting clearly defined and transparent operating rules that are stringently enforced; improving the maintenance of existing flood infrastructure rather than spending money on new dams and embankments; undertaking a credible and participatory performance appraisal of existing infrastructure, and removing embankments that are found to be ineffective; and producing transparent disaster management plans intended to be implemented in a participatory way. Perhaps most importantly, India needs to assess the potential impacts of climate change on rainfall and on the performance of flood-related infrastructure, and begin planning for the necessary adaptation to the changing climate.

In addition, the two following programs, both of which are already being tried in India, deserve much wider implementation:

People-driven flood forecasting: The River Basin Friends is a people's network of more than 300 organizations located in the Ganga-Brahmaputra-Meghna basin. Official flood forecasting from the central government is often insufficient to predict impacts at the local level, and the information cannot usually reach people in vulnerable locations. So River Basin Friends began its own initiative to commence an early flood warning mechanism which reaches people all the way downstream in Bangladesh. It has more than 1,000 members of different disciplines, living in different parts of the basin, each of whom helps circulate flood forecasting messages from upstream locations to downstream locations, using phones and email. People in the central hub in Assam collect information from different sources, and the peoples' network in upstream locations of the Brahmaputra basin processes and analyzes it. The final flood early warning messages are then formulated for different vulnerable locations and disseminated to these locations.

This has been going on quite effectively for at least the last three years. More in-depth study of this remarkable initiative needs to be done, as it has the potential to provide lessons for many other communities.

Groundwater Recharging to Manage Floods: India's Central Ground Water Board estimates that a quarter of monsoon run-off could be captured and stored in aquifers. Out of the 214 billion cubic meters that could be stored, around three-quarters could be retrieved and used to irrigate 32 million hectares.[4]

Removal of even a fraction of this 214 billion cubic meters from rivers during floods would have a tremendous impact. While there has not yet been any attempt to realize this potential, India's Finance Minister in February 2007 proposed spending US$419 million on a new groundwater recharge scheme. It remains to be seen how the scheme will be formulated and implemented and what will be its impact.

In conclusion, there is plentiful and mounting evidence that structural measures have been largely ineffective in controlling India's floods, and in fact, have worsened flooding in many parts of the country. Yet the state and national governments in India – with support from international agencies like the World Bank, the Asian Development Bank and the Japanese Bank for International Cooperation – is pushing for more, not less of the same structural solutions. The opportunity provided by the report of the World Commission on Dams in reviewing planning and decision-making frameworks for large dams appears to have been completely lost on India's water managers. The people, however, are fighting against flood control in a number of places. One notable example is growing opposition to building embankments in Bihar. The mounting opposition to India's "river-linking" plans is another indication of this trend. SANDRP has called for a national, independent enquiry into the floods during the 2006 monsoon, especially with regards to sudden releases from dams. We are calling for more transparency in dam operations, and a review of operating procedures. We hope that public pressure from these various campaigns, along with the good example of initiatives like people-centered flood forecasting and groundwater recharge projects, will help lead India toward a more sensible approach to floods. ■

A woman in Bihar, India cooks for her family in their flood-camp on an embankment. Each monsoon, people who live on lands within the embankments are flooded out. Photo: Nagendra Prasad Singh

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Himanshu Thakkar has done extensive research on India's large dams. He can be reached at ht.sandrp@gmail.com.

Notes

1 http://www.sandrp.in/floods/dam_floods_0806_pr.pdf
2 Live storage capacity is the useful storage capacity of the reservoir, above the minimum drawdown level for a reservoir.
3 Hofer, T. and B. Messerli (2006) *Floods in Bangladesh: History, Dynamics and Rethinking the Role of the Himalayas,* United States University, Tokyo
4 Union Water Resources Minister in Lok Sabha Dec. 10, 2001

ASSESSING THE IMPACTS OF CLIMATE CHANGE

Unfortunately, there has been no systematic assessment of the impact of climate change on hydrology of the rivers and the performance of water projects in India. SANDRP recently asked (under India's Right to Information Act) two of the Government of India's premier organisations, namely the Central Water Commission and the Central Electricity Authority, if any study of the impact of climate change on water projects has been done. The answer from both was no.

However, some of the proponents of large dams have been trying to push greater storage capacity through large dams in the name of reducing the impacts of climate change. Such blind advocacy cannot benefit anyone. On the contrary, a performance review of water storage projects shows that on average in each of the past 12 years, storage capacity equal to at least 6.5 Sardar Sarovar reservoirs remains unutilized. Similarly, a study of siltation of existing storage capacity shows that India may be losing 1.32 billion cubic meters (BCM) of storage capacity in each year, when gross addition to storage capacity is about 1.98 BCM per year. This indicates that we may be losing two-thirds of created storage capacity due to siltation. Nothing credible is being done to arrest the siltation. Climate change is only likely to increase siltation due to glacier melt and also greater frequency of high rainfall incidents.

Based on available information on climate change, both smaller storage reservoirs and underground storages are likely to perform more efficiently, because they are less vulnerable to damage from floods, and to losses through evaporation and siltation.

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Early Adopters: Advances in Flood Management

The soft path to flood management embraces a sophisticated set of approaches intended to reduce development in the most flood-prone areas, adapt to and work with the forces of nature, and improve emergency response. Below are a few examples of where these approaches are being tried.

The Loire

Leaving the floodplain: Following the 1993 Great Flood on the Mississippi River, federal disaster laws were amended to set aside a percentage of all disaster relief for relocation, land acquisition and other forms of hazard mitigation. Since that time, more than 10,000 homes and businesses throughout the Mississippi watershed have been relocated from the river bottoms. The entire town of Valmeyer, Illinois moved to higher ground. Some towns moved just their most flood-prone sections.

While expensive, moving out of the floodplain becomes cost-effective when another flood strikes. The cost of moving 5,100 homes and businesses in Illinois and Missouri was $66 million, but those structures had previously received $191 million in insurance payments from past floods, according to American Rivers.

***Loire Grandeur Nature* Plan:** The Loire is France's longest river, with a watershed that covers a fifth of the country. It has escaped most of the engineering interventions which have so damaged other major European rivers, and still supports a remarkable diversity of wildlife and beautiful scenery. The main justification for a dam planned on the upper Loire in the 1980s was that it would prevent floods. In response, activist group SOS Loire Vivante worked with hydrologists and engineers to devise an alternative approach for managing floods. This encompassed improving the flood warning system; enforcing regulations to prevent construction in areas most at risk; improved protection for the most threatened buildings; minor works to clear the river bed and banks of obstacles to the free flow of water; and creating a committee of local residents, elected officials, NGOs and businesses to oversee implementation of the plan. In 1994, the government shelved the plan to build the dam, and adopted SOS Loire Vivante's flood management strategy. The flood strategy is part of a major plan called *Loire Grandeur Nature* in which central and local governments are working with environmentalists and landowners to restore, protect and manage ecosystems in the Loire basin. www.rivernet.org/loire/plgn.htm

Giving more room to the Rhine: Since the early 1990s, the five countries through which the Rhine flows have recognized the need to reduce flood risk by restoring floodplain ecosystems. "We've paved over too many meadows and straightened too many rivers," said Josef Leinen, a German environment minister, after the severe flooding on the Rhine in 1994. In 1998, the International Commission for the Protection of the Rhine adopted a 20-year Action Plan on Flood Defense. Key components of the plan include an increase in flood storage through the removal of embankments and restoration of river and floodplain ecosystems, and improved flood mapping, education, warning and evacuation systems. The full implementation of the plan is estimated to cost at least 12 billion. www.iksr.org.

Napa creates a living river: A 10-year, $220-million project to reduce floods on the Napa River in Northern California will remove levees and restore about 200 hectares of grazing lands to tidal marsh; remove some buildings in the lowest parts of the flood zone; replant native trees and shrubs to reduce bank erosion and sedimentation; set back some levees to give the river room to spread, and other features. The plan was devised by a broad coalition, and was eventually embraced by none other than the US Army Corps of Engineers as a replacement for its own plan for more floodwalls, levees and dredging. http://tinyurl.com/2fd8zw

The Napa River in its most urban setting, in 2004. When floods hit, pools of industrial waste were washed across the city. Chemical companies have since cleaned up and converted these pits to flood terraces as part of the restoration work. Photo: Napa Flood and Water Conservation District

The Kissimmee River being channelized, 1961. Photo: South Florida Water Management District

Yangtze wetlands restoration: A 1998 flood in the Yangtze basin breached 2,000 embankments, inundated 28,500 square kilometers of agricultural land, and left 2.5 million people homeless. The disaster prompted Beijing to pass a Flood Control Act which signaled a shift from a dependence on structural flood control to greater use of non-structural measures. One such project will restore lakes and wetlands that can absorb high river flow along the middle Yangtze. Managed by WWF-Beijing and local governments, the five-year restoration initiative plans to restore 20,000 square kilometers of wetlands in central China. In addition to flood protection, the project will also improve fisheries, and give a boost to migratory birds. Wildlife species have begun to return to restored areas. The program includes projects to develop alternative livelihoods for rice farmers who move off their land to aid the restoration effort.

Restoring African floodplains: Floodplain wetlands have been severely degraded by changes in natural flooding patterns caused by upstream dams and water diversions. Artificial flood releases below large dams are being tested as a means of wetland management in a number of African nations. In Nigeria, artificial flood releases from the Tiga and Challawa Gorge Dams have been promising, and if continued, could help restore the Komadugu-Yobe basin's ecosystems. Studies have demonstrated that floodplain conditions along the Senegal River below Manantali Dam would be improved with only a small reduction in hydropower, and that the cost of the lost hydropower is substantially outweighed by the economic benefits to agriculture and fisheries. The challenge in promoting artificial releases from dams is to overcome the political power of dam operators who may see little benefit in foregoing income for the benefit of farmers and fishers downstream.

In the Zambezi river basin, research is demonstrating that prescribed flood releases from Cahora Bassa Dam could provide millions of dollars in benefits from increased shrimp production, improved quality of wildlife grazing lands, restored floodplain fisheries, and other social and ecological benefits. Scientist Rich Beilfuss says changing the management of Cahora Bassa Dam would reduce impacts from bigger floods as well, such as those that hit Mozambique this year. "With little or no reduction in total hydropower generation, the dam could release a prescribed flood early in the wet season that would not only have great benefits for people and wildlife downstream, but would also reduce the risk of large floods later in the flood season by increasing the available reservoir storage for incoming flows," he states. "Flow releases would be of modest size – sufficient in magnitude to spread floodwaters into the floodplains of the Zambezi Delta, and timed to enable flood-recession cropping systems, but not on the scale of the large, damaging floods. It's important to note that extreme flooding events like the 2001 flood, though infrequent, are inevitable because even large dams like Cahora Bassa and Kariba cannot fully capture Zambezi flows during years of very high regional rainfall."

Zambezi study: http://tinyurl.com/274q8l
Prescribed flooding: http://tinyurl.com/yo3xw8

Restoring river meanders in Florida: The Kissimmee River Restoration Project, begun in the 1990s, will restore over 10,000 hectares of river and floodplain ecosystems including 69 kilometers of meandering river channel. The project will undo some of the damage done by a flood control project dating from the 1960s, in which the Army Corps of Engineers dredged a straight canal through the floodplain. The ongoing restoration will also restore habitat for birds, fish, and other wildlife. www.sfwmd.gov/org/erd/krr/

European Flood Action Program: Between 1998 and 2004, Europe suffered over 100 major damaging floods, including the catastrophic floods along the Danube and Elbe rivers in summer 2002, and severe floods in 2005. Since 1998, floods in Europe have caused some 700 deaths, the displacement of about half a million people and at least 25 billion Euros in economic losses. In January 2006, the European Commission adopted a proposal to help member states reduce the impacts of floods on shared rivers through prevention and preparedness. The voluntary plan includes recommendations to restore natural flood control systems such as wetlands; avoid new development in floodplains; improve flood risk assessment and mapping; increase public awareness, and support better policies and flood risk management plans.

Drava restoration: One of Europe's largest river restoration projects is helping bring back natural flood control and better wildlife habitat on Austria's Drava River. The river had been straightened decades ago for flood control. WWF Austria reports that the 6.3 million restoration project has increased natural flood retention by 10 million cubic meters, by setting aside 200 hectares in open space in the floodplain. The floodwave is now estimated to be slowed by as much as an hour downstream. Endangered species have new habitat, and fish populations have doubled. The project was cheaper than conventional flood control proposals.

The Drava before (left) and after restoration. Photos: WWF Austria

DAMS, RIVERS AND PEOPLE IN 2006: AN OVERVIEW by Peter Bosshard

Millions of people depend on Lake Victoria for their livelihoods. The lake has shrunk in part due to over-releases from dams.

■ **Lake Victoria drained by dams:** The world's second largest lake was at record low levels in 2006, affecting millions of people in Kenya, Tanzania and Uganda. A report by an independent hydrologist published by IRN in February revealed that the operation of two existing dams was the main reason for the declining water levels. The dam primarily responsible for the decline was built by the World Bank, which used a highly optimistic and much-contested estimate of how much water would flow out of the lake to power the dams.

■ **Sardar Sarovar rising:** On March 8, the Indian authorities decided to raise the height of the Sardar Sarovar Dam in the Narmada Valley by another 12 meters. This decision violated orders by India's Supreme Court, which stipulate that any increase in the dam height must be preceded by resettlement and rehabilitation measures. The increase, which was completed at the end of the year, submerged the homes of thousands of families during the 2006 monsoon season.

■ **San Joaquin restoration moves forward:** Water will return to a dry stretch of California's San Joaquin River by 2009, according to a settlement filed in federal court in 2006. The agreement caps an 18-year legal battle over how much water should be allowed to flow from the Friant Dam to allow salmon to return to the river. The San Joaquin is California's second longest river. The settlement will restore 246 km of the San Joaquin River – making it one of the biggest restoration projects in the US.

■ **Carbon credits for big dams:** The Xiaogushan Dam in China was registered as eligible to receive Kyoto Protocol carbon credits in August 2006. The World Bank persuaded the UN's Clean Development Mechanism to approve this dam on the grounds that it needed income from selling credits to go forward, even though the project was already nearing completion. Credits are only supposed to be granted to projects that would not go forward without this financial boost. This is just the latest example of developers and carbon consultants cheating the carbon trading system.

■ **Unsafe dams:** The privately owned Kaloko Dam in Hawai'i breached on March 14, resulting in seven deaths and massive flooding. A 2005 report by the American Society of Civil Engineers identified 22 dams in Hawaii that raised safety concerns, but Kaloko was not on the list of dams rated "high-hazard" structures that could cause deaths and significant damage if they failed. Other dams collapsed in Southern Austria, Shaanxi province (China), and Gusau (Nigeria) during 2006. In July, the failure of a diversion tunnel resulted in the uncontrolled drainage of the reservoir of the newly built Campos Novos Dam in Brazil, the world's third-largest concrete-faced rock-fill dam.

■ **Record floods** on the Danube affected several Central European countries in April. Mozambique's Zambezi valley was hit by major floods in February. Floods also affected Northern Thailand, parts of China, North Korea, Ethiopia, Jammu & Kashmir in India, Turkey, Malaysia, and the Horn of Africa. Earlier during 2006, the Horn of Africa had been hit by a devastating drought. Record droughts also hit Australia, the United Kingdom, and parts of the United States.

The funeral procession for Eduardo Maya Manrique, a community activist who was murdered in Mexico last year for his work to halt the La Parota Dam.

■ **Human rights abused:** On April 22, militias employed by the Merowe Dam authorities in Sudan killed three villagers and wounded 47 who were resisting their eviction to desert locations. The massacre was one of many killings of anti-dam activists in 2006. Andres Arroyo Segura, an activist against the proposed Baba Dam, was killed in Ecuador. Rafael Markus "Makoy" Bangit and Alice Omengan, two activists for indigenous rights who were also fighting dam projects, were killed in separate incidents in the Cordillera region of the Philippines. Omengan's husband,

The failure of the Kaloko Dam in Hawaii killed seven.

The flooded Danube

Constancio "Chandu" Claver, was wounded in the attack. In China, Fu Xiancai, an advocate for the people displaced by the Three Gorges Dam, was attacked and severely wounded.

■ **Three Gorges milestone:** China completed construction of the main wall of the Three Gorges Dam, the world's largest hydropower project on May 20. So far, one million people have been displaced for the project, and the authorities announced that another 300,000 people would be displaced. Meanwhile, dam construction in China continues apace. In 2006, construction began on the $1.8 billion, 4,200 megawatt Laxiwa Dam on the Yellow River, and on the $3.7 billion, 6,000 megawatt Xiangjiaba Dam on the Yangtze.

■ **Tehri Dam complete:** The hydroelectric plant of the Tehri Dam in India became operational and started electricity generation in July. Located in an earthquake-prone zone in the Himalayan foothills, the $1.2 billion project submerged a town with a population of 14,000 and all or part of 112 villages.

■ **Inspection Panel faults Pakistan project:** On October 31, the World Bank discussed the findings of a report by the Inspection Panel, the Bank's independent appeals mechanism, on the Pakistan National Drainage Project. The Panel report found that the drainage project led to widespread environmental harm and suffering among local communities, and violated six of the World Bank's binding operational policies. The project contributed to deadly floods in 2003.

■ **Corruption punished:** After years of procrastination, the World Bank in November debarred the German engineering firm Lahmeyer International from receiving further Bank contracts for up to seven years for bribing the chief official of the Lesotho Highlands Water Project. In the first case of cross-debarment, the European Bank for Reconstruction and Development decided to also blacklist the company because of corruption in the World Bank project.

■ **Big Hydro's new clothes:** The International Hydropower Association made efforts to promote what it perceives as sustainable hydropower in 2006, with a new sustainability agenda, a website, and the adoption of (voluntary) guidelines for dam builders to assess the sustainability of their projects. The scores in the guidelines are based on self-assessments to questions that have a decidedly pro-hydro bias, and very few teeth. The industry lobby group is pushing the guidelines as its alternative to the recommendations found in the World Commission on Dams' final report.

■ **Renewable energy soars:** Advances in solar, wind, geothermal and ocean power brought the world closer to a green-energy future. California adopted a "Million Solar Roofs" law to dramatically increase solar power in the state. Meanwhile, Germany led the world for installed solar photovoltaics. Wind energy remained the fastest growing source of new energy globally. Some new turbines now provide as much as 6 megawatts per turbine. Solar cells continued to get more efficient and cheaper, and large-scale "concentrating solar" plants began to take off, with large new projects underway in Spain and the US, and a proposal for a 150 MW project in Egypt. Pilot projects for various types of ocean power were developed, and new policies meant to encourage their development were adopted in Britain and Portugal.

■ **Poverty fuels water crisis:** The UN Development Programme's 2006 Human Development Report was devoted to water. Unlike the World Bank and many industry bodies, the UNDP report argued that the global water crisis was "rooted in power, poverty and inequality, not in physical availability." Published in November, the report supported a similar analysis which IRN had published at the 4th World Water Forum in Mexico City in March.

■ **IFC supports pulp mill:** In November, the International Finance Corporation approved $200 million in support of the $1.2 billion Botnia pulp and paper mill on the banks of the Uruguay River. The mill will have massive impacts on air and water quality, and led to an ongoing political conflict between Argentina and Uruguay. Project opponents blocked a bridge from Argentina to Uruguay for several months.

■ **Madeira River dams stalled:** After independent experts found grave faults in the environmental studies for the Santo Antônio and Jirau dams on Brazil's Madeira River, the Bolivian government protested construction of the dams in December. The Madeira River, a principal tributary of the Amazon, supports a treasure trove of biodiversity, including 33 endangered mammal species. The dams would have a total capacity of 6,450 megawatts, and could result in the flooding of forests in neighboring Bolivia.

■ **Sacred Lake spared:** In early November, local authorities in China canceled plans to build the Megoe Tso Dam in favor of tourism development. The Megoe Tso project (also known as Mugecuo Dam) would have severely impacted a sacred lake and important center of biodiversity in Eastern Tibet.

Megoe Tso Lake in Tibet was spared when a dam project was cancelled.

2007 RIVER HOTSPOTS by Peter Bosshard

North America

1. Take down the Klamath dams: In January 2007, the US government ordered a dam operator to install salmon passages at four large dams on the Klamath River in the Pacific Northwest. Decommissioning the dams would be cheaper than modifying them, so the government decision could trigger the largest dam removal project in history.

2. New dams proposed: California Governor Arnold Schwarzenegger will ask voters to invest $4 billion to build two new dams in the already heavily dammed state. Schwarzenegger cites population growth and climate change as reasons to build the new dams. Opponents say a better solution is to invest more in water use efficiency and recycling.

Latin America

3. The Amazon as power plant: Studies are proceeding for the 11,200 megawatts (MW) Belo Monte Dam, the first of a series of new dams planned on the Xingu River in the Brazilian Amazon. The Brazilian government has plans for the construction of at least 60 new dams in the Amazon basin, and has indicated it will weaken environmental protection and indigenous rights guarantees to clear the way for the dams.

4. Damming Patagonia: Spanish company Endesa recently began environmental impact studies for a series of four dams on the Baker and Pascua Rivers in Chilean Patagonia. The dams would have a total generating capacity of 2,400 MW, and would require construction of a 1,200 mile transmission line system through pristine ecosystems to transport the energy to industrial centers in northern Chile.

Africa

5. World's biggest dam: African governments are currently assessing the possibility of building a massive dam complex in the Democratic Republic of Congo that would divert the whole Congo River. With a capacity of 40,000 MW and a price tag of $50-80 billion, the Grand Inga Project would be the world's largest hydropower project. Its

electricity would serve urban and industrial centers, and bypass the rural poor.

6. Victoria Nile damned: With support from the World Bank, construction of the Bujagali Dam on the Nile is expected to start in 2007. Ugandan NGOs say that the project violates binding World Bank policies, and have filed a complaint with the Bank's appeal mechanism, the Inspection Panel. Bujagali would be the third dam within a few miles of Lake Victoria; two existing dams have been implicated in draining Lake Victoria.

7. Ethiopia's dam boom: Ethiopia has become Africa's busiest dam-construction site, with three hydropower dams under construction. The government hopes to generate millions of dollars in foreign currency by exporting electricity to neighboring countries. Currently under construction are the Tekeze Dam (300 MW), Gilgel Gibe II (420 MW) and Tana Belesse (435 MW). The government plans to build the 240 meter high Gilgel Gibe III Dam on the Omo-Gibe River. So far, no funders for the project have stepped forward.

8. China expands global dam-building: In May 2007, the African Development Bank held its annual meeting in Shanghai. The meeting reflects China's rapidly growing role as a financier of infrastructure projects in Africa. China is already backing the Merowe Dam in Sudan and the Tekeze Dam in Ethiopia, and plans to build the Bui Dam in Ghana and Mphanda Nkuwa Dam in Mozambique.

Europe

9. Damning Turkey's Kurds: The German, Austrian and Swiss governments approved official export guarantees for the Ilisu Dam in Turkey in March 2007. The Ilisu Dam will affect at least 55,000 people, and violates the Common Approaches on the Environment of the export credit agencies of OECD countries. Activists note huge gaps in official studies on the project, and the potential for major human rights abuses in the Kurdish region where the dam is to be built.

Asia

10. Pakistan's big dam: Preliminary work has started on the 3,300 megawatt Bhasha Dam in Northern Pakistan. The dam would be located in an earthquake-prone region and submerge 32 villages, displacing up to 100,000 people. Financial assistance for the $7 billion project has not yet been secured.

11. Northeast India dam begins: In early 2007, construction started on the massive Tipaimukh Dam in the state of Manipur in Northeastern India. If completed, the dam will flood 311 square kilometers of land and 90 villages. It is strongly opposed by the indigenous peoples of Manipur and by downstream Bangladesh.

12. Farewell, Yangtze: The Chinese government plans to build 100 new dams on the Yangtze River. One dam, slated to start construction in 2008, would flood the spectacular and much-revered Tiger Leaping Gorge and forcibly displace 100,000 people.

13. Dam-rush in the Mekong: Major hydropower cascades are under development on the Sesan and Srepok rivers in Vietnam, and the Sekong River in Laos, all tributaries of the Mekong River. Downstream communities in Cambodia would be most affected and are calling for a halt to construction until cross-border impacts are addressed. With Thailand's renewed interest in purchasing hydropower from Laos, the Lao government has signed agreements with Malaysian, Thai, Chinese, Russian and Vietnamese investors to build more than 13 dams on Mekong tributaries.

Fast Facts on Levees, Dams and Floods

A Flood of Damages

Number of people the UN estimates will live in the path of a potential damaging flood by 2050: 2 billion
Increase over today's figures: 100%

Annual number of "major floods" worldwide:
1950s to 1970s: 7-9
1980s: 20
1990s: 34

Number of damaging floods in Europe from 1998-2002: 100
Approximate number of people displaced: 500,000
Cost of damages: $30 billion

Amount spent by US government on flood-control schemes (mainly dams and levees), 1960-85: $38 billion

Average inflation-adjusted cost of flood damage every year from 1964 to 1993: $4.6 billion

Increase in cost of flood damages during that time over previous 30-year period: Approximately 66%

Increase in length of embankments in Indian state of Bihar from 1952-98: 22 times

Percent increase in flood-prone area in Bihar in that time: approx. 300

Percent increase in flood damages in Bihar between the 1950s and 1970s: almost 400

Number of people in Bihar living inside embankments: 2 million

Regulated Rivers

Length of levees that separate US rivers from their floodplains: >40,000 km

Percent of floodplain lost in the Danube basin: 92
Percent lost in the Rhine, Elbe and Tiza basins: >80

Area of Louisiana's coastal wetlands that has disappeared since 1930s: >4,900 sq. km.

Height, in places, of the bed of China's Yellow River above the surrounding flood plain: 20 meters

Levees and Dams: Technical Difficulties

Number of levee failures during "Great Flood" of 1993 in the Mississippi Basin: 1,576
As a percent of all levees in the flood zone: 68

Area inundated by reservoirs worldwide: >260,000 sq. km.

Percent of China's 85,000 dams in need of urgent repairs: >33

Annual property-damage cost of dam failures in US in the mid-2000s: $100 million

Number of US dams now classified as "unsafe": >3,500
Total investment needed to bring them into safety compliance: >$30 billion

A Better Way

Percent of India's monsoon run-off that could be captured and stored as groundwater: 25

Percent of that stored water that could be retrieved later for irrigation: 75

Estimated amount of water that 0.4 hectares of wetland can store: >6,000 cubic meters

Estimated value of 3,800 hectares of intact wetlands on the Charles River (Massachusetts)
for flood protection alone: $17 million per year

Cost of moving 5,100 homes and businesses in Illinois and Missouri after the Great Flood: $66 million

Insurance payments used to repair and rebuild those structures in past floods: $191 million

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About International Rivers Network

IRN's mission is to protect rivers and defend the rights of communities that depend on them. IRN opposes destructive dams and the development model they advance, and encourages better ways of meeting people's needs for water and energy and protection from destructive floods.

This report can be downloaded at www.irn.org

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