"Role of Dams on the Development and Management of River Basins. A General Review"

Rough Version

The problem is not the dams.

It is the hunger.

It is the thirst.

It is the darkness of a township.

It is township and rural huts without running water, light or sanitation.

It is the time wasted in gathering water by hand.

There is a real pressing need for power in every sense of the word.

Nelson Mandela

Contenido

1. INTRODUCTION

Water :" The Life Blood of Mankind"

Without dams human progress does not occur. History has proven this. There are 45,000 large dams worldwide serving humanity by providing water for domestic, industrial and agricultural use, generating electricity and attenuating floods. At the same time, dams require measures to minimize and mitigate impacts on local populations and ecosystems. As society's needs for water, electricity and food increase, new dams will be needed. For this need to be met, future dams must be designed and operated in a sustainable fashion, recognizing the potential for existing projects to be made more productive and for other options to be developed (III World Water Forum, Kyoto, 2003)

As Gupta said "water is the "lifeblood of mankind", it is a limited and finite resource, unevenly distributed in time and space, and already scarce in many areas. Millions of people round the world walk kilometres each day to bring water for survival. On the other hand, there are millions and millions of acres covered with water and water everywhere but not a drop to drink (roughly 93% of the water on earth is seawater)." (Lecornu, 2002).

The total amount of renewable water resources is 40,000 km3; however the available amount is only 12,500, meaning 30% (Berga, 2004).

Dams are made by men either to divert water from its natural stream or to save it for later release. In that way, human activity modifies nature. This is the function of dams, to manage water streams and make them more useful to human needs. That management creates impacts on nature as does any human use of natural resources.

These reservoirs provide 3,500 Km3 of water for human use, to be added to the 9,000 that could be obtained from the river natural regime.

Managing water streams to satisfy human needs greatly enhances universal public health and economic development, but also impacts the natural environment.

In any debate about the benefits and impacts of the use of natural resources or the development of infrastructure, and the role that they play concerning human welfare, the starting point must be that the development of mankind, such as we conceive it, is by definition a severe modification of nature, in ways that we are not always capable of accurately forecasting.

This document provides a reflection on the role played by dams as a key to the stimulation of development, especially during the 20th century, in order to identify their potential to solve many of the problems faced by mankind, particularly those concerning water resources and energy.

Thus, learning from past experiences, the role of dams in facing the 21st century challenges could be illuminated.

Future documents will address technologies and specific matters, such as drinking water supply, irrigation, hydropower, etc.

In the meantime ICOLD is developing an overview and analysis of the environmental impacts caused by the construction and operation of large dams. This task is being carried out by specific technical committees and various national committees. In this paper, we haven't intended to make a thorough analysis on the subject, which doesn't reduce their importance.

ICOLD (Dams and environment) mandates to its members:

"a) Concern for the environment, including both natural conditions and social aspects, must be manifest from the first planning steps, throughout all phases of design and implementation, and during the entire operating life of a project."

OBJECTIVES

The aim of this report is to explain the role of dams in the development of river basins. We have stated that dams are simply tools for the management of water resources in river basins.

ICOLD advocates the principle that society must: 'balance the need for the development of water resources with the conservation of the environment in a way which will not compromise future generations (...)'. The committee on "The Role of Dams in the Development and Management of River Basins" was established in 1999 with Terms of Reference to widen the scope of dam decision making and management to a broader perspective by studying the impact of dams on entire river basins.

Water is essential for life on this planet, the basis for human society, and all living ecosystems and habitats.

The world today is subject to increased pressure on land and water resources caused by increases in population and industrial development. Less than 1% of the planet's water is available for human consumption. More than 1.2 billion people have no access to safe drinking water.

Millennium development goals mandate a reduction in that figure by 2015. However, by 2007, it had grown and no tendency toward reduction has been observed. (UMA Mexico, 2007)

Dams have been built for thousands of years – to manage flood waters, to harness falling water for power, to supply water for drinking and for industry, and to irrigate crops. At least 45000 large dams have been built as a response to meet energy or water supply needs. Dams have made important and significant contributions to human development, and the benefits derived from them have been considerable. They are indispensable in present society. Water control structures, including dams, serve a wide range of purposes for different stakeholders in society, including domestic users, farmers, and industries.

However, reservoirs have direct and indirect social and environmental impacts. Since the social and environmental costs of dams have not always been fully accounted for in economic terms, their true benefits and costs are often unclear.

ICOLD is aware of that problem and advises its members that "any tendency to overstate the benefits and understate the costs must be strictly avoided" (ICOLD Dams and Environment).

It is not surprising that dams have become the focus of debate regarding sustainable economic development. Essentially simply stating that adverse environmental and social impacts are outweighed by environmental and social benefits is no longer acceptable.

Dams have fragmented half the world's rivers into stair steps of reservoirs but at the same time they have satisfied the needs of humankind and allowed progress of society albeit under a model that could be put under discussion. Although dams have displaced millions of people from some areas, they are also stemming the massive emigration of young people seeking better opportunities (Andonov et al., 2006).

Many point to the social and economic development benefits of dams such as providing electric power, flood control, irrigation or domestic water supply. Others argue that project sponsors frequently downplay the adverse impacts of dams, including the potential burden of increasing foreign debts, forced displacement of people, irreparable damage to the environment, and inequitable sharing of costs and benefits. Often neither the complete costs nor value of benefits are properly documented. The options of doing nothing or choosing other alternatives are also not well documented. It is therefore not surprising that dams have become a focus of debate regarding sustainable economic development.

Mankind faces critical challenges to its own survival, caused by unprecedented increases in population with a universal desire for improving living standards and quality of life. Increased recognition of the need to preserving the life-supporting functions of nature exacerbates the situation. The challenge is to balance the need for increasing water and energy supplies with the inevitable adverse effects on the environment. Mankind needs to rethink the management of freshwater resources and the detrimental side effects of our choices.

The main aim of this committee is to provide insights so that, in the future, ICOLD can more effectively address the environmental and social aspects of the development and management of river basins, which are nowadays considered as the basic units for planning and management.

This report focuses on the process of integrated river basin planning and management that has become an extremely diverse process involving a wide range of economic, ecological and social goals. River basins play a vital role in sustaining ecosystems and, as the major source of freshwater, are vital to mankind. Good management for sustainable development is the goal with all of its social, environmental and economic dimensions.

This report begins with an analysis of the role of dams in river basins and their contribution satisfying people needs. Afterwards we deal with the main effects of dams on various fields of concern, and how the impacts on the environment can be assessed. Social and economic effects both direct and indirect must be included.

Later integrated river basin management is dealt with, considering the basins as planning units for the development and management of water resources.

Finally decision taking processes and stakeholders participation in different stages of planning, design and operation, are discussed.

A basic tenet of IWRM in IWRM is to learn from others' experience. The report includes many interesting examples from different countries.

THE PROBLEM IS NOT THE DAMS

A balanced view of the role of dams is necessary today. It is just as unacceptable to be an irrational detractor of dams as it is to have a thoughtless pro-dam stance. Neither of these views is based on a balanced knowledge of the role of dams.

As the quote by Nelson Mandela on the cover states, "the problem is not the dams". It is rather the more pervasive problems such as hunger, thirst and poverty.

Poverty throughout the world today is characterized by a lack of clean water, food, health assistance and energy supply; all of these issues require water that is dependable in quality and quantity. Less developed communities, where poverty is more widespread, also suffer from the natural risks of floods and droughts.

Water is an essential element for human existence, health and economic development. Projects that include water supply improvement through regulation of stream flows and production of energy as key elements of development are, therefore, essential tools for the betterment of humankind. Benefits of such projects include water supply for irrigation, drinkable water, sewage, and energy supply.

PROBLEMS	SOLUTIONS	TOOLS
Poverty Starvation Thirst	Improvement of water supply through stream regulation Increase in energy	Dams Wells Irrigation projects

Floods	supply,	Recycling key resources
Droughts	Protection against floods and droughts,	Resource management
Lack of energy	Enhanced education	Hospitals
Illnesses	Health assistance	Medicine
Lack of social progress		Electrical generation plants
		Desalination

Table 1. Problems, solutions, tools

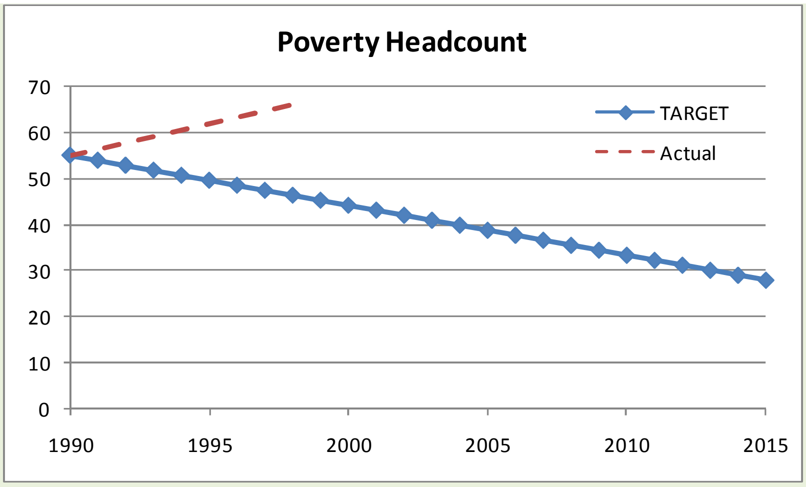
However, in order to consider potential solutions, how do we define the costs? And, how do we evaluate the benefits? There are not only direct and indirect project costs for the community, but also social and environmental costs. For instance, how can we evaluate the benefits of water or energy in a community that lacks these things for subsistence? 'Sustained underdevelopment', as defined by professor Lafitte[1] (IHA, 2001) cannot continue to be accepted by the global community.

Millennium goals are not restricted to the cases in which they are profitable; on the contrary, they have to be considered as an ethical command.

Currently, in most severe areas, indicators of Millennium Development Goals are regressing. If we don't want to renounce the target, we have to start recognizing this fact.

The government of Malawi and its development partners are reorienting their work around the Goals. Despite the commitments to reducing poverty and advancing other human developments, Malawi is already falling short in a number of ways. Progress in the implementation of the Millennium Development Goals (MDG) is most of the cases out of track. Malawi has seen high school drop-out rates, low access to basic health care, deteriorating environment and life expectance plummeting due to HIV/AIDS.

[1] "The result of decision-makers hastily imposing the 26 WCD guidelines (making them regulations) would be that the process of studying and constructing dams would become extremely lengthy, costly, and even more uncertain. Financing organizations might only support countries applying these rules, some aspects of which are impractical. This would initiate a process of sustainable under-development, and may increase divisions between countries that have developed reservoirs and those that have not." IHA reaction to the WCD report (Lafitte et al.) Feb, 2001.http://www.dams.org/report/reaction/reaction_iha2.htm.



Malawi: Millenium development goals report. 2003

It is not easy to translate the costs and benefits of social development solely in monetary terms. Ultimately, the sustainability of any resource development must be addressed because it is now recognized as a crucial global environmental factor.

A way to compare the benefits and the costs of different alternatives is proposed below. It consists in evaluating the economic and social benefits (both direct and indirect) per unit (1 cubic metre of water or 1 kilowatt hour of energy) and an alternative's social, economic and environmental costs are similarly evaluated.

We can introduce two different criteria: above minimal standards and below minimal standards. In the first case the community can opt to leave things as they are. However, in the second case, leaving things as they are is inadmissible on the grounds of human dignity.

Since there is a wide range of tools for resolving these basic problems, significant effort may be needed to determine the optimum plan. The list of "tools" includes both infrastructure and organizational tools such as, construction of flow regulation facilities, exploitation of underground water, residual water recycling, improving the efficiency of water use within existent systems, sea water desalination, surface water transfers from surplus basins, optimised supply and demand management and education in resource conservation. Throughout, the decision making process, decision makers need to be aware that there may be a cost that the community may not be able to accept, whether it be social, environmental or economic.

All of these tools should be simple elements in a development program. We should not have a preconceived concept about which project (or combination of tools) is best. We should attempt to choose the alternative that provides the community with the greatest benefits while exacting the lowest cost, including social and environmental costs. In some cases, a dam or a canal may be the tool that constitutes the best option; in other cases, they may not be the most desirable. A key issue is how to explain to the community the real costs and benefits in a clear and unbiased way.

The imperative is clear: any tool that is used to solve a problem (whether a dam, a canal, a series of wells, or operational changes) must simply be evaluated as part of a broader development project. The best option will result from comparing not only economic costs but social and environmental ones as well. The dam is neither the problem nor the goal: it must form part of the broader context.

This broader development project must be responsible for its benefits as well as its costs. Its components (tools) must be those that offer the best solution to the cost-benefit equation.

The decision-making processes need to involve the procedures to select the optimum tools in each case.

From the technical community's point of view, one simply cannot dogmatize about the complexities of human organization. Therefore, the recommendations to decision-makers will always be subject to the rules that regulate the social coexistence, both national and international, and with respect for each country's national sovereignty.

Chapter five will deal with the IRBM approach (integrated river basin management) as a means of management within the concept of IWRM (integrated water resources management) and the responsibilities and actions of the different agents involved.

2. THE ROLE OF DAMS

INTRODUCTION

WHAT DAMS ARE FOR

Civilizations have used dams for thousands of years for water supply, flood control, navigation, and in more modern times, hydroelectric power generation and recreation. Sanitation and environmental remediation functions can be also added. Even dams developed for a single purpose have incidental benefits.

On the other hand dams basically alter rivers and the management of water resources frequently entails a relocation of the derived benefits.

With a plain and direct language, we shall survey the functions of dams, which we shall identify through a simple review of the huge number of papers that have been written about tem as a prior step before identifying their benefits.

Dams allow us to

- Divert water from basins to the places where it is needed;
- Create waterfalls that give us clean and renewable energy to be profited;
- Regulate river flows and store the spare water at a given moment in order to use it later: they regulate flows;
- Guarantee our water availability for drinking, sanitation, fire fighting, irrigation and enjoyment;
- Improve river navigability;
- Protect us from river floods;
- Recharge aquifers;
- Use the environment recreationally;
- Compensate the underground water levels reduced by the progressive lost of wet zones and over pumping of aquifers; and
-

Two strategies are used to assess the performance of dams in producing the societal benefits:

- Analytic models

- Empirical experiences

Later we will identify recent developments of potential simulation models which try to identify and estimate benefits and costs. First it is necessary to point out the diverse purposes and benefits derived from dams.

Currently, we would propose to make that determination using a broadly based investigation that would consider:

- The water resources available – stream flows and precipitation patterns in the basin including underground flows.
- Environmental needs within the basin (fisheries, terrestrial wildlife, riparian habitat, etc.)
- Economic needs of the community
- Economic benefits of alternative solution systems (including the increased value of land under the proposed scheme)
- Economic impacts of alternative solution systems (can the community afford it?)
- Social needs of the community (improvements in lifestyle, health and longevity)
- Social impacts of alternative solution systems (displacements, loss of traditional way of life)

In the past International Symposium "Dams in the Societies of the 21th Century", held in Barcelona (2006), some innovative proposals on quantitative analysis based on mathematical models of the effect of infrastructures in regional and national economies were presented. Two examples concerning Laos and Iran are introduced in the next boxes.

Laos (Tada, 2006)

Generally we evaluated economic aspects of dams by means of cost performance or Internal Ratio of Return (IRR) and seldom studied macroeconomic effects of dams on whole countries.

The case study presented for the Laos People's Democratic Republic represents an investment about 50% of GPD (Gross Domestic Product) and it is evaluated by mean of macroeconomic models.

On the average NT2 (case study) GDP rises by about 7% because the project.

Iran (Noori et al.*, 2006)*

Several analytical economic tools are available to asses direct and "ripple" (secondary and tertiary market) effects on the economy of the region or nation, not only for cost and benefits but also accounting for risk and uncertainty and discounting the future.

Using macro-economic models that consider extensive data and the huge investment to be carried out, the results can be more closely foreseen.

As shown in this report, patterns of water use were changing in parallel with the history of humankind.

- Early periods: social lives are significantly modified by natural events and conditions, among them the natural regime of water resources.
- Then human activities became less dependent on the location of water resources, even providing water from great distances. This is the construction oriented stage.
- Finally a comprehensive oriented water management stage must be adopted because of water quality deterioration and over-exploitation of aquifers.

At that last stage positive and negative impacts are taken into account choosing solutions both structural as non-structural measures as dams, transfers, as well as regulation and economic instruments.

Models must also evaluate negative (costs) and positive (benefits) aspects of the foreseen activities related to specific economic objectives. From national point of view, shadow prices are totally different from market values.

The three types of macro-economic models are Input-Output (I-O), social accounting matrix (SAM), and Computable General Equilibrium (CGE). Last one let us to assess secondary and tertiary effects on the economy of the region.

Even as encouraging advances in this direction are observed, we must realize that we are still far from building an entirely accurate prediction model of all of the integral effects on the economy. Dealing properly with the internalization of indirect costs and benefits is even more difficult.

The unavailability of a reliable holistic model forces us to carry out a partial analysis but, with that awareness the results can be rationally discussed.

QUANTIFYING THE ROLE OF DAMS

On the other hand, after modelling and forecasting the effect of each alternative solution in a generalized modelling scheme, we would need to evaluate the final role of any proposed dams in quantitative terms.

In theory, their role could be quantified as the impact that they induce on some specific indicators of the overall socio-economic system. If we estimate the state of the overall system through any index, for instance HDI -Human Development Index-, we could say that the difference between this index with and without dams in the locale is the quantitative role that dams are playing there. The estimate could be stated in terms of this difference per unit of water or energy.

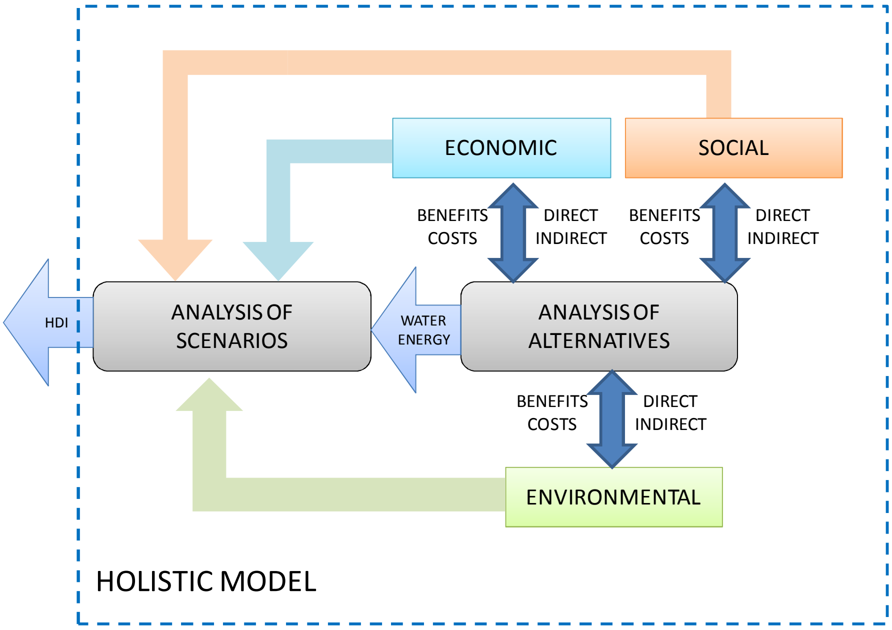


Figure: Social, Economical and Environmental issues are related not only with alternative proposals but also with predicted scenarios.

If we are talking just of water supply for meeting people's needs, the role played, as identified by the index, for the last supplied cubic meter of stored water would be the marginal role in that state of development. It would then be necessary to identify the real costs for every alternative, taking into account social and environmental costs.

But we want to be able to compare different alternatives that produce the same effectiveness in solving people’s needs and promoting the societial changes (for instance 1 m^3 of supplied water or 1 supplied KWh). Sometimes comparisons have been made among alternatives that do not attain the same goals; such comparisons are erroneous. A valid comparison of alternatives needs to consider their effectiveness and efficiency in providing the same level of desired results. This should be obvious but has not always is taken into account when alternative proposals are considered.

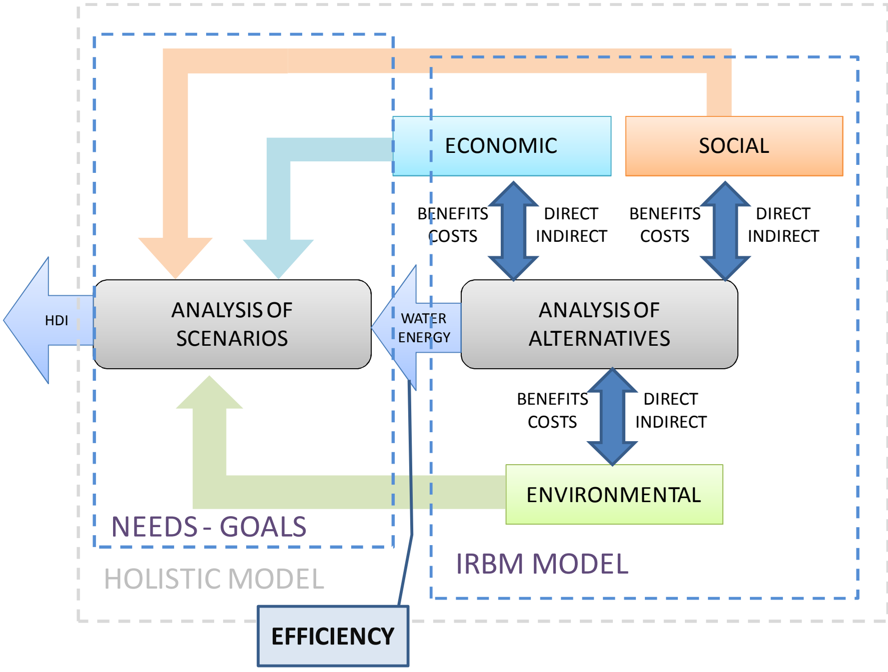


Figure: Isolating subsystems using efficiency of proposals means certain loss of congruency.

Special attention must be given to the levels of success reached in meeting goals when formulating and considering alternatives.

Assessing the impact of different alternatives on HDI or other general indexes, would be the best way of comparing them. However, the difficulties to carry out such predictions must be realized.

ICOLD committee of "The Role of Dams on the Development and Management of River Basins" is about to release an independent bulletin analysing the worldwide available models used in IRBM studies as a complement of this general report. Most of the models are contrasted in terms of technical and hydrological analyses for water resources planning or management purposes. A few provide suitable mechanisms for linking with economic forecasting models but none is the perfect holistic model to predict expected HDI (Human development Index).

THE EMPIRICAL APPROACH

The other evaluation strategy is the empirical approach. As part of such studies, the planners should understand the history of water management in developed countries to understand how the planning process has evolved. The role of dams in many countries has been and is still a changing one that will evolve as social-economical conditions change and with increased understanding or appreciation of the needs of the natural environment. A short survey of our recent developing past will provide a clear illustration about the role that dams have played and how they have contributed to our development, from providing basic necessities to endowing the benefits of a more developed society. As an example, the history of water development in Spain is briefly described in order to take advantage of successful experiences and learn from possible mistakes.

The Spanish experience (Cifres, 2002)

Let us take the Spanish case as an exemplary *a posteriori* illustration about the role that dams can play in the different developing stages that communities go through. The hope being that our experience will be able to be imported by people that still have to travel a similar journey.

Potentially Spain is a model of dam use, which should be exported for several reasons:

- Spain can be thought as a developed country.
- It does not enjoy a wet climate as most other developed countries, sharing semi-arid conditions with a lot of developing countries.
- It has enjoyed dam benefits for nearly two thousand years.
- It manages the resources in the realm of hydrographic basins.
- It has a participatory evaluation system of environmental impact in a politically democratic structure.
- Dam projects are inserted into a hydrological planning framework which has wider goals.

Historically, dams in Spain, beginning with the Roman empire and extending through the middle ages and up to the modern age, were derivation ones, *i.e.* designed with the purpose of storing small quantities of water for later domestic supply.

Beginning with the twentieth century, dams also provided the possibility of developing local electrification. Thus, they made it possible to improve the quality of life and modify habits and economical growth at a time when the population was predominantly rural.

Irrigation had been limited to natural river regulation and by the difficulties of transporting the crops to consumer centres. The incipient increase in the number of regulation reservoirs during the first half of the twentieth century along with improvements in transportation contributed to the development of irrigation and modified the social-economical structures in the countryside.

The 1950's and 1960's brought about two very important qualitative changes in the role of dams. First, there were resources available that made possible huge regulation works and started a massive development of irrigation schemes. At the same time, long distance transmission of electrical energy became feasible. These advances enhanced the role of dams in resource regulation and for energy production at locations far from consumer centres. Large regulation dams promoted by the government and electric companies to produce electrical energy were a determining factor in the Spanish economic advance.

But this energy supply being available wherever needed had another effect. As irrigation demand increased above the regulated water flow supply, an increase in groundwater withdrawal resulted. Such groundwater schemes were not always correctly evaluated, and often lacked sustainability.

As development progressed and the standard of living and the economic value of the country increased, society demanded more security for people and goods, especially greater protection against floods. Dams again played a major role, and many flood control projects appeared.

In the 1980's a new concern arose about water resource use: some aquifers started showing signs of over pumping. Legislation was adopted to promote the use of multi-purpose reservoirs. Some wet areas, that had been drained and developed, suffered from such effects and the aquifer levels fell, making their use more expensive and in some cases not-sustainable.

These circumstances involve a new role for dams in a future that has already begun, involving the construction of dams with environmental correction as a goal: recovering ecological flows, aquifer recharging and maintaining minimum reservoir levels.

As a summary, the six generations of dams have played different roles: local water supply, local electric powering, irrigation growth as a basis for economic development, regional scale electric supply, flood control and environmental mitigation. All of these according to the needs and musts of social and economic development. Nowadays, the economic value of the water that is regulated by reservoirs in Spain can be estimated at 28,000 million USA dollars per year, which represents nearly 6 % of Spanish Gross National Product (Berga, 2001), without including the benefit from flood routing. Flooding in Spain 'costs' 30 lives and 500 million dollars in material direct losses per year. Today the Spanish example of dam use and planning should be understood as being directly applicable to several developing countries (Berga *et al.*, 2002).

RENEWABLE ENERGY GENERATION

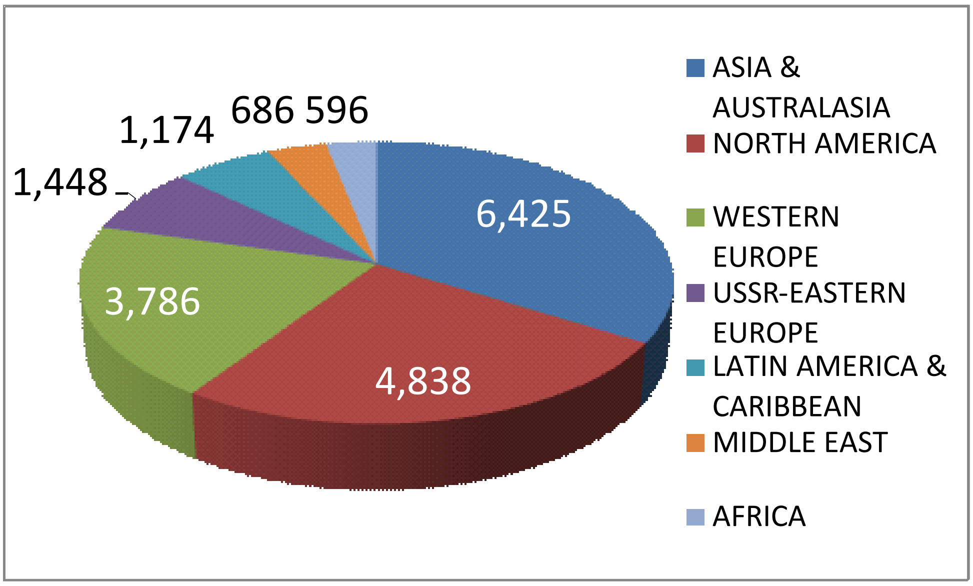
Fossil fuels represent 75% of the world's energy production.

The greenhouse effect and global warming demand the substitution of these energy sources for clean energies (without emissions of CO^2 and other gases) that can also be renewable.

Currently only biomass and hydroelectric generation represent significant quantities of clean renewable energy. Solar and wind energy certainly have important roles for the future although the total of their development is expected to be relatively small in the near term.

Hydroelectric energy represents about 20% of the energy produced on the planet (2,800 Twh/year) and it is the biggest source of profitable clean and renewable energy. More than 8,200 dams have energy production as their main objective. Of this total, 80% of the energy is produced by 2,000 large dams. And, 90% of the total was developed after 1950, accelerated by advances in energy transport technology. More than half of the total is in the most industrialised countries, which have developed 70% of their potential that is economically feasible. Worldwide, more than 50,000 small stations (small hydro) provide local supply. In the future many additional small stations should be able to alleviate underdevelopment and poverty. Moreover, dams with hydroelectric stations enable efficient power grid regulation and collaborate to meet peak demands.

The total electric energy produced in the world is 18,953Twh/year (2007), distributed as is shown in the following figure:

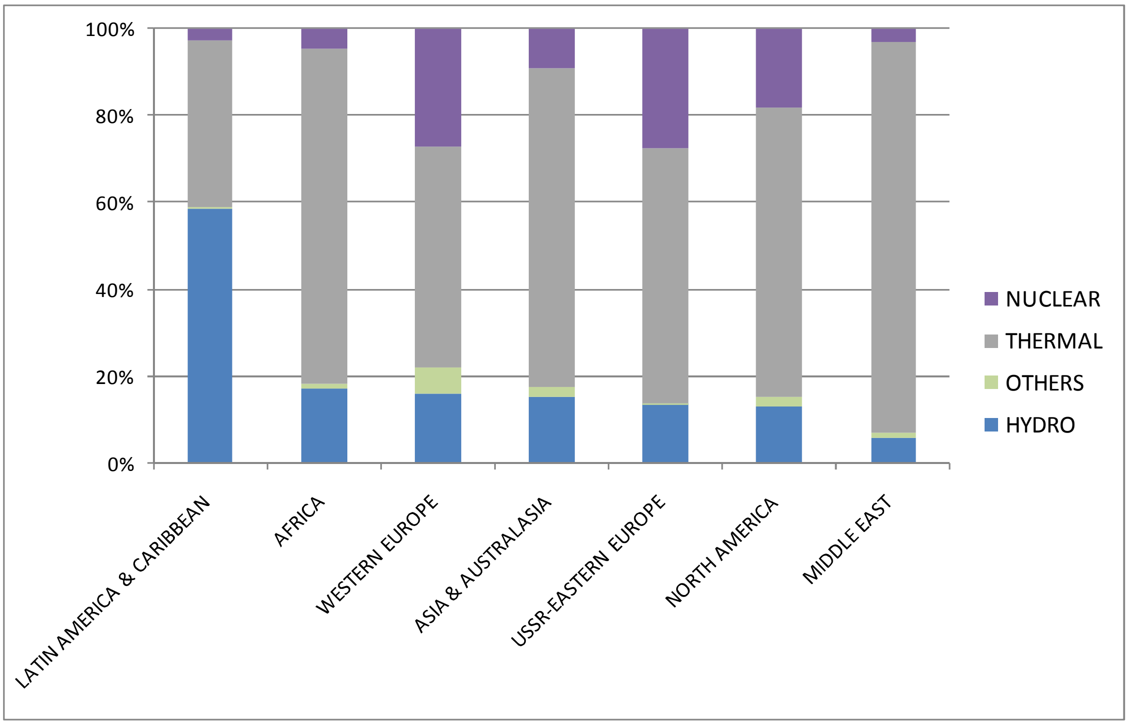


ELECTRICITY - WORLD GENERATION (TWh). According OLADE Report (2007)

The world's undeveloped hydropotential that is theoretically viable is 14,400 Twh/year. About 57% of that figure was considered economically viable. With increases in petrol prices and consideration of factors related to reduction of greenhouse gas emissions, this percentage could rise by 15%, therefore, it could be thought of a production around 2.5 times the current one, reaching 7000 Twh/year. Half of the useable potential is in only five countries: China, India, Brazil, Russia and Congo (Lamperiére et al, 2006).

The economic viability, nevertheless, depends on the policies of pricing and would be much greater if an internalization of the environmental costs were imposed which considers costs associated with the effects of greenhouse gasses. This would drastically change the studies of economic viability by altering the market competition among the energy sources, thus increasing the percentage of feasible hydroenergy.

Here are highlights and examples from Latin America.



Percentages of the energy sources used in the electric generation. (ICOLD).

We can observe that it is in Latin America where a major role for hydroelectric energy is being played. Given the renewable character of hydroelectric energy, a more sustainable scenario for energy can, therefore, be seen in this region.

Brazil stands as a very representative example.

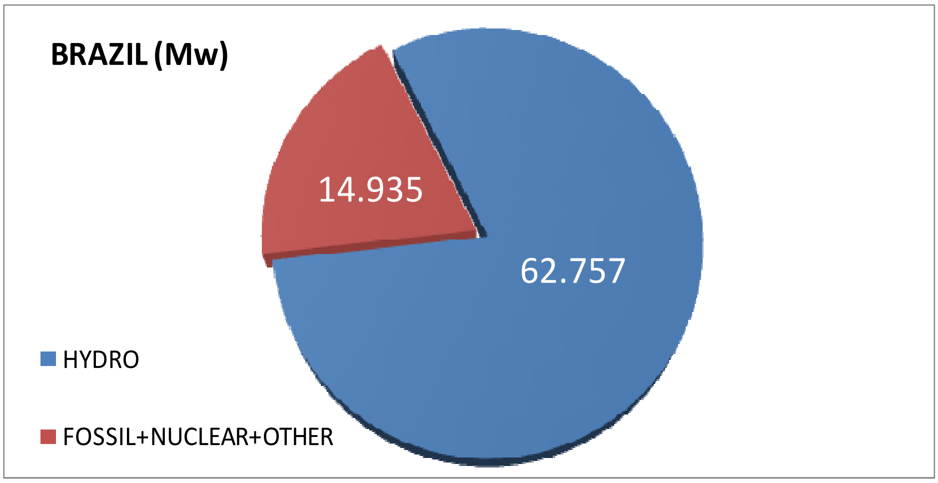
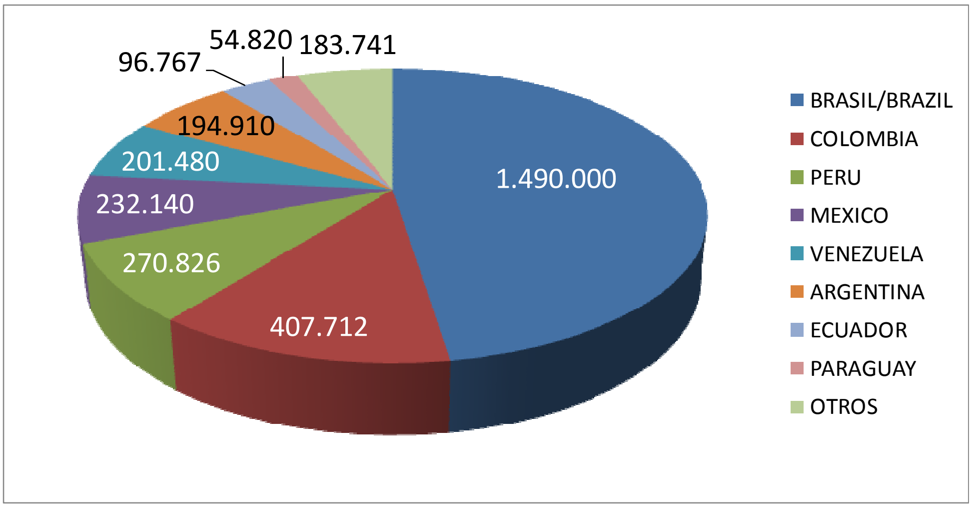


Figure: Brazil power installed capacity

Currently, 80% of electricity production is hydropower from dams. This figure represents just a small part of the total hydropower resources in Brazil, estimated at 258,000 Mw.

Even so, the little over a thousand terawatts-hour generated in Latin America are far from the technical and economically viable potential.



Hydropower potential en Latin America & Caribe. (OLADE 2007)

Paraguay (Abud et al.*, 2006)*

The contribution of the ITAIPU Binacional Project to the economies of Paraguay and Brazil is clear by the figures of energy supplied to both countries: 97% of the energy consumption of Paraguay and 25% of Brazil's. This cheap high-quality energy easily enables payments of royalties to the countries and promotion of social programs for surrounding communities through cooperation agreements with governmental and non-governmental organizations.

Asia is also developing its hydropotential by means of new dams, thus taking advantage of its own natural and renewable resources.

Pakistan (Majeed, 2006)

Mangla and Tarbela dams provide 70% of storage capacity in the country. Another significant reservoir, Kalabagh dam was too recent to be included in the 2006 report. The report concludes that sustainability of the economy of the country is only possible through the building dams for storage, hydropower and flood control.

The climate and conditions in Pakistan is such that there would not be enough water for irrigation without dams.

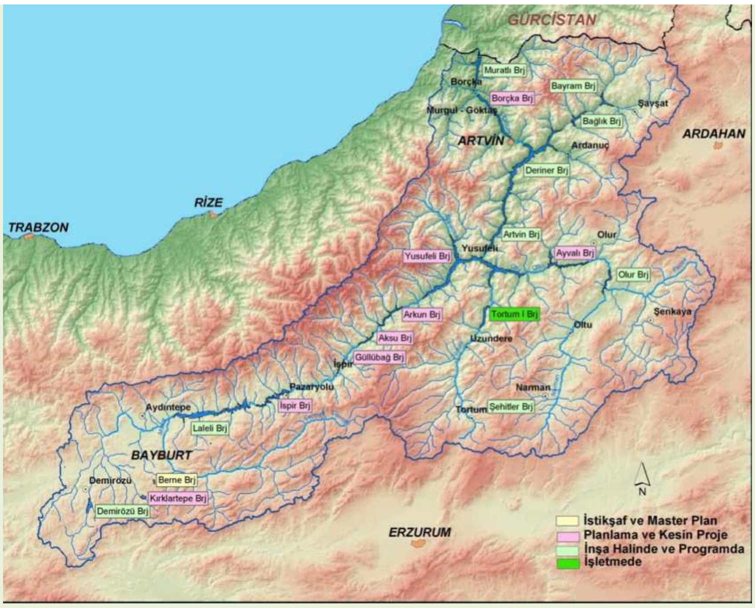
A 30-year pause in the construction of dams obligated Pakistan to develop thermal projects and increase its importation of heating oil. These alternative developments necessitated an increase in tariffs and resulted in water shortages.

The development of Kalabagh dam facilitated the stabilization of electric tariffs due its economical operating costs.

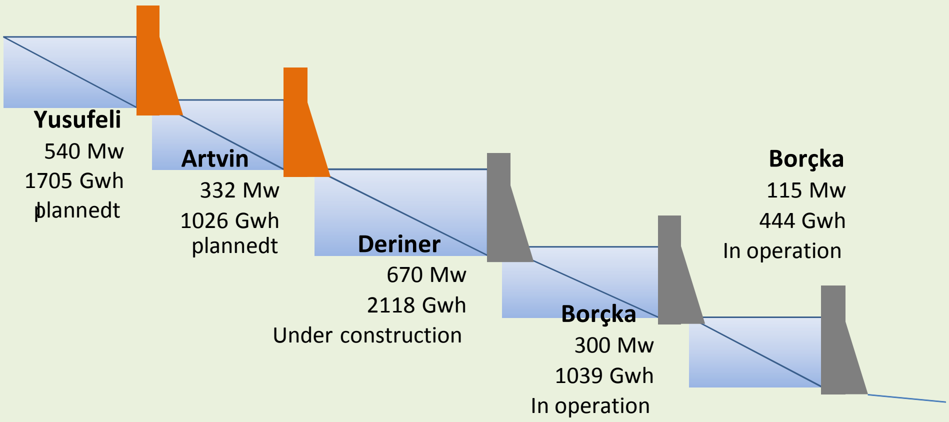
Dams in Pakistan are providing affordable electric energy for agriculture, industrial and domestic sectors and assuring water supply for food security. They are providing enhanced social justice for the country in the future.

Turkey, with a potential of 433 Twh/year is developing its 29% of its economically feasible hydropower by means of a major plan for new dams that will provide 130 Twh per year. This will help balance its electric market which is currently highly dependent on imported energy.

Çoruh river basin.

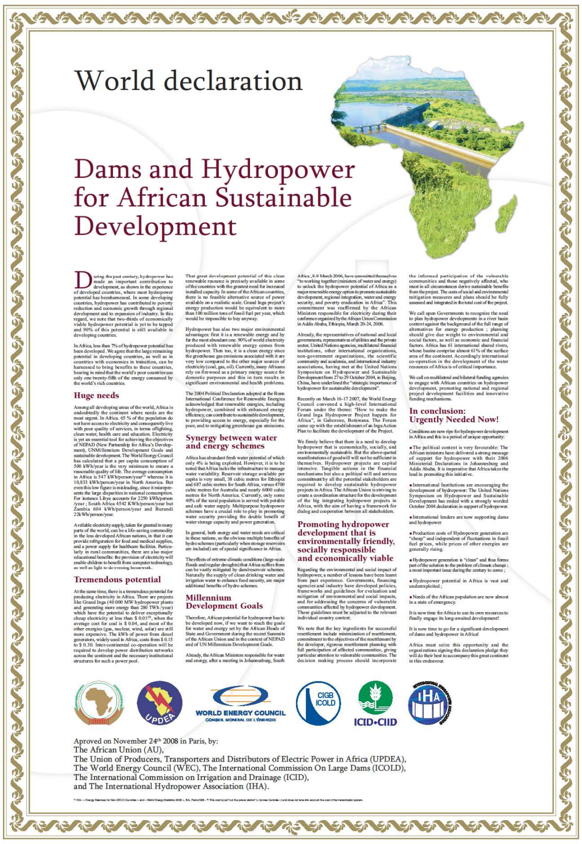


A cascade of reservoirs is being implanted to develop all its economically feasible hydropotential.



Çoruh river cascade.

The case of Africa must be highlighted. The African hydropotential is 1100 TWh (13 % of the world’s), but only 8% of the potential has developed in the continent where the availability of electricity is lowest.



ICOLD promoted, with several other concerned institutions, the World Declaration for Africa, held in Paris in November 2008.

The African Union (AU), The Union of Producers, Transporters and Distributors of Electric Power in Africa (UPDEA), The World Energy Council (WEC), The International Commission On Large Dams (ICOLD), The International Commission on Irrigation and Drainage (ICID), and The International Hydropower Association (IHA) signed this document to face the challenges related with Millennium Development Goals through an environmentally friendly, socially responsible and economically viable promotion of its tremendous hydro-potential.

"Among all developing areas of the world, Africa is undoubtedly the continent where needs are the most urgent. In Africa. 65 % of the population do not have access to electricity and consequently live with poor quality of services, in terms of lighting, clean water, health care and education. Electricity is yet an essential tool for achieving the objectives of NEPAD (New Partnership for Africa's Development), UN Millennium Development Goals and sustainable development. The World Energy Council has calculated that a per capita consumption of 500 kWh/year is the very minimum to ensure a reasonable quality of life. The average consumption in Africa is 547 kWh/person/year [1] whereas it is 10,833 kWh/person/year in North America.

But even this low figure is misleading, since it misrepresents the large disparities in national consumption. For instance Libya accounts for 2250 kWh/person/year; South Africa 4542 KWh/person/year but Zambia 604 kWh/person/year and Burundi 22kWh/person/year.

A reliable electricity supply, taken for granted in many parts of the world, can be a life-saving commodity in the less developed African nations, in that it can provide refrigeration for food and medical supplies, and a power supply for healthcare facilities.

Particularly in rural communities, there are also major educational benefits: the provision of electricity will enable children to benefit from computer technology, as *well as light to do evening homework*".

1 From "World declaration. Dams and Hydropower for African Sustainable Development". Paris 2008.

WATER SUPPLY

Mankind has generated a demand of water consumption that has grown more detached from the natural availability, both spatially and seasonally.

Historically, opportunities for civilizations to develop were determined by the environment and the natural resources. Settlements occurred along coastlines and rivers and prospered according to the advantages of transport, agriculture and development afforded by access to the resources offered by nature.

Under these circumstances, and at very low levels of demand, mankind attended to his water needs for human consumption, in rural and urban areas, as well as for irrigation. Civilization was limited by the availability of natural sources and suffered its temporal variability with droughts, epidemics and famines being the main consequences.

The power and ability to modify the environment (by creating routes of communication) and to transport resources and goods on a large-scale resulted in spatial growth of populations driven by factors other than proximity to natural water resources.

The exigencies of reliably providing water for its growing needs has forced civilization to struggle with the temporary variability by means of river regulation.

We must take into account that fresh water is a finite resource and only represents 2.5 % of the total volume of water available on our planet. Additionally a large amount of fresh water remains frozen in the Arctic and the Antarctic. The volume of fresh water available in the world has been estimated in 9000 km^3 and in many countries … such liquid and the population are not uniformly distributed; therefore, it becomes necessary to build reservoirs to supply the areas of insufficient availability.

It is not simply coincidence that the major developed countries had the opportunity of building dams before building became so discouraged. Such is the case for the United States, the countries of Europe, Japan and China. Nowadays the socio-economic situation is not so critical in these countries because they already have available reservoirs to impound water during seasons where there is a surplus, and to supply it rationally in during dry spells. .

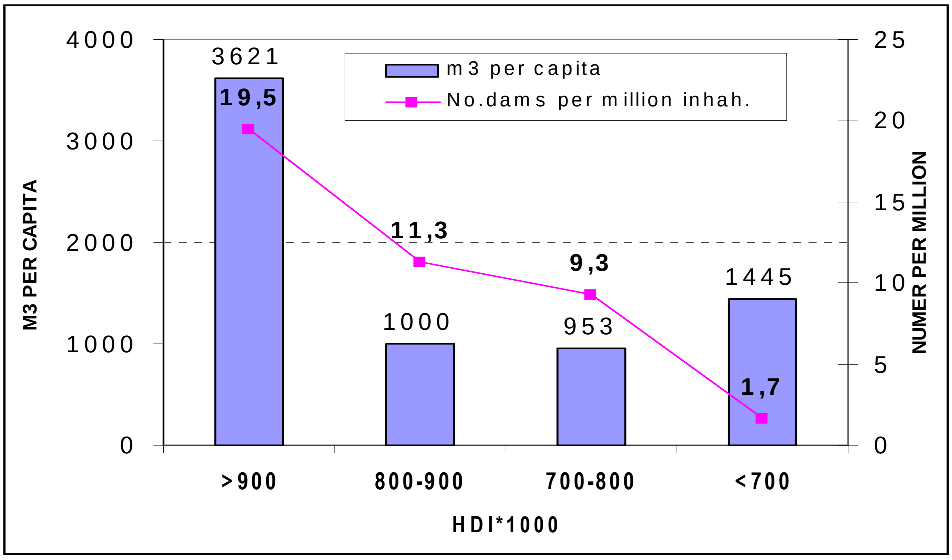
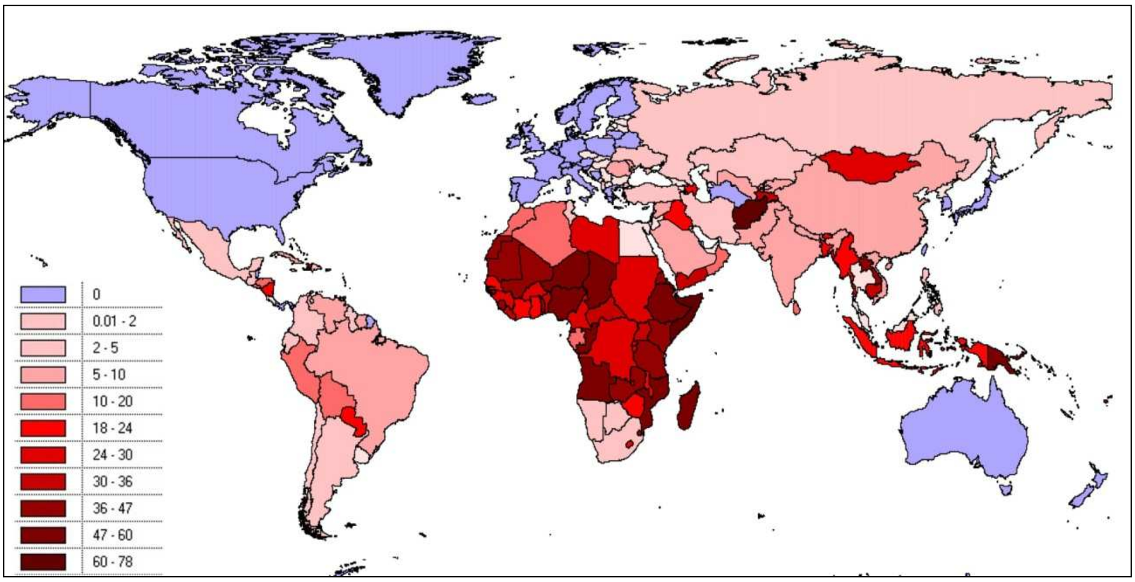


Figure: Human Development Index (U.N. Development Programme) versus Number of dams and water available resources (Berga, 2007)

Stored Water has different has different applications: domestic, agricultural and for industrial processes and power generation, just to mention the most important uses. In terms of human needs, irrigation and animal consumption, water is so scarce in some regions that it would become impossible to supply the total volume required during course of a whole year, unless impounded water was available from a dam. Where no nearby dams exist, water supply to towns is accomplished by groundwater extraction. Since this public service is of such vital importance, aquifers are often overexploited with the risk of depleting them and ruining them forever. In areas close to the sea, this over drafting of groundwater induces contamination of the aquifer as a result of saline intrusion (Maza & Ortega, 2000).

In general, access to fresh water, under acceptable conditions, is completely tied to the availability, not only of the resources, but also of the necessary hydraulic infrastructures for its management. The lack of access to fresh water is concentrated in the areas without the necessary infrastructure to develop and deliver it.



Percentage of the population without access to fresh water under acceptable conditions (source: UNDP. 2008).

IRRIGATION

Irrigation supports 17% of arable land and 40% of total crops around the world.

About 700-900 million people have food to eat because of the water supplied by dams.

Approximately 1,000 Km^3 of water for irrigation is provided from volumes stored in artificial reservoirs, most (80 %) in developed countries. Only 100 Km^3 come from 120,000 small reservoirs of less than 10 Hm^3 of capacity and another 100 Km^3 from 5000 medium reservoirs between 10 and 100 Hm^3.

The scarcity of suitable lands for irrigation coupled with climate change, which will increase the needs of irrigation, impedes the evaluation of the future needs for irrigation at to address the forecasted increases in population and the corresponding demand for increased production of food.

There are two crucial issues that must not be overlooked:

a) The greater the reservoir capacity the lesser cost of stored and supplied waters to meet irrigation demands. Whenever possible, sharing infrastructures for several communities or irrigated areas, even for multiple purposes, is always a better option than a single beneficiary – single use reservoir.

b) Seasonal conservancy of river water resources enhances the feasibly of irrigation wherever seasonal needs of agriculture don't coincide with the availability of natural water resources. However, it is hyper-annual regulation that really provides the guaranties to fight recurring droughts.

Both reasons support an integrated strategy not only for planning but also for management at basin level (IRBM).

Role of dams in agricultural development: Nigeria as a study case.

The economy of Nigeria at pre-independence was mainly dominated by agriculture. The level of education was low and urbanization was not the trend. Therefore, a greater proportion of the population devoted their time to rain-fed agricultural production. The country prospered through the export of various agricultural produce such as cocoa, groundnut, rubber, palm oil etc. Shortly after independence, the increasing demand for hydrocarbons in Europe and America led to an astronomical increase in the income generated from crude oil. Unfortunately, rather than investing the revenue in agricultural production, the importation of all kinds of consumer goods took precedent. The agricultural sector was drained of its valuable labour force because of the drift from rural areas into the cities resulting in the decline of agriculture as a major revenue generator for the country.

The population of Nigeria was recently estimated to be 150 million with about 80 percent under 40 years of age. Rain-fed agricultural production through as practiced at pre-independence days, cannot appeal to the young and enterprising Nigerian population of the 21st Century. Experts agree that large scale irrigated farming holds promise for the future of the Nigerian economy and the welfare of its people. The irrigation needs, coupled with the demand for energy and water supply for the large population, call for the construction of large dams.

The present and the expected future contributions of large dams to the regional economy of state governments and to the national economy of Nigeria cannot be overstated. The significant benefits afforded by dams advocate the improvement of sources of funding for large-scale multipurpose large dam projects to ensure the various identified dam sites are accorded appropriate priority in the national development plan.

Food and nutrition are growing problems for the national and regional governments in Nigeria. Domestic food production supported by rain-fed farming cannot meet the demand of our growing population, which in the last twenty years has become more urbanized.

The development of large dams in the country to support irrigation began about 1976 following the creation of a ministry for water resources development and irrigation. This served to increase the prospect of agricultural production. Studies have shown that existing large dams constructed in the past thirty years have irrigable areas of 320×10^3 ha. Conversely, downstream development has achieved only 70×10^3 ha – an estimate which is less than 20 percent of the total irrigable area.

Since 1985, with the intention of rejuvenating agricultural production after years of neglect due to an overdependence on crude oil sales, the Federal Government of Nigeria has progressively increased the ban on imports of major foodstuffs. Reports show that agricultural production is currently increasing at the rate of about 8 percent per annum, much ahead of the population growth rate of about 2.5 percent. However, rain-fed farming accounts for much of the recorded increase because the downstream irrigation developments of most large dams have been hindered due to lack of capital, high interest rates and inadequate incentives for large scale farmers.

(After Johnson and Adewumi, 2006)

The clearest way to show the need for dams was stated by Abdoulaye Wade, President of Senegal, while they were negotiating with Spanish Government: "Send emigrants back, but give us dams[2],..They would allow to irrigate our land …. We would like material and machinery more than money..We would be able to stop desertization and that would stop emigration”.

DRINKING & INDUSTRIAL WATER SUPPLY

Since ancient times, mankind has taken advantage of natural water resources where they were available and easy to obtain. Cities were settled by flowing streams or were supplied by wells which reached underground waters.

There were few cases of water stored in reservoirs to assure the need for drinking water, Even so, we can still find some very ancient examples around the world. Limitations in reservoir capacity due to limitations in dam height served to limit the prosperity of cities when regulated river water was the only solution for providing supplies of freshwater.

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[2] Le journal de Dimanche. May 2006.

Proserpina Roman dam (II century A.D.) for drinking water supply in Emerita Augusta (Mérida- Spain). Is a 20 m high dam which still regulates the Adelfas spring with a reservoir of 5 Hm^3 of capacity.

At the beginning of 21st century urban population exceeded, for the first time, rural's. In 2008 more than 3.3 billion people were settled in cities, foreshadowing a rapid growth reaching the amount of 5 billion by 2030.

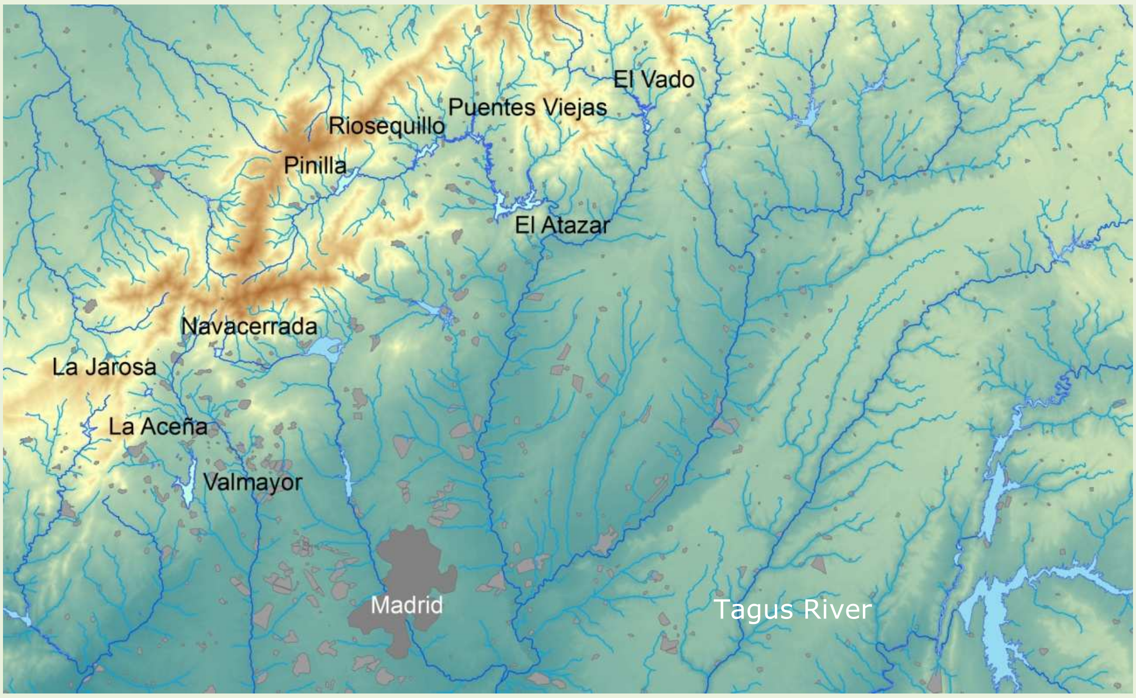
Many locations, where water resources are more severely constrained, will need to increase water storage to assure guaranties and availabilities. More dams will be necessary to simply maintain keep up services as the population continues growing. Desalination plants to access sea water can only help in coastal areas and practical extraction and recharge rates limit the utility of underground resources as complementary tools.

Madrid drinking and industrial water supply system.

Canal de Isabel II is the public facilities service company which manages water supply for Madrid metropolitan area. Its infrastructure includes large reservoir system to assure clean water for more than 6 million people. These reservoirs are located in the Lozoya, Jarama, Guadalix, Guadarrama, Manzanares, Aulencia y Alberche basins. First one provides two thirds of total volume.

Reservoir	Year	Capacity hm^3
Lozoya basin		589
El Villar	1879	22,4
Puentes Viejas	1939	53
Riosequillo	1958	50
Pinilla	1967	38,1
El Atazar	1972	425,3
Jarama basin		55,7
El Vado	1960	55,7
Guadalix basin		40,9
Pedrezuela	1968	40,9
Manzanares basin		102
Manzanares el Real	1912-1971	91,2
Navacerrada	1969	11
Guadarrama basin		132
Navalmedio	1969	0,7
La Jarosa	1969	7,2
Valmayor	1976	124,4
Alberche basin		26
Los Morales	1988	2,3
La Aceña	1991	23,7

Dams for drinking water supply in Madrid metropolitan area



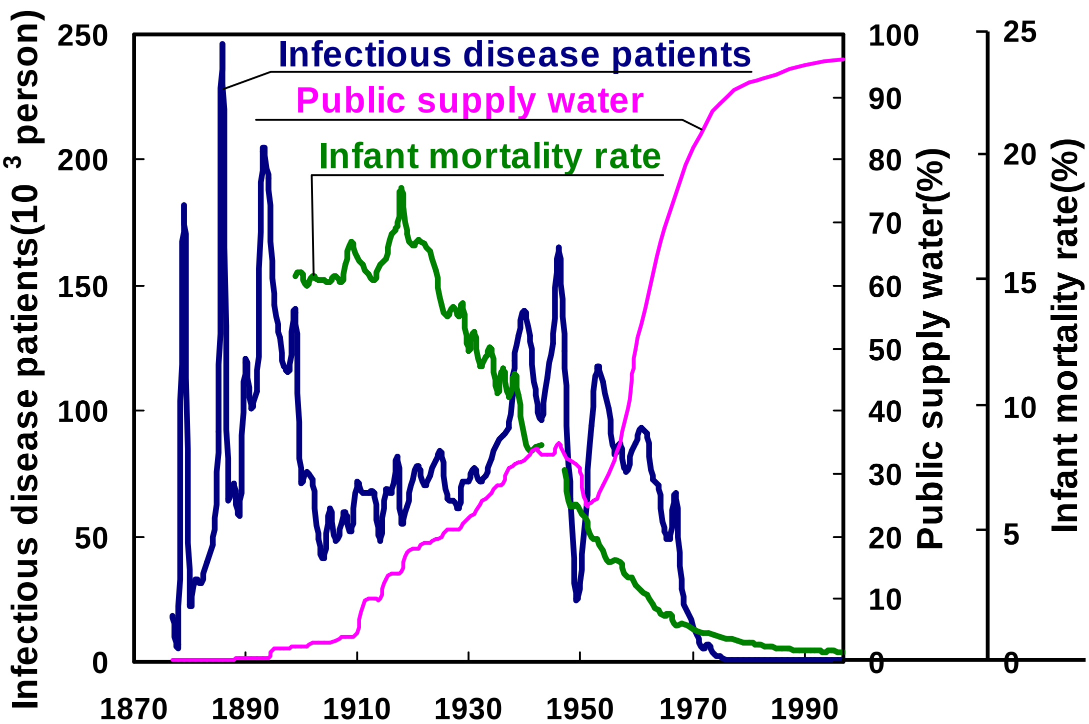
Main reservoirs guaranteeing fresh water for Madrid metropolitan area

Underground waters.

Canal Isabel II also has 81 facilities to access underground water resources taking advantage of 6 areas to add complementary volumes to the main distribution network. Underground water resources are used as a "strategic resource" for drought periods or emergencies due to breakdowns. So, during regular hydrological periods, Madrid is supplied just by surface water resources, regulated by its reservoir system. This supply is augmented by aquifers and other sources during times of scarcity of in surface reservoirs. On average, underground storage is exploited once each 4 or 5 years. The aquifers can be recovered during this cycle and thus guaranteeing their sustainability.

The correlation between water infrastructure coverage and public health seems to be obvious. Nevertheless one can be astonished by observing the evolution of infant mortality or waterborne illnesses when clean water supplies and sanitation facilities are implemented.

Japan, as any other developed country, was blessed by this story. In the plot is shown how cholera, dysentery, typhoid fever or paratyphoid as well as infant mortality practically disappeared as its hydraulic infrastructure was developed.

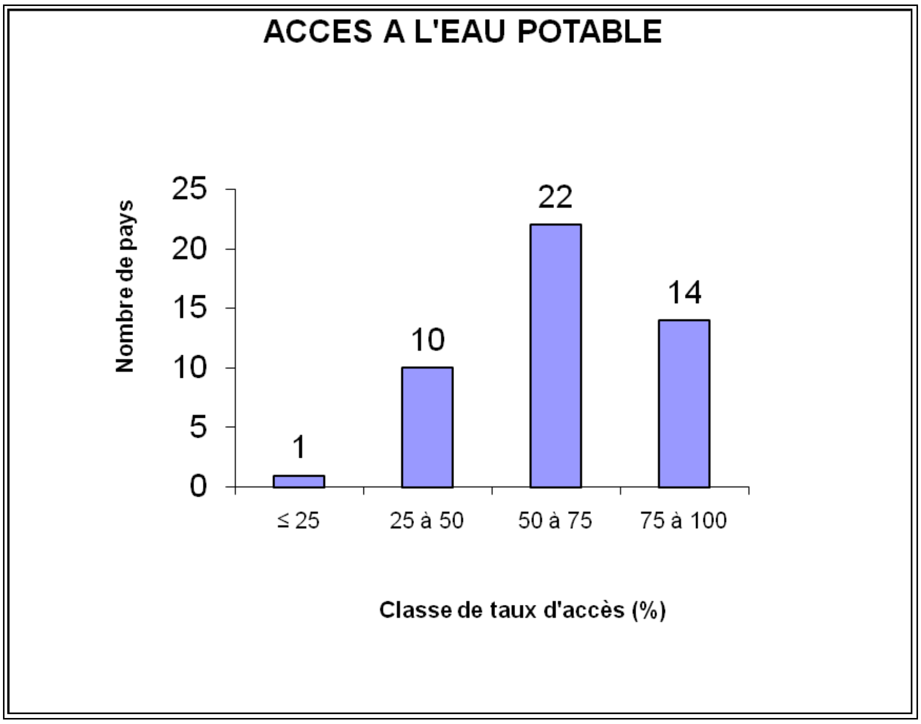


After Norihisa Matsumoto (2008)

The adverse effects resulting from the lack of infrastructure for the storage, distribution and sanitation of water resources in keeping pace with growth of megacities in the Third World is even more clear.

The WHO estimates that every year 1.8 million of children of the whole world (900.000 in sub-Saharan Africa alone) die as a direct consequence of diarrhea and other diseases caused by contaminated waters and insufficient sanitation.

One of every three children of the underdeveloped world - more than 500 million children - lacks access to any type of sanitation facility; and about 400 million children, one of every five, do not have access to potable water. At the same time, the contaminated water and lack of suitable sanitation cause 4,000 infantile deaths a day. In Africa, where currently scarcely 50% of inhabitants have access to potable water, and where cities are quickly concentrating populations, dams are becoming more and more needed.



After Adama, 2008

"At the present rate, it is unlikely that the Millennium Development Goal of reducing by half the proportion of people without sustainable access to drinking water by 2015, can be achieved universally" (A.K.BISWAS, 2006)).

FLOOD CONTROL

ICOLD has been keenly involved in documenting and improving the role of dams in flood damage mitigation for the past several years. A Technical Committee on "Floods and Dams" was specifically created whose bulletins are the technical references that ICOLD offers to the interested community. This report doesn't pretend remake this huge volume of work. We suggest that the reader review ICOLD Bulletin No. 131 "Role of Dams in Flood Mitigation - A Review" published in 2006.

Some considerations about the role that dams play in helping mankind in facing this natural risk are summarized below.

Floods present a significant impact on human lives, induce a serious social consequences and cause very high economic losses. Moreover, floods hinder sustainable development by severely impacting its three basic elements: social, through loss of life and human settlements; economic, though damages to property and infrastructure, and loss of commerce at local, regional and national levels; and environmental, when reversible or irreversible impaction occur to fluvial habitats.

During the 20th Century floods have been the most destructive natural disaster on a worldwide scale. They account for about 30% of all consequences from natural catastrophes (32% in terms of people affected and economic losses and 26% in terms of casualties).

The eighteen most severe disasters occurring during the 1990's account for more than US$10 billion economic losses. Among these disasters were seven extreme floods including: 1993 in the USA (Mississippi), in 1991, 1996 and in 1998 in China, in 1995 in North Korea or in 1990 in Venezuela with more than 20,000 casualties. (Berga, 2002)

The figures of Yangtze River alone are terrifying. During the 20th Century, floods claimed more than 400,000 direct deaths, excluding those due to illnesses, plagues or hunger derived from economic damages.

Just two major floods, in 1931 and 1935 with 145,000 and 141,000 casualties, account for most of the damages.

The flood protection provided by the Three Gorges Project will reduce the return period of downstream flood risks from 10 to 100 years.

Its flood control role is designed to be compatible with the other functions provided by this project. A significant part of its hydro-energy production is sacrificed to gain useful capacity for flood routing during the monsoon season.

By definition, dams modify the distribution of probabilities of downstream flows. In addition to guaranteeing minimum discharges to support water uses, dams reduce the probability of high peak discharges but cannot completely eliminate them.

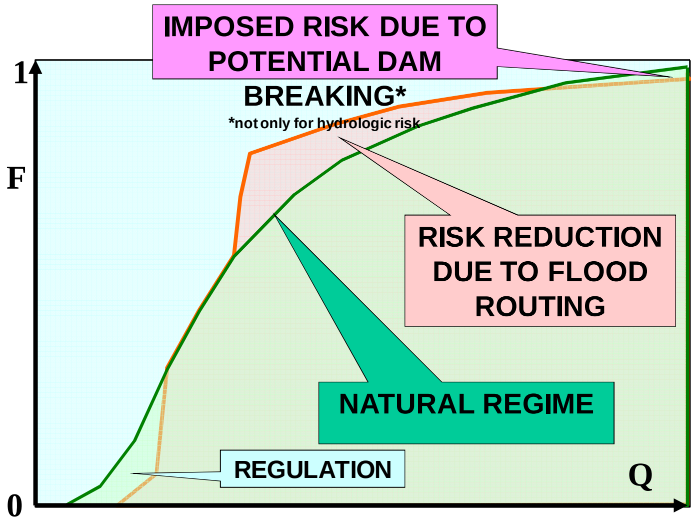


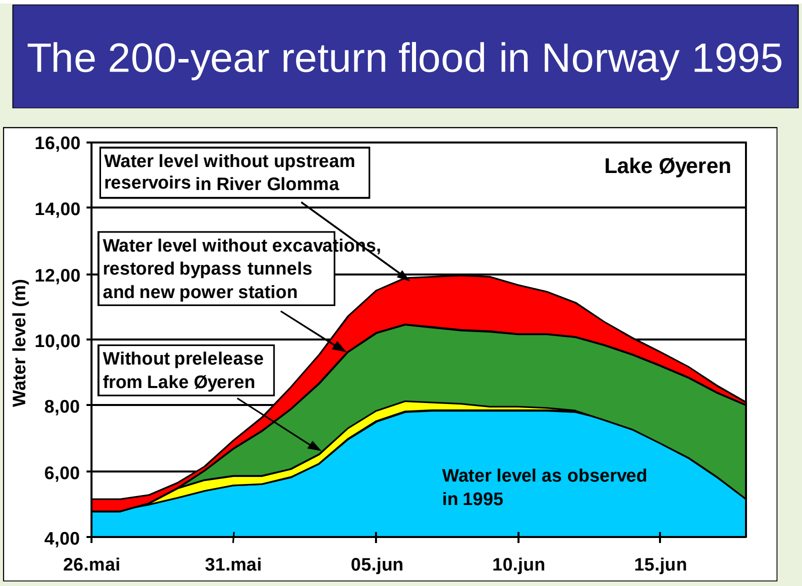
Figure: Distribution of probabilities modification due to the existence of a dam (downstream)

At very high discharges the effect of dams diminishes. And, there is even an added new risk, that of dam failure. This risk must be minimized by hydrological, geological and structural safety policies.

It's clear that both structural and non-structural measures must be combined to reach high levels of safety for protection against floods.

As an example, consider the case of 1995 flood in Glomma River (Norway) [Pöl Mellqist].

- Water discharge: 3 700 m^3/s
- Estimated size of flood: 200 years return period.
- The effects of three flood level reduction measures are shown in the figure below:
  - Flood routing by upstream reservoirs
  - Capacity improvements by excavations and real-time management of reservoirs and power stations.
  - Pre-release discharges based on flood forecasts.
- The results were:
  - No loss of life.
  - Prevented damages of property estimated at NOK 2,000,000,000.

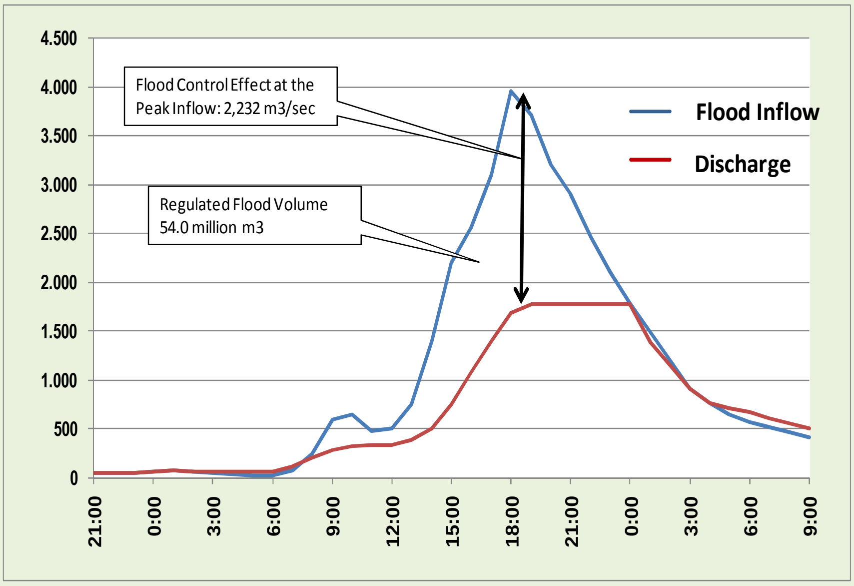


Maneuvering handled by the GLB Water Management Association and The Norwegian Water Management and Electricity Directorate (NVE)

The importance of dams for flood mitigation is even more clearly seen in cases where heavy storms produce flash floods as in some regions as Japan.

Flood control in Japan.

In Japan, flood control is performed to reduce flood damage for most of the year, mainly during the snow-melt season, the early summer rainy season and the typhoon season. On average, flood control is performed about 400 times during each year.



A total of 93 dams have been constructed to regulate floods. The approximately 3.7 trillion yen invested in these projects (the flood control portion) is estimated to have prevented more than 402 trillion yen in flood damages during the 15-year period from 1987 to 2001.

Flood control operation of Sameura Dam during Typhoon No 16 in 2004

Taken from "Role of dams in Japan". 2008

Even when flood control has not been formally incorporated into the design of a dam, its reservoir is still capable of some degree of flood reduction.

A description of the Flood Control System on the Paraná River in Brazil is described as an example of the integration of flood control with hydroelectric production. Brazil operates a large array of huge reservoirs to maximize the energy produced while at the same time providing protection from floods. The largest integrated reservoir system within one basin is located on the South/Southeast Interlinked System. There are 41 reservoirs in the Paraná River Basin which are set along the country's most developed axis.

MANAGING FLOODS IN BRAZIL

The majority of the reservoirs were developed for the purpose of generating electrical energy. Flood control operations were not initially foreseen. Once the downstream flows were somewhat reduced by the presence of the reservoirs, small populations started to settle next to the river margins. They were exposed to occasional rising river levels caused by the opening of spillway gates. Because of the risk of flooding, flood control rules were established for all the power plants. Outflow constraints were set and a flood-forecast system was developed via use of telemetry and meteorology.

To attenuate floods the Operator, uses projections to establish an empty volume allocation in each reservoir, which is called the flood control volume. Then during the rainy season, the reservoirs are able to retain part of the inflow. Thus, the downstream damage caused by floods can be avoided or reduced. However, there is a trade-off between flood control and electric energy production, since maximum energy production occurs when the reservoirs at their maximum capacity.

In mid-January 1992, heavy and long-lasting rains affected the Southeast Region of Brazil over a period of 10 days. This stationary front brought floods to many sites along the Alto Paraná river. The most serious flooding occurred at the headwaters of the Grande river. The total volume of rainfall in that month reached a value 200% above the average value for some stations located at the headwaters of Grande River. The greatest flood in 60 years occurred at the Camargos and Furnas power plants. The maximum daily flow rates reached 1,630 m^3/s and 9,000 m^3/s, respectively. Even with the flood control volume established within the Camargos Reservoir, it was not possible to avoid damaging floods immediately downstream from Camargos.

However, the flood control operation was considered successful for the rest of the power plants located in the Paraná River Basin. There were no sugar mills affected by flooding, no loss of crops or cattle, no damage to villages located in the river margins and, consequently, no loss of human life. The application of flood control measures in energy operation has resulted in social and economic benefits through the reduction of flood impacts downstream from the basin Power Plants.

Erton Carvalho, 2001.

It should be noted that reducing risks downstream could create a false sense of security, which can lead to increased in building in the flood plan. Organizational measures (land planning, land use controls, flood warning systems) should be linked to flood control facilities, such as dams or channelling, to assure their effectiveness.

Request for investments in protection measures against floods should be based on the concept of sustainability so that the creation of flood control infrastructure does not increase the vulnerability of the territory.

TRANSPORTATION

Dams not only create barriers on waterways; they also enhance navigation by increasing water depths and reducing velocities, costs and hazards. The difficulties created by the use of locks are more than adequately compensated by improvements to whole transportation systems. In many cases dams enhance intermodal transportation and support commerce by moving freight in a more fuel efficient manner than trucks or trains.

Reservoirs often provide major improvements in water-borne transport through a river basin. The velocity within the reservoir is always much slower than the unregulated flow, providing significant economies in upstream movement of goods. A reservoir may even provide possibilities for river borne transport where none existed before the project. Such traffic of people and goods among the towns and hamlets created along the shores of the new man-made lake promotes the economic development of the region.

Outstanding examples are:

- The Danube River in Europe, with its associated canals, that provides a regulated transport route from the North Sea to the Black Sea touching many of the countries of Europe.

- The Three Gorges project on the Yangtze River in China provides some 650 km of reservoir reaching to Chongqing. River shipping along central the Yangtze River reach is estimated to increase from 10 million to 50 million tons annually, reducing transportation costs by about 30-37 percent. Also navigation risks have been drastically reduced between Yichang and Chongqing, enhancing the irreplaceable trade route between eastern China and its inland plateaus.

- The Mississippi River in the USA provides a transport route controlled by locks at dams along its length so that goods can reach the northern states from the Gulf of Mexico.

- The Canal de Panamá, was possible as a result of the construction of the Gatun dam, creating a reservoir of 425 km^2 whose water level reaches the Pacific basin border. The Madden Dam allows the regulation of the Chagres River satisfying the water source needs of the Lake Gatun and the navigation canal.

- Yacireta Reservoir operation on Parana River combined with appropriate level forecasting in Argentinean downstream reaches allows, not only the betterment of navigation conditions but also transport cost efficiencies based on forecasted water levels and velocities.

Dams enhance transportation by mitigating:

- Insufficient depth in waterways during some seasonal periods.

- Obstructions and insufficient breath of natural channels.

- Hazards of night-time navigation in narrow reaches.

- Fuel consumption.

However, unless preventative measures are planned and implemented, some concerns may arise, including:

- Gravel deposition along upstream reservoir areas due to low flow velocities.
- Reduced water quality caused by insufficient flows in reservoirs and canals.

Successful implementation of large scale navigation improvements requires sufficient discharge regimes. This restricts overall water resource management in the basin and could create conflicts with other uses or environmental policies. IRBM has to address these issues in a way that takes advantages of synergies and balances controversial interests in an adequate way.

ECOLOGICAL MITIGATION

The role of dams as tools for ecological mitigation is a relatively new concept. The use of dams for conservation of the environment is gradually receiving recognition. New needs have been identified, such as requiring minimum reservoir levels that are ecologically compatible with the fish population and providing minimum flows to sustain aquatic habitat. In some cases, stream flow releases need to be varied for ecological purposes; instead of steady flows, releases of higher variability are required. Environmental demands for flows to re-equilibrate wetlands have also been instituted. Each of these environmental measures usually places a demand on reservoir capacity that was probably not originally contemplated. These additional requirements then may require an expansion of reservoir capacity to achieve or maintain existing reservoir benefits. Additionally these new requirements may occur at a time when larger flood control concerns are causing larger amounts of storage to be dedicated to flood control.

These circumstances involve a new role for dams, resulting in the construction of dams with the environmental mitigation as a goal: guarantee of ecological flows, constant water routing in a queue of large reservoirs, and/or aquifer recharging. In some reservoirs, multilevel intakes have been constructed to control the temperatures of downstream releases to support aquatic life.

Some references in Spain show how some dams can play a special role providing environmental benefits. Interesting case studies are Algar Dam, recharging over-exploited groundwater aquifers, or Alarcón Dam, guarantying ecological flows threatened by excessive pumping from surrounding aquifers.

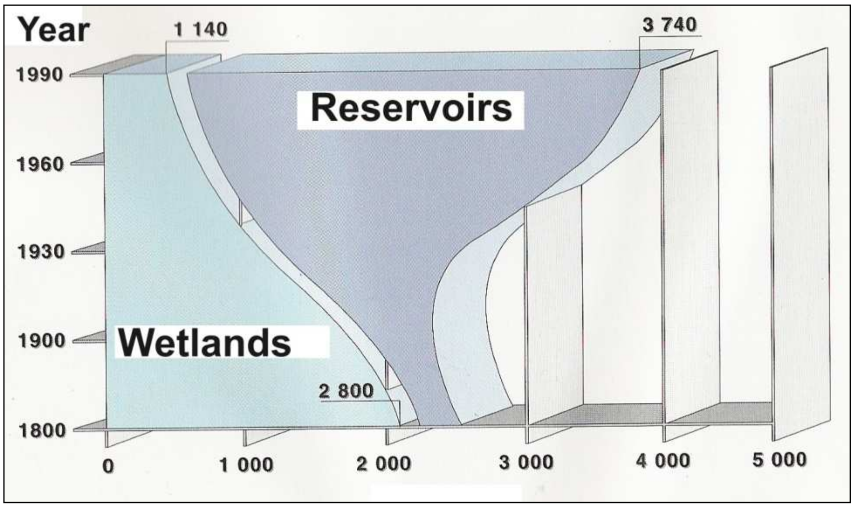


Figure. Evolution of natural wetlands and artificial reservoir mirror since two centuries in Spain. Source: "Dams & Environment. Spanish Ministry of Environment".

Large storage dams offer calm water and wetlands substitutions that are nowadays compensating for losses of traditional habitats for migratory species. Artificial lakes made by dam construction are also replacing former wetlands that have been artificially drained. Some of manmade lakes are already included in the RAMSAR site list. As an added role, dams provide an environmental benefit that is closely related with biodiversity care. Worldwide we can also find some cases where dams have created water bodies that reflect ecosystem values, especially for wildlife or fisheries. Some reservoirs support substantial wildlife populations and others have had productive and valuable national parks declared along their shores.

Thus, we can also stated that dams allow us addressing emerging concerns such as compensation for loss of on-land storage through paving of urban watersheds and loss of glaciers and snowpack due to climate change.

OTHER ROLES

FOSTERING THE DEVELOPMENT OF FISH-BREEDING INDUSTRIES

Reservoirs can be used as fish breeding facilities. By means of an initial seeding of selected fish species, a fishing industry can be developed. Communities living close to the reservoir area receive this benefit. However, care must be taken that the fish species introduced are compatible with the native species.

TOURIST DEVELOPMENTS

There is a large potential for tourist attractions at artificial lakes. Included are: water skiing, sailing and boating, sport fishing, and camping. All of these activities require human resources to provide the associated services like hotels and restaurants, boat rental and the selling of different goods. Many of these jobs are filled by persons living near the reservoir.

The Japanese Government makes detailed survey of the recreational use of reservoirs every three years. According to the results of the 2003 survey, the total number of visitors to the 98 major multi-purpose dam reservoirs was estimated as much as 13.85 million in that year. As an average, a reservoir attracted 141 thousand people a year. A leisurely stroll is the most favoured activity around reservoirs, followed by visiting dam museums and shops, outdoor exercises, sports, and fishing. Miyagase Dam, adjacent to the Tokyo Metropolitan Area, attracted the largest number of visitors (1.35 million). The dams most capable of attracting many visitors feature easy access from major cities and/or nice sports-recreational facilities *(Tatsuo Hamaguchi, Japan Commission on Large Dams)*

3. EFFECTS OF DAMS

It's clear that dams modify nature for human benefit. This modification causes an impact on the environment. Environmental effects of dams have been, for many years, a major concern for professionals concerned with all aspects of dams. ICOLD attaches great importance to the environmental and social aspects of dams. First edition of its position "Dams and Environment" was published in 1980.

The ICOLD Committee on the Environment was formed in 1972 and has been renewed four times since, reflecting the constant concern for the environment. Environmental effects have been a central question in eight symposia and congresses promoted by ICOLD since 1973.

Additionally ICOLD works continuously on environmental issues related to dam construction and management. Ten bulletins directly related with the environment have been published by ICOLD.[3]This report cannot and must not replace those highly recommended workers.

Thus far this report has considered many of the benefits that dams provide to humankind. We will now complement that discussion by considering the effects on dams on the environment but without repeating the substantial volume of work already produced by ICOLD. Later in this report we will be examining the effects of dams from an overall perspective of watersheds.

From micro-climate changes, water quality and temperature, through environmental geology, to terrestrial and aquatic flora and fauna, the effects on natural ecosystems, must be taken into account at both the project and river basin level. Additionally social effects, local and regional conflicts and stakeholders' perspectives have to be considered and balanced.

Several example cases are briefly presented to highlight particular environmental aspects in order to provide a background for later discussion.

Induced Microclimate Changes around TGP.

According the applied models for studies made for Three Gorges Project Environmental Impact Assessment, this great reservoir will induce some changes in the adjacent microclimate. The surrounding area has a humid subtropical climate with average of temperature about 18ºC, varying from 3.6ºC in January reaching 29ºC in July. Its mean annual rainfall is 1100 mm, concentrated mainly (80%) in monsoon

[3] ICOLD bulletin dealing with environmental issues are listed here below.
Bulletin 35 (1980) Dams and the Environment
Bulletin 37 (1981) Dam Projects and Environmental Success
Bulletin 50 (1985) Dams and the Environment - Notes on Regional Influences
Bulletin 65 (1988) Dams and Environment - Cases Histories
Bulletin 66 (1989) Dams and Environment - The Zuiderzee Damming
Bulletin 86 (1992) Dams and Environment - Socio-Economic Impacts
Bulletin 90 (1993) Dams and Environment - Geophysical Impacts
Bulletin 96 (1994) Dams and Environment - Water Quality and Climate
Bulletin 100 (1995) Dams and Environment - Ridracoli: A model achievement
Bulletin 103 (1996) Tailings Dams and Environment - Review and Recommendations
Bulletin 115 (1999) Dealing with reservoir sedimentation
Bulletin 116 (1999) Dams and fishes - Review and recommendations
Bulletin 124 (2002) Reservoir landslides : investigation and management - Guidelines and case histories
Bulletin 128 (2004) Management of reservoir water quality - Introduction and recommendations
Bulletin 132 (2008) Shared Rivers : Principles and practices
Bulletin 140 (2009) Sediment transport and deposition in reservoirs

season of May to October. The reservoir will induce some effects on the surrounding microclimate extending from its shoreline to a distance of less than 10 km. Changes in air temperatures, according theoretical predictions, will be measurable up to 1-2 km from reservoir shoreline and for about 400 m above the water surface. The annual mean temperature will be increased by 0.3 – 1ºC in winter and will decrease 0.9-1.2ºC in summer. Maximum annual temperature will decrease by 4ºC while the minimum will be increased by 3ºC. Microclimate changes will have both positive and negative effects on agriculture and in people's lives. Frost will start later and end earlier to the benefit of fruit crops. The less extreme summer temperatures and more prevalent breeze will be considered a beneficial effect by many. Absolute humidity will rise by 0.4 g/Kg increasing vapour pressure between 20 and 30 Pa in winter and between 130 and 180 Pa in summer. The average precipitation in the basin will increase by about 3 mm, less on the upwind side and more on the downstream side of the reservoir. According mathematical models, the number of foggy days will increase from 35 per year to 36-37. Winds in vicinity of the reservoir will increase but without changing its stratification. Winters will be little more humid and foggy, affecting fluvial, terrestrial and air transportation. Acid rain from cities will be dispersed over greater areas. Some mitigating measures such as modification of agricultural techniques, implementation of short-term weather forecasting systems for transportation assistance and preventative measures to reduce acid rain are being considered.

EFFECTS ON AQUATIC LIFE

The Net Environmental Benefit of the Los Vaqueros Project, California, USA

During the planning of the Los Vaqueros Project in California, possible impacts to several threatened and endangered species were identified. In developing the Los Vaqueros solution, the Contra Costa Water District (CCWD) staff and consultants worked with permitting agencies to determine appropriate ways to mitigate environmental impacts on listed species, as well as candidate species. Ultimately, they had to show that the Los Vaqueros Project would have a net environmental benefit to the San Joaquin-Sacramento Rivers Delta – and it does. The ability to store water in the off-stream reservoir means that the existing pumping plants extracting water from the Delta areas no longer need to operate continuously, as they had in the past. This enables CCWD to shut down both of its Delta intakes for 30 days each spring when the protected Chinook salmon and Delta smelt are spawning.

EFFECTS OF SEDIMENTATION

Impacts caused by dams include the retention of sediments, nutrients and micro-organisms in the reservoirs, which can cause significant changes in watercourse ecosystems. Events such as upstream flooding, reservoir life span reduction and erosion of the downstream river channel occur with greater or lesser intensity in all dams, regardless the size or the watercourse where they are located.

Sediment settles in the river upstream of a reservoir where velocities are slowed, on riverbanks and in the riverbed, as well as in both active and dead storage zones of a reservoir. As a result, reservoir storage and regulation capacities are decreased with the corresponding impacts on the various uses of the water (power generation, irrigation, etc.). In a cascading system, the upstream dams reduce the inflow of sediment to the downstream reservoirs. In this case, the resulting benefits to the downstream project ought be considered and shared by both projects. Occupation and expanded agricultural use of soil resources in the basin made possible by the availability of water from the reservoirs often cause increased erosion, carrying more sediment to the watercourses and reservoirs unless mitigated good agricultural land use practices established as a part of the plan for irrigation.

Smaller reservoirs are generally subject to quicker degradation because they are usually located in areas of steeper slopes, subject to greater erosion. There are cases when a single flood can cause complete degradation of the reservoir or drastically reduce its volume. On the other hand, some dams are still under operation after two thousand years. Sediment control works and techniques are becoming more and more important in increasing the life span and ensuring the continued operation of projects.

The Nile basin given the benefits and concerns, including sediment transportation, provided by the High Asswan Dam and other planned proposals, from the past to the near future, will be discussed in a separate bulletin. This will be part of a series of case studies from around the world.

ICOLD created a technical committee on sedimentation, with high-level specialists, who work on this very important issue. The ICOLD bulletin No 140, "Sediment Transport and Deposition in Reservoirs," provides additional detail on this matter.

ECONOMIC AND SOCIAL EFFECTS OF RESERVOIR PROJECTS

LOCAL AND REGIONAL DEVELOPMENT

Water resources development around the world has taken many different forms and directions. Humans have long sought ways of capturing, storing, cleaning, and redirecting freshwater resources in efforts to reduce their vulnerability to irregular river flows and unpredictable rainfall. Early agricultural civilizations established themselves in regions where rainfall and runoff could be easily and reliably tapped. The first irrigation canals permitted farmers to grow crops in drier regions and permitted longer growing seasons. The growth of cities required advances in the sciences of civil engineering and greater knowledge of the hydrology of distant sources. And, industrial societies in many parts of the world modified the hydrologic cycle through construction of large dams (Gleick, 2000). No one would deny that human societies need water for drinking, washing, for agriculture and energy.

The Worldwatch Institute (2006) reports that underdeveloped countries having water infrastructure are growing at a rate of 3.7% by year, while countries lacking of these infrastructure are only growing at 0.1%.

Often regional development is due to the existence of dams and the use of their impounded water. Las Vegas in the USA is an example. The north-western part of Mexico, particularly in the states of Sinaloa and Sonora, provides another example of this situation. If the water is developed for irrigation and large irrigation districts are formed, the associated agricultural expansion brings additional prosperity to the region. This may result in the creation of new urban centres and further development of the existing ones because of the need for and economic ability to increase commercial, industrial and service activities. Many cities and towns would not exist nowadays if the dams operating at present had not been built in years past.

If the social impact of the water development project is acknowledged, it is very important to present facts and to have the community aware of the advantages, and at the same time, publicize among the people the efforts that were taken to mitigate, decrease or prevent the negative effects (Maza & Ortega, 2000).

It is generally recognized that large dams have major environmental and social impacts. In order to address these concerns many new projects are accompanied by environmental impact assessments which are, indeed, mandatory in many countries (Marshall, 1994). An environmental impact assessment must describe, among other matters, the positive and negative social impacts of the project.

Among the potential positive social impacts the following should be considered:

- Development and arrangement of resettlements through concentration of the population in such locations that will facilitate the government to construct the required public facilities: electricity, clean water, secondary schools, employment etc,
- The program designed for the resettlements (agriculture, estates, animal husbandry, fishery, small industries, etc) will increase the annual income of the population as compared to their income in their original locations,
- The creation of new work opportunities and the development of working skills of the local population during the project construction period as well as the operation period,
- The mitigation of floods which will enhance the safety of local people and increase the agricultural production of downstream areas that are currently experiencing damages from seasonal inundations.

- The provision of new renewable and clean energy.
- The improvement of guarantees for irrigation water and therefore improve the economic standards of people in the beneficiary area.
- The improvement of sanitary conditions and, therefore, a reduction of some waterborne diseases and general improvement overall health.

In addition to positive impacts, potential negative social impacts must be considered such as:

- Villages that would be inundated, as well as rice fields, plantations, forests, field and residential areas.
- Families will have to be resettled in new locations.
- Loss of Public facilities such as utilities, schools, offices, roads, mosques or churches, etc.
- Loss of ancient relics and areas of special cultural importance.
- The temporary loss of income of people while being relocated and the worry of facing an uncertain life in a new place. The adequacy of practices undertaken to avoid such undesirable effects.
- Social jealousy that may result from the presence of new comers in resettlement areas and the potential loss of jobs to manpower from the other areas.

Although impact assessments are now being carried out more widely, their contributions to successful project implementation can still be uncertain. The development of large dams has displayed a high degree of variability in delivering predicted water and electricity services, and related social benefits. In some cases there are significant adverse impacts on rivers downstream and a heavy toll on communities affected by the construction of dams.

DISPLACEMENT AND RESETTLEMENT

A review of case histories of displacement and resettlement reveals several common themes for improvement. These include: better estimation of the costs in terms of equipment, personnel and capital; a lack of surveys of such things as soil, in order to determine the suitability of the new settlements; insufficient preparation of the new sites, which results in the people relying on famine relief; poor communication between authorities and those to be resettled; and increased death rates among the resettled populations, due to new diseases and stress. General problems that are inevitable, but which may still be mitigated, are, for example, disruption of cultural patterns and family ties, and the removal of people from their ancestral land.

The ICOLD Bulletin "Dams and Environment" provides the following recommendation:

f) Involuntary resettlement must be handled with special care, managerial skill and political concern based on comprehensive social research, and sound planning for implementation. The associated costs must be included in the comparative economic analyses of alternative projects, but should be managed independently to make sure that the affected population will be properly compensated. For the population involved, resettlement must result in a clear improvement of their living standard, because the people directly affected by a project should always be the first to benefit instead of suffering for the benefit of others [For that reason, under a law dating back to 1916, communities in Switzerland are entitled to considerable annual payments and quotas of free energy for granting the rights to hydropower development on their territory]. Special care must be given to vulnerable ethnic groups.

The attention given to environmental and social issues early in the site selection and project formulation processes paid dividends during the recent licensing of two major hydro plants and dams on Brazil's Jordao River (Fonseca and Burian, 2001). The authors contend that by giving full consideration to environmental and social factors throughout the process of identifying alternatives and selecting the proposed scheme, the Brazilian utility Companhia Paranaense de Energia (COPEL) greatly reduced the time and cost necessary to obtain the licenses from the Paranà State environmental authority. Redesigned projects have less environmental impacts, higher costs, lower generating capacity, and greater public and market acceptance (Veltrop, 2002).

As Dr Pircher, former president of ICOLD, stated in his Geoffrey Binnie Lecture in 1992, "Dam projects are judged by their social and political acceptability, which generally entails more than the familiar technical, economic and financial criteria." Before a political decision about a dam project is taken, it is necessary to develop creditable plans that address and resolve or mitigate the significant impacts identified in the Environmental Impact Assessment (EIA) (Engel, 1995). Important are the trade-offs; losses of one group against gains by another; the impoverishment of some people, and the possibility of the exclusion of people from the decision making process. Of utmost importance is the need to initiate prior consultations with all affected people at the start of project planning. This procedure does not include the right of veto for anyone. Instead, it takes into account that gains and losses are equitably distributed among stakeholders, land acquisition from resettlers should be adequately compensated, resettled people should advance economically, all options should be evaluated objectively, existing facilities should be optimized, and harm to the environment should be avoided to the maximum extent possible (Veltrop, 2002).

Rehabilitation of the Mane, India (S. P. Sen, India, 2002)

While building the concrete dam over the river Rangit, located in the State of Sikkim, small Buddhists relics called “Mane” were to be submerged. A negotiation with Buddhists Lamas to rehabilitate and relocate the Mane had taken place. The rehabilitation and relocation was in a much better form and in a much better location that satisfied the majority of the Buddhist community. Initially, the local ethnic group had some adverse feelings against the project and its related development. As the project gradually involved the local people in building of infrastructure, forestation, and other activities, they slowly reoriented themselves with the active support of their religious head. Today there is no person who has not been properly rewarded over and above the financial benefit that the community received during the construction phase of the project.

Lesotho Highlands Water Project (R. Mochebelele, Lesotho)

During the engineering phase of the Lesotho Highlands Water Project the government undertook detailed studies to see what impacts the project would have on both the physical and socio-economic environment. The conclusions and recommendations of the various plans were compiled and consolidated into an Environmental Action Plan composed of three plans namely: i) The Compensation Plan which addressed direct losses such as houses, arable land, grazing land, etc., by the affected people; ii) The Natural Environment and Heritage Plan which assessed the effects on the natural environment including, among others, fauna and flora; iii) The Rural Development Plan which addresses and mitigates negative socio-economic impacts, seeks to improve the standard of living and initiates sustainable development within affected communities. The Treaty signed in 1986 states that the standard of living of the affected people should not be worse than before the project was implemented. Among the Rural Development Plan projects to be undertaken are those to restore and increase productive capacity, to enhance household income, to build on the opportunities presented by the project, and to provide the basis for the social and economic development of the region. Specific programs and projects are: Skills Training Projects, Livestock and Range Management Projects, Horticulture, Subsistence and Commercial Fisheries, Rural Feeder Roads, Land Use Planning with the people, Tourism, etc.

Dam construction and reservoir formation have increasingly caused relocation and resettlement of populations. This influences the cultural behaviour of both the relocated and original people in the new region. The issue here is not a mere indemnification or compensatory process, but a commitment to educate and retrain people, and to offer better conditions so they can be have new job opportunities.

In Brazil, the area covered by reservoirs is estimated to be over 30,000 km^2. This has resulted in a resettlement of more than 324,000 people to different villages, different agricultural systems and different lifestyles. Indian territories, in Brazil, are preserved according to constitutional law. Any project or impact in such areas can only be approved through a formal authorization from Congress. This fact has very much restricted the construction of reservoirs in the Amazon River basin.

CONFLICTS OF INTEREST UPSTREAM AND DOWNSTREAM OF DAMS

Conflicts of interest between regions upstream and downstream of dams and reservoirs are generally related to the various purposes of the project. Where dams have as part of their purpose the protection of downstream population and properties from flooding, the project is planned and operating rules are usually developed and applied so that the reservoir provides flood control. The purpose of those plans and rules is to limit, within a given probability, outflows so that that human life losses, significant economic damages, and major environmental impacts are minimized. On the other hand, the various pre-existing uses of the upstream reservoir area (towns, transportation systems, properties in general, etc.) may limit the possible reservoir area and capacity. Consequently, the temporary capacity for flood storage of large inflows is restricted.

Good practices in land use management and zoning (territory) policies must be adopted simultaneously the decision to implement a project in order to avoid the effect of a false sense of safety induced by dams or other flood protection infrastructures.

A very interesting example is that of the Paraná River Basin cascade located in southern central Brazil. The forty-six reservoirs that comprise the cascade have a total volume of 260 x10^9 m^3, of which 129 x 10^9 m^3 were originally designated for power generation.

The cascade begins at the Furnas Power Station reservoir, the most important reservoir in the system as far as regulation and flood control are concerned. The cascade ends in the Itaipu Power Station, which has a 12,600 MW power output (2 more turbines, 700 MW each, are presently being installed).

Erton Carvalho, Brazil

The development and occupation of areas on the banks of the rivers downstream from the dams has sometimes resulted in the inappropriate establishment of towns close to the river channel. If this occurs there will likely be an increased flood risk. Because of the encroachment of developed areas into the flood plain, flooding can become more frequent and intense, damaging buildings, industrial facilities, agricultural areas and, of greater concern, the riverside population. These damages occur in spite of the reduction in flood flows provided by flood control regulation of the reservoirs.

Conflicts of interest between upstream and downstream regions in dam sites are also aggravated by the required reservoir operating rules. These rules must provide gradual and slow opening of spillway gates, in order to avoid sudden, artificial downstream floods that could jeopardize people and properties located near the watercourses. A warning system ought to be used to establish permanent communication between the responsible reservoir operators and the authorities in charge of the safety of local communities in each district or county in the basin.

Following dam construction, particularly when the reservoir is being filled, the project operators are obligated to provide a minimum downstream flow, to maintain the river ecosystem. This requirement, if imposed downstream flows that are greater than necessary (perhaps determined without a proper scientific analysis), can generate unnecessary conflicts between sustaining the ecosystem and obtaining the benefits for which the project was constructed.

In general, conflicts arising from river navigation in rivers regulated by dams result from the necessity of maintaining a minimum flow downstream of the dam to assure navigation during the dry seasons. These requirements may hamper other uses of the water, particularly power generation. The Três Marias multipurpose reservoir, with a volume of 21 x 10^9 m^3, is required to maintain a minimum downstream flow of 340 m^3/s for navigation purposes. In conjunction with the downstream reservoirs, this requirement provides a navigable waterway of 1,745 km length.

Conflicting interests along the river Brahmaputra, India (S. P. Sen, India, 2002)

The River Brahmaputra originates in Tibet and travels about 3600 km, through India and Bangladesh on its journey to the Bay of Bengal. The last 300-400 km of the river in India is a river of sorrow. Every year, it floods huge areas on both banks causing distress in Assam. Every year, two to three million people are affected by floods along the river. A large flood control project has been proposed upstream in the state of Arunachal Pradesh. However, two of major towns would be submerged and resettlement of 10,000-20,000 people would be required. The people of Arunachal Pradesh want to harness the same Brahmaputra further upstream by building smaller dams for hydro power stations. The conflict of interests between two groups of people in the same basin remains unresolved with potential benefits forgone by all.

CONCLUSIONS REGARDING EFFECTS OF DAMS

Mankind faces a number of critical challenges to its own survival, such as an unprecedented increase in population with a universal desire for improving living standards and quality of life, as well as recognition of the need for conserving the life-supporting functions of nature. The challenge is to balance the need for increasing water and energy supply with the inevitable adverse effects on the environment and impacts on the local people.

For ICOLD, some strategic issues are: improvement of environmental assessments; increasing reservoir life through erosion-sediment-flood techniques; reduction of construction cost and improvement of dam safety. Specific issues for ICOLD include: optimal reservoir design for river regulation and flood storage, pollution control and water quality, effects on downstream releases, groundwater levels, and reservoir operation during droughts. Also needed are improved integration and optimization of dams and hydroelectric projects in overall basin development (Veltrop, 1995). Sustainability means delivering economic, environmental, and social value to shareholders, customers, and stakeholders. Principles for sustainability are: adopting a long-term view, working with stakeholders, focusing on equity while avoiding persistent conflicts and uncertainties, and innovating (Veltrop, 2002).

4. SUSTAINABLE DEVELOPMENT OF RIVER BASINS

Sustainable Development of River Basins means development with acceptable effects on the physical, social, economic and natural environment, which do not compromise the use of the water resources for future generations.

FUNCTIONS OF RIVERS

Rivers perform many important functions without being controlled by mankind:

- They drain of surplus water from river basins.
- Through the erosion and transport of sediments and nutrients, they maintain an ever changing equilibrium in the river basin and its delta.
- Water and suspended material are transported long distances and distributed by rivers.
- They provide environments for unique aquatic communities in the river and on the adjacent floodplain.
- They produce natural products and services valuable to humans such as fish for food, naturally cleansing the water for domestic, agricultural and industrial purposes, transportation, and providing an environment for human settlement and cultivation.

River basin elements include both the flowing freshwater and the adjacent terrestrial environment. The interrelationships between the various elements of the 'river basin' (upstream-downstream, tributary-mainstream, highlands-lowlands-deltas, land-water, groundwater-surface water, populations-ecosystems, etc.) are so strong that the basin system as a whole is the logical level for environmental and water management measures and decision making. Water management policies for local, national and international entities need to be coordinated and policies formulated for the river basin entity. An integrated approach, in which environmental and developmental viewpoints and interests are balanced, is essential to develop policies for water resources development and management on a basin wide basis.

To ensure the sustainable multi-functional use of all water resources, mankind must move towards management and development of river basins on a basin-wide basis, regardless of international boundaries. Hydrological conditions, environmental constraints, and social and economic needs vary in different regions of the world, and every river basin will therefore need its own specific policies for management and development. Because of these regional differences, a universal blueprint for river basin management and development cannot be developed. We have to develop sound procedures by learning from successful experiences in sustainable river basin management and development.

BALANCING HUMAN USES AND ECOSYSTEMS

Human existence on earth has inherent conflicts with nature; in using natural resources, some interference with nature must occur. Nature also is not consistent and does not continuously maintain its character. Evolution will always occur and humans must continuously adapt to that evolution. Droughts, flood, erosion, storms, earthquakes and other natural calamities are misfortunes to which man must adapt. Effective river basin management and development that meet the goals of the present without compromising the ability of the river basin system to meet the needs of future generations is essential for a sustainable system. Effective river basin management must balance the social, environmental and economic conditions in the region.

To balance social, economic and ecological requirements, priorities need to be set, giving special attention to vital human needs and sustainable water management. The principle of sustainability means developing balanced objectives, avoiding dominance of a single objective and respecting the ecosystem, which is the basic resource for economic and social development. Future generations will then not be confronted with irreversible changes precluding the restoration of ecosystem conditions or the exploitation of the river system for other uses. When priorities have been set, specific human uses of water can be stimulated, stabilised, reduced or abolished.

INTEGRATED RIVER BASIN MANAGEMENT

Concepts such as Integrated Water Resources Management (IWRM) and Integrated River Basin Management (IRBM) have been supported by various organizations as two approaches that must be followed in order to reach a sustainable use, development and conservancy of water ecosystems, including the health and well being mankind among them.

The State of the Art Report (2007) of International Hydrological Programme of UNESCO states that, at this time, few case studies of IWRM and IRBM have been published and disseminated.

Separate bulletins with case studies from ICOLD member countries are planned for release independently of this general report in order to help overcome this lack of information.

Additionally state of the art of methodologies and techniques for the implementation of IWRM at basin level will be presented.

Next we shall review some terms, previously defined, that are needed to understand the case studies within the context of IWRM and IRBM.

CONCEPT OF BASIN

To consider a river basin in terms of the holistic, sustainable approach described in this report, it is necessary to consider the entire basin, from the topographic divide to the sea where the basin ends. National boundaries do not delineate the basin – only topographic/geographic boundaries are considered. There are some basins, such as the Okavango in Africa, that do not end in the sea. These situations require special consideration.

Some topographic catchment areas are inter-connected with neighbouring ones, sharing underground aquifers that have influence in their hydrologic cycle.

Moreover, neighbouring hydrographic systems historically have been artificially connected form a social geography that cannot be ignored. Very often such circumstances have created historical rights and relationships that must be taken into account even more strongly than the merely topographic borders.

Such cases provide one more example of situations where mankind's changes to nature and the environment cannot be reverted to a primeval state in terms of social, political and even natural contexts.

Thus, when an isolated system has to be defined for its analysis, a careful re-consideration of planning and management limits is needed.

From the point of view of IRBM the concept of basin must include inter-related water systems. "District"[4] as considered in the European Water Framework Directive can be used as an alternative proposal. (EU, 2000).

BASIN MANAGEMENT

The goal of river basin management is to manage water development systems together with the associated lakes, riverbeds, banks, groundwater, and tidal salt marshes and mudflats, as a complete entity in relation to human interests. Authorities at all levels, national water agencies, river commissions, stakeholders and the general public, each have their own responsibilities in the implementation of sustainable river basin management.

The following elements are essential for achieving sustainable river basin management:

Basin wide planning should balance all user and environmental needs for water resources, in the present and for the long term. Vital human and ecosystem needs may have to be given special attention.

- Participation in Decision-making: Local empowerment and public and stakeholder participation in decision-making will strengthen river basin management.
- Demand-Resource Management: An essential part of sustainable river basin water management must be to control the demands for resources. Decisions may have to be taken that certain uses or projects cannot be accommodated because the resource is a finite quantity and essential ecological flows and storage need to be maintained.
- Compliance/Enforcement: Methodologies for monitoring and assessment of commitments by entities whether national, regional or local, under river basin agreements must be developed. Methods of enforcement of management agreements must also be established.
- Human and financial capacities: Long-term availability of sufficient human and financial capacity is a necessity.

[4] The area of land and sea, made up of one or more neighbouring river basins together with their associated groundwaters and coastal waters, which is identified as the main unit for management of river basins.

As an example of a River Basin Water management, the following is a brief description of *the plan for Fitzroy Basin, Australia*.

Queensland's water management has undergone an era of rapid change. The passing of Water Act 2000 was soon followed by the establishment of SunWater corporation. The first Water Resource Plan for the Fitzroy Basin was issued in 1999. The State Government announced its intention to prepare the first Resource Operation Plan in November 2000, and requested SunWater to prepare proposed water management arrangements for the Nogoa Mackenzie, Dawson Valley, and Lower Fitzroy Water Supply Schemes. SunWater embarked on an intense program to develop the proposed arrangements, involving the evaluation of current operational strategies, sourcing of improved data on infrastructure and allocations, and the development of improved operational, water trading, and monitoring rules to meet government and business objectives. Those proposed arrangements are being adopted into preparation of the Fitzroy Resource Operations Plan.

OPERATION MODEL FOR OPTIMUM COMPATIBILITY IN CHINA

"In order to maximize the benefits obtained from reservoir operation, optimization models should be applied. Both long-term and short-term optimization models should be included, and they should be coupled appropriately to consider both long-term and short-term benefits. This paper presents a methodology to couple the long-term and short-term optimization models. The methodology is applied to reservoir operations to show the obtained benefits. Discretized Deterministic Dynamic Programming (DDDP) is used as the optimization algorithm, and is applied to both long-term and short-term optimization models. The long-term DDDP model uses the historical monthly average inflows as the inputs, and the outputs are the monthly average releases and water levels. The monthly water levels are then interpolated into daily water levels, which are used as the terminal conditions for the short-term optimization model. For each short term optimization cycle, the initial water level is the actual water level reached at the end of the previous stage. The short-term DDDP model optimizes the operation within the short-term optimization cycle, but only the first day's optimization results (the release and water level) are applied for real operation. This process is repeated iteratively until the end of the long-term optimization cycle is reached. The overall optimization time horizon is one hydrological year. Then the benefits obtained over the whole hydrological year are calculated and compared to the actual benefits obtained from the real reservoir operation. This coupling methodology is applied to a reservoir sited on the main channel of the Qingjiang River (a tributary of Changjiang River) in China. The benefits from the reservoir operation are interpreted as the electricity obtained. The results showed that on average, there is a 7% increase in electricity generated compared to the actual electricity generated (2.2×109kW.h) by applying this coupling method and for the pre-assumed quality of inflow forecasted."

(After Xiaohua Dong et al., 2006)

DAMS AS ELEMENTS OF DEVELOPMENT

Dams allow us to divert water from streams to places where it is needed, create clean and renewable energy, allow us to regulate river flows and store water in order to use it later. They regulate flows, improve assurance for domestic supply, irrigation and industrial uses, improve river navigability, protect us from floods, recharge aquifers, encourage use of the recreational environment, and provide compensation of the water levels reduced by the progressive loss of wetlands. The role that dams have played in our development has been a changing one and it will continue to change in accordance with the evolution of our social-economic and ecological needs.

As an example, *the construction of four dams, for flood control, irrigation and hydropower, on the River Damodar*, a major tributary of river Ganges, has advanced agriculture and industry in the districts of West Bengal and Bihar States (population 20 million) such that they have become one of the richest districts in India. Today this region not only has many major industries but also the most intensively irrigated land with highest production of rice. The area also has developed an extensive educational network, road system, and group of medical facilities. This has resulted in a reduction in childhood death rates and improvements in adult education and literacy, public health, communication, and water supply. However, it is very difficult to determine the condition and gains of those relocated from the reservoir areas.

[Siba Prasad Sen, India]

DAMS AS INSTRUMENTS FOR WATER MANAGEMENT

The decision-making processes should be focused on the goals to be achieved in the basin within the framework of the management of the water system. Dams must be recognized as just one instrument in the river basin management toolbox that can be used to reach the goals. The challenge of each proposed project is to determine how a solution can be realized in which the effects of the reservoirs are accommodated within the limits of the natural ecosystem of the river basin. Authorities over entire river basins exist in many nations. Their responsibilities vary from security against flooding to reduction of sedimentation and comprehensive ecosystem management. It is important to realize that whatever management or development steps are implemented in a river basin, the river must continue to function at least at the minimum level for sustaining the ecology of the basin.

A good rule for integrated management is to maintain the original, natural ecosystem conditions as closely as possible. Extreme deviations from the natural state often lead to unexpected and undesirable effects: not only is the original ecological system destroyed, but the traditional benefits of the river basin are also affected. In many river basins, agriculture is essential to the lives of the inhabitants, and great departures from the established flow patterns will directly affect the economics of the region, and even food supplies may be jeopardized. Fisheries are impaired by the building of dams that impede the movements of migratory species. Regulating river flow and river morphology for shipping may lead to flooding problems.

OPTIMIZING BENEFITS OF EXISTING DAMS

It can be worthwhile to modify existing dams to optimize benefits and enhance environmental mitigation and restoration, control reservoir sedimentation, improve dam safety, maximize reservoir life through structural and operational measures, control pollution, improve water quality in reservoirs with concurrent improvements in the quality of downstream releases and groundwater, and afforestation (conversion of land not previously forested into forest by planting trees). Studies of these issues show that they are providing significant results. Benefits of afforestation for example, include the reduction of erosion of fertile soil, less sedimentation in reservoirs and lowered influx of nutrients that degrade the water quality in the reservoir.

If transformation of the ecosystem is unavoidable, it must be directed in such a way as to permit equally vital natural functions to be fulfilled. These kinds of systems and changes require special attention, but must always be geared to achieve the most beneficial combination of the functions of man and nature. The basic premise must be that the functioning of a river basin must be tailored to the needs of society on the condition that the ecosystems involved can continue to function in a beneficial way.

MULTIPURPOSE.

Many dams that were constructed for a single aim may increase their value by means of the introduction of other uses, transforming the dam in a multipurpose dam. This transformation can mitigate some negative effects, mainly of social character, besides improving its economic performance.

The integrated river basin approach is a basis for identifying multi-purpose aspects of dams in relation to the overall planning or management district. Integrated River Basin Studies are a basic form of an environmental impact assessment study. As such, they can identify significant issues concerning potential improvements of existing infrastructure, like dams, as well as for new proposed alternatives and even the introduction of new uses on existing reservoirs. The potential improvements may, in many cases, have conflicting demands in terms of water usage. A typical case is when an existing hydropower reservoir is required to be used to provide water for drinking supply or irrigation.

ZAMBIA

The Itezhi-tezhi reservoir on the Kafue River in Zambia is currently being assessed for additional potential benefits from increased power production by heightening the dam. The issue is that of assessing corresponding benefits to 6500 km^2 of wetlands downstream and considerations for other consumptive users such as irrigation.

In the case of Itezhi-tezhi dam, it is envisaged that a well planned, operated and adapted load management practice to optimise the coordination of hydro generation at Itezhi-tezhi, Kafue Gorge Upper and Kafue Gorge Lower from Itezh-itezhi reservoir may successfully facilitate the accommodation of other water based economic activities like tourism and irrigation.

(After Simainga, 2006)

Some other examples from Barcelona 2006 symposium are recommended:

Normatov & Petrov (Tajikistan)

Implicit in multi-purpose projects is the competition among interests. Seasonal patterns for hydro and irrigation can be out of phase with each other. Simplified models help to find the optimal operation to maximize regional benefits while considering even social aspects.

Marizza et al (Agentina)

Improvements on the benefits of dams can be achieved by means of meteorological techniques and hydrological forecasts. Special mention is made of the cases where the various purposes are conflict and even involving different players. Municipal supply and irrigation water, flood control and hydropower generation share infrastructure but have temporal needs. The objective sought is the greatest overall social benefit.

Dong et al (China)

In order to maximize the benefits obtained from reservoir operation, both long-term and short-term optimization models can be coupled. They show that an increase of over 7% of total energy production can be achieved using these techniques. The basic function is to maximize the gross benefit, taking into account conflicting objectives. If forecasting is available, through the use of stochastic models, extra benefits may also be obtained versus traditional rule curves.

Simainga (Zambia)

There still lies tremendous potential that could yield an economic value to surrounding and associated areas.

Redesigning existing large dams for multipurpose objectives can address some social and economic needs and mitigate some negative impacts in the affected area.

Dormant potential must be exploited in order to achieve the maximum benefit thus improving economic rates of return.

It's necessary to review the project operation periodically. Many unforeseen issues emerge during the commissioning phase and the first years of operation.

Pongolapoort Dam in South Africa

The Pongolapoort Dam in the Phongolo River at Jozini in Northern Natal/Kwazulu, approximately 100 km south of the Mozambique border, was completed in 1970. The manmade flooding of the floodplain pans downstream of Pongolapoort Dam, by means of controlled releases from the dam is an example of worldwide interest, and could perhaps be emulated elsewhere. Monitoring environmental effects of the flooding of the plains during these releases allowed optimization procedures leading to improved quality of crops and better lifestyle for the inhabitants than had occurred under the previous natural system. Flood control by the dam itself is also a benefit and its storage is utilized mainly to enable artificially controlled watering of the flood-plains to be carried out.

Valuable lessons for the future were gained from the subsequent development of the management system.

- A large storage floodplain can be managed to maintain the resource base in a sustainable way by manmade releases from an adequate size impoundment.
- With the correct community involvement the rural peoples' perspectives changed from very negative to positive, as virtually all of the 60,000 to 70,000 inhabitants accepted the controlled releases to be beneficial to their interest, both in the subsistence assurance and the flood risk management categories.
- The over-exploitation of a sensitive resource base, such as the staple-food supplies from the existing floodplain pans, must be guarded against. Sustainability is at risk due to both excessive flooding possibilities as well as inadequate inundation. Care must be taken not to encroach flooding into environmental and ecologically sensitive areas.
- There are more lessons to be learnt regarding the design and placement of outlet structures on impoundments for artificial floodplain management. Limnological criteria are very important considerations and specialists in ecological planning should be consulted in that regard.
- It appears as if sustainable utilization of a well-managed natural flood-plain resource can provide a better cumulative 'quality of life' than monoculture cropping, but this would need a competent resource study in economics.

- Intensive ongoing long term ecological monitoring of a managed flood-plain is essential for maximising benefits on a sustainable basis due to the complexity and long time scales (often over fifty years) of ecological processes. The integrated environmental management process is a multi-disciplinary team approach, in which participants must keep to their primary fields of interest.

- Ecological resource planning and utilization, especially where community issues are at stake, should be handled by competent environmental and social scientists as well as engineers; drawing upon specialist inputs from relevant basic science, engineering and technology.

The manmade flooding of Pongola flood-plain pans by means of artificial releases from Pongolapoort Dam is an ongoing process and new lessons about ecological resource utilization and community involvement are continuously being learned.

[After Bruwer & Jordaan, 1994]

Progress in this area requires:

- Taking care of the ecosystem. Man has the right to make use of an area, a river basin or river but also must take care of the ecological processes of the basin toward the goal of beneficially functioning ecosystems.

- The value of the ecosystem must be recognized in administration and management. It is very important to value the ecosystem and incorporate its care in the administration and management of dam projects in order to give the attention needed to the ecological component of the river basin.

- Preparing, guiding and monitoring changes or transformation in the ecosystem.

If a decision is taken to intervene in the ecosystem, the changes or transformation must be thoroughly prepared (e.g. by research), guided, and kept under ongoing review. These are essential components of management of a large-scale sustainable water resources project.

"Good Operation of Reservoirs May Improve Benefits of Existing Dams" from Iranian National Committee on Large Dams (IRCOLD) is about to be included as an special contribution for a separate bulletin providing more detail for some case studies.

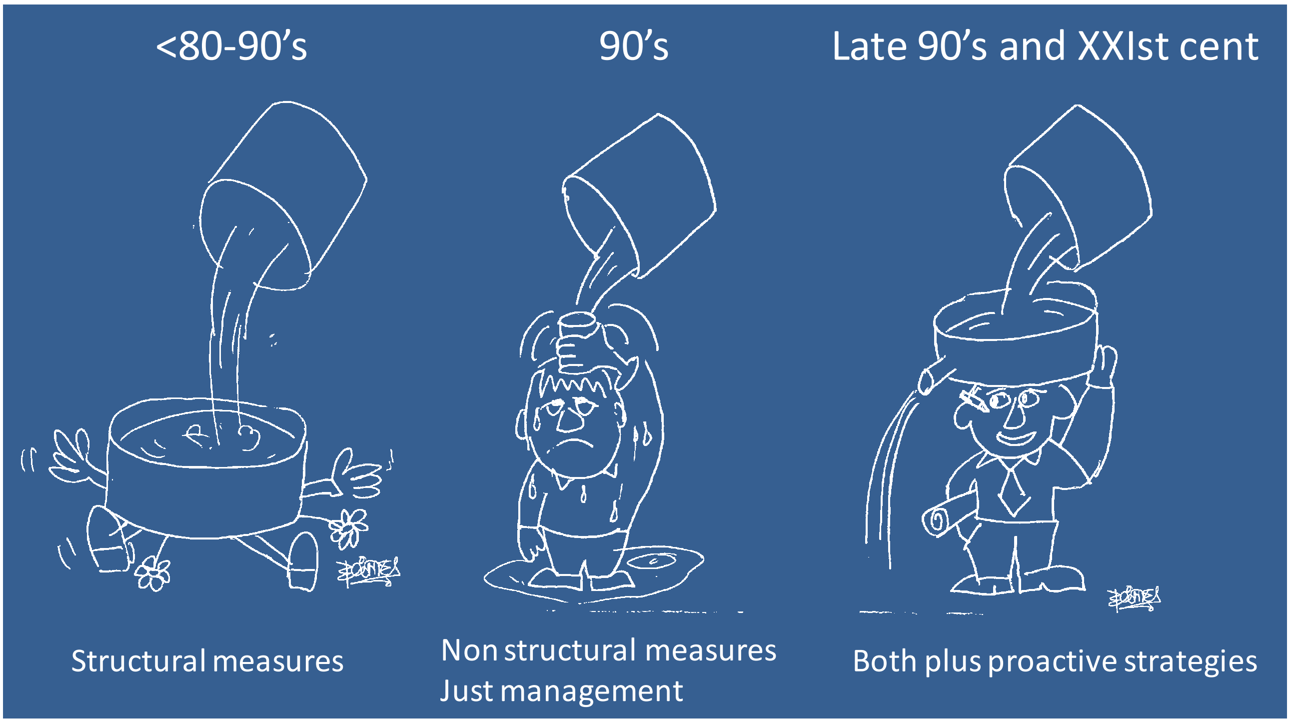
ALTERNATIVE OPTIONS TO RESERVOIR DEVELOPMENT

When the needs are water supply, flood control and electricity production, what realistic options and alternatives does society have, and what are the short and long-term consequences? All options to augment the available water supply, including increased storage through the use of groundwater recharge, dams on the mainstream and diversion to off-stream reservoirs, need to be considered, while ensuring, in each case, that all those who will be affected will also benefit.

During two last decades of 20th Century, two extreme positions were held:

1. Structural alternatives as the only proposal to solve water resources problems.
2. Demand management as the only admissible tool to be considered.

Nowadays a reasonable combination of both proposals is the most common position.



Different pendulum stages.

ICOLD supports any balanced comparison of alternatives even as a mandate:

d) Projects must be judged everywhere and without exception by the state-of-the-art of the technologies involved and by current standards of environmental care. The scope for reducing any detrimental impacts on the environment through alternative solutions, project modifications in response to particular needs, or mitigating measures should be thoroughly investigated, evaluated and implemented. (ICOLD. Dams and Environment)

If the community lives above identified minimum standards, one option is to accept the status quo. In such cases, a consequence analysis should be performed for that alternative. In a systematic probabilistic optimization process, the benefits of the different alternatives may be estimated fairly reliably. However, the associated indirect costs in terms of negative long-term effects on the social and physical environment are very uncertain and usually dominate the outcome of the comparative analyses."

The effects of interventions in the field of water management must be assessed at the scale of the entire river basin and over the long run. In the decision-making process, attention should be paid to alternatives in addition to dams, such as enhancement of groundwater storage, direct diversion to off-stream reservoirs and even the 'do-nothing' alternative. The 'do-nothing' alternative (inaction) is one of the available options, and should be equally considered.

But, as we have stated in chapter 1.2., if the community lives below minimal standards, leaving things as they are is inadmissible on the grounds of human dignity. Under these circumstances we can recall JFK's words: "there are costs and risks to every course of action, but they are far less than the long-range risks and costs of comfortable inaction".

Important aspects that should be kept in mind during the process, are that solar, wind, ocean wave and tidal power, represent renewable sources of clean energy. In the foreseeable future however, these options can only provide a small fraction of the levels of output required. In the meantime, non-renewable thermal power plants (fuelled by coal, oil and other combustible matter with a lot of unwanted pollution side effects) are being built rather than dams for hydropower. And in the poor, rural parts of the third world millions continue to burn whatever organic matter they can find. One of the reasons for the preference of thermal plants to dams is that any negative social and environmental effects caused by dams are felt locally, and the indirect costs are included in the economic assessment. The upfront investments are also generally lower than for multi-million dollar dam projects and hence easier to fund for a poor country. On the other hand, the harmful gases and air pollution produced by thermal power appear more remote and are not yet generally included in economic assessments, when options are compared. This happens even in developing countries where hydropower is the only natural energy resource available.

Very often, and more so in recent years, dams are multipurpose, creating benefits in more than one way. This must be taken into account when environmental and social benefits and costs are compared with the benefits and costs of other options. The attractiveness of reservoirs for recreation is often a significant benefit in areas where natural lakes are scarce or non-existent.

Alternative options for water management can include smaller-scale, locally managed technical, institutional, and economic solutions, including micro-dams, run-of-river hydro systems, shallow wells, low-cost pumps, water-conserving land management methods, and rainwater harvesting approaches that are part of or building on traditional experiences in local communities (after Gleick, 2000).

However, 95% of the storage and 80% of the benefits of dams are supplied by 10% of the "large dams". About 40,000 among the 50,000 existing large dams are practically small dams representing few per cent of the overall benefits (ICOLD, 2006)

Scale matters about large dam projects: A 10% larger water infrastructure project is shown to have 7% lower unit costs and 3% higher returns on investment, but large projects require combination with small irrigation systems of local smallholders (farmers) to be effective (IWMI, 2006)

COST OF ENERGY AND SUSTAINABILITY OF ALTERNATIVES

It is not always easy to translate social and environmental costs of a project into economic terms. In some cases, environmental impacts can be evaluated in economic terms but in some others this becomes difficult, as it is the case of a cultural or historical loss or the reduction of biodiversity.

A great part of the energy produced in the world comes from fossil combustibles that release huge quantities of pollutants, especially carbon monoxide and dioxide, into the atmosphere. One of its effects is the 'greenhouse effect' that has climate change as its main potential consequence. Hydroelectric energy produces 90 % of total renewable energy, but it only produces 19 % of the total energy in the world.

While studying the sustainability of any development project, its energy cost should be analysed. The energy which is applied to every cubic metre of water supplied, should be an essential factor in the comparison of alternatives. By internalising costs, we must be able to evaluate the sustainability of alternatives that imply high energetic costs like desalination.

Dams usually supply water at very low energy cost, because solar energy, transformed into potential energy as a part of the hydrologic cycle, 'puts' water at the starting point of distribution schemes. So, the water furnished by rivers and dams is often 'clean' water from the energy point of view. Most of other alternatives need to use to need certain amount of energy to develop the same quantity of water. The consideration of the energy cost, taking into account equivalent emissions, therefore, is essential in studying alternatives to dams.

Other considerations are the prospects of inflation and currency devaluations over the life of the project, the debt service of the loans used to fund the capital costs and use of valid economic analyses that equalize the lives of the various alternatives being compared. Usually dams produce their benefit with relatively high capital cost but low operating cost and over a longer lifespan than other alternatives. Capital costs become fixed at the time of construction but operating costs increase annually primarily with the cost of energy (fossil fuels), supplies and labor, at a rate which may *be even more than general inflation. So the cost per benefit obtained (cu meter of water, kwh of electricity) from a dam usually does not increase over time an much as it does in other alternatives. If a project produces benefits and the society it benefits prospers, the cost of its commodity seems like a bargin 20 to 50 years hence.*

Moreover, multipurpose dams, when hydropower is amongst the intended uses, can provide a positive balance of energy and a significant contribution to funding the project. In the short term, hydroelectric projects may offer a shorter road to sustainability than projects based on fossil fuel sources. Let us take as an example the fact that the hydroelectric capacity in the USA (73,500 MW) can produce over 300,000 GW/h per year, which, if they were produced by fossil combustibles (129 million tons of coal), would imply an atmospheric pollution increasing by 7.7 million tons and 296 tons of carbon dioxide, in addition to other emissions (COPA, 2001).

In conclusion, an environmental approach should recognize that hydroelectric projects offer the best application of sustainable energy, at least for the present, of any technology is available provide water and energy to mankind. And therefore, dams provide more food and health assistance than any other real, reliable and sustainable alternatives. Environmental globalization is a fact of life in the 21st century and we are all stakeholders.

5. DECISION-MAKING PROCESS OF DAM PROJECTS

The public or community involvement process focuses on the rights and duty of stakeholders to participate in public decision making. The aim of the process is to incorporate the expectations, necessities, and points of view of citizens who are affected or benefited by the economic and social aspects of the project. At the same time such involvement may develop a sense of responsibility for and acceptance of decisions or recommendations that need to be made in order for the project to be implemented. (IWRA).

Historically, decisions on the construction of infrastructure in river basins were made on the basis of identified need and the economics of the alternatives. Stakeholders, locally and regionally, more or less accepted such decisions. Recently, however, everyone wants to understand the advantages and disadvantages of each alternative and how the negative consequences are to be mitigated and by whom. Infrastructures must be planned and engineered to achieve the needs and reflect the values of the diverse populations they are meant to serve.

Evaluating the benefits and costs of a water resources development project for all stakeholders is now a critical issue. Will the benefits of the project, water supply, flood control, irrigation, electric generation and recreation, offset the project's alteration of the natural environment?

An integrated approach to evaluation of water resources projects, including dams, has been applied in recent years. That integrated approach does not focus only on the traditional evaluation of economic costs and benefits; instead, it is based on the concept of sustainable development. Sponsors and regulating agencies can no longer only propose where, when and how to build a project, but must first identify the need for the project and identify those it will serve. During the feasibility study phase of a dam project, more attention must be given to how people will be relocated, how river ecology will be affected, and whether the public perceives a need for the project (Yong, 2003).

FIVE STAGES AND DECISION POINTS

The World Commission on Dams (2000) identified five key stages and associated decision points for the energy and water sector. These steps and associated decision points are generic and need to be interpreted within the overall planning contexts of individual countries.

1. Needs assessment: validating the needs for water and energy services

2. Selecting alternatives: identifying the preferred development plan from among the full range of options.

Where a dam emerges as a preferred option, the following key decision points occur for project preparation, implementation and operation.

3. Project preparation: verifying agreements are in place before tender for the construction contract.

4. Project implementation: confirming compliance before commissioning.

5. Project operation: adapting to changing contexts.

The decision making process involves multiple participants. In a recent thesis by Van de Riet (2003), policy analysis is defined as "facilitating the policymaking process by producing policy-relevant information that can be utilized to resolve problems in specific political settings. Finding solutions to problems is thus the core of policy analysis. The methodology of policy analysis draws from and integrates elements of many scientific disciplines. These include operations research, economics, statistics, political science, sociology and psychology". Concerning stages 1 and 2, the World Bank (2003) considers that good practices of national policies are:

- A national or regional policy for the management of water resources, energy, irrigation, water supply, flood protection etc., should set out objectives and priorities.

- A general option assessment (e.g. demand-side versus supply-side) at the macro level that will give clear and persistent political signals to future developers on type of development needed.

- Environmental and nature conservation policies and plans that identify areas where nature is protected and project development is prohibited.

- A national or regional environmental policy should set out objectives for managing rivers and water resource.

The Working Group of the International Energy Agency (IEA, ***yyyy***) analysed information on environmental and social impacts of hydropower and stated five ethical principles that any assessment should consider: optimality; stewardship; fairness and justice; participatory decision-making; and prudence and control.

Where this process includes a storage project as a feasible alternative, governments, in accordance with the U.N. Declarations on Humans Rights and the Right to Development, the Millennium Declaration and the World Summit on Sustainable Development, will seek to ensure that any storage project should (ICOLD, 2003):

- be implemented as a result of a thorough review of all other available options, based on expert assessment of the benefits and impacts of all such available options;

- be developed in accordance with national environmental laws, regulations and should meet any recommended guidelines as far as possible;

- follow a credible environmental impact review process which includes public consultation at an early stage, in accordance with national legislation;

- as far as is practicable, stakeholders who are acting in the best interest of those in the region, should be involved in the planning process, and negotiated outcomes should be sought;

- implement best practices to mitigate environmental and social impacts, in particular the resettlement of displaced people;

- ensure that locally affected communities benefit directly from the project on completion, both in the short and long term; and, compensate affected people for any impacts which cannot be mitigated.

Future decisions on dam building must be based on an assessment of the advantages and disadvantages of building dams and of the alternatives. It is therefore important to consider the socio-economic and welfare advantages of a dam for the population it is intended to serve. The discussion of alternatives to building dams and of what their economic costs and environmental and social consequences of such alternatives would be must also be a part of the total decision-making process. All this must be undertaken in an open and participatory framework. These key points will be developed in the next subchapters.

ECONOMIC EVALUATION OF RESERVOIR PROJECTS

COST BENEFIT ANALYSIS (CBA)

Because the potential economic, environmental and social impacts of dam projects are significant, decisions to construct water resources projects need to be based on the best available analysis. In particular, they require cost-benefit analyses that are clear, comprehensive and based on accepted economic and accounting principles. (Chutubtim, 2001).

Based on the experience, it can be concluded that in most countries cost/benefit analyses (CBAs) are an important part of the decision-making process for dam construction. They are carried out in different phases of the decision-making process on behalf of different project proponents. However, environmental effects of dams have not always been incorporated in CBAs. Furthermore, only directly quantifiable effects, such as fishery and recreation, were usually included. Today, environmental effects are incorporated in decision-making through other tools, such as an environmental impact assessment, compensation analyses and environmental indices. Due to continuous improvements and development of economic valuation methods, since 1970s in particular, various valuation techniques now exist that allow for the incorporation of environmental effects in decision-making processes of water resources projects.

It must be recognized that the use economic valuation is not undisputed and that other instruments exist that allow for the incorporation of environmental effects in decision-making processes of dams. Which instrument is applied depends on the context in which the dam is constructed: in some countries rules and regulations call for social CBAs, while in other countries may call for environmental impact assessments. Whichever instrument is chosen is not important, but the need to include environmental effects of the proposed project in decision making is critical. In the pursuit of balanced decisions in which both costs and benefits need to weighed, economic valuation of ecosystems can be very useful and transparent for decision-makers (Schuijt, 2002).

Some examples of CBA in Norway

Because all water resource projects are unique, and very few case studies have been evaluated in a consistent manner, a few cases from Norway are presented as examples. The dams were built from 1940s to 2004 and represent different variations of rock-fill dams, concrete dams, sizes and locations with respect to arctic conditions. The costs were difficult to identify because of several reasons:

- In Norwegian water resource (mainly hydropower) development from the 1970's and onwards, environmental considerations are generally included in the planning costs and it is very difficult to identify the costs of environmental protections in the final project costs.

- Another difficulty is that the flood reduction potential provided by reservoirs has, by tradition, never been included in the costs or the benefits of hydro power projects. In the Glomma and Laagen rivers (Norway), the existing hydropower reservoirs and the way they were operated, significantly reduced the damages of the flood in 1995. The damage compensation paid by the government and insurance companies to private stakeholders after this flood was equivalent to 316 million US$. What the compensation would have been without the beneficial effect of the hydropower system cannot be estimated.

a) Costs of Planning, Construction, Operation and Maintenance of Dams, Environmental costs and benefits, and Social costs and benefits

In all, 8 cases with usable data were found. Planning costs seems to be in the region of 7 – 13 % of total costs, - construction costs between 85 – 95 %. The only reliable figures for operation and maintenance cost are given in one case (4 %).

b) Environmental costs

The data consist of only six cases. The ages of the dams are from 50 years to one year. Environmental costs seem to be in the range of 2 – 12 % of total project costs. However, it is often difficult to identify the "environmental" costs connected to decisions made in planning and licensing.

Some conclusions about the environmental costs and benefits of the Dokkfløyvatn Dam project are interesting:

- In the reservoir, relics from Stone Age (rock carvings) and Iron Age charcoal and iron production were discovered. Also pitfalls to trap elk and primitive log running dams were discovered. The power company spent more than NOK 21 million or 2.4 million € / 3 million US$ (February 2004) to dig out, register and preserve these artefacts.

- The value of the fish population was assumed to be reduced. The developer paid a onetime (lumpsum) compensation to the owners of fishing rights. In addition, the power company must stock the affected parts of the watercourse with trout each year. The Norwegian legal system requires compensation for both private stakeholders and the rights of the common public. In total, 4 % of the project investments are estimated to be related to environmental assessments, remedial measures and economic compensations.

c) Social Costs

Only reasonable reliable data from three cases were available. Social costs are difficult to identify. For example, when an access road is built to a dam site (often with specifications in excess of what's actually needed by the contractors) and then handed over to the local community for private or public use later on, - how much should be credited social costs and how much pure construction costs? Or bridges? Or power lines? Or waste rock piles later used to build public roads or levelling areas for industry or home construction? Or buildings handed over to the municipality for a multitude of purposes? There will always be an element of judgement in these matters.

The Norwegian Institute of Urban and Regional Research (NIBR) published, in 1990, some of their findings of the social impacts of a particular project. NIBR's main conclusions were:

Positive Effects:

- The project was well planned and executed in an efficient way.
- The total costs (NOK 2,400 million or 345 million € / 272 million US$ (February 2004)), were less than originally budgeted.
- Roughly 60 % of the construction work was done by personnel employed locally.
- 25 % of supplies for construction work and articles of consumption were supplied by local / regional firms. The activity was clearly stimulating for the local trade.
- The project was located within the borders of three different municipalities. These municipalities received, in money and other forms of compensation more than NOK 103 million or 11.7 million € / 14.8 million US$ (February 2004)
- Supplies to the power stations (electro – mechanical components) were mainly produced within Norway. The imported share is estimated to 10 – 12 %.
- The project created at least 1.5 man-years of work per million NOK invested (3 000 man-years) and the local / regional portion of this is approximately 50 %.
- The population in the area has been stable over the last 25 years before the hydro power development took place and so far this long term trend seems not to have changed during the construction period or the years after which this study covers.

Effects, assumed negative or "not necessarily positive" were few:

- In the construction period, the rise in expenses for "turn-key" housing estates was 30 %
- During the construction period the traffic of especially heavy vehicles caused noise, dust and traffic hazards.
- There may have been some changes in local employment such as a shift from low paid work to higher paid employments and hence some stress on the local employment market, temporary loss of labour to the higher "priced" work at the project site etc. On the other hand this increases the purchasing power of the individual worker and the tax- income to the municipality.

All things considered, the development project has been beneficial for the local/regional community. More resent analysis of hydropower development work in a neighbouring area (2004) support this figures. In this more recent case, the total economic benefit to the community in form of licensing fees, compensations, taxes etc. amounts to:

- A lump-sum payment to the municipality: NOK 5.5 million (623,000 € / 790,000 US$)
- Yearly taxes, fees and compensations: NOK 20 million (2.3 million € / 2.9 million US$)
- Value of new / upgraded roads and bridges and other infrastructures.

d) Economic Cost / Benefit ratio

Nine Norwegian projects were studied. The energy output was in the range of 30 – 1000 GWh/year. The ratio invested capital €/ kWh was in the range of 0.005 – 0.28. In five of nine cases this ratio was in the range of 0.01 – 0.02.

There is no doubt, however, that the construction and operation of the Norwegian hydro power system, with an average output of 118 TWh / year, has had a profound impact on the Norwegian society in many ways. And, since about 70% of this power production is from reservoirs, the role of dams and water management is closely linked to the hydro power industry in Norway.

GUIDELINES FOR MAKING A COST-BENEFIT ANALYSIS (CBA)

A cost-benefit analysis (CBA) is an economic evaluation technique. It can be used to appraise whether a project is worth undertaking and it can be used to determine its optimal size. Since the 1970s, CBA has become the World Bank's dominant decision support system for project appraisal. It is used to evaluate all costs and benefits of a dam project, and to determine whether the project, if constructed, will improve the social welfare of all those concerned, individually and collectively. According to Boardman (1996), the main steps for performing a CBA of a dam construction project are as follows:

- Define a referent group (the populations to be benefited and/or support the cost)
- Select a portfolio of alternative projects
- Identify potential (physical) impacts of the project
- Predict quantitative impacts over the life of the project
- Monetize all impacts
- Discount for time to find present values
- Sum: Add up benefits and costs
- Perform sensitivity analysis
- Recommend the alternative with the largest net social welfare value.

(1) Define a referent group

A referent group is a group of individuals whose welfare will be accounted for when assessing the costs and benefits of a particular project. The referent group does not always comprise all the people affected by the project.

In some nations, however, water resource development projects are undertaken from a national perspective. Therefore, the referent group could be the entire population whose welfare is taken into account.

Dams on international rivers[5] present special problems as the people affected are not confined to those in the project nation. Decision makers should be aware of the political ramifications of a project on neighbouring countries, even if such impact is exclusive of project costs and benefits.

(2) Select a portfolio of alternative projects

The following issues commonly affect the alternatives available in water development projects:

[5] Highly recommended ICOLD publication: "Bulletin 132 - Shared Rivers : Principles and practices". 2008.

- Timing: Could the project be delayed to a later date?
- Hydropower plant option: Could hydroelectric capability be included?
- Material: The dam could be made from various materials such as earthfill, rockfill or concrete, which also affect the length of the construction period.
- Size: The dam could be made according to different heights and capacities.
- Mitigation measures: fish ladders for migratory species; operational constraints on flows and reservoir levels, etc.
- In practice, it is useful initially to consider an expanded choice set. A brainstorming session at an early stage will help expand the range of options. In this step, a small subset of the most attractive project alternatives should be selected. The specific characteristics of each alternative are essential for the scientists, engineers, ecologists, socialists and economists involved in the project concerned to evaluate its feasibility.

(3) Identify potential (physical) impacts of the project

Once the preferred project has been identified, all the experts in the relevant fields involved will identify the potential impacts of the project. At this stage, all direct/indirect and tangible/intangible impacts must be fully described.

(4) Predict quantitative impacts over the life of the project

Water resources projects have impacts over extended periods of time. Experts have to predict the magnitude of all impacts in terms of measurable units over the life of a particular project. For instance, the area of irrigation, the amount of electricity and the amount of water supply can be quantified and measured. If there are any impacts that cannot be quantified or measured in physical units, for example, social and cultural impacts, experts should provide descriptive information. Sometimes, the required information may not be available for prediction. In such a case, experts will have to make certain assumptions to estimate anticipated impacts.

(5) Monetize all impacts

In this step, experts have to put all impacts in monetary terms so that the costs and benefits can be compared. Market prices may not be appropriate because they are not adjusted for subsidies, taxes, environmental and social externalities and therefore do not reflect the true value or opportunity costs of these impacts and need to be skilfully adjusted. We must realize the enormous difficulties, in most of the cases, to accomplish this task, and qualitative alternatives must be not rejected as a substitutive way.

(6) Discount for time to find present values

Before adding the positive and negative impacts of a dam project, the monetary costs and benefits that occur at different time periods have to be adjusted. Future costs and benefits have to be discounted by a discount rate so that they are comparable as if they were evaluated on the same time base.

(7) Sum: Add up benefits and costs

All discounted costs and benefits will be summed up to obtain the projected net benefits. The results of the appraisal are then presented in the forms of Net Present Value (NPV), Benefit-Cost Ratio (B/C ratio) and Internal Rate of Return (IRR). Where there is only one potential project, it is viable if the NPV of social benefits is positive, the B/C ratio is greater than 1 and/or the IRR is larger than the social discount rate.

(8) Perform sensitivity analysis

This step attempts to deal with uncertainty. Sensitivity analysis will be performed with respect to uncertain variables that have been identified, such as the magnitude of impacts and the valuation per unit of impact.

(9) Recommend the alternative with the largest net social welfare value

Finally, the experts have to make a recommendation on the most efficient project that gives the highest positive net benefit value. These guidelines will not go into the details of each step of a CBA. Rather, they will focus on how to make economic valuations and interpretations according to economic criteria. While it is known that a CBA is perfectly consistent with economic principles, it is a very costly and time-consuming process, particularly in the valuation of costs and benefits. These guidelines aim to assist project analysts and commissioning bodies in conducting cost-benefit analyses in a more practical and efficacious manner (Chutubti, 2001).

EQUITABLE BENEFIT SHARING AND STAKEHOLDER PARTICIPATION

Many of the primary beneficiaries of dams often live far away from the dam sites but people living in the project-affected area sustain most of the negative impacts of dams. Resettlement and rehabilitation practice has been evolving enormously over the years. The main phases can be summarized as:

- forced resettlement (until the '60s);
- do no harm ('70s);

- resettlement as a development opportunity ('80s and '90s);
- project[6] as a development opportunity ('90s);
- sharing the project's economic rent (emerging trend). Win-Win strategies are nowadays unavoidable.

There are economic, strategic and ethical considerations for fairly redistributing the benefits from dams to project-affected populations. A study by the World Bank Group (2002), which is part of its Dams Planning and Management Action Plan, focuses on mechanisms that ensure a direct monetary redistribution of project-related revenues to project-affected populations. The study describes five main types of mechanisms associated with the existence of an economic rent and related to monetary benefits:

- Redistribution of part of the dam's revenue to local or regional authorities in the form of royalties tied to power generation or water charges;
- Establishment of development funds financed from power sales;
- Part of full ownership of the project by project-affected populations (equity sharing);
- Levying property taxes by local authorities; and,
- Granting preferential electricity rates and fees for other water related services to local companies and project-affected populations.

In addition, non-monetary mechanisms, such as the allocation of fishing rights to re-settlers in a newly created reservoir, access to improved infrastructures or priority hiring of project-affected people on construction works or in operation activities, may be considered.

The study by The World Bank Group shows that, in practice, designing benefit sharing mechanisms is a complex task that involves reconciling the conflicting goals and values of concerned stakeholders, taking into account a fixed amount of benefits. The existence of an economic rent does not mean that monetary flows from dam operation allow for a redistribution of benefits. The implementation of benefit sharing mechanisms may include steps, provisions and safeguards that provide assurances that the goals are achieved.

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[6] Not only resettlement but also other actions on reservoir area are part of the project since its conception.

The success of dam projects will depend on open communication between the project authorities and the affected communities. This communication should help to assess the suitability of programmes and to gauge their acceptability by the people. In the planning process of water management projects a large number of stakeholders are involved. With respect to water resources, one can distinguish not only politicians, government agencies, international financing agencies, construction companies, tourists, farmers and drinking water companies, but also social groups, nature itself and environmentalists. Special attention is needed include to the affected people as partners in the planning process.

Public participation is a generic term identifying, on the one hand, an ethical and democratic value, and on the other hand, a series of technical procedures, also called participatory processes. The value upon which public participation is developed considers that every individual has the democratic right to take part in public decision-making processes when the decisions made and issues addressed by these processes somehow affect their lives. There exist legitimate points of view which are different from the ones presented by elected or appointed authorities; there exists, outside the state administration, a valuable knowledge of expected or perceived consequences of a public project. Local authorities and the state are no longer the only source entitled to say what the 'general interest' is; and, these authorities may be contested.

Public participation and empowerment are necessary conditions for achieving sustainable development. To ensure effective participation, independent of the goodwill of the authorities, rights of access to information, active participation in decision-making processes, and access to justice need to be legally established. Responsibilities, in the process of decision-making, should remain clear: it is the government, the politically responsible body, which in the end should make the decision; it is, therefore, the responsibility of this body that its decision is of the 'highest quality'.

The key elements for the success of a public involvement program were already described in 1969 in the Skeffington report:

- To do much more than formal hearings, inquiries or exhibitions of plans and proposals;
- To link public participation and representative democratic mechanisms;
- To control the professional power of planners and decision makers.
- To avoid limited or erroneous representatives of citizens, not taking into account all the population, problems or existing interests.
- To avoid the possibility that public participation would lead to excluding proposals or enormous costs affecting wider interests or the whole community.

During the project planning stakeholders should have the opportunity to express their concerns and thereby help shape plan formulation in workshops and meetings to be held at key decision points in the planning process. These meetings should be publicized via direct mail and through the media. As part of the notice announcing each meeting, the results of the project's studies to date should be summarized in sufficient detail for participants to prepare for their participation. These detailed notices or bulletins also give people who are not able to attend the meetings sufficient information to comment by mail.

A professional facilitator should conduct each meeting, and a professional recorder should summarize public comments on an easel pad (or on a projected screen) in front of all participants. Following each meeting, a prepared and broadly distributed 'response summary', in which responses to every question asked and every concern raised have been included, should be sent to the participants.

In addition to holding open forums, it is important to coordinate extensively with federal and state environmental resource agencies, public bodies, and environmental interest groups to attempt to avoid or minimize environmental impacts in formulating a broadly accepted alternative. In addition, discussions should be conducted with county and city agencies as to how various alternatives could fit into local plans for open space, recreation, and current and planned land uses. The support of these groups for, or at least acceptance of, a project will contribute substantially to overall public support for the project.

During project design and construction, public views are still important in sustaining support for the overall project. Efforts that could be important are recreation planning, construction awareness and property acquisition. From the local perspective, the prospect that public outdoor recreation facilities would be part of the project could be a major factor in achieving broad local community support. A community-based recreation working group could be formed to participate in the recreation planning process: choosing the recreation opportunities to be provided and helping to site the facilities. This group could contribute to the development of a comprehensive plan that has strong public support.

The construction itself could introduce new concerns about how it might affect nearby residents. Therefore, a series of public construction awareness meetings could be conducted with those residents to discuss potential construction impacts and what the contractors could do to be good neighbours. During all phases of project development, the public should be kept updated on project progress and issues through project newsletters and news broadcasts. Tours of the construction areas for organizations can also be valuable public relations activities. Programmes aimed at sustainable development within the communities directly affected by the project after construction are essential to ensure the long-term support and even protection of the works (Mochebelele, 1994).

An Example Of Public Participation in California, USA (Darling, 1998)

Because the Los Vaqueros Project in California does not increase the water supply, it does not induce residential and commercial growth in the area, which often is a source of public and regulatory opposition for water projects in the USA. Contra Costa Water District (CCWD) has a contract with the US Bureau of Reclamation for 195,000 acre-feet of water a year, and currently uses approximately 130,000 acre-feet. There is no increase in water supply as a result of Los Vaqueros. It is an off-stream storage reservoir, which does not require damming a major stream.

The District also had in place an active public communication program, which included sharing information and progress reports about Los Vaqueros through community newsletters, fact sheets, a web site (www.ccwater.com), and a telephone hotline. The objective of the communication program was keep the public and special interest groups informed with the most current and reliable information and to minimize the effort staff would have to spend reacting or doing damage control because of misinformed individuals and groups.

Los Vaqueros impacted over 100 property owners. The project was formally adopted by CCWD's Board of Directors in October 1993, and the first construction contracts were awarded in September 1994. The District had only secured possession rights to construct (as opposed to the ultimate fee title) for many of the parcels. The issues associated with property owner impacts and severance were resolved in parallel with construction.

SOME LESSONS LEARNED

Sometimes, the lack of participation in public involvement processes by people who are being affected by a project is due to their trust that the government or administration is looking out for their interests. On the other hand, sometimes public participation is held to seek legitimacy of proposals that have already been decided upon.

Equity in costs and benefits implies a knowledge of externalities that are very complex and which necessitate the use debatable procedures. For instance, how should one ascertain the increased value of land after implementation of flood control schemes?

It's absolutely necessary to gain credibility from stakeholders and that is only possible by believing in the process yourself. Playing the role of a fair arbitrator between opposing positions and trying not to just defend a proposal requires believing in public participation as a democratic tool more than in your own criteria.

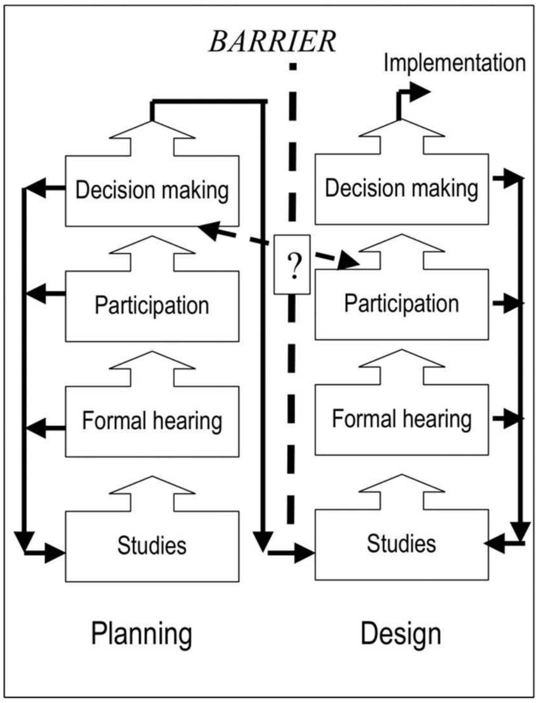
Transparency, and well defined rules and schedules are as essential to the success of a public involvement process as is the knowledge "a priori" of the range of possibilities, boundary conditions and the scope of the discussion. Postulating scopes that are too wide or larger than permitted can be interpreted as promising possibilities that have to be rejected at once. This can become a source of frustration that discourages meaningful participation.

However, there will be always people who remain frustrated, including those *who, for each solution, find a problem*.

PROPOSAL

Rules must be defined or set out for each public participation process. The rules should define the scope and abilities of the public agents participating in the process. Such rules are intended to appropriately focus the process so that the agents involved do not have to engage in discussions on matters that do not pertain to the project at hand, or items over which they have no control such as past projects of past decisions by higher authorities. Incorporating such rules can make the process more palatable to many participants, allow more time for meaningful discussion on matters that can be acted upon by the public agent and enhance the public trust of the process by not placing the public agent in a position to make commitments over matters which he or she has not authority.

Additionally the rules for a public participation process should provide a means for feedback to be given to participants of the public involvement process at the various stages in the planning and implementation a project.



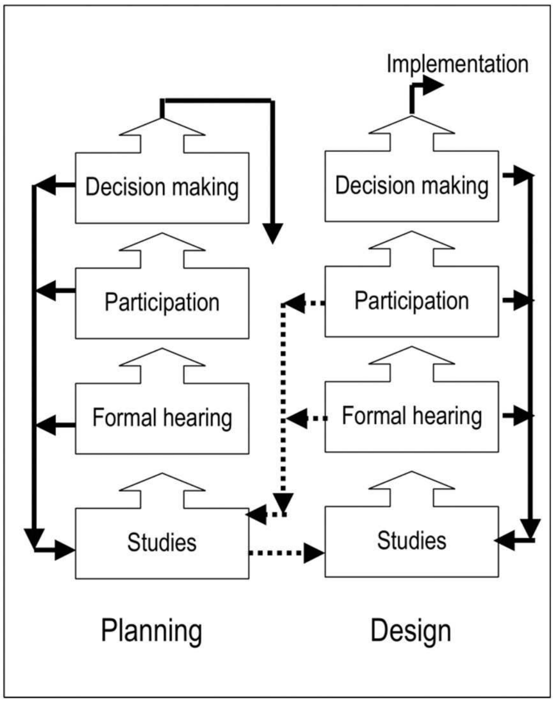


Figure: On the left side classical processes are shown where planners and decision makers are not able to take into account local participation. On the right side is an alternative which provides for some feedback in planning from the first stage of public participation.

Then, situations such as described below can be avoided: *"The polarization that developed between groups have been caused, in many cases, by state/project officials who were unable to provide opportune, truthful and objective information to the crowd and thereby made the consultation unmeaningful with the result that people were effectively denied participation in the formulation of project policies that affected them".*

A good public involvement program is characterized by rules of conduct that clearly separate the roles of politicians, officials and professionals.

REEVALUATION AND NEED FOR MONITORING

Monitoring of the consequences of dams is a key element in a dam project in order to understand the real impacts of the reservoir on the river basin, to evaluate whether the goals of the project have been reached, to learn from past experiences and to provide data for making better decisions in the future as part of a continuous improvement process.

A good monitoring program should cover the hydrological, environmental, social, economic and political consequences of the dam project.

An example from Thuringia in Germany illustrates the procedures:

Thuringian Dam Administration plans the completion of the drinking water reservoir Leibis-Lichte in the Thuringia State Area. This project is necessary to avoid a serious decrease in water quality and water quantity. Indeed, the construction of this dam and the management of the new reservoir will implicate serious changes of the environment. This is why an impact study was done in order to estimate all possible environmental changes all around of the planned reservoir. Appreciable damages would result from flooding and by the 'barrier effect' of the dam. Beside these effects, the environmental authority was afraid of a negative impact on a protection zone recommended by European Union, located downstream of the reservoir. The approval to complete the reservoir system by a dam is connected with the compensation measures for all environmental impacts. One element of this compensation plan is the preparation of guidelines for an ecological water management plan for the reservoir in order to reduce the negative influence on the ecosystem downstream.

Furthermore, a monitoring program will be implemented to investigate all natural components in the river system downstream of the planned dam. The aim of this program is to document conditions and limit impacts on the environment before, during and after the construction of the new reservoir.

[Harmut Willmitzer, Germany]

6. CONCLUSIONS AND RECOMMENDATIONS

This chapter summarizes key messages from previous chapters, and delineates a 'Business Plan" for ICOLD. ICOLD might want to consider developing something similar to IHA's "Sustainability Guidelines" and propose them to ICOLD members as a self assessment tool for project planning/ implementation/ operation.

In this report the actions advocated are based on integrated water resources management, which includes the planning and management of water resources and land. This takes account of social, economic and environmental factors and integrates surface water, groundwater and the ecosystems through which they flow. It recognises the importance of water quality issues. In this, special attention should be paid to the local people whose livelihood depends of the river basin.

Water resources management on the scale of river basins is a prerequisite for achieving sustainable living conditions for all forms of life in our interdependent and rapidly changing world.

Integrated water resources management depends on collaboration and partnerships at all levels, from individual citizens to international organizations, based on a political commitment to, and wider societal awareness of, the need for water security and the sustainable management of water resources. To achieve integrated water resources management, there is a need for coherent national and, where appropriate, regional and international policies to overcome fragmentation, and for transparent and accountable institutions at all levels.

Mankind faces a number of critical challenges to its own survival, such as an unprecedented increase in population with a universal desire for improving living standards and quality of life, as well as recognition of the need for conserving the life-supporting functions of nature. The challenge is to balance the need for increasing water and energy supply with the inevitable adverse effects on the environment and impacts on the local people.

For ICOLD, some important issues are: improvement of environmental assessments; increasing reservoir life through erosion-sediment-flood techniques; reduction of construction cost, improvement of dam safety, but primarily to meet the needs of people particularly those who are trapped living conditions that are below acceptable standards. Specific issues for ICOLD include: optimal reservoir design for river regulation and flood storage; pollution control and water quality; effects from downstream releases; groundwater levels; and reservoir operation during droughts. Also needed is optimization of dams and hydroelectric projects in overall basin development (Veltrop, 1995). Sustainability means delivering economic, environmental, and social value to shareholders, customers, and stakeholders. Principles for sustainability are: adopting a long-term view, working with stakeholders, focusing on equity while avoiding persistent conflicts and uncertainties, and innovating (Veltrop, 2002).

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8. THE COMMITTEE

This report was prepared by the following members of the ICOLD Committee on the Role of Dams in the Development and Management of River Basins:

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Vicechairmanship	India
Vicechairmanship	Iran
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	Portugal
	Slovakia
	Turkey
	United States
	Zimbabwe

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