

**PART A**

**GENERAL PRINCIPLES**

This part of the book will present the general principles and concepts of lake management. A detailed approach to concrete lake management problems - eutrophication, acidification, fishery yield etc. will be presented in later volumes of this guideline book series. This book should therefore be considered as a presentation of the basis for the other guideline books, as it attempts to touch on all aspects of lake management: the ecological, limnological, technological, economic and social ones.

The multidisciplinary and holistic views of lake management are emphasized in the introduction. It may also be called the macroscopic view, as not only a single lake components or even the lake, but the entire watershed is considered.

Chapter 2 presents the basic ecological concepts of lake management. The chapter is named ecosystem concepts with emphasis on system. The chapter reviews how a lake is working as an *ecosystem*.

Chapter 3 summarizes the problems of lakes and reservoirs. Later volumes in the guideline series will focus on particular problems such as eutrophication, toxic substances and fishery. Therefore, this chapter will not deal with the problems in detail but only present some general principles and a summary on lake management problems.

After recognition of the problems must follow an assessment of the problems. Consequently, chapter 4 surveys qualitative and quantitative assessment methods as the next step.

In chapter 5 a quantitative assessment of the sources to the problem by using mass balances is presented, followed in chapter 6 by a review of modelling, which is a more and more widely used tool in lake management since it enables the scientist and the manager to overview complex systems and problems.

Chapter 7 reviews the remedial techniques, that we have at disposition of an environmentally sound solution to the problems. The chapter deals not only with environmental technology but also with the ecological engineering methods, that may be applied to solve some of the problems for instance those related to the non-point sources or to carry out lake restoration.

The last chapter of this part focuses on planning and management of comprehensive environmental planning. This chapter touches on the social-economic aspects of lake management and present also the application of environmental impact assessment (EIA) as a useful tool in environmental management and planning. The holistic, macroscopic views and the importance of considering all aspects from ecological to social-economic simultaneously are particularly emphasized in this chapter.

The measurements and samplings which need to obtain a first information on lake structures and functions are summarized in a flowchart presented in the appendix.

## CHAPTER 1

### GENERAL INTRODUCTION

Lakes are open systems i.e. they exchange energy and mass with the environment. The state of the lake is obviously strongly dependent on these exchange processes, which are described by use of what is called *external variables or forcing functions* (they describe the forces on the lake as function of time). Forcing functions are either controllable or noncontrollable. The latter are for instance precipitation, wind, solar radiation, etc., while the controllable ones are, for instance, in- and outflow of water, nutrients and toxic substances.

The state of the lake is described by use of *state variables or internal variables*. Examples are phytoplankton-, nutrients- and fish concentrations.

The core of lake management is to find the relations between the forcing function and state variable and to use the knowledge of these relations to change the controllable forcing function to achieve a desired state of the lake. The tools (quantification methods, models) implemented to obtain the relationships are described in chapter 5 and 6, while the method (remedial techniques) available to change the controllable forcing functions are mentioned in chapter 7. The relations of these concepts are illustrated in Fig. 1.1.

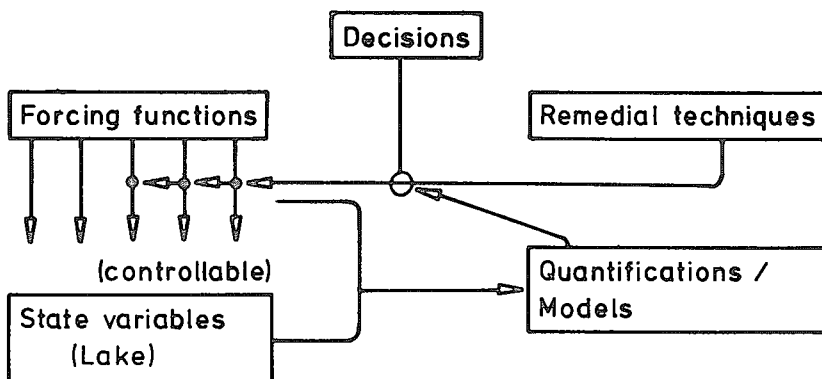


Figure 1.1 Relations of the concepts given in the text.

However, lakes are integrated parts of the entire watershed. As they are open systems the watershed will influence the lake, and the lake will influence the watershed. It is therefore hardly possible to manage the lake

as a system, separated from the watershed and its environment. This emphasises the need for system approaches and modelling, as you need to survey a complex ecosystem and even an entire watershed. Therefore, good management strategies do not imply that a problem is analyzed as an isolated matter, but it is always required to relate environmental problems to the entire lake **and** its environment. Fig. 1.2. illustrates an example of bad or lack of management, which unfortunately is often seen in practice. A lake is used for the production of drinking water and the water authorities may put a lot of effort into the production of high quality drinking water. Separately from this issue, the waste water authorities may be concerned with the influence of waste water on the water quality of the lake. No coordination between the 2 authorities takes place. If good management is used first of all, a coordination between the production of drinking water and treatment of waste water must take place.

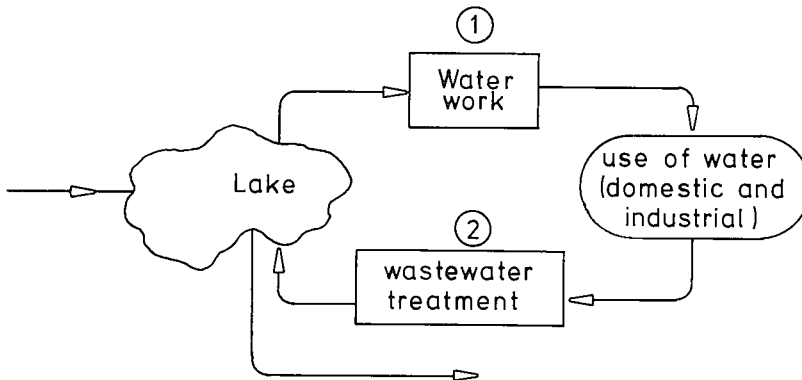


Figure 1.2 An example of bad lake management.

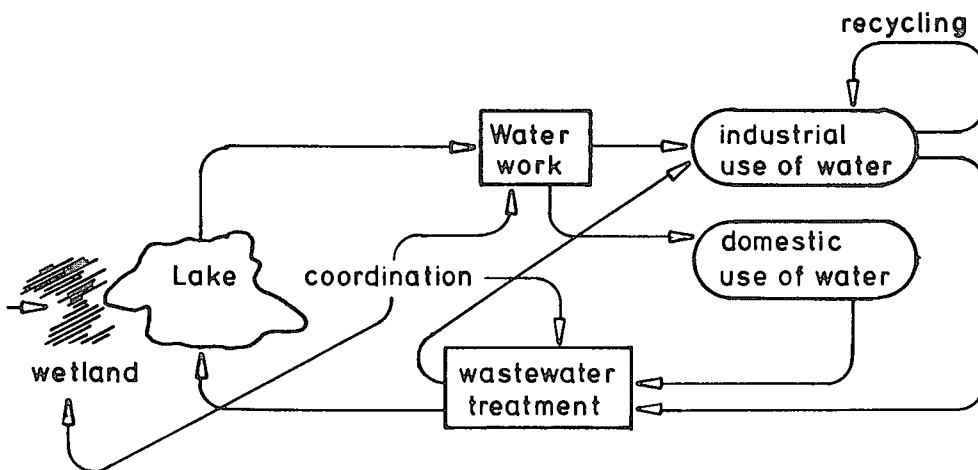


Figure 1.3 Illustration of a good management strategy.

Furthermore, it should be considered to recycle the water partly. Some industries may be able to recycle their water or use partly treated waste water and thereby decrease the cost of drinking water and treatment of waste water and even the impact on the ecosystem. This better management strategy is illustrated in Fig. 1.3.

Another illustration of the difference between good and bad management strategy is shown in the same figures. In Fig. 1.2. the emission of nutrients from agriculture is not considered. Consequently, the lake water will be very eutrophic and/or it is required to apply a very advanced and expensive waste water treatment. In Fig. 1.3. wetlands are maintained along the shores of the tributaries to work as traps for the nutrients coming from nonpoint sources. This will reduce the need for advanced waste water treatment and also for a more comprehensive treatment of the portable water.

The conclusion of these considerations is clear: go a step backwards and use a "*macroscope*" to consider the entire ecosystem and its environment as one system and optimize on that level.

The importance of this approach to lake and reservoir management must be assessed from two standpoints, with regard to theoretical and applied objectives:

- 1) With respect to the importance of the catchment area as the site of the principal sources supplying the lake, not only in hydrological and energetic terms but also in chemical, that is to say, nutrient and toxic substance terms.

- 2) With respect to the goals of management taking into account the relationship existing between the properties of the catchment area and the trophic-productive level of a lake system situated in a given catchment area.

The underlying concept which meets these premises is that of "loading" and has given rise to that of "loading tolerance" of a lake system in terms of its morphological, hydrological and overall limnological conditions.

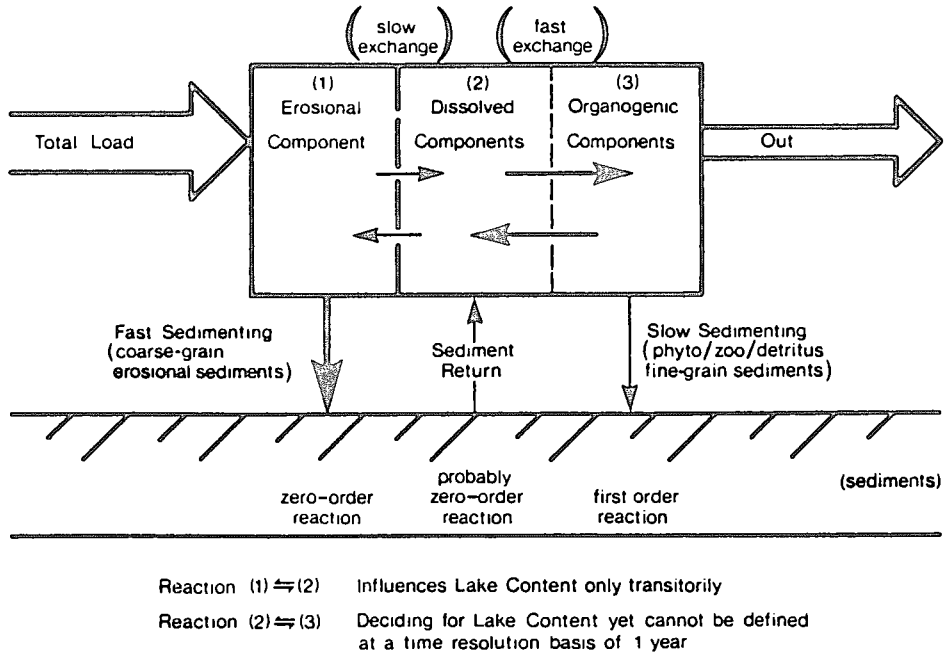
The diagram presented in Fig. 1.4 illustrates the connection between the external load and the major processes and compartmental routes inside the lake. While classical limnology dealt mainly with compartments and processes inside a lake, this diagram attempts to emphasize that the external nutrient load is the food of the cyclical processes within the system, that is to say, the system is preserved or changed, precisely as a

function of this food. Therefore, loading as a concept takes on a position of fundamental importance both in theoretical research and in practice.

It follows furthermore from this approach to the problem that - to understand the operation of the system, lake or impoundment, in its totality - it is necessary to describe its dynamics not only in qualitative terms but **in terms of mass flow and balance**, that is to say in exact terms of how much material enters, leaves and remains in circulation.

From the foregoing, we may already attempt an initial conclusion of a practical nature. A lake system with a short water renewal time will be balanced - following a variation in the external nutrient load - at a trophic level different from that of a lake system with slower renewal. This is due to the fact that the **retention time of the substances within the production cycle** will be longer, the longer the renewal time of the body of water. Therefore, a lake system with slow water renewal will be more susceptible to eutrophication, toxic substances and pH-changes, in relation to a given load, than a system with rapid water renewal. The quantitative aspect of this concept will be considered below.

CONCEPTUAL MODEL



**Figure 1.4** Conceptual model, illustrating the connection between the external load and the major processes and compartmental routes inside the lake.

Implicitly, Fig. 1.4 provides additional hints for practical eutrophication management for such cases where external nutrient load control is impossible or only partially possible. Eutrophication can partially be controlled by slowing down or altering lake internal mechanisms and processes. Alternative interventions into lake dynamics can be quite varied, can be applied singly, or in combination, including external load manipulations.