EX POST EVALUATION OF DAMS AND RELATED WATER PROJECTS: PATTERNS, PROBLEMS, AND POTENTIAL

Report to the World Commission on Dams
Cape Town, South Africa
Revised Draft
May 4, 2000

James L. Wescoat Jr. and Sarah Halvorson
Department of Geography, Campus Box 260
University of Colorado at Boulder
Boulder, CO USA 80309

Fax: (303) 492-7501; Phone: (303) 492-4877
Email: wescoat@spot.colorado.edu

ACKNOWLEDGEMENTS

This report presents preliminary results of an international survey of ex post evaluations of water projects, programs and policies related to large dams. The survey was inspired by Professor Gilbert F. White's repeated calls for post audits, and his criticisms that few comprehensive studies have been undertaken to date. We are grateful to Professor White for his encouragement and comments on an earlier draft.

This report draws together material and insights relevant to large dam and reservoir projects in different regions of the world. Drs. Sanjeev Khagram and Thayer Scudder indicated that these materials may be of interest to the World Commission on Dams. Although this report is a work in progress, it was able to identify several unresolved conceptual issues, useful electronic search tools, and patterns of ex post evaluation in different water subsectors and regions of the world.

The report builds upon previous efforts that we wish to acknowledge here. The survey was initiated in an undergraduate geography course on World Water Problems at the University of Colorado at Boulder. We would like to acknowledge the creative contributions and hard work of the 100 students in that class. The Dams group contributors included Sarah Bunten (South Asia), Jonathan Coles (South America), Melissa Crandell (North America), Albert Dudley, Mark Jones (East and Southeast Asia), Angela Lovergine (Africa), Dean Matheson (Former Soviet Union), and Robert Waggoner (Europe). James Washburn helped maintain the momentum of the project by re-examining and editing the initial results and providing a generous contribution to the University of Colorado Foundation to support further development. Mr. Fengjing Liu conducted a search for books in Chinese on Three Gorges Dam. The electronic search procedures were first developed for the U.N. Food and Agriculture Organization's Investment Centre, with support and guidance from Dr. Random Dubois, Senior Environmental Officer. They were refined for the World Water Problems course, and further refined for this report. Dr. Jeffrey W. Jacobs of the National Research Council (NRC) Water Science and Technology Board and Dr. Thayer Scudder offered helpful comments on an earlier draft.

As noted above, this survey of ex post evaluations is very much at a preliminary stage. It was not possible within the timeframe of this desk study to analyze the material identified, or to identify “Best Practices” of ex post evaluation. Those are priorities for future research. However, it was possible, at this stage, to identify issues, tools, and patterns of ex post evaluation that are of interest to the World Commission on Dams.

CONTENTS

EXECUTIVE SUMMARY

This paper reports on a global survey of *ex post evaluations* and *post audits* of completed dams and related water projects. Ex post evaluations assess the *actual* impacts of completed water projects, programs, and policies for the people, environments, and landscapes affected. Professor Gilbert White has criticized the lack of detailed ex post evaluations, but no broad inventory of such studies has been attempted to date. Using systematic bibliographic search procedures, a team of students at the University of Colorado at Boulder identified ex post evaluations for different water subsectors, regions, and types of impacts. While this broad scope did not provide a detailed treatment of large dams, it does help situate dams within the broader context of water resource evaluation.

After briefly discussing the importance of ex post evaluation, this report presents three sets of findings:

1) Conceptual issues and necessary refinements;
2) Bibliographic tools and information management needs; and
3) International patterns and trends.

To appraise the usefulness of the bibliographic methods, search results for Tarbela Dam, which is located in the Indus river basin in Pakistan and is one of the WCD's *Focal Dam case studies*, are attached.

Problem Statement

* **Ex post evaluations, or post audits, are essential to determine the "lessons learned" from large dam projects, and to apply those lessons to future decisions about dam design, operations, refurbishment, and decommissioning. Ex post evaluations should be:**

- **Comprehensive**
- **Integrated**
- **Long-term**
- **Cumulative**
- **Adaptive**

Ex post evaluations, or post audits, examine the actual consequences of completed dam projects for the peoples, environments, and landscapes affected. Evaluation ranges from continuous monitoring to episodic studies, and it may involve time scales of years to decades. It assesses the effects of a dam's presence, its operations, and its linkages with related water and environmental management activities. Where dams are part of larger river basin and regional development programs, the scope of evaluation should include all project and program components that, in conjunction with dams, affect environment and society.

Ideally, an ex post evaluation would have the following attributes: it would be

comprehensive, integrated, long-term, cumulative, and *adaptive*. *Comprehensive* ex post evaluation includes the full array of environmental, social, economic, and institutional impacts of dams and related water projects. *Integrated* ex post evaluation examines the interactions among these different types of impacts. *Long-term* evaluation monitors impacts that occur over time scales of serveral decades or more. *Cumulative impact assessment* considers how the impacts of one dam are related to the impacts of other dams and other structural and non-structural measures of water management in a region (e.g., of the river basin scale). And *adaptive management* is used to continuously assess and adjust dam-related decisions within the changing context of environmental and social conditions.

*** There are large scientific and evaluation literatures on the effects of dams that are relevant for ex post evaluation. However, broad evaluations of completed projects appear to be few in number, narrow in scope, poorly integrated across impact categories and scales, and inadequately linked with dam operations decisions.**

Research on the impacts of large dams has grown rapidly in recent decades. Frameworks for monitoring and evaluating impacts have also become sophisticated. Although these studies and frameworks are clearly relevant for ex post evaluation, completed evaluations are rarely comprehensive, integrated, adaptive, or long-term. These problems are addressed in section 1 of this report.

To appraise the status of ex post evaluation in different water subsectors and regions, this report addresses three problems: 1) Conceptual issues and necessary refinements; 2) Bibliographic tools and information management needs; and 3) International patterns and trends.

Conceptual Issues and Necessary Refinements

*** There has been good progress in designing monitoring and evaluation frameworks that focus on major categories of impacts and indicators. Further conceptual refinements are needed to define examples of "Best Practices" in ex post evaluation. These include:**

1. Evaluating interactions among different types of dam-related impacts (i.e., physical, biological, socio-economic, institutional, and cultural impacts).

2. Evaluating dam-related impacts within broader contexts of water management (e.g., river basin management); international trends (e.g., changing prices, technologies, and values); and non-structural alternatives. A basic challenge is to provide a sound basis for comparing the impacts of structural with non-structural programs of water and environmental management.

3. Drawing useful comparisons between ex post evaluations conducted in different geographic regions and contexts. Although case study methods are well-developed, the logic, methods, and applications of comparative evaluation remain rudimentary. As a result, we are not yet in a position to determine "Best Practices" of ex post evaluation, which is a high priority.

4. Improving the use and utility of ex post evaluation results, e.g., in programs of "adaptive management" of dam operations; and in planning, refurbishment, and decommissioning decisions.

These conceptual refinements require closer coordination between water resources research, monitoring, and ex post evaluation than generally occurs. They are addressed in section 2 of the report.

Bibliographic Tools and Information Management Needs

*** Scientific and evaluation studies are increasingly accessible through electronic libraries, databases, and communication networks. However, these emerging information management resources and tools are not effectively utilized. In addition, completed ex post evaluations are not well catalogued or archived. They are difficult to identify and obtain. The main information management needs are to:**

1. Insure access to information for all stakeholders and affected groups. Access to internet resources is a high priority.

2. Develop systematic and efficient search procedures and bibliographic tools (examples presented in appendix A).

3. Develop common terminology for cataloguing and accessing ex post evaluations.

4. Develop electronically-accessible archives of completed ex post evaluations. Access to multilateral reports is improving. Access to technical consulting reports and doctoral dissertations on social and environmental aspects of dams needs attention.

5. Improve cataloging of and access to "gray literature" reports and non-English language publications. In addition to consulting reports, publications in non-English and non-European languages are underutilized.

6. Publish regular summaries of ex post evaluations in scientific and technical journals.

These information management needs are discussed in section 3 of the report.

International Patterns and Trends

*** Using comparable search terms, this project identified ex post evaluations of completed water projects in electronic libraries and databases. Library searches included books, doctoral dissertations, and journal articles on water resources, engineering, and environmental studies. Development databases included the World Bank, USAID, and British Library of Development Studies. Although additional searches are needed,**

preliminary results suggest that:

1. There is a small, but significant, number of ex post evaluations in some geographic regions and water subsectors. These evaluations are sometimes detailed, but they are rarely comprehensive, integrated, long-term, cumulative or adaptive.

2. The literature of ex post evaluation reflects historical shifts in water development and activism programs more than well-designed strategies for long-term monitoring, evaluation, and decision-making.

3. There seems to be more analysis of projects under construction (e.g., Three Gorges, GAP, and Sardar Sarovar) than of the long-term impacts of completed projects.

4. There are important regional exceptions to these patterns (e.g., monitoring of the Lesotho Highlands water project, the Glen Canyon Dam Adaptive Management Program; and World Commission on Dams Focal Dam case studies).

5. A regional perspective helps identify different concerns, approaches, gaps, and lessons. There is a need to identify "Best Practices" among these regional examples.

Although there are many common approaches, ecosystem effects appear to receive comparatively detailed attention in North America, Europe, and the former Soviet Union; social effects receive detailed attention in Africa, South America, and South Asia; political effects in the Middle East; and so on. Regional patterns and examples highlight the gaps in current practice that stand in the way of comprehensive, integrated, long-term, cumulative, and adaptive ex post evaluation. These regional examples are discussed in section 4 of the report.

Tarbela Dam and Indus River Basin Case Study

*** Tarbela Dam is a major component of the Indus Basin Development Program, initiated by the Indus Waters Treaty of 1960. In searching for ex post evaluations of the dam itself and of its contribution to larger basin impacts, we found that:**

1. There is a significant technical literature on Tarbela Dam and selected problems of reservoir management. But there was no comprehensive, integrated, adaptive, or long-term ex post evaluation of upstream and downstream effects of the dam.

2. The search identified an important literature on the broad agricultural and economic effects of Indus basin development, some of which are attributable to Tarbela Dam, which speaks to concerns about the cumulative impacts of complex river basin development. However, the Indus basin literature has given less attention to ecological and socioeconomic impacts. Although that may be changing, integrating ecological, socio-economic, and institutional impacts remains a major challenge.

3. Draft bibliographies for this report and the focal dam case study were compared. The focal dam case study identified a large number of government and donor publications. The search procedures in this study yielded a larger number of scientific and technical publications. We conclude that neither the project nor scientific literatures are circulating effectively among the people who need them.

4. Indus basin evaluations have been closely associated with dam investment decisions at the national level. It is not clear whether scientific evaluations have influenced dam operations, refurbishment, and planning decisions. The Tarbela Dam and Indus River Basin case studies are discussed in section 5 of the report.

Conclusions and Recommendations

This study generally supports Professor Gilbert F. White's critique that few comprehensive ex post evaluations have been conducted. However, it also identifies partial exceptions, and it provides useful methods for finding those exceptions. To improve the use of ex post evaluation, five key steps are needed:

1) Conduct additional searches for a reference set of specific dams.
2) Improve access to previous evaluations through archiving and cataloguing.
3) Synthesize evaluation data and findings to identify "best practices."
4) Develop a coordinated international strategy and resources for implementing ex post evaluation.
5) Independently appraise the use and utility of completed ex post evaluations.

INTRODUCTION

Ex post evaluations, or post audits, assess the *actual* impacts of *completed* water projects, programs, and policies for the people, environments, and landscapes that are affected. Ex post evaluation of a large dam would measure, monitor, and assess the full array of impacts related to that dam -- from its design, construction, presence, operation, maintenance and refurbishment, to its ultimate decommissioning.

Well-designed ex post evaluations can help draw short and long-term lessons for dam and reservoir management. Where dams have already been built, they can help guide technical, environmental, and social adjustments in affected areas. In places where dams have not yet been built, they can help assess alternative courses of action.

Professor Gilbert F. White (1978, 1996, 1998) has drawn attention to the surprisingly small number of ex post evaluations of completed water projects -- as compared with the many studies that estimate the *potential* effects of *planned* projects. Among the many reasons, he notes that detailed ex post evaluations are difficult to conduct, not always welcomed by management

organizations, and difficult to apply in changing or different geographic contexts. Professor Thayer Scudder (pers. comm. 2000) notes that panels of experts have been convened to evaluate several complex projects (e.g., panels of experts for the China-Xiaolangi Multipurpose Project and China-Ertan II Hydroelectric Project, Lesotho Highlands Water Project, and other projects in Laos, Nepal, Swaziland and Uganda). But if panels of experts and independent review panels lack reliable monitoring data and evaluations, they are less able to identify promising alternatives (cf. LIMA et al., 2000).

There have been few attempts to systematically compile and examine the ex post evaluations that have been prepared. The World Commission on Dam's focal case studies and cross-check studies constitute important steps, as do earlier bibliographic syntheses and case studies (Burt, and Watts, 1996; Gleick, 1998; Goldsmith and Hildyard, 1984, 1986ab; McCully, 1996; ICOLD Congresses and Bulletins, e.g., 1973, 1988, 1992; World Bank, 1994, 1996). A series of international reviews of large "man-made lakes" initiated in a 1969 FAO report raised a broad spectrum of questions about impacts and have continuing value, but they did not attempt a systematic appraisal of available findings (Ackermann, White, and Worthington, 1973; Lagler, 1969; Stanley and Alpers, 1975; White et al., 1972; White, 1975). *Man-Made Lakes* (Ackermann, White, and Worthington, 1973), for example, included 13 case studies, with relatively detailed treatment of Volta Lake in Ghana and Lake Kariba in Zambia and Zimbabwe, but with limited integration.

This report presents the current findings of a project at the University of Colorado at Boulder that seeks to systematically identify and examine ex post evaluations of different water subsectors in regions around the world. Initiated in an undergraduate course of 100 students, the project has developed a conceptual approach and bibliographic tools to search for detailed case studies of completed water projects. While not focused primarily on large dams, the project includes dams and helps situate ex post evaluation of dams within a broader water resources context. At the request of the WCD, we conducted additional searches focusing on dams re-examined search results.

After briefly discussing the nature and importance of ex post evaluation, this report presents three sets of findings: 1) Conceptual issues and necessary refinements; 2) Bibliographic tools and information management needs; and 3) International patterns and trends. To appraise the usefulness of the University of Colorado search procedures, results are presented for Tarbela Dam and the Indus River basin in Pakistan, which is one of the WCD's focal case studies.

1. PROBLEM STATEMENT AND APPROACH

***Ex post evaluations, or post audits, are essential to determine the "lessons learned" from large dam projects, and to apply those lessons to future decisions about dam design, operations, refurbishment, and decommissioning. Ex post evaluations should be:**

- ***Comprehensive***
- ***Integrated***

- ***Long-term***
- ***Cumulative***
- ***Adaptive***

In 1997, an IUCN and World Bank report on Large Dams: Learning from the Past, Looking at the Future stated that:

> Every five years or so a comprehensive ex post evaluation should be carried out to verify whether project expectations have been met and to determine where further remedial action, to be paid by the project, is required. Ex-post evaluations play an important role in understanding the real environmental and social impact of large dams (pp. 32-3).

Ex post evaluation can also help guide decisions about dam design, operations, refurbishment, and decommissioning.

The challenges of ex post evaluation are many. They examine impacts that may be difficult or expensive to measure, and that often involve processes independent of the dam. In addition to the five-year timeframe mentioned above, ex post evaluation may involve continuous monitoring of some variables, seasonal or annual monitoring of others, and decadal or multi-decadal assessment of others. It would assess the effects of a dam's presence, its operations, and its linkages with related water management activities.

The *scope* of ex post evaluation should encompass the "whole project." In addition to the design and operation of the dam, the scope should include effects of end-uses of water and hydropower. Where dams are part of larger river basin and regional development programs, it should include other project and program components that, in conjunction with dams, have cumulative impacts on environment and society. We used this broad definition of scope when searching for ex post evaluations.

Ideally, ex post evaluations should have the following attributes: they shoud be *comprehensive, integrated, long-term, cumulative* and *adaptive* (figure 1). A **C*omprehensive*** evaluation would encompass the full array of hydrologic, ecological, socioeconomic, cultural, and institutional impacts of dams and related water projects. It would employ indicators meaningful to affected groups (Mulvihill, 1997; Nazarea, 1998). Good progress has been made toward identifying the types of impacts to be measured (for a list see "Checklist for key potential environmental and social impacts caused by large dam projects," IUCN and World Bank, 1997, pp. 37-39). The Goldsmith and Hildyard (1986b) bibliography is organized under 14 major categories of effects. *Man-Made Lakes* (Ackermann, White, and Worthington, 1973) examined 15 categories of physical, biological, and social effects. The sheer range and number of potential information needs requires a strategy for prioritizing classes of variables that are likely to have long-term value. Most water resources agencies keep basic hydrologic, water, and land use data useful for evaluation purposes (e.g., US Bureau of Reclamation, 1991), but few undertake comprehensive monitoring. For purposes of this study, a comprehensive evaluation is one that

gives detailed treatment to at least several major categories of impacts.

Integrated evaluation would examine the interactions among these different categories of dam-related impacts (e.g., environmental, socioeconomic, cultural, and institutional). It would examine the impacts of a dam within the broader context of the watersheds, ecosystems, and geographic regions that are affected. Limited progress has been made toward these aims.

Long-term evaluation of a dam begins with baseline studies. It includes the period of project construction and the impact evaluation reports that development organizations prepare five to ten years after completion. It extends to the multi-decadal time scales in which long-term impacts of construction, operations, modifications and decommissioning occur (ASCE Task Committee, 1997; USCOLD, 1996). Progress has been made in some areas toward setting up long-term monitoring programs. Although it is difficult to distinguish the long-term impacts attributable to a dam from other causes, that is a challenge that historians may help address (Jackson, 1997).

Cumulative impact assessment considers how the effects of a particular dam are related to other water projects, including non-structural water management, at the river basin and regional scales. It thus combines *comprehensive, integrated* and *long-term* evaluation. Not surprisingly, it is rarely undertaken, though WCD Focal Dam case studies take some important steps forward (e.g., Ortolano, Cushing, et al., 1999).

Adaptive ex post evaluation goes even further by responding to, scientifically experimenting with, and helping guide dam and related water management decisions in a river basin. It draws upon *comprehensive, integrated, long-term*, and *cumulative* impact evaluation. Emerging paradigms of adaptive dam and reservoir management involve close collaboration among stakeholders, managers, and scientists to identify management objectives and information needs. They involve formal experimentation with management alternatives; monitoring the impacts of management actions; and making adjustments based on those impacts. They respond to broader trends in social, environmental, and economic values. These characteristics indicate that while individual evaluations may involve short periods of time, adaptive evaluations occur on time scales of decades.

White (1988b) suggests that ex post evaluations are more likely to make a difference in decision-making if: 1) The operating agency is directly involved in the design and interpretation of the post-audit; 2) The post-audit consciously challenges the assumptions on which the program is based; and 3) Post-audits are used in step-by-step monitoring and adjustment rather than a long-term comprehensive report. While agency involvement increases the usefulness of evaluation, it is also essential to involve *independent scientific and technical organizations* to ensure objectivity, creativity, and credibility in evaluation. Experiments underway in adaptive dam and reservoir management (e.g., at Glen Canyon Dam on the Colorado River, USA) are testing these propositions about the roles of scientific and operating organizations and collaboration among them.

--Insert Figure 1 on This Page--

These five criteria of *comprehensive*, *integrated*, *long-term*, *cumulative,* and *adaptive* ex post evaluation were used to identify the existing literature on completed water projects in different subsectors and regions of the world. In so doing, we considered four hypotheses:

> **Hyp. 1: Few ex post evaluations of water projects have been published.** To test this hypothesis, we worked with Gilbert White to develop an initial list of publications that we knew about, and then compared it with search results from five large electronic libraries.
>
> **Hyp. 2: In fact, many ex post evaluations have been conducted, but they exist in the "gray literature."** To test this hypothesis, we searched on-line databases of two major development organizations, the World Bank and USAID.
>
> **Hyp. 3: Many ex post evaluations exist, but they have not been catalogued.** To test this hypothesis we contacted water experts in each region and subsector asking them to identify the ex post evaluations influential in their work.
>
> **Hyp. 4: The scope and content of ex post evaluations varies by region, subsector, and type of evidence.** To test this hypothesis, we plan to compare the results from different regions and subsectors.

In the course of examining these general hypotheses about ex post evaluation of completed water projects, we found that:

*** There are large scientific and evaluation literatures relevant to the ex post evaluation of large dams. However, major evaluations of completed projects are few in number, narrow in scope, poorly integrated across impact categories and scales, and inadequately linked to dam operations decisions. To improve ex post evaluation, an international group should analyze these studies and strive to identify "Best Practices."**

Scientific research and reporting on the impacts of large dams has grown rapidly in recent decades. In addition to general electronic libraries and databases, this study drew upon specialized bibliographies in Goldsmith and Hildyard, 1986b; publications and congresses of ICOLD; electronic archives of the International Rivers Network; Environmental Engineering Abstracts, sec. 441 on dams, reservoirs, and hydropower; and Scudder, 1997. These literatures are large and growing.

But, as we shall show in section four, even in the context of a single evaluation program, studies are rarely comprehensive, integrated, long-term, cumulative, or adaptive. The Glen Canyon Dam Adaptive Management Program provides a good example. The Glen Canyon Environmental Studies examined the effects of Glen Canyon Dam on the Grand Canyon of the Colorado River for 12 years. It produced enormous bodies of data, publications, and unpublished reports from 1982 to 1995 (National Research Council, 1996a). Thus, the first scientific challenge the Adaptive Management Program was data integration and research synthesis, which

identified additional gaps and inconsistencies.

A scientific review of the research and monitoring program acknowledged it to be one of the leading experiment in adaptive management of dam operations worldwide (National Research Council, 1999). However, the review also raised concerns about the limited integration of physical, biological, socioeconomic, and cultural resources impact assessments. If these problems arise within a single research and monitoring program, it is unlikely that information produced by disparate programs will yield comprehensive, integrated, long-term, cumulative, or adaptive evaluations – not without far greater coordination and synthesis than has occurred to date.

Evaluation frameworks and methods have become increasingly sophisticated. The U.N. Development Programme, Evaluation Office (1998) has distinguished among project "inputs," "activities," "outputs," "outcomes," and "impacts." It defines "impacts" as long-term changes (greater than 2-3 years) in people, institutions, and conditions. The World Bank, Operations Evaluation Department (1997) uses similar terminology, but it conducts "impact evaluations," after 5 to 8 years (cf. Buky, 1989). Some ten World Bank "safeguard policies" are relevant to the environmental and social impacts of dams. The World Bank conducted a preliminary review of its large dam experience, which included the project rationale, development impact, and social and environmental impact (World Bank, 1996). Although none of the Impact Evaluation Reports listed on its website in 1999 focus specifically on large dams, several irrigation project evaluations include dams and related facilities. The U.S. Agency for International Development (USAID) has developed Performance Monitoring Plans and Evaluations methods that use "established indicators, baselines, and targets." ICOLD has addressed monitoring issues at tailings dams and for dam safety (e.g., ICOLD, 1996). Emerging programs of ecosystem management have developed sophisticated monitoring designs (Davis, 1992). These are just a few of the conceptual frameworks in use.

Although these expanding literatures and frameworks are clearly relevant for ex post evaluation, without further conceptual refinements, they are not likely to yield evaluations that are comprehensive, integrated, long-term, cumulative, and adaptive.

2. CONCEPTUAL ISSUES AND NECESSARY REFINEMENTS

*** There has been good progress in defining evaluation issues and evaluation frameworks that focus on major categories of impacts and indicators. Further conceptual refinements are needed to:**

1. Evaluate interactions among different types of dam-related impacts (e.g., physical, biological, socio-economic, cultural, institutional, and political impacts at local and regional scales). The most consistent pattern of ex post evaluations identified in this report involves separate treatment of technical, economic, social, and environmental impacts (cf. IUCN and World Bank, 1997). These established categories of "physical", "biological", "social", and

"economic" impact assessment may actually hamper progress toward integrated evaluation.

Several integrative alternatives seem promising. The ecosystem approach has begun to integrate physical and biological impacts, but has not adequately incorporated social impacts (Walters, 1997). Economic valuation methods strive to measure trade-offs among commensurable impacts, but have yet to be widely accepted by stakeholders (for a review see National Research Council, 1999). Political processes can be integrative (see Dreze, Samson, and Singh, 1997; and Espeland, 1998). Watershed, landscape, cultural ecological, and political ecological approaches also deserve consideration (Batterbury and Bebbington, 1999; Bryant and Bailey, 1997; Doolette and MacGrath, 1990; Forman, 1995). Although integration is generally desirable, it must allow for and encourage new and pluralistic conceptual approaches.

2. Evaluate dam impacts within broader contexts, scales, and alternatives of resource management. Although it would be a major accomplishment just to achieve comprehensive evaluation of local dam and reservoir impacts, it is also necessary to examine more distant impacts and the broader contexts of those impacts. The role of dams in river basin development is generally well-known, but the river basin impacts attributable to individual dams are rarely evaluated. The impacts of dams in other geographic contexts (e.g., ecological regions, economic regions, political jurisdictions, and "hydrocommons" [water supply regions]) are also important. In an important series of ex post evaluations of the Columbia Basin Project, for example, Macinko (1963, 1975) noted the importance of changing international markets, prices, and technologies. Restructuring and privatization in the electric power industry might now be added to this list of exogenous factors.

In addition to ensuring a full evaluation, these broader contextual approaches could help expand the range of structural and non-structural alternatives that are considered. A basic challenge is to provide a sound basis for comparing the impacts of structural with non-structural programs (e.g., comparing average annual flood losses when floodplains are structurally controlled with those when floodplain zoning is enforced). For example, a comparative evaluation of flood loss vulnerability in 17 areas following construction of projects financed by the Flood Control Act of 1936 contributed to the initiation of floodplain management by the U.S. Army Corps of Engineers (White, et al., 1958).

3. Draw practical comparisons between ex post evaluations conducted in different geographic contexts. Even if comprehensive ex post evaluations were conducted, it is not self-evident where and how they can be used. Dam builders and critics frequently draw lessons from experience in one place for other places, but the logic and methods of those comparisons require further refinement (Dixon, 1989; McCully, 1996; Ragin, 1987; World Bank, 1996). Few of the ex post evaluations that we identified involved detailed comparative analysis. As ex post evaluations become more comprehensive, integrated, long-term, cumulative, and adaptive, the difficulty of making practical comparisons will grow (Jacobs, 1999). A comparative study of flood hazards mitigation programs in mainland Asia revealed that few of the studies produced in one basin are circulating or used in other basins (Jacobs and Wescoat, 1994). Scudder (pers. comm., 2000) notes that reports of panels of experts on dams should also be publicly released,

widely circulated, and analytically compared. The WCD has taken important steps in these directions with its focal case studies and cross-check survey.

4. Improve the use and utility of ex post evaluation results (e.g., in dam planning, operations, refurbishment, and decommissioning decisions). In our initial survey, we found almost no evidence concerning the use or usefulness of ex post evaluations. We suspect that some of the most detailed studies (e.g. doctoral dissertations and consulting reports) are not known to stakeholders. Archiving of "gray literature" reports, and worldwide access to scientific publications, is limited (the Middle East Water Information Network [MEWIN], at the University of Pennsylvania, is an important exception—see http://www.ssc.upenn.edu/~mewin/)/

For ex post evaluations to be more useful, in addition to being well-designed and executed, they must be well-catalogued, centrally archived, and readily accessible. And it is to these issues that we now turn.

3. BIBLIOGRAPHIC TOOLS AND INFORMATION MANAGEMENT NEEDS

*** Evaluation studies are increasingly accessible through electronic libraries, databases, and communication networks.**

As recently as five years ago, most research libraries had their own separate catalogs. Although some of those catalogs were electronic, few were linked in master catalogs or accessible to outside users. Now those libraries are more readily and centrally accessible to users with internet access. The evaluation reports of development organizations are also increasingly available in electronic databases. Previously, it was so difficult to locate and obtain water resources studies outside of the major research centers that those studies were underutilized and water planners were in a sense "excused" from using them. With new library and information management tools, there are expanding opportunities to draw upon previous case studies, and fewer excuses not to.

Among the challenges involved in using these new information resources are: 1) knowing where to find them; 2) knowing how to search them efficiently; and 3) knowing how to manage and use the information obtained. In earlier work with development organizations and researchers, we have found that:

*** Emerging information resources and tools are not effectively utilized. Systematic and efficient search procedures and tools are needed.**

At the outset of our studies, researchers and water managers reported that they use ad hoc bibliographic search procedures, that they spent too much time in unproductive internet use, and that they had insufficient time for exhaustive searches. At the same time, they recognized the value and need to know about the information relevant to their projects. We suspect that dam

managers, scientists, stakeholders, and activists will make increasing use of internet resources. Consequently, this project sought to develop bibliographic search procedures that identify the most ex post evaluations in the shortest amount of time possible.

The search tool developed for this study included three key components: 1) Identify the most relevant electronic libraries; 2) select appropriate search terms; 3) develop a system for recording and compiling results. These components are briefly described below; search forms are attached in Appendix A.

1. Identify relevant electronic libraries and databases. Our initial project used the following libraries and databases.

a. FirstSearch Worldcat -- one of the largest electronic libraries of books.

b. Dissertation Abstracts -- one of the largest libraries of theses and dissertations.

c. Water Resources Abstracts -- includes water resources articles and reports.

d. Geobase -- includes geographic articles.

e. British Library of Development Studies (BLDS) -- a specialized development library.

f. World Bank -- OED and JOLIS libraries.

g. USAID -- DEXS libraries.

Notes: 1. We selectively used other databases, such as AGRICOLA (the U.S. National Agricultural Library), HAZARDS (the Natural Hazards Research, Application and Information Center), MEDLINE (for health impacts), and four other article indexes (KNOWLEDGE CITE, ENVIRONMENT, UNCOVER, APPLIEDSCITECH, and ARTICLE1ST). 2. We have subsequently become aware of and begun searching two specialized engineering databases relevant to large dams: EiCompendex; and Environmental Engineering Abstracts, section 441 on dams, reservoirs, and hydropower.

2. Use appropriate search terms. This task is crucial for balancing the dual aims of systematic and efficient searching. We used four categories of search terms: a) technical/sector terms; b) environmental terms; c) social terms; and d) geographic terms. In this case, technical and sector terms would include "dam," "barrage," "spillway," "reservoir," "hydropower," "hydroelectric," "river basin development" and so on. It is important to use technical thesauruses to identify appropriate terms (e.g., the ICOLD technical dictionary for dam-related terms; AGROVOC and ICID for irrigation terms; INFOTERRA for environmental terms; and *Columbia Gazetteer of the World*, 1998, for geographic terms). When searching for studies of a particular dam, the dam name alone may be sufficient. For studies of river basins or categories of impacts, however, searching with pairs of terms is recommended.

Notes: 1. The terms "ex post evaluation" and "post audit" are not widely or consistently used (e.g., they are not in the ICOLD technical dictionary or U.S. Bureau of Reclamation on-line glossary). Thus, they are not sufficient for bibliographic searching, which led us to experiment with other general terms such as “impacts,” “evaluation,” and “case studies,” but with uneven results.

3. Develop a system for recording, selecting, and managing search results. As information resources and evaluation challenges expand, it will be increasingly important to record and manage search results systematically. Forms for this purpose are included in App. A. One of the key challenges in evaluating search results is judging whether a publication is likely to be a detailed ex post evaluation. For example, many "environmental assessments" deal with the potential impacts of planned projects and not the actual impacts of completed projects. Many evaluations are either too brief or narrowly focused to qualify as comprehensive ex post evaluations. When we found that team members made different judgments about the same research results, we developed criteria for judging titles and abstracts to be included in the results.

These three tasks describe the mechanics of using new information resources more efficiently and systematically. In our experience, these three tasks are not widely practiced by water resources specialists. In addition, we found several continuing problems related to the information resources on ex post evaluation:

*** The main challenges associated with using information resources on ex post evaluation of large dams in the future will be to:**

1. Insure access for all stakeholders, affected groups, and their representatives. While access is expanding, it does not often extend to poor, illiterate, and other marginalized groups. Build information alliances, networks, and services to elicit and provide information to all groups.

2. Develop search procedures and bibliographic tools that focus on large dams (NB: general water resources tools are included in appendix A).

3. Develop common terminology for cataloguing and accessing ex post evaluations. As noted above, the terms "ex post" and "post audit" are not commonly used in publications or technical dictionaries.

4. Develop electronically-accessible archives of completed ex post evaluations. As information resources on large dams are identified and compiled, they should be maintained and made available in electronically-accessible archives for long-term use. Several models may be considered. For example, IRN and USAID have searchable archives, while MEWIN (the Middle East Water Information Network-- http://www.ssc.upenn.edu/~mewin) and IRN (http://www.irn.org) also have fee services. Some of the electronic libraries used here are only

available on a subscription basis.

5. Improve cataloging of and access to "gray literature" reports and non-English language publications. Access to unpublished technical reports is at an early stage. Reports in non-European languages are especially difficult to locate. For example, while a search for publications on the "Three Gorges" dam in WORLDCAT yielded 31 books in Chinese, a search of the National Library in China and Peking University Library yielded 248 books in Chinese (App. B).

6. Publish regular summaries of completed ex post evaluations and "best practices" in scientific and technical journals. The editors of established professional (e.g., International Water Power and Dam Construction) and scientific journals (e.g., Regulated Rivers) may be interested in carrying a regular series of notices about ex post evaluations to inform readers of completed studies and to help increase their use.

4. INTERNATIONAL PATTERNS

General Searches

*** At the most general level, the search terms "ex post" and "post audit" yielded a small, but significant, number of ex post evaluations of large dams and related water subsectors.**

Before beginning the search, we developed a list of ex post evaluations, based on our previous knowledge, to test against search results (e.g., Doolette and Magrath, 1990; Galloway, 1980; Goldsmith and Hildyard, 1986b; Gunnerson, 1989; Interim Committee for the Coordination of Investigations of the Lower Mekong Basin, 1982; Jacobsen, 1989; Lee, 1990; Macinko, 1963, 1975; Michel, 1967; Mittler, 1997; Rogers, Lydon, and Seckler, 1994; Scudder, 1997; White, 1977, 1988ab; Morse, 1992; Uphoff, 1992; White, et al., 1958; White et al., 1972). Most of these studies involve dams or barrages, to some extent, but they have no strong geographic or topical concentration.

Searching the world's libraries and databases with the terms "ex post evaluation" and "post audit" yielded a few case studies of large dams. In the dams literature (e.g., ICOLD/CIGB publications), the term "evaluation" has often denoted geotechnical and safety studies. In other fields, these terms commonly refer to economic benefit-cost evaluation of water projects and policies (Haveman, 1972; Martin and Thackston, 1980; Maxwell, 1973). Many of these studies were conducted in the 1970s and are now dated. Exceptions included ex post evaluations of the:

* Libby Dam Project in Idaho, USA (Ciliberti, 1980).

* Kpong Hydroelectric Project, Ghana (Ofori-Cudjoe, 1990).

* Pick-Sloan Reservoir Program, USA (Feeney, 1995).

* Weber Basin Project in Utah, USA (Andrews et al., 1974).

* Ridracoli Dam, Italy (Grillenzoni et al., 1994; ICOLD, 1995)

* A conference in Hungary on ex post evaluation (Bokhari, 1975; Dagen, 1975; Duckstein, 1975; Macinko, 1975; Ress, 1975).

Numerous post audits have been conducted on related water subsectors. Although they vary widely in scope and content, they may have conceptual, methodological, and contextual relevance for evaluating dams. Search results included:

* National water plans (Kay and Mitchell, 1998).

* Flood control (Fischl, 1993; Galloway, 1980; Gruntfest, 1997; Oyen and Barnard, 1975; Palanisiami and Easter, 1984; Ramirez et al., 1988).

* Navigation (Seley, 1971).

* Irrigation projects (e.g., Erikson and Bhatti, 1993; Hatzius, 1994; Howe, 1986; India NBARD, 1997; Kontogeorgakos, 1991; Kulshreshtha and Russell, 1988; Olokesusi and Areola, 1993; Psychoudakis et al., 1995; Sander, 1980; Walker, Peterson and Coward, 1979). There are large evaluation literatures, for example, on the On-Farm Water Management and Command Water Management programs in Pakistan.

* Domestic water and sanitation (e.g., numerous evaluations of the Intenational Decade, e.g., Cairncross, 1992; Edwards and Salt, 1993).

* Water pollution (Adler et al, 1993; Cohen, 1995; Rich and Moffitt, 1982); and water quality models (Lesht et al., 1991).

* Watershed projects (Maxwell, 1973; Ninan, 1998).

These general search results display few significant patterns. In historical and geographical terms, they reflect shifts in water development programs more than evolving strategies for long-term monitoring, evaluation, and decision-making. Analytically, they focus on economic impacts and, secondarily, environmental and other social effects.

This general search yielded many more studies than our initial list based on previous knowledge, but it identified only a few of the items on that list. We conclude that searching with the terms "ex post" and "post audit" is necessary but not sufficient for identifying detailed case studies of large dams.

*** Searches for detailed case studies of "dams" yielded many evaluations, but few that qualify as comprehensive, integrated, long-term, cumulative, or adaptive. Professor Gilbert F. White noted the large number of planning studies compared to ex post evaluations. Here we add that there appear to be more ex post evaluations of projects under construction (e.g., Three Gorges, GAP, and Sardar Sarovar) than of the long-term impacts of completed projects.**

Research on dam impacts includes a growing body of work on regulated rivers (e.g., see Ward and Stanford, 1979, and the journal *Regulated Rivers*). In broader terms, evaluation of projects under construction is perhaps the largest body of evidence that we identified. In addition to progress reports and assessments by funding and managing organizations, there are large scientific, journalistic, and activist literatures on large dams under construction. Today, these include the Sardar Sarovar, GAP, and Three Gorges projects. A decade ago, they included dams such as Itaipu, Kariba, Farakka barrage, and so on.

Taken together, these interim evaluations have become increasingly *comprehensive*, in terms of the range of issues addressed. They may also seem *adaptive* (i.e., by responding to and having an influence on project activities). But few of them are *integrated* or *cumulative*, and they are more likely to forecast than actually measure *long-term* impacts. Without these additional attributes, they seem unlikely to be truly *adaptive* for the peoples and places that are affected.

***An Example: The Glen Canyon Dam Adaptive Management Program*.**

An important exception to this general pattern is underway in the Glen Canyon Dam Adaptive Management Program on the Colorado River in the USA, which is using long-term monitoring and research to guide adaptive management of dam operations. This program, established in 1996, consists of stakeholder, technical, and scientific groups. The stakeholder group has defined a vision statement for the program, measurable dam management objectives, and policy guidance. The Grand Canyon Monitoring and Research Center, a science center, has drafted a long-term strategic plan and let initial contracts for monitoring and research on the downstream physical, biological, socio-economic, and cultural impacts of dam operations. The program intends to use an "ecosystem approach" to design, evaluate, and recommend adjustments in flow releases. The first "controlled flood," released in March 1996, was the subject of a detailed scientific evaluation (American Geophysical Union, 1999). Independent scientific review is provided by the U.S. National Research Council and science advisory panels.

The GCMRC publishes an annual State of the Canyon report, and hosts a biennial ecosystem science symposium. To identify and reduce data inconsistencies and scientific gaps in its predecessor program, the Glen Canyon Environmental Studies (1982-1995, U.S. Bureau of Reclamation, 1995; and National Research Council, 1987, 1991, 1996), it has commissioned integration reports on physical, biological and cultural resources

(Grams and Schmidt, 1999; Patten, 1998; SWCA, 1998; Valdez and Carothers, 1998). It has also commissioned a conceptual ecosystem model to identify key linkages and management alternatives.

The Glen Canyon Dam Adaptive Management Program thus aims to be comprehensive, integrated, long-term, and adaptive. It provides an excellent case study of the challenges embedded in those aims (National Research Council, 1999). For example, stakeholders identified 176 information needs for monitoring and research, which were *comprehensive* for some topics (e.g., sediment transport) but narrow for others (e.g., environmental economics). Despite major efforts at *integration,* gaps persist between the physical and biological programs, and between those programs and the fledgling socio-economic program. Good integration has been achieved between cultural resources monitoring and other programs, but sustaining meaningful tribal participation has been a concern. The Glen Canyon Dam Adaptive Management Program has not yet been fully integrated with related programs in the upper or lower Colorado River basins, including dam operations experiments at Flaming Gorge Dam—and thus has not yet encompassed *cumulative impact assessment* on a river basin scale. Although the program is designed to be *long-term*, it has concentrated on annual and 5-year cycles with less attention to the multi-decadal and centennial time scales associated with long-term impacts. The Grand Canyon Monitoring and Research program also strives to be *adaptive*. Thus far, it has responded effectively to stakeholder interests. It remains to be seen how well those stakeholder processes respond to changing ecosystem conditions and broaden the range of choice among dam operations and other water management alternatives.

Notwithstanding these limitations, the scope, aims, and accomplishments of the Glen Canyon Dam Adaptive Management Program to date are impressive. It has launched research and monitoring programs and made progress toward data integration and synthesis. The annual budgets for these activities are just over US$ 7 million per year, of which roughly US$ 5 million is spent on monitoring and research. Although some stakeholders expect this figure will decrease, others think it will increase. The first generation of experimental programs are often expensive, but these figures give a sense of the resources required in the US for ex post evaluation that involves detailed monitoring.

At the global scale, it is important to recognize that while Glen Canyon Dam and the other ex post evaluations discussed below offer useful models, they number in the 100s, which is small compared with the tens of thousands of large dams and hydropower facilities in the world. This fact should be kept in mind in the section that follows.

Regional Searches

***Our students searched for detailed case studies of completed water projects in**

different regions of the world. They purposely experimented with different terms and procedures, and the searches consequently were redone with more consistent methods. Most sources were identified in internet searches while others were added from bibliographies identified in those searches. Further searching is needed that focuses on on dam names as search terms and uses the *World Register of Dams* and WCD *Cross Check Survey* for sample design. We can therefore offer only illustrative examples of partial ex post evaluations along with preliminary observations about regional survey results:

1. In North America, there are large technical, scientific and activist literatures on the impacts of dams but only a few studies that aim to provide broad ex post evaluations. One doctoral dissertation focused on Libby Dam in Idaho, USA (Ciliberti, 1979). Macinko (1963, 1975) conducted a series of evaluations of the Columbia Basin Project, supplied by Grand Coullee Dam, which revealed the important roles of changing international markets, prices and technologies in project impacts. Macinko's 1975 paper was presented in an international symposium devoted to ex post evaluation within a river basin framework, sponsored by the U.N. Development Programme and National Water Authority of Hungary in 1975 (UNDP, 1975).

The Glen Canyon Dam Adaptive Management Program, described above, is perhaps the most comprehensive monitoring and evaluation of a single dam in the U.S. (National Research Council 1996, 1999; U.S. Bureau of Reclamation, 1995). Other dam-related evaluations in the upper Colorado River basin are underway at Flaming Gorge Dam and the Aspinall Unit (e.g., McAda, 1991); in the Upper Colorado River Basin Recovery Implementation Program; the San Juan River Basin Recovery Implementation Program; the Multi-Species Recovery Program in the Lower Colorado River; and emerging bilateral restoration efforts in the Colorado River delta. Evaluation of experimental flow releases for sediment transport and habitat restoration has occurred on other rivers, including the Trinity River in California (Wilcock, 1995).

A basin-wide program for adaptive management of a system of dams is underway in the Columbia and Snake river basins (National Research Council, 1996b; Independent Scientific Group, 1996; Northwest Power Planning Council [http://www.nwppc.org]; Volkman and McConnaha, 1993; and Weitkamp, 1994). In 1999, the Snake River program faced highly controversial dam operations decisions that were not resolved at the time of this report. The draft Focal Dam case study of Grand Coullee Dam and the Columbia River Basin (Ortolano, Cushing, et al., December 1999) presents a comprehensive, long-term, cumulative perspective. In addition to identifying cumulative environmental and socio-economic impacts, it calls for further integration, application, and refinement of cumulative impact assessment (ibid., p. 145).

Other important experiments in adaptive management are underway in the Upper Mississippi River, Platte River, Everglades, and California Bay-Delta regions. They involve, but are not primarily focused upon, dam operations (CALFED [http://calfed.ca.gov/]; Gunderson et al., 1995; and Natural Resources Law Center, 1997). The Tennessee Valley Authority (TVA) has a long record of both reservoir operation and institutional evaluations (Hargrove, 1994; Selznick, 1964; TVA, 1991;Yeager, 1992abc), though its future scope is unclear due to government and electric power industry restructuring. The U.S. Army Corps of Engineers also has dam and

reservoir operations research programs (e.g., Dickerson,1999).

Although not focused on dams, per se, a collection of ex post evaluation studies was edited by Gunnerson (1989) and published by the American Society of Civil Engineers (ASCE). One case study built upon a pioneering evaluation of U.S. Army Corps of Engineers programs in the Yazoo-Mississippi delta (Galloway, 1979). Another emphasized the contributions of historical research and specifically oral history (Rosen and Robinson, 1989). White et al. (1958) evaluated the impacts of the Flood Control Act of 1936, which included dams, levees, and non-structural actions, on urban floodplain occupance twenty years later. With a few important exceptions (Jackson, 1995; Kollgaard and Chadwick, 1988; and Schneiders, 1997), there has been limited connection between historical research and ex post evaluation.

The ASCE (1997) has published guidelines on the retirement of dams and hydroelectric facilities, and evaluation is planned for recently decommissioned dams on the Elwha River in Washington state (U.S. Bureau of Reclamation, 1996). Espeland (1998) conducted a detailed case study of Orme dam, in Arizona, which was not built. Detailed evaluations are also undertaken during relicensing of hydroelectric facilities (Natural Resources Law Center, 1997). Indeed, more detailed searching is needed in the Federal Energy Regulatory Commission's *Records and Information Management System* (RIMS), which archives the Office of Hydropower Licensing's "Operations Reports," "Environmental and Public Use Inspection Reports," and compliance audits for the more than 1,000 licensed hydropower plants in the U.S. (http://rimsweb1.ferc.fed.us/rims/).

Until 1992, the U.S. Bureau of Reclamation collected annual *Summary Statistics* of land and water resources related to its reservoir and irrigation projects. Surveys of river basin development and policy have also provided a long-term perspective on hydropower development and impacts (President's Water Resources Policy Commission, 1950; Driver, 1997). Sustaining these regular and episodic programs of data collection and compilation is important for long-term ex post evaluation.

In addition to bilateral evaluations, e.g., Great Lakes water quality conditions, Canada has addressed a broad spectrum of environmental and social issues associated with hydropower development in British Columbia, Ontario, Quebec and other provinces (Froschauer, 1993; KGS Group, 1991; Manore, 1995; Rangarajan, 1996; Smith, 1982). James Bay Hydroelectric projects and other dams have been the focus of ethnographic evaluations of Indian claims (Bellegarde, 1997; Prentice, 1998; Waldram, 1983). Six important studies of potential environmental, social, and institutional impacts of the Great Whale project in Quebec, and ex post evaluations of the planning process, were identified (Alfonso and McAllister, 1994; Great Whale Public Review Support Office, 1993ab; Maxwell, Lee, Briscoe, and Suzuki, 1997; Poslums, 1993; and Mulvihill, 1997). Although our initial survey identified several detailed doctoral dissertations, such as Mulvihill's (1997) study of the Great Whale Project and the need for facilitation of "interparadigmatic dialogue", we suspect that a much larger literature of government and hydropower industry relicensing evaluations is also available.

2. In Central and South America, we found no comprehensive ex post evaluation of a major dam and related river basin project. Lee (1990) conducted a comparative evaluation of "management performance" in four projects in Mendoza, Argentina; the Bogata River valley, Columbia; the Tinajones Irrigation project in Lambayeque, Peru; and the Limari River valley, Chile. These projects included reservoir storage. Although the analysis did not consider dam impacts in detail, it did present a framework for comparing "internal" and "external" factors affecting management performance, which is useful for cumulative impact assessment. The International Lake Environment Committee (1994) convened a comparative workshop on the regional social and environmental effects of reservoir development in the La Plata River basin.

We identified a concentration of individual dam-related studies in the Brazilian Amazon. Doctoral dissertations and masters theses, which generally have limited circulation, are an especially important source of detailed evaluations (e.g., Biery-Hamilton, 1994; Ferradas, 1990; Ledesma, 1996; Lemos de Sa, 1995; Ribeiro, 1988; and Viana, 1997). Non-governmental organizations (such as IRN, Cultural Survival, Witness for Peace, and GATE) offer broader critiques.

Analyses of social impacts have focused on the Tucurui dam and related projects in Belem, Brazil (Biery-Hamilton, 1987); the Xingu River in Brazil (Cultural Survival, 1990); the Itaparica dam project (Horgan, 1999; World Bank, 1998); and the Sobradinho Hydroelectric project on the San Francisco River (Lima-Daou, 1994/1996). MacDonald (1989) examined social aspects of the Uruguai River basin project effects over the ten-year time frame of 1979-1989. Ferradas (1990) examined how communication processes shape impacts in the Yacyreta Hydroelectric dam relocation process. An institutional analysis (Ribeiro, 1988), on the Yacyreta Hydroelectric High Dam in Argentina and Paraguay on the Parana River focused on how a consortium of state corporations, consultants, and contractors affect local people. Case studies of resistance to dam impacts in Brazil include Cummings (1995) and Cultural Survival (1990).

Our initial survey identified few evaluations in Central America, so we conducted a search in seven electronic databases for the seven Central American dams listed in the World Commission on Dams Cross-Check Survey: the Arenal dam in Costa Rica, Maguaca dam in the Dominican Republic, Cerron Grande dam in El Salvador, Chixoy dam in Guatemala, Morazan dam in Honduras, and Bayano and Fortuna dams in Panama. This search yielded planning and evaluation reports of the Chixoy hydroelectric project in Guatemala (Goodland, 1974; Hernandez Sanchez, 1986; Partridge, 1983; and Stewart,1995). The Partridge (1983) study compares the Chixoy and Arenal projects; and we found a series of other publications that assess economic, institutional, and downstream hydrologic effects of the Arenal project in Costa Rica (Aylward, 1998; Aylward, Echeverria, and Barbier, 1995; Aylward and Fernandez-Gonzalez, 1998; and de Wet, published in Cernea and Guggenheim, 1993). Several studies evaluate resettlement programs in Mexico (Gates, 1988; Hemond, 1994; Partridge, Brown, and Nugent, 1982). A doctoral dissertation on the Bayano hydroelectric complex in eastern Panama assessed local social, political, and economic consequences of that project (Wali, 1984).

Several conferences have drawn together groups affected by dams in different parts of the

region (e.g., Stanley and Alpers, 1975; Man-Made Lakes and Human Health, 1977; and an International Meeting of People Affected by Dams, 1997, sponsored by the International Rivers Network).

Evaluations of environmental impacts in South and Central America include Paiva (1977) on reservoirs in Brazil; and Braga, Rocha, and Tundisi's (1998) survey of environmental impacts in Brazil. More specific environmental impact studies include the effects of Samuel Hydroelectric Dam on birds and mammals in Brazil (Lemos de Sa, 1995, on the Samuel Hydroelectric dam); downstream effects on fish in the Jamari River of Brazil (Viana, 1997); and "greenhouse gas" releases from Brazilian reservoirs (Fearnside, 1995). One study sought to integrate hydrologic, aquatic, and riparian environmental impacts in the Parana Basin (Bonetto, Wais, and Castello, 1989). Another study (Ledesma, 1996) examined the economic and hydrologic benefits of watershed management for reservoir sedimentation management in the Aguacate reservoir in the Dominican Republic.

Several studies have sought broad coverage of environmental, economic, and social impacts in South America (e.g., Kohlhepp, 1987, on Itaipu dam on the Rio Parana; and Biery-Hamilton, 1994, at the community scale). For the most part, our preliminary survey did not identify comprehensive, integrated, adaptive or long-term case studies. The LIMA (2000) focal dam case study of the Tucurui hydropower complex includes interactive and cumulative effects at multiple scales. With few exceptions, the literature cited above (as in most regions) suggests that there are major gaps between hydrologic, economic, social, and environmental evaluations. Fragmentation of issues is discussed critically by Cummings (1995) in a case study of Balbina Dam in Brazil.

3. Our survey of Africa was selective. Several examples and patterns of ex post evaluation are noted below. First, there seems to be a larger comparative literature on dams and reservoirs in Africa than in other regions (e.g., Adams, 1992; Durkoh, 1992; Lagler, 1969; Obeng, 1969; Rubin and Warren, 1968; Scudder, 1988; Sharma, 1996; White et al., 1972; White, 1975; Woolridge, 1991). Secondly, evaluations of African dams seem to have been more closely related to, and complemented by, evaluations of river basin development and establishment of reservoir research stations than in other regions (e.g., Kainji Lake Research Project, Nigeria; Lake Kariba Fisheries Research Institute, Zambia and Zimbabwe; Lake Nasser Development Centre, Egypt; and Volta Lake Research Project, Ghana).

Several evaluations of the High Aswan Dam in the Nile River basin extend beyond the dam and reservoir to encompass at least the lower basin (e.g., Abu-Zeid and El Shibini, 1997; ICOLD, 1993; Smith, 1982; Walton, 1981; and White, 1988). Broader assessments of Nile River basin development include dam impacts (e.g., Anstey and Shady, 1991; El Moattasen, 1992; Allan and Howell, 1994). Further upstream, the Gezira scheme and Jonglei canal projects have received broad reviews (Barnett, 1991; Howell et al., 1988).

West African dams and associated developments have been surveyed in Grove (1985). Evaluations of the Volta River Project include pioneering studies of resettlement and

environmental impacts (Ackermann et al., 1973; Chambers, 1970; Hart, 1980; Obeng, 1977). Impacts of Manantali and Diama Dams on floodplain agriculature in the Senegal River basin, and experimental releases, have been the subject several detailed investigations as well as a monitoring program (Hollis, 1990; Horowitz, et al., 1990; Koenig, 1988; LeMarquand, 1990; Paduart, 1992; and Scudder, 1991). Individual studies of downstream floodplain impacts in Nigeria include Adams (1985) and Thomas (1996).

East African dams and reservoirs have received comparative attention (Roggeri, 1985), as well as studies of individual projects, e.g., on the Tana River in Kenya (Hughes, 1984).

Evaluations of impacts in southern Africa include broad appraisals of the Kafue and Kariba dams in the Zambezi River basin (Ackermann et al., 1973, pp. 132-69; Howard and Williams, 1978; Scudder, 1993; and most recently the focal dam case study by Soils Incorporated, et al., 2000); the Southern Okavango Integrated Water Development Project (Scudder et al., 1993); as well as individual studies of dam failure in South Africa (Wagener et al., 1997); and downstream ecological effects in the Buffalo River (O'Keefe and Palmer, 1990). The Lesotho Highlands Water Project has received some of the most extensive documentation, especially of an international hydropower project, which include publications by panels of experts, consulting reports, and doctoral dissertations over the past decade (e.g., Coopers & Lybrand, 1989; Hunting-Consult 4 Joint Venture, 1997; Kalinga, 1999; Thoalane, 1991; United Nations Development Programme, 1995; and Wallis, 1993). The Lesotho Highlands Development Authority and related agencies have compiled volumes of publications on the project and its impacts (Lesotho Highlands Development Authority, 1990, 1996, 1997; Lesotho Highlands Water Project, 1990, 1996; and Lesotho National Environment Secretariat, 1995).

4. One distinctive contribution of evaluations in the Middle East, is their emphasis on geopolitical causes and consequences of dams and related water development. Although not focused on individual dams, the literature on Middle Eastern international water politics, conflict and cooperation addresses the broad international context of water development and may have relevance for other regions (e.g., Biswas et al.,1994; Kolars and Mitchell, 1991; Lonergan and Brooks, 1994; Lowi, 1993; Murakami, 1995; Naff and Mattson, 1984; Waterbury, 1979; Wolf, 1995).

Substantive investigations include an ex post evaluation of the lower Seyhan project (Benli et al., 1988). The WCD draft case study of the Aslantas Dam and Ceyhan River basin provides a broad evaluation of projected and actual effects and includes a chapter on interactive, cumulative and basin-wide impacts, which are important steps toward ex post evaluation, though the study notes the absence of an integrated basinwide approach (Agrin, December 1999). Other dam impact studies in the Tigris and Euphrates basins include Al-Himyari (1984), Al-Layla, et al. (1990), Al-Taiee (1990), Kolars and Mitchell (1991), and Beaumont (1996). Further searching is needed on dam impacts in Turkey (e.g. Hay, 1994; Soyupak et al., 1994) and Iran, which have major dam construction programs.

Although not focused on dams, other recent studies and resources on Middle Eastern

water provide useful baseline information and frameworks for future evaluations (e.g., the MEWIN database at the University of Pennsylvania; and the Committee on Sustainable Water Supplies for the Middle East, 1999). To our knowledge, MEWIN is the first attempt to systematically archive technical consulting reports and government publications, as well as scientific books and articles.

5. We did not search systematically in Europe and the former Soviet Union, but several broad surveys and examples of partial ex post evaluations were identified in our initial survey (cf. ICOLD, 1990). For example:

Environmental evaluations have been prepared for the Ridracoli Dam, Italy (Grillenzoni, et al., 1994; and ICOLD, 1995); Gabcikova-Nagymaros hydropower project (Kozova, Lisicky, and Micklos, 1994; Vranovski, 1997); the lower Ebro River (Canicio, Ibanez and Prat, 1996); and the lower Drava (Bonacci, Tadic, and Trninic, 1992). Loughborough University in Britain has helped pioneer research on regulated rivers (e.g., Petts, 1984).

The experiments of Nordic and European countries in adaptive management of hydropower facilities are comparable with the North American case studies discussed above, and they warrant detailed assessment (e.g., using documents of the Norges vassdrags—og energidirektorat; http://www.nve.no; T. Ziegler, pers. comm.). The role of Nordic countries in international hydropower projects is reviewed in *Dams as Aid* (Usher, 1997). One thesis examined different community responses to dams in northern Finland (Eilitta, 1986).

In Russia, impacts on the Volga river are reviewed by Paraboutchev and Larionov (1996) and operation of Sayano-Shushenskoe hydropower complex by Bryzgalov (1994).

In a fascinating reconstruction of long-term ecological and economic evaluation, Glantz et al. (1999) have documented what was known about effects of water development in the Aral Sea basin, which included dams as well as other facilities, and what difference that knowledge made for water management decisions in the region. Their study suggests that the Soviet scientific literature on the effects of dams was much larger than what is reflected in recently published western European-language sources.

6. Evaluations in East and Southeast Asia include, as noted earlier, a growing literature on projects under construction such as the Three Gorges Project (Dai Qing, 1998; Whitney and Luk, 1993). The Three Gorges case underscores the importance of searching for ex post evaluations in Chinese, the results of which are presented below in App. B (Liu, 1999). The reported nationalist aims of dam construction in China (Jun-Jing, 1997; Yin, 1996) has parallels in many other regions of the world, but to our knowledge there has been little analysis of the *actual effects* of dam construction on nationalist sentiments and other political and cultural attitudes.

Japan initiated a reservoir monitoring and "Follow-up System," in 1997 (described in the WCD Thematic Review, Options Assessment IV.5, *Operations, Monitoring and*

Decommissioning of Dams, March 2000 draft) (see also Ikebuchi, Okada, and Sakakibara, 1998, on reservoir policies and evaluations related to dams in Japan).

In Southeast Asia, there have been several partial ex post evaluations of the Nam Pong dam in Thailand, the Lam Pao dam in northeast Thailand, the Srinagarind Dam in Thailand, and the Nam Theun dam in Laos (Committee for Coordination of Investigations of the Lower Mekong Basin, 1992; Manat, 1982). Aditjondro (1993) has analyzed media representation of dam impacts in Indonesia. This search revealed some of the errors inherent in bibliographic methods when it identified an ex post evaluation for Pa Mong Dam, which has not yet been built (Wu, 1983).

The literatures on the impacts of projects in the Murray-Darling river basin in Australia (e.g.. Benniston, et al.,1989) and Clutha River in New Zealand (Reeves, 1994) are similar in scope and disciplinary foci to those of Europe and North America. An interesting, albeit brief, comparison was made of dam projects in Australia, New Zealand, and British Columbia (Sewell, 1987).

In addition to these ex post evaluations of individual dams, there is a rich literature on Mekong river basin management (Hori, forthcoming; Jacobs, 1995; Lacroze, 1998). Indeed, as Jacobs (1992) suggests, much of the Mekong Committee's non-structural achievements in hydrometeorological, flood forecasting, and international coordination occurred *in lieu* of the mainstem dam construction that was originally envisioned, which may represent an interesting opportunity to compare structural and non-structural approaches.

7. In South Asia, there have been important ex post evaluations of the hydrological and social impacts of dams. Evaluation of the social and economic impacts of dams goes back to the late 1950s and early 1960s in India (Singh and Singh, 1959, 1965). The WCD draft country study for India (March 2000) notes the absence "post-facto monitoring and assessment", which has limited an understanding cumulative economic and environmental impacts.

As in China, many evaluations focus on projects that are planned or under construction, such as the Narmada River projects in India (Morse, et al., 1992). The Narmada projects have yielded important case studies of the complex dynamics of social impact evaluation by government agencies; local, national, and international non-governmental organizations; and marginalized groups (Baviskar, 1992; Dreze, Samson, and Singh, 1997; Ali-Bogaert, 1997).

The impacts of involuntary resettlement and other social changes have been examined in other states, such as Orissa (Baboo, 1991, 1992; Patnaik, 1989); Gujarat (Gumber, 1992); Aurangabad, Madhya Pradesh (Joshi, 1982); Andhra Pradesh (Sawant, 1985); Goa (Paranjpye, Bholnekar, and John, 1991).

Historical perspectives on dam development in India have been conducted for the Cauvery River basin (Michael, 1979) and the Periyar Dam (Mohanakrishnan and Verma, 1997).

There is a long record of geotechnical investigations by the Geological Survey of India, e.g., on dams in Rajasthan (Kasliwal, 1992); the Kerala Bhavani Hydroelectric Project, Palghat District, Kerala; the Gundlakamma Reservoir Project, Prakasam District, Andhra Pradesh; Tenughat Dam Project, Hazaribagh District, Bihar; and the Cheyyeru Dam, Cuddapah District, Andhra Pradesh.

Partial ex post evaluations related to Bangladesh have included Farakka barrage (Begum, 1987; Sinha, 1996); the Flood Action Plan (Rogers, et al., 1994); the Chandpur Irrigation Project (Hirst and Ibrahim, 1996; Mirza and Ericksen, 1996; Thompson, 1989); and evaluations of water supply and sanitation programs of the International Centre for Diarrhoeal Disease Research.

Nepal has many dam planning studies and environmental impact assessments but few long-term case studies of completed dams (e.g., of the Kosi and Gandak projects). As in other countries and regions surveyed here, there are a larger number of evaluations of completed irrigation and water and sanitation projects (e.g., Lam, 1994; Ostrom, Lam, and Lee, 1994).

We found only a few ex post evaluations of individual dams in Sri Lanka, but a much richer evaluation literature on river basin development projects that include dams, especially the Gal Oya and Mahaveli projects. Evaluations of Gal Oya river basin development have included a retrospective analysis of multiple projects and generations of settlers, based on field notes, participatory processes, and remote sensing (Uphoff, 1992; see also Abeyratne, 1982; Amarasinghe, 1998; Jayasekara, 1987; Murray-Rust, 1983; Perera, 1991; and Wijayaratna, 1986).

Two studies evaluate the social and environmental effects of the Kotmale dam and hydropower project in the Accelerated Mahaveli Development Programme (Gildestad, 1990; Hanneson, 1989). Evaluations of the Mahaveli Ganga Programme (incl. the Kirindi Oya project) have encompassed broad issues of watershed change, cropping practices, land tenure, resettlement, gender, conflict, malaria, and project administration (e.g., Karunaratne, 1991; Karunatilake, 1995; Sorenson, 1996; The Blurring of a Vision, 1995; USAID reports; Ulluwishewa, 1991; Zoysa, 1995).

Pakistan has contributed a large evaluation literature on Indus basin development (e.g., Ahmad and Kutcher, 1992; Duloy and O'Mara, 1984; Lieftinck et al., 1968; Michel, 1968; Water Sector Investment Planning Study, 1990). As indicated in the case study below, there has been less research on the social and environmental impacts than on technical and economic assessment of Indus basin dams.

5. TARBELA AND INDUS RIVER BASIN CASE STUDY

*** Tarbela Dam is a major component of the Indus Basin Development Program, initiated by the Indus Waters Treaty of 1960. Comparison of draft bibliographies for this report and the WCD Focal Dam case study for Tarbela Dam indicate that neither the scientific nor project literatures circulate efficiently among the groups who need them.**

This search is more detailed and systematic than those described above, and the results were reported in a separate *Appendix C -- Tarbela Dam Bibliography* for the benefit of the WCD Focal Case Study group. The search examined the following databases: Applied Science and Technology, Article1st, BLDS, Cambridge biological sciences, Dissertation Abstracts, EiCompendex, Environment, Geobase, Georef, USAID-DEXS, Water Resources Abstracts, Web of Science, World Bank JOLIS, Worldcat.

Our bibliographic search identified a large technical literature on Tarbela Dam, which concentrates on seismology, geotechnical studies, reservoir sedimentation, slope stability, and environmental effects of sedimentation (see Appendix C). Our search yielded few environmental studies and no published evaluations of resettlement impacts. This suggests that there has been no comprehensive, integrated, long-term, or adaptive ex post evaluation of Tarbela Dam to date.

However, there is a significant literature on Tarbela Dam's contributions to and context within the broader program of Indus basin development, and thus at least some of its cumulative impacts (e.g., Asianics Agro-Dev. International (Pvt) Ltd., December 1999). The literature on Indus basin development is very large (for a review see, Wescoat, Halvorson, Mustafa, forthcoming 2000; Wescoat, 1999). Indus basin modelling efforts incorporate and simulate the impacts of Tarbela within the larger Indus basin system (e.g., Ahmad and Kutcher, 1992; Duloy and O'Mara, 1984; Lieftinck et al., 1968; Water Sector Investment Planning Study, 1990 [these Indus basin references are listed in the general South Asia bibliography section below while Tarbela Dam references are reported in Appendix C]). Although little of this Indus basin literature focuses on the environmental impacts of Tarbela dam, it does provide useful economic information for cumulative impact assessment.

Finally, the Tarbela Dam search indicates the type of results that can be obtained with systematic bibliographic search procedures that focus on an individual dam. A comparison of the draft bibliographies for this report and the Tarbela Dam focal case study (which were produced independently) shows that both studies identified the major Indus basin development reports (e.g., Duloy and O'Mara, 1984; and Lieftinck et al., 1968). The Focal Dam case study draft identified a much richer body of evaluation reports by the Water and Power Development Authority and World Bank than this study. Those project reports supported its analysis of "post-Tarbela" effects (Asianics Agro-Dev. International (Pvt) Ltd., December 1999). Interestingly, the focal dam case study cited few of the scientific and technical studies identified in this report (Appendix C). Although there are several plausible explanations for these different patterns of citation, they suggest that scientific publications and internal project reports may not be circulating efficiently even among groups who need and actively search for them.

CONCLUSIONS AND RECOMMENDATIONS

It seems likely that additional searching for literature on dams in the World Register of Dams and Cross Check Survey, would yield a wealth of partial ex post evaluations of dam

impacts. But it also seems likely that few of those evaluations would prove to be comprehensive, integrated, long-term, cumulative or adaptive. Such findings have five main implications:

- First, further bibliographic searches, along the lines outlined above, are needed to reconstruct past impacts and monitoring baselines for specific dams and river basins. A reference set of dams should be identified for long-term monitoring and evaluation.

- Second, a coordinated international scientific and institutional effort is needed to improve access to and use of previous evaluations through electronic archiving and cataloguing. Access must be improved for all social groups.

- Third, improved use entails synthesis of data and findings drawn from disparate sources, which will help determine "Best Practices" of ex post evaluation.

- Fourth, to reduce the need for painstaking reconstruction and synthesis in the future, a coordinated international strategy and resources are needed to implement comprehensive, integrated, long-term, cumulative and adaptive evaluations.

- Fifth, priority should be given to appraising the actual use and usefulness of ex post evaluations for the peoples, environments, and landscapes associated with them. These appraisals should involve operating agencies, non-governmental organizations, and independent scientific groups.

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APPENDIX A: Bibliographic Search Procedures And Forms

This memo describes the original bibliographic search instructions used in this project. The FAO On-line search forms and Library Search Forms are attached. As the initial results varied in reliability and consistency, most of the searches discussed above were redone. However, the information search and management techniques may be still be of interest. Students were given the following instructions:

Preparation

1. Read the background memo on **Designing the Search for Case Studies**.

2. Fill out the four key word sections of your **FAO On-line search form**. Identify 10-15 key words in each section. Then choose what you believe will be the 2-4 most important key words in each category. You may wish to add the words "ex post" and "post audit" to your list.

3. Make 6 copies of the **Library Search Form**.

4. List pairs of key words that you will search on the **Library Search Forms**.

5. Buy several IBM disks to download your search results.

Required Library Searches

1. WorldCat = comprehensive book catalog. From the Chinook web page, click on Article Access, then FirstSearch, then Gold, then WorldCat. Search by "subject".

2. Dissertation Abstracts = doctoral dissertations. From Chinook, click on Article Access, then FirstSearch, then Silver, then Diss.

3. Water Resources Abstracts = specialized water library. From Chinook, click on Article Access, then Silver Platter Science Files; then the 2 Water Resources Abstracts boxes; then add your search terms; and display results.

4. GEOBASE = specialized geography database. Follow same instructions as for Water Resources Abstracts.

5. BLDS = specialized economic development library. Start at htt://www.ids.ac.uk/ Click on BLDS Bibliographic Database, then Search.

Additional Library Searches

Search **ONE** additional libraries relevant to your topic or region (e.g. AGRICOLA or CABI for irrigation; AFSA for fisheries; MEDLINE for health and sanitation; LAWPAC or UN Treaty

Index for law; HAZARDS for floods and droughts; ENVIRONMENT or BIOSIS for environmental impacts; ECONLIT for economic impacts; etc.).

Results

1. Record the number of "hits" for each key word search on your **Library Search Form**.

2. For results of less than 10 hits, print your results. For 10 to 100 hits, delete items that are clearly irrelevant, then download the remaining, potentially important, case studies to a diskette. Give the file a name, and record the file name on your **Library Search Form**.

3. Use the following criteria to select up to 10 citations from each of the 6 libraries you searched as potentially important case studies (no more than 60, or less than 20, references):

a. Is it a "detailed" study (e.g., book or long article based at least in part field research on rather than short article or editorial)?

b. Is it an "academic" study (e.g., published by a scholarly press or peer-reviewed science journal rather than a newspaper or popular press).

c. Does it focus on a "specific" water policy, project or program (rather than general water development or, for example, irrigation projects).

d. Does it evaluate the "actual consequences" of that water policy, project or program? That is:

i. The economic, social, and/or environmental consequences.

ii. The consequences of "completed," rather than "planned," policies, projects, or programs.

4. Print out your list of 20 to 60 references. Make two copies, one for yourself and one for a 3-ring Working Group notebook. Also keep your library search diskettes in that notebook.

APPPENDIX B: Selected Search Results -- Chinese Books On Three Gorges Dam (Liu)

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