

CHAPTER 1

INTRODUCTION

1.1 OBJECTIVE

The sustainability principle, to be discussed in detail in Chapter 2, calls for an integrated consideration of economic, social and environmental issues related to development, while addressing both intra- and inter-generational equity.

The objective of this report is to translate the general sustainability principle into the reservoir context and to provide a set of concrete planning, design and management criteria that could be used for selection of a reservoir option that compares favourably to other reservoir and non-reservoir alternatives.

In order to fulfil this objective, the present report has the following aims:

- (1) To review the current status and anticipated future needs for reservoirs in order to develop a new approach that can address existing criticisms of reservoirs.
- (2) To analyse the general notion of sustainable development and to interpret it in the context of reservoirs.
- (3) To discuss non-reservoir alternatives to be integrated with reservoir options for sustainable water resources management.
- (4) To present selected reservoir design and management techniques that can help implementation of the sustainability principle.
- (5) To show selected examples of design and management of existing reservoirs highlighting different aspects of sustainability.
- (6) To present a checklist which may guide sustainable reservoir development and management in practice.

1.2 BACKGROUND AND SCOPE

Water storage is the basic means of controlling water availability over time and in space. Storage of water, needed in vast quantities in virtually every human activity, is essential for human beings as well as other living species.

The bodies of camels and cacti are adapted for the function of storing water, indispensable for sustaining life. Different storage media have existed naturally in the world or have been developed by humans and utilized throughout history. While groundwater aquifers, lakes, snowpacks, soil moisture etc. are natural water reserves, a manmade reservoir is a structural means for storing water. Humans have been building reservoirs over thousands of years. The oldest ruin of a dam is Sadd El-Kafara 30 km south of Cairo, Egypt (length 104 m, height 11 m and storage capacity $0.57 \cdot 10^6 \text{ m}^3$) built around 2800 BC for water supply and believed to be destroyed by its first flood (Biswas, 1970). One of the oldest existing reservoirs in the world is Mannoh-Ike in Japan (height 32 m, area 1.4 km^2 and storage capacity $15.4 \cdot 10^6 \text{ m}^3$) that was built prior to the 9th century AD and is still used for paddy field irrigation.

There are a great number of large dams all over the world, most of which have been built in the 20th century. The present rate of construction is of the order 250 dams a year (ICOLD, 1988). It is projected that the world population may reach 8 billion by 2020 and 10 billion by 2050 with dramatic consequences for enhanced urbanization and increased food and drinking water requirements to provide safe living conditions for all people. The demands for irrigation water, municipal and industrial water supply, flood control, hydropower generation and navigation become tremendous. Undoubtedly, reservoirs are among the most important physical means to meet such needs.

There is increasing concern about the social and environmental effects of reservoirs. Some experts claim that large reservoirs built from the late 1950s to the 1970s, mainly for hydropower, are economically inefficient and have strong negative ecological impacts. The same holds for some irrigation reservoirs in arid and semiarid regions. Many undesirable cases are reported by Pearce (1992). In developed countries, the environmental concern is increasing to such a level that practically no new major reservoirs may be constructed and in some cases existing dams are going to be removed to restore the original flow regime of the river for natural aquatic habitats. The construction of the Three Gorges Dam in China was finally approved in 1992 and is now underway. The dam will be 185 m high and the reservoir, on the average, 2 km wide and 600 km long. The primary purposes are flood control, hydroelectric power generation and navigation. While the economic expectations are large, some believe that the benefits are overestimated and are concerned with adverse socio-cultural and environmental effects, including resettlement of more than a million people and potential sedimentation problems (Dai Qing, 1996).

Criticism of reservoirs does not come only from extreme environmentalists. It is reflecting the global concern for the Earth environment. The World Commission on Environment and Development (WCED) introduced the sustainable development principle (WCED, 1987)

which subsequently was turned into the UN action plan, Agenda 21, by UNCED (1992). The concept of sustainable development with intra- and inter-generational equity motivated various leading policy agencies to reconsider the environmental impacts of their projects. For instance, the World Bank changed its funding policy for water projects (Cernea & Le Moigne, 1989), and the US Bureau of Reclamation shifted their major concern from development to management in the 1990s (Beard, 1994). With these new policies, financial and other institutions, national and international, are now expressing support for the implementation of the sustainability principle.

It is a plain fact that more freshwater is necessary for the future development of society and support of the increasing world population. On the world scale, new reservoirs will be needed as one of the most effective means of acquiring and controlling water. However, they have to be built and managed in a sustainable way. How should the necessary reservoirs be designed, constructed and managed to meet the requirements for sustainable development? How can existing reservoirs be managed efficiently, reliably and flexibly under increasing uncertainty? How can the reservoirs be rehabilitated and their life time prolonged for increased safety and better performance? The answers are not simple, but much needed.

There have been attempts to apply the general sustainability principle to water management, but very few have addressed reservoirs in particular. Partly this may be due to the difficulties in assessing the needs for, and the environmental impacts of reservoirs. Emphasis on environmental concerns often results in an oversimplified view and one-sided arguments against reservoirs. Instead, appropriate attention should be given to more environmental care in the management of reservoirs. This report intends to provide the scientific background for application of the sustainability principle to reservoirs.

In the rest of Chapter 1, the current status of the basic statistics of reservoirs is reviewed to identify where we are and what the problems are. Section 1.3 provides the information on the current status and the expected future needs of reservoirs and Section 1.4, various critiques of present reservoirs. A fairly comprehensive review of the criticisms is made since this constitutes the basis for the new proposal of this report.

In Chapter 2, the notion of “sustainable development” is reviewed and translated into the reservoir context. Section 2.1 discusses the key components of the principle and the related follow-up discussions, and Section 2.2 translates the basic principle into reservoir design and management strategies. Furthermore, based upon these interpretations, it presents some concrete proposals and discussions on criteria and an introduction to a checklist that may be useful in practice to achieve sustainable reservoir development and management.

The following two chapters, 3 and 4, discuss the two basic components of sustainable reservoirs, i.e. integrated water resources management, which

includes the non-reservoir option as an important component, and the systems approach for design and management of reservoirs. Chapter 3 compares reservoirs with non-reservoir alternatives attempting to judge their advantages and disadvantages in an objective way. Typically, a reservoir serves multiple purposes in the presence of conflicting objectives, so that when comparing alternatives, a number of single-purpose projects must be compared to a multi-purpose reservoir. Demand management is considered important wherever it is possible as an alternative to or a combinatorial part of reservoir options.

Chapter 4 presents the engineering and systems analytical techniques for efficient use of existing reservoirs. Section 4.1 discusses some basic principles of reservoir analysis, as well as basic requirements imposed by the sustainability paradigm. Section 4.2 illustrates the importance of the hydrological input for reservoir design and management. Section 4.3 illustrates four possible ways to address the requirements of sustainability in reservoir analysis: De Novo programming for reservoir development, reassessment of existing reservoirs, cost/benefit allocation for reservoir redevelopment and the Least Marginal Environmental Impact (LMEI) rule for reservoir sizing.

Chapter 5 presents case studies of existing reservoirs in Norway, Egypt, USA and Japan, the current status of reservoir management and the directions of the future managerial innovation. They are not necessarily examples of sustainable reservoirs that this report considers as model cases. Rather, it is admitted that there are no model cases. The case studies show how each reservoir is struggling with the changing needs of society which may serve as lessons in other situations.

Chapter 6 concludes this report with the authors' views on the current status of reservoirs and the directions in which to go in the form of a set of checklists to be used as a practical reference at respectively the planning, design, construction, operation and maintenance stages.

1.3 CURRENT STATUS OF RESERVOIRS

In this section, the current status of reservoirs is reviewed in respect of numbers and sizes, land efficiency with respect to hydropower generation, sedimentation and the future needs of reservoirs.

1.3.1 Number, size and shape of reservoirs

According to the World Dam Register (ICOLD, 1988), there were 36 235 large dams (defined as higher than 15 m) in the world in 1986 in a total of 133 countries (79 ICOLD member countries and 54 non-member countries). There were 427 dams in 1900 and about 29 900 dams were built between 1951 and