DamRight!

WWF's Dams Initiative

An Investor's Guide to Dams

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Cover image:
Itaipu dam – The biggest dam in the world, located on the Paraná River between Brazil and Paraguay.

M GUNTHER, WWF-CANON

Foreword

Dams are among the most destructive developments that impact on rivers and ecosystems, threatening both wildlife and people. According to the United Nation's 2003 World Water Development report, 60% of the world's 227 largest rivers are severely fragmented by dams, diversions and canals leading to the degradation of ecosystems that play an essential role in filtering and assuring freshwater resources. Dams can also bring substantial benefits by providing water for irrigation, electricity from hydropower or flood protection. However, as the authoritative World Commission on Dams (WCD) has shown, the benefits of dams are often exaggerated, while the social and environmental costs tend to get underestimated. The WCD has also shown that there is a way forward by applying a new framework for decision-making. WWF has welcomed the report of the WCD and is urging decision-makers to apply the WCD's recommendations.

Foreword

A WCD based approach to decision-making on dams should have major benefits for investors, be they governments, multilateral banks, export credit agencies or commercial banks. Poorly designed projects, exaggerated forecasts of returns and reputational risk have made many dam projects a risky investment. Following WCD guidelines through comprehensive needs and options assessments, stakeholders involvement and avoiding or minimising environmental and social impacts, will reduce investment risk.

The world's needs for water and energy are rising fast but unless these needs are met sustainably, the costs - whether economic, social or environmental will be huge. With this guide, WWF hopes to contribute to a new approach to decision-making by providing investors with a detailed overview of the benefits, costs and risks to be taken into account when considering investments in dams. We are convinced that a more responsible approach to investment can lead to more sustainable energy and water supply options that meet the needs of people and protect our rivers.

Dr. Ute Collier
Dams Initiative Leader
WWF International
March 2003

Agoyan Hydroelectric Dam on the Pastaza River near Banos Andes Mountains, Ecuador

K SCHAFER, WWF-CANON

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Executive summary

WWF's Investor's Guide to Dams provides a wide range of investors – officials of commercial and multi-lateral development banks, government aid agencies, export credit agencies and governments – with an overview of the benefits, costs, and risks associated with dam investments, as well as options for mitigating impacts. A checklist to aid decision-making is provided.

Large dam[1] projects are amongst the most controversial construction projects, with often substantial environmental and social impacts. In response to the controversies surrounding dam construction, the World Commission on Dams (WCD) was established by the World Bank and IUCN (The World Conservation Union) in 1998. Following consultations with a wide range of stakeholders, the WCD conducted a comprehensive review of the performance and impacts of large dams and, in 2000, issued a report with recommendations for a new framework for decision-makers.

The Guide outlines criteria for sound water infrastructure projects developed using the WCD's guidelines. In the first instance, a thorough needs assessment has to be conducted of the proposed project, to determine actual needs for water, energy and flood control. It is also necessary to assess alternative ways of providing services, and to look beyond dams at ways of meeting real needs. When weighing alternatives, the financial implications need to be determined, both in the short and long term. Water is a valuable resource, often subject to heated political debates and controversies, having the potential to cause conflicts or cement close ties, and investors need to be aware of possible political 'minefields'. Variables upon which a decision for dam construction was based may change over time, and a periodic review during the long planning process is therefore prudent.

The Investor's Guide examines the financial pitfalls that an investor should avoid. Exaggerated projections of benefits may mislead investors, and an overview is provided of areas where exaggeration often occurs, such as the market for power, irrigation benefits and cumulative benefits of multipurpose dams. Geological instability can pose significant risk to investment, especially when dam failure affects many lives and livelihoods, and needs to be well studied and understood. Delays in construction may be caused by many factors, but are often foreseeable – invariably, they lead to cost overruns and add an extra burden to the investor. Resettlement is one of the most controversial and costly areas of dam development and is best avoided wherever possible. Long-term costs of maintenance can offset some of the benefits. While decommissioning is rarely carried out at present, this is becoming more common and can add to the long-term costs. In many instances the state – rather than the end users – covers hidden costs of services or resources provided, and this may affect cost recovery and repayment of loans.

There is overwhelming evidence that where a dam project is not well conceived, its benefits are often less than anticipated, with many negative impacts. While there are some options for minimising the negative social and environmental impacts of dams, these have in the past often not been very successful. It is important that environmental and social assessments are implemented at various stages during a project cycle. In the initial pre-feasibility stage of formulation and design, these inputs should – as far as possible – be used to adjust the design and thus avoid impacts.

Dams will by their nature have some environmental impacts. Thus, if there are other, more sustainable options that achieve the same goals, they should be favoured over large dams. These will usually also be a safer financial investment. However, if needs and options have been carefully assessed; if all stakeholders have been fully involved and mitigation measures, where feasible, included in the project design and if costs and benefits have been weighed up properly, a dam may be an acceptable investment. The WCD findings and its guidelines, together with this guide, should allow investors to avoid the worst pitfalls in decision-making on dams and assist in identifying good projects for investment.

1. According to the International Commission on Large Dams, a large dam is 15 m or more high. Dams between 5 and 15 metres with a resevoir volume of more than 3 million cubic metres are also classified as large dams.

An investor's checklist

Benefits

Assessment of benefits

- For all types of dams:
  - Is the output based on accurate, long-term figures?
  - Is the expected lifespan accurate? i.e. based on reliable sedimentation figures, based on broad data sets, and taking into account possible changes in river basin land use.
  - Have local climate change and/or global climate changes been taken into account, or will these affect viability?
- Hydropower dams:
  - Is hydropower a viable alternative on the regional market?
  - Is the plant load factor realistic?
  - PPAs: are these reasonable, even if the energy sector is being deregulated?
- Irrigation dams: are expected achievements in terms of cropped or planted areas accurate?
- Multi-purpose dams.
  - Are the various uses compatible?
  - Are the expected benefits for tourism, recreation and fishing realistic?

Cost recovery and dam beneficiaries

- Are beneficiaries being charged for the services provided by the dams? Do these reflect the real costs? Does the state cover the hidden costs? Will this affect cost recovery and repayment of loans?

Costs

Time and cost overruns

- Are the geological studies, EIA and/or social assessments carried out during the feasibility stage accurate and reliable, or are there any potential 'skeletons in the closet'?
- Are there any potential legal or political constraints to implementing the project (e.g. because of the special status of the area)?
- Have agreements been reached on the realistic costs of resettling those affected, as well as on locations for relocating displaced residents? Has this been based on the full and active involvement of major stakeholders, or has the dialogue been limited?
- Is the finance from all sources guaranteed, or are there some conditions that still have to be met?

Assessment of numbers of displaced persons and the area of flooded land

- Have the Environmental Impact Assessment (EIA) and/or social studies been carried out independently, or by an agency or company with ties to the project proponent?
- Does the assessment meet national legal requirements and the requirements of other investors (e.g. bilateral donors, banks)?
- Is the status of the dam site disputed in any way? E.g. is it a protected area, historical site or heritage area?
- Have the numbers of those affected been accurately assessed or are these optimistic? When was this figure determined? Is there likely to be population growth or an influx of new people before the dam is built?
- Does the assessment accurately cover:
  - Human health issues
  - Cultural heritage and historical issues
  - Water quality and hydrology
  - Sediments and morphology
  - The degradation of wetlands
  - Potential loss of biodiversity
  - Fish and fisheries
  - Climatic effects

Maintenance and decommissioning costs

- What are the costs associated with maintenance e.g. of an irrigation network or power transmission systems, and who is responsible for this?
- What are the requirements regarding decommissioning? When is the dam up for review or renewal of its operational permit? Is the investor indemnified against later claims?

Displacement of other businesses

- What are the projected effects on commerce (sensu lato) in the project area?

Risks

Geological instability

- Has the geology of the area been well studied and understood? Is the geology complex or simple?
- Has the geological report been produced by an independent company or agency, or one that stands to gain from implementing the project?
- Is there known seismic activity in the area?
- Has the area/design been modelled for reservoir-induced seismicity?
- Are the slopes of surrounding hills known to be susceptible to landslides?
- Are the dam's foundations solid?

Sovereign risk

- What is the country's recent history on the servicing of loans?
- Is there a risk of defaulting on payments?
- Are investors protected by a third party (e.g. the World Bank)?
- Has the market been accurately assessed, simplifying repayment, or have benefits been exaggerated?

Corruption

- Is the project subject to open tender, or is the investor obliged to make use of the services of 'favoured' companies?
- Has there been a recent history of (large) cost overruns on large projects in the country?
- How does the country rate on Transparency International's Corruption Perception Index?

Introduction

1.1 The benefits and costs of dams

Dams have played an important role in development for centuries, if not millenia. The socio-economic benefits of dams typically include power, irrigation, municipal and industrial water supply, improved navigation, flood control, recreation and fisheries. In this sense, dams have facilitated economic development and job creation in many parts of the world. These benefits are the reasons why dams have been built for centuries – and in some regions even for millennia.

However, dams cost a great deal of capital upfront – in some cases, significant in relation to the GDP of the countries that promote them. Once constructed, they tend to last a long time, many dams over a hundred years old are still functioning. Mistakes therefore tend to be extremely costly and long lasting.

Evidence has been mounting that the financial, social and environmental costs of dams are often underestimated, while the benefits are generally exaggerated, making dams a risky investment. Because they serve smaller irrigation areas than envisaged or crops are sold for lower than expected prices, the actual benefits of dam-associated irrigation tend to be less than projected. Additionally, geological instability can incur far higher expenditures than expected. Indeed any over optimistic forecast can cause significant delays during construction and thus, invariably, higher costs. A recent review of World Bank funded hydropower projects showed an average schedule slippage of 28% (Bacon and Besant Jones, 1998). Not only can maintenance costs turn out to be much higher than expected – especially for ageing dams – financial and economic analyses of dams often entirely overlook decommissioning costs.

K SCHAFER, WWF-CANON

Weiss Dam, Coosa river, Alabama, United States of America

Large dams can have widespread environmental and social impacts. However, the costs related to the displacement of people, inundated lands and businesses, loss of biodiversity and fisheries are generally underestimated, or not accounted for at all. Other effects, such as the alteration of natural river dynamics, changes in downstream sediment patterns and alteration of riverbanks can have serious consequences but are seldom fully taken into account at the project appraisal stage.

1.2 The World Commission on Dams

These impacts have meant that many large dam projects are subject to substantial local opposition and international pressure on investors from non-governmental organisations. Responding to this controversy, the World Bank and IUCN (The World Conservation Union) set up the World Commission on Dams (WCD) in May 1998. Following consultations with a wide range of stakeholders, this body carried out a comprehensive review of the world's large dams, looking at the performance and impacts of large dams, at alternatives and at a range of issues relating to all stages of dam projects. The Commission's twelve members included people from government, NGOs and the private sector, with emphasis on both a geographical and professional balance. A WCD forum with 68 institutions from 36 countries provided a "sounding board" for the Commission's members.

The WCD's report *Dams and Development: A New Framework for Decision-Making* was launched in November 2000. It concluded that while dams have indeed contributed to human development and provided considerable benefits, this has been achieved at a high price, especially in terms of the social disruption of those displaced and the damage to the natural environment of downstream communities.

To improve this situation for future projects, the WCD proposed a decision-making framework based on five principles: equity, sustainability, efficiency, participatory decision-making and accountability.

The WCD's main *recommendations* related to strategic priorities for decision-making include:

- The need for clear public acceptance, including the provision of reliable information to enable stakeholders to make informed decisions and participate effectively in decision-making. With regard to indigenous people, this must include prior informed consent.
- A comprehensive assessment of all the options, ensuring in particular that social and environmental aspects are given equal weight alongside technical factors.
- A post-project review of existing dams, both from a technical and social point of view.
- The development of a basin-wide understanding of the aquatic ecosystem and of ways of maintaining it.
- The recognition that the benefits of dams should be widely shared.
- Checks and balances to ensure that at all stages and procedures comply with agreed standards.
- Special attention to transnational impacts.

Box 1:
WCD key findings

Technical, financial and economic performance

Many dams had failed to deliver the expected benefits. Dams designed for irrigation and multi-purpose dams seem to be particularly deficient in this respect. Delays and cost overruns during construction were common. There is an often unrecognised need for long-term monitoring of dams to ensure that the premises under which they were established (hydrological conditions, sediment load, suitability of land for irrigation, etc.) remain valid.

Ecosystem and large dams

The overall impact of large dams has been negative, including the loss of forests and species in flooded areas, biodiversity loss and the cumulative impacts of several dams in the same river basin. Measures to mitigate these effects such as fish passes have not always performed as well as intended.

People and large dams

Cumulatively, dams have displaced some 40 to 80 million people. The livelihoods of many others adversely affected by their construction have usually not been considered or compensated. Even where there was compensation, many resettled people suffered long-term losses that had not been taken into account. The benefits of large dams have not always been equitably distributed.

Specific recommendations are made for stakeholders including national governments, civil society groups, affected peoples' organisations, professional associations, the private sector, aid agencies and development banks.

The donor community, bilateral agencies, multi-lateral development agencies, and many national governments have welcomed the WCD, while the dam construction industry, and interest groups such as the International Commission on Large Dams (ICOLD) have been less enthusiastic. In WWF's view, the WCD's report is an important step towards better decision-making on dams. Now the challenge is for investors to consider the practical application of the WCD's guidelines, to assist in identifying less risky investments.

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Dead trees drowned by Itaipu lake created by the dam in the Atlantic rainforest

1.3 Trends in dam finance

Worldwide, about US$30-45 billion is invested annually in the construction of dams. Over the past decade, US$25-30 billion has been spent each year on the construction of dams in developing countries. Typically, US$15 billion went to hydropower dams, US$10 billion to irrigation, and several billion to water supply. The lion's share of investment went into large dams of which there are more than 45,000 worldwide.

It is striking that, while the demand for energy, drinking water and irrigation continues to grow, net investment in dams has declined to below the level of the 1980s. Between 1970 and 1985, for example, the World Bank funded an average of 26 dams a year; in the 1990s this dropped to only four dams a year. However, in its 2003 Water Resources Strategy, the World Bank (2003) announced that it will re-engage in "high reward – high risk" dams financing. Similarly, the Asian Development Bank has not funded an irrigation dam since 1989, and investments in hydropower and water supply dams have also significantly declined. Although this trend towards declining investment can be partially explained by an overall reduction in funds, it is also the result of a greater awareness of the social and environmental consequences of large dams, and of the fact that the 'best sites' have already been taken. Such factors make the initiation of new dam projects increasingly sensitive and difficult.

Although much of the debate on dams has focused on donor policies, only about 8% of total dam finance is provided by bilateral and multilateral funding agencies. Significantly, about 80% of the investment in dams is provided by the public sector – state-owned utilities, government departments and agencies. These are supported by the private sector, multilateral development banks, bilateral aid and export credit agencies (ECAs). While considerable and still the largest portion, public-sector funding of dams has been falling. This is not only because governments are faced by direct financial constraints, but also because cost recovery has often proved to be poor. Governments are therefore increasingly inclined to turn to the private sector, and currently the inflow of private finance is in the order of US$ 0.5-1.1 billion annually – and rising. At present, most projects involve multipurpose dams with irrigation components, often carried out on a BOT (Build, Own/Operate, Transfer) basis. Dam project financing deals are highly leveraged, with debt typically accounting for 70 to 80% of total financing.

While increased awareness of the social and environmental costs of dams has led to a great improvement in donor guidelines and (to a lesser extent) their enforcement, such systems, which are often self-regulatory, are currently lacking for the private sector and national governments. Given the trend towards more private funding of dams, action in this area is urgently needed.

1.4 Aim of the guide

This guide was written to help those with the onerous task of determining whether a proposed dam constitutes a viable, low impact and low risk investment. The Guide targets officials of commercial and multilateral development banks, government aid agencies, Export Credit Agencies (ECAs) and governments. In particular, the guide considers:

a) The role of needs and options assessment;
b) Common financial pitfalls that have been associated with dam investments;
c) Options for mitigating social and environmental impacts of dams.

It is appreciated that different kind of investors have different concerns as regards decision-making on dams. The Guide aims to provide a general overview of the key issues of relevance to a wide range of investors, with a focus on financial viability and environmental and social considerations.

When it is appropriate to invest in dams?

2.1 Needs assessments

For an investment as large as a dam, an accurate needs assessment is essential – otherwise the project may fail to satisfy its objectives and produce a suitable return. This is particularly important where a dam project is likely to consume a large part of the country's financial resources for several years – in the expectation of course that it will benefit the country's economy in the longer term.

Whatever the purpose of the project, the first question should be "is the dam necessary?" This should never be a foregone conclusion and it should not be implicitly assumed that the project is meeting a real need. It may be that demand side management could reduce the need or that the demand has been overestimated.

Needs assessments for different types of dam projects:

i ***Public water supply*** According to the United Nations (2003), up to 7 billion people in 60 countries will be faced with water scarcity by 2050. No one would deny that this problem needs to be addressed urgently. However, water conservation and demand management can play an important role.

One option is leakage control. It is not uncommon for distribution networks to lose up to 30% of the water put into them. Reducing leakage, particularly the cumulative effect of mending several small leaks in an ageing distribution systems, can be a very effective investment.

There are many water conservation options such as dual flush toilets, efficient showerheads and grey water recycling.

The use of water for industry also needs to be examined. Experience in South Africa has shown that after water supply restrictions following a severe drought, industry changed to more efficient water use practices.

ii ***Energy*** With globally two billion people without access to modern energy services, electricity demand is set to continue rising fast. However, energy planners tend to overestimate demand growth and many countries (including developing countries) have excess electricity generating plant capacity. Options for energy efficiency (demand side) improvements in appliances or industrial processes often exist but are ignored due to market and institutional barriers, as recognised by the WCD. A careful assessment of demand forecasts and energy efficiency options is thus crucial.

Box 2
Thailand electricity Demand Side Management (DSM) programme

Recent experience from Thailand has shown that a great potential for DSM exists not only in industrialised but also in developing countries, in particular for minimising peak demand. A Thai DSM programme focusing on efficiency improvements in lighting, refrigeration and air conditioning has exceeded its target by 317%, resulting in a saving of 692 MW peak capacity. The programme has proven extremely cost effective with DSM costing 1.3 US cents per kWh, as opposed to 5 US cents per kWh for electricity from new coal fired power plants. DSM also has the benefit that it can be added quickly and in small increments.

Source: Peter Dupont, talk given at workshop on The Changing Face of Electricity Markets in the Mekong River Basin. 28-29 January, 2003. Phnom Penh.

iii Irrigation Irrigation accounts for 70% of all water withdrawals worldwide. Some crops, such as cotton or grapes, are much more water intensive than others and demand can be reduced by switching to less water intensive crops. Existing surface water irrigation systems are often incredibly inefficient, with much of the water being lost as seepage. For example, 40% of the water diverted from the Indus basin in Pakistan is lost. There is much scope for improving the performance of existing systems, for example through canal lining, thus reducing the need for new dams. With spray irrigation, losses can be cut even further, to around 20%. Effective system maintenance is also important for stemming water loss.

iv Flood control It has to be recognised – as with any flood mitigation scheme – that it will not be possible to handle every major flood. There is a danger that development will proceed in the flood plain in the belief that it is "safe" but cause serious loss of property and life when major flooding occurs. Planning controls, which prohibit construction in the flood plain, can reduce the need for flood protection for dams.

v Multi-purpose The extra benefits of a multi-purpose dam can only accrue if, firstly, there is a real need for the additional uses and, secondly, the economics take into account the reduced benefits for specific uses due to conflicting operating requirements. For example, a dam cannot be both partially empty to catch the next flood and maximise hydropower production. Another typical situation in temperate areas is that irrigation releases are needed in summer and power releases are needed to provide electricity for heating in winter.

2.2 Alternative ways of providing services - assessing options

If a definite need has been established, there are two reasons why it is worth investigating alternatives. Firstly, a dam is likely to be more acceptable politically to stakeholders if it can be shown that all alternatives have been looked at and, where feasible, implemented. Secondly, if there are no economically viable alternative options, then construction of a dam is more likely to be financially justified.

i Public water supply The first alternative to consider is whether there is any way of optimising the use of existing resources. Possibilities might include abstracting water from a river when flows are high and pumping from groundwater when they are low. Another option is the construction of an off-stream reservoir. Although such a reservoir suffers from many of the problems associated with impounding reservoirs, and additionally may require energy to fill it using pumps, it avoids disruption to the flow patterns of water and sediment, which can have negative environmental consequences, and impede the free passage of fish. Rainwater harvesting is another option.

ii Energy The main advantage of hydropower is that it makes use of a renewable, indigenous resource. However, it is often possible to produce hydropower without a large dam. Run-of-the-river schemes can provide a lot of the benefit at far lower cost. Mini and micro hydro schemes and other renewable energy sources such as wind, solar and biomass can provide viable alternatives, especially for rural electrification in developing countries. Such small-scale, decentralised alternatives can also remove the need for investing in expensive distribution grids.

Fossil-fuel power plants are another option, although they are less desirable from a climate change perspective, especially coal fired plants. Highly efficient natural gas power plants provide a relatively low carbon alternative for the short to medium term while some renewable sources are still under development. They can be built quickly and in small modules. However, gas plants might not be a suitable option where natural gas supplies are dependent on expensive imports. In the longer term, fuel cell systems based on hydrogen show promise and solar power is likely to become much more competitive as prices drop.

Overall, when looking at alternatives for hydropower dams, it is important to integrate both demand and supply side options and to consider meeting capacity needs through a variety of smaller scale options rather than one large dam.

C MARAIS, WWF-CANON

Solar power is a good option for decentralized energy systems.

iii Irrigation Food need not necessarily come from irrigated agriculture. Alternative crops, cropping patterns, or judicious use of readily available (non-irrigation) water resources may provide sustainable livelihoods. Rainwater harvesting (for example run-off from roads and roofs) can provide an alternative to large reservoirs and is already practised in many countries. There is also scope for reusing urban wastewater (after treatment) for agriculture, as is already practised in Israel where it provides 22% of agricultural water demand.

iv Flood control There are almost always alternatives to dam construction for flood control. The best option is often the reinstatement of natural flood plains where they have been affected by development. In terms of structural measures, one option is the construction of embankments to provide protection for specific infrastructure at risk. Whereas in the past these were constructed with little consideration of the effect on downstream communities, it is now realised that by removing the peak-absorbing effects of flood plains (which in effect become natural sponges), they can exacerbate the level of flooding downstream. That said, if only limited flood embankments are required, they could be a cheap and effective way of providing flood protection.

The other alternative is to construct flood diversion channels. These can be effective, but sometimes use valuable land that has to be kept free of buildings and agriculture. For completeness the option of enlarging the river channels should be mentioned. This is rarely successful. If there are no other changes to patterns of flows and sediment, the river will tend to return to its original profile after a few years.

The WCD has found that numerous market, institutional and regulatory barriers hinder the emergence and widespread application of an appropriate mix of options in response to energy and water needs. It is thus important that options are comprehensively and fairly evaluated by all stakeholders.

2.3 Ongoing review

As it can take more than a decade from the initial proposal to the construction of a dam, there is always the possibility of major changes influencing the assessment of needs and options, both nationally and internationally. At a national level there could be a new government with a different set of priorities or a major change in government policy. Typical external changes include the price of fossil fuels or the availability and prices of foodstuffs or other energy technologies. Such changes can radically affect calculations of the financial benefits of the dam or even eliminate its very raison d'être.

At the very start of the project, a number of decision points need to be determined, at which all basic assumptions will be questioned and the calculations of the economic viability of the dam re-evaluated. Re-evaluation should take place when international finance is sought, when tenders are invited for the detailed design of the dam and before tenders for construction are invited. The latter two are especially important as, once tenders have been awarded, there could be serious cost implications if the contract is cancelled, even before work has started.

Financial pitfalls to avoid when investing in dams

3.1 Exaggerated projections of benefits

The review carried out by the WCD has found that costs are often underestimated while benefits such as electricity generated, irrigation, domestic and industrial water supply, navigation, recreation and fisheries are exaggerated. This can be due to a number of reasons.

P GLENDELL, WWF-CANON

Lock gates and hydropower station at Gabcikovo, Slovakia

Water availability The timing and volume of the water available is crucial and inherently difficult to predict. Very often, models used to predict outputs are based on very short term and incomplete flow records or 'overlook' the periodic occurrence of droughts. Investors should question the data on which such models have been based to assess the reliability of projections.

Life span Underestimated levels of sediment flows into dams tend to result in overestimating the life span of dams. All dams accumulate sediments unless special allowances are made in the design for sediment release, and this affects the useful life of a dam. The Sanmenxia dam on the Yellow River in PR China, for example, found its hydroelectric turbines crippled by sediments only a few years after completion in 1962. By 1973, dam capacity had been reduced by 70% due to silting, necessitating expensive modifications of the design so that sediments could be flushed out.

An investor needs to ask how sediment loading has been determined – is this based on actual field studies or has it only been estimated? Sediment loading depends on erosion in the catchment, and this is rarely a static figure, but one dependent on land use. The investor needs to be aware of possible changes in land use, and seek guarantees that erosion does not seriously affect the lifespan of the dam.

Climate change Global climate change may also have an impact on dam viability. Climate change – now widely accepted as a given – is predicted to increase severe droughts and flooding, both of which are detrimental to dam operations, particularly in the case of hydroelectric dams. Predictions on power output become uncertain, and investors should allow for this risk.

Furthermore, hydropower dams are often promoted as a solution to climate change. However, all reservoirs and dams emit greenhouse gases such as carbon dioxide and methane. In the initial stages, much of this is due to the rotting of flooded vegetation, but this process usually continues with the deposition of organic matter by inflowing streams. This affects all reservoirs at all latitudes, although studies suggest that shallow, warm tropical reservoirs are more likely to be large emitters than deep, cold boreal reservoirs.

Hydropower performance Case studies carried out by the WCD found that hydroelectric power has performed reasonably well and in some cases better than expected. However, there is huge variability in performance with hydropower plants operating at 12-82% of their maximum capacity (i.e. a 'plant factor' of 12-82%). A recent analysis of 21 large hydropower plants arrived at an average factor of 36% (McCully, 1996). Feasibility studies often tend to be more optimistic, and benefits are exaggerated, for example, because of the difficulty in estimating future (peak) energy demand. High demand forecasts overestimate the economic benefits from peak loads in particular. The economic benefits of hydroelectric power should be valued at market prices rather than current (often subsidised) tariffs. Failure to do this may lead to over-optimistic benefits in some appraisals, or be overly pessimistic in other appraisals, where tariffs are well below economic prices.

The viability of a hydroelectric dam may depend on an expensive Power Purchase Agreement (PPA), and those buying the power may seek to avoid commitments, for example, if an energy market is deregulated. PPAs may be renegotiated but procedures may be lengthy and are often hard-fought.

Irrigated area Irrigation benefits tend to be significantly smaller than initially estimated. In the WCD case studies, actual achievements in terms of cropped or planted areas ranged between 60% and 85% of projected net benefits for most dams reviewed. Output prices were also lower than expected in some cases.

Other benefits Other benefits from dams in terms of tourism, recreation and fisheries are sometimes exaggerated. However, in other cases, such benefits are not taken into account at all. The danger is to value fisheries benefits from dams while not taking into account the foregone benefits of recreation and fisheries downstream. This also holds for flood control. While dams can play a role in preventing flood damage, the foregone benefits of annual floods in terms of natural fertilisation of agricultural areas should also be incorporated in a full estimation of dam costs and benefits.

3.2 Time and cost overruns

"Completed on time, within budget and to specification" is the mantra of project management. Unfortunately, with major schemes the first of these targets is often not attained. Time overruns are usually associated with the original budget being greatly exceeded.

Time overruns are expensive. In an analysis of the construction of 30 large dams worldwide, McCully (1996) found that time overruns ranged from 14-280%, and that cost overruns – corrected for inflation – ranged from 17% to a massive 2900%, averaging at 342%.

In the case of a dam, construction delays may be due to unforeseen factors such as inclement weather or unexpected geological conditions. However, dam construction is rarely delayed by totally unforeseen events. It should be noted that some of these "unknowns" can be predicted statistically. For example, if heavy rain or extended periods of severe frost could cause a delay in construction, an analysis of past weather patterns should give an idea of the viability of assumptions concerning construction conditions. Another weather-related factor, which can lead to time overruns, is the period needed to fill the dam once construction is complete. Where inflows are highly seasonal, a construction delay of a few months can lead to a whole year's operational delay. Also if the period in which construction is completed is drier than normal, the inflows may be insufficient to fill the reservoir as quickly as anticipated.

In reality, these factors are rarely looked at in detail as addressing them would add additional costs. A more detailed geological survey would take time and might not even then identify all potential problems, particularly in the case of tunnels (often an essential part of dam projects). Allowing extra construction time for possible delays increases the cost and therefore reduces the potential viability of the project. At the bidding stage, it is clearly not in the contractor's interest to add extra cost to allow for potential delays, yet it is obviously in the interests of project financiers to consider such substantial risks.

Another type of delay can arise if issues relating to legal or political considerations remain unresolved before construction. If, for example, agreement has not been made on the payment of resettlement costs and on the location to which displaced residents will be moved, this could result in a delay in the reservoir being filled.

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3.3 Inaccurate assessment of displaced peoples and inundated lands

Great care needs to be taken in assessing the human and territorial impacts of dams. While it is relatively easy to estimate from topographic maps and the designed top water level the extent of the area to be flooded, and thus to identify what must be flooded, the impact on displaced persons, their livelihoods and the wider environmental effects are far more difficult issues. Usually the latter are assessed in an environmental impact assessment (EIA) or a social assessment. Such studies should be carried out by an independent team possessing all the requisite expertise, but unfortunately this is not always the case and EIAs can turn into a rubber stamping exercise.

All peripheral areas around the dam will be affected to some degree. In some cases the peripheral area will be very close to the dam. For example, it might include a farm that becomes uneconomic as it is reduced in size and access roads are flooded. In other cases, the peripheral area might extend much further and farmers and fishers downstream might be impacted by the loss of flood recession agriculture and of fisheries.

There are very few parts of the world where good quality land is available to locate displaced residents and their commercial activities. While this may be particularly severe in the case of agricultural communities, it will affect the site chosen for homes for displaced people whatever their economic basis. The influx of "immigrants" into areas chosen to receive those displaced will have a disruptive effect both on the local economy and on existing social structures.

Over time, communities develop a social structure, based on religious, political or other affinities. When members of these groups are transferred to other established communities, there is liable to be disruption as new arrivals seek to re-establish bonds with their former communities and at the same time develop a working relationship with the community they have joined. In a sense therefore, the members of these communities and the land on which they live should be considered part of the "displaced" population and the cost of the impact on their livelihoods incorporated in estimates of construction costs.

Lastly, although the loss of livelihood of those affected may to some extent be compensated by "resettlement plans", these rarely cover actual losses. Compensation is usually determined at a fixed rate by a central planning agency and implemented by local government. Often this does not approach the true market value of lost assets, let alone cover the loss of income and livelihood. In other cases, little or no compensation is provided (Box 3). Even where the "resettlement plan" appears to provide equivalent value property there will invariably be other costs. For example, it may be necessary to adapt to new agricultural techniques in the case of agricultural land.

Box 3
Three Gorges dam, PR China

In the Three Gorges Project (TGP) in China an estimated 1.3 to 1.9 million people will be relocated. Government officials claim that the quality of life of the displaced persons will improve after relocation. They will have better land for cultivation and the TGP will facilitate industrialisation along the rivers. The Government will provide financial assistance to speed up local economic development, instead of compensating the affected people with a lump sum, and displaced persons will not be directly compensated. However, at least some of these people will be resettled in upland areas where land is less fertile, and many of these upland areas are already over-exploited.

The human impacts are often underestimated, possibly due to inaccurate criteria, population growth between the time of the initial estimate and the final construction, and the influx of people. In an analysis of those displaced by the construction of 14 large dams, mainly in Asia and Africa, McCully (1996) found that local populations had been significantly underestimated in all cases, ranging in absolute numbers from 3,900 to almost 300,000 people (in the case of the Sardar Sarovar dam in India).

Resettlement programmes that are regarded as unjust can lead to widespread protests and civil unrest, and this can in turn have political and financial repercussions. Recent claims against the Japanese-funded Kotopanjang dam on the Indonesian island of Sumatra (Box 4) is going hand-in-hand with social unrest that may eventually take its political toll. The construction of the Sardar Sarovar (Narmada) dam in India has caused widespread unrest and political conflict, along with a multitude of lawsuits and claims that have yet to be settled.

K SCHAFER, WWF-CANON

Recovery of dead wood obstructing Petit Saut dam, French Guyana.

Box 4
Sumatra residents file lawsuit against Japanese dam project

In September 2002, almost 3,900 residents of the Indonesian island of Sumatra filed a lawsuit against the Japanese government, Japan International Cooperation Agency, the state-run Japan Bank for International Cooperation and Tokyo Electric Power Services Company for perceived damages caused by the construction of the 31 billion yen Kotopanjang dam.

In the lawsuit, the plaintiffs claim they were forcibly resettled after the dam was completed in 1997. Also, they claim they have been left without proper living facilities, including clean water, on the land where they were resettled, and with no job opportunities. The plaintiffs also demand that the defendants urge the Indonesian government to remove the dam and restore their living conditions and the natural state.

The plaintiffs are represented by a group of Japanese lawyers, and their Japanese supporters said they expect the lawsuit to present an opportunity to review how Overseas Development Assistance (ODA) is used. They said Japanese ODA-funded development projects are increasingly seen as inefficient as far as improving living conditions in recipient countries, while only Japanese consulting firms and construction companies actually benefit.

3.4 Geological instability and dam failure

Dam sites are, by their very nature, susceptible to seismic activity. Dams are built in valleys and the shape of the valley influences the size of the dam wall and the volume of water stored. However, a valley implies recent erosion (in geological terms). This in turn suggests that uplift has taken place and this may be associated with geological instability. Indeed many dams have an active fault below them.

Building a dam in an area of known seismic activity need not, in itself, be dangerous. The forces, both vertical and horizontal, arising from earthquakes are fairly well understood and the design can take account of them. It will of course add to the cost of the dam and may also restrict the options available to the designer.

In certain cases, however, knowledge of the history of seismic activity has not been a good indicator of seismic activity once a dam has been constructed. This is due to an effect known as *reservoir induced seismicity*. Although in part the extra seismic activity may be due to the "weight" of the water, the main effect is due to water seeping into pores in the underlying rock strata and altering the way in which these respond to existing stresses. Indeed some seismologists use the term *reservoir-triggered seismicity* to describe this process. It usually only lasts a few years, during which the surrounding strata reach a new stable equilibrium, and the long-term effects are limited by the available tectonic energy. However, in some cases, the extent of this phenomenon is unknown, as network seismometers are unable to record the resulting earthquakes in detail. It is usually not possible to predict whether or not a particular reservoir will trigger additional seismic activity (see Box 5) as this depends on stresses at earthquake depths. The current lack of knowledge about these stresses makes it extremely difficult to predict earthquakes.

> Building a dam in an area of known seismic activity need not, of itself, be dangerous.

In the case of earthquakes induced by a dam, it is necessary to consider how any claims against the dam operator for consequential damage will be met. It will certainly be necessary for the dam operator to ensure that their public liability insurance covers such an eventuality.

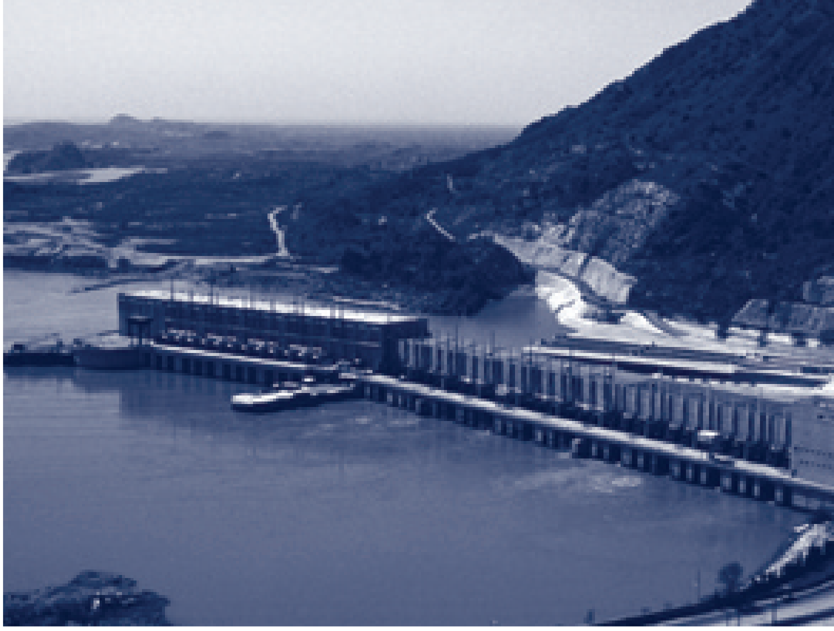
Box 5
Koyna dam, India

This dam was built in a basalt region of the Peninsula shield of India. Seismic monitoring before the dam was constructed registered little activity. After the dam came into use in 1963, loud sounds were reported near to the dam and more detailed seismic monitoring was carried out. The Konya and Pavel lineaments, which intersect to the south of the dam, were identified as the major area of induced seismicity.

A small earthquake occurred in September 1967, followed by a larger one upstream of the reservoir site (magnitude: 5.0 on the Richter scale). Some structural damage near to the epicentre was reported. Seismic activity continued to increase until in December 1967 an earthquake with a magnitude of 6.5 was recorded. The dam was damaged, but did not collapse. Other earthquakes in 1972 and 1980 were attributed to rapid filling of the lake. It was concluded that by controlling the rate of filling – at least at this particular site – it was possible to control the incidence of reservoir-induced seismic activity.

Another potential problem is that of landslides occurring upstream of the dam. Such landslides generally occur when the slopes of the side of a valley becomes unstable following a period of heavy rain. In some cases the problem posed by this is the fact that a river channel is blocked and a temporary but very unstable "dam" is created. However in the case of an existing reservoir the problem occurs if a large quantity of soil and rock cascade into the reservoir upstream of the dam, displacing the water in the reservoir and causing the dam to suddenly overflow. While all well designed dams have a spillway designed to handle the maximum likely flood, a sudden rush of water flow over the dam can often have catastrophic results. McCully (1996) lists 46 recorded large dam failures from 1860-1995 that have each resulted in the deaths of more than 10 people and eight of these have each resulted in the deaths of over 1,000.

Other geology-related factors include the stability of the foundations. It goes without saying that unless the dam is built on solid foundations it can fail. Normally geological and soil investigations are one of the most expensive parts of the design process. When dams have collapsed in the past, the reasons have often been complex. It invariably seems to be a malign combination of circumstances in which the geological stability of the site plays a significant role. Sometimes bad weather and saturated soils after heavy rain also contribute; at other times it is a combination of structural shortcomings and poor foundations. Bad spillway design has also sometimes led to the foundations being eroded causing structural weaknesses.



S K CHNG, WWF-CANON

Tarbella hydroelectric power plant, Pakistan.

3.5 Displaced business spin-off

The influx of workers for dam construction may, for a time, help local businesses. However, once construction has finished, businesses that have geared up to deal with the visitors will be left without customers. An associated problem is that the temporary work offered by the dam construction may draw workers from other businesses, which can drive up wages – as businesses seek to retain their staff – as well as the cost of goods and services for those not involved in the dam project.

Building a dam can have economic implications relating to the purpose of the dam itself. If it is built for irrigation, it will have an effect on the costs of agricultural production over a wide area. It is, for example, possible that before the construction of a dam, much irrigation would be rain fed and work practices and food distribution would reflect this. The dam may make it possible for new crops to be produced more competitively. On other hand it might help produce cash crops for export, thus increasing the demand for locally produced food, as those who had previously fed themselves on their own land become workers on commercial farms.

In short, the effects of major dam construction on economic activities over an area far from the dam itself could be substantial. These effects are not easy to predict. This can have long-term implications for investors. If a dam is to produce electricity, its viability depends on customers for energy. If it is to increase agriculture it requires consumers to buy the products. Should a dam have negative effects on the local population this could have a knock-on effect on the viability of the dam.

3.6 Sovereign risk and corruption

Sovereign risk

Sovereign risk can impose higher costs on dam development and the level of risk should be fully assessed before commencing the promotion of a dam project. Sovereign risk implies the possibility that conditions will develop in a country which inhibit repayment of funds due from that country, such as changes in legal approvals, exchange controls, strikes or declarations of war. In a large dam project with a long gestation period for construction and operation the possibility of such risks cannot be adequately determined at an early stage. In case of a low investment grade credit rating and high sovereign risk, multiple payment security mechanisms could be established that secures investors against possible future defaults on payments.

Issues that arise are (i) breach of contract by government organizations, such as state owned utilities, (ii) availability and convertibility of foreign exchange, (iii) changes in law (tax and labour laws), and (iv) political *force majeure* events. In addition to a guarantee provided by the country government and partial risk guarantees by the multilateral institutions, at least the first two issues are addressed through payment security, such as liquidity facility and debt service reserve account. The establishment of any such accounts raises the cost of the project and in turn puts a heavy burden on the borrowers. A weak regulatory framework and overall macro-economic reform process raises the levels of political risks and necessitates the establishment of multiple payment security mechanisms.

A weak regulatory framework and overall macro-economic reform process raises the levels of political risks and necessitates the establishment of multiple payment security mechanisms.

Other international dimensions can complicate the situation. For example if part of the repayment is expected to come from sales of power to another country, this could increase the risk as the economic situation in the second country may deteriorate, reducing the need for electricity, or that country may develop alternative methods of power generation. The problem takes on a different character when private finance is involved. In such cases lenders often demand that the government underwrites the risks. While this might minimise the risk, it does not of course eliminate it.

In case of the occurrence of an event such as mentioned above, and in case of a dispute arising from an interpretation of such events, it is important to set out an appropriate dispute resolution mechanism. It is common for a country where the judicial system and administration is weak to agree to an international arbitration court and rules.

Corruption

Corruption has been associated with a number of dam projects. In some cases, however, the amounts siphoned off from a dam project can be huge. The Itaipú dam on border of Brazil-Paraguay on the Paraná River is currently the world's most powerful hydropower dam, with a generating capacity of 12,600 MW. It was originally projected to cost US$3.4 billion but, due to skim-offs by military rulers and their political allies, the final costs eventually ballooned to about US$20 billion. Similarly, the costs for building the 3,600 MW Yacyretá dam – located downstream of the Itaipú in Argentina – increased from US$2.7 billion to an eventual US$11.5 billion, in a process that was famously described by the Argentinean President Carlos Menem in 1990 as "a monument to corruption". One of the measures investors can

take to assess the possible risk of corruption is to check the rating of a particular country on Transparency International's Corruption Perception.

The WCD report proposes that corruption be tackled by an "Integrity Pact". This approach is recommended in preference to government legislation as introducing such legislation might be time consuming and it would avoid some questions of which jurisdiction has authority. Such a pact has two main objectives:

(i) All parties, including competing tenderers, agree to refrain from bribery.

(ii) To reduce the additional unproductive costs to states of bribery.

One of the other themes of the WCD is stakeholder participation and openness. This also would help to avoid corruption.

It would be naïve to suggest that implementation of these recommendations would, by themselves, eliminate the distortion of economic evaluation that bribery causes. However, there does appear to a be a concerted international attempt to tackle this problem and the more that can be done to recognise its existence is likely to lead to improved financial probity in the long-term.

Box 6
Acres convicted in Lesotho

The US$ 8 billion Lesotho Highlands Water Project (LHWP) is designed to divert water from the upper Orange River in Lesotho, to the urban and industrial Gauteng region in South Africa, through a series of dams and tunnels excavated through the mountains. The first dam in the multi-dam scheme (Katse) has been completed and the second (Mohale) is currently under construction. The Katse dam affected 27,000 persons, of which 2,000 were resettled.

In addition to social and environmental problems, however, LHWP has been plagued by corruption scandals. On 20 September 2002, the Canadian firm Acres International Ltd. - also involved in the Three Gorges Dam (China), Nam Theun 2 (Laos) and Bujagali (Uganda) - was convicted by the Lesotho High Court of paying bribes to Lesotho government officials win contracts on the LHWP. Acres now faces disbarment from further World Bank contracts. Twelve other companies are also under investigation as part of the same probe, including Italy's Impregilo, France's Spie Batignolles and Dumez International, and Germany's Lahmeyer - which will be next to stand trial.

...originally projected to cost US$3.4 billion but, due to skim-offs by military rulers and their political allies, the final costs eventually ballooned to about US$20 billion.

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3.7 Maintenance and decommissioning costs

While the initial cost of building the dam may be huge, other recurring costs can also be an important part of the financial equation. In general, the running costs of the dam itself are relatively well understood. They include hiring staff for operations and maintenance and the cost of maintenance materials. What is often less well understood are the maintenance and operating costs associated with the benefits the dam is intended to provide. Typical costs associated include new distribution and drainage channels for irrigation and new power lines and transformers for hydropower. Further, all dams become increasingly expensive to maintain in a structurally sound state as they age.

E PARKER, WWF-CANON

Yanzhou hydro-power station on the Lishui River Hunan Province China Project number: CN0088

At the end of its working life there may be a need to decommission the dam. This may involve breaching, or removing and disposing of the dam structure and associated equipment. The reasons for removal typically include aesthetics, fish and wildlife habitat improvement, removal of safety hazards, creation of recreation opportunities, and improvement of water quality. However, decommissioning may have unexpected impacts such as the contaminated sediments that were released into a river after the removal of the Fort Edward Dam in New York State.

The decommissioning and removal of these three dams, which ranged from 4-15 metres in height, each cost in the range of US$1.0 – 2.3 million.

In countries like the United States and France, dams are licensed for a set period and if this licence is not renewed, or required upgrading is too expensive, then the dam must be removed, which is costly. In France, more than 100 dams were assessed for concession renewal in 1994, and of these only three in the Loire River basin were rejected. The decommissioning and removal of these three dams, which ranged from 4-15 metres in height, each cost in the range of US$1.0 – 2.3 million.

The impact on different types of investors will vary with the type of investment. If it is a BOT-type investment, the impact will depend on the period of operation. The longer the period of operation – the higher will be the weight of maintenance on the overall financial equation. If finance is of the form of Build-Own-Operate (BOO) then all the costs of maintenance and decommissioning will affect financial viability. Whatever the type of investment, it could be considered unwise to neglect potentially large costs as to do so might make it appear that investment could not be justified on valid economic criteria.

3.8 Cost recovery and dam beneficiaries

Many dams are multi-purpose, providing hydropower, irrigation, fishery and flood control, and in setting charges for the various uses, it is necessary to devise a formula to allocate cost to the different users. In general, it is not unusual for hydroelectric power to subsidise other uses.

Pitfalls

A key question is whether large capital investments are to be recovered from beneficiaries, or if only the much lower operational costs need to be covered from charges to end users. In many countries, only part or all of the operational costs are recovered, and capital investments are covered by public funds. In several dams (notably in Turkey and Laos PDR) funded under BOT agreements, both capital investments and operational costs are being recovered from end users. In the instance of Turkey and Laos this is fairly easy, as these involve hydropower dams; in practice it is easier to recover costs from users of electricity, as defaulting individuals can be sanctioned by the turn of a switch. In many instances, however, the cost of hydroelectricity rarely reflects the full cost of investment. Fees may be nominal, or set at a fixed rate per household regardless of the power used. Non-collection of power charges, underassessments and illegal tapping of electricity further complicate matters.

Similarly, full cost charging for water services is the exception rather than the rule. There are a few countries that base their water price on full recurrent costs, but very few that include capital expenditures in their water charges. On the other side of the balance sheet are countries that provide water for free or against a nominal charge. In many countries this nominal charge is so nominal that it is hardly worth collecting.

When many of the direct beneficiaries of the dam are unable or unwilling to pay for the benefits provided, cost recovery becomes a problem, and in addition to capital investments, dam operations may also need to be subsidised out of public funds.

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M GUNTHER, WWF-CANON

Construction site of the Three Gorges Dam on the Yangtze river, Hubei Province. The Dam will be the largest hydro electric dam in the world. The controversial dam will stretch more than two kilometres across the Yangtze River, create a reservoir more than 600 kilometres long, cause the forcible resettlement of more than 1.3 million people, destroy the habitat for a number of endangered aquatic species and flood over 1200 cultural antiquities and archaeological sites. The dam will cost over US$70 billion.

3.9 Inadequate insurance cover

At an early stage of project planning it is important that all risks to the investment be considered and evaluated. This may take the form of a series of wide ranging "what if" questions. They should cover "natural risks" due to weather or geology, political risks and changing global patterns of consumption. A classic example is the assumed future price of carbon-based fuels where these are being considered as an alternative to hydropower. The extent to which the "what if questions" are answered in detail depends on the risk to satisfactory outcome. If, say, most of the return is anticipated to come from a neighbouring country purchasing electricity, then that country's financial stability should be considered in detail.

It may be possible to insure against certain eventualities, as at least some of the risks can be assessed according to the principles of probability. The chances of a drought, for example, can be gauged from an analysis of past flow records. The credit records of national, public or private organisations expected to pay for the output of a dam can be inspected and insurance taken out against non-payment.

In some cases it may not be possible to obtain insurance. In others it may be government policy not to take out insurance, as it is considered that the government effectively self-insures against these risks. Whatever the reason, the financial impact of these risks should be considered.

Pitfalls

4 Impact mitigation and avoidance

Dams have the potential to make headlines – often in the negative sense, and especially when the 'news' concerns major social or environmental impacts. This has consequences for investment, as it may tarnish the reputation of companies and banks involved. International standards have been formulated for the development of large dams, for example by the World Bank and the Asian Development Bank, and responsible firms should be seen to be complying fully with these standards. Application of the WCD guidelines may need a revision of these standards.

Due to the way in which environmental assessment is traditionally embedded in the project development cycle, mitigation is the most widely practised response to the environmental impacts of large dams. Until recently, dam projects only underwent environmental and social assessments after they had been formulated and designed. What has emerged in the past decade is that mitigation often fails to achieve the desired objectives. Fish passes, for example, usually are inefficient if they work at all, and wildlife 'rescue' operations have no net benefit. Also, resettlement plans often fail to safeguard basic livelihoods, in spite of significant investments of funds and time. Avoiding the need for resettlement is clearly the best option – provided alternative sites are available – or at least keeping the need for resettlement to a minimum.

The WCD (2000) evaluated 87 projects for which impacts had been recorded, and found that mitigation had been carried out on less than 25% of the anticipated environmental impacts. Even worse, where mitigation was carried out, it was effective in only 20% of the cases, while in a further 40% of the cases it had no beneficial effect. Annex 2 discusses options for mitigating environmental impacts in more detail.

It is now generally acknowledged that environmental assessment in general, and environmental impact assessment of dam projects in particular, needs to be carried out in the early stages of project planning, formulation and design. Only in this way can weaknesses be detected in advance, and alternative strategies proposed, rather than trying to limit the impacts of a flawed design. As a result of this recognition, it is now more commonplace for environmental and social assessments to be implemented at various stages during a project, including pre-feasibility, feasibility, construction and operations. In the initial pre-feasibility stage of formulation and design, these inputs should – as far as possible – be used to adjust the design and thus avoid impacts. This may involve relocation of a dam to an alternative location, substituting a single large dam for several smaller dams, or finding alternative sources of energy if the main aim was hydroelectric power generation.

Later inputs during the feasibility stage, when detailed designs have been made, should focus on modifying designs and identifying ways to mitigate potential impacts. This could, for example, involve fitting aeration baffles in outfalls, re-aligning an access road to avoid a graveyard, or planning for managed floods to maintain downstream wetlands. On the whole, good site selection (e.g. not building large dams on the mainstream of a river system) and better dam design can reduce impacts.

The potential impacts of and issues faced during dam design, construction and operations are summarised in Table 1, along with an indication of the degree to which these can be avoided and/or mitigated. Also indicated are the potential costs and benefits of avoidance and/or mitigation.

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Key

*	--	= unavoidable/ineffective
	+	= some negative effects can be avoided or mitigated
	++	= many negative effects can be avoided or mitigated
	+++	= most negative effects can be avoided or mitigated
**	--	= none
	+	= minor
	++	= moderate
	+++	= significant

Table 1: **Avoiding or mitigating potential impacts**

Potential issues & impacts	Potential negative effect:		Costs**	Benefits**
	Avoidance*	Mitigation*		
Geological stability	+++	--	++	+++
Sovereign risk	++	--	+	+++
Time and cost overruns	+++	+	++(+)	+++
Inaccurate assessment of displaced peoples and inundated lands	++	++	++	+++
Displacement of other businesses	++	++	+(+)	++(+)
Human health	++	++	++	++
Cultural heritage	++(+)	+	++(+)	+++
Water quality	++	+++	++(+)	++(+)
Hydrology	+	++	+++	+++
Sediments & morphology	+	++	+++	++(+)
Degradation of wetlands	+	+(+)	++	++
Loss of biodiversity	++	++	++(+)	+++
Fish and fisheries	+	++	++	++
Climatic effects	+	+	+	+

A more detailed discussion of environmental mitigation options can be found in Appendix 2.

Regional or river basin planning

Planning the location, size and outlay of a dam within the framework provided by regional or river basin planning, allows comparison between various sites, and an assessment of alternatives. It also makes it possible to determine whether the planned dam is consistent with (projected) land use and to estimate the potential impacts on resources and land users. This makes it possible to identify the best site and design the best scale and layout, in order to avoid or minimise impacts. Although this seems the most obvious approach, this route is often not taken. Other approaches may be taken for political or administrative reasons, for example, if a river basin straddles state or national borders. A rational approach may be adopted, for example, to identify a suitable location but not when considering size or layout.

Locating sites off the mainstreams of rivers

An approach that can substantially alleviate major environmental impacts is the siting of dams off the mainstream of rivers – that is on a tributary rather than on the main channel of a river. This can significantly reduce downstream effects, as only a part of the main flow is siphoned off, and the effects on floods, sediments, river transportation and wetlands and fisheries, for example, are minor by comparison. The advantages of locating the dam on a tributary depends of course on the relative sizes of the tributary and main channel at the point of confluence, and if there are any major differences in water quality, sediment load, and animal and plant life.

Impact

More information

Websites

Association of State Dam Safety Officials
www.damsafety.org

Asian Development Bank evaluation study on construction of four dams
www.adb.org/Documents/PERs/ss-36.pdf

Dams and health
www.solidaritetshuset.org/fivas/pub/power_c/k3.htm

Earthscan Dams and Development website
www.earthscan.co.uk/dams/links.htm

ICOLD International Commission on Large Dams *(Commission Internationale des Grandes Barrages)*
genepi.louis-jean.com/cigb/index.html

International Energy Agency (IEA) website on Hydropower and the Environment
www.ieahydro.org/Environment/Hy-Envir.html

International Journal on Hydropower & Dams
www.hydropower-dams.com

International Rivers Network
www.irn.org

IUCN Wetlands & Water Resources Program
www.iucn.org/themes/wetlands/index.html

Transparency International *(Corruption Perception)*
www.transparency.org/cpi/2001/cpi2001.html

UNEP Dams and Development Project
www.unep-dams.org

WWF International Dams Initiative
www.panda.org/dams

World Bank
www.worldbank.org/html/extdr/pb/dams/

World Commission on Dams
www.dams.org

References

Asian Development Bank (1999)
Special evaluation study on the social and environmental impacts of selected hydropower projects.
www.adb.org/Documents/PERs/ss-36.pdf

Bacon, R. W. and Besant-Jones J. E. (1998)
Estimating Construction Costs and Schedules: Experience with Power Generation Projects in Developing Countries.
Energy Policy. Vol 26. No. 4, pp. 317-333

Delphi International Limited (1996)
The Bakun Hydroelectric Project: A Financial Analysis. 13 pages, available from D.I.Ltd, 36 Great Queen Street, London WC2B 5AA, United Kingdom.

IUCN – World Conservation Union & World Bank (1997)
Large Dams. Learning from the Past, looking to the Future. Gland & Washington, 150 pp.

McCully, P. (1996) – Silenced Rivers – The Ecology and Politics of Large Dams. Zed Books, London & New Jersey, 350 pp.

United Nations (2003)
Water for People, Water for Life. UNESCO, Paris.

World Bank (1994-96)
Environmental Assessment Sourcebook. Vol.1: Policies, procedures and cross-sectoral issues, 244 pp.; Vol.2: Sectoral guidelines, 304 pp.; Vol.3: Guidelines for Environmental Assessment of Energy and Industry Projects, 252 pp.

World Bank (2003)
Water Resources Strategy, Washington.

World Commission on Dams (2000)
Dams and Development. A New Framework for Decision-Making. Earthscan Publications Ltd, London. 356 pp.

Glossary of terms

Biodiversity - all living things on Earth (plants, animals and micro-organisms), and the differences that make each species unique.

BOO – build, operate, own

BOT – build, operate, transfer

ECA – Export Credit Agency

Ecosystem – an interconnected and symbiotic grouping of animals, plants, fungi, and microorganisms.

EIA – environmental impact assessment

Eutrophication – Natural eutrophication is the process by which lakes gradually age and become more productive. It normally takes thousands of years to progress. However, the creation of a dam and a reservoir can greatly accelerate this process. Eutrophication in these situations can be water pollution caused by the decomposition of excessive plant nutrients.

Flood plain – area bordering a river which is flooded when the river rises over its normal banks

Fossil fuel - a fuel, such as coal, oil, and natural gas, produced by the decomposition of ancient (fossilised) plants and animals

Geomorphology – the science concerned with the form of the land surface and the processes which create it.

Hydrology – science that deals with the transportation and distribution of water in the atmosphere, on and beneath the earth's surface.

ODA – overseas development assistance

Outfalls – channels or pipes designed to carry water released from a dam.

PPA – power purchasing agreement

Renewable energy – energy resources such as wind power or solar energy that can keep producing indefinitely without being depleted.

Resettlement – the act of moving people and their animals to a new area of habitation.

River basin – the area covered by a river, including its many tributaries, from its source to the sea.

Run-off – precipitation that the ground does not absorb and that ultimately reaches rivers, lakes or oceans.

Sediment – material deposited by water, wind or glaciers.

Watershed – a region or area over which water flows into a particular lake, reservoir, stream, or river.

WCD – World Commission on Dams

Wetlands – land (marshes or swamps) saturated with water constantly or recurrently.

Annex 1: Case Study: Bakun dam, Malaysia

The Bakun dam project illustrates many of the financial pitfalls that may face investors in large dams: technical uncertainties, high risks, over-optimistic projections of returns, time and budget overruns and an unpredictable market.

The Bakun dam on the Balui River in Sarawak, Eastern Malaysia, was first planned in the early 1960s. Due to various controversies, it has been suspended several times, but at present construction is steaming ahead, albeit in a scaled-down version. As originally planned, the dam would have had a height of 205m and the flooded area would have extended over 700 km^2 - about the size of Singapore. When completed it would have been the largest dam in Southeast Asia with a catchment area of 14,750 km^2. Most of the power generated (maximum 2400 MW, running 6 turbines) was originally planned to be transported to Peninsular Malaysia via 665 km of overland high voltage power lines and 670 km of underwater power lines. The controversies plaguing the dam are mainly environmental and social, but also concern the high risk to which investors are exposed.

The project was first proposed in 1962, and some initial work began in the 1980s. It was suspended indefinitely in 1990 due to 'environmental and social concerns', but resurrected again in 1993. In 1994, the local company Ekran Berhad was awarded a turnkey contract to manage the project, in a joint venture that included the State Government of Sarawak, Tenaga Nasional Berhad, Sarawak Electricity Supply Corporation and Malaysia Mining Corporation Bhd. The international tender was awarded in June 1996 to an international consortium led by the Swedish-Swiss firm Asea, Brown Boveri (ABB), together with Companhia Brasileira de Projetos e Obras. The firms Lahmeyer (Germany) and Harza (USA) carried out feasibility studies and were responsible for dam design and project supervision. Construction subsequently began in 1996, but was postponed a second time in 1997 – due to the Asian economic crisis – and the contract with ABB was withdrawn (see Box A1.1).

In mid-1999, work resumed on the river diversion tunnels, a major component of the project, which has since been completed, and the involuntary resettlement of about 10,000 people. The Malaysian government has taken control of the project and negotiated financial settlements with the firms involved. The underwater transmission concept has been abandoned, and the Malaysian government is exploring the possibility of sales of electricity to Brunei and Indonesia. While it had appeared likely that the project would be scaled back from its 2,400-MW capacity, the Malaysian government announced in February 2001 that it had decided to complete the project on its original scale. This decision has been reversed yet again, and it now appears that a scaled-down version will be pursued. Bids were received in July 2002 for the main construction work for the dam, and an overall contract was expected to be awarded by the end of 2002. Since initiation, cost estimates rose from an initial $3.8 billion in the late 1980s, to $7 billion in 2001.

The secrecy surrounding the project has fuelled criticism. Feasibility studies and reports on the Bakun project commissioned by the government have been classified under the Official Secrets Act, making it a criminal offence for anyone to see them or use their information. Apart from limited consultation with indigenous people there has been little or no dialogue with the public.

Risks

An independent investment analysis carried out in 1996 (Delphi, 1996) concluded that the risk to investors was very high, certainly in relation to relatively low returns of only 11.5% (contrary to original rates of return of at least 16% projected in 1983). The main risks to investors were related to:

- Probable cost overruns due to geological problems (identified by the World Bank, among others)
- Over-optimistic power sales forecasts that do not take into account the probable vagaries in hydrology, dam leakage, local climate and active storage area. Global climate change – likely to result in increased floods and more severe droughts – creates further uncertainties and risks.
- Negotiated Power Purchase Agreements (PPAs) that are reasonable under present conditions, but could represent a major liability to investors if the power market is liberated.
- Uncertain long-term performance, as this depends on various factors such as dam leakages, geological stability, sedimentation rates and the durability of undersea cables.
- Additional risks (e.g. dam failure, dam-induced seismicity, overtopping and other liabilities) for which only limited insurance is likely to be available, leaving many risks to be borne by the investors themselves.

Other analysts report that the regional market for hydroelectricity is limited, as thermal plants present the oil-rich states of Sarawak and Brunei, and the Indonesian provinces of Kalimantan with a much cheaper alternative.

Social and environmental concerns

Construction of the Bakun dam has resulted in the involuntary resettlement of about 10,000 indigenous people from various ethnic groups – Kayan, Ukit, Penan, and Kenyah – originally living in 15 longhouse communities in the Ulu Balui and Ulu Belaga areas. Once completed, the dam will inundate the villages, lands, spiritual homes and ancestral graves of these people.

From 1998 to 1999 about 10,000 people were resettled in Sungai Asap, about 30 km from the dam site. The displaced persons are represented by a People's Committee, which has met with government officials on various occasions to voice their concerns. In 2000, the committee claimed that many of those resettled had not been given due compensation for their traditional lands and farms. They also expressed unhappiness about the area of land given to them in their new settlement, the high price of housing, a drop in incomes, and a lack of job opportunities following the move. They were also disappointed about the poor basic infrastructure in the Sungai Asap area.

Environmental concerns have mainly focused on the loss of rainforest, as 73% of the 700 km^2 dam site was covered with primary rain forest when clearing began in the 1980s. Critics claim that, due to (illegal) logging practices, only 5% of primary forest was left in Sarawak by the mid-1990s, and that the Bakun project further aggravates this situation.

Anti-Bakun lobby

During the 1980s and 1990s, there were many public protests against the construction of the dam, both by environmentalists and on behalf of indigenous people. These protests were both local and international, with the international lobby mainly targeting potential investors. In the United Kingdom it became known that several of the major investment houses were known or believed to have major holdings in Ekran Berhad, including Perpetual Investment Management Services Ltd, Invesco Mim, Abbey Life, Barclays (BZW) and Scottish Equitable. As part of an international lobbying effort, letters were sent to these and hundreds of other institutional investors and fund managers in February 1997 warning them of the financial, environmental and social risks involved in the Bakun project.

In the meantime, solid arguments had won over most people. Most investors considered the Bakun project to be too risky to form an attractive investment, and The Economist warned against "misguided infrastructure projects, such as the Bakun dam in Borneo" (29 March 2001).

While domestic Malaysian banks and investors were seen as the main source of funds, funding from foreign private sources were also clearly a priority for the originally proposed project. However, the effort devoted to obtaining foreign private funding illustrates the obstacles encountered in financing such a project without subsidies.

It has often been argued by dam opponents that large dam projects could not be implemented without large subsidies from governments or multilateral development banks. The difficulties encountered by the Malaysians in getting foreign private investors interested suggest that this is the case here.

Box A1.1
A company stumbles: ABB and the Bakun dam

The Swiss-Swedish engineering firm Asea - Brown Boveri (ABB) was created by a merger in 1988. With divisions specialising in power generation, power transmission and distribution, financial services, transportation and industrial and building systems, ABB made steady profits and witnessed a 5-fold increase in its share value in its first eight years. For 1996, ABB reported orders of US$36.3 billion, a net income of US$1.23 billion, revenues of US$34.6 billion and a return on equity of 22.2%. For the first half of 1997, the company reported orders up 14% and net income up 2%, despite low demand in Western Europe and adverse currency exchange rates. Much of the growth was accounted for by just one order: a $3 billion contract to supply six 420-megawatt hydro generators to the Bakun Hydroelectric Project in Malaysia – at the time the largest order ever received in ABB's history.

In September 1997, ABB announced the termination of its contract with the Bakun Hydroelectric Corporation (BHEC); at the same time BHEC issued a press release stating that "an agreement is no longer possible" in a long-running dispute over the terms of its contract with ABB. The dispute centred on cost overruns and general financial difficulties, as BHEC found it impossible to raise project finance in the face of huge potential liabilities. ABB had been warned of the risks by Malaysian and international human rights and environmental activists and informed that it risked "both losing a huge sum of money and gaining many years of atrocious publicity."

After terminating the contract, ABB had to write off about US$100 million in losses, and the company's senior management had to face shareholders' wrath and doubts about their corporate judgement in what was widely perceived as "ABB's failure to heed warnings about the flimsy financial viability of Bakun." In terms of their share of the world hydroelectric market, ABB slipped from first to third position behind rivals General Electric and Siemens.

In 2000, ABB sold off its hydro division to the power sector specialist Alstom, and refocused from conventional power generation projects in favour of sustainable programmes such as wind power and high- efficiency gas-driven micro-turbines.

Annex 2: Mitigating environmental impacts

A.2.1 Physical aspects

Water quality

Riverine water quality may be affected, eliminating fish species downstream, due to the construction and operations of a dam or reservoir. These effects may include lowering of water temperatures and oxygen levels, eutrophication, and changes in silt load. The temperature of released waters can be controlled to some extent by having multi-level outlets in the reservoir, or by adjusting the timing of releases. Similarly, the installation of air draughts in the water-release ports can boost oxygen levels by aerating released water. Thorough removal of organic matter from areas prior to inundation can significantly reduce initial eutrophication issues. However, removal programmes are never 100% successful and there is always incoming organic matter to deal with, entering from main channel and local tributaries. Stabilisation usually follows after one to two decades, as long as there are no major changes in land use in the basin. River basin management programmes focusing on maximising soil protection and minimising erosion can further reduce potential eutrophication problems, while at the same time reducing siltation and boosting the useful life of the dam.

Hydrology

Dams and reservoirs, by their very nature, modify natural flow patterns, changing both the volume, season and timing of discharges, and altering the natural dynamics of a river. Concern about such impacts on the ecology of regulated rivers has encouraged efforts to quantify and preserve the flow patterns required for the survival of aquatic species. Aquatic ecosystems and wetlands in general are best preserved under natural, pristine conditions. Flows maintained in regulated rivers for the sake of preserving semi- natural conditions, functions and ecosystems, called 'environmental flows', can partly compensate for impacts from dams.

Environmental releases of water mean foregoing other benefits, and optimising flows. Finding a balance between demand (for e.g. electricity and irrigation) and downstream environmental requirements is a complicated and often daunting task. Detailed information is needed about the requirements of aquatic ecosystems, including water demand, seasonal dynamics, and sediment patterns. We also need to know how this all fits together and interacts. In addition, many variables need to be monitored, including reservoir water levels, rainfall, soil moisture, and flows from tributaries. Lastly, there may be resistance from existing beneficiaries of the dam facility, as irrigators, operators of hydroelectric power stations and downstream farmers may object to a re-distribution of perceived benefits.

Many floodplain and river delta ecosystems do not require only steady flows, but are dependent on regular floods for their maintenance or survival. Managed flood releases present an option (Box 16).

Sediments and morphology

Sediments are normally trapped in dams and reservoirs, reducing the useful life of a dam, and multiple dams are known to remove 99% of sediment. Less sediment moving downstream inevitably leads to scouring and erosion of the river channel and banks, affecting river vegetation and damage riverbank structures such as roads, buildings and bridges.

Dams can be designed to allow periodic flushing of sediments, but the effectiveness of these mitigation measures is limited. Firstly, the process involves releasing water that could have been used for other purposes (e.g. generation of electricity or irrigation), and there is a general reluctance to 'waste' water for this purpose. Secondly, the process involves releasing sediment in a more controlled way than under more natural circumstances, and this is not distributed to the same extent as under peak flood conditions.

A.2.2 Biological aspects

Wetlands & biodiversity

Dams directly affect downstream wetlands, as the incidence and severity of flooding decreases, and water quality and sediment loads are altered. "No net loss" regulations are sometimes presented as a means for preserving wetlands. Under such programmes, new wetlands may be artificially created elsewhere after loss is incurred due to the creation of a storage reservoir upstream. The value of such newly created wetlands, however, is limited, as they are usually unstable and species-deficient, especially in the initial stages. No-net-loss programmes are usually ineffective in preserving biodiversity, unless large investments are made in the translocation of species to the newly created sites. Loss of habitat in reservoir areas has in some areas led to programmes for mass trapping and relocation of wildlife species prior to inundation. An evaluation of such programmes at the Kariba (Zambia-Zimbabwe) and Tucurui (Brazil) dams found that there was little or no benefit, as no new habitat was "available" and translocated wildlife competed with resident wildlife at new sites. Other alternatives include "off-setting", involving the setting aside or planting (in the case of forests) similar nearby habitats as protected areas, and establishing trust funds for conservation efforts.

Exotic species and habitat change

Dams eliminate peak discharges that naturally flush river systems. This may allow certain species to gain a foothold, or cause others that normally occur at low levels to proliferate and invade large areas. This potential problem can be managed to some extent by allowing periodic controlled or managed floods (Box A 2.1), although this may not be popular with all downstream inhabitants, including users of water resources. Non-indigenous species may also be introduced in dams and reservoirs and then inadvertently released into the river system. The only way of dealing with this is by incorporating the management of non-indigenous species into dam operation, with staff trained in identifying such species, preventing their (accidental) introduction, and removing them when this is an appropriate response.

Aquatic weeds and/or algal blooms are often linked with eutrophication, and management should involve tackling both the species involved and the underlying water quality issue (see above). Aquatic weeds can be manually removed (e.g. with mechanical floating harvesters), sprayed with herbicides (not recommended, as even relatively benign compounds such as Glyphosate affect water quality, aquatic life, and end users), or by using biological control. Waterhyacinth has successfully been managed in recent years by introducing two species of weevil – Neochetina eichhorniae and Neochetina bruchi – both in reservoirs and in large natural systems accidentally infested with

Box A2.1
Managed flood releases

A managed flood is defined as a controlled release of water from a reservoir to inundate a specific area of floodplain or river delta to maintain (or restore) downstream ecosystems in some desired state that sustains ecological processes and natural resources for dependent livelihoods. At a workshop on Managed Flood Releases held in Lusaka, Zambia on 13-14 March 2001, a set of guidelines were defined for managed releases, involving the following steps:

Feasibility stage:
- define objectives for flood release;
- assess overall technical and financial feasibility;

Design stage:
- develop stakeholder participation and technical expertise;
- define links between floods and the ecosystem;
- define flood release options;
- assess impacts of flood options
- select the best flood option

Implementation stage:
- design and build engineering structures;
- make releases; and
- monitor, evaluate and adapt release programme.

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waterhyacinth. The approach is not without risk, as once the programme is successful and the weed species declines, the control agent may seek an alternative host. In the case of Lake Victoria in East Africa, the weevils introduced to control waterhyacinth subsequently infected lakeside cassave plantations.

Fish migration, passes and habitat fragmentation

Dam construction, especially multiple dams along a single river, can cause habitat fragmentation and isolation. This may form a barrier for fish migration, and lead to the demise of migratory species, and a loss of fisheries and biodiversity. To overcome this problem and mitigate losses, the use of fish passes has been introduced in dam construction, especially during the past 50 years.

Fish passes are a technical means for allowing fish to migrate past a dam or reservoir by locally reducing the flow rate, and may consist of series of stepped ponds (so-called "fish ladders"), vertical slots, or even sophisticated "fish elevators". Where effective, they can significantly reduce the impacts on the migration of species such as salmon and sturgeon moving upstream. However, recent reviews (e.g. WCD, 2000) show that few fish passes have been fitted in most large dams, even in wealthy countries such as Australia and the USA. Even where they have been fitted, their effectiveness is often low due to faulty design, as this must take into account - among other things - the size and nature of the migrating fish, the discharge of the river, and the size of the dam. Owing to a scarcity of information about tropical fish, designs in tropical countries have often been based on educated guesswork and experience from temperate regions, often resulting in failure. In areas where they are effective, fish passes are not without risk as they may be fitted with nets and thus abused as elaborate fish trapping devices.

M DÉPRAZ, WWF-CANON

Fishing at dusk Mekong river Vientiane, Laos

Living Waters
Conserving the source of life

This Guide was prepared with the assistance of ARCADIS Euroconsult, P.O.Box 441
6800 AK Arnhem
The Netherlands
www.Euroconsult.nl
e-mail: ICMS@arcadis.nl

ARCADIS EUROCONSULT

DamRight!
WWF's Dams Initiative
Panda House
Weyside Park, Godalming
Surrey, GU7 1XR
Tel: +44 (0) 1483 426 444
Fax: +44 (0) 1483 426 409
e-mail: dams@wwf.org.uk
www.panda.org/dams

WWF International
Avenue du Mont Blanc
1196 Gland
Switzerland
Tel: +41 22 364 9027
Fax: +41 22 364 0526

WWF

WWF's mission is to stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature, by:
– conserving the world's biological diversity
– ensuring that the use of renewable natural resources is sustainable
– promoting the reduction of pollution and wasteful consumption.

Conserving the source of life