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Dams and the Environment

Considerations in World Bank Projects

John A. Dixon, Lee M. Talbot, and Guy J.-M. Le Moigne

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ABSTRACT

With growing environmental awareness worldwide during the 1970s and 1980s, increased attention has been focused on dams and their associated water resources projects. This paper explores the relation between dams and the environment--both the effect of dams on the environment, and the effect of the environment on dams--and the economic analysis of these effects.

Dams are large social investments built to fulfill one or more of four primary purposes: domestic and industrial water supply, energy production, irrigation, and flood control. In addition to these direct benefits there are many associated environmental and social effects, some of which are benefits but more of which are likely to be costs. (Resettlement is a major social issue associated with most dam projects and is handled in detail in other Technical Papers.) The economic analysis of dams must include all associated benefits and costs, both direct and indirect, both in assessing the proposed project and in evaluating alternatives.

This paper reviews the environmental factors associated with large storage dam projects and the economic analysis of environmental effects. Consideration is given to environmental effects that occur upstream, on-site, and downstream and techniques of economic analysis that can be used to value environmental effects in monetary terms.

Samples of actual and proposed dam projects are examined to see what can be learned from completed projects and what are the environmental issues associated with several proposed dams. As expected with such major investments, there is a complex set of factors, some good, some bad, that have to be balanced. The paper concludes with the World Bank's response to this issue and some of the lessons that can be learned from analysis of past projects.

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PREFACE

The World Bank recognizes its responsibility to properly take environmental factors into consideration in its projects. Water resources projects, including the construction of dams and their associated impoundments, are no exception. In response to growing concern about the environmental impact of dams, the Bank has sponsored a series of activities focused on this topic. In 1985, an inventory of major dam-related projects was completed, with an update in 1987, by Mr. T. Mermel. During 1986-1987, Mr. L. Talbot reviewed how the Bank has handled environmental aspects of dam projects in the period since 1970. A one-day seminar on the topic was held at the Bank in 1987. Senior Bank staff (Messrs. Schuh, Le Moigne, Cernea, and Goodland) presented a paper discussing the Bank's experience with social and environmental impacts on dams at the Sixteenth Congress on Large Dams organized in 1988 by the International Commission on Large Dams (ICOLD).

This report sums up the key issues and conclusions of the one-day seminar, "Dams and the Environment: Considerations in Bank Projects", held at the World Bank on June 18, 1987, sponsored by the Agriculture and Rural Development Department. The seminar was attended by over 50 specialists, mostly from the Bank but including experts from other development banks and donor groups.

The seminar was organized to explore the relation between dams and the environment--the impact of dams on the environment, and the impact of the environment on dams--and how the Bank can better take these concerns into account in its own work. Addressing the seminar participants, Mr. V. Rajagopalan, vice president for sector policy and research, emphasized the importance placed by the Bank on the proper consideration and handling of the environmental impact of dam projects and other water resources projects that have dam components.

Although involuntary resettlement was not included in the seminar as an independent topic since it had been handled in depth in other special seminars and in Bank publications, it was regarded throughout the discussions as a crucial social (and economic) component of most major dam projects.

The seminar focused on two themes--the environmental effects associated with dams, and the economic analysis of these effects. Materials were presented via formal papers, case studies and panel discussions. This report reflects the points raised and the discussions that took place at the seminar. Some of the topics are presented in more detail in light of their significance. The report is organized into six chapters. Chapter 1 states the environmental problem and its consequences. Chapter 2 is a summary overview of the Bank's experience with dam projects and how it has paid increasing attention to environmental concerns over time. Chapter 3 examines the environmental dimension in more detail--the impact of dams on the environment and the effect of the environment on the dam. As such, this chapter includes upstream, on-site and downstream effects.

Economic analysis of environmental and other off-site effects is discussed in Chapter 4. To the extent these effects can be quantified and monetized, they can be entered into the broader economic analysis of the project. If inclusion of these costs make the proposed project "unprofitable", alternative formulations need to be considered.

Chapter 5 presents selected examples of the issues raised by certain major dam projects, some of which have already been built, some of which have been delayed, and some of which are still under consideration.

Chapter 6 begins with a discussion of the Bank's present policies and procedures on several specific topics relating to dams and ends with general observations.

The manuscript was reviewed by a number of individuals within and outside of the Bank. The authors would like to thank Mr. Michael Cernea, Mr. Cristoph Diewald, and Mr. Robert Goodland of the Bank for their helpful suggestions. Mr. Diewald also prepared the annex on the Narmada projects in India. Prof. David Pearce of the London Environmental Economics Center provided useful comments on Chapter 4.

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CHAPTER 1. THE PROBLEM AND ITS CONSEQUENCES

Major dams are large social investments, usually built to fulfill one or more of four primary purposes:

- domestic and industrial water supply;
- energy production;
- irrigation; and
- flood control.

By their very nature, dams and their associated reservoirs create changes in the pre-existing environment. Waters are impounded, upstream areas are inundated, people are frequently displaced from the reservoir area. There are also downstream effects that result from changes in the quantity, quality, timing, and use of water flows. Some of these impacts are positive, others are negative.

This report overviews the range of environmental effects associated with storage dam projects. Causality can go in two directions: dams have impacts on the environment and the environment, in turn, can have major impacts on dams. (The term "dam" or "dam project" is used here as a short-form for the more complete term "dam and its associated reservoir." Smaller dams and diversion structures such as barrages are not the topic of this report although some of the same environmental effects are also associated with such structures.) Whatever the direction of causality, the important point is that because of these environmental effects, the production of the goods and services for which dam projects are built is either enhanced or reduced.

The term "environmental effects", in its broad definition, includes both the physical and social aspects. Changes in water quantity or quality, or soil erosion and sedimentation, are physical environmental effects. The involuntary resettlement of people and the disruption of their productive systems and life styles are social effects, as well as the impact of relocation on the populations inhabiting the new host areas. The key to this approach is to emphasize that all these impacts together are caused by the dam project and affect the project's viability and its benefits and costs. It would be an error to take into account only the physical aspects or only the social impact. Indirect impacts need also to be taken into account just as much as the direct output of irrigation water, energy, flood control or domestic and industrial water supply.

One way to represent this variety of interactions (primarily the physical ones, which are reflected in more detail) is illustrated in Figure I.I (Rangeley, 1988). This figure uses a linear approach to the larger system within which a dam is located. In the upper watershed (used in this report to mean the basin/catchment draining into the reservoir) there are environmental conditions that affect the reservoir. The reservoir, in turn, has various impacts (both beneficial and negative) both on-site and on the downstream environment. Finally, there are indirect or secondary effects on the main downstream "service areas"--irrigation, domestic and industrial water supply, and hydropower.

Figure 1.1

STORAGE DAMS AND THE ENVIRONMENT

CHAIN OF MAIN EVENTS

EFFECT OF ENVIRONMENT ON THE RESERVOIR

EFFECTS	CONSEQUENCES
- Precipitation	- Run-off (for storage) with extreme events of floods & low flows
- Soil erosion	- Siltation of reservoir and outlet - blockage.
- Pollutants & natural chemicals	- Deterioration of water quality
- Aquatic life & waterfowl	- Settlement on reservoir
- Evaporation	- Water loss
- Climate	- Low temperature water inflows
- Debris	- Outlet blockage.

↓

RESERVOIR

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EFFECT OF THE RESERVOIR AND ITS STORAGE FUNCTION ON THE ENVIRONMENT

EFFECTS	CONSEQUENCES
- Smaller variations in downstream streamflows	- More plentiful and reliable supplies of water; less flood damage; lower after-flood crop production; less flood plain fisheries; more/less estuarial salinity depending on topography. less bank erosion.
- Lower silt content of water	- Lower cost of water management; downstream erosion.
- Inundation of land	- Displacement of settlers; damage to fauna & flora, archaeology, and infrastructure; loss of land.
- Creation of lake/pond	- Recreation; new fisheries; better animal watering but disruption of migration routes; eutrophication.
- Creation of gravity head	- Command of irrigable land; potential power production.
- Lower flows downstream	- More estuarial salinity (in extreme cases).
- Temperature	- Better conditions for users (warmer water, less frazzle ice).
- Interception of river	- Interference with fish migration.
- Inundation of forests	- Poor water quality for potable purposes.
- Induced seismicity	- Induced landslides.
- Reservoir drawdown	- Dry season cropping/grazing.
- Subterranean leakage	- Rise in groundwater.
- Construction activity	- Economic development; environmental change.

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SECONDARY EFFECTS ON "SERVICE AREAS" AND SYSTEMS DOWNSTREAM

IRRIGATION

EFFECTS	CONSEQUENCES
- Lower silt content in water	- Lower O&M cost; better water management leading to less water logging. - Changes in fauna and flora.
- More regular supply of water	- Adoption of perennial in place of non-perennial irrigation with better crop production. - Expansion of irrigated area. - Better control of some pests and diseases; less control over others.
- Additional water supply	- More waterlogging but, with good management, better salinity control.
- Gravity supply to irrigation system (where feasible)	- Lower energy consumption.
- Regulated river flows	- Lower pumping costs.

Note: Almost all storage dams supplement water supplies to existing run-of-river systems.

DOMESTIC & INDUSTRIAL WATER SUPPLY

EFFECTS	CONSEQUENCES
- More reliable supplies **	- Less failures and less rationing hence better public health control. - Better repulsion of salt intrusion in estuaries giving more sustainable rural water supplies.
- Lower biological quality *	- Higher treatment cost.
- Higher chemical quality *	- Lower treatment cost.
- Wider spatial availability of water **	- Less concentration of urban areas and industries.
- Poorer taste * **	- Higher treatment cost.
- Lower silt contents **	- Lower treatment cost.

Notes: * compared with groundwater
** compared with run-of-river

POWER

EFFECTS	CONSEQUENCES
- Non-thermal energy production	- Displaces fossil fuel and nuclear power and their associated environmental effect.
- Renewable energy source	- Sustainable production.
- Lower cost of production	- Permits special industries such as smelting - Provides low cost domestic amenities.
- Simplicity of operation	- Less failure in regions with few skilled human resources.
- Lumpy investment	- Debt burden.

Note: Treats fossil fuel and nuclear power as the alternative sources to hydroelectric (excludes tidal wave, and other sources.

These and the other interactions involved will be examined in more detail later, as well as economic analysis of the main effects. Clearly there are major and far-reaching effects created by the construction and operation of a storage dam and its reservoir.

Major Projects: Large Benefits And Large Costs

There is no doubt that hydropower and irrigation dams are large infrastructural investments that produce major economic benefits. In the past decade, however, there has been a growing concern about the costs of dams in terms of indirect environmental and social effects. Some people take the extreme view that all large dams are bad and that new construction should be stopped or greatly modified. A more balanced approach realizes that there are legitimate concerns raised by critics, but that there are also legitimate needs that dams fulfill.

Among the important benefits from dams in the future will be their role in assuring domestic water supplies to rapidly growing populations, both urban and rural. Although also subject to contamination, surface waters in reservoirs are easier to flush or treat than groundwater; once groundwater is contaminated it may take a very long time to purify.

Power benefits are also likely to grow in importance. As alternative power sources are questioned on safety or environmental grounds (e.g., nuclear, thermal), hydropower generation may become increasingly attractive and sought after. The long lead time for major projects, however, means that needs 15 years in the future require action today. Energy conservation can reduce short-term power demands but economic and population growth inevitably mean increasing long-term demands for electricity. These water and power benefits have to be carefully considered when assessing the importance of possible negative environmental effects.

The role of environmental considerations in dam projects is now well recognized by the World Bank. The basic policy has been presented by President Barber Conable as outlined in a May, 1987 speech to the World Resources Institute (Conable 1987). In that speech Mr. Conable stated that "I believe we can make ecology and economics mutually reinforcing disciplines. By looking closely at market forces and broadly at all key sectors of development activity, we can identify both the effective and perverse factors shaping and misshaping the environment."

Focusing on dam projects, G. Edward Schuh, then Director of the Agriculture and Rural Development Department, speaking at the opening of the 1987 dam seminar, made the following points (Schuh 1987):

> "It is difficult to overstate the economic significance of dams. The naive perspective on conservation tends to view land as ultimately the limiting factor to economic development. The evidence, however, suggests that water may be the limiting resource..."

Dr. Schuh went on to discuss the rapid increases in fresh water demand due to economic development and population increase and the valuable roles storage dams provide in terms of regulating the availability of water and generating power.

> The issue today is, "Why should we consider the environmental aspects of dams in the first place?" The trite answer is because the Bank is strongly criticized in some quarters for neglect of these issues. The real answer is that dams have

important environmental consequences, and these consequences affect the overall contributions to economic development that dams make to economic development.

Environmental consequences of dams are important in large part because they interfere with the way things would ordinarily take place:

- First, dams do not contribute to economic development in a net sense unless their benefits are larger than their costs, where costs include environmental damage. Failing to take account of environmental consequences is only to mislead oneself about the contributions of the dams to economic growth. Ignoring these costs, of course, does not make the dams any more important to the growth process. Whether environmental costs are accounted for or not, they are still there.

- There can be significant environmental benefits of dams. When they occur, they should be taken into account in the same way that the environmental costs should be taken into account.

- A consideration of environmental costs and benefits should expand far beyond the immediate confines of the dam and reservoir...

- There are similar costs down-stream from the dam, and these also should be taken into account in appraising the project. These costs include, among other things, the damage to non-domestic plants and animals.

- A careful assessment of Bank projects requires the collaboration of economists and other social scientists with engineers and other technical people...

- Finally, we should recognize that assessing environmental consequences is not a one-time issue - something to be done as part of appraisal but then left to chance from then on."

The World Bank And Dam Projects

Development projects involving dams represent large investments, are an important part of the World Bank's lending program, and are an area of particular visibility and concern to the public and the governments involved.

The World Bank has provided financing for dams to over 100 countries and since 1970 alone, it has undertaken over 400 projects involving dams, spread throughout the world. The distribution of projects involving dams is about 14% in Sub-Saharan Africa, 13% in Latin America and the Caribbean, 37% in South Asia, 17% in East Asia and 19% in Europe, the Middle East, and North Africa.

Compared to the worldwide processes of dam building, however, the World Bank is involved with only a small percentage of all large dam projects (those over 15 meters in height). According to ICOLD, the International Commission on Large Dams, there are over 35,000 large dams in existence (exclusive of China). Of these, some 11,000 were constructed in the 1951-82 period, or an average of 344 dams per year. More recently during the 1975-82 period, the rate of construction dropped to 258 dams per year. In contrast, the

Bank may be a major funding agency for about 5 to 10 dams per year, oı less than 5 percent of the average annual construction of dams worldwide.

A number of these dams, however, are major projects and this leads to considerable international attention to Bank work in this area, and to considerable criticism of these projects. Some of this criticism focusses entirely on dams and the Bank's role in them.[1]/ Other criticism of the Bank's role in dam construction is included within broader criticism of the environmental costs of development assistance in general.[2]/

It is important to recognize that such criticism is by no means limited to the industrialized nations. There is increasing examination of dams and of the Bank's role in them, from both governmental and non-governmental sources, in many developing nations. This concern has resulted, for example, in the decision by national governments not to proceed with two major hydro projects, the Nam Choan Project in Thailand and the Silent Valley Project in India. In both cases substantial funds had already been invested, but the projects were halted because of public pressure on government, and the resultant recognition by government that when the environmental and political costs were considered, the costs outweighed the expected benefits.

These were highly visible and publicized cases, but they are not isolated examples. They are indicative of the changing attitudes toward dam projects by the governments and peoples in developing nations. More basically, they are indicative of growing recognition of the importance of environmental factors when evaluating the economic attractiveness of proposed projects.

In most cases, the incorporation of environmental concerns can be and is handled by design or management measures. This is increasingly common now and helps avoid the confrontations and delays that have been associated with certain projects in the past. The

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1/ *Examples of the publications which are the most critical of the World Bank's dam projects include the following reports:*

Blackwelder, B. and P. Carlson (1986). "Disasters in International Water Development." Washington: Environmental Policy Institute

Goldsmith, E. and N. Hildyard (1984, 1985). The Social and Environmental Effects of Large Dams, Two Volumes. Wadebridge Ecological Centre, U.K.

In addition, two periodicals that frequently comment on dams and environmental issues are the following:

International Dams Newsletter, now retitled World Rivers Review. San Francisco, California.

The Ecologist. United Kingdom (most recently Vol 15, Numbers 1/2 and 5/6, 1985).

2/ *See, for example, Schwartzman, S. (1986). Bankrolling Disasters: International Development Banks and the Global Environment. San Francisco: Sierra Club.*

end result is projects that yield greater net benefits to society. There may be some increased up-front expenditures, but they are justified by the expected benefits. Properly done, the systematic application of the expanded environmental-economic analysis advocated here can help prevent delays or cancellation of projects.

In some cases, the Bank's initial assessment has led it to decline further involvement with a proposed project. This is true where the proposed project is either economically unattractive and not the best alternative, or where major concerns, such as resettlement, have not been adequately handled. The Bank is also increasingly reluctant to come into a project late, or as an add-on to a dam already under construction. In these cases, it is difficult to enforce adequate environmental safeguards. Of course, the Bank receives no recognition from its critics for projects that it decides not to finance.

CHAPTER 2. THE WORLD BANK'S APPROACH TO THE ENVIRONMENTAL IMPACT OF DAMS

In the fifteen years since environmental concerns were institutionalized in the World Bank there has been a dramatic improvement in the attention given to environmental factors associated with the dams which the Bank has financed. In order to assess this development the Agriculture and Rural Development Department commissioned a review of major dam projects (Talbot, 1987).

The review included those dams financed through World Bank projects appraised since 1972, when the Bank's newly established Environmental Unit developed terms of reference for the environmental reconnaissance of dams, up through 1985. The review also considered new dams currently under consideration and dams for which additional work is being proposed (including additional hydro units and irrigation facilities). The dams covered by this review include those designed for hydroelectric, irrigation, water supply, and flood control; many are multi-purpose projects. The resettlement aspects of these projects were examined in depth in a special sociological study.

The main objectives of the review were to obtain an overview of how the Bank has dealt with the environmental impacts of dams which it has financed, to make an assessment of the effectiveness of the Bank's approach, and to make appropriate recommendations.

The Project Cycle

The Bank's policy is to integrate consideration of environmental aspects into the project itself; as such, the Bank's environmental procedures follow the project cycle. Since the early 1970's, when the Office of Environmental Affairs was first set up, there has been increasing attention to the environmental impacts of dams (and associated resettlement issues). The main steps in the project cycle, and the Bank's environmental procedures at each stage, follow:

Identification stage. In the Identification Stage the Project Officer prepares a Project Brief which should contain, among other things, measures to avoid costs to the environment. These environmental investigations are usually called "Environmental" reconnaissances or studies.

In some cases these environmental studies are part of the pre-feasibility studies. However, in most cases they are part of the feasibility studies in the Preparation Stage. The reviewed reports often are not clear on the division of effort into formal stages, but the important consideration, of course, is whether or not environmental investigations have been undertaken and appropriate measures taken.

Preparation stage. At the completion of this stage, measures should have been designed to identify and avoid or mitigate serious environmental risks, and to enhance environmental benefits. Problems which merit attention but do not require further work are indicated, and matters which require further study may be identified.

The findings of the pre-feasibility or feasibility study environmental reconnaissance should be incorporated into the results of the preparation stage. However, in reviewing the files there is little direct reference to this need, particularly in the earlier files.

Appraisal stage. The actual detailed analysis of the economic, sociological, technical, financial, and environmental viability of a proposed project is carried out at the appraisal stage. As a part of this stage the Bank assesses and evaluates the environmental findings, identifies potential adverse effects and determines the adequacy of the environmental measures proposed to prevent, mitigate or remedy potential problems. The documentation should describe the environmental measures which are to be provided and there should be agreement on what environmental provisions are to be incorporated into the overall budget, design and operation of the project. Environmental considerations are included under "Major Aspects of Project Appraisal" and the results are summarized in the Staff Appraisal Report for the project.

Appraisal reports from 1972-1985 were reviewed to see how environmental concerns were handled. (World Bank, 1985; Mermel, 1986). The findings are presented in two parts: the earlier period (1972-1982) and the more recent years (1983-1985). Only slightly more than half of the appraisal reports issued prior to 1983 explicitly referred to environmental considerations. Resettlement was usually considered under the environmental section in these reports. Examples of environmental factors mentioned include the following:

- Some referred to an ecological study in progress or an agreement by the government or borrower to carry out a reconnaissance study.

- A few referred to agreement by the borrower or government to carry out a specific study of some environmental factor, most often health effects linked to water borne diseases or parasites, but occasionally subjects such as sedimentation (Magat Dam, Philippines), and forestry or fisheries (Lupohlo Dam, Swaziland).

- Where environmental factors other than resettlement or diseases were mentioned, most reports said that the studies or surveys concluded that no significant environmental impact would be occasioned by the project.

- A very few mentioned some other environmental considerations such as areas affected by flooding, archeological, historical or cultural sites, wildlife (Chung Ju Dam, Korea), sea water intrusion (Yong San Gang Dam, Korea), foreshore drawdown area (Magat Dam, Philippines), impact on ground water and growth of water weeds (Phitsanulok Dam, Thailand), and inundation of marketable timber and mineral resources (Bang Lang Dam, Thailand).

All of the dams which have appraisal reports dated from 1983 through 1985 have environmental reports within the Staff Appraisal Reports. In the case of the 13 dams that were approved within the 1983-1985 period the environmental reports range from brief paragraphs (e.g. Upper Indravati Hydro,and the Gujarat Medium Irrigation II, India; and the Khrysokhou Irrigation and the Southern Conveyor Projects, Cyprus) to substantially more extensive coverage (e.g. the Narmada River Development Projects, India; Kedung Ombo Multipurpose Dam and Irrigation Project and Thirteenth Power Projects, Indonesia; and Second Water Supply Project in Korea).

Loan stage. Normally project issues such as environmental measures are settled prior to formal negotiations. However, if necessary they may be discussed during the negotiations between the Bank and the borrower. Environmental covenants may be incorporated in the Loan Agreement. This appears to have been uncommon, particularly in the earlier projects. When present, the covenants usually refer to resettlement and health considerations, more rarely to matters such as training or establishment of environmental units in the construction authority or host government. As discussed by Mermel in the Seminar, construction tenders should explicitly outline the environmental requirements of the contractors to minimize the negative environmental impacts associated with construction.

"Agreements", "Understandings", or "Assurances" between the Bank and the borrower are more common than formal covenants. In the most recently approved dams these have included such measures as:

- carrying out an agreed upon environmental plan and furnishing the Bank with reports;
- establishing an Environmental Management Unit to manage the project;
- further study, in some cases explicitly to lead to action (e.g. establishment of protected areas);
- mid-term review and post-completion inspection or monitoring; and
- afforestation.

Implementation - supervision. Supervision missions routinely review environmental aspects with the borrower to ensure that the measures agreed upon are adequate and effective. If additional measures are found necessary, arrangements should be made for their implementation.

Completion - evaluation. When the project is completed a routine Project Completion Report is prepared. It is intended that a completion report should describe the results of the environmental measures in the project and comment on their appropriateness, costs, adequacy, and administration, along with any problems arising or changes made in the course of the project. On the basis of these reports the Bank can identify those projects which have significant environmental issues that need additional attention.

In the sample of project completion reports reviewed, however, environmental issues were rarely mentioned and it does not appear that environmental considerations received much attention at this stage. In some cases a Post-Audit is carried out by the Operations Evaluation Department. The Post Audit appears to offer an important opportunity to determine whether or not environmental measures have been successful.

Proportion Of Dams Receiving Environmental Consideration

On the basis of a review of appraisal reports and selected project files, it appears that explicit environmental attention was given to about half the dams listed in the Inventory of Dams Related to World Bank Projects (World Bank, 1985) which have appraisal reports completed since 1972. Significant findings from this analysis include:

- Hydropower dams or dams with a hydropower component make up 45% of the total dams involved; the other 55% are primarily irrigation, water supply or flood control dams.
- 49% of the total dams listed have environmental reports.

in the update done for dam projects for the years 1983 to 1985 (Mermel, 1986), it was found that all of the dams have environmental reports. It is interesting to note that the percent of dams that have a power component has declined to 30%; the other 70% are for irrigation and water supply. Of course, the important question is not how many dams had formal environmental reports, but, how many projects actually took environmental concerns into account. Nevertheless, there has been a definite increase over time in the formal recognition given to environmental aspects.

General Findings And Conclusions

Based on the review carried out on Bank projects from 1972 to 1985, the following general findings and conclusions were developed. (These points are developed in greater detail in Talbot, 1987):

The Bank has been involved with approximately 400 dams or dam projects during the period of review. These projects represent a large investment, are an important part of the Bank's lending, and are an area of particular visibility and concern to the public and the governments involved. Over this period there has been a growing sophistication in the Bank's approach to the environmental impact of dams, but there are still significant issues which need to be addressed.

The most important single issue in the Bank's entire dam project process is the determination of whether the dam should be built (or supported by the Bank) in the first place. This decision is based on an economic justification. However, it is not evident that the basis for that economic determination includes economic analysis of environmental factors which can significantly affect the sustainability, costs and benefits of the project. Similarly, there seems to be little recognition that there are positive as well as negative environmental consequences of dams.

Based on the review, it appears that in many cases the environmental considerations, where they exist, are brought into the procedure too far "downstream" to have adequate impact on the design of the project. There is no evidence that environmental considerations play any role in the Identification Stage, and by the time they are considered, plans for the location and general features of the dams may already be determined.

If environmental considerations are brought in late they cannot contribute adequately to the decision and design process, and are then considered as an obstruction to the process rather than as a contribution.

Most environmental consideration is limited to the immediate area and time of the project itself, not to basin-wide impacts. Similarly, the influence of water releases from the project on agricultural activities, basin wide, tend to be ignored.

Off-shore impacts represent another example of the type of important environmental factors which are not usually considered. Most large dams and water projects have significant effects (through changes in water flow regime, sedimentation, salinity, and other water quality factors) on estuaries and associated water. These effects can be both positive and negative. The impacts on fisheries and other coastal resources may therefore be overlooked.

Most attention has been placed on a project analysis, even when there are plans for a series of dams (e.g. the Narmada project). Cumulative and feed-back effects may thus be ignored. In some cases it is necessary to take a regional or sectoral perspective in order to capture these cumulative effects.

In many cases "indirect" factors such as the secondary effects of road construction (providing access which may lead to unplanned settlement and destructive cultivation, illegal logging, other vegetation clearance, poaching, or erosion) have received little or no attention in the Bank's dam projects. In some cases these factors may have larger long term impacts than the actual dam construction itself. Even in those cases in which they were identified as issues, usually little was done in the way of recommendations or subsequent action, other than a statement that the government would prevent them or look after the problem.

The environmental assessments rarely consider positive environmental factors, i.e., how environmental conditions can contribute to the success of the project, and how the project can produce and enhance environmental benefits as well as costs. While in most cases it has been difficult to confirm in definitive terms what has been accomplished by the Bank's environmental approach, there have been some cases in which it has achieved clearly identifiable results.

Examples of positive factors include--but are not limited to--changes in location of the dam site, adjustments in dam height, development of fish ladders, clearance of vegetation from impoundment areas, adjustments to the minimum or seasonal downstream flow, establishment of parks or reserved areas to protect watershed and biological diversity, efforts made to salvage or protect cultural properties, establishment of environmental units and training of environmental specialists, and consideration given to a variety of disease and fishery matters. However, this brief review does not do justice to the Bank's continuing effort to strengthen its approach to incorporating environmental considerations into its dam projects.

In conclusion, during the period 1972 to 1985 the environmental approach of the Bank has evolved and improved significantly. At its best the approach is comprehensive and effective, but consistency in its application is lacking. Until recently a high percentage of dams still received little recorded environmental consideration and there has been considerable regional variation. Within this context, therefore, the growing environmental concerns of the Bank can build upon a strengthening base, both of experience with past projects as well as clear recognition of the wide range of important environmental and social effects that need to be considered.

CHAPTER 3: ENVIRONMENTAL FACTORS

The preceding chapters have argued for inclusion of environmental and social factors into the process of project design and evaluation. Bank projects are designed by Government technical agencies or by consulting firms. These teams increasingly include specialists in specific environmental factors such as botanists, zoologists, water quality chemists, sociologists, geomorphologists, hydrologists and others concerned with environmental impacts. It should be noted that, in the past, the preparation teams for dam projects did not, quite often, concern themselves with resettlement planning. Traditionally, resettlement and other sociological issues were left to be solved after project appraisal, usually by secondary agencies. The World Bank is now paying much greater attention to how these issues are handled and demands that feasibility plans for dam projects include the advance planning for population displacement and resettlement as well.

Bank staff are expected to be aware of relevant environmental factors, identify specific needs, and take appropriate steps. Three questions, therefore, naturally arise: what are the likely environmental effects associated with dam projects?, how do we assess them and decide on relative importance?, and how do we incorporate these aspects in the financial and economic analysis of alternative designs for the project? This chapter focuses on the first two questions (identification and assessment); Chapter 4 deals with the economic dimension.

What Are Environmental Factors?

As mentioned before in this report, "environment" is a broad term that includes both physical, biological, and social impacts. Changes in productivity of downstream agricultural fields or fisheries are included, just as is the question of population resettlement. Environmental effects may occur upstream, on-site, or downstream. Some effects may be defined as "impact of the environment on the dam," others are the more usual "impact of the dam on the environment." The defining concept, however, is the same in both cases: the existence of some impact or effect that is related to the dam project and has an impact, in turn, on the economic well-being or social welfare of peoples and societies. These effects often are indirect and are felt off-site, but not in all cases (e.g. an unplanned for reservoir fishery can produce major on-site benefits).

Note that the focus of this paper is not on the direct project outputs--hydropower, irrigation water, urban water supply, flood mitigation. The values of these beneficial products of the project are naturally included as part of the analysis. Environmental factors may, however, have an impact on the production of these direct project goods and services. If their production increases, this is an environmental benefit; if production declines, then it is an environmental cost. In some cases, there are no major adverse environmental effects.

Figure 1.1 presented one listing of possible environmental effects based on the location of impacts--upstream, on-site, and downstream; some impacts are positive, others are negative. Figure 3.1 presents another approach to understanding the environmental aspects of dam/projects (Goodland, 1985). This figure focuses on the goods or services affected (e.g. health, water quality or navigation). Again, some impacts are positive, others are negative. The different, yet complementary approaches to understanding the

Figure 3.1 Environmental Aspects of Hydroprojects

1.	HEALTH	Some water-related diseases can increase unless precautions are implemented (e.g. vector control, prevention) schistosomiasis, onchocerciasis, encephalitis, malaria, etc. Remediation usually impossible; prevention is the only cost-effective approach.
2.	RESETTLEMENT	of people is expensive and time-consuming when done acceptably. The people can (and should) be better off afterwards. Can hydroprojects become regional development projects, which integrate rural development for people, with watershed management and irrigation? Resettlement of vulnerable ethnic unacculturated minorities should be avoided; if unavoidable, special precautions are necessary.
3.	WILDLIFE	Extinction can be minimized by siting. Loss of wildlife can be mitigated by including a wildland management unit, equivalent to the inundated tract in the watershed. Biotic rescue can assist.
4.	FISH	migrations (if any) will be impaired without passage facilities. Fish promotion in the reservoir can mitigate and produce more than before the project.
5.	BIOMASS REMOVAL	related to whatever water quality is needed downstream, to fisheries, and to navigation. Valuable timbers and fuel should be salvaged; "opportunity cost" of lost timber and foregone use of inundated land should be internalized.
6.	WATER WEEDS	proliferation can increase disease vectors, and transpiration increases water loss and impairs fish and water quality (e.g. Water Hyacinth (Eichhornia), Water Lettuce (Pistia)). Clogging impairs navigation, recreation and irrigation. Some potential to use weeds for compost, biogas, fodder.
7.	WATER QUALITY	within reservoir and downstream; saline intrustions; water retention time (i.e. flow/volume), loss of flushing; decrease nutrients in estuary; pollution monitoring (agricultural leachates, industries).
8.	EROSION	upstream leads to sedimentation which can impair storage; watershed management should be routine. Increased erosivity below dam.
9.	DRAWDOWN STRIP	useful for recession agriculture (with disease and access precautions).
10.	CULTURAL PROPERTY	Archeological, historic, paleontologic, religious and esthetic or natural unique values or sites should be conserved or salvaged.
11.	MULTIPLE USE	can be optimized by tourism, irrigation, fisheries, recreation. Regulation improves seasonal rivers into perennial waterways; advantages for drinking and irrigation.
12.	NAVIGATION	may need special provisions such as locks, cleared shipping lanes, and access ramps if drawdown is large. Lake transport may become economically advantageous.
13.	INDUCED SEISMICITY	Tectonic movements may increase or decrease; monitoring is becoming routine.
14.	INTACT RIVERS	Hydro and other developments are better concentrated on the same rivers in order to preserve representative rivers in their natural states.

Source: R. Goodland (1985).

environmental dimensions of dam projects found in Figures 1.1 and 3.1 illustrate the complexity of the topic. They share several common points that are important:

First, it is important to re-emphasize that not all environmental effects are negative and entail costs only. They can also be good and generate benefits. It is as important to identify the contributions of environmental factors to the project, as it is to identify the negative impacts and the constraints they may impose. Both environmental costs and benefits must be taken into account. Sometimes one physical component will produce both environmental benefits and environmental costs. For example, the creation of a dam and reservoir may block a fish migration route, thereby reducing fish stock and catch. At the same time, the reservoir can create a potential lake fishery as well as recreational benefits. Whether or not these benefits are "environmental effects" or project outputs is a semantic difference depending on how the project was designed. The welfare effects are the same in either case and they should be taken into account.

Second, when they occur, most of the environmental processes involved in dam construction and operation are interconnected. People displaced from the inundated area of the reservoir, or those whose movement is facilitated by the reservoir and dam construction activities, may move upstream into the watershed. Their logging and cultivation may create additional erosion, leading to increased sedimentation in the present and future reservoirs, reducing storage capacity. Sediment, in turn, affects water quality, and may reduce the capacity for electricity generation, and provision of water supplies and other intended benefits. At the same time, sediment trapped in a reservoir can improve downstream water quality and therefore provide economic benefits for irrigation and water supply users. In general, the characteristics of water releases from the dam affect such factors as downstream river flow, streambed configuration, water quality, associated cultivation, and river and ocean fisheries. The dam can also affect conditions elsewhere in the river basin through changing subsurface water levels, resettlement of displaced peoples, and changes in land use patterns.

As major investments, dams can have large impacts on regional development and create induced growth of new population centers and industrial activity. The cumulative effects of such projects may be substantially different from the effects of individual projects. Consequently, consideration must be given to the cumulative environmental effects of the proposed project added to those of other existing projects, those under development in the basin, or those induced as a result of the initial project.

Major Environmental Factors

Not all dam projects have significant adverse environmental consequences. Whether or not they exist, however, must be determined. One approach to identification of likely environmental factors is to examine the three broad regions associated with any dam project: the dam and its reservoir, the upstream area, and the downstream area. (Figure 1.1 is one representation of this concept.) Some environmental factors are common to all regions, others to only one or two. Similarly, not all of the factors listed necessarily pertain to all dams, nor will all of them necessarily be found in any one dam. For example, some impoundment areas may not include villages, agricultural land, or marketable timber, but the possibility should be considered.

The following listing is a brief summary of major factors. Detailed discussions are found in many sources; in particular, the International Commission on Large Dams (ICOLD) has produced several excellent references (ICOLD, 1981, 1985, 1987) as has the American Society of Civil Engineers (1978). The 1981 ICOLD Bulletin, Dam Projects and Environmental Success, discusses general environmental problems and remedies, health problems, beneficial side effects, and monitoring and control of project. The 1985 Bulletin, Dams and the Environment:

Notes on Regional Influences, focuses on the particular environmental concerns in each of three climatic regions: temperate; tropical, sub-tropical and arid; and severe winter environments.

The Dam And Impoundment Area

Specific provisions must be made to eliminate or mitigate environmental damage in the impoundment area during and after construction. Some of these effects are the responsibility of the contractor and others are the responsibility of various government agencies.

Provisions should be incorporated into construction tenders so that the eventual contractor clearly recognizes its responsibility for construction related impacts. The Bank has formalized instructions for contractors that cover many points, including the following:

- location of borrow areas and borrow pits;
- air and water pollution from construction equipment, earth movement, and living quarters;
- screening of laborers for imported water-related diseases;
- solid waste disposal;
- siting of contractor facilities and other infrastructure to minimize destruction of the natural landscape; and,
- noise pollution.

Other environmental effects found in the dam and impoundment area may be the responsibility of the contractor, the project authority, or various government agencies. These environmental impacts can be both negative and positive and include the following:

- **Population influx**, associated with the need for labor for construction, may cause problems including pollution and a variety of linked social effects including health, security, and impact on local cultures;
- **Direct effects on people**: reservoir creation may involve inundation of houses, villages, farms and infrastructure such as roads and transmission lines. When people are involved, involuntary resettlement is required. Involuntary resettlement imposes major social and economic costs; it requires particular attention and has been the subject of special in-depth consideration by the World Bank (see Cernea, 1988a, 1988b, and Cernea and Le Moigne, 1989 for details on the Bank's policy and operational guidelines regarding the planning, economic analysis, and implementation of involuntary resettlement);
- **Cultural/historical sites**: inundation of sites or areas of historic, religious, aesthetic or other particular cultural value, and sites of archeological and paleontological significance requires special attention. (For World Bank

experiences with cultural property, see Technical Paper No. 62, Goodland and Webb, 1987);

- <u>Inundation of agricultural land</u>, especially highly productive bottom lands;

- <u>Inundation of forest land</u>, may mean the loss of valuable timber and species diversity. Salvage lumbering can recover some of this potential loss and provide other reservoir benefits; species loss may not be replaceable;

- <u>Inundation of wildlife habitat</u>, particularly habitat of threatened species with consequent impact on biological diversity;

- <u>Inundation of potentially valuable mineral resources</u>;

- <u>Inundated vegetation</u>: biomass left in the reservoir can affect water quality if the water is to be used for potable purposes, reservoir fishing (for example, through interference with nets), operation and longevity of dam and associated machinery (e.g., effect of floating debris, chemical reactions, and wear on turbines);

- <u>Water weeds</u>: Proliferation of water weeds can increase disease vectors, affect water quality and fisheries, increase water loss (through transpiration), affect navigation, recreation and fishing, and clog irrigation structures and turbines;

- <u>Fisheries</u>: The dam will block fish migrations in the river, although fish ladders may sometimes be practical. Substantial new reservoir fisheries are often possible if carefully planned and managed. In the Saguling reservoir in Indonesia, for example, the reservoir fishery helped those resettled to restore or even surpass their previous income levels. Similar results have been observed elsewhere including Thailand (Nam Pong) and in Gujarat, India;

- <u>Water quality</u> within the reservoir is, in part, dependent on what happens upstream and retention time within the reservoir. Quality may be affected by salt accumulation, eutrophication from weeds and biomass decay, turbidity, pollution from agricultural, industrial and human wastes, and fish processing. By trapping sediment, the reservoir provides better quality water downstream with less suspended matter. See Garzon (1984) for a fuller discussion of water quality in hydroelectric projects;

- <u>Health</u>: Establishment of the reservoir and associated water management structures (e.g., canals and ditches) can create conditions fostering establishment and spread of water-related diseases such as schistosomiasis, onchocerciasis, encephalitis, and malaria. Prevention, where possible, is essential, since treatment to eliminate most disease vectors is difficult (or impossible) and expensive once they become established. In other cases, availability of regulated water supplies for municipal and industrial use (M and I) can have major beneficial effects;

- <u>Effect of drawdown regime</u>, which may create agricultural possibilities, as well as health, recreational, aesthetic,and access problems;

- <u>Seismicity</u> may be induced by large reservoirs;

- <u>Ground water level</u> in the surrounding area may be altered;

- **Local climate** may be modified by large reservoirs, especially in terms of humidity and local fog;

- **Temperature** of released water may be higher or lower than ambient river temperature (depending on pattern of release); this will have varying impacts on downstream water users;

Upstream Considerations

A variety of upstream considerations can affect the dam and its reservoir. While not directly "caused" by the dam, these effects may be induced or exacerbated by the dam. For example, dam construction and reservoir filling may provide access to a previously remote and inaccessible area. The induced population in-migration may lead to increased agricultural or mining activities with major implications for soil erosion, sedimentation, and water quality. Some of the more important upstream considerations follow:

Sedimentation is a major problem for many dam projects. Unfortunately, our knowledge of sediment delivery patterns is imperfect and much of the sediment flowing into a reservoir may have started its movement some time ago. These questions are discussed in detail in Mahmood (1987). There is no question that reservoirs will gradually fill with sediment, the question is at what rate and what can be economically done (if anything) to influence that rate. Dead storage capacity is built into most reservoir designs to act as low cost, and effective, sediment traps.

Increased population settlement and economic development in the upper catchment or watershed usually increase soil movement. The timing and ultimate impact of this increased movement on the reservoir varies greatly from case to case.

The major sources of sediment are the following:

- **Existing sediment**: sediment resulting from previous natural or induced erosion remains in the bed of watercourses and elsewhere in the watershed area, and will continue to flow into the reservoir, particularly in periods of heavy rainfall (especially in "young" geological areas, such as the Himalayas);

- **Unusual natural sedimentation**: natural events such as volcanic activity, earthquakes, mudslides, typhoons and "100 year precipitation events" may cause heavy sedimentation regardless of watershed management measures;

- **Road building and other construction**, not necessarily associated with the dam project, can cause soil erosion and associated sedimentation;

- **Erosion** from (usually unplanned) clearance of vegetation, logging, and cultivation by people who have moved into the watershed areas as a direct or indirect result of the construction of the dam project. This is largely a planning and regulation problem.

Changes in land use caused directly or indirectly by the dam and dam construction, primarily from increases in population due to planned or unplanned resettlement from inundated areas or elsewhere. These changes may also go on without the project; the question is the rate of change. In-migration from both downstream and outside the river basin area is often facilitated by the project (improved access due to new roads and water transport). The resource and environmental effects include the following:

- Cultivation on unsuitable sites, often unplanned, using unstable or otherwise unsuitable lands (e.g., steep slopes, poor soils) leading to soil erosion and sedimentation;

- Logging, usually unplanned and often illegal, which results in denudation, unsustainable exploitation of the resource, and erosion;

- Poaching, i.e., illegal, unsustainable exploitation of wildlife;

- Denudation of vegetation for cultivation, fuel collection, and logging;

- Loss of wildland and wildlife habitat, with impact on endangered species and reduction of biological diversity;

- Negative impacts on aesthetic and scenic qualities of the area and the potential for certain recreational uses. The reservoir, however, may create recreational benefits;

- Pollution from settlements and cultivation;

Changed watershed hydrology. The changes in land use patterns, if extensive enough, may affect the timing and magnitude of runoff, especially during major storm events. Changed vegetative patterns may also influence dry season stream flow. Hamilton and King (1983) discuss the relationships between surface cover and hydrology in detail.

Salt inflows from the watershed may accumulate in the reservoir and affect water quality. Similarly, catchment runoff may carry increased quantities of agricultural chemicals and fertilizer with resultant impacts on reservoir water quality.

Downstream Considerations

Numerous impacts are felt downstream. Many are positive and are the reasons why dams are built--increased irrigation, improved water control, hydropower generation and water supply benefits. Whether they are considered direct or indirect project effects, there are other environmental and resource impacts that can be both positive and negative. Among these are the following:

- Impact on river fishery due to changes in flow regime, effect of dam blocking fish migration, changes in water quality (e.g., loss of nutrients trapped by dam, pollution from irrigation return flow, and increased water turbidity);

- Effect on traditional flood plain cultivation through changes in flow and flooding regime, and loss of annual "top dressing" fertilization from limited flooding. Control of severe flooding can also yield benefits through reduced crop and property losses;

- Impact on other water projects: changes in stream flow and water releases from the dam affect dams and irrigation projects elsewhere in the lower basin. The impacts can be both positive and negative. Reduced silt content in water, for example, will lower downstream O & M costs and permit better water management; lower silt levels also decrease potable water treatment costs. On the other hand, weed growth in existing canals may increase with perennial water supplies;

- Impact on municipal and industrial water supply downstream can have both positive and negative effects depending on water quantity and quality;

- Stream bed changes are one possible, but not a common result of the changed water flow and sediment load. This includes the possibility of increased stream bed erosion below the dam due to "hungry" water (with reduced silt loads) being released from the dam;

- Effect on estuarine and marine fisheries and marine biota, including endangered species, through change in flow regime, change in water quality (e.g., pollution from toxic chemical and salts from irrigation return flow to river) and loss of nutrients;

- Salt intrusion into estuarine and lower river basin areas may result from sustained or seasonal reduction in river flow;

- Groundwater level changes: Higher levels due to the high water levels in the reservoir. Downstream, in old flood plain areas, the groundwater level may fall but in irrigated areas, it may rise;

- Health problems from water-related diseases or parasites (similar health problems may also occur in the reservoir itself), primarily from irrigation and associated canals;

- Effects on wildlife and wildlands through loss of or change in habitat may result in an impact on biological diversity.

Assessing Likely Importance

Identification of likely environmental or resource impacts is the first step. Once they have been identified, it is necessary to assess or evaluate which impacts are important and need to be taken into account. Not all impacts are of equal importance and limits on data and resources (money, trained staff, time) mean that decisions must be made on which impacts to consider further.

Certain effects are so obviously important that they will always be included in the expanded analysis: involuntary resettlement is one example. Others may or may not be important. For example, the reservoir may flood a tropical forest and destroy this diverse ecosystem. Are similar areas available nearby? Are there any endangered species that may be driven to extinction? Are there unique cultural or historic sites such as the Abu Simbel monument that was moved to prevent its inundation by Lake Nasser created by the Aswan High Dam?

Given a trained multidisciplinary study team, the most important effects are usually well identified and quantified. Experience from similar projects in the same country or in geographically similar settings can provide valuable guidance and the Bank has considerable in-house expertise on these topics. Assessment is a skill, not a check-list activity.

Steps For Incorporating Environmental Factors

In the preparation of any project involving dams the first step is to make sure that the environmental factors involved are identified, i.e., to see which ones occur and should be considered in connection with the project. They must be considered early enough in the process so that major potential impacts are incorporated into the first steps of project identification, and if necessary, adjustments made in the location or design of the project. (Only in extreme cases will cancellation of a project be necessary).

To accomplish this requires that virtually any major dam project has an environmental reconnaissance at the identification stage in order to determine the existence and approximate scope of any environmental problem. The essential tools here are environmental guidelines for the identification stage, and good terms of reference for the reconnaissance.

Once environmental factors are identified and their potential importance assessed, this information is incorporated into the process of analyzing options or alternative designs for the project. To the extent that environmental factors can be evaluated in tangible form, they are included in the economic analysis of alternatives. Chapter 4 discusses this in greater detail. Intangibles should also be included in the analysis in a qualitative manner.

Where consultants are employed to carry out the environmental reconnaissance and any further environmental studies contributing to the preparation stage, adequate terms of reference must be provided. These should spell out the scope of the effort, the detail needed, and other requirements for specific recommendations where actions are needed to deal with environmental problems.

It is also important to have comprehensive environmental guidelines for use in the appraisal stage. In most dam projects, there should be specialists on sociological, biological, and physical factors in the appraisal team. These topics will have been identified in the earlier reconnaissance studies.

The environmental treatment of the remainder of the stages can be dealt with in much the same manner. Essential back up information and expertise may be obtained through the Technical Divisions and Departments, but the responsibility for seeing that the environmental factors are adequately considered rests with the staff involved with the individual projects.

CHAPTER 4: ECONOMIC ASPECTS

Overview

Dams are large, lumpy investments; in fact, they are frequently part of some of the largest capital investments made by a country. In a new irrigation scheme, the cost of the dam varies from a few percent to up to about 20 percent of the total investment. For energy projects alone, the cost of the dam is likely to be between 20 and 50 percent of the total investment excluding distribution but including transmission costs. For urban water supply, if all associated costs are included (pipelines, treatment plant, services, reservoirs and main distribution) the cost of the dam itself, though large, may only be a small proportion of the total investment. As such, dams represent major, long term commitments of scarce capital resources.

Once made, the investment is fixed and only fairly minor components can be moved or have any salvage value. Therefore the potential costs of making a poor investment decision are very large.

Given the fact that large storage dams are social investments, a social perspective is essential in evaluating the benefits and costs associated with dam projects. For example, many cities depend on dams for raw water storage; modern irrigation developments frequently rely on stored water to provide perennial water; in some countries hydroelectric power is a key to local and regional economic growth and industrial development. Traditional economic analysis of dam projects includes the construction and operation, maintenance, and replacement (OM and R) costs as well as these expected benefits in terms of hydropower generated, irrigation provided, flooding avoided and water supplied for domestic and industrial use. In some cases, recreational benefits may be important. In addition, there are associated environmental and resource costs and benefits that must also be taken into account.

The logic for a wider analysis has several dimensions. First, given the key position of a dam in a regional investment strategy, it is prudent to safeguard that investment by taking appropriate actions to prevent loss of direct project benefits--the water and power provided by the dam. Chapter 3 described environmental factors associated with dams both caused by the dam and that affect its functioning. A number of these are adverse such as a high rate of soil erosion in the upper catchment and sedimentation of the reservoir, changes in water quality, and second-order effects such as soil salinization or waterlogging in newly irrigated areas or the proliferation of human parasites in perennial irrigation made possible through water storage. These effects directly affect the generation of project benefits over time. Since most of these are costs they reduce the financial and economic attractiveness of the project.

Similarly, any direct environmental benefits, such as a new reservoir fishery, a tourism industry, or the reduction of the suspended matter content of the water should be counted as benefits.

Second, there may be important indirect effects caused by the dam and its associated environmental impacts. Fisheries, both downstream and in coastal areas may be hurt by changes in water quantity and quality including a lowering of water temperature. If there are migratory fish species within the river (e.g., salmon, sturgeons), their productivity or very survival can also be affected. There can also be significant indirect environmental benefits of dams. Changes in stream flow after dam construction can result in reduced salt-water intrusion in coastal areas, depending on how water releases are regulated. When environmental benefits occur, they should be taken into account in the same way as environmental costs.

Third, there are frequently important social impacts associated with dams. These include the major problem of involuntary resettlement for those people previously living in the reservoir area and the spontaneous voluntary movement of settlers into the watershed (reservoir basin) above the dam. Immigration is often accelerated by the improved access provided during dam construction. (There are even reports of new settlement in the proposed reservoir area in hope by settlers of receiving compensation when it is flooded.) Other social impacts are caused by changing economic patterns as a result of dam-induced developments, both upstream and downstream.

The net effect of these factors may be to increase or decrease the economic returns from the dam project. Those in the international community who are very critical of large dams, a small but very vocal group, have focussed considerable attention on what one report called "fudging the books" (Goldsmith and Hildyard, 1984). This point of view asserts that there is a systematic bias in the economic analysis of projects on the part of dam proponents. These views go beyond economic arguments and are often highly emotional. In a two-volume set, The Social and Environmental Effect of Large Dams, (1984, 1985), Goldsmith and Hildyard state that "those who stand to gain politically and financially from the building of a large dam are willing to go to inordinate lengths to ensure that it will be built. Among other things, they are willing purposefully to mislead those who must be persuaded of the dam's desirability and viability before the go-ahead to build it will actually be given. This they do by grossly exaggerating the dam's likely benefits and seriously underestimating its probable costs--in particular its social and ecological costs which, as we have seen, are often ignored." The benefits of dam projects are given considerably less attention.

Among the "sins" of economic analysis outlined in the Goldsmith-Hildyard report are the following:

1. Using unrealistically low discount rates,
2. Over-estimating job creation potential,
3. Failing to account for energy costs,
4. Over-estimating the benefits of flood control,
5. Ignoring costs of decommissioning,
6. Over-estimating the life of dams,
7. Under-estimating construction costs,
8. Over-estimating irrigation and recreation benefits, and
9. Under-estimating environmental costs.

Some of these charges are obviously "straw men." The use of too low a discount rate is a common charge made by critics when dam proponents are using long-term direct project benefits to justify a project. If environmental costs are included, however, the critics will claim that the discount rate is too high and therefore ignores long-term costs.

And yet, when some of the rhetoric is removed, the Bank shares many of the same concerns about correctly estimating the economic and social effects of projects, both benefits and costs. The first three chapters of this report have focused on the identification of environmental and resource effects associated with dam projects---both those caused by the project and those that affect the project's productivity. These data are important information for a broader economic analysis of proposed projects.

In order both to respond to outside criticism and to conduct a wider, more environmentally sound appraisal of dam projects, therefore, several conditions must be met. First, it must be accepted that environmental costs or benefits are real costs and benefits that must be included in the analysis. Under-estimating or ignoring environmental costs is no longer acceptable. Second, the identification of the likely environmental impacts requires the skills of a mix of disciplines. Third, environmental effects change over time and monitoring is required, both to evaluate on-going activities and to identify potential problem areas and take appropriate action. Ideally, monitoring must start before construction to establish baseline data.

The tools of economic analysis are well developed for carrying out standard financial and economic evaluations of dam projects. In the past two decades, much work has been done on applying economic analysis to environmental effects. For some categories of effects, the analysis is quite straightforward; for others, the appropriate techniques are still evolving. The remainder of this chapter reviews some of the economic approaches available for incorporating the monetary value of environmental effects into the economic analysis of dams.

Economic Measurement Of Environmental Effects

The resource, environmental or social impacts of dams can be grouped into several categories. One set of impacts are the changes in the social or physical environment that have direct effects on people. These include the dislocation of people from the dam and reservoir site and associated involuntary resettlement, the disruption of traditional lifestyles, and the special concerns of tribal peoples. These very important effects are discussed in other Bank documents (e.g., Involuntary Resettlement in Development Projects, M.M. Cernea; World Bank Technical Paper No. 80, 1988) and are the subject of various Bank Operational Manual Statements. Because of the extensive coverage of this topic in other Bank seminars, involuntary resettlement was not included in the seminar reported on here and is not included in detail in this report.

A second set of impacts are what have been called "boundary effects" or non-negotiable issues. These include legal or other factors based on societal considerations. Examples include legal requirements in some countries that the habitat of endangered species cannot be harmed. In other cases unique cultural, historical or religious sites are similarly "off-limits" to development. No attempts made to place monetary values on these considerations--they are frequently based on societal or political decisions.

One category of such impacts is what can be called the "snail darter" syndrome after the famous case of the snail darter, a small fish, and the Tellico Dam in the United States. In this case a legal requirement for preservation of an endangered species' habitat became the focus of a major legal and media battle when the initial environmental analysis indicated that the reservoir would destroy the only known habitat of the snail darter. Legally, the habitat could not be destroyed. Completion of the dam was delayed for years after many millions of dollars had already been invested.

The dam was finally built but in all of the discussions, scant consideration was given to the benefits or costs of snail darter preservation per se. (Parenthetically, a strong case could be made that the Tellico dam was uneconomic even on a narrow direct benefit-cost criteria. In addition, another snail darter population was later found in a nearby location. For a full discussion of this case see Davis 1988). This type of case is the exception and is not a main concern here.

The third set of impacts are those that have direct productivity effects and that impose economic costs or confer economic benefits on society and individuals. These are the major focus of this chapter even though other types of effects, particularly the resettlement impacts just mentioned, may impose major social costs that must not be ignored.

Concentrating on this last set of environmental effects---productivity impacts and directly measurable benefits and costs---a list of the main types of environmental costs and benefits associated with dams include the following:

- soil erosion and sedimentation,
- land lost by reservoir flooding and dam construction,
- salinization and/or water logging in newly irrigated areas,
- changed system hydrology,
- health effects,
- fishery effects, and
- recreational benefits.

More benefits and costs could be listed, some of which are quite hard to value (e.g., what is the value of a submerged archeological or religious site?). As one example, however, consider the case of soil erosion and reservoir sedimentation. The physical processes have been extensively studied; it is known that soil erosion and sedimentation are the result of both natural and man-made processes. The costs due to lost reservoir storage capacity are also very large if live storage is curtailed (sediment filling of dead storage is acceptable and is the usual case). In a recent World Bank technical paper on reservoir sedimentation, K. Mahmood estimated the replacement cost for lost reservoir capacity of major world dams at some $6 billion per year. [3]/ While part of this lost capacity is due to natural erosion, part is created by man. In addition, this annual cost is expected to increase over time. As Mahmood

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3/ K. Mahmood, 1987, Reservoir Sedimentation: Impact, Extent, Mitigation. Washington, DC: World Bank Technical Paper No. 71. The $6 billion annual cost is derived from an extrapolation of the worldwide rate of sedimentation in major reservoirs, an estimated annual capacity loss of 50 km3, and a replacement cost of $120 million per km3.

pointed out "In many basins, additional sites are hard to find, and in general, remaining sites for storage reservoirs are more difficult, and, hence, more expensive to develop."

Environmental impacts may also be a major contributing factor to construction delays or even outright cancellation of projects. While cancellation is not yet common (though certainly not unheard of, e.g., Nam Choam in Thailand, Silent Valley in India, or the Franklin Dam in Tasmania, Australia) construction delays, sometimes stretching into years, are frequently encountered. Goodland (1985) contains a useful description of the Silent Valley and Franklin Dam examples and the reasons why these projects were cancelled. In addition to financing problems, delays are also often caused by incomplete assessments of environmental or social impacts in the initial appraisal and design stages. Just as a heavily sedimented reservoir imposes large costs on society, a delayed or cancelled project can also be very costly in terms of project benefits foregone and past investment.

A proper environmental and social analysis, therefore, can help assess whether or not the positive benefits are larger than the negative costs (including environmental damage). With this analysis, some proposed projects may not prove to be the optimal solution. In that case, other alternative projects should be considered in the search to find the least cost way of supplying the desired water and power benefits.

Analytical Techniques

This chapter cannot present a detailed discussion of all the techniques available for placing economic values on environmental effects. Recent work has expanded the list of environmental or resource impacts that can be evaluated in tangible (monetary) terms and included in the economic analysis. Many of the most useful approaches rely on changes in productivity that can be valued using market prices. Table 4.1 lists some of the environmental aspects of dam projects, their economic impacts (both benefits and costs) and selected valuation approaches that can be used to value them. The table does not present an exhaustive list, it is merely indicative of where one can start.

As seen in Table 4.1, many of the environmental effects and their economic impacts can be valued using change in production techniques or preventive costs or replacement costs approaches. All of these approaches rely on use of actual expenditures (or in some cases potential expenditures) valued using market prices. With proper identification of the cause-effect relationships, there is little doubt that these impacts reflect real welfare changes -- either positive, in the case of benefits, or more commonly negative, in the case of costs.

Other approaches used to value environmental benefits and costs rely on "surrogate markets" such as in the travel cost and property value approaches. Health care costs and loss of earnings techniques may be used to value health-related effects. These approaches are described later in this chapter.

In all cases the aim of the analysis is the same--to properly identify likely environmental benefits or costs arising from the dam project and incorporate them into the overall economic analysis of the project. The actual process of valuation of environmental effects requires their translation into monetary terms. Considerable literature exists on the valuation process; discussion of techniques and examples are found in Sinden and Worrell, 1979; Krutilla and Fisher, 1982; Hufschmidt et al., 1983; Dixon and Hufschmidt, 1986; and Dixon et al., 1988. This chapter briefly reviews several of the most commonly used or potentially useful approaches associated with dam-related environmental effects: changes in productivity,

Table 4.1: **Selected Environmental Effects and their Economic Impacts**

Environmental Effect	Economic Impact	Benefit (B) Cost (C)	Representative Valuation Technique
Environment on Dams			
1. Soil erosion - upstream, sedimentation in reservoir	reduced reservoir capacity; change in capacity; change in water quality; decrease in power	B,C	change in production, preventive expenditures, replacement costs.
Dams on the Environment			
1. Chemical water quality - changes in reservoir and downstream	increased/reduced treatment cost reduced fish catch, loss of production	B,C	preventive expenditures, changes in production.
2. Reduction in silt load, downstream	loss of fertilizer, reduced siltation of canals, better water control	B,C	replacement costs, preventive expenditures avoided.
3. Water temperature changes (drop)	reduction of crop yields (esp. rice)	C	changes in production.
4. Health - water related diseases (humans and animals)	sickness, hospital care care, death; decrease meat and milk production	B,C	loss of earnings, health care costs.
5. Fishery - impacts on fish irrigation, spawning	both loss and increase in fish production	B,C	changes in production, preventive expenditures.
6. Recreation - in the reservoir or river	value of recreation opportunities gained or lost, tourism	B,C	travel cost approach, property value approach.
7. Wildlife and biodiversity	creation or loss of species, habitat and genetic resources	B,C	opportunity cost approach, tourism values lost, replacement costs.
8. Involuntary resettlement	cost of new infrastructure, social costs	B,C	replacement cost approach, "social costs", relocation costs
9. Discharge variations, excessive diurnal variation	disturbs flora and fauna, human use, drownings, recession agriculture	C	relocation costs, changes in production.
10. Flood attenuation	reduces after flood cultivation; reduces flood damage.	B,C	changes in production, flood damages avoided.

opportunity cost, preventive expenditures, land value approaches, travel cost, replacement cost and relocation costs.

Starting The Analysis

Among the hardest tasks for the economist or project analyst is to decide which of the environmental and resource impacts are important and then how to measure them and include them in monetary terms. There is no "cookbook" answer; the analyst must think through each problem, identify important impacts, make decisions, and make all assumptions explicit. Among the various environmental effects of dam projects some general guidelines that should be of help in setting up the analysis follow:

- Start simply with the most obvious, most easily valued environmental impacts. This may mean looking for impacts on the environment arising directly from the project that result in changes in productivity and that can be valued using market prices. (Sometimes market prices are distorted and one has to make appropriate adjustment via use of shadow prices). Table 4.1 listed categories of major effects and their economic impacts. Secondary effects may be very important, both ecologically and economically, but the analyst would do best to start with the effects that have directly measurable productivity changes that can be valued by market prices. Secondary effects can then be incorporated to the extent knowledge, data and resources permit.

- There is a useful symmetry in benefits and costs: a benefit forgone is a cost while a cost avoided is a benefit. A reduction in dam height, for example, may mean that fewer people need to be resettled from the reservoir. This reduction in resettlement costs is a benefit of the decision. Of course, the reduced height also creates "costs" due to reduced hydropower, irrigation or flood control benefits. These may be more difficult to establish and value. The analyst should always look at both the benefit and cost sides of any action and approach valuation in the most feasible and cost-effective way.

  The distinction between benefits (costs avoided) and costs is the reference point from which changes are measured.

- All assumptions should be stated explicitly. This is particularly important in valuing effects on the environment because other analysts may wish to challenge the results and can only do so if the assumptions and the data are clearly presented. Of course, the analysis should be carried out in a with-and-without-project framework. That is, the analysis must compare the likely situation without the project with what is expected to occur with the project. In many areas, existing forces are leading to growing environmental degradation (and poverty) and this process would continue or even accelerate without the project. In this case, the with-project situation must be compared to a deteriorating without-project scenario.

Techniques In Which Market Prices Are Used To Value A Change In Production Or Costs

The following brief descriptions present some of the most directly useful valuation approaches for dam-related environmental and resource effects.

Changes in productivity. Techniques using changes in productivity as the basis for measurement are direct extensions of traditional benefit-cost analyses. Physical changes in production are valued using "economic" or accounting prices, usually based on market prices for inputs and outputs or, when distortions exist, appropriately modified market prices (e.g. shadow prices). The monetary values thus derived are then incorporated into the economic analysis of the dam project. This approach is based directly on neo-classical welfare economics and the determination of social welfare. The benefits and costs of an action are counted regardless of whether they occur within the project boundaries or beyond them.

Several steps must be taken in order to use this technique:

(i) Changes in productivity caused by the project have to be identified both on-site and off-site. In addition to the direct project outputs associated with the dam (e.g. hydropower, irrigation, water supply, flood control) there may be other indirect on-site effects such as the benefits of a reservoir fishery or a tourism/recreation industry. Changes off-site (both positive and negative) include all relevant environmental or economic externalities. These off-site effects must be included to give a true picture of project impacts.

(ii) Assumptions will also have to be made about the time over which the changes in productivity must be measured, the 'correct' prices to use (e.g. shadow prices) and any future changes expected in relative prices.

In the case of dam projects, the change in productivity approach can be used for various on-site and off-site effects: fisheries and draw-down cultivation in the reservoir area, changes in crop production, and changes in fishery production, both in-stream and in affected coastal areas. Upstream environmental effects, such as changes in land use patterns and associated soil erosion/sedimentation will also affect the primary productivity of the reservoir. These latter impacts may be difficult to measure for the "without project" scenario due to rapidly changing rural settlement patterns. These costs can also be valued by the change in productivity approach.

<u>Opportunity cost</u>. This approach is based on the concept that the cost of not using a site for a dam and reservoir can be estimated by what has to be given up for the sake of preserving the site by not building the project there. This approach can be used when there are ecological or historical reasons for not developing a certain site and these reasons cannot be easily expressed in monetary terms. The opportunity-cost approach is, therefore, a way of measuring the "cost of preservation." This information, in turn, is used to evaluate the options open to a decision maker. These options include various alternatives and the do-nothing, "without-project" alternative. There are instances where the opportunity cost of preservation is found to be low relative to the expected (although non-monetized) benefits, thereby resulting in a decision to preserve or to conserve the site in its natural state. This is not a valuation technique <u>per se</u>, as it only estimates the development benefits foregone, not the magnitude of preservation benefits.

The first step of the analysis is a conventional benefit-cost analysis of the proposed project. If the traditional project analysis shows the project to be uneconomic, the analysis need go no further. (It should be noted that for some types of projects, such as urban water supply, the "benefits" are very hard to value and the analysis, therefore, uses the cost-effectiveness approach to identify the least cost alternative. Cost-effectiveness analysis may not be suitable for multi-purpose projects). If, however, the proposed project does have positive net benefits, (or is the least cost alternative), these must be weighed against the benefits of the site preservation alternative (e.g. no dam construction), which cannot be easily measured.

One well-known example of the use of this technique is the Hell's Canyon Study in the United States of America (Krutilla, 1969; Krutilla and Fisher, 1985). It had been proposed to dam the canyon for the generation of hydro-electric power which would have altered, irrevocably, a unique area of wilderness. Rather than trying to value all the benefits of the canyon in its natural state, the analysts produced conventional benefit-cost analyses both of the proposed project and of its next cheapest alternative. The analysis showed that even under a variety of assumptions, the benefits of the project were not large enough to justify the irreversible loss of a unique natural area. The decision makers chose not to build the dam since the opportunity cost of preservation, i.e., the additional expense of generating power from another source, was thought to be worth paying for the sake of preserving Hell's Canyon in its natural state.

Preventive expenditures. It is sometimes possible to establish the minimum value that an individual will put on the quality of his or her environment by determining just how much people are prepared to spend in preventing damage either to it or to themselves. This is also true of communities or nations. Valuation performed in this manner is known as the 'preventive expenditure' or 'mitigative expenditure' approach. It gives a minimum estimate for two reasons: the actual level of expenditures may be constrained by income or there may be an additional amount of consumer's surplus even after the preventive expenditure has been made. Whereas cost-effectiveness analysis examines the direct cost of meeting some pre-determined target or standard, this technique examines actual expenditures in order to determine the importance individuals attach to impacts on the environment.

Theoretically a rational individual would incur mitigating costs if:

$$N' + E < N$$

where N = original level of perceived damage

N' = mitigated level of perceived damage
E = mitigation expenditure

A rational individual will continue to incur mitigation costs as long as the damages forgone exceed the mitigation expenditure at the margin, or

$$(N - N') > E$$

The demand for the mitigation of environmental damage can be seen as a surrogate demand for environmental protection. Clearly, individuals or communities will commit their resources only if their subjective estimate of the benefits is at least as great as the costs. In the case of dam-cum-reservoir projects this approach can be used to assess expenditures associated with changes in water quality (or quantity), soil-erosion and sedimentation, or fishery related impacts among others (see Table 4.1).

The assumptions implicit in this kind of analysis are that:

(i) accurate data on the costs and the effects of the mitigating expenditures are available;

(ii) there are no major secondary benefits associated with the preventive expenditures. If there are large secondary benefits, they should be included in the analysis.

Techniques in Which Surrogate Market Prices Are Used

Many aspects of the environment have no established tangible value or market price. Things like clean air, unobstructed views, and pleasant surroundings are public goods and hence direct market prices for them are rarely available. In many cases, however, it is possible to estimate an implicit value for an environmental good or service by means of the price paid for another good which is marketed. Dam projects and their associated reservoirs can provide environmental benefits through creation of recreational sites and water-front property. In some countries these amenities may be of considerable value.

Surrogate market techniques, therefore, offer approaches which use an actual market price with which to value an unmarketed quality of the environment. The basic assumption is that the price differential, arrived at after all other variables except environmental quality have been controlled for, reflects a purchaser's valuation of the environmental qualities at issue. For example, information on costs of travel to visit a recreation site is used to determine an implicit value for the recreational benefit (an environmental service).

While there are some limitations to these techniques (to be discussed later), they can, in certain cases, be very useful in valuing a wide range of environmental qualities.

Land value approaches. Land value approaches are based on the principle that an observable market price (usually that of retail land prices) can be used to evaluate a combination of impacts. If nearby parcels of land are priced differently, for example, any differences between them will normally be due to one of two factors: the productivity of the piece of land, or unpriced environmental qualities. In the case of a dam and reservoir this environmental quality may relate to scenic views or access to water (as on a reservoir).

If there are productivity impacts these can be evaluated by measuring the change in the value of output using the approach described earlier; the capitalized value of productivity should be partly reflected in the retail price of land. In addition, however, there may be other unpriced impacts that are also incorporated in land values. These include the amenity benefits (nearness to water, views) associated with the dam and reservoir. By examining land prices and the capitalized value of production from that land, the residual can be determined. Part of this residual represents the 'surrogate' value of environmental or other unpriced factors. When land is not used for any direct production activity (such as forestry or grazing), the land values recorded are almost entirely due to environmental or amenity values. Details on this approach can be found in Hufschmidt, et al. (1983).

In sum, the land value approach uses market prices for land with varying attributes as a measure for determining the value of an environmental attribute which is not normally priced. It is, of course, essential when using this method to ensure that any differences are net of the value of the direct effects on productivity (although the latter are valid measures of environmental benefits from many soil and water resources management projects).

Travel cost. The travel cost approach has been used extensively in developed countries to value recreational goods and services. Developed in the late 1950s and 1960s (Clawson 1959; Clawson and Knetsch 1966) it is based on the simple proposition that observed behavior can be used to derive a demand curve and to estimate a value (including consumer's surplus) for an unpriced environmental good by treating increasing travel costs as a surrogate for variable admission prices.

The transactional price for most goods can be considered to be an expression of willingness to pay for the right to consume the good or the utility received from it.

Recreational (or cultural, historic or scenic) goods are, however, a different case. Usually such goods (a public park will be used here as an example) are provided either free of charge or for a nominal admission fee. The value of the benefits or utility derived from a park developed around a reservoir, however, is often much larger than the fee; the difference is equal to the consumer's surplus of the park users. In order to estimate the total amount of consumer's surplus we must derive a demand curve from the actual use of the park.

The present pattern of park use is determined by means of a survey. Respondents are questioned about the time and money they spend travelling to the park, distance to the site, and a variety of other socio-economic variables. The park users' zones of origin are usually defined in terms of increasing distance from, or cost of travel to, the park. A survey will normally show that the frequency with which people use the park (usually measured as number of visits per thousand of population in each zone) is inversely related to their distance from the site. The more it costs, in time and money, to get there, the less frequently an individual will use the park, all other factors held equal. If plotted, this information will appear as in Figure 4.1.

In order to derive the demand curve, a number of assumptions must be made and a number of steps must be taken. The first assumption is that individuals can be grouped into residential zones where the inhabitants have similar preferences. Second, we assume that people will react to increasing travel costs in much the same way as they would react to increased admission charges at the park. This means that at some level of admission fee (or cost of travel) no one would use the park because, given other recreational options, it would be too expensive. Then we make a calculation of visitation rates from all origin zones, taking into account a number of variables related to income, cost of travel, and other elements.

In its simplest form a regression equation is derived that relates visitation rates to the cost of travel. This is then used via a series of steps to determine the area of consumer's surplus for park users in each zone. The consumer's surplus from all zones is added together to estimate the total consumer's surplus for users of the park.

It should be stressed that the amount of the travel cost per se is not equal to the value of the park. The travel cost data are only used to estimate a demand curve. Further, the approach uses pre-established patterns of use and is heavily influenced by the existence of other sites. Numerous refinements of the approach are possible and many of them are discussed in considerable detail in the literature.

In a dam/reservoir project, for example, the travel-cost technique could be used to place a value on the associated recreational facilities, but only after the reservoir was in use. (An analysis of a similar reservoir could be done to derive an estimate of recreational benefits before the proposed reservoir is built. Obviously this would have to be handled very carefully and all assumptions be made explicit.)

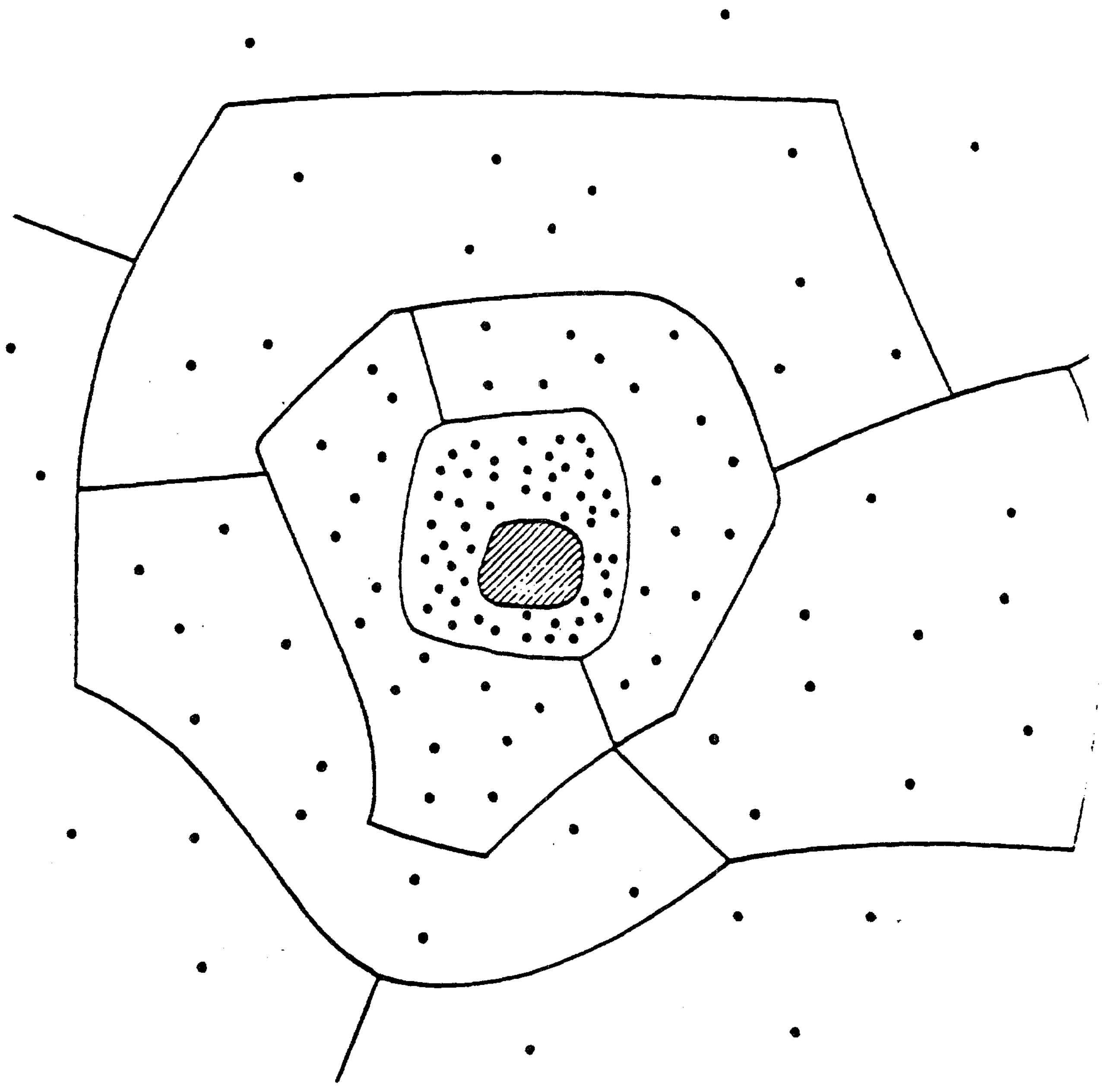
The value of cultural or historical sites threatened by development projects could also be analyzed by the travel cost method. In such cases the value obtained should clearly be identified as a minimum valuation of only part of the total value of the resource.

<u>Cost Analysis Techniques</u>

Cost-analysis techniques depend on estimates of potential expenditures to value a developmental impact on the environment. These approaches examine the costs that would be involved if some impact on the environment were to be mitigated by replacing the facilities or services which had been damaged or destroyed. This information is then used to decide

Figure 4.1

PLOT OF HYPOTHETICAL SURVEY DATA
USED IN THE TRAVEL-COST APPROACH



Note: Each dot represents 10 visitors to the park. For each zone (1-8) a variation rate (visitors per 1,000 population) is developed.

whether it is more efficient to take preventive measure beforehand or compensatory measures after the event.

Both techniques presented here are similar; they are presented separately, however, because there are certain situations in which one will be more appropriate than another.

Replacement costs. The basic premise of the replacement-cost approach is that the costs incurred in replacing productive assets damaged by a project can be measured, and that these costs can be interpreted as an estimate of the benefits presumed to flow from measures taken to prevent that damage from occurring. The rationale for this technique is similar to that for preventive expenditures except that the replacement costs are not a subjective valuation of the potential damages but, rather, are the true costs of replacement if damage has actually occurred. The approach can thus be interpreted as an 'accounting procedure' used to work out whether it is more efficient to let damage happen and then to repair it or to prevent it from happening in the first place. It gives an estimate of the upper limit but does not really measure the benefits of environmental protection per se.

The assumptions implicit in this type of analysis are:

(i) the damages are measurable;

(ii) the replacement costs are calculable and are not greater than the value of the productive resource destroyed, and therefore it is economically efficient to make the replacement. If this assumption is not true, it would not make sense from an economic perspective to replace the resource lost (although there may be social or political reasons to do so); and

(iii) any secondary benefits associated with the preventive expenditures should be included as benefits in the analysis.

In case of dam and reservoir projects this approach can be used to evaluate various environmental effects and alternative mitigation measures. The simplest example is the problem of resettlement. Resettlement of people displaced by a reservoir and construction site, either rural farmers, small villages or even larger urban areas, is a costly and difficult process. The costs of replacing the lost facilities and recreating viable economic-social systems in another location are calculable. These are a form of replacement cost and should be considered in assessing the overall profitability of the project. The impacts of alternative dam heights on replacement costs must be considered as well as the implication of dam height on construction costs and generation of power, irrigation or flood control benefits. In The Three Gorges project in China, discussed in the next chapter, this is an important consideration.

An instream fishery may be threatened by a dam that intercepts a natural migration path. In this case the replacement cost to protect and maintain the fishery may consist of fish ladders or other means to permit some degree of migration and natural biological cycles. These costs are then compared to the cost of allowing the fishery to disappear or suffer reduced productivity. In this example the dam project is debited with the amount of the replacement costs (if these are less than the value of the fish that would be lost) or the value of the lost fish (assuming replacement costs are larger than this).

In general, the replacement cost approach can be useful when an effect on the environment has caused, or will cause, money to be spent on replacing a physical asset.

When that asset is a road, dam or bridge, the technique is straightforward. When it is soil, water or aquatic life its application is the same but the problems of measurement are greater. The change in productivity approach can also be useful in these case. When impacts on the environment result in physical economic externalities then this approach can frequently be used to bring those externalities into the analysis.

Relocation of infrastructure costs. This is a variant of the replacement-cost technique. In it, the actual costs of relocating a physical facility because of changes in the quality of the environment are used to evaluate the potential benefits (and associated costs) of preventing the environmental change. For example, the construction of a dam may interrupt stream flow downstream and require relocation of irrigation canal intakes. This relocation cost is part of the total cost of the project. If the dam improves the downstream situation, the additional benefits (or cost savings) are counted as a benefit of the project.

CHAPTER 5: SELECTED EXAMPLES

This chapter contains six examples of major storage dam projects from Asia, Africa and Latin America that illustrate a variety of environmental factors. Three projects have been completed, three are still in the design stage, and at least one, the Nam Choan Dam in Thailand has been postponed indefinitely, largely for environmental reasons.

These examples are based on secondary sources and are not complete case studies of any of the projects. The goal has been to illustrate some of the questions that have been raised and how, in some cases, the project proponents have responded to these concerns.

The Tarbela Dam and Aswan High Dam examples are completed projects, the former built with World Bank assistance. Both are massive projects, and the dams and their reservoirs have had far reaching impacts on the economy and environment of Pakistan and Egypt.

The Narmada Valley program in India is a regional development scheme that is still in its initial phase of development. The overall scheme involves construction of several major and numerous minor dams. The Bank has been involved with components of this program.

The other examples are quite different. The proposed Three Gorges Dam on the Yangtze in central China would be, if constructed, one of the major dams in the world and the largest hydropower dam yet built. As with all major projects of its type, the Three Gorges Dam raises questions about the involuntary resettlement of those displaced by the reservoir. Itaipu, a joint Brazil-Paraguay project, will have an installed capacity of 12,600 MW when completed. Resettlement and compensation for land losses are important issues with this project. The last example, the much smaller Nam Choan Dam in Thailand has been effectively cancelled, largely on environmental grounds.

Each of these examples illustrates different dimensions of the dams/environment tradeoff. Each dam has been or is being built to provide important benefits. The associated environmental and social aspects, both positive and negative, are also important and demand attention. These tradeoffs, and how they have been handled in different situations, are a central theme of this paper and the entire process of project decision-making.

Tarbela Dam Project--Pakistan [4/]

Tarbela Dam is the key feature of the Indus Basin Project and is the largest earth-fill dam in the world. Designed to provide regulated water supplies for irrigation, hydroelectric power, and some flood control benefits, the dam is part of the multi-billion dollar development that had the primary purpose of replacing water that would be taken from the eastern rivers of the Punjab in Pakistan.

Construction of Tarbela began in 1968 and reservoir filling started in 1976. As soon as filling began, however, a number of technical problems developed and a ten-year effort costing hundreds of millions of dollars was needed to overcome them. The total cost of the Tarbela Project, including remedial works, rose from some $800 million in 1966 to about $1.5 billion on completion, expressed in current dollars.

4/ This description is based on internal Bank reports on the project.

In addition to supplying water and generating hydroelectric power, Tarbela has certain associated environmental effects. Even before Tarbela, the continuous use of Indus water for irrigation for over a century had significant impacts on the hydrological balance of the Basin. Seepage from canals and continual irrigation had resulted in a gradual upward movement of the groundwater table; with limited drainage, problems of waterlogging and salinity arose over large areas with their adverse effects on productivity. A tubewell program in both the public and private sectors was developed to lower the groundwater level. In some areas, a system of drains was constructed.

To the extent that Tarbela captures and makes available greater quantities of water for irrigation, it could aggravate these problems if the water deliveries are not well managed. However, the additional water supplies are very small compared with the total amount served into the irrigation system. All Tarbela water is used in times of scarcity when over-watering by farmers is less likely.

Better management of water of the Indus through the regulation provided by Tarbela can yield benefits by supplying increased surface water to areas with saline groundwater aquifers which are not suitable as a supplementary source of supply.

In a country with as extensive an irrigation network as Pakistan, a project like Tarbela operates as part of a system. In this case, the careful conjunctive management of groundwater and surface water can help alleviate the dual problems of waterlogging and salinity created by past irrigation development.

The Tarbela Dam is also affected by the naturally high sediment load in the Indus. Originally, it was calculated that Tarbela would lose 90 percent of its capacity to siltation in about 50 years. From more recent observations, it is now estimated that the period will extend to 150 years or more. To the extent that Tarbela is a sediment trap, it releases water of a better quality than it receives and this has advantages when devising improved methods for water management in the irrigation system.

Aswan High Dam—Egypt 5/

The High Dam at Aswan, the second dam built near the first cataract on the Nile, was designed to serve three basic functions: to store water from the annual flood to allow regulated releases for irrigation and other purposes throughout the year, to generate hydroelectric power, and to control floods in the Nile.

Construction began in 1960 and the dam was completed in 1967. By 1970 all major power facilities were in place. The massive size of the dam and its reservoir, and the major changes in hydrology as a result of its construction, have lead to considerable international attention being focused on the dam and its environmental impacts (see Biswas and Chu, 1987). Recent articles by Gilbert White and A. M. Shalaby (1988) assess the environmental effects of the High Dam 18 years after its completion. This example is largely drawn from those articles.

The dam achieved its major project goals: it has provided flood control, enlarged irrigation cropping, and increased power generation. In fact, the water stored in the reservoir allowed Egypt to avoid potentially disastrous agricultural shortfalls resulting from

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5/ This description is based on reports by A.T. Biswas and Chu Koping, 1987; A.M. Shalaby, 1988; and G.F. White, 1988.

the recent period of drought starting in 1979. The environmental effects of the project are examined in two parts--those created by the reservoir, and downstream effects.

The reservoir, called Lake Nasser in Egypt and Lake Nubia in Sudan, is massive with a capacity of 162 cubic kilometers. Filling of the reservoir displaced 50,000 to 60,000 people in Egypt and some 53,000 people in the Sudanese portion. Most of the displaced Egyptians have been resettled on agricultural lands downstream from the dam; health has improved through reductions in infectious diseases. Fishing in the reservoir has somewhat expectedly become a major industry and annual catches have ranged from an average of 20-26,000 tons to as high as 34,000 tons in 1981. About 7,000 fishermen are employed in this industry. At the time of construction much international attention focused on archaeological sites and the programs to relocate such monuments as Abu Simbel and Philae are well known. The new reservoir traps about 85 million cubic meters of the 96 million cubic meters of silt carried by the Nile on average each year. This is largely accommodated in the dead storage capacity of the reservoir; at present rates it will take about 350 years to fill the equivalent of the deadstorage in the reservoir.

The retention of silt in the reservoir has an impact downstream through reduced flood delivery of nutrients to farmers' fields, increased coastal erosion, and some channel degradation below the dam.

From published information (Shalaby and White) the main downstream effects are:

- Channel degradation from the release of relatively silt-free waters resulted in degradation in bed level of between 25 and 70 cms. Measures are being taken to strengthen certain downstream structures and a pilot project to cover the first 22 km of the channel has begun;

- Navigation benefited from the regulation of Nile River flow; maximum fluctuation in water level decreased from 9 to 3 meters. Navigation also developed in the reservoir behind the dam;

- Water quality changed in various ways: turbidity dropped with the reduction in the silt load but the amount of dissolved solids has increased by about 30 percent. Shalaby estimates that the loss of nitrogen fertilizer from silt that is no longer deposited on the downstream fields amounts to about 1,800 tons of nitrogen a year with an annual monetary value of about $150,000. This does not include the value of other nutrients and trace elements;

- Irrigation benefits resulted from increased reliability of supply to existing irrigated fields, conversion of some areas from basin irrigation to perennial irrigation, and horizontal expansion of agriculture into new areas. At the same time, some agricultural lands were lost due to waterlogging and salinity and alkalinization. The loss of agricultural lands to industrial and urban uses also continued. On balance, both net irrigated and cropped areas increased with a resulting increase in production;

- Drainage has been a major problem. Due to rapid expansion of perennial irrigation, overuse of water, poor land levelling and intensification of agricultural production, groundwater levels have risen in many areas. Drainage problems are being addressed by greater use of tile drains, remodelling and deepening of main drains, and improved water management practices;

- Fisheries, both in the downstream part of the Nile and in the eastern Mediterranean, declined. The number of species caught also declined;

- Aquatic Weeds have become a common problem in many downstream areas as a result of clearer water and improved year-round water availability. Weeds are being controlled by manual, chemical and biological means;

- Agricultural production grew due to an increase in the cropping intensity, a direct result of the enhanced availability of irrigation water. Yields, on average, increased with use of irrigation, new seeds, and chemical fertilizer. The large scale drainage program has helped counteract the negative effects (waterlogging, salinity) of perennial irrigation;

- Endemic diseases. Schistosomiasis and malaria are endemic diseases in Egypt wherever perennial irrigation is practiced. Available evidence indicates that, on average, urinary schistosomiasis has declined (in part due to a major village water supply program) but intestinal schistosomiasis has spread somewhat in the delta and was transmitted to parts of Upper Egypt. So far there has been no evidence of malaria along the reservoir.

In sum, the evaluation of the past 21 years since completion of the high dam at Aswan has found that the project has had a profound impact on Egypt and the Nile. Irrigation, power and flood control benefits have all been achieved and are large. The dam gave important protection to Egypt during the African drought and, in particular, during the critically "dry" year of 1983. (There are some who believe that the dam paid for itself in that one year that was almost as bad as 1913). Most environmental impacts were anticipated in advance and in some cases corrective measures have been taken. White notes in his article that water quality effects were given much less attention than water quantity effects. Some of the quality effects have been negative and necessitate further study and remedial measures. With any major dam project such as the High Dam, there are bound to be some surprises; some environmental effects will be greater and others less than anticipated. The requirement for monitoring, post-audits and continued study are all evident.

The Narmada Valley Development Program in India 6/

India, like China, is a densely populated country that has an extensive irrigated agriculture and a growing hydropower sector. Major storage dams play an important role in producing irrigation, hydropower and flood control benefits. Future dam development, however, is affected by growing concern about resettlement issues, environmental impacts, and the economics of large dams.

A current focus of attention is the development proposed for the Narmada Valley in the states of Gujarat, Madhya Pradesh, and Maharashtra. The Narmada Valley Development program is an overall master plan building some 30 major and over 130 medium dams to harness the largest west-flowing river on the subcontinent for hydropower and irrigation and regulate seasonal flows.

6/ *This description is based on reports by Bharat Dogra, 1985; C. Diewald, 1988; J. Bandyopadhyay, 1985; and D.W. Levenhagen, 1987.*

Critics charge that the entire project, if implemented, will require the involuntary resettlement of over one million people. One of the first major dams, the Sardar Sarovar, will create a 210 km long reservoir and displace over 67,000 people, many of whom are tribal minorities. The reservoir will inundate over 11,600 hectares, and sizable forest areas will be lost.

Whereas Nehru once hailed dams as "the temples of modern India" because of their contribution to economic development and modernization, many critics are now questioning their economic and social benefits. Environmental effects and related impacts are a major source of this concern. The litany of problems is a familiar one--sedimentation of reservoirs, poor implementation of irrigation, waterlogging and salinization, waterborne diseases, loss of forest areas and cultural historical sites, and resettlement. All of these result in either reduced benefits or increased costs, thereby reducing the economic attractiveness of projects.

The most severe critics see collusion between the vested interests of construction companies, senior officials and politicians as a driving force behind large dam projects. Discussing dam projects in India, one observer states that "between the claims and the performance, there has been a wide gulf. Indeed, in some cases, had the claims not been so exaggerated and the social, ecological, and economic costs so understated, it is doubtful if the dams would ever have been built" (Dogra 1986). Although it is not possible to verify this claim, similar statements have been made about some projects in the US and other countries.

The World Bank and other international funders are caught in the middle of this debate. Dams are social investments and the costs must be justified by the expected benefits. Since these costs and benefits are traditionally measured in monetary terms, the correct and full economic accounting of all costs and benefits, including environmental costs, is essential. The Narmada Valley controversy over resettlement and forestry losses are only one reflection of this.

In response to these concerns, the Bank sponsored a major environmental impact report on the Sardar Sarovar and Narmada Sagar complex (Levenhagen, 1987). This study carefully reviewed the range of physical, social and environmental issues associated with these dams. The consultant also considered the future situation for both project areas with and without the dams.

Although it is not possible to go into all of the details of the study, Levenhagen pointed out both the pros and cons of each project. In particular, he notes the major and continuing degradation of land and water resources in both project areas, largely due to overpopulation and poverty. The projects should help alleviate some of these problems, although they will create others, especially in terms of resettlement. If the second major dam planned, the Narmada Sagar, is built, up to 80,000 people may have to be resettled.

Although the Bank has comprehensive guidelines for involuntary resettlement, implementation must be carried out by national or state governments and this is one of the major concerns of most critics.

A concise description of the Narmada projects, their environmental effects, and the Bank's involvement written by Mr. Christoph Diewald is given in the annex to this report. It is clear that there are major economic benefits from the Narmada project and associated environmental and social concerns.

The Three Gorges Project - China 7/

The proposed Three Gorges Dam on the Yangtze River in central China will be the world's largest dam if it is built. Located 30 km upstream of Yichang, the dam would create a 500 km long reservoir and flood part of the world famous Three Gorges. Designed for hydropower production, flood control, and navigation (but not irrigation), the dam will also have important environmental and social consequences, both upstream (largely due to resettlement) and downstream.

Under consideration for over half a century, the Three Gorges Dam has recently become the focus of considerable international attention. Environmentalists are concerned about its ecological and social impacts, while, at the same time, various countries are assisting China with engineering and design studies connected with the project.

The environmental concerns focus on several main aspects: reservoir flooding and resettlement, changes in sediment flow, loss of scenic areas, health impacts, interference with fish migration, and downstream problems associated with changed water flows. (For a general description of the project and some of the associated environmental concerns, see Boxer, 1988; Wu, 1988; and the 1988 Fall and Winter issues of *Chinese Geography and Environment*).

Initial analyses indicate that resettlement of people displaced by the reservoir is the single largest problem created by the dam. This view is confirmed by a study carried out by a Canadian consortium of Consultants (CYJV Feasibility Report on TGP, Oct. 1988) and vetted by a panel of international experts financed by the World Bank. Land in central China is scarce and finding suitable areas for resettlement will be difficult. The costs for resettlement are also high. There is an obvious connection between dam height, hydropower potential, area of reservoir, and numbers of people resettled. Balancing the benefits and costs associated with various dam heights is thus a major concern.

For example, very early plans called for a dam with an installed capacity of some 25,000 MW. Such a project was estimated to cost about $20 billion and required the resettlement of more than 1.5 million people. Present planning is considering a normal pool level (NPL) 150 to 180 m above sea level that would require resettlement of 540,000 to 1,200,000 people (about 60% urban population, 40% rural). Installed capacity will be from 13,000 to 20,000 MW; projected costs are around $12 to $15 billion. Even the smaller project, however, would be one of the world's major dams with a generating capacity 400 MW larger than the current largest hydroelectric dam, Brazil's Itaipu.

The focus on dam height and resettlement is appropriate given the enormous economic and social costs involved. However, other environmental factors are also important including the following:

Sediment flows. There is debate between dam proponents and opponents on the impact of the dam on water and sediment flows within the river system. Because of its location, the actual capacity of the reservoir will not be very large (the reservoir will be long, narrow, and of medium depth) and the hydro-electric production will essentially be generated on a run-of-river basis. According to the CYJV report, the total storage capacity of the reservoir with a

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7/ *This description is based on reports by B. Boxer, 1988; Cheng Zuemin, 1988; Wu Guoping, 1988; the Chinese Geography and Environment magazine; and CYJV Feasibility Report.*

retention level of 183 m will be 48.1 cu. km. of which 31 cu. km. can be used for flood control; that is 7 to 10% of average annual inflow to the reservoir of 451 cu. km., and less than 5% of the 1000 cu. km. average annual discharge to the estuary. It is expected that when the dam is first closed the reservoir will act as a sediment trap for some time, but then after the system stabilizes a large share of sediment inflow will be passed on downstream.

Aesthetic concerns. The Three Gorges are in a reach where the Yangtze is forced through narrow canyons and is famous for its beauty. Part of this scenic beauty would be lost by the creation of the reservoir.

Endangered species. A number of unique or endangered species are found in the Yangtze itself or in its associated system. These include the Chinese sturgeons, the Siberian crane, and the Yangtze River dolphin. The earlier closure in 1981 of the Gezhouba Dam has already had a negative effect on sturgeons and an artificial breeding program is being implemented to restock the river.

Reservoir fishery. Creation of the reservoir is expected to lead to a change in fish species from those commonly found in fast-flowing water to those favoring slower flowing water. The latter include the commercially important so-called "family fish" like carp, blackcarp, grasscarp, and bighead. Total fish catch is expected to increase.

Health effects. The most important endemic disease in the Three Gorges reservoir area is malaria; Chinese scientists feel that it can be effectively controlled. Schistosomiasis is not a problem in the Three Gorges area.

This brief examination of the main environmental concerns associated with the proposed Three Gorges Project indicates some of the tradeoffs involved in such massive undertakings. Each of the environmental concerns has associated economic costs (and in some cases benefits). Some of these costs and benefits are calculated by comparison with the next best alternative and many of them can be expressed in monetary terms.

Projects of this size pose a special challenge since they represent sucha major investment affecting large areas and very large populations. The skills of a wide range of disciplines are needed to understand and assess the complex interactions created by the project as a whole and by its separate features and mode of operation. We reproduce below the conclusion reached by the World Bank's appointed Panel of Experts (and endorsed by the World Bank) after reviewing the feasibility report prepared by the Canadian consultant:

(a) The Panel of Experts is satisfied that the consultant has fulfilled the terms of reference under which this work was to be carried out. In view of the analysis presented in the CYJV report, it appears that the feasibility of the Three Gorges Project (TGP) has been demonstrated for an NPL 150m or 160m above sea level. The Panel endorses the consultant's recommendation to select the NPL 160m scheme.

(b) The recommended scheme is economically and financially feasible. It would generate annually about 76 billion kilowatt hours of electricity, an output which represents a modest fraction of the demand expected in Central and East China by the turn of the century, when the project would be commissioned. The recommended scheme is more economic than its best alternative which would consist of smaller dams and coal-fired plants. The project cost, to be spread mostly over 15 years, is equivalent to about one year of the financial commitments to be made in the power sector in the early 1990's.

(c) A key advantage of the project lies in the flood protection it would provide to the millions of people located downstream in the flatlands: the quantifiable benefits alone would approach or exceed the cost of human resettlement upstream. No feasible alternative would provide flood control benefits of this magnitude. The recommended scheme would also help navigation on the Yangtze River almost all the way to the city of Chongqing.

(d) The report contains evidence that increasing the NPL from 160m to 170m and higher would not be an economically viable proposition. This would not substantially increase flood control benefits and the incremental cost most likely would exceed the additional economic benefits. Resettlement problems at higher pool levels may become unmanageable.

(e) The report represents a significant advance in the quality of feasibility studies on resettlement and is acceptable at this stage of planning. Nevertheless, there should be no question that the resettlement of more than 700,000 people will be a difficult task under the best of circumstances and that considerable additional work will have to be done if the decision is taken to proceed with the project. Plans must be made for appropriate institutional and financial arrangements for resettlement if the proposed program is to be implemented.

(f) One major *environmental impact* of the project is on the appearance of the rapids and the gorges because in the dry season the recommended scheme would raise the water level of the river by 60 to 90m. Siltation is a problem but can be managed essentially by lowering the reservoir level by 20m and flushing sediments during the flood season. The project has also clear environmental benefits: as it would substitute hydropower for about 20 millions tons of coal, it would greatly alleviate the problem of ash disposal, the emission into the atmosphere of carbon dioxide and sulphur dioxide by 4.5 million tons. It would also reduce the disposal of waste heat into the rivers of central China. The adverse consequences of the project on natural habitat and on rare and endangered species is relatively small because of the high level of human activity along the Yangtze river for centuries. A series of small dams on tributary rivers would have a greater environmental impact. Furthermore, studies confirm that any adverse impact can be mitigated, and with the help of the budget considered in the study a plan for positive environmental protection and enhancement over a broad area is contemplated. However, extensive additional work - paarticularly for the reaches located downstream of the site - would have to be carried out at an early stage if the project is to proceed.

In spite of the generally favorable findings by the Panel of Experts and the large amount of work already done on the TGP, in early 1989 the Chinese government decided to delay any decisions on the project for a number of years. The project is not included in the list of projects prepared by the Ministry of Water Resources for the eighth Five Year Plan period (1991-1995).

Italpu Dam—Brazil/Paraguay [8/]

Itaipu Dam, located on the Parana River which forms the border between Brazil and Paraguay, has the largest installed hydropower capacity in the world--12,600 mw. As part of Brazil's overall program to develop its hydropower resources, Itaipu is the cornerstone of the development of the Parana basin that will have over 41,000 mw of capacity when a number of current projects are completed in the 1990s. This brief description of Itaipu is based on Kohlhepp (1987).

A joint undertaking between Brazil and Paraguay, most of the power generated will serve the rapidly growing Brazilian economy. Paraguay will sell most of its share. Begun in the mid-1970s, work on the dam was completed in 1982 and reservoir filling began. The reservoir is approximately 170 km long and narrow, only 7 km at its widest. It covers 1,460 km2 at high water and 1,350 km2 at normal stage level when it would hold 29 billion m3 of water.

Aside from numerous superlatives due to its size and capacity, Itaipu represents an interesting political and environmental case. The political dimension is due to the dual ownership of the river and the economic might of Brazil compared to Paraguay. This is covered in some detail in Kohlhepp (1988). The environmental dimensions of the project revolve around resettlement issues, compensation payments, and the Brazilian response to these issues.

Loss of forest cover on the Brazilian side is not a concern since the natural forest in the areas to be flooded, as in the rest of the state in general, has been largely destroyed by colonization processes over the past 30 years. One social problem associated with the dam was the compulsory purchase of flooded land and associated resettlement of some 8,000 families. Problems arose with ascertaining ownership and establishing appropriate compensation rates.

Environmental effects of the project included climatic effects, hydrological consequences, seismic problems, impacts on the aquatic and terrestrial ecosystem, and health problems. Although hampered by lack of long-term observations and data for the "pre-Itaipu period," most of the environmental concerns have been handled by the project.

Two innovative programs implemented by the Itaipu authorities are the "Mymba Kuera" and "Gralha Azul" projects. The former program attempted to minimize the effects of reservoir flooding on the fauna of the region by catching animals and releasing them in biological reserves. The "Gralha Azul" project is designed to create and afforest a protective zone around the reservoir on the Brazilian side. This project has had numerous implementation delays but represents an attempt to partially protect the reservoir from sedimentation and water contamination.

Other environmental concerns discussed by Kohlhepp include aquatic weeds and their control, affects on fish populations, and sediment flows and the impact of development of agriculture and other water control structures in the upper watershed. Health problems, including water quality and water-borne diseases as well as vector-borne diseases such as malaria and schistosomiasis, are all major concerns.

8/ This description is based on a report by G. Kohlhepp, 1987.

In sum, Itaipu has many of the social and environmental concerns associated with any major dam and reservoir project. Given the previously disturbed nature of the reservoir site, environmental concerns focus more on health, seismicity, and sedimentation than on loss of natural ecosystems. Environmental benefits from tourism and fishery development are expected from the project.

The Nam Choan Dam - Thailand [9/]

The Nam Choan Dam, a $400 million project first proposed in 1982 for the Kwae Yai River in western Thailand, has been the topic of heated national and international debate. Located in the Thung Yai Wildlife Sanctuary, opposition focussed on the destructive impact of dam and reservoir construction. Resettlement is not a major issue in this remote and sparsely settled site. Along with the contiguous Huai Kha Khaeng Wildlife Sanctuary, these two sanctuaries cover an area of 5,800 km2, and are the largest remaining relatively undisturbed forest areas in Thailand. They are also home to numerous rare or endangered animal species.

Designed for hydropower generation, the Nam Choan Dam would have supplied 580 MW or about 1-2 percent of Thailand's energy needs. Opposition to the dam, as reported in the Thai and international press, has focussed on two major points: (1) Thailand did not need to construct the dam to meet its energy needs. Other energy sources are available (including lignite and natural gas) and taking energy conservation measures would be cheaper than building new generating capacity; (2) Construction of the dam would open up both sanctuaries to illegal settlement, timber poaching and other harmful uses. In a country where a large part of the forest lands have been lost in the past 30 years, this is a major concern. Regulations have been largely ineffective in preventing encroachment and conversion of "protected" areas.

The debate over the dam resulted in the government setting up a special committee, chaired by the Deputy Prime Minister, to investigate the controversy. Various working groups reviewed the earlier studies and conducted their own analyses. This review was completed in early 1988 and resulted with the project being delayed indefinitely--in effect cancelled.

In a 1987 publication, *Consider the Costs: A Position Paper on the Nam Choan Dam*, Wildlife Fund Thailand presented a variety of arguments as to why the dam should not be built. The paper ended with a list of 24 reasons for stopping the project including the following:

- o loss of rich forest land;
- o violation of Thai wildlife laws;
- o threat to wildlife;
- o local opposition;
- o loss of a unique ecosystem;

9/ This description is based on a report by the Wildlife Fund, Thailand, 1987 and various issues of the Bangkok Post and the Nation, two English language Bangkok newspapers.

- o inadequate EIA;
- o other alternatives are available;
- o risk of landslides, earthquakes, and dam failure;
- o loss of archeological sites;
- o reduced fish yields;
- o decreased tourism potential.

Whether or not all of these points are valid is not the issue here. The fact is that public concerns about a major development project were strong enough to create a national debate over the dam and its location. In some ways, Nam Choan became a symbol (irregardless of its merits) of a common pattern of siting major facilities without proper concern for possible resource or environmental impacts and public involvement.

Press reports focussed on the threat of encroachment into a wildlife sanctuary and the fact that alternative energy sources were available. EGAT, the Electricity Generating Authority of Thailand, estimated that smaller substitute projects would cost 20 percent more to supply the same amount of electricity. It is unclear whether EGAT's cost estimates for Nam Choan had taken any environmental costs into account. If these had been considered, the opportunity cost of not using the Nam Choan site might have been substantially reduced.

The Nam Choan case illustrates the potential for major public controversy over locations for new dams. A fuller economic analysis of the resource and environmental costs of the Nam Choan site might have led EGAT to consider alternative power sources earlier. Alternatively, the government could consider the opportunity cost of using alternative energy sources and weigh this cost against the unquantified benefits of protecting a unique ecosystem.

Concluding Comments

The examples given could be repeated for a number of other major dam projects in other areas. The environmental and social concerns are similar--resettlement of large numbers of people, destruction of forests and unique habitats, and health and hydrologic problems associated with water impoundment.

To the critics, almost all large dams are bad. To those promoting the projects, the hydropower, irrigation, and flood control benefits justify the investment. As illustrated by the cases of Tarbela, the Aswan High Dam, the Three Gorges, Itaipu, Nam Choan and Narmada, there are legitimate points on both sides. There are major benefits, just as there are major costs. A careful examination of all benefits and costs is required, one that includes direct project outputs as well as environmental and social costs. In the final analysis, there may well be some dams that cannot be justified economically once all costs are considered. These projects should not be built. In most cases, however, the analysis will identify the likely environmental and social costs and permit proper mitigative measures to be taken, and still produce economic benefits that exceed total economic costs.

Just as environmental assessments must be done early in the planning process, public involvement is also crucial to smooth project formulation. The cancellation of the Nam Choan Dam and the continuing problems with the Narmada projects illustrate the growing role played by individuals, public groups, and the press, both domestically and internationally, in the decision-making process for large dam projects.

CHAPTER 6: THE WORLD BANK'S RESPONSE

This report has outlined some of the main environmental and economic dimensions of large storage dam projects. Chapter 2 reviewed the history of the Bank's environmental attention to dam projects during the past 15 or more years. As is clear from the discussion there and in the other chapters, much has been learned about likely environmental and social problems and the Bank is responding to these challenges. For a discussion of recent developments in the Bank's thinking on dam and water resources projects, see Olivares (1986) and Schuh, et al (1988).

It is clear that dams provide major social benefits and will continue to be built. The challenge is do these projects in a way that maximizes net social benefits.

A number of lessons can be learned from the Bank's experience: that effective economic development requires paying adequate and systematic attention to environmental factors, including sound management of natural resources; that it is possible to prevent or greatly reduce environmental damage at a cost which is financially acceptable to borrowers; that measures to assure environmental protection can often be shown to have economic benefits that exceed their economic costs, and that even in cases where it is not practical to quantify them, these benefits, especially the avoidance of irreversible effects, may justify the cost of protection; and that preventive measures provide more effective and substantially less costly protection than later remedial measures.

The scope of the Bank's environmental concerns is very broad, potentially including all the factors which may affect the natural and social conditions surrounding humans and other living things. The environmental concerns of the Bank are also long term, taking into account both present and future generations. The Bank recognizes that some environmental effects may require many years before they become evident. Consequently, Bank policy requires consideration of the environmental aspects of projects in a longer time frame (i.e., decades and longer) than is the case for most other projects. Since considerable uncertainty exists about the magnitudes of some long-term effects, the Bank emphasizes the importance of prudence when assessing environmental impacts, especially when these are potentially irreversible, as in the case of extinction of species or conversion of ecosystems.

Recognizing the great differences between its member countries, the Bank has not adopted general environmental standards. Instead, it deals with each project individually from an environmental point of view, with due respect to its total setting and the ability of the authorities concerned to manage the environment.

In terms of dam projects, the Bank's policy is to integrate environmental aspects totally into the project itself; the Bank's procedures for incorporating environmental considerations into the project cycle were described in Chapter 2. The Bank has issued a new Operational Directive in March 1989 on environmental aspects of dams and reservoirs. This comprehensive and detailed new policy lays down procedures designed to ensure that all environmental aspects of such projects become routinely and systematically integrated into project design and operation. The policy specifies categories of environmental effects to be addressed, the area of influence to be considered, and suggested terms of reference for consultants and contractors.

Additional Policies And Procedures

In addition to the Bank's general environmental policies discussed above, the Bank has adopted other specific policies on several major environmentally-linked factors associated with dam projects. These include involuntary resettlement of people, tribal people, cultural property, wildlands, dam safety, pesticides, and health aspects of pesticide use. Several of these are discussed below.

Involuntary resettlement. The Bank's general policy is that involuntary resettlement should be avoided or minimized and alternative solutions must be explored. When a development project requires that people be relocated, it is the Bank's intention to help ensure that the productive base and income-earning ability of those affected are improved, so that they share the benefits of the new development and are compensated for transitional hardships. The displaced people should regain at least their previous standard of living and, at the relocation site, they should be assisted to become socially and economically integrated into the host communities.

The responsibility for relocating the affected group rests with the government, but the Bank assists the responsible agency to ensure that an appropriate course of action is followed. The costs of resettlement must be included in the economic and financial analyses of the project. As far as possible, the Bank encourages government policies that permit families to choose their future from a number of acceptable alternatives, and to assist them to rebuild their lives through their own efforts.

The general problems of handling involuntary resettlement in development projects is addressed in detail in a recent World Bank Technical Paper (Cernea, 1988). This document contains policy guidelines as well as analytical and planning tools for preparing projects involving involuntary resettlement.

Tribal people. The Bank's policy on involuntary resettlement is complemented by a separate policy where tribal people are involved (World Bank, 1982). The Bank will not assist development projects that knowingly encroach on traditional territories being used or occupied by tribal people without provision of adequate safeguards. The Bank must also be satisfied that relevant government agencies can implement measures to effectively protect their integrity and well-being.

From the national and tribal peoples' viewpoint, extreme measures that perpetuate isolation from the national society and important social services, and measures that promote forced acculturation are to be avoided. The Bank will not assist with a project if it appears that tribal people have been forcibly dispossessed and cleared from the area without being given culturally and economically viable alternatives.

Cultural property. One area of concern with certain dam projects is the inundation or associated loss of cultural properties. Cultural property includes sites having archeological (prehistoric), paleontological, historical, religious, and unique natural values.

The World Bank's general policy is to assist in the preservation of cultural properties and to seek to avoid their loss in any project in which the Bank is involved, regardless of whether the Bank is itself funding the part of the project that may affect the property.

The Bank normally will not finance projects that will significantly damage non-replicable cultural property and will assist only those projects that are sited or designed so as to prevent such damage.

The Bank will assist in the protection and enhancement of cultural properties encountered in Bank-financed projects, rather than leaving that protection to chance. Deviation from this policy may be justified only where expected project benefits are great and the loss of or damage to cultural property is judged by competent authorities to be unavoidable, minor, or otherwise acceptable. Guidelines for the management of cultural properties are found in World Bank Technical Paper No. 62 (Goodland and Webb, 1987).

Wildlands. Wildlands are specific natural land and water areas in a state virtually unmodified by human activity. While further conversion of some natural land and water areas to more intensive uses (e.g., through clearing, inundation, and conversion) will be necessary to meet development objectives, other pristine areas may yield more benefits to present and future generations if maintained in their natural state. These areas provide important environmental services or essential habitat for endangered species or tribal peoples. The Bank's objective, therefore, is to seek a balance between preserving the environmental values of the world's more important remaining wildlands, and converting some of them to more intensive, immediate human uses (Ledec and Goodland, 1988).

The Bank will normally decline to finance projects involving wildlands of special concern, i.e., areas which are recognized to be exceptionally important in conserving biological diversity or perpetuating services. These areas may be identified and officially designated by national governments or by national and/or international scientific communities. Even where wildlands other than those of special concern are involved, the Bank prefers to site projects on already converted lands. Deviations from this policy must be specifically justified.

Where conversion of wildlands is justified, less valuable wildlands should be converted rather than more valuable ones. The wildland loss must be compensated for by including a wildland management component in the project that directly supports preservation of an ecologically similar area.

A Look To The Future

The future outlook for dam projects presents an interesting dichotomy. On the one hand population and economic growth both increase the demands for the goods and services produced by dams--hydropower, water for irrigation, industries and domestic use, and flood control. On the other hand, greater population densities and larger in-place investments make the siting of new dams and their associated reservoirs and infrastructure more difficult. Fewer easily developed sites are available and the problems (and costs) associated with resettlement increase rapidly.

The World Bank's response to these conditions poses a major challenge. Increased outside attention to all aspects of dam siting, design, construction and project implementation necessitate pro-active, rather than merely reactive planning. Many of the decisions made on projects will result in certain environmental, social and economic costs. The goal, however, is to minimize these costs and still provide the benefits for which dams are built.

We conclude this report with the final paragraph from a recent paper on the social and environmental impacts of dams prepared by four senior Bank staff (Schuh, Le Moigne, Cernea, and Goodland, 1988). This statement of guarded optimism notes that progress has been made but that further improvements in procedures are needed:

> "The challenge is large and the Bank has developed new policies to meet environmental as well as social and economic goals. But most projects up to

now score only average in operating practice and in the implementation of new or established policies with respect to the environment. There is, therefore, much scope for improvement before project performance in these areas become satisfactory. The Bank believes that procedures for that social and environmental protection are available, affordable, feasible, and tested and that their implementation can prevent damage and mitigate many socio-cultural and environmental costs. It is necessary, however, to have the political will and socio-technical expertise to insist on environmental prudence and the willingness to pay the necessary costs."

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ANNEX

INDIA: NARMADA PROJECTS

The Narmada River And Its Valley

The Narmada River is the largest west-flowing river of India. It rises in the highlands of eastern Madhya Pradesh and flows for 1,312 km, mostly in a narrow valley, to the Bay of Cambay, draining a basin of about 98,800 km^2. In its course, the river drops from an elevation of 1,051 m to sea level. The riparian states are Madhya Pradesh (MP), Gujarat and Maharashtra, in the order of their shares in basin territory.

The major urban and industrial centers of the basin are the cities of Jabalpur and Hoshangabad in MP, and Bharuch in Gujarat. The cities of Indore in MP and Baroda (Vadodara) in Gujarat are located just outside the basin boundaries, but are the dominant growth centers influencing the valley economy and likely to benefit from its development.

More than 90% of the river's average annual flow of about 41,000 million m^3 occurs during the monsoon season (June through September), so that effective use of its water resources can only be achieved through storage of the flows in reservoirs.

Narmada River Development

Plans for harnessing the river for irrigation and power generation had been drawn up beginning in 1948. However, the water resources of the Narmada River have so far remained largely undeveloped, mainly due to inter-state water disputes which protracted for over 30 years until they were finally resolved by the Narmada Water Disputes Tribunal in 1979. The Tribunal allocated water shares to the three riparian states, MP (65%), Gujarat (32%), Rajasthan (2%) and Maharashtra (1%). The main purposes of water resource development are, in the order of priority (but not in terms of volume of water use), the provision of drinking water, industrial water supply, irrigation and power generation.

The Narmada River Development, a multi-state program to be undertaken over a period of some fifty years, would ultimately comprise some thirty major and many more medium and minor water projects in the basin.

All the waters will not be used inside the basin. MP is planning diversions into the Son-Tons basin and into the Malva Plateau areas to the north. Gujarat is implementing a major project (Sardar Sarovar Project, see below) which would divert not only most of Gujarat's water share into the north-central Gujarat plains and the Saurashtra and Kutch peninsulae, but also Rajasthan's share.

Salient Features of Narmada Basin Development (Tentative)

	IRRIGATION		BENEFICIARIES		POWER	
	CCA a (m ha)	Annual Irrigation (M ha)	Farm Families (M)	Rural Pop (M)	Installed Capacity (MW)	Annual Production b (10^6 KWh)
MP	2.8	3.1	0.8	6.0	2,050	4,100
Gujarat	1.9	2.0	0.4	4.5	1,450	3,500
Rajasthan	<0.1	<0.1	<0.1	0.2	-	-
Maharashtra	<0.1	<0.1	<0.1	0.1	-	-
Total	4.8	5.2	1.2	10.8	3,500	7,000

a/ Cultivable command area.
b/ At a 25% plant load factor (in the early years of development)

The program is not, at this moment, a fully planned sequence of projects coordinated by a single agency; it rather consists of the indicative master plan of MP for a series of projects in MP and the ongoing Sardar Sarovar Project in Gujarat. A few major projects in the basin have been completed or are in progress (without World Bank assistance). A schematic representation of the planned projects along the main river is given in Figure 1.

The creation of large storage facilities is considered a *sine-qua-non* for harnessing the river's flows. The Tribunal ruled on the "full reservoir levels" for the two most important storage facilities in the basin, the **Narmada Sagar** [10]/ dam in MP (end of middle basin) and the **Sardar Sarovar** dam, downstream of Narmada Sagar in Gujarat state and at the lower end of the basin. Either dam would be a key part of a **multi-purpose** water resource development project. The Narmada Sagar dam would be the centerpiece of the **Narmada Sagar Complex** of irrigation and power facilities in the lower river basin in MP, which would consist ultimately of three hydropower plants (Narmada Sagar, Omkareshwar and Maheshwar) and two major irrigation schemes (Narmada Sagar and Omkareshwar) with a total command area of some 300,000 ha. The Sardar Sarovar reservoir, located in MP, Maharashtra and Gujarat states, will regulate river flows to provide Gujarat and Rajasthan with their allocated shares, but it will not be sufficient to do so. Thus Gujarat must rely on regulated water releases from the proposed Narmada Sagar dam upstream, which, according to the Tribunal, must be completed no later than Sardar Sarovar dam. Some works on Sardar Sarovar Project started in the early eighties, but construction took off on a large scale only in 1987, after the Government of India had given its environmental clearance to both the Sardar Sarovar Project (SSP) and Narmada Sagar Project (NSP). The government of MP intends to start works for the NSP as soon as possible. [11]/.

10/ Now called Indira Sagar dam by the Government of Madhya Pradesh. The earlier name is being retained in this note.

11/ Works on a river diversion tunnel and some preliminary excavations have already started.

World Bank Involvement

Sardar Sarovar Project

The World Bank is supporting at this time only the multi-purpose Sardar Sarovar Project in the state of Gujarat. The project consists of a large concrete dam, a 1,200 MW underground riverbed powerhouse, a 250 MW canalhead powerhouse, a regulation weir downstream of Sardar Sarovar at Garudeshwar (for pumpback operation) , transmission lines, a water conveyance system including the Narmada main canal (450 km) to the Rajasthan border, branch and distributary canals to transport municipal and industrial water supplies as well as irrigation water, a water delivery and drainage network to serve an irrigation command area of about 1.9 million ha, groundwater development (both for augmenting surface water supplies and for drainage of excess groundwater) and command area development works such as field supply and drainage channels, land levelling, and rural roads. The project also includes a hydro-meteorological network covering the whole Narmada basin, seismic monitoring stations, and the establishment of an effective organization for operation and maintenance of project facilities.

Narmada Sagar Project

The Bank has been requested by the Government of India to fund the multipurpose Narmada Sagar Project in MP. The project in its entirety would encompass a large concrete dam across the Narmada river in the Khandwa district of MP, creating a reservoir with a surface of 913 km^2 and a gross storage volume of about 12,000 million m^3, a 1,000 MW powerhouse, transmission line to Indore, and an irrigation and drainage scheme with a command area of about 141,000 ha. The Narmada Sagar reservoir would provide regulation of river flows not only for the Narmada Sagar Project itself, but also for the future Omkareshwar multipurpose project located just downstream of NS dam and the Maheshwar power project located between Omkareshwar and Sardar Sarovar reservoir, as well as for the Sardar Sarovar Project. The creation of Narmada Sagar reservoir would necessitate the resettlement and rehabilitation of some 95,000 people. 12/ Construction of a diversion tunnel and some preliminary excavation works have started, but award of major contracts for dam and powerhouse may await the finalization of loan arrangements with the Bank.

The development of the entire Narmada valley water resources has been talked about for the last 40 years, and it will take another 50 years or so to complete it. The Bank has taken note of MP's Master Plan for basin development, but has not endorsed it in any way.

Benefits

Water For People And Livestock

The recent disastrous droughts in many parts of India have demonstrated once again the vulnerability of humans and livestock to the vagaries of the monsoon. The proportion of water to be released from reservoirs for drinking water and industrial uses may be small, but

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12/ More exact figures for people who (a) will have to move entirely; (b) will have to move their houseplots within village boundaries but do not lose any agricultural land; and (c) will not have to move but will lose a minor part of their land to the reservoir, are currently being reassessed on the basis of detailed surveys. People falling under the first category will number approximately 80,000.

it is extremely important nevertheless. Population growth may be reduced in the future, but even so the sheer number of additional consumers over the next 20 to 50 years will require substantial additions to water supply. This must be planned for now. Where is such water to come from? Ground water aquifers are limited without additional percolation from surface water imports (from irrigation), and are nearing the limits of economical exploitation in some areas in Gujarat. It is difficult to conceive of a scenario in which India can afford to let the waters of a major river such as the Narmada run wasted to the sea over the medium or long term, whether such waters would otherwise be used for irrigation or for village, municipal and industrial water consumers. Certainly, providing for drinking and industrial water alone may not justify dams as large as those planned now. But one may expect that the use of Narmada waters for these purposes will become increasingly important over time, possibly exceeding what planners are now setting aside for these uses.

Irrigation And Its Beneficiaries

Taken together, the two projects will make possible the irrigation of some 2.2[12] million ha of land in MP and Gujarat, and another 70,000 ha in the state of Rajasthan. (The Narmada Sagar Project will **directly** irrigate only some 141,000 ha, but it will make possible irrigation of vastly larger areas downstream, in the proposed Omkareshwar Project and in the Sardar Sarovar command, through water stored in its reservoir.[13]) The majority of these lands are chronically drought prone, as was borne out by the third consecutive year of disastrous drought that hit these in 1987/88.

The number of people now cultivating the land to be irrigated are estimated at some 4.5 to 5.0 million. They are by no means all rich; many of them are desperately poor. This compares to some 170,000 people that will be affected by submergence.

The two Narmada projects are the first irrigation projects in India for which detailed **criteria and rules of operation** have been defined at the planning stage, covering matters such as the type and extent of services to be delivered by the operating agency to the users, both in terms of irrigation **and** drainage, definition of service areas, responsibilities of agency and users, emergency operating rules, and arrangements for operation and maintenance. The actual designs of the irrigation and drainage systems will reflect these rules and criteria. An important feature of these rules is that water will be **delivered to users in strict proportion to cultivable area owned** within the irrigation command, and that deliveries to individual fields will be **rotated** within a "chak" area (20-60 ha block) by the users themselves in accordance with a **set time schedule**. This rationing principle is already being followed with substantial success in northwest India. It amounts to equitable and reliable distribution of water among users, which is scarce in relation to irrigable land.

Power Generation

Both Narmada projects will produce electric power. This power will boost the **peaking** capacity of the Western Region power grid. It is important to understand the intended role of power plants within a system. The demand of power consumers is very unevenly distributed over time: demand may be maximum for a few hours during a day, but much less during other times. A power system must be able to supply that peak demand; at other times it will by necessity run

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13/ *Comparisons have been made between the size of the submergence area of Narmada Sagar (913 km2) versus the size of the Narmada Sagar irrigation command (1410 km2), resulting in a high ratio of 0.64. Such comparison is not meaningful for a multipurpose project.*

at less than capacity. Certain plants will always supply the "base load"; these are usually thermal plants which cannot be flexibly switched on and off. Other plants are designed to serve additional loads during a day, and a few will serve the peak loads. Peaking power is most economically provided by hydro plants (and very short "needle" peaks by gas turbines). During the wet season, when reservoirs are full and spilling, hydro plants can be operated around the clock and thus can serve the "base load" for a few weeks; during such time, base load thermal plants can be taken out of service for maintenance.

Generation at the Sardar Sarovar riverbed powerhouse will gradually diminish as consumptive use of river waters in the basin increases, but since the plant is designed for pump storage operation [14/], it will be able to maintain a certain level of peaking capacity throughout the plant's life. Generation at Narmada Sagar will also decrease over time, but not as much as at Sardar Sarovar, because regulated releases will have to be made to Sardar Sarovar indefinitely, and these releases will always be used to generate power at Narmada Sagar. No pump storage is provided for at Narmada Sagar.

Electric power, and particularly peaking power, is an extremely scarce and unreliable commodity in India. True, power is consumed more by urban households than by the rural poor. But it is also consumed, and to a much larger extent, by industry and by modern agriculture. Power shortages have hampered industrial production and employment in India substantially, and continue to do so. There are places in India where farmers get only one hour of power supply a day to run their pumpsets for irrigation. Industry and irrigated agriculture employ many people, and again, few of those are "rich". India cannot rely on rainfed agriculture alone to provide employment to its ever growing labor force. It must develop its industries for this purpose also; and power is a very essential ingredient for this. From an environmental point of view, there are few sources of energy cleaner than hydropower.

Flood Moderation

All major reservoirs in the valley that are currently envisaged will, taken together, regulate less than 50% of the mean annual river flow. This is a rather low degree of regulation, and reflects the extreme concentration of river flows over a four month period in any year typical for India's monsoon climate. It will allow only very limited carry-over storage of river waters from one year to the next, and little flood moderation. No reservoir space has been allocated to flood moderation in the Sardar Sarovar and Narmada Sagar Projects, although there is always a cushion between the normal "full reservoir level" and the "maximum water level" allowed during floods.

Flood moderation is thus not a major objective of the Narmada projects. However, careful operation of reservoirs in combination with a state-of-the-art flood forecasting system, can and will produce some significant mitigation of flood flows, for example, if reservoir levels are lowered in anticipation of a flood.

The spillways for the two dams are designed to pass the so called "probable maximum flood", which is a hypothetical flood event based on an unfavorable combination of the worst

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14/ Water is pumped back at night with cheap surplus energy from thermal plants, and released for generation of high value peak power during the day. The Garudeshwar weir below Sardar Sarovar dam is designed to create a small reservoir (pool) for pump storage.

storms observed in the region. Sophisticated models have been used to simulate such worst case scenario.

Concerns

The Bank is fully aware of the consequences, in terms of resettlement of people and impact on the natural environment that these projects may have. In the case of the Sardar Sarovar Project, much of the Bank's dialogue with the Borrower (India) and the executing state governments (Gujarat, MP and Maharashtra) was, and remains, focused on such consequences. Appropriate provisions have been incorporated into Bank agreements with central and state government authorities, and during Bank reviews of project progress - which typically occur at least twice a year - Bank staff dedicates considerable time and effort to ensuring that such provisions are implemented.

The Government of India and the concerned states have recognized the need for a basin-wide environmental management plan, and are putting into place institutional arrangements to address this need and to coordinate activities (through the Narmada Control Authority, as reconstituted in 1987). The Bank fully supports this endeavor and maintains a dialogue with the authorities in this regard.

It has been argued that large dam projects such as these increase the gap between rich and poor in a country and that the poorest sections of the population bear all the costs while the rich get the benefits. This need not be so. Large dam projects, **if carefully planned, designed and implemented, can** have substantial benefits for poorer economies and for their people, in terms of drinking water, water for irrigation, electric power, flood control, and fisheries. There is no reason why this careful planning and implementation should not be possible if proper institutional and managerial arrangements are in place. The Bank believes that these dams are essential means to support future economic growth of the country, without which there are scant chances to reduce poverty substantially.

Resettlement

The Bank requires that involuntary displacement is subject to a comprehensive, detailed and feasible plan for resettlement and rehabilitation of the displaced population before it gives its approval for a loan, and the necessity of restoring or even improving displaced people's livelihood is gradually becoming an integral part of the states' policies for resettlement and rehabilitation.

The Narmada projects that the Bank is or considers supporting will not adversely affect the livelihood of one million people, as has been stated by some; this figure relates probably to the long-term basin development program; even then, it appears too high an estimate (in terms of today's population). In the case of the Sardar Sarovar Project, some 70,000 people will be affected, but not all of them will have to move. Many will be able to shift just their house site, often within the confines of the village where they live now. In the case of the proposed Narmada Sagar Project, it is expected that some 95,000 people will be affected, but again, not all of them in a drastic way. Some 80,000 may actually have to move away. 15/ The Bank will make sure, in working with the concerned state governments, that a satisfactory alternative livelihood will be provided to the displaced persons, preferably one based on agricultural land and equal to or better than before resettlement.

15/ This number is currently being reassessed on the basis of more detailed village and family surveys.

Small Scale Alternatives

It has been proposed that in order to satisfy the needs for drinking water and irrigation, many smaller projects should be set up rather than a few very large reservoirs. If one stipulates that all the small reservoirs together should have the same storage capacity as the few large ones, then the "small scale" alternative will submerge vastly more land than the "large dam" alternative. The ratio of storage volume to area submerged becomes more favorable, the larger the reservoirs.

The full reservoir levels of Sardar Sarovar and Narmada Sagar have been set by the Tribunal. They are related to the water allocations to the Sardar Sarovar party states; both reservoirs are needed, at the stipulated full reservoir level, to be able to serve Gujarat and Rajasthan with their allocated shares. The Tribunal had examined the merits of an alternative to the high-level Sardar Sarovar dam, involving three smaller reservoirs, a low level Sardar Sarovar, plus Jalsindhi and Harinphal reservoirs upstream. It came to the conclusion that a high-level Sardar Sarovar, without Jalsindhi and Harinphal, would be the preferable alternative.

Forests

The projects that Bank supports or may support will not flood 200,000 ha of cultivated land, or 350,000 ha of forests, as has been stated by some critics. Taken together, the two projects mentioned above will flood some 43,000 ha of cultivated land, and some 51,000 ha of forest land, much of it already denuded. In the case of Narmada Sagar, 40,332 ha of forest land would be submerged. Of this, 10,996 ha are only nominally forest land and have no trees (riverbeds, roads, natural blanks, encroachments, cultivated land in forest villages, revenue forests, etc.). Of the remaining 29,336 ha, at most two-thirds, say 20,000 ha, are under actual teak or mixed forest, the rest is severely degraded or denuded. Virtually all of the 11,000 ha of forest land to be submerged by Sardar Sarovar is severely degraded or denuded.

The Bank shares the concerns about deforestation. Flooding forest lands certainly adds to the problem, but one should note that it is not the most important factor contributing to the disappearance of tree cover in India. Forests are being damaged or cleared, mainly illegally, for a variety of other reasons, including the need of a growing population for fuelwood and fodder for cattle, as well as industrial needs (timber and pulp). Given the ongoing trend of forest destruction, the forests of the Narmada valley may not have too many years to survive unless urgent remedial action is taken which addresses the **major causes** of deforestation and land degradation. Under the proposed Narmada Sagar Project, the Bank would support efforts designed to help reverse the trend of ongoing environmental degradation.

The Government of India made it one of the conditions of its environmental clearance of the projects in April 1987 that the states concerned commit to afforestation elsewhere, as compensation for the forest loss, in an equivalent area to that submerged, or in an area **twice as large** if this afforestation is to be done on denuded or degraded forest land. The Government of India is closely monitoring the states' afforestation measures, and the Bank stands ready to support these financially, if the replanting is done in a way that ensures the sustainability of the forests, and if it benefits the local population directly. In the case of the Narmada Sagar Project, the government of MP plans to do the compensatory tree planting in the immediate impact area (watershed) of the reservoir, where also much of the priority watersheds for soil conservation measures are located.

Sedimentation

Sedimentation of reservoirs is a serious concern. However, it is not a phenomenon that large dams are causing, it is one that affects their useful life. It is well known that soil erosion in India (and elsewhere) is serious and on the increase, due to many factors, but mainly due to deforestation and degradation of pasture and crop lands. The Narmada valley is no exception to this. While the discussion of erosion and siltation in the context of large dams is useful, it contributes little to the debate of pros and cons of large dams. Soil erosion, deforestation, land degradation, etc. are issues that must be addressed urgently, **whether large dams are to be built or not**, as they affect the productivity of land and the stability of the environment in general. In economic and environmental terms, the future siltation of reservoirs is an important concern, but secondary to the ongoing deterioration of land resources.

Government of India has stipulated that the concerned state governments have to implement a catchment protection program to reduce siltation that would shorten the useful life of the reservoirs. The Bank fully endorses this requirement, but considers this even more important as a measure to conserve or restore the agricultural and silvicultural productivity of basin lands. In the case of Narmada Sagar, the proposed Area Development Project would support, *inter alia,* a watershed management program covering some 300,000 ha [16/], in which innovative, low-cost and durable *in-situ* soil and moisture conservation measures would be introduced. Extensive and detailed survey and mapping activities have been started some years ago to define areas of priority concern and to define the appropriate treatment and management of such areas. Plans for a similar program for Sardar Sarovar watershed are being prepared.

Waterlogging

A rise of the groundwater table into the root zone of crops is called waterlogging. It has a detrimental effect on crop yields and often leads to (secondary) soil salinization. Waterlogging is a consequence of insufficient drainage and is often caused by deep percolation of surface irrigation water after a number of years. Losses of surface irrigation water to the groundwater are unavoidable to a degree; proper field irrigation techniques can, however, reduce them to a minimum. Moreover, such losses can be recovered in large part through pumping of groundwater **(recycling)**, which has the added benefit of keeping the groundwater table from rising to hazardous levels. **Conjunctive use** of surface and groundwater for irrigation is an effective means not only to increase the overall efficiency of water use, but also to provide sufficient (vertical) sub-surface drainage. Where such conjunctive use is not possible (e.g., because of saline groundwater), pumping and dumping of groundwater may still be possible. In other cases, other (horizontal) drainage arrangements will have to be chosen.

The Bank is well aware of the ever-present potential of water logging from surface irrigation and insists on proper studies of the likely response of groundwater aquifers to irrigation and on **proper groundwater monitoring and drainage arrangements.**

Some areas in the Narmada basin are quite susceptible to waterlogging, particularly the deep black cotton soils of the middle basin (Bargi and Tawa command areas). The command area of the Sardar Sarovar Project (up to the Mahi river) also may become waterlogged without proper drainage.

16/ Part of a larger program to treat high priority areas in the catchment between Narmada Sagar and Bargi dams, estimated to extend to some 800,000 ha ultimately.

For both the Sardar Sarovar 17/ and the Narmada Sagar/Omkareshwar command areas, groundwater and drainage modelling studies were carried out. These studies gave indications as to how and under what conditions water logging may result from the planned surface water irrigation. Criteria and rules of operation for these schemes were formulated that oblige the operating agencies to monitor the behavior of the groundwater table over the entire areas, and to intervene with appropriate drainage arrangements before hazardous groundwater levels might be reached. In addition, both schemes incorporate in their plans conjunctive use of surface and groundwater as a preventive measure. In the case of Narmada Sagar, an appropriate mix of surface and groundwater for irrigation has been planned: 30% of total water applications will have to come from groundwater. 18/ The concerned agencies will rely on **private groundwater development** first, and will only intervene with public groundwater development or other special drainage measures if and when private development turns out to be insufficient. This is a reasonable expectation as surface water will be more limited than the extent of the irrigable areas and as surface water will not be available year round for perennial crops. Farmers will have an incentive to build wells even with surface irrigation available to them, as borne out by experience in existing irrigation schemes.

Wildlife

In the areas to be inundated many rare species of plant and animal life are found. From past surveys, there is no indication that any species unique to the submergence areas would be lost; species may be rare, even endangered, but they are not unique. Nevertheless, efforts must be made to salvage whatever can be saved. More detailed surveys are in progress for Narmada Sagar , and a comprehensive study has been commissioned to provide not only an inventory of what is there, but also to come up with feasible plans how to evacuate wildlife to adjacent areas. Such studies are currently delayed with regard to Sardar Sarovar, and the Bank has taken this up with the concerned authorities.

Water-Borne Diseases

There is a concern regarding water-related diseases. The Bank is concerned with the potential threat of Schistosomiasis (Bilharzia), the presence of which in India has only been confirmed in a small village in Maharashtra state, but which could at some time become a real danger if not monitored carefully. The Bank has mounted, in collaboration with the Government of India and the World Health Organization, a survey of samples of the population and of water bodies in the Narmada valley to determine whether the disease was present either in humans or in the snails that are hosts of the schistosomes. The results were negative. There are, of course, concerns regarding Malaria, which is definitely present in the valley and elsewhere in India. The Bank rests assured that this is indeed very much an ongoing concern of the Indian health administration. The Narmada dam projects have no special design or operating characteristics to prevent Malaria from arising out of water stored in reservoirs. A feasible technology for preventing this effectively is really not available. (Frequent fluctuations of the reservoir or spreading of a special film over the water surface have been mentioned, but are not considered feasible). The irrigation systems to be built, however, will incorporate concrete lining of all canals and channels, and are thus designed in part to minimize the hazards of stagnant water and

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17/ For the area between Narmada and Mahi rivers in Gujarat. Further studies are required for the remainder of the command area.

18/ 30:70 is the mix at the field level; the corresponding mix at the source (canal intake and pumps) would be 20:80.

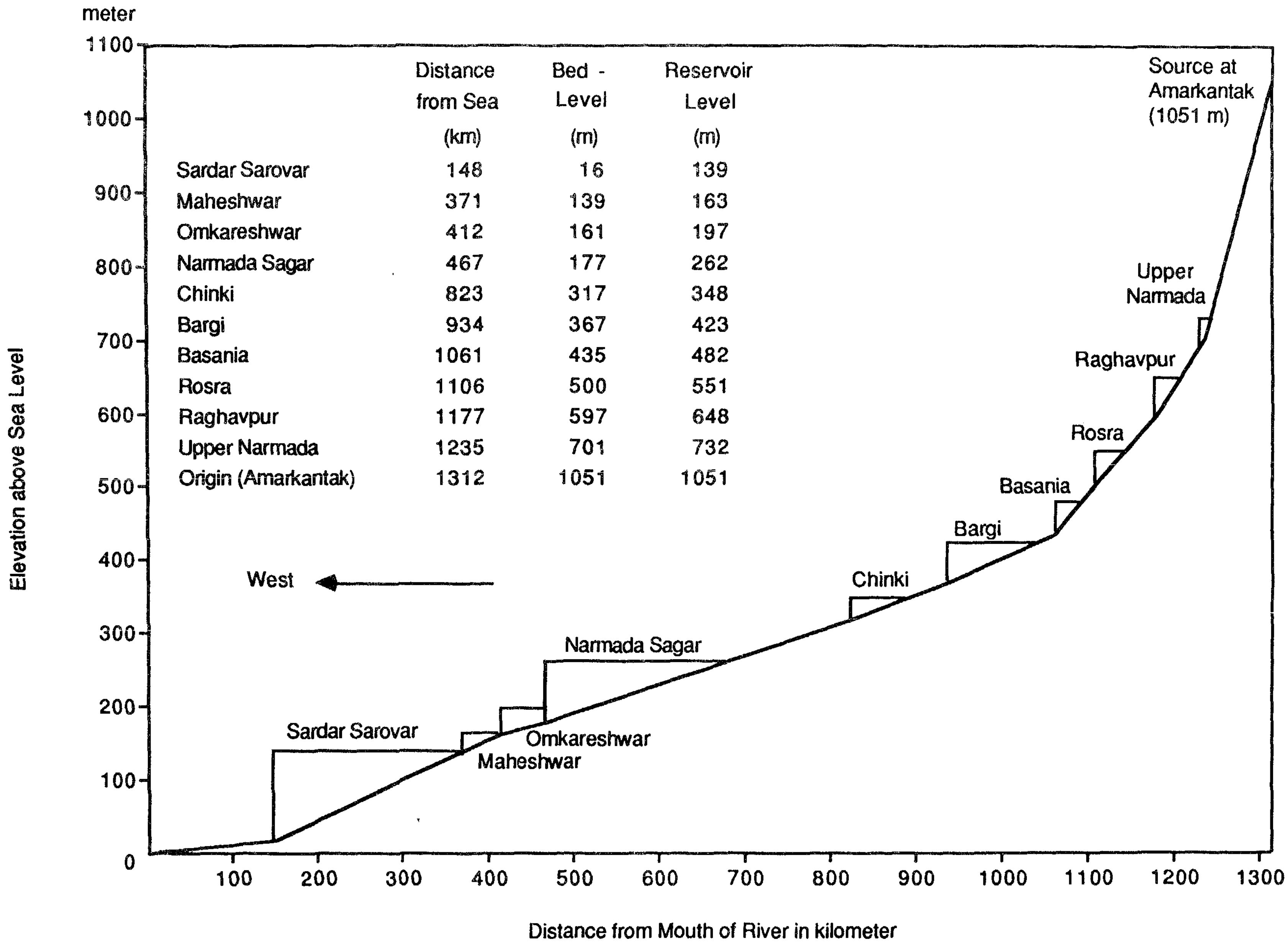
mosquito breeding. The Indian health services are known to make all efforts to monitor the incidence of the disease and to provide the appropriate treatment.

Some people are concerned about **weed growth** in reservoirs, presumably with reference to infestation by water weeds such as the water hyacinth. This has not been a concern in large reservoirs in India so far, although it must be watched carefully, and particularly for smaller reservoirs and tanks.

Seismicity

Detailed studies regarding possible earthquakes had been undertaken before designs for the Narmada Sagar and Sardar Sarovar dams were finalized. The Bank has assured itself that the designs are safe from failure due to earthquakes. Concerns have been voiced that large reservoirs will induce seismic activity in the area, but the scientific evidence for this phenomenon is not fully clear. It is believed that while such reservoir-induced seismicity is possible, this does not increase the magnitude or general likelihood of seismic shocks but may contribute to such shocks occurring earlier than they would have occurred otherwise.

Major Reservoirs on Narmada River (Main Stem)



	Distance from Sea (km)	Bed - Level (m)	Reservoir Level (m)
Sardar Sarovar	148	16	139
Maheshwar	371	139	163
Omkareshwar	412	161	197
Narmada Sagar	467	177	262
Chinki	823	317	348
Bargi	934	367	423
Basania	1061	435	482
Rosra	1106	500	551
Raghavpur	1177	597	648
Upper Narmada	1235	701	732
Origin (Amarkantak)	1312	1051	1051

FIGURE A.1

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