

CHAPTER 13

Recommendations

EDUCATION AND TRAINING

1. Principles of simulation modelling should be introduced as regular courses or parts of courses at the graduate and post-graduate levels of institutions interested in environmental research, particularly in developing countries. Also, courses or parts of courses should give graduate students an understanding of decision processes.

2. Encouragement should be given to training of people (not necessarily graduates or post-graduates) who have some understanding both of the environmental modelling and decision processes, and who thus may facilitate communication between decision-makers and environmental modellers. Training courses or seminars should also be arranged to introduce systems analysis and simulation modelling to scientists who may be considered to act as a link between modellers on the one hand and various echelons of decision-makers on the other.

3. Regional workshops should be organized for senior public officials concerned with environmental problems in both developed and developing countries, directed to improving their understanding of the modelling approach. In particular, decision-makers should be made aware of both the potential and the limitations of modelling; the importance of the underlying assumptions of any model in evaluating results; and the conditions under which some alternative approach to environmental problems might be preferable.

4. Young graduates doing environmental research in developing countries should be offered the opportunity to have practical training in simulation modelling in centres ready to provide such training. Reciprocal facilities for graduates from the developed countries to obtain experience in countries of the Third World would also be valuable.

MODELLING STANDARDS AND PRINCIPLES

5. For new projects involving modelling of environmental effects, especially in the developing countries, it is recommended that independent advice be sought from persons with experience in this area *before* a modelling approach or a particular existing model is selected for application.

6. Collection of data for a modelling project should always be preceded by the building of a preliminary model, which can guide the collection of data and reduce the risk of wasting resources by accumulating information which subsequently may not be useful.

7. Modelling scientists should pay special attention to criteria for choosing from among different models of the same system. Where sound validation data and a

well-defined objective function are available the problem may not arise, but this situation is exceptional.

8. For models intended for decision-making, the client should be in frequent direct contact with the modeller to insure a mutual understanding of the services and the capabilities of the model being developed.

9. The practice of modellers should be to declare models as *operational* only after they are validated and a comprehensive sensitivity analysis has been carried out.

MODELLING INFORMATION AND DOCUMENTATION

10. A study group should be convened to produce standards for formulating and documenting environmental models in order that these models be directly comparable, more easily transferable, and in turn incorporated into larger modelling systems.

11. A practical manual on simulation modelling of environmental problems should be edited by an experienced exponent of the art. The handbook should be addressed both to decision-makers who wish to undertake simulation modelling of an environmental problem and to scientists who have no experience in modelling. The handbook should contain special and pragmatic advice for the developing countries.

12. A manual of case studies of simulation modelling should be prepared. These studies should be presented in sufficient depth to illustrate and indicate the advantages and disadvantages of the models used. Moreover, this document should address the problems associated with creating an interface between decision-makers and modellers, the management of individual scientists in modelling research teams, and the presentation of model results. Specific examples of successes and failures should be described to illustrate these issues.

13. An inventory should be prepared of fully operational models available for transfer and application to Third World problems. This inventory should indicate those models from developed countries whose applications these countries are prepared to sponsor.

RESEARCH AND INTERNATIONAL COOPERATION

14. Research should be encouraged on a variety of statistical problems which have been identified in the present volume. Of particular importance are those problems related to the estimation of model parameters, model validation, and sensitivity analysis.

15. Special attention should be given to the difficulties of inter-facing models from different disciplines and at different scales of space and time. In particular, this will be the case with physical, biological, and socio-economic models, when some inputs are measurable while others are in terms of value judgements.

16. Existing techniques for optimization of space and time distribution of monitoring stations should be examined on an inter-disciplinary basis. Each discipline has solved or ignored this problem in its own particular way, but no attempt has yet been made to synthesize across disciplines or environmental media.

17. It is important to extend very substantially all forms of international

cooperation bearing on problems of environmental simulation modelling. This includes the organization of international conferences; the creation of working groups for the purposes of designing specific models; and exchanges of lecturers, research scientists, computer programmers, and computer programmes.

18. A major effort should be made to call the attention of those Unions and Scientific Committees of the International Council of Scientific Unions (ICSU) whose expertise is within the physical, mathematical, and biological sciences, to the need for basic or applied research in those scientific problems involved in environmental simulation which are not fully understood and which presently require, for their simulation, the use of empirical relations, unjustified assumptions, or guesses.