Pages 253-256 in J.C.J. Nihoul, ed.
Modeling of Marine Systems. Elsevier
Press, Amsterdam. 1975.

CHAPTER 16

ESTUARIES

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16.1. MODELLING IN ESTUARINE SYSTEMS

In the following an attempt is made to outline the specific problems of modelling of estuaries as characterized by the discharge of fresh water into a partially enclosed sea water body.

The hydrodynamical regime and exchange mechanisms encountered in estuaries lead to specific chemical, biological and geological processes requiring specially adapted models.

16.2. MODELLING OF PHYSICAL ESTUARINE PROCESSES

A wide variety of estuarine models has been developed; the more simplified ones, which are mathematically more tractable, involve averaging properties over space and time. These over-simplifications of the models may well violate the basic physics of the circulation processes, but still give reasonable representations of overall observed distributions and are used to compute the flushing time or the exchange ratio for the estuary.

More elaborate models based on the equations for conservation of mass and momentum and taking into account the geomorphology, the tidal flow and the river flow have further been developed to evaluate the physical processes within estuaries which produce the observed distributions.

Simulation methods

The one-dimensional approach is well developed within the accuracy of

Contribution No. 839, Center for Environmental and
Estuarine Studies of the University of Maryland.

the parametric expression of mixing. Some question remains concerning conservation of mass in presently used computations. The two-dimensional approach is coming out of the experimental phase into operational computations.

Two methods of coupling the hydrodynamics with the transport processes can be used. These are the computation of the hydrodynamics simultaneously with the advective diffusion equation, both computed with the same timestep, and the computation of the advective diffusion equation with a much larger timestep than in the hydrodynamics equation. In the latter case serious questions concerning conservation of mass can be raised. Attempts to solve the baroclinic problem with numerical methods have not yet been developed into an operational method.

Three-dimensional computations are now being approached by finite differences over the vertical in addition to the horizontal finite-difference approximation and by analytical solutions of the vertical velocity field.

Presently no three-dimensional model of estuaries is operational, but further development using computers now being made can lead to operational models which can be used for scientific inquiry and solution of most engineering and estuarine management problems.

Analytical methods

Analytical methods are at present inadequate for the solution of engineering and management problems, but they contribute considerably to scientific inquiry.

Presently diffusive transports are introduced into the computational methods by parametric expressions derived from empirical relations. Further inquiry into the nature of these relations is urgently required. This inadequacy is particularly evident in deep estuaries where multi-layered velocity fields are prevailing.

6.3. MODELLING OF CHEMICAL ESTUARINE SYSTEMS

For modelling of chemical processes the important examples of state variables are salinity (which is used as an index of mixing), temperature, p^E, concentration of dissolved oxygen, pH, alkalinity, concentrations of organic matter, nutrients (P, N, Si), certain metals and particulate material. Other variables may become important in specific situations (pollution). For the correct expression of state variables, a knowledge of chemical speciation is needed. In practice there is usually a crude distinction of operationally defined fractions (e.g. dissolved, particulate, organic) but ideally the true chemical speciation should be known. This is a more complex task for estuarine waters than for oceanic and fresh waters because of the pronounced gradient of ionic strength.

For conservative (non-interactive) constituents their distribution is more readily modelled as it may be computed from the mixing properties provided by the physical model. For non-conservative (interactive) constituents there may be special boundary conditions to consider because of possible significant exchanges between the estuarine water and (a) the bottom sediments and interstitial waters and (b) the atmosphere. A chemical model will normally incorporate biological processes. We have little information on rates of uptake and release by organisms which is applicable to the highly variable conditions in estuaries. Similar considerations arise with the equally important task of incorporating interactions between dissolved and suspended particulate matter. These processes can often be described by parametric expressions without detailed knowledge of the individual processes concerned, but such knowledge may sometimes be needed to understand the mechanism. By comparing predictions based on various formulations of such parametric expressions with the real situation, greater insight may be gained into the factors controlling such biological and geochemical processes.

Sedimentation should be considered as an important removal process. Therefore, we recommend that models of sedimentary processes (flocculation, deposition, resuspension) be developed.

From the sedimentologist's standpoint a rough distinction can be made between movements of a coarse fraction (sand) and a fine fraction (silt). In the case of appreciable sand movements the morphology of the system is also changed and this in turn causes modification of the hydrodynamic system. No models for these interactions are available. In the fine fraction it would be of great importance to understand the dynamics of formation of the so-called turbidity maximum, including the processes of grain size selection.

16.4. ESTUARINE BIOLOGICAL MODELLING

The history of estuarine biological modelling is long and varied. Models of single organisms and processes have often been quite detailed aids to understanding. In keeping with the purpose of this conference, however, consideration will be limited to ecosystem models which can be combined with physical and chemical models to yield a total simulation of the estuary.

In what follows, the ecosystem models under discussion have time as the independent variable. This is not to imply that the spatial variation has been excluded. Rather the models are considered as distributed sources and sinks which may be inserted into the equation of continuity of species to yield the full temporal and spatial distributions.

Estuarine ecosystems models are generally of low resolution, usually employing combinations of the broad categories listed below as model compartments·

Biotic	*Abiotic*
phytoplankton	nutrients
zooplankton	temperature
nekton	salinity
microbes	turbidity
benthos	detritus

The combination of interactions among the above state variables will vary with the investigator and the estuary being modelled. The totality of the mathematical statements made about these interactions is small and tends to be constrained, perhaps needlessly, by historical modelling efforts.

Investigators are urged to be liberal in experimenting with the spectrum of little-used or novel functions as better descriptions of the mechanisms of interaction.

The values of the coefficients used in the mathematical statements are determined by: (1) independent laboratory measurement; (2) educated guesses; (3) regression to prototype data; (4) budget computations; and (5) combinations and/or iterations upon the above.

16.5. CONCLUSIONS

So far, most simplifications have been done by considering separately the chemical, biological, physical and geological subsystems. Also needed are models that are simplified in resolution without eliminating the main physical, chemical, geological and biological processes. The highest priority should be given to the development of such ecosystem models.

There exist very few truly verified estuarine models. This paucity is due largely to the costs involved in obtaining quality prototype data. Certainly prototype data should deal adequately with the time and length scales involved. At best, all data should also be taken simultaneously. Obtaining such copious data requires prodigious man-power, equipment, vessel use, analytical facility and computer software. Nevertheless, such coordinated efforts are essential if the estuary is even to be understood in the holistic sense.