solution. However, once it comes to the point where the least costly environmental impact would be obtained from an alternative and not from a reservoir project increment, the reservoir project would not be developed under the LMEI rule to a scale where net economic benefits are maximized. In these cases, the LMEI rule acts as a constraint on the economically optimal development of the reservoir project, while still allowing optimal development to proceed via the alternative which minimizes environmental costs. In other words, as far as economic efficiency is concerned, there is no difference between the two. The LMEI rule just requires a reservoir planner to give up the reservoir option and to achieve the same objective by alternative means.

The LMEI rule is considered superior to a rule which maximizes net project benefits subject to an arbitrary limit on the environmental constraint related to the minimum attainable from alternative solutions. In the case of demand management alternatives, for example, environmental costs are likely to be very low; yet, under the arbitrary constraint on reservoir development, this low environmental cost alternative would never be considerable. The LMEI rule avoids these problems by tracing an environmentally least costly path of development up to the point where the *marginal benefit* equals the *marginal cost*.

Conclusions

The least marginal environmental impact (LMEI) rule was proposed to ensure the selection of the least environmentally destructive choice among the equally productive solutions. There are many disputes as to whether or not to create a reservoir in order to achieve a goal. But the most important issue would be the size and the location of reservoirs. There is no reason to create a reservoir of the size where the marginal environmental loss becomes more than that of alternative solutions elsewhere.

4.4 CONCLUSIONS

This chapter of mixed contributions deals with the design and management of reservoirs. Issues involved in implementing sustainability principles to the complex task of reservoir design and management are discussed. Various contributions, addressing sustainability in different ways, illustrate a variety of sustainability definitions. A unique solution for sustainable reservoir design and management has not been detected. However, innovative thinking and serious effort aimed at addressing sustainability have been presented.

In looking at the time series analysis of reservoir inflows a compromise has to be found between the reliability of estimation of statistical characteristics and the complexity of the model. The application of detailed physically-based models enables simulation of a wide range of possible variations in runoff factors and human activities in a watershed for different possible combinations of meteorological inputs.

In looking at the importance of hydrological forecasts the following conclusions have been identified:

- small reservoirs are more vulnerable to forecasting errors than large ones; and
- in the case of large reservoirs, good forecasts can reduce considerably the storage necessary to attain a given release level.

The improvement of hydrometeorological forecasting results in "virtual capacity expansion" and improves reservoir sustainability by:

- reducing the size of new reservoirs and at the same time minimizing the environmental destruction;
- gaining more benefits from the existing reservoirs; and
- offsetting anticipated developmental needs for new reservoirs.

In the consideration of a new approach for reservoir design based on De Novo programming considerable benefits in comparison to classical optimization are acknowledged. The reservoir sizing problem is formulated realistically as a system of several non-commensurate objectives. The design of the entire resource portfolio could shape the feasible decision space to achieve the metaoptimum, i.e. the optimal solution for which all objectives are optimized simultaneously. The allowable budget, or penalty/benefit function, to be spent on the purchase, or design, of the resource portfolio will then determine the feasibility of the metaoptimal solution. It is expected that with the physical resource capacities being inflexible (fixed), or the system budget being insufficient, it may not be possible to achieve the metaoptimal solution. The design of the system may shape the feasible region in such a way that a solution (or the set of non-dominated points) which is "closer" to the metaoptimum is obtained.

Reassessment of existing reservoirs has been identified as one of the realistic demands imposed by sustainability. A methodology based on the integrated use of reservoir storage simulation and reservoir yield optimization has been demonstrated to be capable of addressing different sustainability issues successfully.

One of the critical barriers in implementing the reassessment and redevelopment of an existing reservoir system is the allocation and reallocation of costs and benefits which accrue due to the modification of the system or of a newly created system. A more realistic approach than the traditional separable cost remaining benefit approach is necessary to promote various coalitions to initiate the development and redevelopment plans. The new methodology based on Shapley values demonstrates a mechanism to introduce more fairness in cost/benefit allocation which will surely contribute to encouraging more investment for redevelopment rather than in new development.

The least marginal environmental impact rule is proposed to ensure the selection of the least environmentally destructive choice among the equally productive solutions. Its application in reservoir design is of great potential when questions of reservoir location and storage capacity are addressed. There is no reason to create a reservoir of the size where the marginal environmental loss becomes more than that of alternative means elsewhere.

It is our wish and hope that some of the contributions presented in this chapter will be criticized, some be accepted and all will help in moving reservoir design and management to a new level. A level at which we will be able to look at the reservoirs in a more realistic way. A level at which we will be able to think about compromises. A level at which new ideas are going to be born.

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