PRACTICAL ENVIRONMENTAL SIMULATION MODELS FOR LAKES AND RESERVOIRS, THEIR DEVELOPMENT AND NEEDS

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I have briefly reviewed the research progress made in practical environmental simulation models for lakes and reservoirs since 1970's and summarized the relation between practical demand and model progress. Vertically one dimensional models for the prediction of water temperature in reservoirs were developed during the first stage of the model development. Practical demand for the appropriate management of dam reservoirs stimulated the development of these models. Also developed were turbidity and eutrophication models for reservoirs during this stage. Detailed model have been developed following the development of computers. Recent water quality models for lakes and reservoirs contain a number of parameters of which values must be determined arbitrarily. I pointed out it is important to develop the appropriate method to determine parameter values during model calibration to take advantage of the recent detailed models. Also, acquisition of precise field data for model input is important. For the future direction of practical environmental models for lakes and reservoirs, I emphasized the necessity of the development of the structurally dynamic ecological model to deal with the environmental change of large degree, coupling of water quality model and sediment model, and the development of habitat model to better assess the environmental impact of human activities.

Key Words **:** *ecosystem, environmental model, lake, reservoir, water quality*

1. INTRODUCTION

Environmental simulation models for lakes and reservoirs have been developed for many purposes. Herein, I deal with models for practical purposes, that is to say, models developed to assess environmental consequences occurred in lakes and reservoirs by human impacts. Models to simulate water quality change seem to be used most frequently among lake and reservoir models. A number of applications can be found for dam reservoirs. Environmental impact assessment has been mandated for the construction of large dams of which reservoir area is larger than 100 ha since 1997 in Japan. Besides these large dams, the environmental impact of the construction of all dams under the administration of the Ministry of Land, Infrastructure, Transport and Tourism have to be assessed in similar manners to the mandated environmental impact assessment. This increased the number of the application of water quality model for dam reservoirs in Japan. Since practical models to simulate the environment of lakes and reservoirs are developed according to the demand from real projects, recent increase of the application of reservoir water quality model stimulates further sophistication of the model. I will discuss the development of practical environmental simulation models for lakes and reservoirs following the demand from real projects.

2. HISTORICAL DEVELOPMENT

Historical development of the water quality model for lakes and reservoirs is discussed here. Modern numerical water quality simulation model of lakes and reservoirs of which structure is similar to present models started to be introduced in 1970's. Temperature gap between in- and out-flow of dam reservoirs had become environmental concern. Installation of selective withdrawals is one of the effective countermeasures of this matter. Vertically

one dimensional water temperature prediction models for dam reservoirs were developed to simulate the temperature profile in reservoirs and estimate the effectiveness of selective withdrawal. These models can be categorized as the first generation of the numerical water quality models for reservoirs [1), 2)]. Prediction of water temperature is obviously one of the most important matters in environmental hydraulics, since temperature controls not only biological activities but also hydrodynamics through affecting density of water. These first generation models adopt sophisticated method in solving flow in reservoirs. Point sink flow in stratified environment is described as a horizontal flow of which velocity profile is assumed Gaussian distribution and moving layer thickness is estimated by sink flowrate and density gradient around the sink. This analytical flow model had been induced by laboratory experiments[3)-5)]. These first generation type models have been successful in practical application and are still widely used even now.

Discharge of turbid water for months after controlling floods turned out to be a major concern for fishery downstream of dam reservoirs. Since dam reservoirs control floods by storing flood water which is turbid and releasing it for months. If the flood water contains large amount of the suspended solids of which particle size is as fine as a few μm, it takes months for them to settle down onto the bottom of the reservoir and they are discharged downstream.

Application of vertically one dimensional model implies horizontal homogeneity of concerning variables. Although it was appropriate to apply the vertically one dimensional model to temperature simulation, longitudinal heterogeneity of turbidity required vertically two dimensional approach for its simulation. For example, Iwasa et al.[6)] developed such model to simulate the dynamics of turbid water within a dam reservoir in early stage.

Water quality model for natural lakes seems to have been developed being emphasized on water quality concern caused by eutrophication. Lake ecosystem model which include the growth of phytoplankton[7)] started to be developed in 1970's. Di Toro et al. [7)] developed a lake eutrophication model in which eight components (phytoplankton, herbivore zooplankton, carnivore zooplankton, organic phosphorus, inorganic phosphorus, organic nitrogen, ammonium nitrogen and nitrate) were dealt. This model divided a lake into several completely mixed boxes and water quality change was calculated. Advective effect on water quality was simulated by bulk water exchange among the boxes instead of calculating flow velocity. Eutrophication models at early stage were simple because of the limitation of computer resources. Progress of computer allowed the coupling of sophisticated hydrodynamics and complex and detailed water quality model recently.

3. FUTURE NEEDS

There still seem to be several needs for water quality models in practical sense. It is important to develop appropriate method to calibrate parameters and acquire accurate boundary condition data to have reliable simulation. Besides model development, advances in operational technique are highly necessary. In particular, the estimation of external loading is important in water quality simulation. In terms of model development, prediction of ecosystem responses to a large environmental change and evaluation of habitat have high priority. Improvement of water quality of inflowing rivers gradually improves lake water quality at first. However, when this improvement reaches certain extent, sudden environmental shift may happen. Submerged macrophytes seem to play important role in controlling environment in shallow lakes. Coupling of ecosystem component other than plankton in dynamic sense is required to better assess the environment of lakes and reservoirs.

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