The MIT/Marine Industry Collegium

Opportunity Brief # 8

COMPUTER MODELS FOR ENVIRONMENTAL ENGINEERING AND RESEARCH IN NEAR-COASTAL ENVIRONMENTS

A Project of
The Sea Grant Program
Massachusetts Institute of Technology

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COMPUTER MODELS FOR ENVIRONMENTAL ENGINEERING AND RESEARCH IN NEAR-COASTAL ENVIRONMENTS

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Forecasting the physical, chemical, and biological consequences of man-made changes in the near-coastal environment is costly and time-consuming for several reasons. The geographical areas of concern are typically quite large. Many parameters are of interest. The number of field measurements required to produce meaningful data implies the considerable expense of vessels, crew, and equipment. Many of the parameters are affected by variables such as the season, wind speed and direction, and tidal phases, so measurement programs must be carried out over a long term.

Computer models* are a promising new tool for reducing the costs involved. When coupled with appropriate proper field measurements, computer models can provide consultants, government agencies, and industry with drastic cost reductions both in predicting environmental changes and in monitoring the effects of such changes.

With Sea Grant sponsorship, researchers at MIT and other institutions [illegible]

have written a family of computer progra[illegible]

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*Mathematical models or numerical models are formally a more proper name, but the techniques all require digital computers to implement, thus we choose computer models.

and dispersion in a body of water. Using these models, together with selected field measurements as input, it is possible to forecast where a substance (municipal sewage, for example) introduced at some point, will be transported as a result of currents driven by prevailing winds and tides. By modeling the dispersion of a substance, it is further possible to make predictions about concentrations of the substance at various points along its travels. While information on circulation and dispersion patterns is valuable in itself, these two physical processes also form the basis for developing other predictions about chemical and biological transformations that occur when a substance is introduced into near-coastal environments.

The MIT Sea Grant models were developed for Massachusetts Bay, and have been tested, modified, and verified in a variety of applications, including studies of sand and gravel mining and nuclear power plant effluents. The models have also been successfully applied to power-plant site evaluations in Naragansett Bay (Rhode Island), to potential storm surge effects at the proposed Atlantic Electric Generating Stations off the New Jersey coast, to currents in the Great Bay Estuary (New Hampshire), and to tidal flushing of pollutants in Biscayne Bay (Florida) and many other problems.

The Sea Grant models offer several important benefits. First, they are widely applicable. The general programs, complemented with appropriate field data, can be used to model a wide variety of environments. Second, they facilitate the study of alternatives, because it is easy to vary the input data and analyze the results. Third, the models provide information that permits more informed selection of field measurement sites, reducing the costs and minimizing the amount of data needed for an adequate analysis.

Like most sophisticated tools, effective use of the Sea Grant computer models requires a blend of art, science, and experience. They require maintenance, and they can create problems when incorrectly used. Their use requires some competence in computer science, a good understanding of coastal processes, a knowledge of the design of experiments, and some art and skill in applying the general programs to the specific problem at hand.

We see three similar, but different ways in which Collegium members might profit through use of these models.

(1) Governmental agencies and other organizations that need the results of these models far outnumber the companies or individuals who can implement and apply them effectively. As a result, consultants and industrial research groups may use the models in their present form either as a basis of a new business or as a way to make their present environmental consulting and engineering activities more efficient and profitable.

(2) Further extensions to the existing programs are possible and needed. The present models provide a framework within which industrial research groups can build additional extensions and more complete models for their own needs.

(3) Certain problems related to the use and further development of these programs which are apparent to one or more industrial partners might be appropriate for further MIT Sea Grant research projects.

2.0 MODELING OF NEAR COASTAL ENVIRONMENTS

2.1 Scale Models and Mathematical Models

Descriptions of the effects of a particular change in the environment are difficult (and in some senses impossible) to quantify. Effects take place over wide areas and may vary with depth. Thus, a description of "before" and after states may require quantification of many variables (currents, pollutant density, temperature, for example) over three dimensions (x,y,z). All variables are functions of time, as they depend on time of day, tides, lunar cycles and/or season.

Civil engineers have long faced problems of forecasting the migration and fate of dredge spoils, the level of rivers, the effects of modifications of shorelines, dredging, and the like. Historically, scale models (i.e., physical models on a scale of 1:1000, 1:10,000, 1:100,000) have been used to predict the behavior of rivers and of certain near-coastal environments. Unfortunately, scaling over such a wide range is fraught with difficulties. For example, the parameters of interest don't all scale in the same way: some are direct functions of size, some are inverse functions of size, and some are independent of size. Depths must often be scaled differently than length and width. Also, physical scale models are very costly to build and maintain, and their application requires as much art as science. The main shortcoming of scale models is that they are site specific - a model of the Mississippi doesn't help predict flows in the Hudson River. Despite these difficulties, physical scale models are useful when coupled with extensive field measurements.

Finding analytically closed solutions presents grave difficulties.

The differential equations of motion, of continuity, and of conservation of mass can be easily written down, but their formal closed solutions are impossible for anything except the simplest geometry.

Numerical solutions have always been possible, but the computational burdens have been formidable. Over the past two decades the availability and decreasing cost of digital computers have made numerical solutions practical and useful. Partly as a result, there has been a concomitant interest in numerical modeling of fluid processes. Reference [1] gives an excellent summary of the state-of-the-art of numerical modeling as of 1970, and discusses in detail the use of physical models, analogue models, hybrid digital/analogue models, and digital models as solution techniques.

In Reference [1], all the models that use digital computers are implemented using Finite Difference techniques. A more recent development is the use of Finite Element Methods for numerical solutions of differential equations of state for fluid media. Finite Element Methods have been used in structural mechanics over the last decade. As noted in more detail below, the Finite Element Methods provide advantages with respect to flexibility and adaptability over Finite Difference Methods. The range of fluid flow problems that can be modeled by the finite element technique is suggested in the two volumes of Reference [2]. A 1974 bibliography, Reference [3], lists a wide variety of models for near-coastal environments.

2.2 Advantages of Computer Models

Present legislation requires that the environmental impact of a proposed construction project be evaluated not only for the proposed site, but also for one or more alternatives as well. Thus, one might for example, have to show not only temperature fields for one configuration of a cooling water outlet, but for two - or twenty - alternatives. Such requirements indicate both the need and advantages of computer modeling techniques.

Computer models can also be useful in planning and understanding the dynamics of an environment, by giving the planner a tool to forecast relative effects of different scenarios. Computer models allow one to play "what if" games on the environment at a very low cost compared with other modeling techniques or with full scale field-measurements programs. "What if" game playing is a powerful tool for obtaining insights into the behavior of complex systems. It provides a way to simulate the results of experiments without actually carrying out the experiment in the field.

2.3 Models and Measurements

Although models can be extremely powerful tools for researchers, it is important to remember that MODELS ARE NOT REALITY. The use of computer models is generally an exercise in futility without constant reference to the real world through a measurement program that provides data to drive, to test, and to retest the model.

One of the unique advantages of computer models is their ability to shed new understanding on the field measurement program. Such an understanding provides decision-making criteria that can make the required field measurements fewer, less expensive and more reliable, Reference [7]. Improved field data to drive and calibrate the model, in turn, lead to more accurate, less expensive forecasts.

2.4 The Selection of Finite Element Models

The basic criterion for the usefulness of a model is "can it be used to represent the real world in a way that can be verified either analytically or experimentally." Only if this criterion is met can the model be used with some degree of assurance to predict changes or effects in the environment that cannot be verified, because of cost or some other constraints.

Ideally, a model should also satisfy a second criterion of usefulness: it should be convenient to apply in a wide variety of situations in order to justify the substantial time and cost required to create the model.

Numerical models generally satisfy the first criterion easily, but the second criterion is more difficult to satisfy. All numerical methods require that a continuous real system be represented as a set of discrete, finite segments interconnected with one another. Modeling in discrete segments can be done in a number of ways, so long as the variable of interest does not change substantially over one of the finite elements.

The classical Finite Difference Method when applied to a problem with two spatial dimensions requires that the descrete segments be represented as a constant square grid mesh. If a square, fixed-size grid can be made to represent a specific physical environment in a convenient way, then the Finite Difference Method has an advantage over the Finite Element Method; a Finite Difference Model will generally require a smaller amount of computer memory and less computer time for running. However in most cases, researchers today choose the Finite Element Method because of its flexibility.

The Finite Element Method permits the use of more arbitrary geometries, i.e., the shape of the grid may be triangular, rectangular, or square, and the size of the basic element need not be constant. Thus, arbitrary boundary shapes can be represented more easily with the Finite Element Method than with the Finite Difference Method. In addition, areas in which variables are expected to change rapidly (in a spatial sense) can be represented with small grids and areas of slower change can be represented with larger grids. This flexibility in choosing the size and shape of discrete grid elements is the essential merit of the Finite Element Method.

3.0 THE SEA GRANT MODELS FOR NEAR COASTAL ENVIRONMENTS

3.1 Circulation Models

The most important feature of the near-coastal environment is hydrodynamic circulation, since the biological, chemical, and thermal processes are strongly dependent on circulation. The MIT Sea Grant circulation models, which are designed for use in near-coastal environments, are thus an important building block in the development of models of other environmental features. Oil spill models also require circulation patterns as input (see for example Ref. [5]).

3.11 CAFE-1

The basic model, CAFE-1, is a depth-averaged, two-dimensional model that produces current vectors over an area of interest. The current magnitude at each position represents the average, over depth, of the current at that position. This average current when multiplied by a representative area gives a net volume flow through an area. Because the model gives a single velocity, we refer to it as a one-layer model. A typical vector current output, is shown in Figure 1. By integration, a representative particle paths can be obtained as shown in Figure 2.

Grid Layouts. To use CAFE-1 for a specific body of water, one must first divide the area of interest into a finite number of triangular sections. The larger the number of sections (i.e., the smaller each triangle is), the better the correspondence between the model and the actual situation. However, a large number of sections requires a large computer memory and long computer running times. Thus, some "art" is needed to compromise between fine resolution and cost. Variable grid spacing allows one to have fine spatial resolu-

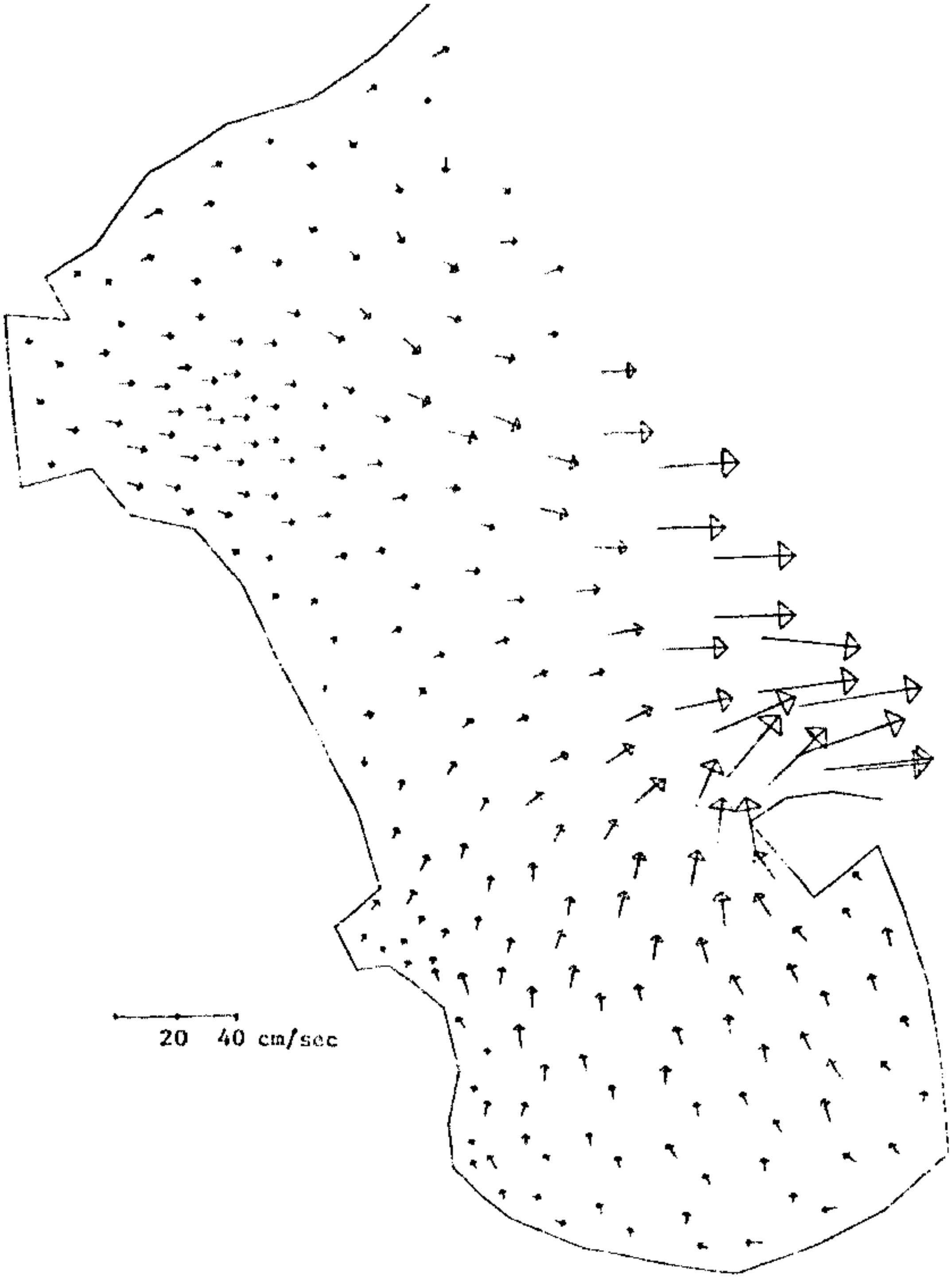
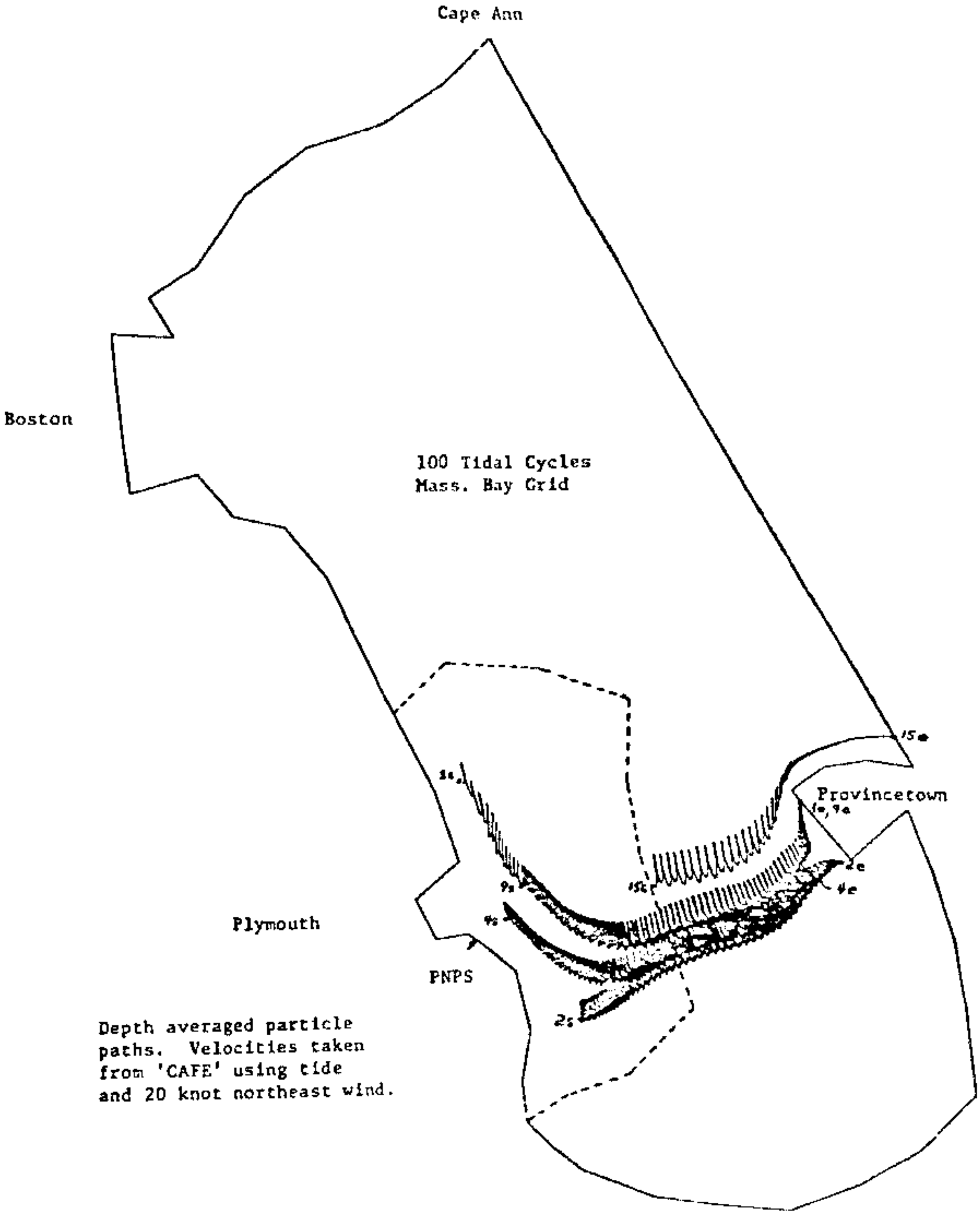


Figure 1. Computed tidal currents in Mass Bay, with an imposed north wind of approximately 10 knots,(τ_y/ρ_o = -0.0000286 m^2/sec^2). t=120000 sec=T/6 after high tide.



Depth averaged particle
paths. Velocities taken
from 'CAFE' using tide
and 20 knot northeast wind.

Figure 2

tion in areas of special interest, in areas where spatial gradients are expected to be large, or near sources of pollution or thermal discharge.

In our studies of Massachusetts Bay, for example, three areas of special interest are reflected in the grid shown in Figure 2: a proposed sand and gravel dredge site, the coast near the Pilgrim Nuclear Power Station (PNPS) and the entrance to the Cape Cod Canal (CCC).

For more detailed studies of a particular area, a powerful stepwise procedure can be used. First, the model can be run using a coarse grid to establish currents and tidal heights on the perimeter of a subarea (dark line in Figure 3). Next, the subarea can be finely divided by a much smaller grid (see Figure 4). The model is then run for the subarea using the values on the perimeters from the first run as input boundary conditions for the second run. Thus, the large, coarse Massachusetts Bay grid shown in Figure 3 was combined with a fine grid around PNPS in Figure 4 to form the system shown in Figure 5. (See Ref. [6].)

Other adaptive procedures and problems are given in Reference [7]. A basic constraint is that the current version of CAFE-1 requires a fairly large core storage - on the order of one-fourth to one-half a megabyte.

Data Input. In modeling, the complete set of data required for the model usually are not known *a priori*. (If all of the input data were known, the model probably would not be necessary.) The process of using a model requires the following procedure: input all of the known data into the model; assume (guess at) values for unknown data; run the model; make field measurements; compare model results and field data; and *then* reestimate

[redacted]

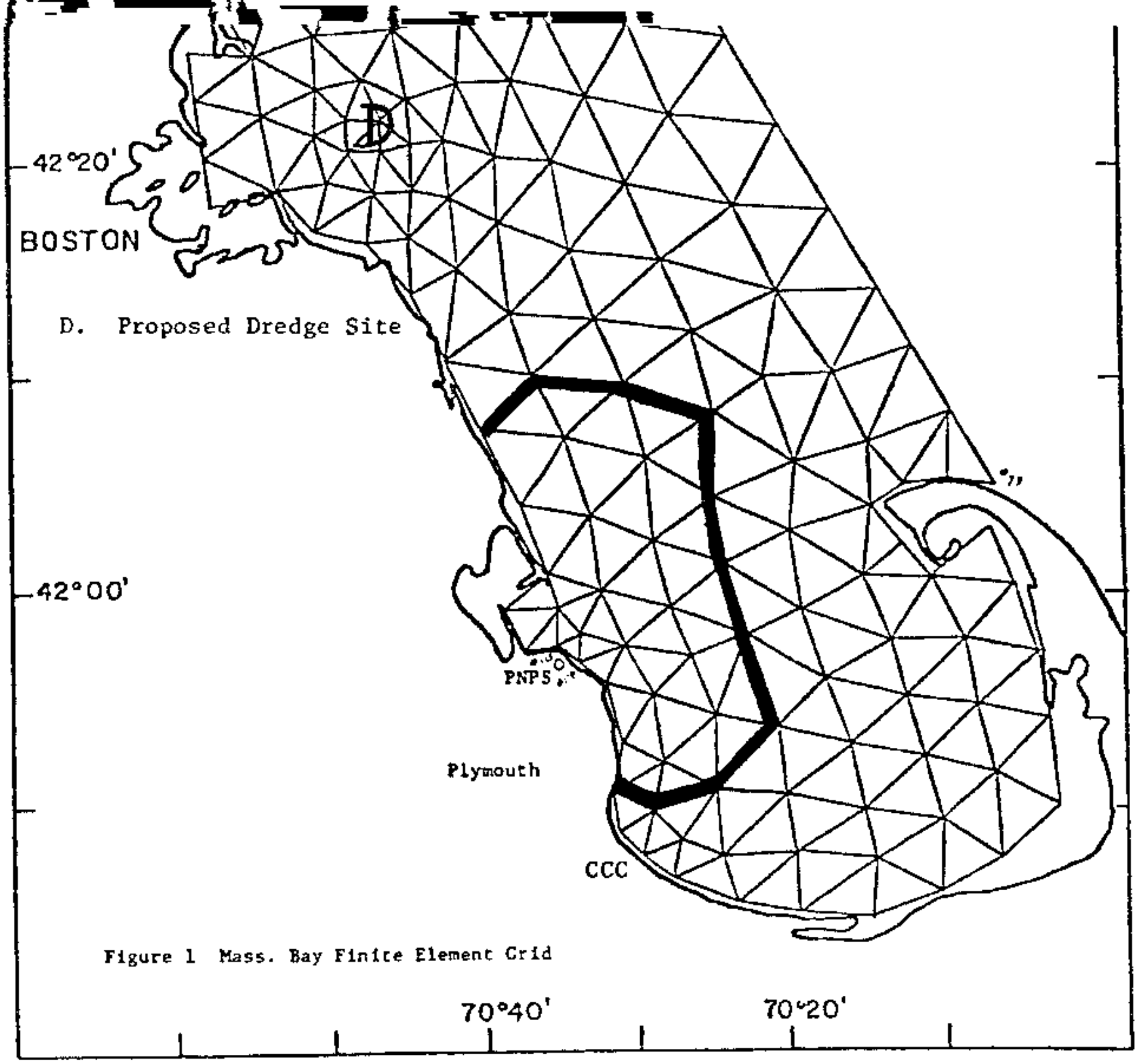


Figure 3. Mass. Bay Finite Element Grid

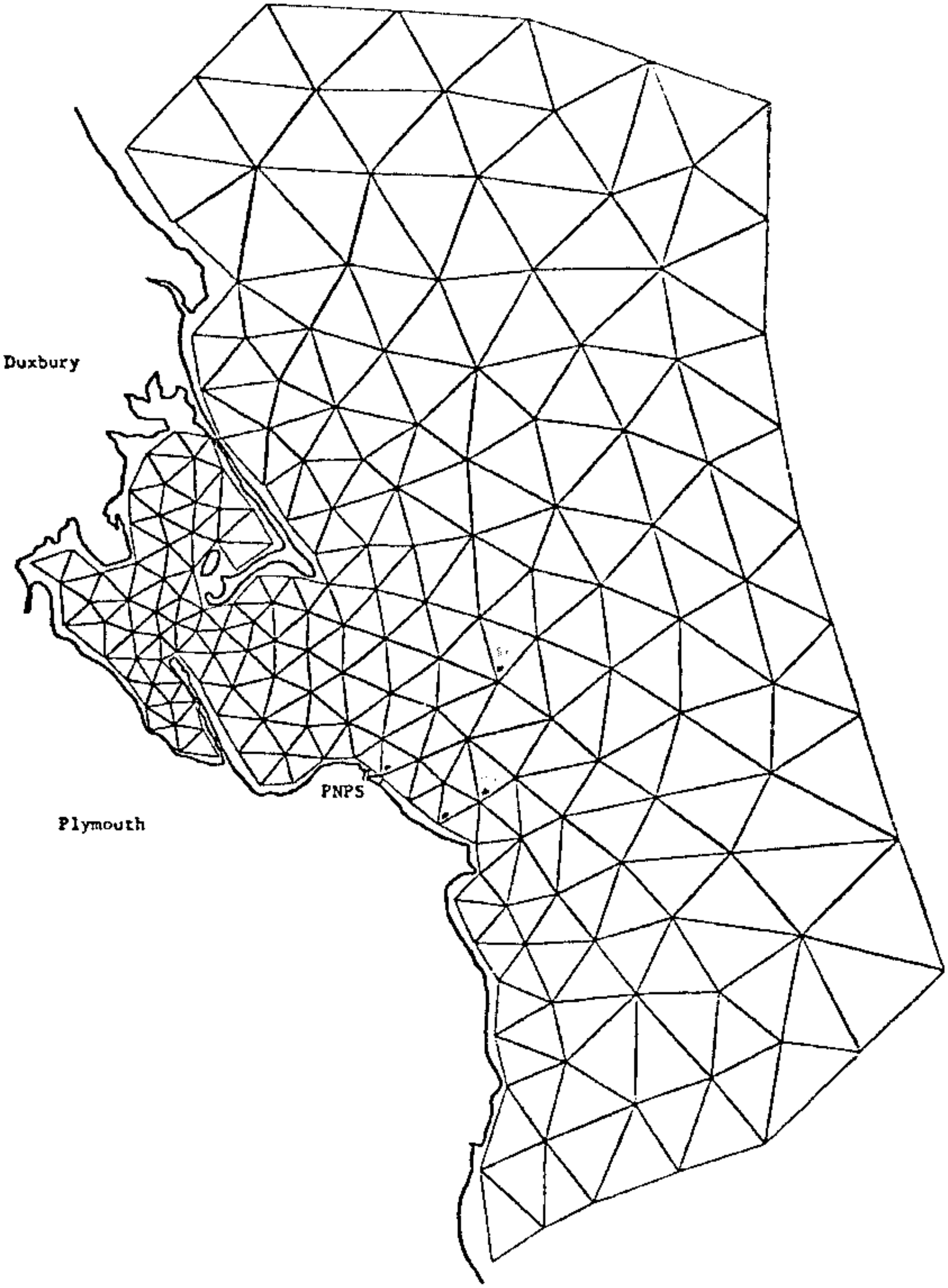


Figure 4. Fine Grid Application

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[redacted]

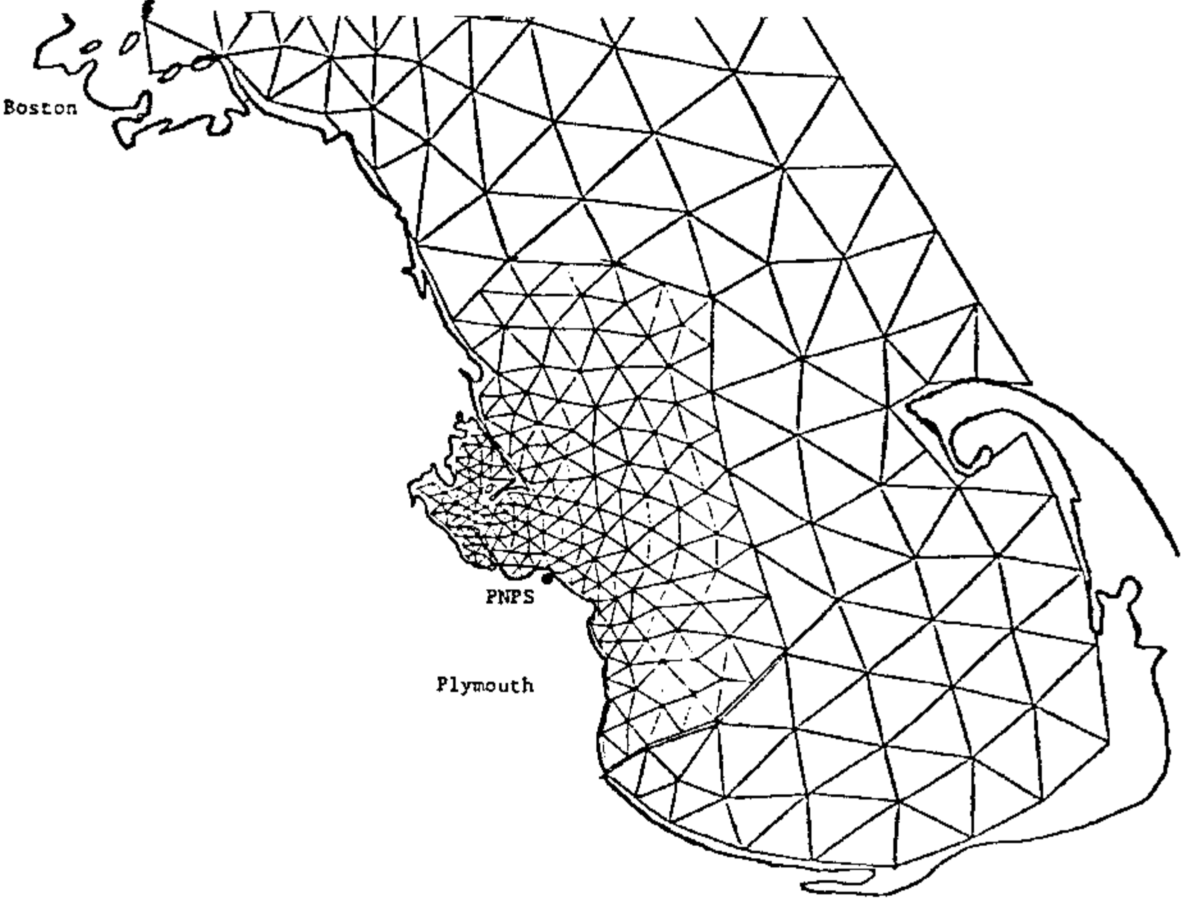


Figure 5. Grid Boundary Matching

tool as well as a forecasting tool.

Data requirements for CAFE-1 are spelled out in detail in Reference [8]. Briefly they are:

(a) mean low water depth at each node;

(b) bottom friction and eddy viscosity coefficient at each node or average volume;

(c) latitude (for Coriolis effect), tidal period, water density;

(d) tidal amplitudes and phases along area boundaries;

(e) location and magnitude of prescribed water flows and heights;

(f) magnitude and direction of wind over time;

(g) initial height and fluxes at each node (initial conditions).

Items (b) and (d) are frequently very difficult to obtain *a priori* and a combination of field measurements and model runs will have to be used to determine appropriate values. We refer to this process as tuning the model.

3.12 CAFE-2

CAFE-2 is a two-layer model corresponding to CAFE-1. It is applicable to environments in which a warm upper layer of water overlies a colder lower layer, as is typical of the near-shore ocean environment in the summer.

Use of the program requires a knowledge of the depth of the upper layer and depth of the lower layer at all grid points. Reasonable approximations are usually known or can be determined from field data.

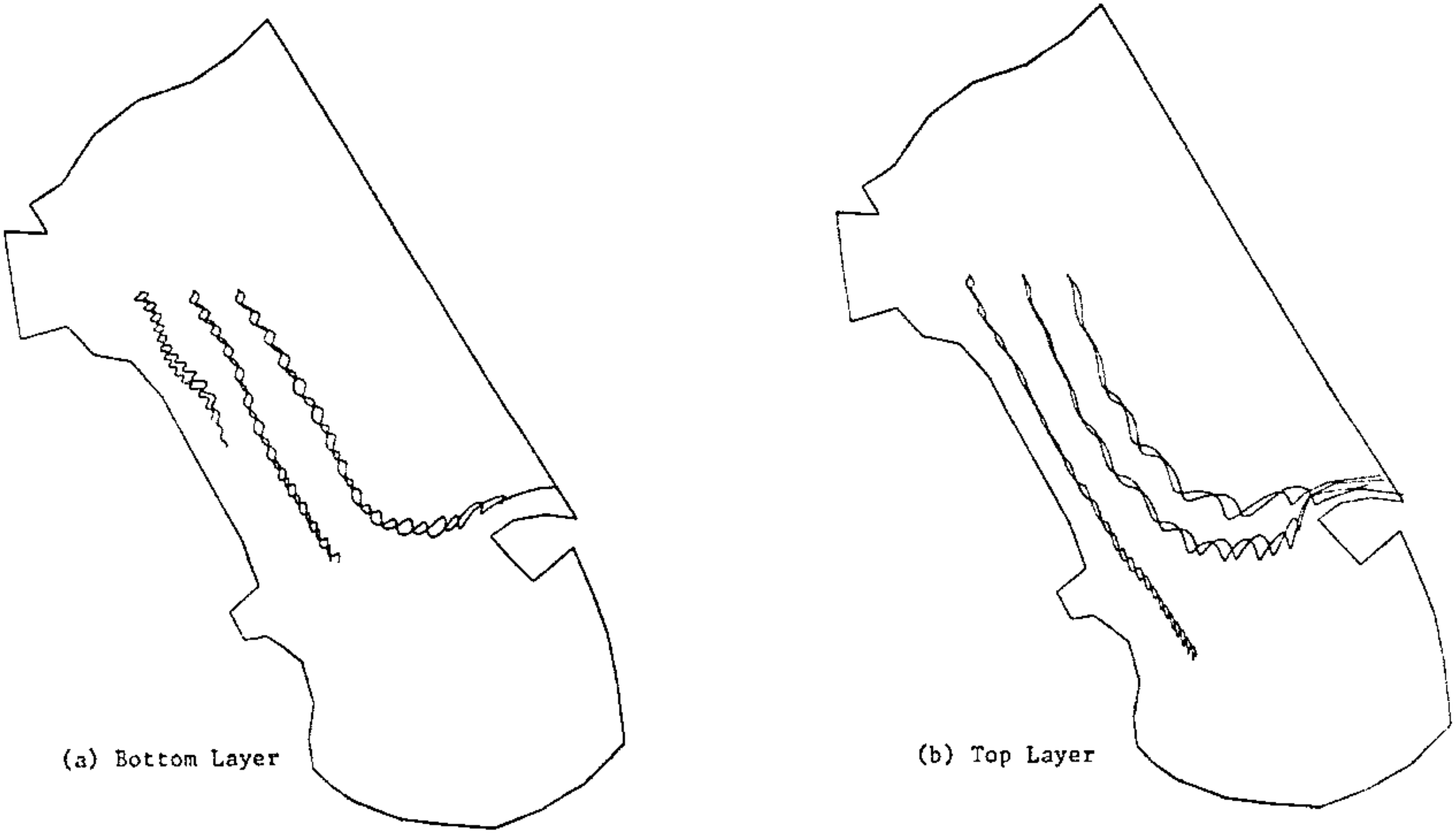
Current and tide data for a two-layer system are especially important, since their values along the ocean boundary provide the prime forcing functions for the model. However, these data are extremely difficult to calibrate and are time-consuming and expensive to measure. Thus effective use of this model is very dependent on the interplay between the model and experimental measurement programs.

Figure 6 shows the output of a typical run of CAFE-2 in which particle paths are shown. The figure suggests that an effluent in the bottom layer would remain trapped in Massachusetts Bay after one week while one in the top layer would be flushed out of the Bay. Relevant applications of this model are given in References [6] and [13].

Although the difficulties of creative use of two-layer models have been emphasized, such models may be essential to provide a useful representation of the "real world." The density stratification and velocity differences (including counter-flows) cannot be investigated with a single-layer model.

3.2 Dispersion Models

Circulation models provide important information about hydraulic flow fields. However, from a practical viewpoint the main interest is not the flow field, but rather the transport and dispersion of some pollutants (or thermal energy) from a source throughout the region of interest. The integrated velocity outputs of CAFE-1 that can trace particle paths are sometimes helpful in qualitatively describing transport. To adequately describe the physical situation, however, a model that solves some form of the convection-diffusion equation is needed. The DISPER models provide such a solution, using the output of CAFE models to provide the basic flow fields. The fundamental simplifying assumption is that the flow fields are not



(a) Bottom Layer

(b) Top Layer

Figure 6. Seven-Day Particle Paths in Mass. Bay

[illegible] be used. Reference [illegible] discusses data relating to appropriate values for dispersion and decay for some sediments found in coastal waters.

The outputs from the program are the depth-averaged concentrations (mass per unit volume) and, for decaying pollutants, average concentrations (mass per unit area) on the bottom. Both quantities are given as functions of time.

The DISPER programs are particularly useful in determining the effects, if any, of the timing of the release of a pollutant at various points in the local tidal cycle. By running the program several times with releases at different times during the tidal cycle, optimal timing for releases may be found.

DISPER-1 is a useful model provided that the vertical water column is well mixed so that such variables as velocity and density are reasonably uniform in the vertical direction. This case obtains in winter months in New England and other Northern waters. In summer months, however, solar heat creates a density stratification. By mid-summer a strong thermocline develops and the water is divided into two-distinct layers. The dynamics of such a system cannot adequately be described by a single-layer model. The influence of the thermocline on dispersion and decay may be profound, even if effects on circulation are small.

The use of a single layer model may also be invalidated as a result of bottom topography. For example, those familiar with the topography of Massachusetts Bay will recognize that Stellwagen Bank must exert a significant influence on the vertical distribution of currents close to the Bank. Thus even in winter, two-layer circulation and dispersion models are probably necessary to provide a meaningful description of dispersion phenomena near the Bank.

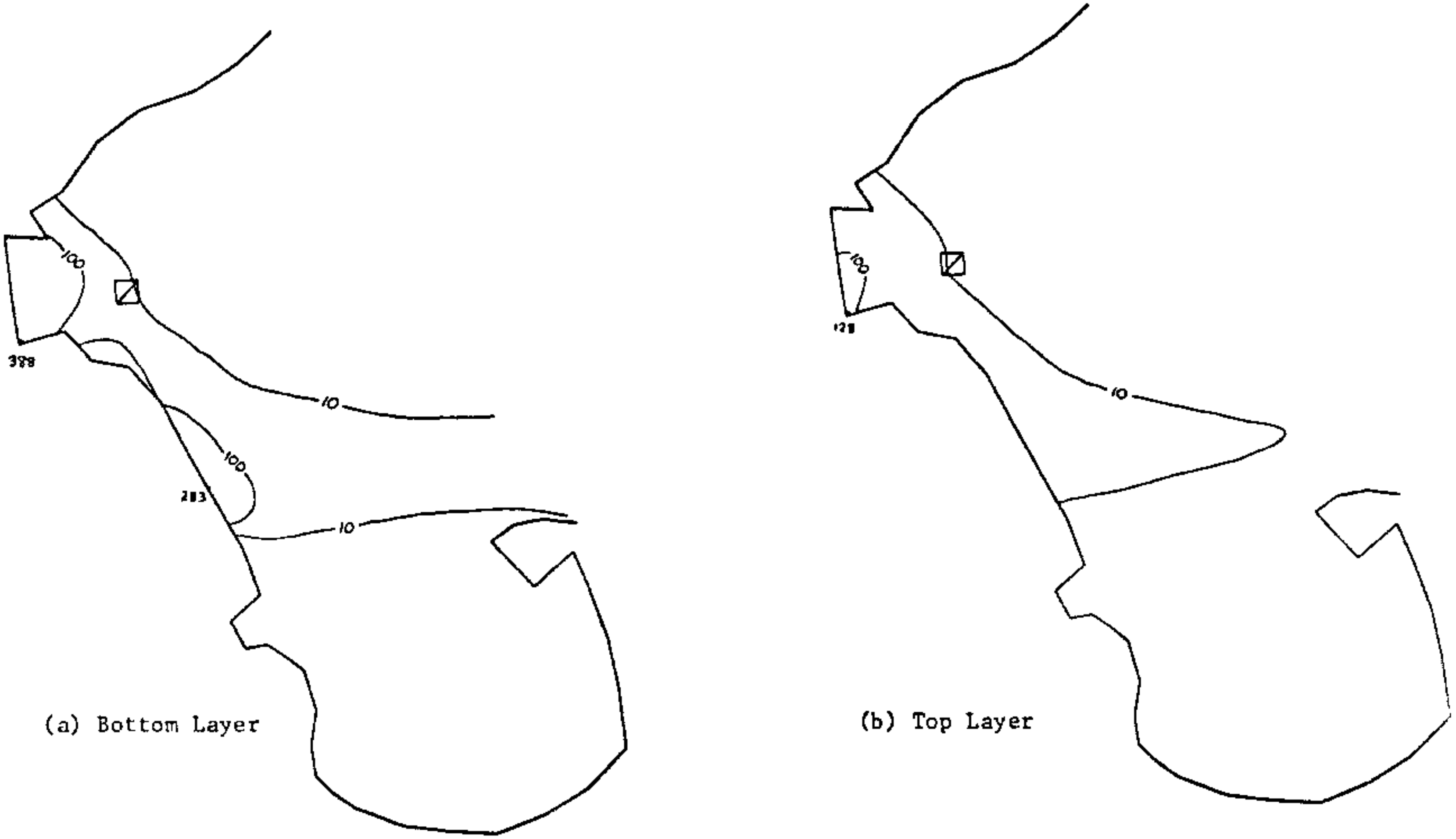
3.22 DISPER-2

DISPER-2 differs from DISPER-1 in ways similar to the way CAFE-2 differs from CAFE-1; that is, input must be specified in two-layers and outputs are given in two-layers. A major limiting factor in the use of the model is the availability of appropriate field data to provide the two-layer inputs.

An additional difficulty in using DISPER-2 is the fact that transport field measurements that will provide data concerning appropriate values for coupling coefficients.

A typical output from a two-layer dispersion model is shown in Figure 7. In this case, the model was used to study the release of a pollutant near the site of the Nomes Project. In the lower layer, circulation is slower than in the top layer, resulting in higher concentration of the dispersant throughout the bay.

The problems of two-layer models have been addressed in References [6] and [13]. Verification studies showed that the model adequately predicts the phenomena it is intended to...with respect to interfacial transport and diffusion and transport in the individual layers." [13]



(a) Bottom Layer

(b) Top Layer

Figure 7. Model Results for HTB Run at Day D+7 (Release at Low Water)

Institutions who are using the models.

4.1 Pilgrim Nuclear Power Station Studies

Pilgrim Nuclear Power Station, owned and operated by the Boston Edison Company, has an open cycle cooling system. For engineering and licensing purposes, more information was required concerning the potential for recirculation of heated water, the origin and fate of biota drawn into the intake, the effects of water currents on the effects of the PNPS throughout Massachusetts Bay, and the flushing of the Bay.

[redacted]

Edison personnel resulted in clarification of the issues as described in Reference [6].

The Sea Grant Models are ideal for this type of problem. The large amount of time used on Boston Edison's IBM 370/158 was more than paid for by the relatively low cost of the experimental program and the immense amount of data obtained relative to the previously poorly understood phenomena.

4.2 A Hypothetical Power Plant at Rome Point, RI

The MIT models were used to investigate the effect on existing flow patterns caused by a hypothetical nuclear electric generating station at Rome Point, RI. A few weeks of tidal data provided the forcing function. Very limited field measurements coupled with the model produced the required information. (See Ref. [7].)

4.3 Hurricane Surges and the Atlantic Generating Station

Under the sponsorship of MIT Sea Grant and Dames and Moore, Inc., James Pagenkopf and Bryon R. Pierce have investigated the application of CAFE-1 to predicting the storm surges in the near-coastal environment. The study was done in conjunction with other studies concerning the safety and environmental impact of the proposed nuclear Atlantic Generating Station.

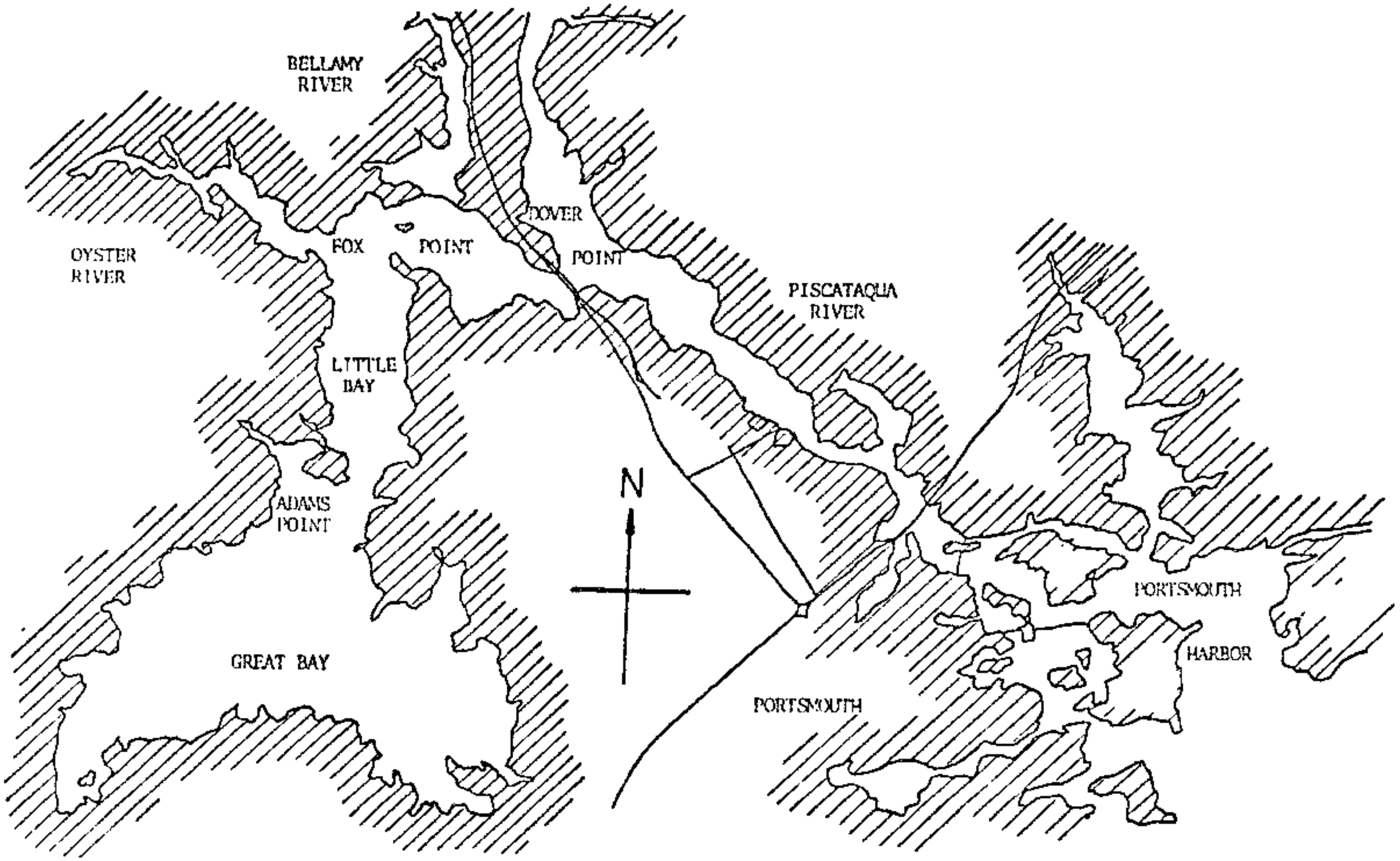
Extensive comparisons were made of Finite Difference Models and Finite Element Models. The models were calibrated using extensive data from the hurricane of September 14, 1974. (See Ref. [10].)

4.4 The Great Bay Estuary

B. Celikkol and R. Reichard of the University of New Hampshire (UNH) are adapting the Sea Grant Models to the Great Bay Estuary, which is one of the largest estuaries opening on the gulf of Maine. Hydrodynamically, it is a complex area as suggested in Figure 8. Great Bay itself is characterized by tidal flows and a network of channels, while the Piscataqua River is characterized by large (fast) tidal flows. Little Bay, which connects Great Bay and the Piscataqua, has complex turbulent flow patterns.

FIGURE 8

GREAT BAY ESTUARY SYSTEM



The model building for this area is perhaps the most ambitious undertaken to date. Four separate interconnecting models are being used to represent Portsmouth Harbor, the Piscataqua River, Little Bay, and Great Bay. The model is in a preliminary operating condition, having been calibrated with a few field measurements. Data from a joint UNH/NOS survey will be used to calibrate the model in more detail. (See Ref. [14].)

The model ultimately will be used to assist state planners in developing a master plan for sewage control in the New Hampshire Sea Coast Region. The model has already been used in forecasting the disposition and fate of dredging fines associated with a dredging project at the Portsmouth Naval Shipyard in Kittery, Maine.

4.5 Biscayne Bay

John Wang and associates, with the support of the Florida Sea Grant Program, have modified CAFE-1 for use in their studies of the circulation in Biscayne Bay and a nuclear power plant cooling pond. At present, investigators are initiating a verification program that involves extensive field measurements of currents in the Bay.

Future dispersion studies will use DISPER-1 in order to determine the flushing action in the Bay.

[illegible] requirements as well as available output formats, including plotter subroutines. Examples and sample runs are given for illustrative purpose. The references cited in the manuals, describe important aspects of application such as parameter estimation, grid set-up and numerical stability.

MIT will provide card decks or tapes for users at a nominal cost, or users may create their own cards and tapes using the complete listing of programs in the manuals.

We prefer you use the MIT tapes or cards to eliminate possible errors in transcription. We keep records of who uses the models so if we (or you) find "bugs" and eliminate them, we can notify all known users. Similarly, if substanital extensions or improvements in the models are made in the course of ongoing research, we would like to inform present users.

The titles of the manuals and other data are given in References 8, 9, 11, and 12. Please direct your requests to Norman Doelling, Manager, Marine Industry Advisory Services, MIT, Room 1-215, 77 Massachusetts Avenue, Cambridge, MA 02139.

7. Wang, J. D. and J. J. Connor. Mathematical Modeling of Near Coastal Circulation. Cambridge, MA: MIT Sea Grant Report 75-13, 1975.

[redacted]

8. [redacted] Finite Element Circulation Model. Cambridge, MA: MIT Department of Civil Engineering, Sea Grant Report 76-11, 1976.

9. User's Manual for CAFE-2, MIT Sea Grant Report 77-6, in press.

10. Pearce, B. R. and J. R. Pagenkopf. Numerical Calculation of Storm Surges: An Evaluation of Techniques. Offshore Technology Conference, Dallas, Texas, 1975.

11. Pagenkopf, J. R., et. al. A User's Manual for "Disper-1": A Two-Dimensional Finite Element Dispersion Model. Cambridge, MA: MIT Department of Civil Engineering, Sea Grant Report 76-12, 1976.

12. User's Manual for DISPER-2, MIT Sea Grant Report 77-7, in press.

[redacted]

13. [redacted] Stratified Waters. Cambridge, MA: Ralph M. Parsons Laboratory, Report No. 219, 1976.

14. Celikkol, B. and R. Reichard. Hydrodynamic Model of the Great Bay Estuarine System. Durham, NH: UNH Sea Grant Report 153, 1976.

APPENDIX A

SOME COMMENTS ON THE LEGAL AND REGULATORY MILIEU REGARDING ENVIRONMENTAL IMPACT STATEMENTS AND COMPUTER MODELS

Section 102(2)(C) of the National Environmental Policy Act of 1969 (NEPA) requires an environmental evaluation of major federal actions that could significantly affect environmental quality. The evaluation must include the environmental impact, the unavoidable effects, the alternatives, the relationship between short and long run costs and benefits, and any irreversible or irretrievable commitments of resources. The result of this evaluation is the Environmental Impact Statement.

The courts have dealt extensively with the interpretation of what constitutes "a major federal action significantly affecting the quality of the human environment" (Reference A1). Today NEPA reaches well beyond the actions of federal agencies to actions which are in any part supported or regulated by the federal government. These actions include but are not limited to (Reference A2):

(1) federal funding of projects proposed by the federal government or other levels of government and private organizations;
(2) issuing of permits by responsible federal agencies for changes or improvements within their jurisdictions;
(3) the leasing of federal land or resource rights;
(4) federal legislation;
(5) administrative duties such as approval for line or rail abandonment by the ICC.

Many states have passed "mini EPAs" which model in whole or in part the national legislation. Rutgers University, using several previous studies as a base, has surveyed the 50 states and reported as of January 1, 1975, that "32 states have acted legislatively or administratively to establish NEPA equivalents within the confines of their political jurisdictions" (Reference A3). The requirement of NEPA for an Environmental Impact Statement is its pivotal element and in one form or another all 32 states have followed suit.

One other aspect of NEPA deserves mention, particularly regarding the role of computer modeling techniques. This is the need for quantification.

Section 102(2)(B) of NEPA requires agencies to "identify and develop methods and procedures--which will insure that presently unquantified environmental amenities and values may be given appropriate consideration in decision-making along with economic and technical considerations."

Several courts have said that a finely tuned and systematic weighing process for environmental values must be incorporated (Reference A4). If cost-benefit analysis is used to aid decision makers, then environmental cost-benefit analysis must be incorporated into the EIS in quantitative form. Mathematical modeling techniques coupled with computers are powerful tools in predicting and quantifying the costs and benefits of various activities.

Exactly what constitutes an adequate EIS has often been a judicial decision. The various guidelines are very broad, but for an EIS to stand up to scrutiny, its methodology must be adequate, clear, and repeatable. Mathematical models are excellent in this regard, and, if used properly, provide the backbone of a very strong EIS.

REFERENCES FOR APPENDIX A

[A1] Anderson, F.R. *NEPA IN THE COURTS: A Legal Analysis of the National Environmental Policy Act.* Baltimore, MD: Johns Hopkins University Press, 1974.
(A good review of the judicial interpretation of NEPA; see also chapter four of Rosen's *Manual for Environmental Impact Evaluation.*)

[A2] Rosen, S.J. *Manual for Environmental Impact Evaluation.* Englewood Cliffs, NJ: Prentice-Hall, 1976, p.7.
(This is an excellent up-to-date overview of the EIS process.)

[A3] Burchell, R.W. and D. Listokin. *The Environmental Impact Handbook.*

Brunswick, NJ: Rutgers-The State University, Center for Urban Policy Research, 1975, pp.7-36.
(A state by state summary on EIS regulations is provided.)

[A4] Calbert Cliff's Coordinating Committee vs Atomic Energy Commission, 499F. 2nd 1109, IELR 20346 (DC cir. 1971).
(A discussion of this case and others can be found in Rosen, p. 21 and Anderson, pp. 247-258.)