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The Large Dam Dilemma

An Exploration of the Impacts of Hydro Projects on People and the Environment in China

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Preface

Published in 1987, the Brundtland Report, Our Common Future, culminated over 2 decades of concern and debate about environmental degradation and human welfare and posed a challenge for societies worldwide to seek sustainable approaches to development. Solutions to the Earth's most difficult and recalcitrant environmental problems were identified as falling at the nexus of the scientific disciplines, which set the agenda for developing interdisciplinary approaches to research and development that continues today. The relatively simplistic notion of "interdisciplinarity" promoting the optimization of environmental, social, and economic needs has now been replaced by the more complicated and realistic concept of "coupled human and natural systems (CHANS)." The CHANS theory approach interconnects human activities and ecosystem functioning and acknowledges the true complexities facing environmental conservation and sustainable development in the twenty-first century.

Meeting the needs of a growing human population for economic development without compromising the long-term integrity of the environmental foundation for all life is the essence of society's search for sustainable development strategies. Among the many environmental challenges facing humankind, including global climate change, deforestation, rangeland degradation, energy production, and loss of biodiversity, those related to the globe's water resources are perhaps the most acute. People sicken and perish and nations stagnate and decline without adequate supplies of clean freshwater. Many believe that water may have already replaced oil as the Earth's most precious and endangered liquid and that the formation of international "water cartels" to control its distribution is not far off.

Water and energy come together in the building of large dams intended for the generation of hydroelectricity. Often termed "clean energy" large-scale hydropower projects are not without their sustainability critics. While it is difficult to counter their ability to produce efficient and effective power in the service of national economic development, the construction of dams and power stations are also known for their negative environmental impacts and mixed effects on the socioeconomic conditions of local people. Hence, it is not surprising that proposals promoting the construction of major hydroelectric dams often face public and scientific scrutiny that sometimes leads to widespread civil unrest, protests, and legal and political repercussions. Understanding the social, economic, and environmental impacts arising from large-scale hydro-projects is a much-needed step toward sustainable development, not as a deterrent to their construction, but as a means for reducing their potentially negative effects.

I am very pleased to see the publication of this timely and informative book, The Large Dam Dilemma: An Exploration of the Impacts of Hydro Projects on People and the Environment in China. I congratulate the authors for their presentation of new research findings from a recent study mainly on the Upper-Mekong River, and their synthesis of other investigations of large dams elsewhere in China. China is currently leading the world in the construction of large-scale dams and it is most appropriate that China also takes the lead in helping improve the sustainability of such important hydro-projects. This book provides a compendium of information and insights that will prove valuable during the planning phase for such projects worldwide. I highly recommend it to scientists, planners, government officials, and public organizations concerned about the protection and sustainable development of the Earth's fragile water resources.

Beijing, People's Republic of China — Hao Wang

Academician, Chinese Academy of Engineering
Professor, China Institute of Water Resources
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Abstract

Large dam construction has significant environmental and social impacts at different scales. This book first summarizes and updates information about the history, distribution, functions, and impacts of large dams, both globally and at China's national level. It then addresses the environmental and social impacts of large dams in China and introduces an empirical study conducted during 2010 in areas affected by dams along the Upper-Mekong River, China. We present innovative methods for assessing the impacts of dams on biological diversity at the watershed scale and impacts on ecological integrity of rivers at the ecosystem scale. Then we developed a framework to assess the impacts of dam construction on different dimensions of wealth of dam-affected households, namely material (land, houses), embodied (knowledge, skills), and relational (infrastructure) wealth; and compare losses and compensations for each dimension. Results indicated that large dam construction has significant negative impacts on biological diversity and ecological integrity; local communities often suffer from wealth loss in all three characterized dimensions, but government compensation policies typically consider only material wealth; and this inequity leads to dissatisfaction on both sides and is the root cause for disagreements and conflicts. These results will prove important to future dam projects in China, and possibly elsewhere, as they suggest that more comprehensive environmental and social impact assessments are needed for large dam projects, and less dissatisfaction will arise from community relocation projects when the affected villagers and decision-makers acknowledge and agree on the degree of losses and resulting compensations in all three dimensions of wealth.

Keywords Large dam • environmental impact • social impact • biodiversity • resettlement • compensation policy

Introduction: The Large Dam Dilemma

Food, water, and energy, three of the most critical issues for human development, are all connected with one facility—large dams. By International Commission on Large Dams' (ICOLD) definition, large dams are those with heights over 15 m (WCD 2000). It is estimated that 30–40 % of irrigated land around the world relies on dams, and irrigated land contributes approximately 40 % of the world agricultural production (WCD 2000; Shah and Kumar 2008). Large dams also have guaranteed water security in many urban and industrialized regions, with reports showing high positive relationships between dam density and water security level (Vorosmarty et al. 2010). They have also been used as an important way to control floods, and presently about 13 % of existing dams have flood control functions (WCD 2000). Electricity generation is another important reason for building large dams, and about 19 % of electricity worldwide is generated by hydropower dams; in 63 countries, hydropower supplies more than 50 % of the electricity (WCD 2000).

Even though large dams have been used as a means of development for a long time, they also have caused various environmental and social problems at different scales. Dams block water and alter natural flow regimes of rivers, which has significant impacts on river ecosystems and fisheries (Poff et al. 1997); the reservoirs formed after dam construction submerge farmland and terrestrial ecosystems (WCD 2000); and dams change the geological conditions of reservoir areas, having the potential to trigger landslides and earthquakes (Kerr and Stone 2009; Pandey and Chadha 2003; Deji 1999). In addition, the negative social consequences of large dams include the effects of millions of people being relocated or displaced, uneven benefit and cost distribution among different groups, and impacts on indigenous and tribal people and their cultures (Égré and Senécal 2003; Tilt et al. 2009).

After the rise of environmentalism (1960s), and especially after the concept of sustainable development became prevalent (1980s), the benefits and costs of building dams are now more comprehensively scrutinized. People first began to question the rationale for using large dams to promote development in the 1970s, and the dam debate intensified worldwide during the 1990s. Since, the rate of dam construction has slowed markedly in developed countries, and in the United States, the rate of decommissioning old dams actually exceeded the rate of construction by 1998 (WCD 2000). However, in developing countries, there are still many large dams under construction or being planned.

Chinese experience in dam construction is largely consistent with the rest of the world (Wang et al. 2013a). China's large dam construction began in the second half of twentieth century, when modernization and developmentalism became the dominant ideologies globally. Large dams became a symbol of reconstruction and development and were used as means for river basin development, flood control, and electricity generation. But because of China's socioeconomic and political peculiarities, Chinese dam construction has its own unique characteristics. As the most populous nation and the second largest and fast growing economy in the world, China has built more large dams than any other country. While the anti-dam movement is increasing in developed countries, China is still ambitiously developing hydropower as part of its long-term national plan. The environmental and social impacts of dams and the involvements of markets and civil society in the decision-making processes for dam construction in China also have different features. Hence, research on Chinese dam issues has both national and global significance.

The future of large dams in the world and in China remains unclear, with many pertinent questions. For example, do we still need to rely heavily on dam-irrigated agriculture, or can applying water-saving technologies and using drought-resistant agricultural crops avoid global food crises? Should we continue to control floods with hydrologic engineering methods, which change the natural features of rivers, or do we appeal to more fundamental approaches, such as restoring degraded environments and reestablishing natural flow regimes? Is hydropower a renewable and clean alternative for fossil fuels, or does energy from dammed rivers have even higher environmental and social costs?

Comprehensive answers to these major questions are beyond the scope of this book, but we hope that our interdisciplinary assessment of large dams in China and elsewhere will identify pathways for doing so. Our approach is to review and synthesize environmental and socioeconomic information about large dams at different scales, including our own recent research on the Upper-Mekong River (Lancang River) in China (Wang et al. 2013a, b; Li et al. 2012a, c, 2013; Zhao et al. 2012a, b, c). We begin by providing a global perspective on large dams, including arguments from both sides of the ongoing debate over their construction (Chap. 1). We then turn our attention to large dams in China by first providing an overview and case studies (Chap. 2) followed by detailed assessments of their environmental (Chap. 3) and socioeconomic (Chap. 4) impacts. Having identified key points to consider when planning the construction of large dams, we conclude with a discussion of how the large dam debate is evolving into decision-making policies in China (Chap. 5). In sum, we hope that this book is a modest, but useful step toward identifying final solutions to the large dam dilemma worldwide.

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Contents

Chapter 1
A Global Review of Large Dam Construction

1.1 History and Distribution of Large Dams in the World

The history of dam construction is as old as human civilization. In ancient Chinese mythology, the legendary tribal leader, Yao, assigned one of his subordinates, Gun, to lead the people to fight a great flood. Gun built dams to block the flood, but they broke and caused an even larger disaster. As punishment, Yao's successor, Shun, killed Gun, and then assigned Gun's son, Yu, to lead the fight against the flood. Yu removed the dams and other barriers blocking the river, allowing the water to flow freely to the ocean, and finally overcame the flood. This story shows the long history of the impacts of dam construction on attempts to control the flow of rivers.

The remains of dams dating back to 6000 BP have been found in Mesopotamia; and irrigation and water supply dams became widespread in many parts of the world by 2000 BP (WCD 2000). The oldest continuously functioning dam is likely one associated with the Dujiangyan Irrigation Project in Sichuan Province, China, which was built in 256 BP and is still providing irrigation water for a large area of farmland on the Chengdu Plain (Zhang and Jin 2008). The first hydropower dam in the world was built about 1890 in the United States (WCD 2000).

Before 1900, there were only about 700 large dams worldwide (Fig. 1.1). Most of the large dams currently in existence were built during the twentieth century. About 5,000 large dams were built during the first half of the century, three-quarters of them in developed countries. Dam construction rapidly increased globally after the Second World War, with the peak occurring between 1970 and 1975, when nearly 5,000 large dams were built worldwide. The rate declined after the 1980s in most parts of the world, especially in North America and Europe (Shah and Kumar 2008; WCD 2000).

According to the World Bank, countries represented by the Organization for Economic Co-operation and Development (OECD) have already developed 70 % of their economically feasible dam potentials, while developing countries are only using 30 % of their potentials. Strikingly, less than 10 % of the potential has been exploited in Africa (World Bank 2009). Since developed countries have built dams on most of

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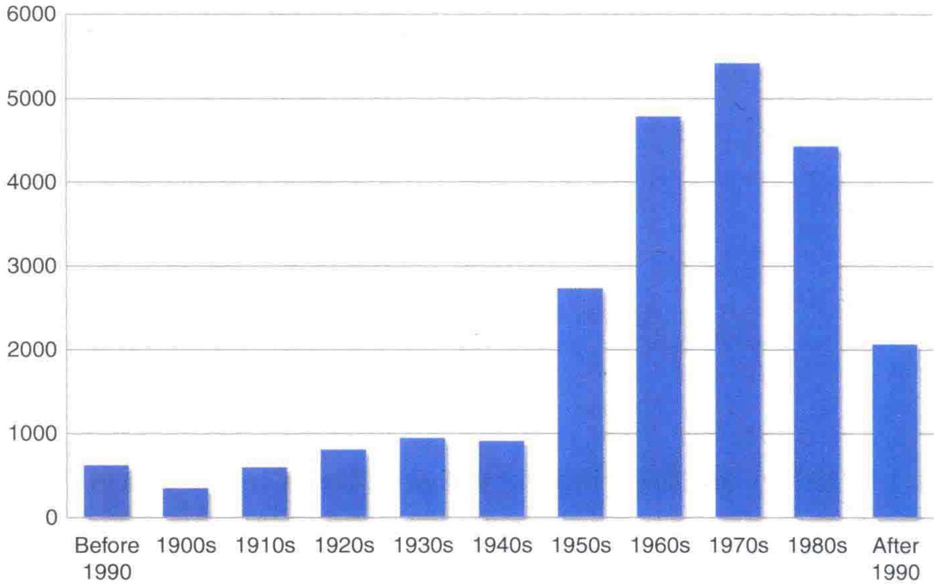

Fig. 1.1 Construction of dams by decade (Data from WCD (2000); *Source*: ICOLD, 1998, excluding over 90 % of large dams in China)

their rivers, they now mainly focus on managing and improving the efficiency of existing dams. But for developing countries, dam construction is considered a promising development opportunity. Therefore, the future of the large dam construction worldwide largely depends on the rate of development activities in these countries.

By the end of twentieth century, more than 45,000 large dams had been built around the world (WCD 2000). Fig. 1.2 shows the worldwide distribution of large dams. Five regions, East Asia, South Asia, North America, Europe, and Southern Africa, have the highest density of large dams.

Asia has not only the most existing dams compared to all other regions, but is also currently experiencing the highest construction rates. China and India, the two most populous countries in the world, are building most of these new large dams. Rapid economic development in these two countries not only demands more energy and water, but also provides the financial resources for major construction projects, such as the building of large dams (Bawa et al. 2010; Liu and Diamond 2005). The top five countries with most of the dams currently under construction are all in Asia: India, with 700–900 new dams under construction; China, with 280; Turkey, with 209; South Korea, with 132; and Japan, with 90 (WCD 2000).

The United States has built the greatest number of large dams in North America, about 8,000. However, by the end of the twentieth century, a new trend was evident as old and poorly functioning dams were decommissioned across the United States. About 15 years ago, the top official at the US Bureau of Reclamation, which had been responsible for building massive dams throughout the American West, declared that the "era of big dams is over" (Longman 2008). In 1998, the speed of decommissioning exceeded that of construction for the first time (WCD 2000).

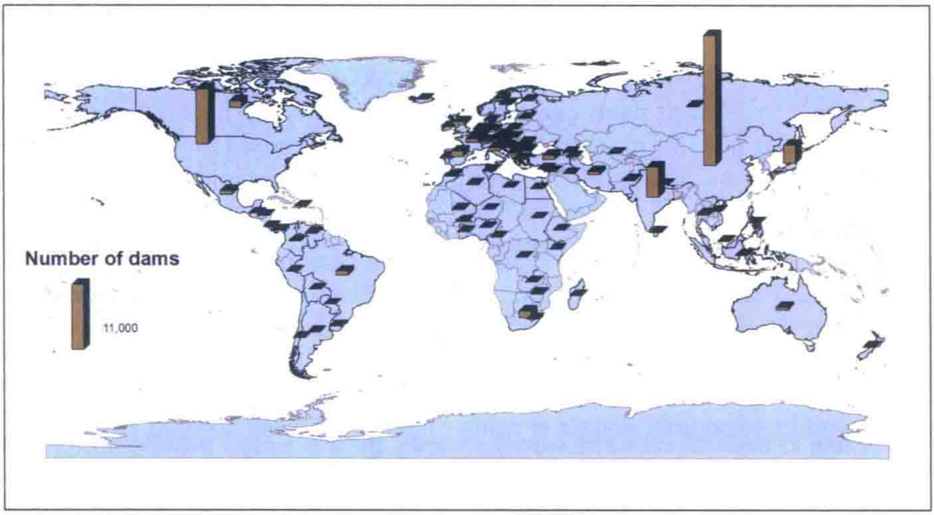

Fig. 1.2 Distribution of large dams in the world (Synthesized from data on ICOLD website: http://www.icold-cigb.org/)

Decommissioning old dams has many benefits for the restoration of riparian systems. However, some studies have shown that the removal of old dams may also cause negative impacts on associated ecosystems as they are forced to readapt to new hydraulic regimes (Poff and Hart 2002; Bednarek 2001) .

Currently, there are about 6,000 large dams in Europe. The pattern of construction of dams and reservoirs in Europe can be illustrated using the United Kingdom and Spain as examples. In the UK, the number of large dams grew rapidly during the nineteenth century, from fewer than 10–175, a rate of 1.7 per year. By 1950, the rate had almost doubled. After 1950, construction took place at a rate of 5.4 dams per year before dropping to zero by the late 1990s. Today, the UK has a total of 486 dams. In contrast, Spain saw the number of reservoirs grow at the rate exceeding 4 per year between 1900 and 1950, before almost doubling and reaching 741 facilities by 1975. By 1990, this figure had more than doubled again (19.5 per year), and today there are 1,172 large dams in Spain, the most in Europe (European Environmental Agency 2010). With suitable sites becoming fewer and environmental concerns becoming greater, the total number of dams in Europe is now growing very slowly.

1.2 Multiple Functions of Large Dams

1.2.1 Irrigation

Large dams have made significant contributions to rapid increases in yields associated with modern agriculture. About one fifth of the world's agricultural land is irrigated, and irrigated agriculture accounts for about 40 % of the agricultural production globally. Half of the world's large dams were built exclusively or primarily for irrigation, and an estimated 30–40 % of the 268 million hectares of irrigated lands worldwide rely on dams (WCD 2000).

The heights of large dams can range from 15 to several hundred meters. But generally, dams used for irrigation are relatively low compared to those constructed for flood control and hydropower. In North China, where precipitation is often inadequate for irrigation and the flow of rivers is generally low, many dams have been built to meet the water needs of cropland (Nickum 1998).

1.2.2 Water Supply

According to research on water supply security, there is a clear positive correlation between the density of dams and security level (Vorosmarty et al. 2010). Many reservoirs were built to provide a reliable supply of water to meet rapidly growing urban and industrial needs, especially in drought-prone regions where natural groundwater sources and existing lakes or rivers were considered inadequate to meet all needs. Globally, about 12 % of all large dams are designated as water supply dams and about 60 % of these are in North America and Europe (WCD 2000). Most metropolitan areas must rely heavily on reservoirs in distant surrounding watersheds for water supply, such as Beijing (Government of Beijing 1981) and New York City (The City of New York 2013).

1.2.3 Electricity Generation

Hydropower provides about 19 % of the world's electricity production, and in some countries, it is the most important power source (WCD 2000). Therefore, dams for hydropower are constructed globally as an important development approach. In addition to the ambitions of many different governments, the World Bank and other development banks also promote large hydropower dams by providing a large number of loans, especially to developing countries (World Bank 2009).

Hydropower is considered to be cleaner than electricity generated by burning fossil fuels. It has almost zero CO_2 emission (if the CO_2 emitted by deteriorating organic matter at the bottom of the reservoirs is not considered), and once completed, no additional inputs are needed other than the maintenance of the power station. In the view of hydraulic engineers, some deep valleys with rapid elevation drops are particularly suitable for building large dams.

The electricity generated from hydropower dams is most often fed into national grids, which benefits people in the whole country. However, local people commonly bear most of the negative impacts from dam construction and the operation of the power station (Magee 2006). This uneven cost-benefit distribution is one of the main equity issues related to large dams.