United States
Environmental Protection
Agency

Office of
Radiation Programs
Washington, D.C. 20460

EPA 520/1-87-013
February 1987

Radiation

EPA

Proceedings of a Meeting on Ocean Modeling Efforts at EPA

PROCEEDINGS OF A MEETING

ON

OCEAN MODELING EFFORTS AT EPA

February 10, 1987

Kung-Wei Yeh
Meeting Coordinator
U.S. Environmental Protection Agency
Office of Radiation Programs

Washington, DC

PREFACE

A meeting on the "Ocean Modeling Efforts at EPA" was convened on February 10, 1987, at EPA Headquarters in Washington, DC. More than forty Environmental Protection Agency scientific and managerial staff, and scientists from the private sector attended the one-day meeting.

This document was developed from conference tapes and view graphs provided by the speakers. It includes ten presentations on Modeling Efforts that address the problems encountered, methodology used, assumptions made and results obtained (or expected). Verbatim transcripts are not included in these proceedings. Detailed information about individual study objectives, findings, and policy implications may be obtained from the appropriate speakers. Addresses for all speakers and attendees are provided in the document.

Copies of this document are being distributed to all speakers and participants. A limited number of additional copies of the document are available for distribution from the Office of Radiation Programs, U.S. Environmental Protection Agency Washington, DC 20460.

TABLE OF CONTENTS

I. Introductory Remarks

By David Janes, Director
Analysis and Support Division
Office of Radiation Programs

Good morning, ladies and gentlemen. Welcome to the Ocean Modeling Efforts meeting. The purpose of this meeting is to discuss ocean modeling efforts in EPA, past and present, with the intent of identifying some common approaches that will aid us in developing regulations.

The Office of Radiation Programs has some specific modeling needs. If we get a request to issue a permit for the disposal of low-level radioactive waste in the ocean, we are required, among other things, to prepare a Radioactive Material Disposal Impact Assessment (RMDIA) as specified in amendments to the Ocean Dumping Act of January 6, 1983.

The RMDIA has two goals. The first is to assess the effects on human health and welfare and the marine environment of solid or solidified low-level radioactive waste disposed of in containers that remain intact during and after disposal. The second is to assess the same impacts if the containers should fail. Most of the scenarios for the disposal of low-level radioactive waste assume containers are placed on the deep ocean floor and examine the potential for dispersion from that point. Conversely, many of you here today are interested in modeling the fate of material disposed on the ocean surface. It seems to me that if you look at long term transport, i.e., over long times and distances, there has to be some commonality between the dispersion of materials originally deposited on the ocean floor and those deposited upon the ocean surface. So there may be some commonality among models that could be combined to make the whole greater than the sum of the individual parts. I noticed from the agenda that this is one of the subjects you will address today.

This initial effort will help us learn what others are doing and how these efforts relate to what each of us does. Hopefully, today's meeting will provide a basis for future discussions and some products that will be useful to us all.

Introductory Remarks

By Bob Zeller, Senior Science Advisor
Office of Marine and Estuarine Protection (OMEP)
Office of Water

Tudor Davies, Director of OMEP, in the Fall of 1984, asked me two questions relevant to today's meeting:

(1) Are mathematical models of transport, fate, and effects potentially useful for decision making in our ocean disposal programs?

(2) Are existing, validated models available that will meet our needs? If not, are potentially useful models being developed?

My answer to the first question was yes and to the second question, a qualified yes. First, validated mathematical models are potentially useful in two related decision areas-- decisions on ocean disposal site designation and permit issuance and decisions on ocean disposal compliance with regulatory requirements and human health and environmental objectives. A key feature of our planned approach to decision making in both areas is the prediction and verification of pollutant transport, fate, and effects. Once we are confident of our predictive capabilities for a given disposal site and circumstances, we can streamline our data collection requirements dramatically and, thereby, save substantial amounts of dollars and time. Thus, applicable and validated math models will be essential for successful implementation of our decision making approach.

My answer to the second question is a qualified yes because, although there are a number of analytic and numerical models in existence, they are either not strictly applicable to our decision making needs, or they are not validated for our ocean disposal sites and circumstances. However, test applications and validation of available models are underway and additional, potentially useful models are under development.

My participation here today signals our keen interest in both the validation status and applicability of available mathematical models as well as the applicability of models that are under development. With this brief introduction, I am looking forward to the presentations by the several modeling experts on today's meeting agenda.

II. Background and Perspectives

By Kung-Wei Yeh
Environmental Studies and Statistics Branch, ASD
Office of Radiation Programs

The exploration and scientific studies of the oceans have always been closely connected with practical demands. The Environmental Protection Agency (EPA) has had a continuing interest in the study of the oceans since the Agency's inception in 1970. Various offices within the Agency are evaluating the ocean as an alternative to land disposal for some toxic and hazardous materials as well as low-level radioactive wastes. The objectives for ocean disposal within program offices may vary but all are similar in that ocean processes are not subject to political, economic, and/or national boundaries.

It happens occasionally in many large organizations, such as EPA, that the left hand does not always know what the right hand is doing. The ocean environment is large, complicated, and subject to many orders of magnitude greater uncertainty than other regions of the earth (Figure 1). To share with other offices the information and experience gained and to exchange concepts and ideas in dealing with a complicated and less known ocean environment, a meeting seems both necessary and valuable. This approach may mutually benefit all program offices with similar interests in the ocean as a permanent repository or dilution/dispersion medium.

Ocean disposal associated with physical processes ranges from small scale turbulence, such as initial mixing of sewage discharged from outfalls, to global scale transport/dispersion of materials not readily biodegraded. The meeting held on February 10, 1987, covered a wide range of physical processes of interest to EPA program offices. The Office of Radiation Programs and Office of Water have conducted monitoring and ocean process studies for low-level radioactive waste, and municipal and industrial wastes respectively since the Congress enacted the Marine Protection, Research and Sanctuaries Act of 1972. Recently, the Office of Solid Waste and Emergency Response began considering ocean disposal as an option for some toxic materials which are restricted by law from being deposited on land. So there is a growing interest in ocean processes by the Agency, particularly with the new Agency stress on evaluating disposal alternatives.

In addition to the high environmental uncertainties of ocean disposal (Figure 1), the costs of ocean monitoring and research are also high. To reduce the costs of monitoring in the ocean, a creditable and defensible ocean transport model may provide reasonable estimates which will help to delineate and assess the consequences of pollutants disposed of in the ocean. This is particularly true for monitoring the deep-ocean bottom environment with depth greater than 4,000 meters.

Recently, modeling methods have been used by the International Atomic Energy Agency (IAEA) to numerically define high-level radioactive wastes which are prohibited from disposal in the ocean, and by the Nuclear Energy Agency (NEA) of the Organization for Economic Cooperation and Development (OECD) to evaluate the continued suitability of the disposal site for low-level radioactive waste in the Northeast Atlantic. A modeling approach certainly is not perfect. However, it provides reasonably good predictions for pollutants carried out and dispersed by ocean processes.

Physical boundaries and current systems vary from one site to another. Hence, the methodologies and assumptions vary for different problems under various physical conditions. For a specific disposal site, care must be taken in selecting a methodology and assumptions for developing the model. In the presentations of February 10, 1987, each speaker has identified the problem which needed to be solved, the methodology used, assumptions made and results obtained (or expected).

It is hoped that this meeting will serve as an initial step to consolidate the growing interests in ocean modeling processes throughout the Agency, and to share the experience, knowledge, and results obtained and to identify areas of cooperation and collaboration on modeling and data collection efforts among the interested program offices.

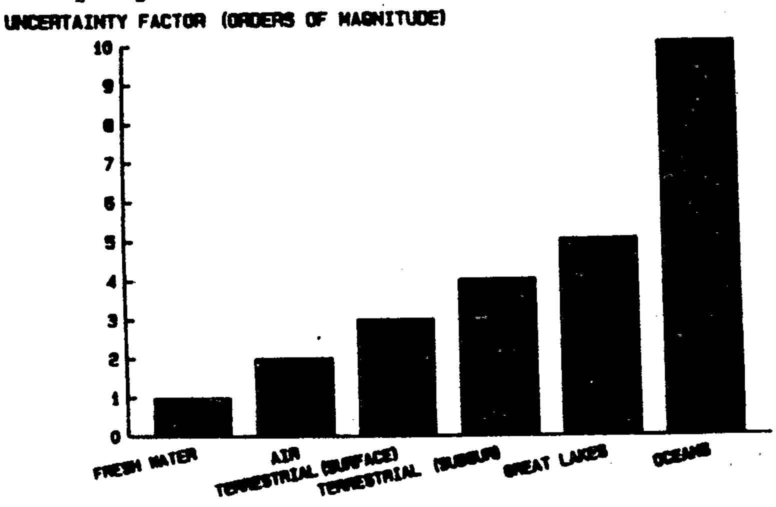


Figure 1. **ENVIRONMENTAL UNCERTAINTY**
(Courtesy of ERL-Narragansett)

III. Presentations

(I) DEEP-OCEAN MODELING EFFORT AT ENVIRONMENTAL RESEARCH LABORATORY - NARRAGANSETT, RI

By John Paul
U.S. Envrionmental Protection Agency
Environmental Research Laboratory
Narragansett, RI

GENERAL PROBLEMS - To estimate risk assessment under the following three cases based on aquatic exposure and effects components, and exposure/dose component for human health:

A. CASE ONE:

1. Problem to be solved- calculate upper bound estimate for upper mixed layer.

2. Methodology used- two-dimensional model

   (a) For near- and far-field: used time dependent, uniform framework, waste load allocation approach, and "upper bound" determination for effects endpoints to estimate whole sludge toxicity, marine water quality criteria and tissue residues (FDA levels).

   (b) For short-term model: used time dependent and individual barge plume to determine short-term impacts with release zone method (RZM) at T = 4 hours, time scale up to 1 week and spatial scale up to the size of the site.

   (c) For long-term model: used long-term, time averaged concentrations of sum of all individual dumps to estimate chronic impacts with time scale up to 30 days and spatial scale up to 300 km.

3. Assumptions made

   (a) Two-dimensional in horizontal plane, uniformly mixed in upper mixed layer,

(b) Contaminants completely conserved in water column,
(c) No particulate settling,
(d) No exchange across air-sea interface,
(e) Treat total concentration of contaminants,
(f) All contaminants biologically available,
(g) No explicit inclusion of Gulf Stream Rings,
(h) Gulf Stream is downstream sink,
(i) Mean flow and dispersion are available from long-term current records.

4. Results obtained- The long-term model has been successfully applied to the following studies:

(a) Deep-water Municipal Disposal Site (Figure I-1),
(b) Sludge loading from NY/NJ municipalities,
(c) Maximum contaminant loading from NY plants (PCB) (Figure I-2),
(d) Composite New Jersey whole sludge toxicity,
(e) Standard application factor,
(f) Water quality criteria for PCB,
(g) FDA tolerance levels for PCB.

B. CASE TWO:

1. Problem to be solved- estimate the benthic flow of sinking sewage sludge particles at offshore disposal sites for the preliminary assessment of potential for benthic impacts due to midshelf or offshelf disposal of sewage sludge and contributions to the design of a monitoring strategy for the measurement of contaminant accumulations on the sea floor.

2. Methodology used- two-dimensional layered model to calculate upper bound estimate for sediment compartment.

3. Assumptions made

(a) Sewage sludge settling velocity data are available,
(b) Current meter statistics from a transect off the coast of Virginia Beach (MASAR program) are available,
(c) Bottom topography was modeled with a cross-shelf profile and without along shelf variation,
(d) Bottom boundary condition was treated as completely absorbing (i.e., resuspension is not considered),
(e) No mass losses due to degradation.

4. Results obtained

   (a) Predicted peak carbon fluxes are less than 0.1 $g/m^2/d$ due to midshelf disposal and 0.005 $g/m^2/d$ due to offshelf disposal (Figure I-3).
   (b) Identified route for transport of pollutants that may gradually accumulate in sediments and benthic species.
   (c) Identified a critical need to improve our understanding of processes affecting vertical transport.
   (d) Proposed an array of sediment traps be deployed along the 2,000-m isobath and the outer shelf to determine potential sites of benthic impact.
   (e) Identified a need to obtain baseline data on current levels of pollutants in tissues of benthic shelf edge fish (Figure I-4).

C. CASE THREE:

1. Problem to be solved- assess the environmental impact of deep-ocean disposal of wastes.

2. Methodology used- a three-dimensional model to estimate concentration in water column and sediment in which Lagrangian coordinates are used for particle trajectories and Eulerian coordinates for contaminant concentrations.

3. Assumption made- fluid is incompressible and Newtonian.

4. Results obtained

   (a) Provided more realistic estimate of concentration for entire water column and flux to the sediments at cost of more computational time and efforts.
   (b) Need monitoring plan for model validation.

Bibliography on Deep-Ocean Modeling at ERL-Narragansett

J.F. Paul, H.A. Walker, and V.J. Bierman, Jr. 1983. Probabilistic approach for the determination of the potential area of influence for waste disposal at the 106-Mile Ocean Disposal Site. Appendix A in: 106 Mile Site characterization update, J.B. Pearce, D.C. Miller, and C. Berman (editors), NOAA Technical Memorandum NMFS-F/NEC-26, National Marine Fisheries Service, Northeast Fisheries Center, Woods Hole, Massachusetts.

T.P. O'Connor, H.A. Walker, J.F. Paul, and V.J. Bierman, Jr. 1985. A strategy for monitoring of contaminant distributions resulting from proposed sewage sludge disposal at the 106-Mile Ocean Disposal Site. Marine Environmental Research, Vol. 16, pp. 127-150.

H.A. Walker, J.A. Nocito, J.F. Paul, V.J. Bierman, Jr., and J.H. Gentile. 1985. Methods for waste load allocation of municipal sewage sludge at the 106-Mile Ocean Disposal Site. Report prepared for Criteria and Standards Division, U.S. Environmental Protection Agency, 113 pages.

J.C. Prager, V.J. Bierman, Jr., J.F. Paul, and J.S. Bonner. 1986. Sampling the oceans for pollution: a risk assessment approach to evaluating low-level radioactive waste disposal at sea. Dangerous Properties of Industrial Materials Report, Vol. 6, No. 3, pp. 2-26.

J.F. Paul, H.A. Walker, and J.A. Nocito. 1986. Lagrangian-Eulerian approach to modeling contaminants. In: Water Forum '86: World Water Issues in Evolution, M. Karamouz, G.R. Baumli, and W.J. Brick (editors), American Society of Civil Engineers, New York, pp. 1301-1308.

J.S. Bonner, C.D. Hunt, J.F. Paul, and V.J. Bierman. 1986. Prediction of vertical transport of low-level radioactive Middlesex soil at a deep-ocean disposal site. Report No. EPA 520/1-86-016, Office of Radiation Programs, U.S. Environmental Protection Agency, 60 pages.

J. Lipton, C. Menzie and R. Wells. 1986. Ocean disposal of municipal sewage sludge: a comparative analysis of mid-shelf and deep ocean dumpsites. Report prepared for Office of Policy Analysis, U.S. Environmental Protection Agency by Abt Associates Inc., Cambridge, Massachusetts, 82 pages.

Development of risk assessment methodology for ocean disposal of municipal sludge. Report No. ECAO-CIN-492, 1986. Prepared for Office of Water Regulations and Standards, U.S. Environmental Protection Agency by Environmental Criteria and Assessment Office, Cincinnati.

J.F. Paul, V.J. Bierman, Jr., H.A. Walker, and J.H. Gentile. In Press. Application of a hazard assessment research strategy for waste disposal at the 106-Mile Ocean Disposal site. In: Oceanic Processes in Marine Pollution, Vol. 4, D.W. Hood, A. Schoener, and P.K. Park (editors), Kreiger Publishing Co.

J.H. Gentile, V.J. Bierman, Jr., J.F. Paul, H.A. Walker, and D.C. Miller. In Press. Hazard assessment research strategy for ocean disposal: concepts and case studies. In: Oceanic Processes in Marine Pollution, Vol. 3, M.A. Champ and P.K. Park (editors), Kreiger Publishing Co.

H.A. Walker, J.F. Paul, and V.J. Bierman, Jr. In Press. A convective-dispersive transport model for wastes disposed of at the 106-Mile Ocean Disposal Site. In: Oceanic Processes in Marine Pollution, Vol. 6, D.J. Baumgartner and I.W. Duedall (editors), Kreiger Publishing Co.

H.A. Walker, J.F. Paul, and V.J. Bierman, Jr. In Press. Methods for waste load allocation of municipal sewage sludge at the 106-Mile Ocean Diposal Site. Environmental Toxicology and Chemistry.

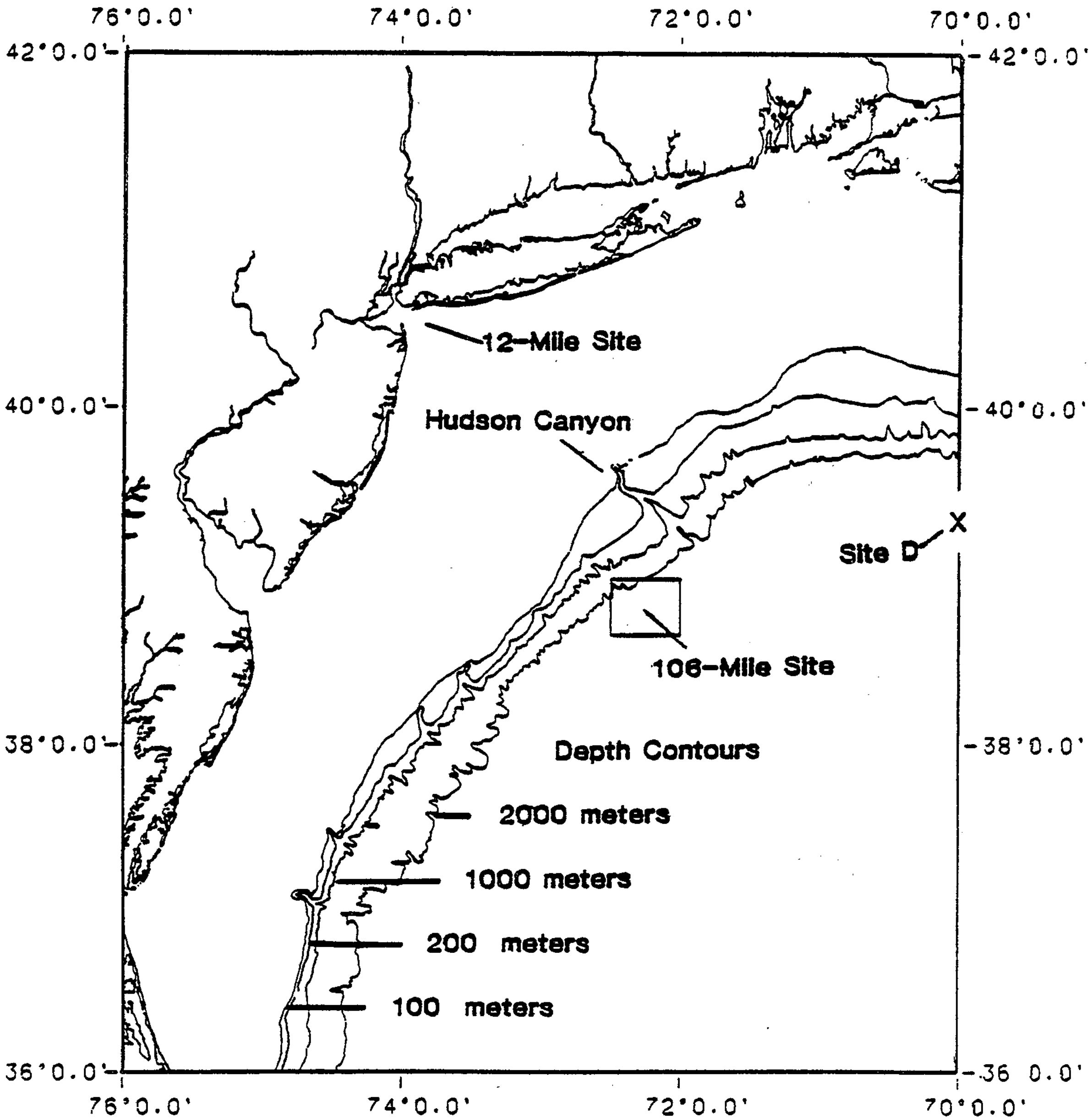


Figure I-1. Deep-water Municipal Disposal Site

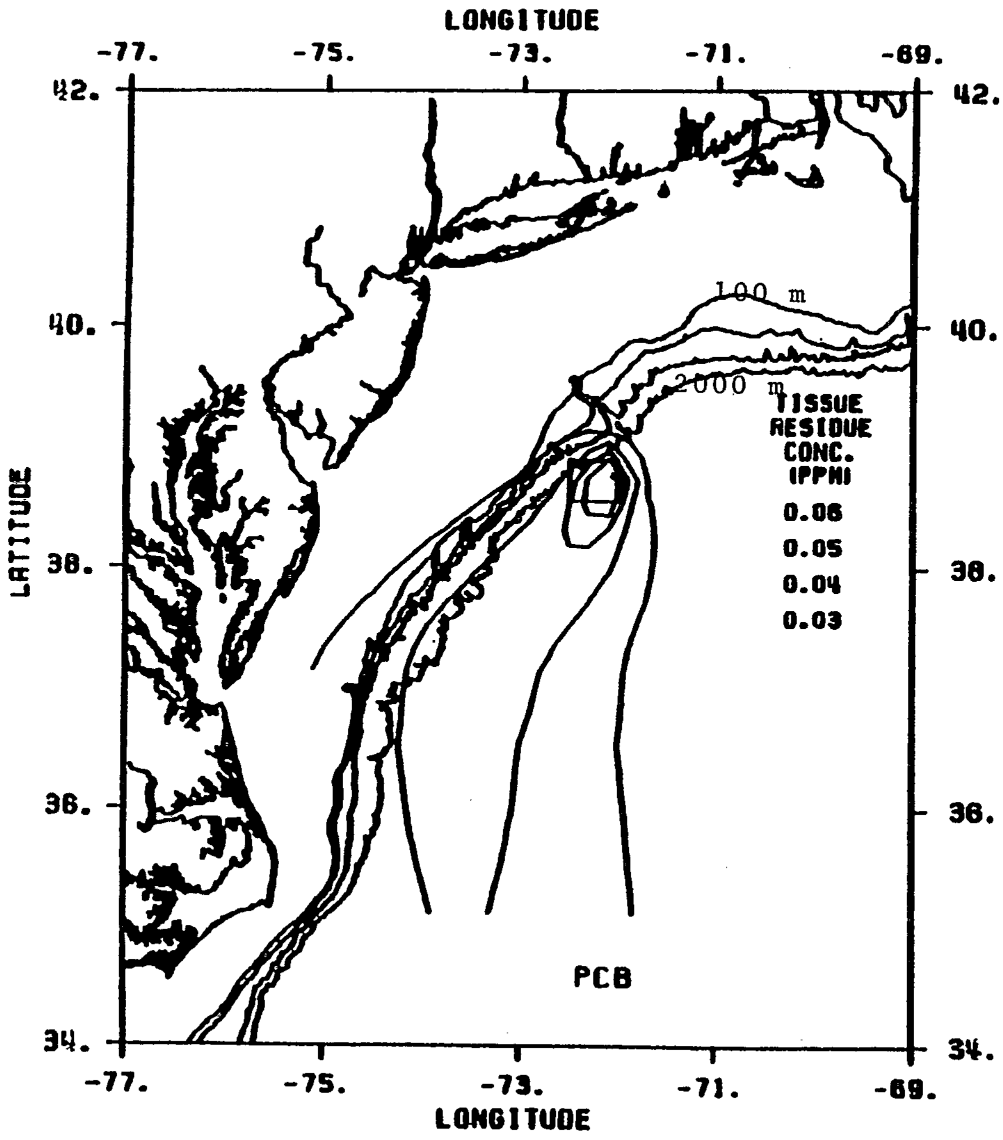


Figure I-2. Maximum contaminated loading from NY plants (PCB)

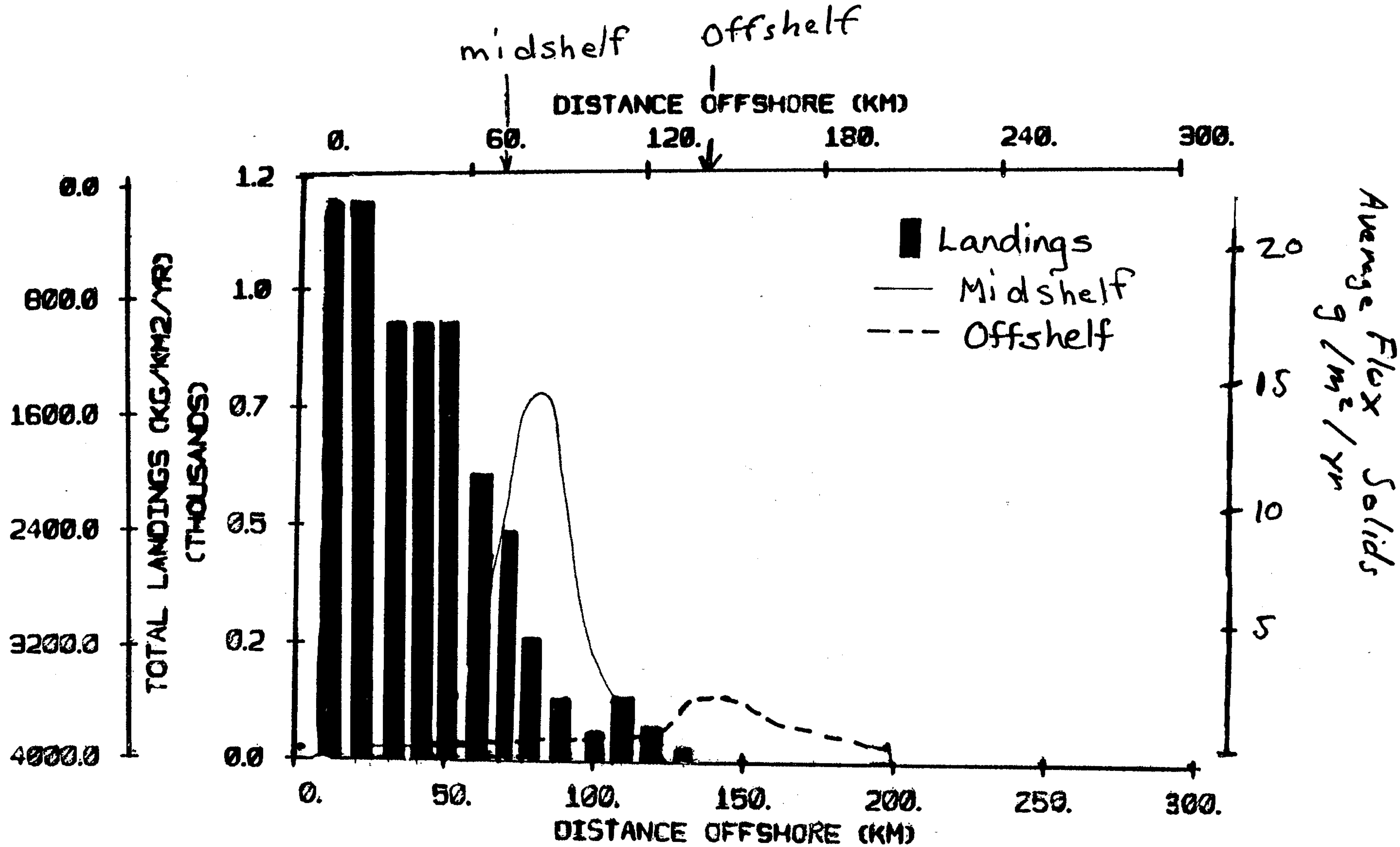


Figure I-3. Predicted peak carbon fluxes

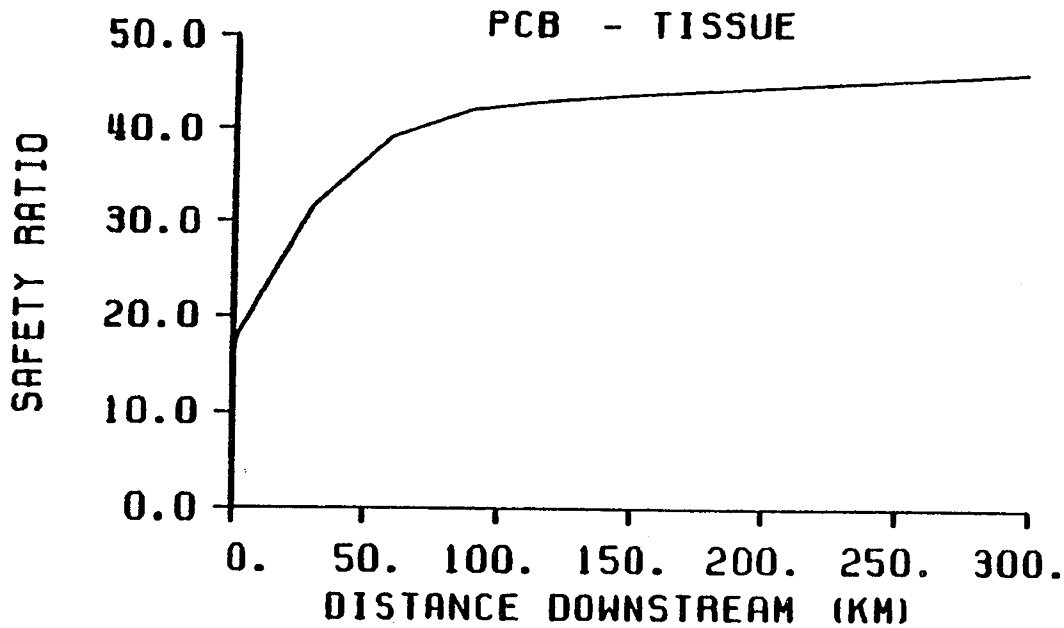


Figure I-4. Baseline data on current levels of pollutants in tissues of benthic shelf edge finish

(II) MODELING EFFORT AT APPLIED SCIENCE ASSOCIATED, INC. (ASA) FOR OFFICE OF POLICY, PLANNING AND EVALUATION:

By Mark Reed
Applied Science Associated, Inc.
Narragansett, RI

1. Problems to be solved- assess the ecological effects of various hypothetical ocean disposal policies pursued over several years.

2. Methodology used:- Ocean Disposal Risk Assessment Model (Figure II-1).

   (a) Pollutant transport is simulated by a two-layer hydrodynamic transport model covering the area of interest.

   (b) Using exposure-response relationships between contaminants and organisms or trophic levels, plus food-web linkages, ecosystem effects are estimated in terms of biomass reductions and bioaccumulation.

   (c) Harvesting rates give a measure of potential human exposure levels.

3. Assumptions made

   (a) Sediment resuspension and transport will only occur at depths less than 100 m from bottom where wave and storm-induced effects become important;

   (b) Current velocities in the site and its vicinities are available from either hydrodynamic models or empirical measurements;

   (c) Ultimate disposition from this mode is either to the sea floor, out the open boundaries, or via decay processes;

   (d) In the long term, the various trophic components of a given ecosystem can be modeled as homogeneously distributed in the horizontal dimension over a specified set of hydrodynamic grid cells;

(e) The generic, or long-term, ecosystem can be represented by trophic compartment;

(f) Dumping rate is constant. Hydrodynamic transport field is steady. Pollutant decay rate has been set to zero.

4. Results obtained- The model has been applied to estuarine, coastal, and offshore areas of the Gulf of Mexico (Figure II-2) and New York Bight (Figures II-3 and II-4). PCB has been selected as the sewage sludge constituent of interest for a policy time horizon of six years (Figure II-4), and twenty years (Figure II-5).

Sensitivity analysis: sensitivity of physical parameters to pollutant-transport estimate.

a. Physical parameters were investigated for their influence to results:

- o horizontal eddy dispersion coefficient,
- o resuspension recurrence rate,
- o particulate settling rates,
- o steady-state advective velocity field,
- o sediment bioturbation rate.

All simulations were run for 2 years with a neutrally buoyant pollutant and no vertical diffusion. It assumes a pollutant loading (or release) rate of 7.6 Kg/day of PCB.

b. Sensitivity of results to ecosystem parameters were investigated:

- o standing stocks,
- o annual primary productivity,
- o half-saturation constant for nitrogen, uptake rate, Kn,
- o upwelling rate.

Results show that standing stocks and annual primary productivity are not sensitive to change in the parameters related to light extension and light limited growth rate.

c. Sensitivity of results to pollutant exposure-biological response relationship mortality rate is a function of threshold concentration, C_o, below which mortality is zero and the concentration LC_{50}, at which 50% mortality is induced.

d. Conclusions:

- The most important transport-model characteristic for determining pollutant fate is the advective velocity field. Correct representation of the currents is of particular importance for near-shore releases.

- Of second importance is horizontal dispersion of the pollutant mass in the water column. The model is fairly sensitive to dispersion coefficient values in the range of 100-500 m^2/s.

- Model results are much less sensitive to parameters such as assimilation, depuration and pollutant-induced mortality rates; for a given pollutant exposure level, ecosystems are most sensitive to trophic structure and predation interactions.

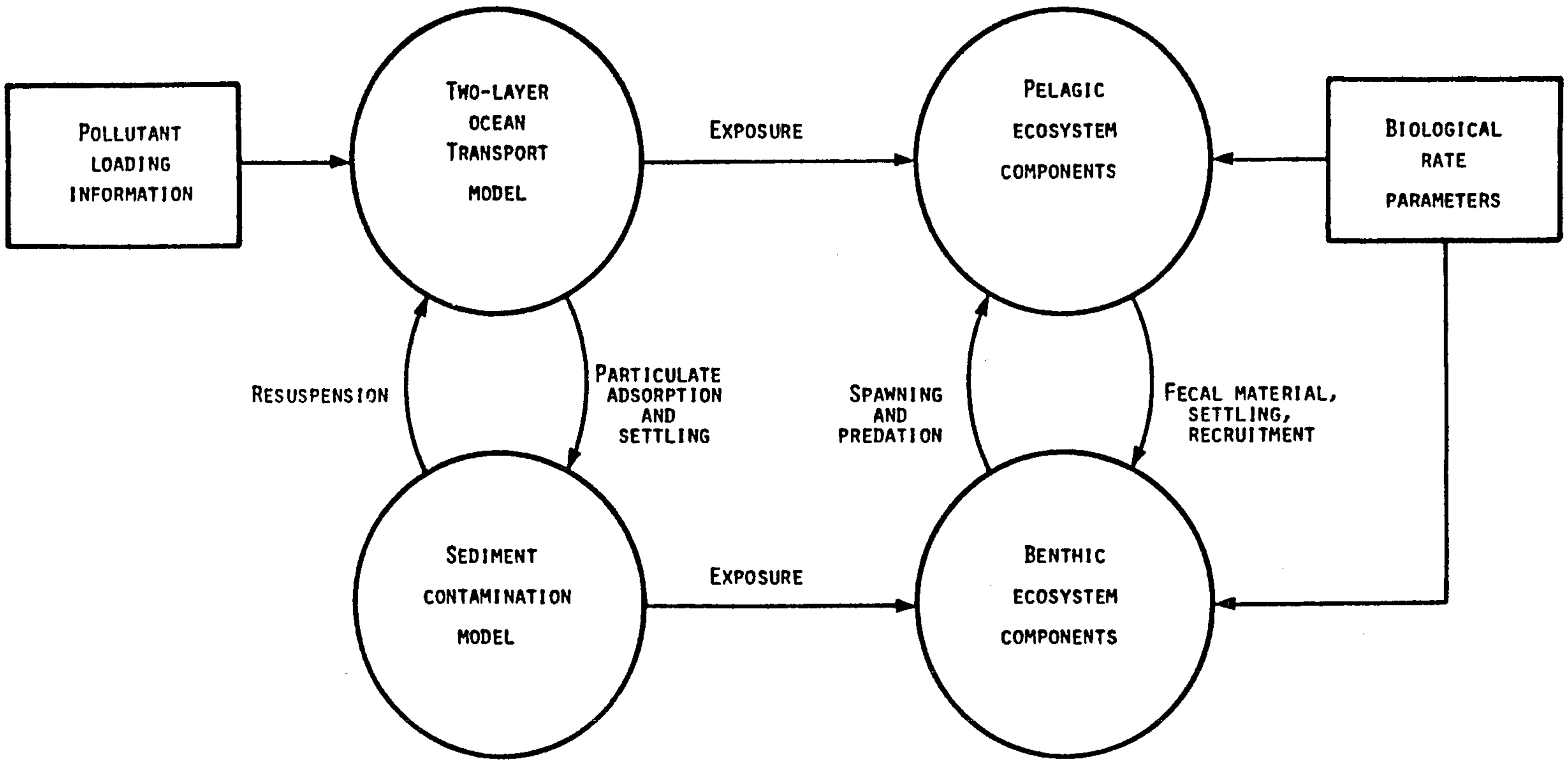


Figure II-1. Model system interaction schematic.

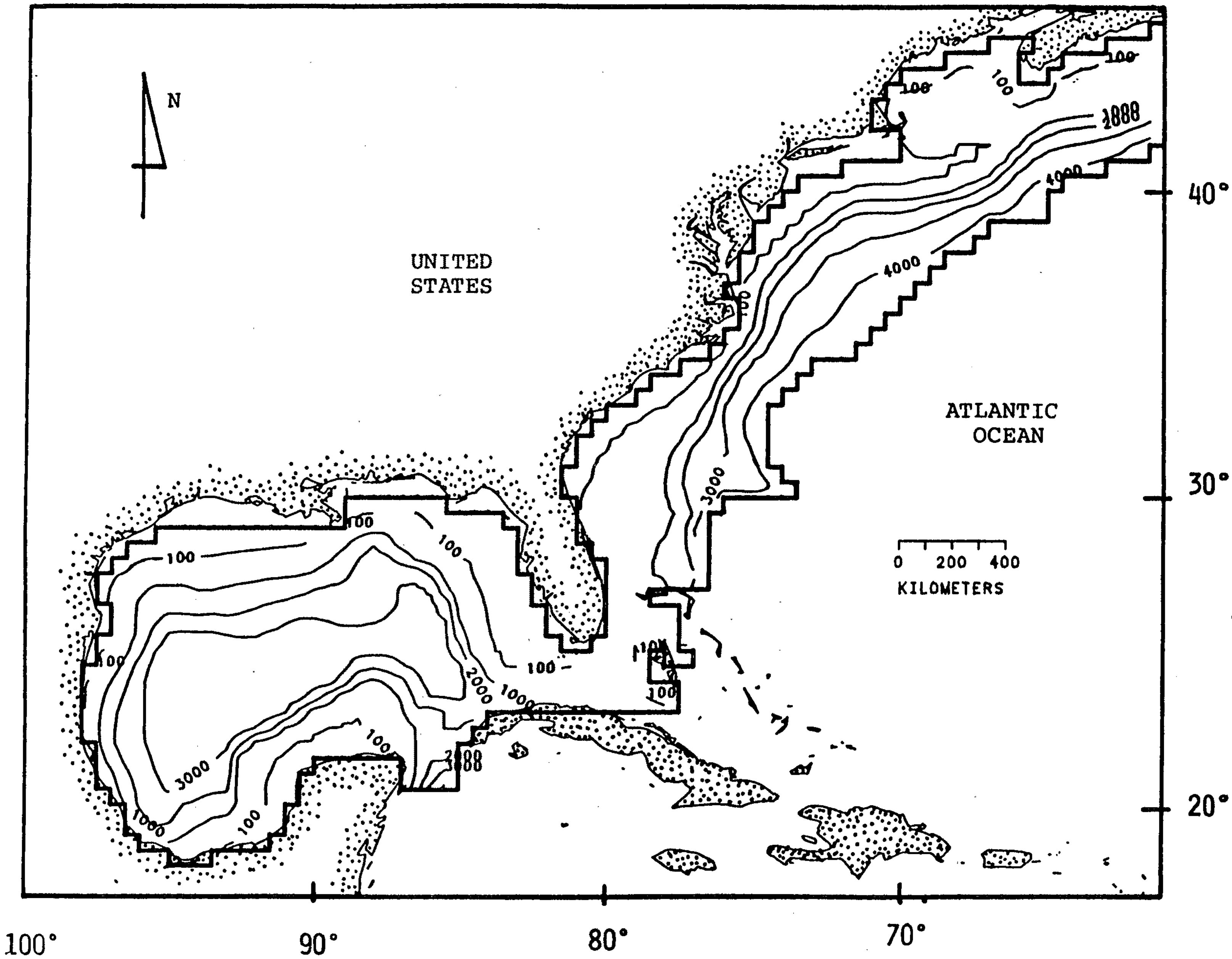


Figure II-2. Bathymetry, coastline, and model grid outline for the Gulf of Mexico and U.S. east coast (depths in meters).

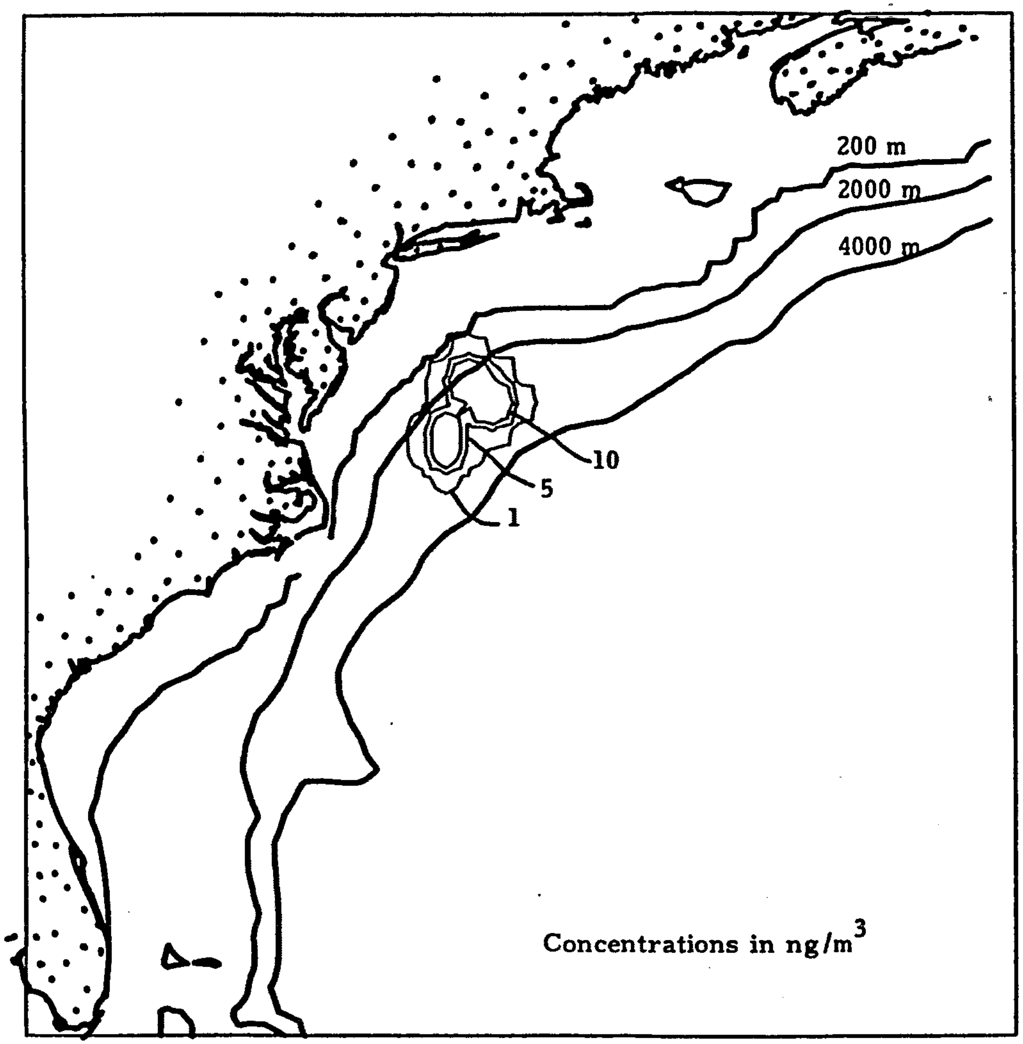


Figure II-3. Modeled PCB concentrations averaged over the upper 100 meters of the water column at the end of simulation.

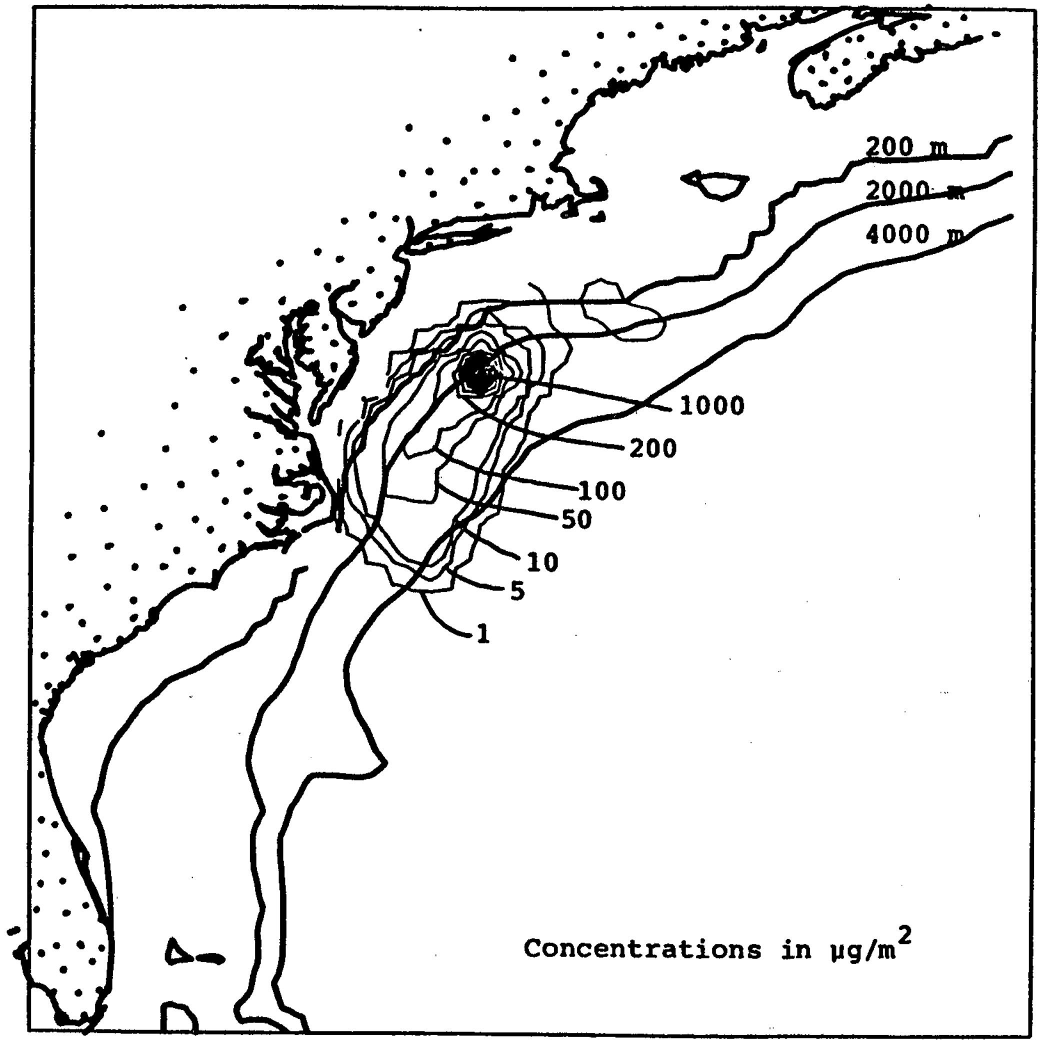
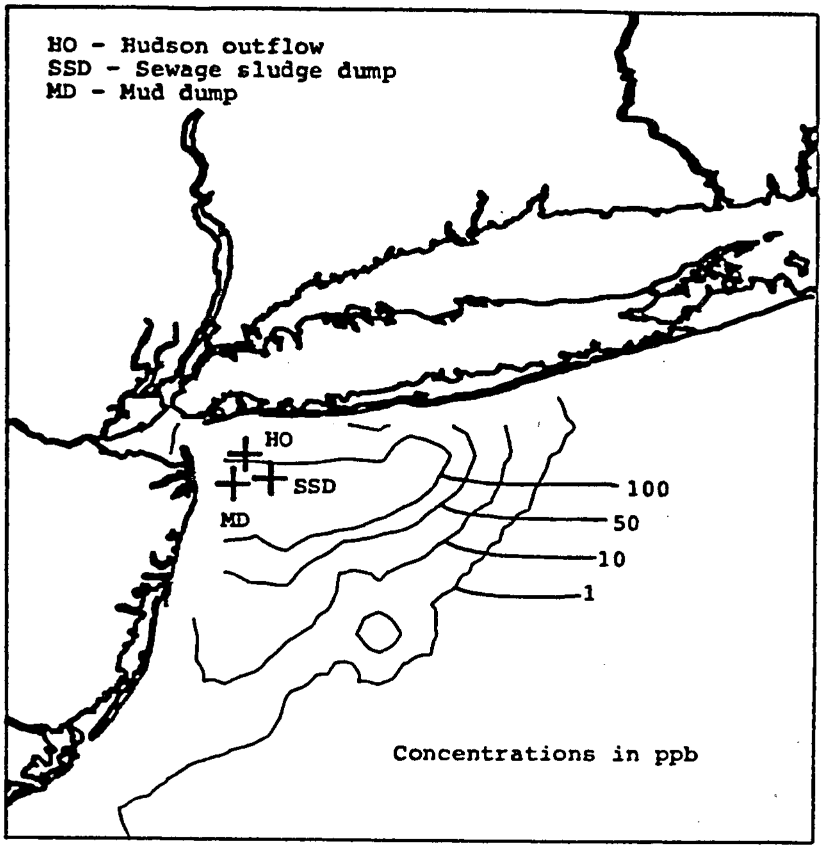
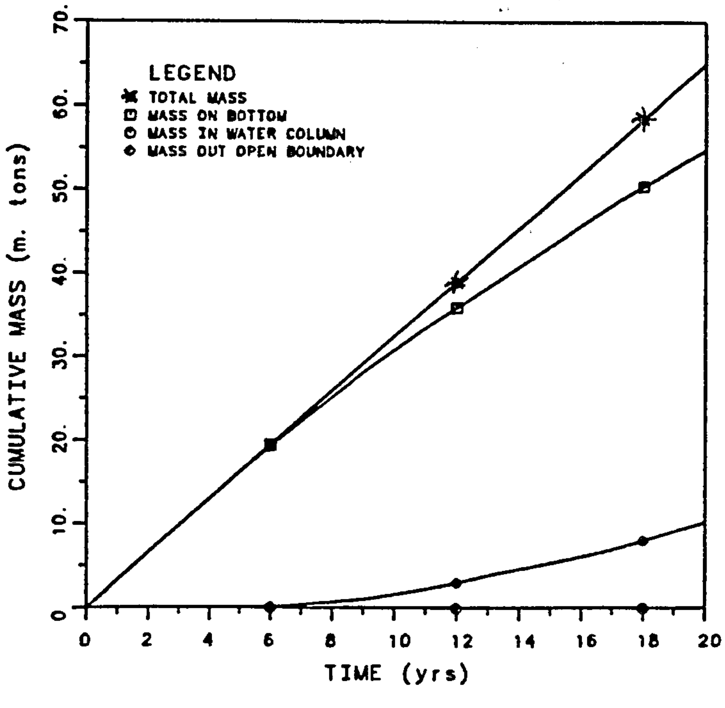


Figure II-4. Modeled sea-floor distributions of PCB from sewage sludge dumping at the 106 site at the end of simulation year 6.



(a)



(b)

Figure II-5. (a) Bottom PCB concentrations at the end of 20 years for twice the expected resuspension frequency; (b) Dynamic balance for twice the expected resuspension frequency.

(III) MODELING EFFORT AT ICF, INC FOR OFFICE OF SOLID WASTE AND EMERGENCY RESPONSE/OSW: A MODIFIED VERSION OF OCEAN DISPOSAL RISK ASSESSMENT MODEL

By Joseph Karam
ICF, Inc.
Washington, DC

1. Problems to be solved- compare risks from land disposal to risks from ocean disposal and ocean incineration approaches as an impact of land disposal restriction.

2. Methodology used- Compare human health risks calculated from Ocean Disposal Assessment Model with dose response curves used by the land disposal risk assessment model, or RCRA Risk-Cost Analysis Model (WET model) and Linear Location Model.

3. Assumptions made

   (a) Steady state release,

   (b) Rate of release equal to the average dumping rate for ocean disposal and that for ocean incineration equal to the sum of stack emission releases and expected fugitive and accidental releases in open ocean for ocean incineration,

   (c) No chemical decay,

   (d) Standard average individual seafood consumption equal to 14.3 g/day, and

   (e) Population exposed is equal to total annual catch in contaminated media divided by average annual individual consumption.

4. Results obtained- the method has been applied to DWD-106 site (Figures III-1 and III-2) for:

   (a) Human health risks:

      1. Expected number of weighted cases and average individual risk,

2. Risk to the most exposed individual,

3. Constituent and medium of concern.

(b) Environmental risks;

1. Ecosystem damage functions,

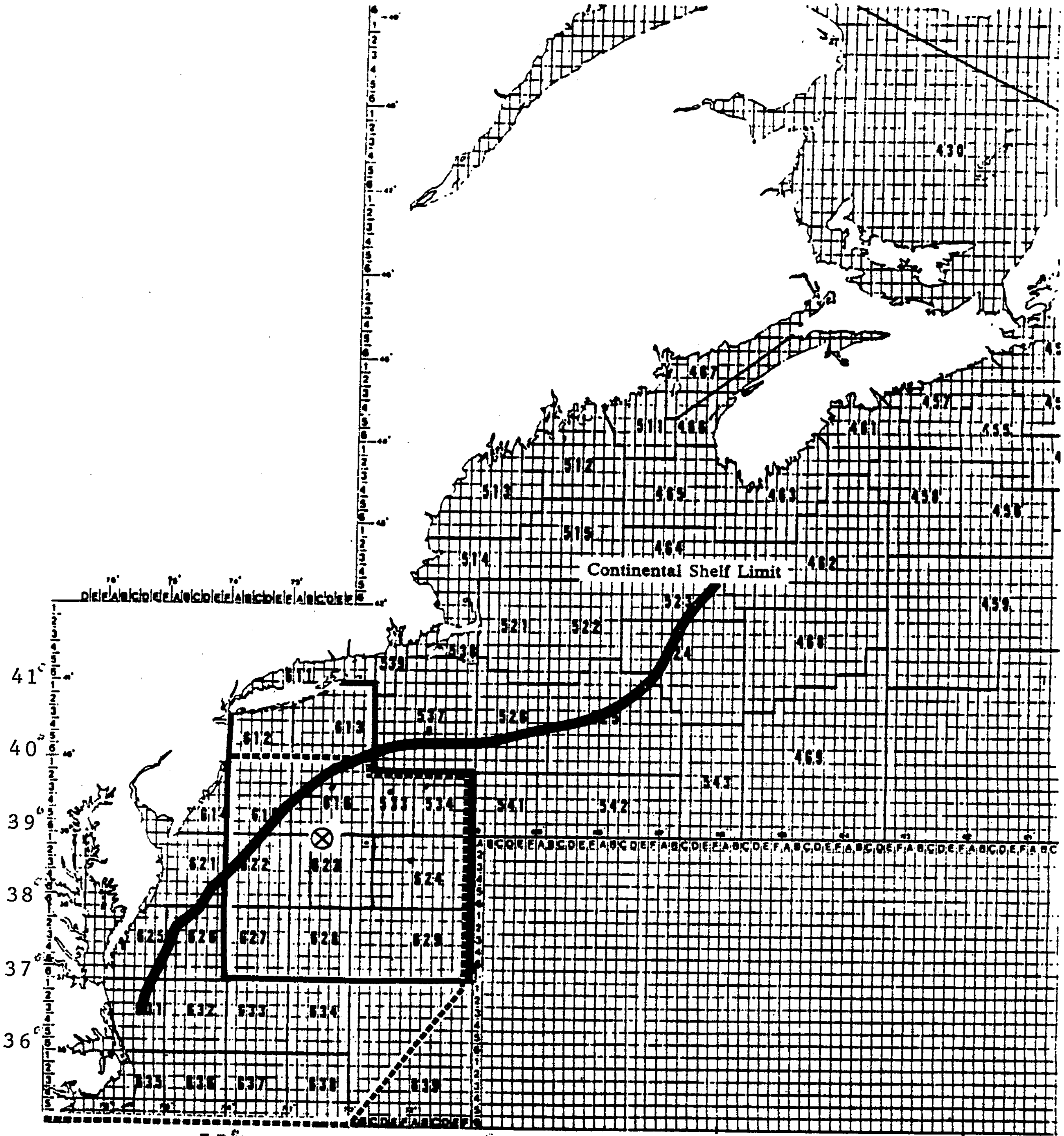
2. Weighted volume of water and weighted area of sediments affected,

3. Damages to the most exposed water column and sediment ecosystems,

4. constituent and medium of concern.

NOTE: This methodology has not been tested or validated.

Largest Contaminated Areas of the Ocean: Chemicals with Low K_pC_{ss} Value*



* KpCss ≤ 1   Where KpCss is the product of the adsorbed-dissolved partition Coeff. and the fraction of suspended solids in ocean.

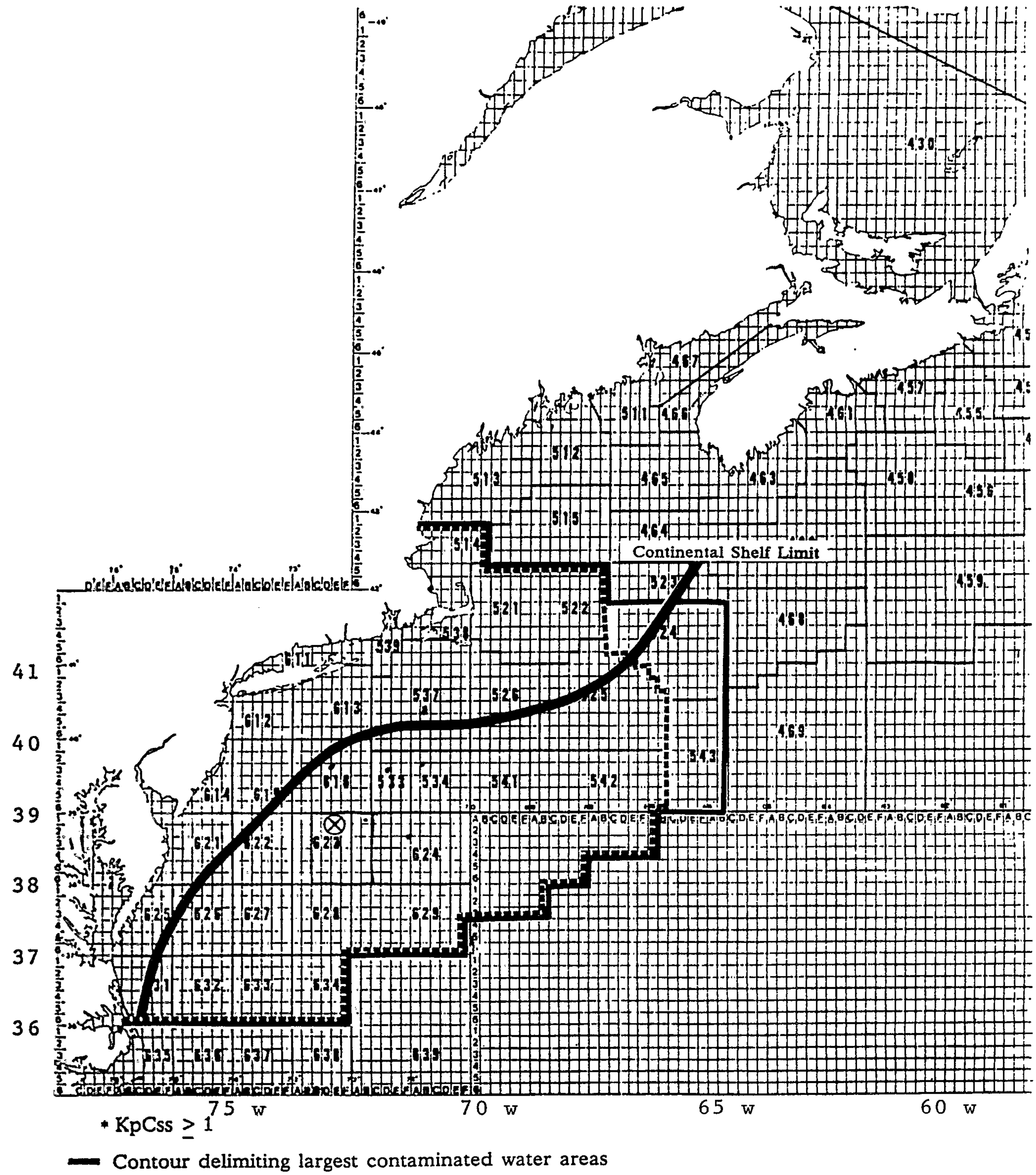
▬ Contour delimiting largest contaminated water areas

--- Contour delimiting largest contaminated sediment areas

⊗ 106-mile site

Figure III-1

Largest Contaminated Areas of the Ocean: Chemicals with High K_pC_{ss} Value*



* KpCss ≥ 1

▬ Contour delimiting largest contaminated water areas

▪▪▪▪ Contour delimiting largest contaminated sediment areas

⊗ 106-mile site

Figure III-2

(IV) MODELING EFFORT AT BATTELLE PACIFIC NORTHWEST LABORATORIES FOR OFFICE OF MARINE AND ESTUARINE PROTECTION/OW:

By Richard Ecker
Battelle Pacific Northwest laboratories
Richland, WA

1. Problem to be solved- provide a tool in assessing the environmental impact of incineration at sea in order to screen ocean incineration permit applications.

2. Methodology used- use INSEA model to predict pollutant concentration in atmosphere and ocean environment. The INSEA model consists of INSEA Atmospheric Transport Submodel, Ocean Transport Submodel, and Criteria Evaluation Submodel.

INSEA Atmospheric Submodel (Figure IV-1 and IV-2)

(1) Assumptions
- o Stationary ship or ship moving along a straight line.
- o Wind speed and direction are constant.

(2) Model considers
- o 3-D Gaussian plume concentration,
- o Wind speed,
- o Plume rise,
- o Wet and dry deposition.

INSEA Oceanic Submodel (Figure IV-3 and IV-4)

(1) Assumptions
- o Steady-state velocity profile.
- o Longitudinal and lateral dispersion are small compared to advection.
- o Instantaneous mixing of contaminants at water surface.
- o Current is in the same direction as wind.

(2) Model considers
- o Longitudinal advection from regional and wind induced currents,
- o Vertical dispersion.

Criteria Evaluation Submodel

(1) Model considers:
- o Acute water quality criteria along centerline of atmospheric plume,
- o Chronic criteria along 100-m offset line,
- o Destruction efficiency,
- o Incinerator feed rate.

(2) Model provides:
- o Allowable contaminant concentrations in incineration feed.

3. Results obtained- The Gaussian plume expression of INSEA model has been applied to incineration-at-sea over the Gulf of Mexico (Figures IV-3 and IV-4).

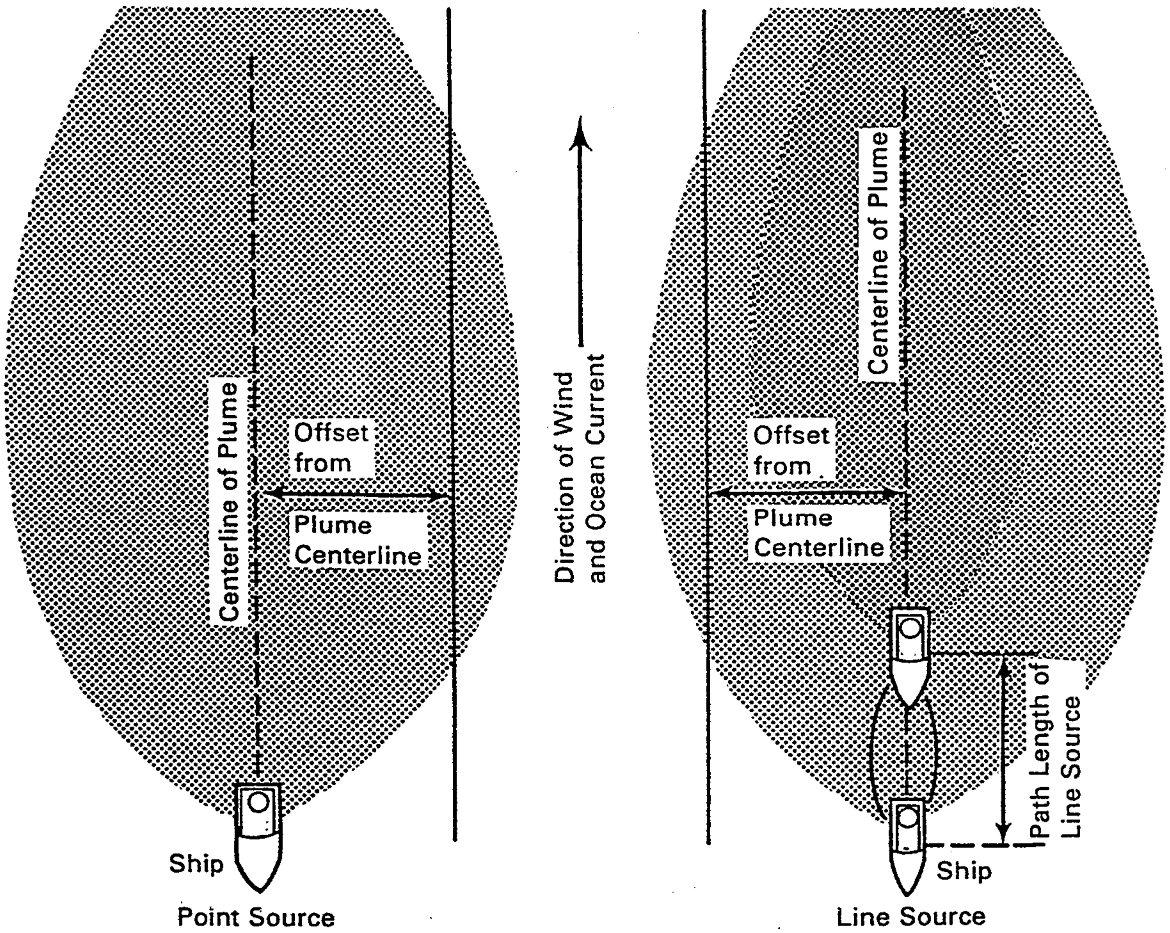


Figure IV-1. INSEA Atmospheric Submodel

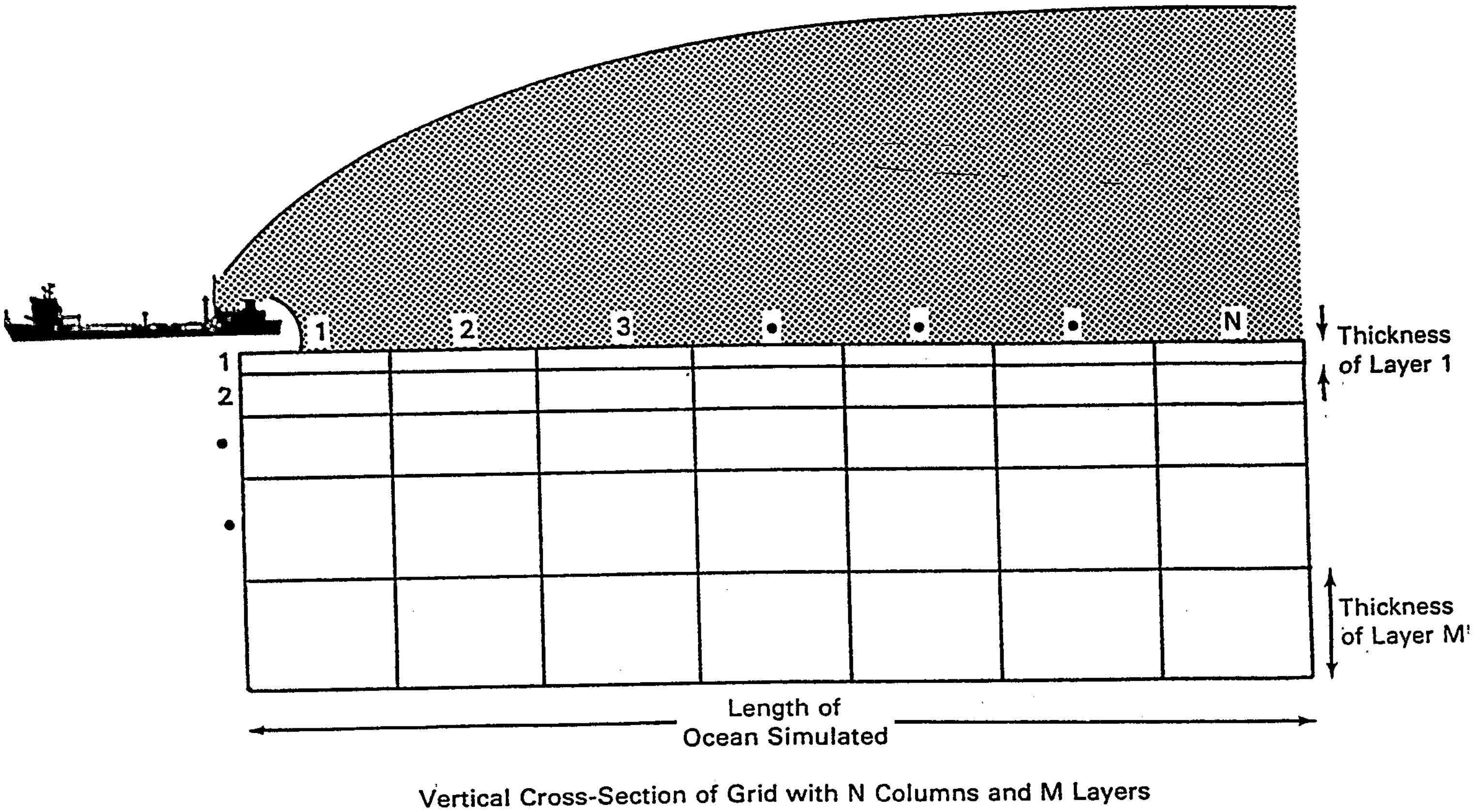


Figure IV-2 . INSEA Atmospheric Submodel

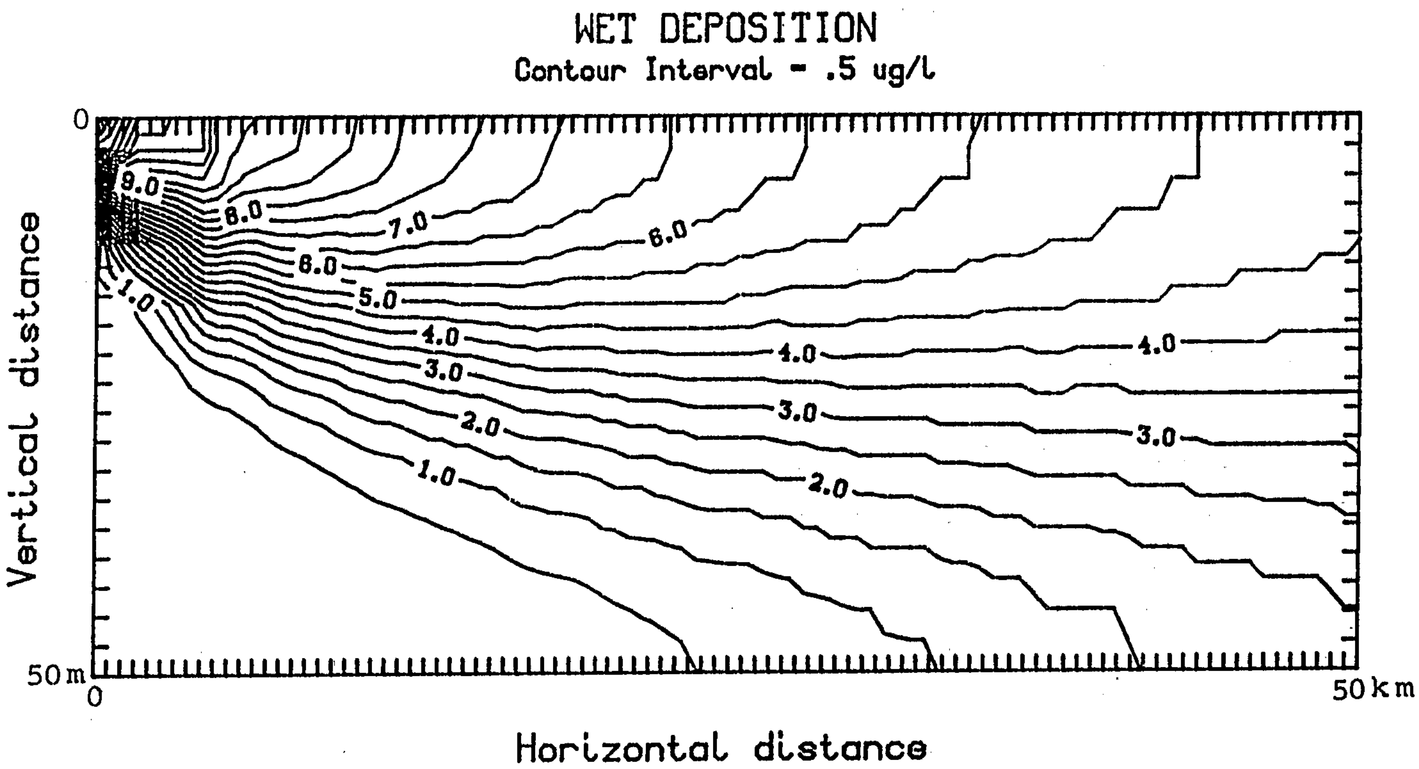


Figure IV-3. INSEA Oceanic Submodel

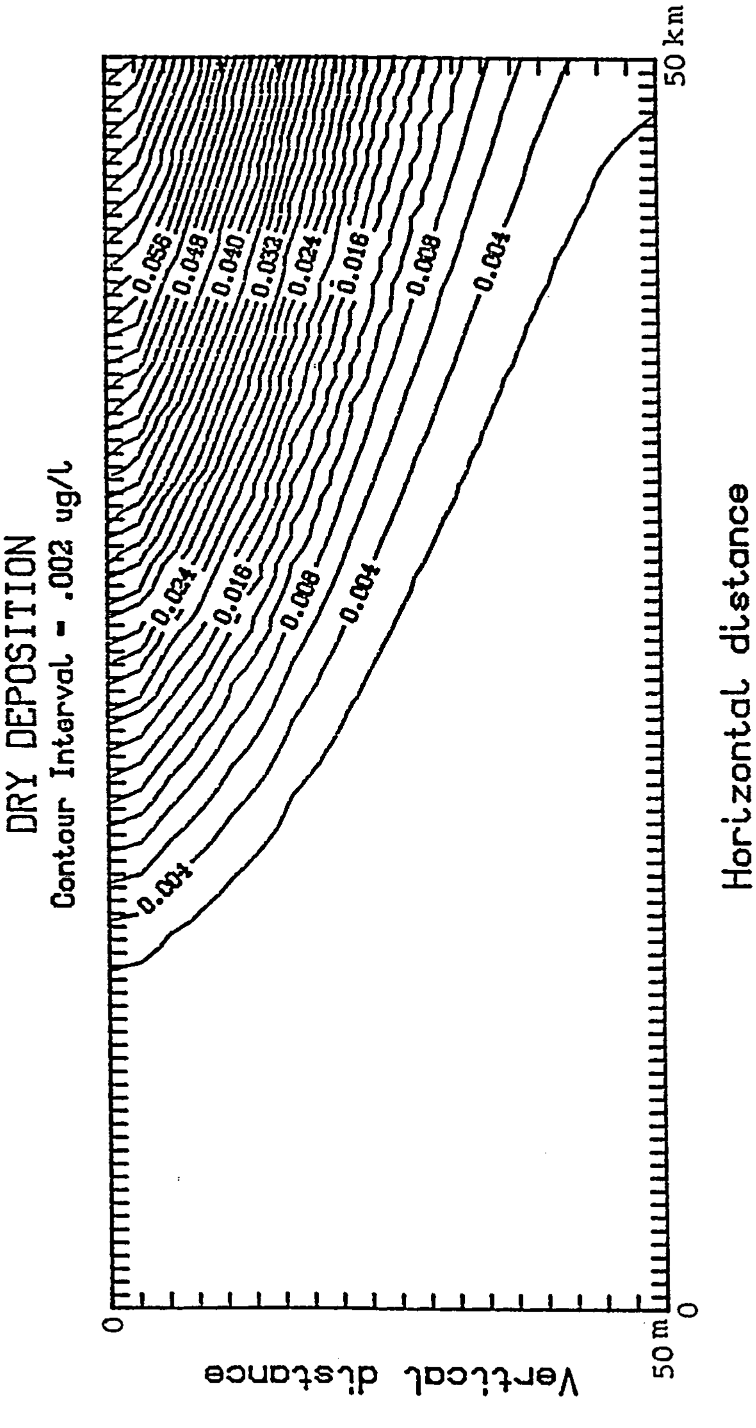


Figure IV-4 . INSEA Oceanic Submodel

(V) MODELING EFFORT AT ERL-NARRAGANSETT, RI: WORK CONDUCTED THROUGH NEWPORT, OREGON FIELD STATION, CERL.

By John Paul and Don Baumgartner
U.S. Environmental Protection Agency
Environmental Research Laboratory
Narragansett, RI

1. Problem to be solved- estimate waste discharged from ocean outfall.

2. Methodology used- empirically derived integral models for plume dynamics (Figure V-1).

3. Assumptions made-

   (a) unstratified crossflow,

   (b) steady state,

   (c) ocean outfall effluent in Gaussian distribution both in vertical and lateral directions.

   Table V-1 lists a summary of numerical model characteristics.

4. Results will be used to:

   (a) Assess impact of ocean outfall discharges;
      1. Macrobenthic sampling strategy to evaluate outfall permits,
      2. Sediment contamination, toxicity, and macrobenthic community impact near ocean outfalls,
      3. Depth profiles of sediment toxicity near ocean outfalls.

   (b) Develop sediment quality criteria for marine and estuarine ecosystems.

   (c) Define the discharge conditions to protect marine ecosystems.

Note: the model has been applied to investigate the sediment toxicity in Eagle Harbor, WA and San Francisco Bay, CA. Table V-2 lists the major research products of application of the model.

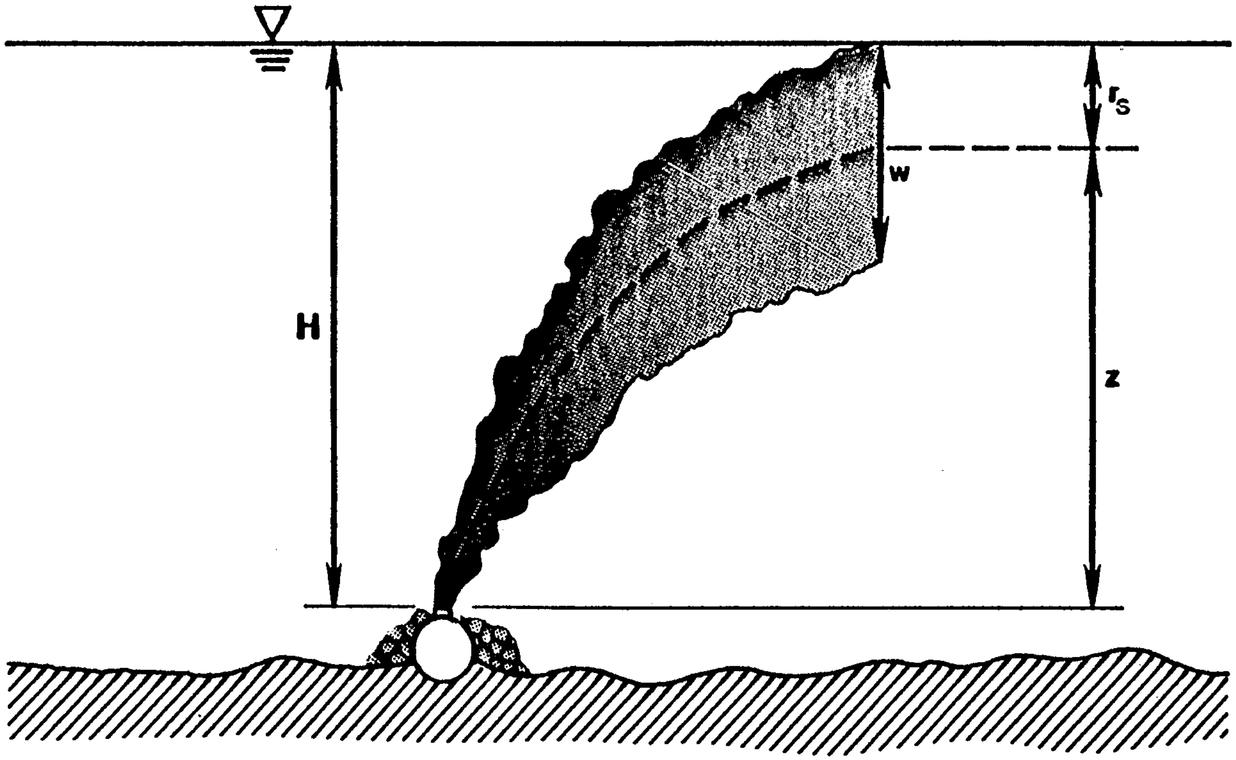


Figure V-1 **Buoyant plume trajectory in an unstratified crossflow.**

TABLE V-1 SUMMARY OF NUMERICAL MODEL CHARACTERISTICS

Parameter	UPLUME	UOUTPLM	UMERGE	UDKHDEN[a]	ULINE
Port[b]	single	single	multiple	multiple	slot/closely spaced
Discharge angle[c]	-5° to 90°	-5° to 90°	-5° to 90°	-5° to 130°	assumes 90°
Density profile	arbitrary	arbitrary	arbitrary	arbitrary	arbitrary
Current speed	no	constant with depth	arbitrary	arbitrary	arbitrary
Current angle relative to the diffuser[d]	n/a	assumes 90°	assumes 90°	45°-135°	0°-180°

[a] For a single port discharge the current angle may be in the range of 0° to 180°. For an angle greater than 90° the program converts it to the supplementary angle. (Note: 0° and 180° give the same results).

[b] All the models except ULINE reduce the data to a single port discharge. UPLUME and UOUTPLM detect merging of adjacent plumes and alert the user, but do not account for this in the remainder of the calculations whereas UMERGE and UDKHDEN do. ULINE converts the data to a slot discharge.

[c] The discharge angle limits are those allowed by the subroutines LIMITS in each of the programs. They are not necessarily the theoretical limits associated with these models. Caution should be exercised when using the models for angles beyond these limits.

[d] 90° is perpendicular to the diffuser. At a discharge angle of 0° (horizontal) and a current angle of 90°, the discharge and the current are parallel and in the same direction.

Table V-2. MAJOR RESEARCH PRODUCTS

I. OCEAN OUTFALL EFFLUENTS: DISCHARGE CONDITIONS TO PROTECT MARINE ECOSYSTEMS.

- A. EFFECTS OF CURRENT DIRECTION ON OCEAN OUTFALL MIXING RATES.
- B. EFFECT OF INTERSTITIAL CHEMICAL ENVIRONMENT ON THE POLLUTANT COMPOSITION OF SEDIMENT-WATER MIXTURES.
- C. EFFECT OF SUSPENDED SOLIDS CONCENTRATIONS AND NATURAL FLOCCULATION ON SEWAGE PARTICULATE SETTLING RATES.
- D. FIELD VALIDATION OF INITIAL DILUTION MODELS.

II. IMPACT ASSESSMENT OF OCEAN OUTFALL DISCHARGES.

- A. MACROBENTHIC SAMPLING STRATEGY TO EVALUATE OUTFALL PERMITS.
- B. SEDIMENT CONTAMINATION, TOXICITY, AND MACROBENTHIC COMMUNITY IMPACTS NEAR OCEAN OUTFALLS.
- C. DEPTH PROFILES OF SEDIMENT TOXICITY NEAR OCEAN OUTFALLS.

III. SEDIMENT QUALITY CRITERIA FOR MARINE AND ESTUARINE ECOSYSTEMS.

- A. EQUILIBRIUM PARTITIONING MODEL AND THE TOXICITY OF METALS AND NONPOLAR ORGANIC COMPOUNDS IN SEDIMENT.
- B. TOXICOLOGICAL INTERACTIONS BETWEEN SEDIMENT CONTAMINANTS.
- C. SEDIMENT BIOASSAY PROTOCOLS.
  1. PROTOCOL FOR LOW SALINITY, ESTUARINE SEDIMENT (<u>COROPHIUM</u>).
  2. EFFECTS OF NATURAL SEDIMENT PROPERTIES ON <u>RHEPOXYNIUS</u>.
- D. SEDIMENT TOXICITY SURVEYS IN EAGLE HARBOR, WA AND SAN FRANCISCO BAY, CA.

(VI) MODELING EFFORT AT BATTELLE PACIFIC NORTHWEST LABORATORIES FOR THE OFFICE OF RADIATION PROGRAMS, EPA

By Yasuo Onishi
Battelle Pacific Northwest Laboratories
Richland, WA

1. Problems to be solved- (1) analyze the environmental impact of proposed ocean disposal operation upon human health and marine life and assess the resulting environmental conditions if disposed containers fail to contain the radioactive wastes as required in the Radioactive Materials Disposal Impact Assessment (RMDIA) of PL 97-424 of 1983, and (2) provide the (numerical) dose/concentration levels to compare with that of comparable land disposal options as required by the London Dumping Convention and U.S. Ocean Disposal Regulations.

2. Methodology used- to meet the above requirements a three-dimensional time dependent Flow, Energy, Salinity, Sediment and Contaminant Transport Model (FLESCOT) of Battelle Pacific Northwest Laboratories (PNL) is intended to simulate the extremely complicated ocean current system which includes Gulf Stream meander, cold and warm core rings and shelf edge exchange processes in the Northwest Atlantic region of EPA's 2800-m, 3800-m and DWD-106 sites (Figure VI-1). Figure VI-2 shows the bathymetry of the Eastern Continental Shelf which includes the region of interest.

3. Assumptions made

   (a) fluid is incompressible,
   (b) only gravitational and Coriolis forces are included as body forces,
   (c) free surface effects are considered,
   (d) fluid is Newtonian,
   (e) equations for turbulent flow are time-averaged,
   (f) the Boussinesq approximation holds (i.e., density changes only very little with height),
   (g) particulate contaminant concentrations are linearly related to dissolved contaminants,
   (h) sediment and particulate (sediment-sorbed) contaminants are divided into three size fractions of cohesive and noncohesive sediments, and
   (i) contaminant decay/degradation are first order reactions.

4. Results Expected

FLESCOT model can predict:

- o sediment concentrations in water column for each of three sediment size fractions,
- o sediment size distributions within ocean bottom,
- o bottom elevation changes due to sediment deposition and resuspension,
- o dissolved contaminant concentrations for each of three sediment size fractions in water column,
- o sediment-sorbed contaminant concentrations for each of three sediment size fractions within ocean bottom,
- o distributions of nonhomogeneous but isotropic turbulent kinetic energy and eddy viscosity or dispersion coefficients.

This model has been applied to 106-Km reach of the Hudson River between Chelsea and the mouth of the river, Figures VI-3, -4, -5 and -6, and Strait of Juan of de Fuca, WA, Figures VI-7, -8, -9, and -10. It has also been applied to Buzzards Bay, MA, Beaufort Sea, AK, and Sequims Bay, WA.

The FLESCOT model will be applied to EPA's 2800-m, 3800-m and DWD-106 sites off the New Jersey-Maryland coasts in the future.

REFERENCES

Hoffman, F. O., D. L. Shaeffer, C. W. Miller and C. T. Garten, Jr. 1978. Proceedings of a Workshop on The Evaluation of Models Used for the Environmental Assessment of Radionuclide Releases. Gatlinburg, TN.

Onishi, Y., D. L. Schreiber and R. B. Codell. 1980. "Mathematical Simulation of Sediment and Radionuclide Transport in the Clinch River, Tennessee." Contaminants and Sediments, R. A. Baker (Ed.), Vol. 1, Ch. 18, Ann Arbor Science Publishers, Inc., Ann Arbor, MI, pp. 393-406.

Onishi, Y. 1981. "Sediment-Contaminant Transport Model." Journal of Hydraulics Division, ASCE, Vol. 107, No. HY9, Proceedings No. 16505, pp. 1089-1107.

Onishi, Y., R. J. Serne, E. M. Arnold, C. E. Cowan and F. L. Thompson. 1981a. Critical Review: Radionuclide Transport, Sediment Transport, and Water Quality Mathematical Modeling; and Radionuclide Adsorption/Desorption Mechanisms. NUREG/CR-1322, PNL-2901, Pacific Northwest Laboratory, Richland, WA.

Onishi, Y., S. M. Brown, A. R. Olsen and M. A. Parkhurst. 1981b. "Chemical Migration and Risk Assessment Methodology." Proceedings of the Conference on Environmental Engineering, ASCE, Atlanta, GA, pp. 165-172.

Onishi, Y., and D. S. Trent. 1982. Mathematical Simulation of Sediment and Radionuclide Transport in Estuaries -- Testing of Three-Dimensional Radionuclide Transport Modeling for the Hudson River Estuary, New York. NUREG/CR-2423, PNL-4109, Pacific Northwest Laboratory, Richland, WA.

Onishi, Y., and F. L. Thompson. 1982. Evaluation of Long-Term Radionuclide Transport and Accumulation in the Coastal Water. Battelle Pacific Northwest Laboratories, Richland, WA.

Jinks, S. M. and M.E. Wrenn. 1975. "Radiocesium Transport in the Hudson River Estuary," Chapter 11 of Environmental Toxicity of Aquatic Radionuclides: Models and Mechanism. Edited by M.W. Miller and J. N. Stannard.

Wrenn, M.E., G. j. Lauer, S. Jinks, L. Hairr, J. Mauro, B. Friedman, D. Wohlgemuth, J. Hernandez and Gary, R'e. 1972. Radioecological Studies of the Hudson River. Progress Report to Con. Edison Company of New York.

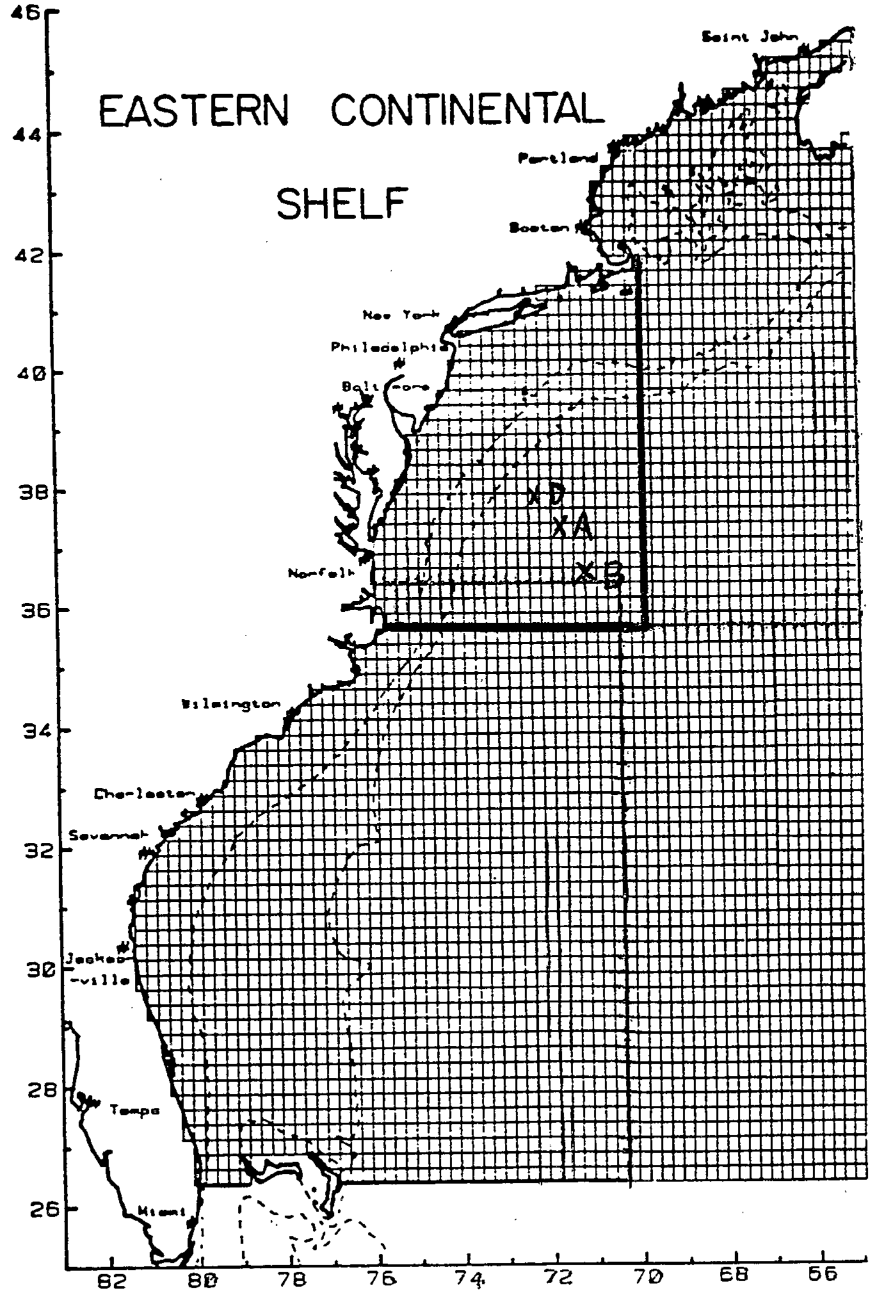


Figure VI-1 A map of the Eastern Continental Shelf showing the computational grid and the subdomains.

D: DWD-106 site.
A: 2800-m site.
B: 3800-m site.

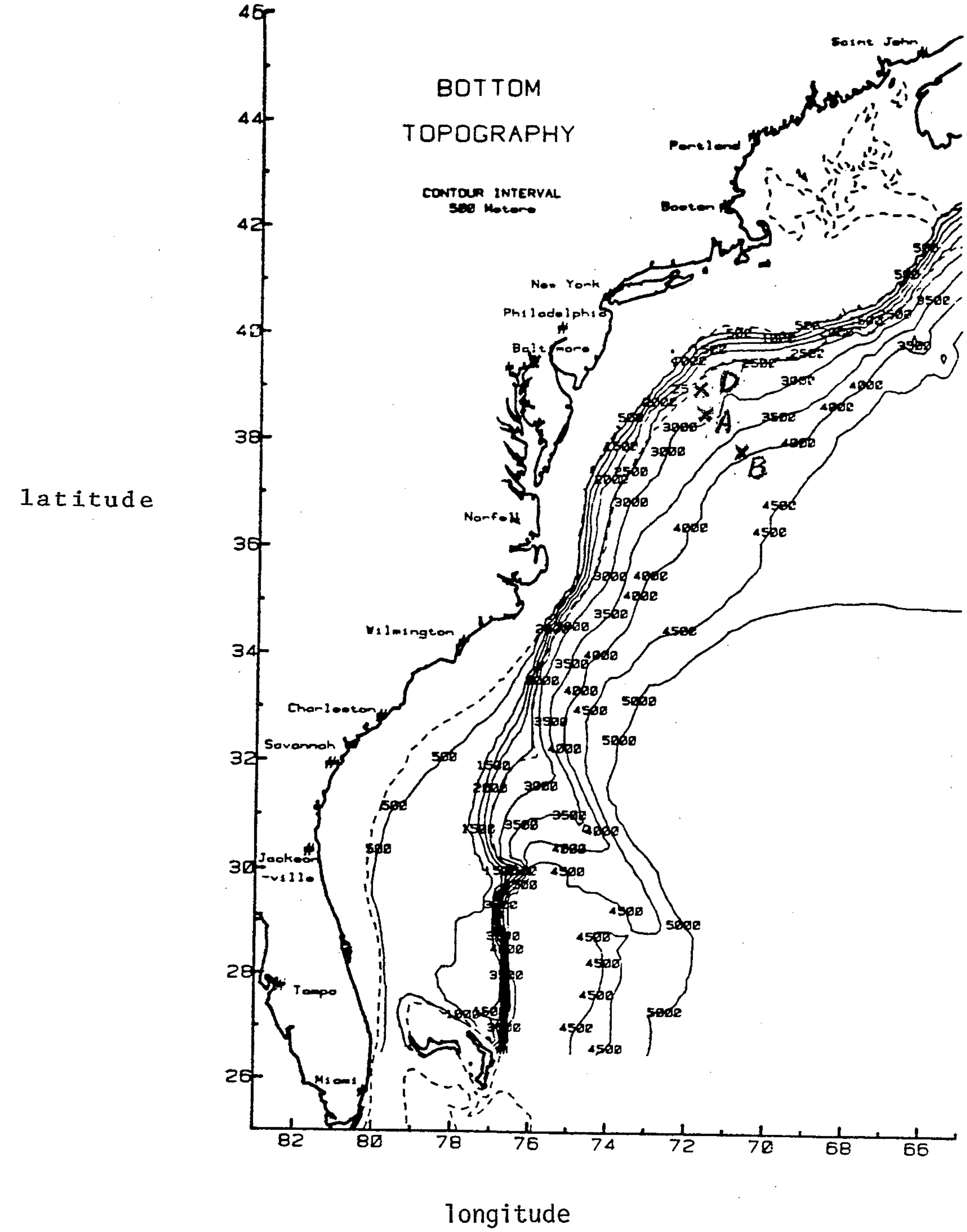


Figure VI-2 A map of the Eastern Continental Shelf showing the bathymetry of the region.
D: DWD-106 site.
A: 2800-m site.
B: 3800-m site.

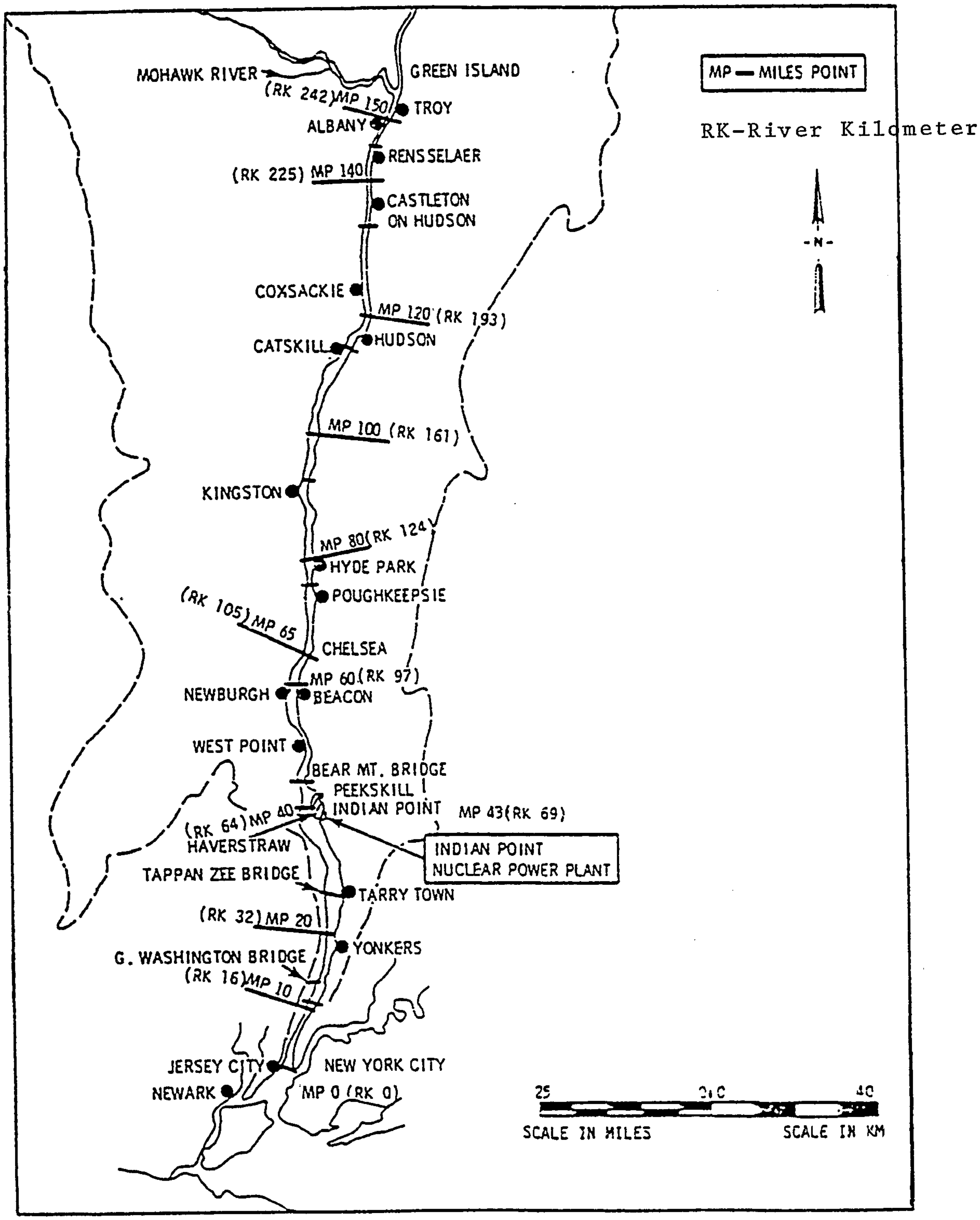


Figure VI-3 Hudson River Estuary

Relationship of ^{137}Cs Distribution Coefficients and Chlorosity in Continuous Water Samples at Indian Point, 1971 (Jinks and Wrenn 1975)

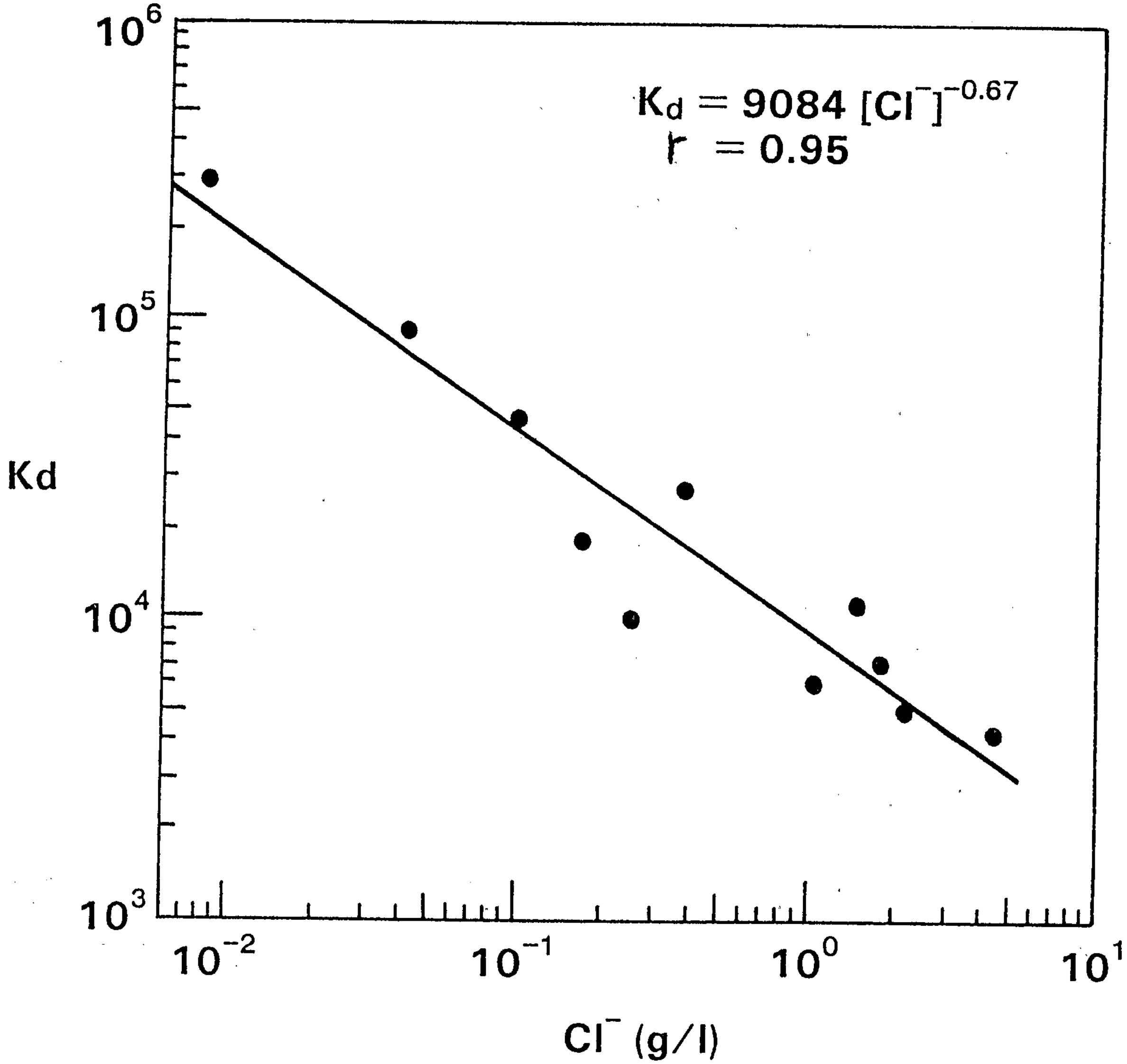


Figure VI-4

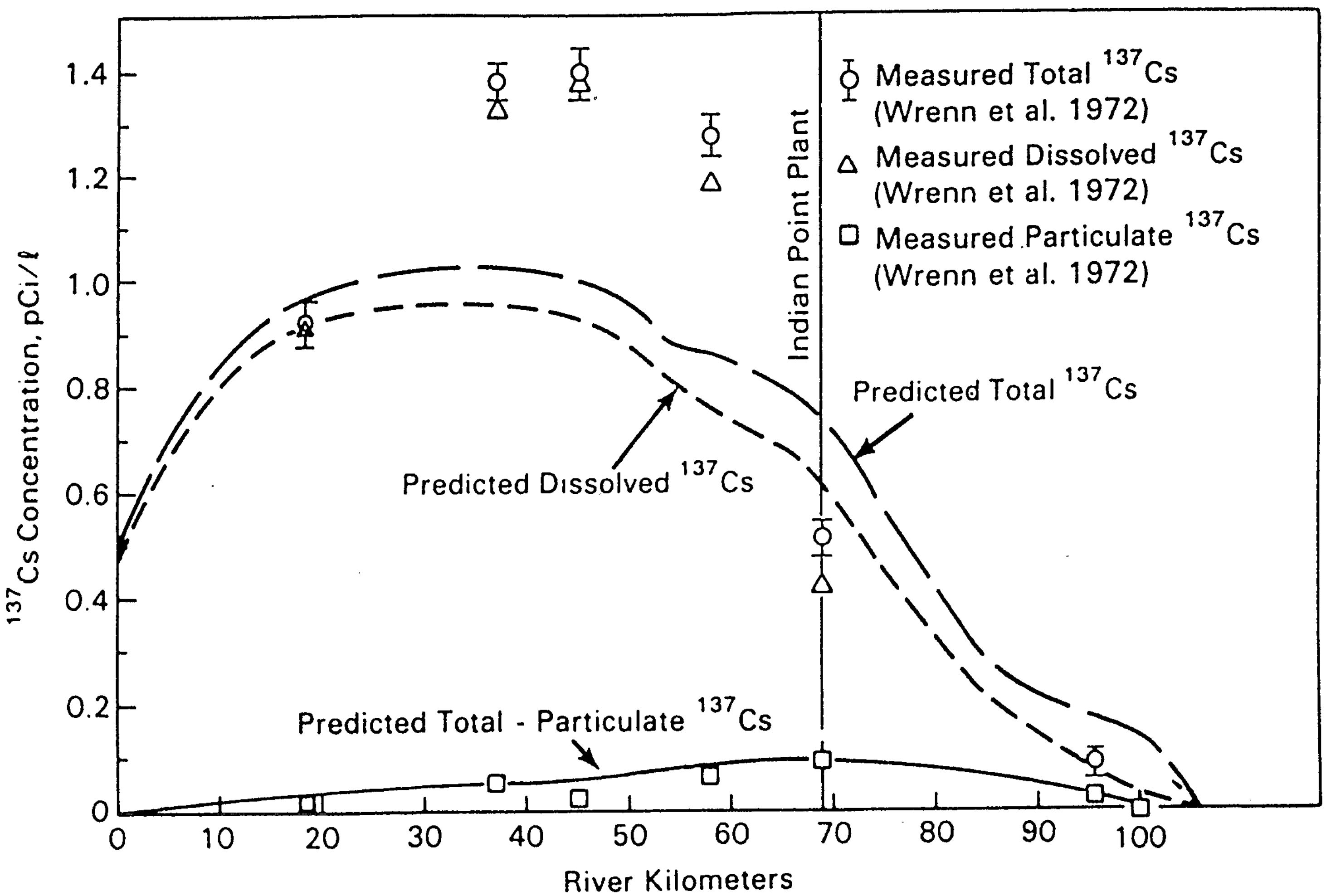


Figure VI-5 Predicted and Measured ^{137}Cs Distributions Along 1200 m from the East Bank 5 m Below Water Surface

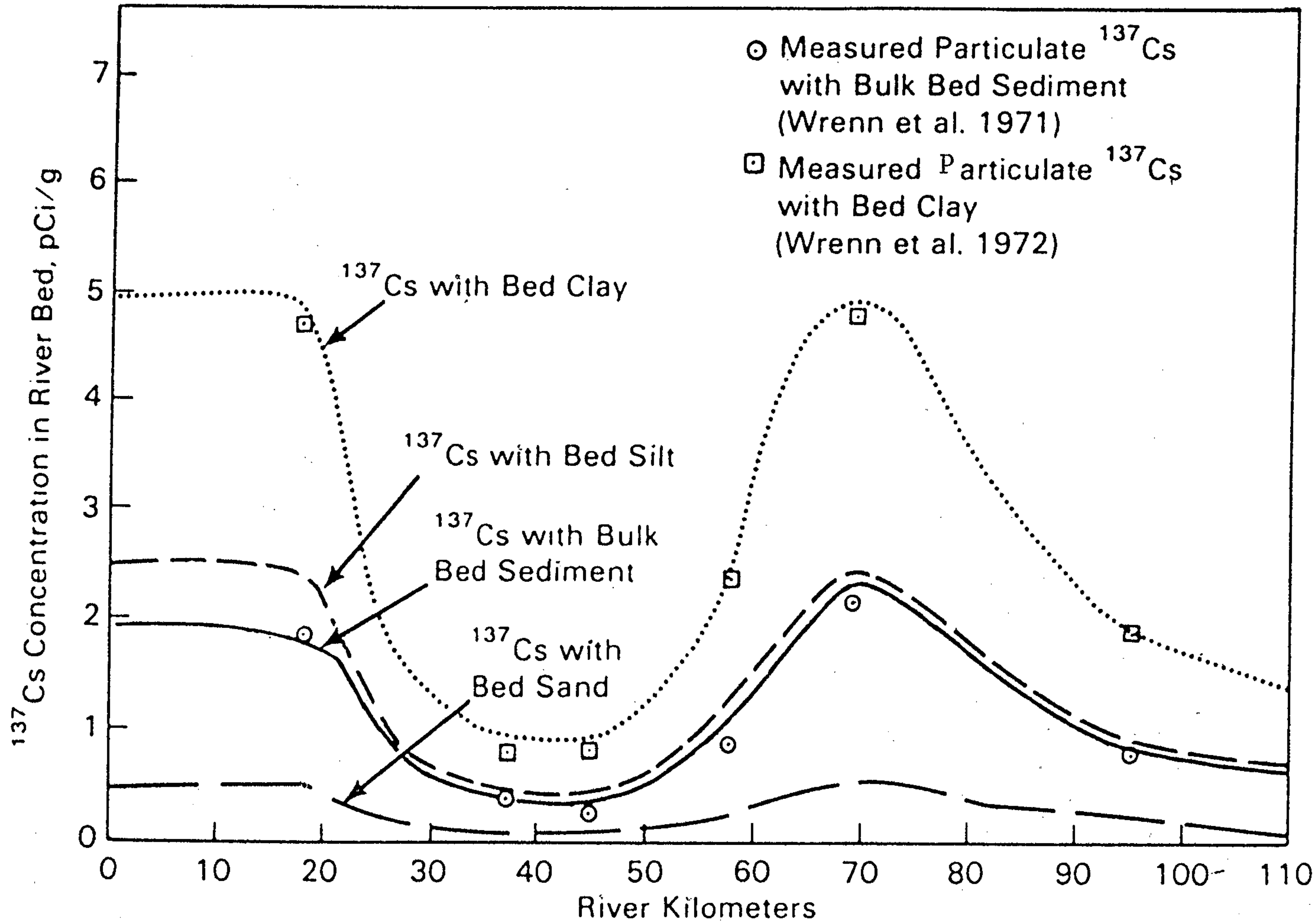


Figure VI-6 Longitudinal Distribution of Particulate ^{137}Cs Concentration Sorbed by Bed Sediment in the Top 10-cm Bed Layer

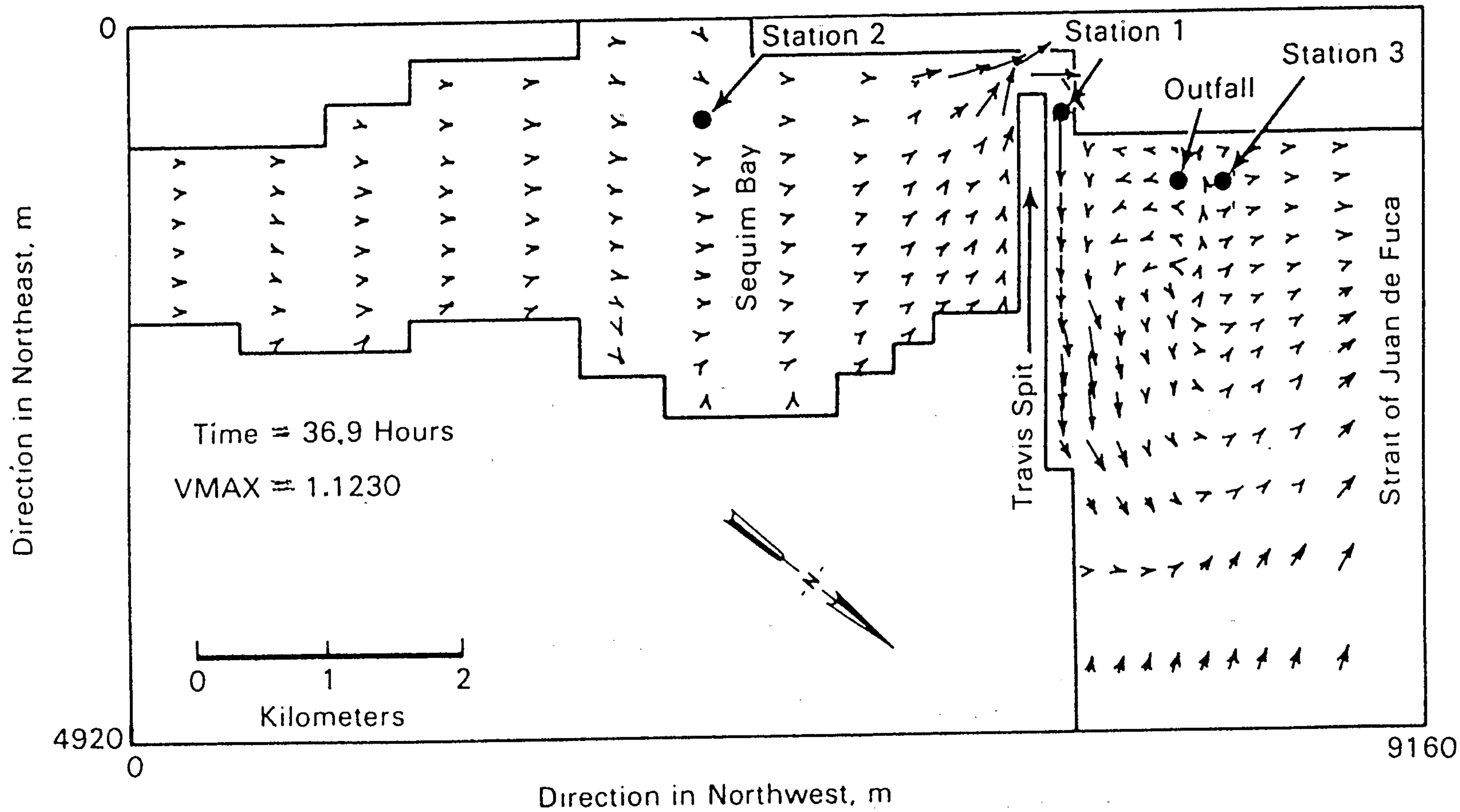


Figure VI-7 Simulated Horizontal Velocity Field on the Top Water Layer Near Maximum Ebb

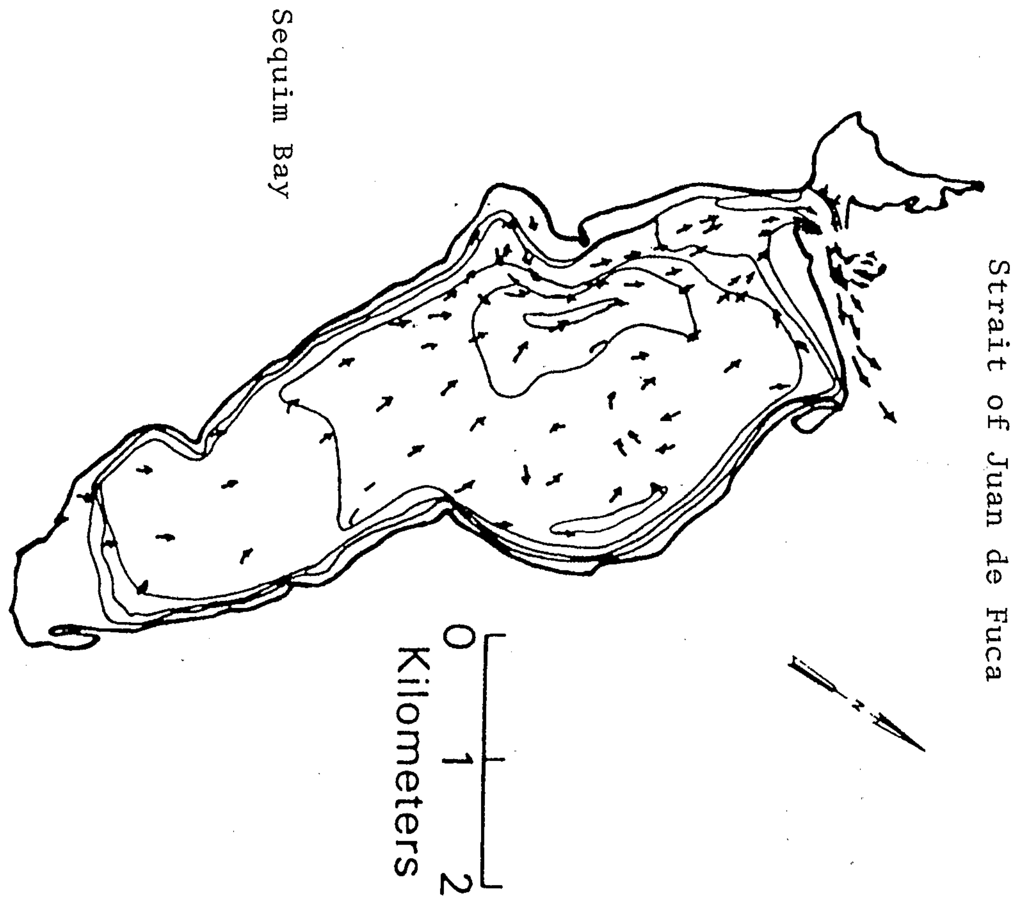


Figure VI-8 Observed General Ebb Tide Current Pattern

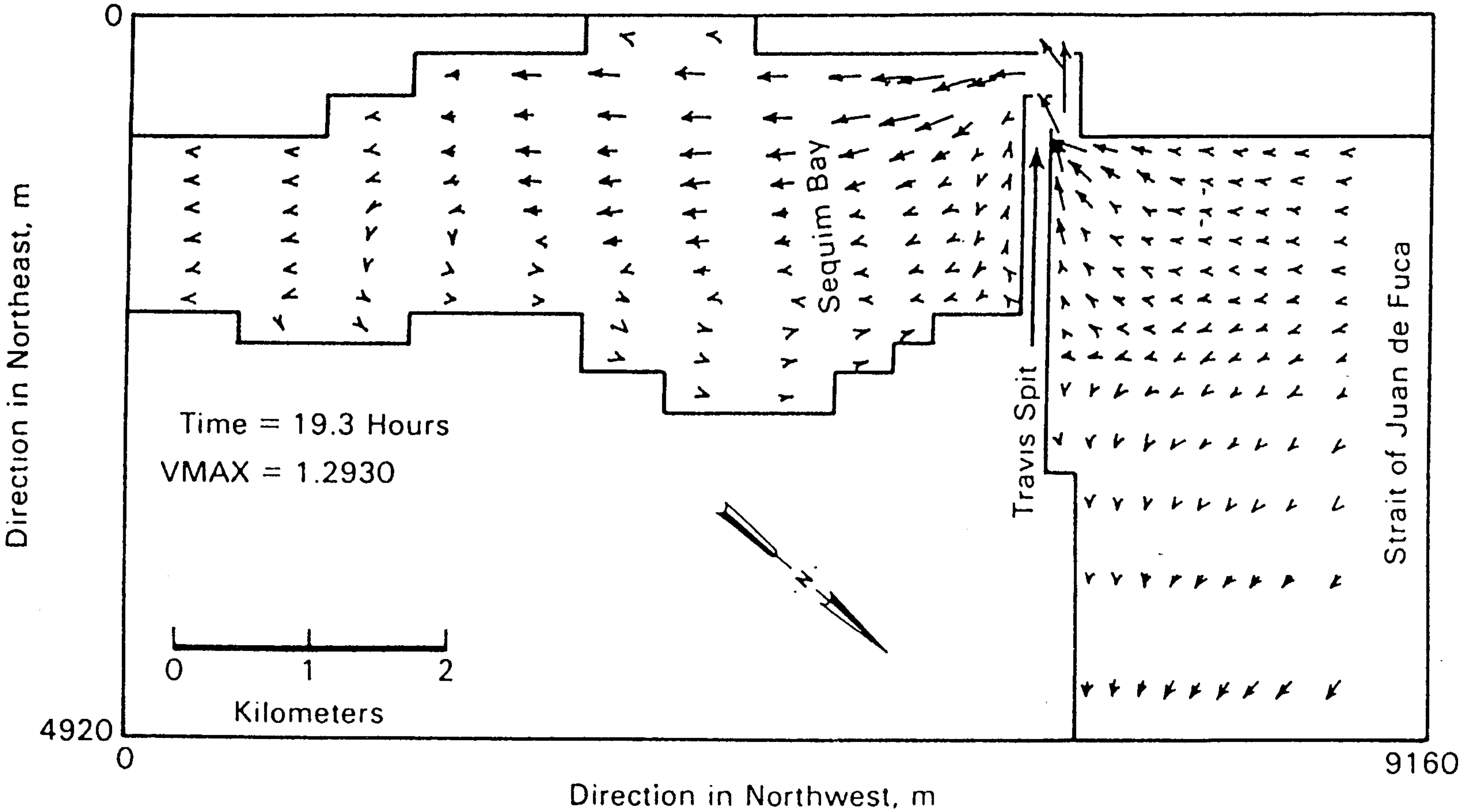


Figure VI-9 Simulated Horizontal Velocity Field on the Top Water Layer Near Maximum Flood

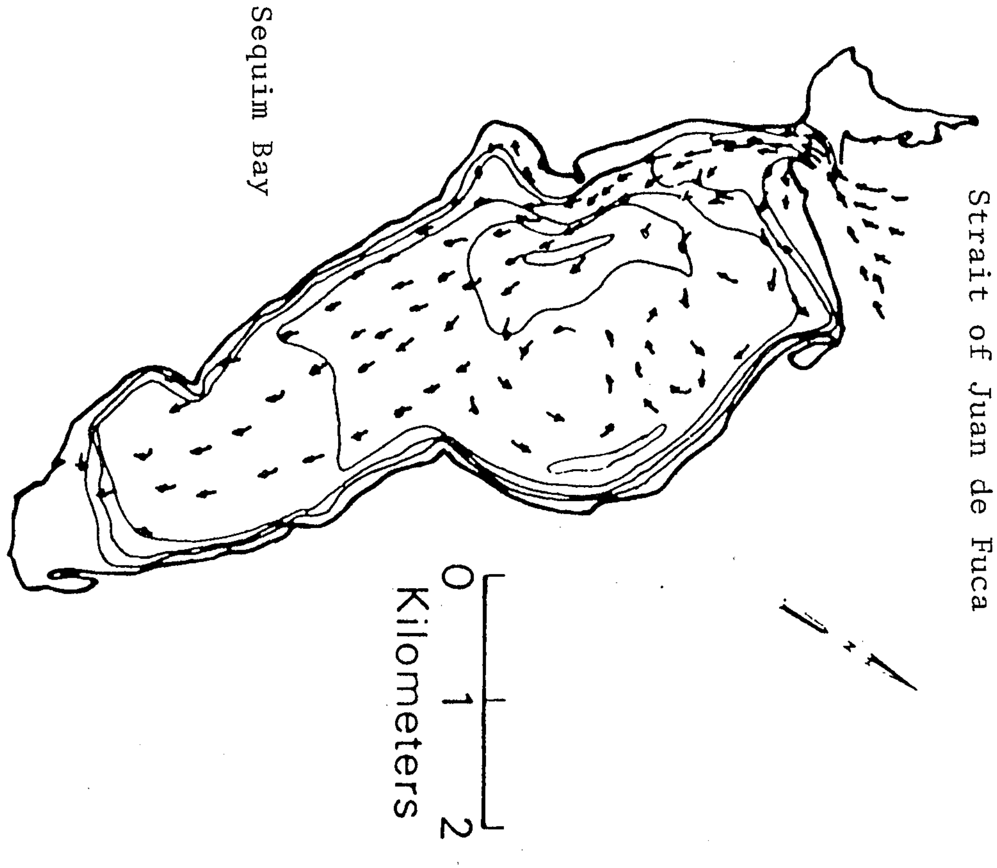


Figure VI-10 Observed General Flood Current Pattern

(VII) DEEP-OCEAN CURRENT MEASUREMENT STUDIES CONDUCTED IN THE ATLANTIC BY SAIC FOR ORP

By Peter Hamilton
Science Application International, Corporation
Raleigh, NC

1. Overview

In 1976, the U.S. Environmental Protection Agency (EPA), Office of Radiation Programs (ORP), initiated a survey of the Atlantic 2800-m low-level radioactive waste (LLW) disposal site. A three-month record was obtained for four mooring containing a total of five meters. The principal findings are that substantial, 3-4 cm/s, southwesterly mean currents were observed near the bottom and that the low frequency part of the spectrum is dominated by fluctuations with about a 16-day period which could be explained as bottom-trapped topographic Rossby waves with horizontal wavelengths of about 200 km. It implies that long-term water mass transport is dominated by the mean flow along the isobaths with excursions of about 300-400 km over three months. The Rossby waves disperse dissolved radionuclides with an effective horizontal diffusion coefficient of 7 x 10^6 cm^2/s. Detailed data and results are contained in the 1982 EPA Report No. 520/1-82-002 titled, "Analysis of Current Meter Records at The Northwest Atlantic 2800-meter Radioactive Waste Dumpsite."

In 1984, the ORP/EPA initiated a study at the Atlantic 3800-m LLW disposal site. The objective of this survey was to determine the potential of radioactive materials, dumped between 1957 and 1959, to move toward shore and/or productive fishing areas. Under an interagency agreement with the Minerals Management Service (MMS), Science Applications International Corporation (SAIC) was contracted to study the currents in and around the 3800-m disposal site area (see Figure VII-1). SAIC was already contracted to MMS to study the Mid-Atlantic Slope and Rise (MASAR) dynamics west of the disposal site to a depth of 3000-m. The incorporation of the field work and resulting data from the disposal site into the MASAR effort was viewed as being mutually beneficial to both programs.

This report presents the final results of the two-year field program, from May 1984 to May 1986, which was conducted to meet the EPA requirements.

2. Program Interrelationship with MASAR

The 3800-m disposal site program was brought into the MASAR program as shown in Figure VII-2. Chris Casagrande (SAIC) was the program manager and Dr. Peter Hamilton (SAIC) conducted the principal interpretative effort of the disposal site data.

The MASAR program, as part of the MMS Outer Continental Shelf (OCS) Environmental Studies Program, focused on the following:

- Eddies, rings, streamers, and other Gulf Stream (GS) related events,
- The Western Boundary Undercurrent (WBUC),
- Circulation in the surface layer above the main thermocline (less than 200 m),
- The shelf/slope front.

To study these phenomena, the MASAR principal investigators used hydrography, satellite imagery data from affiliated programs in the area, and Eulerian current measurements. The location of the 3800-m disposal site current measurement mooring in relation to the MASAR moorings is shown in Figure VII-3.

3. Mooring Design, Deployment, and Rotation

The design used at the 3800-m disposal site is shown in Figure VII-4. Five Aanderaa RCM-5 current meters were attached to the mooring. The meters were spaced at 5, 100, 250, 400, and 1000 m above the ocean floor. The spacing was designed to allow comparison of currents above, at, and below the Hudson Canyon rim. The lower two instruments were in the canyon, the third, level with the rim, and the upper two situated 150 m and 750 m above the rim.

The mooring was deployed in May 1984, rotated three times at approximately six-month intervals, and retrieved in May 1986. A sketch of the Hudson Canyon bathymetry, with the four mooring deployment positions indicated is shown in Figure VII-1.

4. Data Analyses

The fourth deployment was deliberately placed on the western side of the canyon to determine if there is any difference in flow characteristics, particularly mean currents, between the two sides of the channel. The data show that there is no residual circulation within the canyon. The flow above the canyon is about 4 cm/s which indicates that the site was within the Western Boundary Under Current. The 7-Day Low Pass (DLP) current data are presented in Figure VII-5 and the 40-Hour Low Pass (HLP) current data in Figure VII-6. These figures clearly show that the low-frequency motions penetrate all the way to the floor of the canyon and increase in magnitude with depth. However, the temperature spectra show decreasing variance with increasing depth (Figure VII-7). In the case of waves in the canyon, there is a small, down-canyon flux of heat evident from the velocity and temperature records at meters I3, I4, and I5. This may have implications for the flux of pollutants down the canyon despite relatively strong mean flows directed up the canyon.

Note: Additional current measurement data obtained in the Pacific in 1975 and 1977-78 at the Farallon Islands LLW disposal site off San Francisco, CA, were not presented at this meeting. This information, however, is provided in the Appendix.

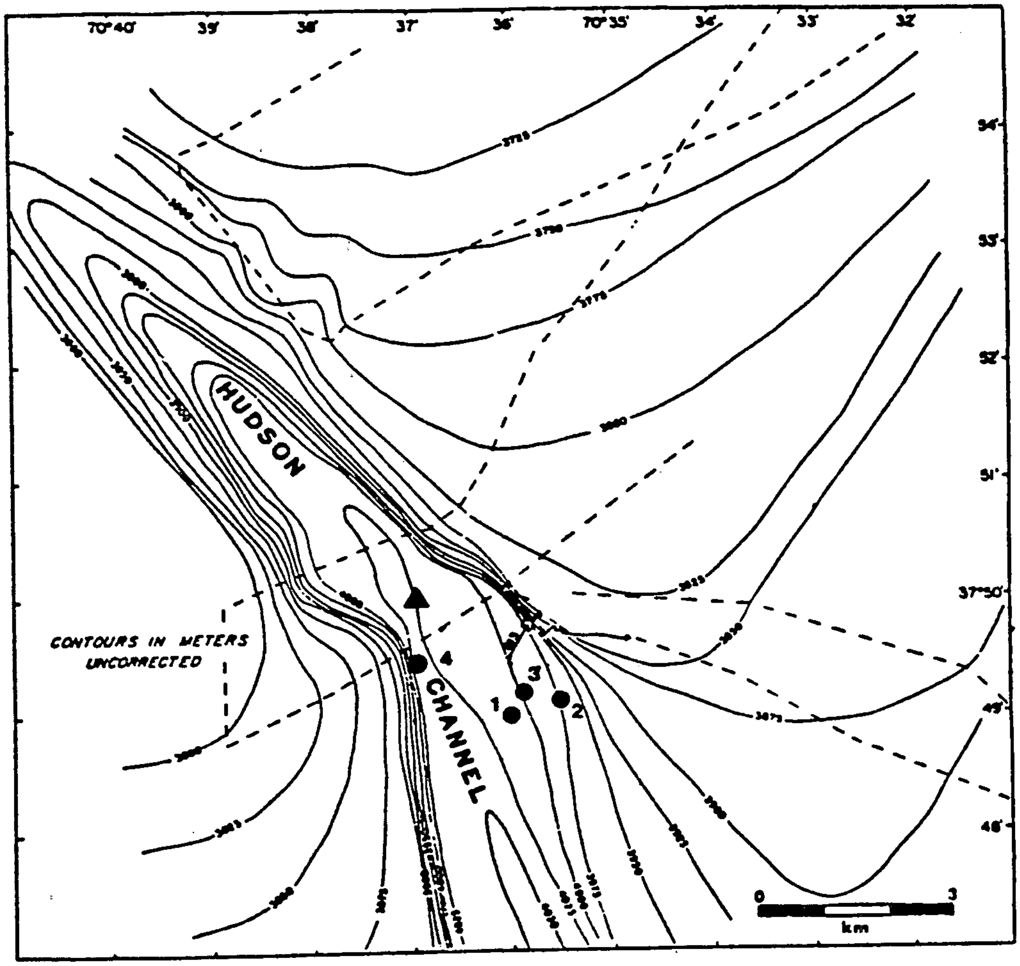


Figure VII-1. Locations of the mooring deployments and the 3800-m low-level radioactive waste disposal site superimposed on the bathymetry of the Hudson Canyon (Hanselman and Ryan, 1983). Positions 1, 2, 3, and 4 refer to the May and October 1984 and April and November 1985 mooring deployment positions, respectively. The triangle represents the center of the 3800-m disposal site.

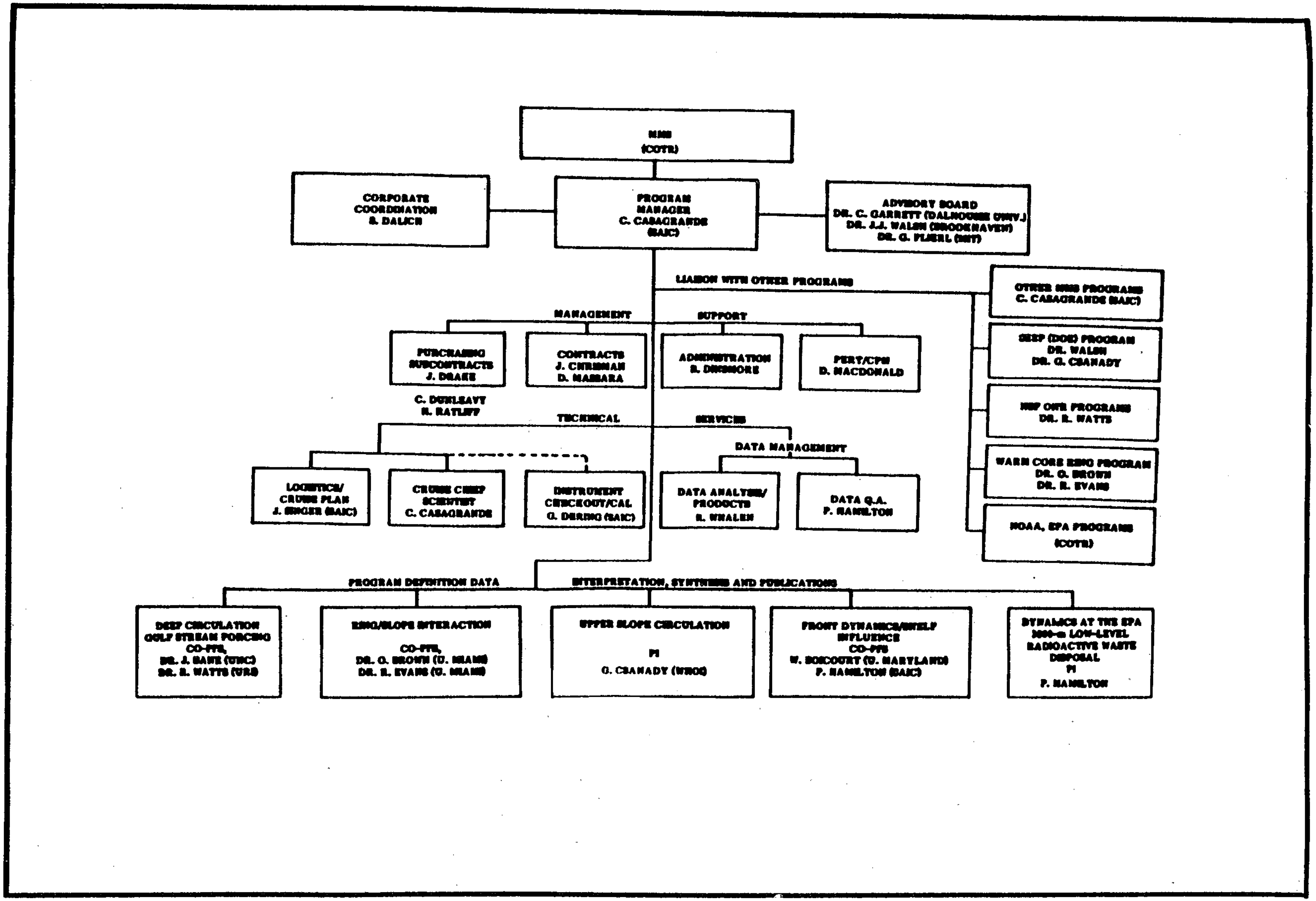


Figure VII-2. Managerial location of the EPA 3800-m low-level radioactive waste disposal site currents investigation within the MASAR program.

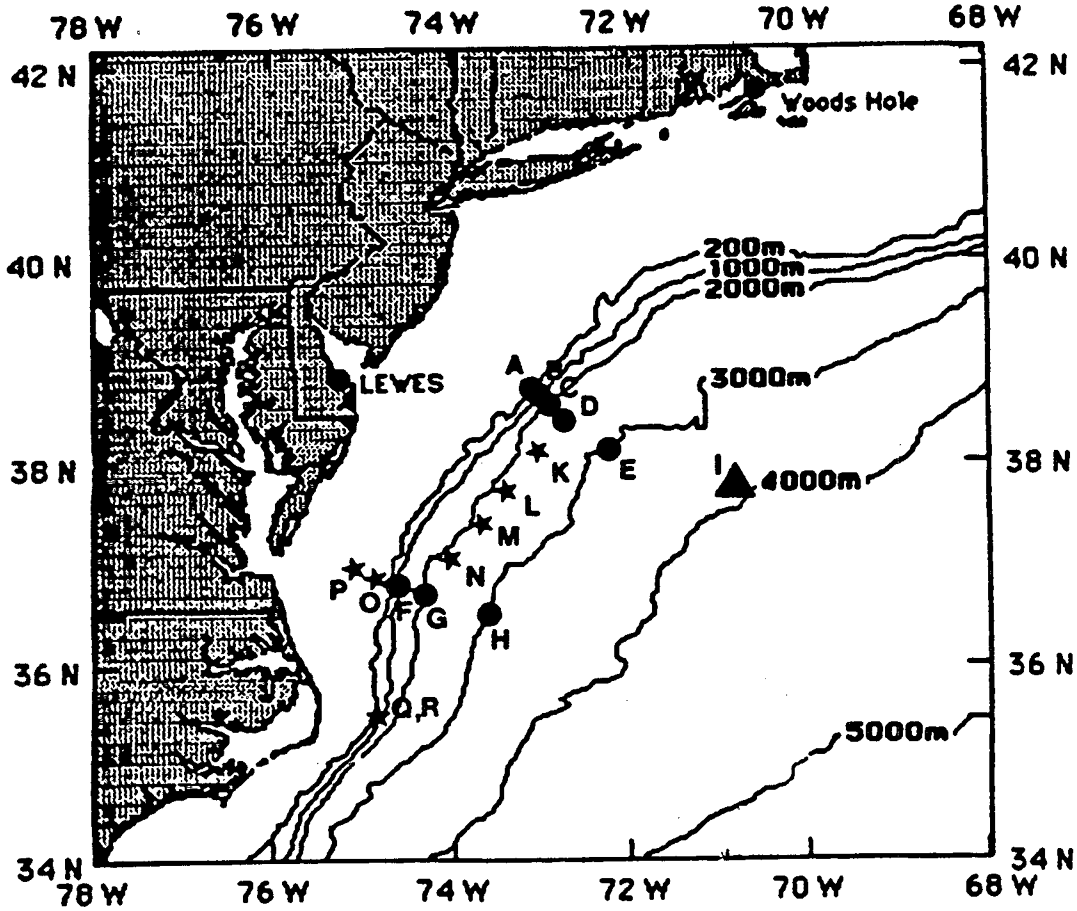


Figure VII-3. Location of the EPA 3800-m low-level radioactive waste disposal site vis a vis the MASAR moorings. The triangle represents mooring I at 3800-m site initially deployed in May 1984, the circles denote MASAR moorings deployed in February 1984, and the stars those deployed in September 1985.

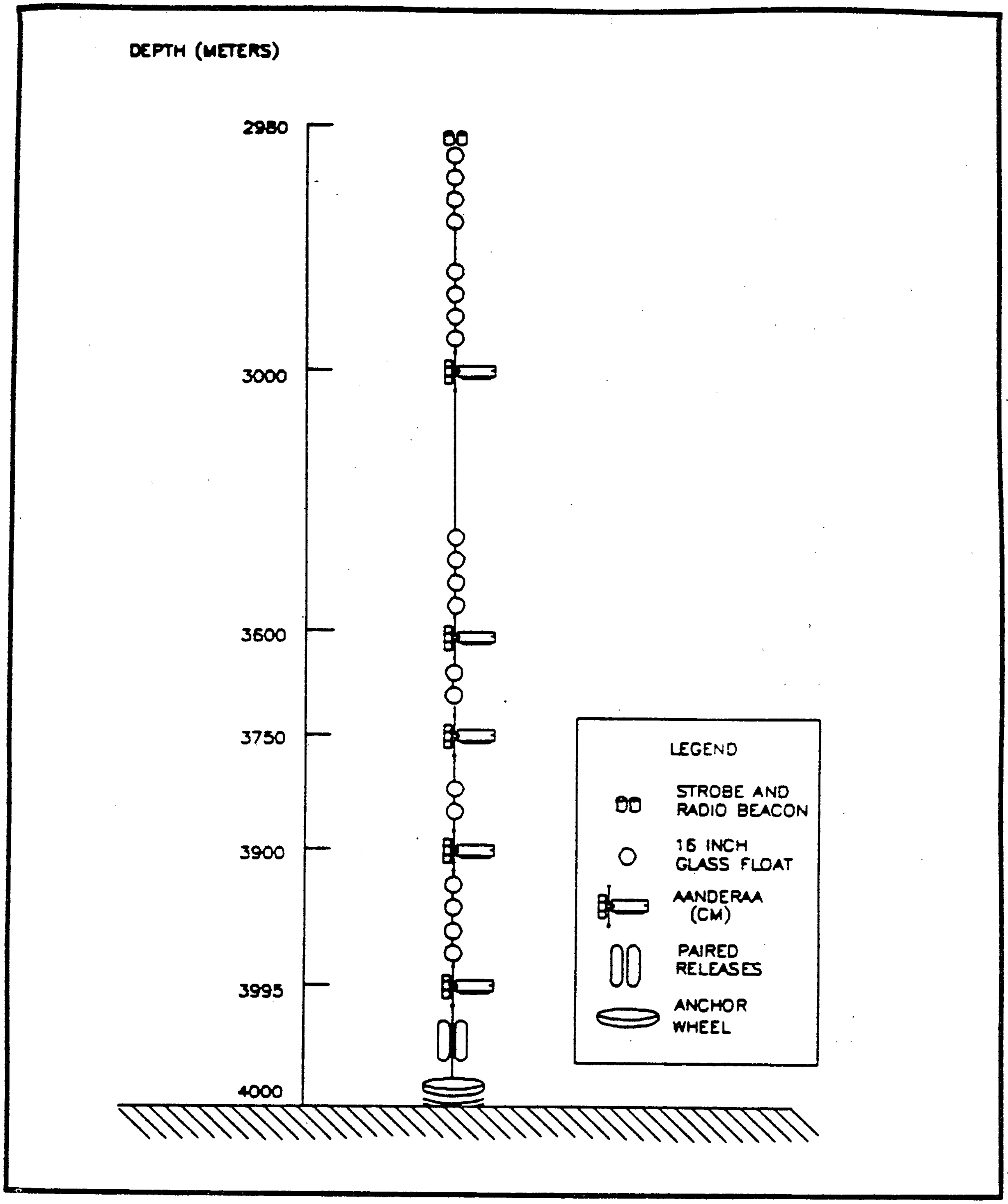


Figure VII-4. Design of Mooring I deployed at the 3800-m low-level radioactive waste disposal site.

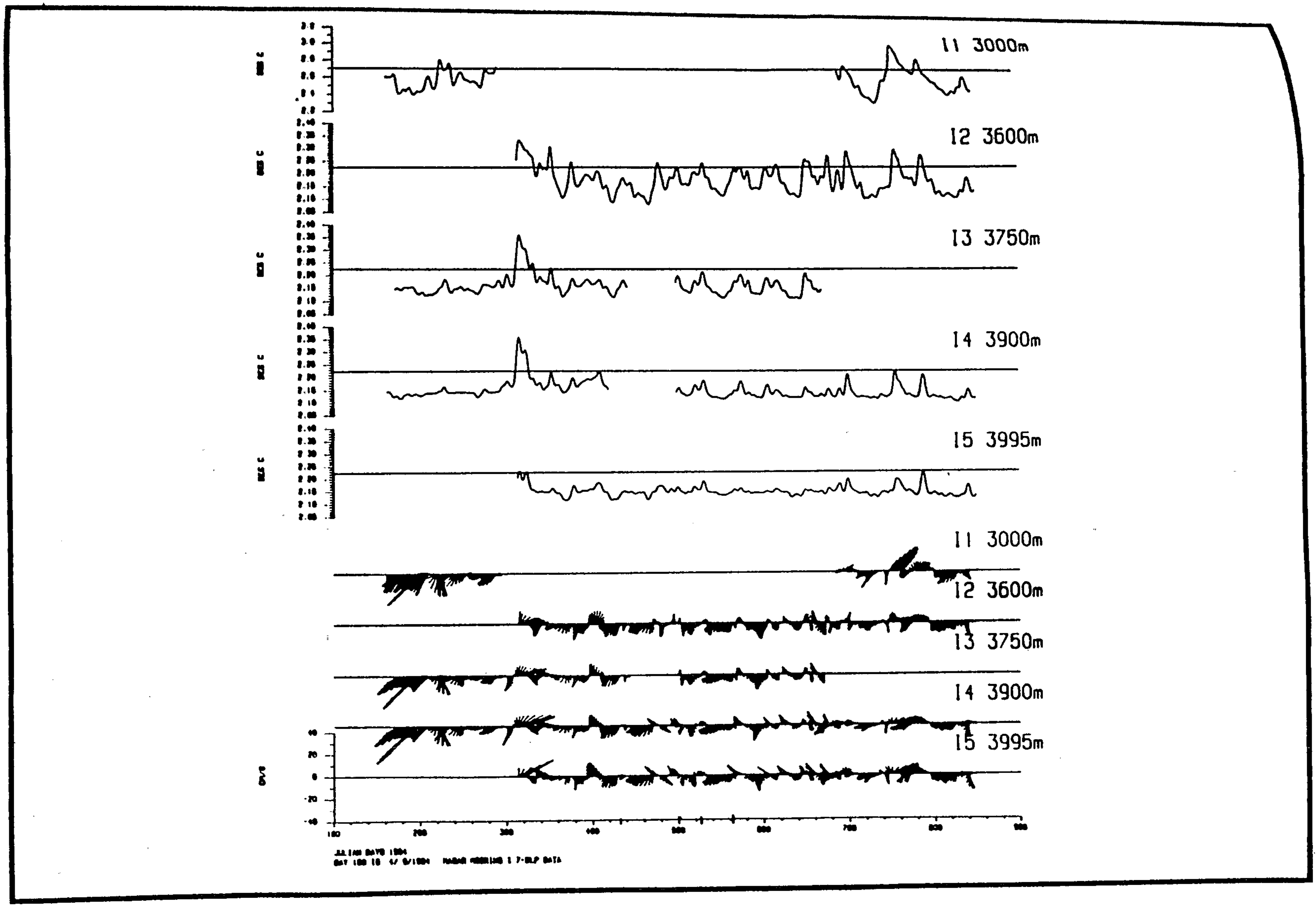


Figure VII-5. 7-DLP currents and temperatures at Mooring I.

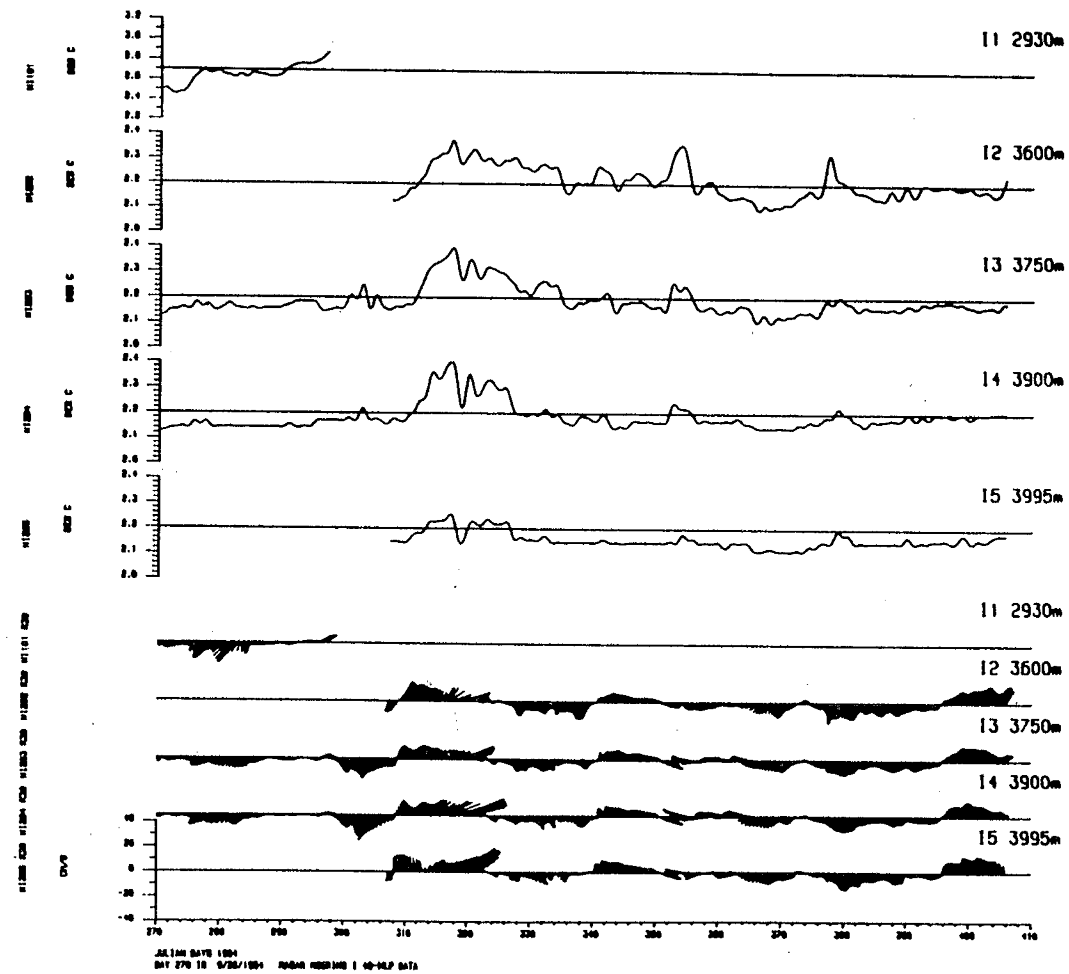


Figure VII-6. Five month record of 40-HLP current and temperature data beginning September 26, 1984 from mooring I a the 3800-m low-level radioactive waste disposal site.

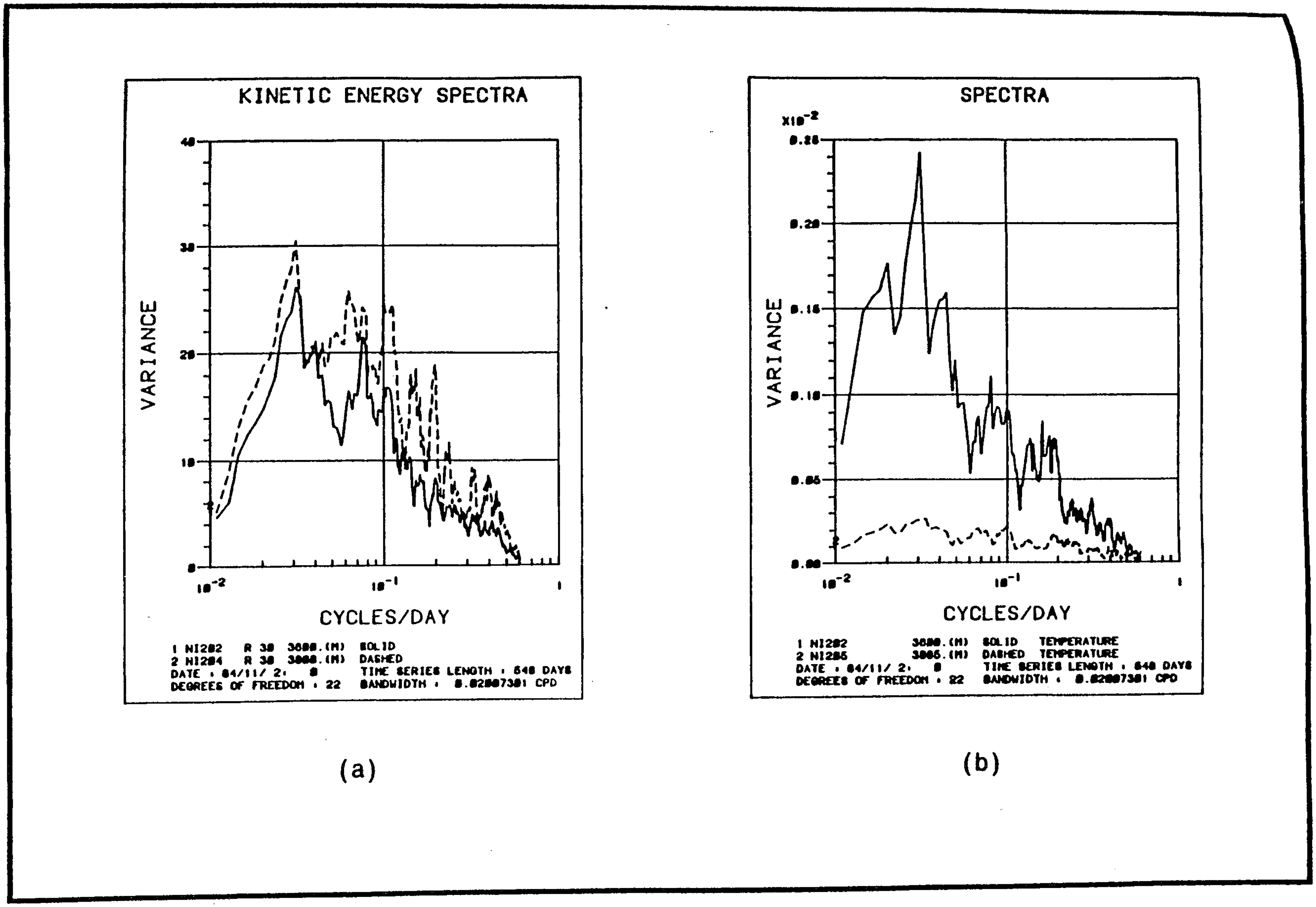


Figure VII-7. Kinetic energy and temperature spectra for (a) I 2 and (b) I 4.

(VIII) DYNALYSIS OF PRINCETON WORK ON HYDROGRAPHIC DATA FROM NATIONAL ARCHIVE CENTERS FOR MMS/DOI

By Kung-Wei Yeh
Environmental Studies and Statistics Branch, ASD
Office of Radiation Programs

1. Data Sources

Observed data play an essential role in the prediction of ocean circulation processes. They provide boundary conditions and initial conditions for computational domains and are indispensable for a diagnostic model of the ocean. Historical data were retrieved from national archive centers such as the National Oceanographic Data Center (NODC), the Fleet Numerical Oceanography Center (FNOC), and the National Climatic Center, in addition to the data collected through MMS and its predecessor, Bureau of Land Management, and Department of Energy, National Science Foundation and Navy in the region of mutual interest.

2. Data Processes

The data from various sources were merged together and sorted and stripped of duplicates. All data were interpolated to the National Oceanographic Data Center's standard level. The resulting data base was subjected to quality control by subjecting each cast to a one-dimensional three-point Turkey filter. This filter chooses the median of the data and the adjacent data value, and is a nonlinear filter with very useful properties: it removes only sharp spikes in the record but leaves the rest of the record virtually unchanged including more gradual changes. Subjecting each cast to a Turkey filter eliminates erroneous data points in that cast. Station casts consisting of temperature, salinity, and Sigma t information at various levels were also subjected to a gross 'stability' check.

3. Data Distributions

Climatological data reduction and analysis were done in two stages. During the first stage, the calculations were done for a domain north of 26.5^{o} N and west of 65^{o} W (Figure VI-2). In the second stage, the domain was extended to 22.75^{o} N. The region is then bounded on the east side by 65^{o} W and on the south by 22.75^{o} N. Hydrographic data has been processed on the 1/4^{o} X 1/4^{o} grid (Figure VIII-1). The surface marine observations have been initially binned on $1/2^{\circ}$ X $1/2^{\circ}$ grid, and interpolated and smoothed on the $1/4^{\circ}$ X $1/4^{\circ}$ grid using the Herring Poisson Objective Analysis Technique which is similar to the Cressman Iterative Difference-Correction Scheme used in numerical weather prediction. This method involves derivation of the distribution of a property over the domain of interest from data observed at isolated points. The final data base comprised 327,888 casts. Figures VIII-2 and VIII-3 present the distributions of the overall number of observations available in the data base before the data reduction process on temperature and salinity at 500- and 1000-m depth.

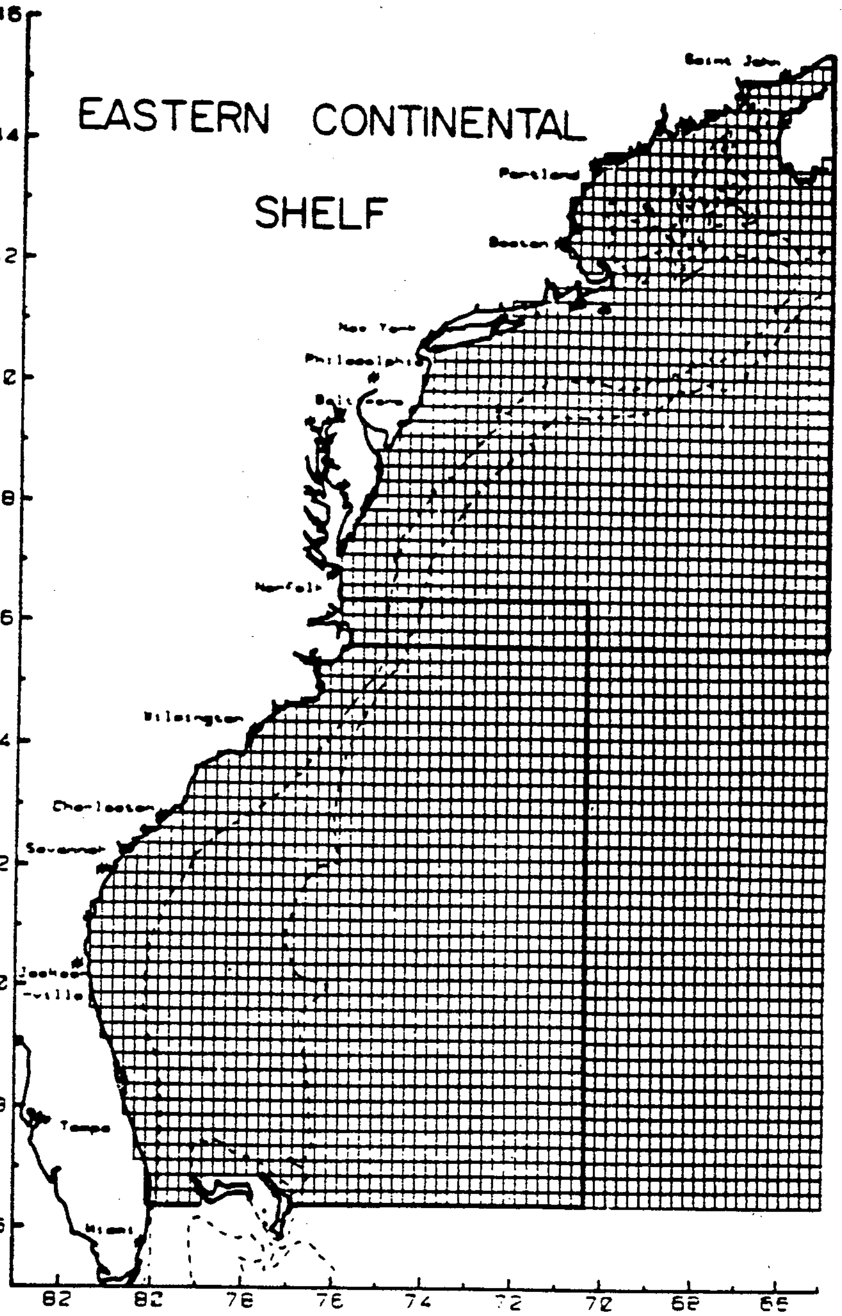


Figure VIII-1 . A map of the Eastern Continental Shelf showing the computational grid and the subdomains on which result are shown.

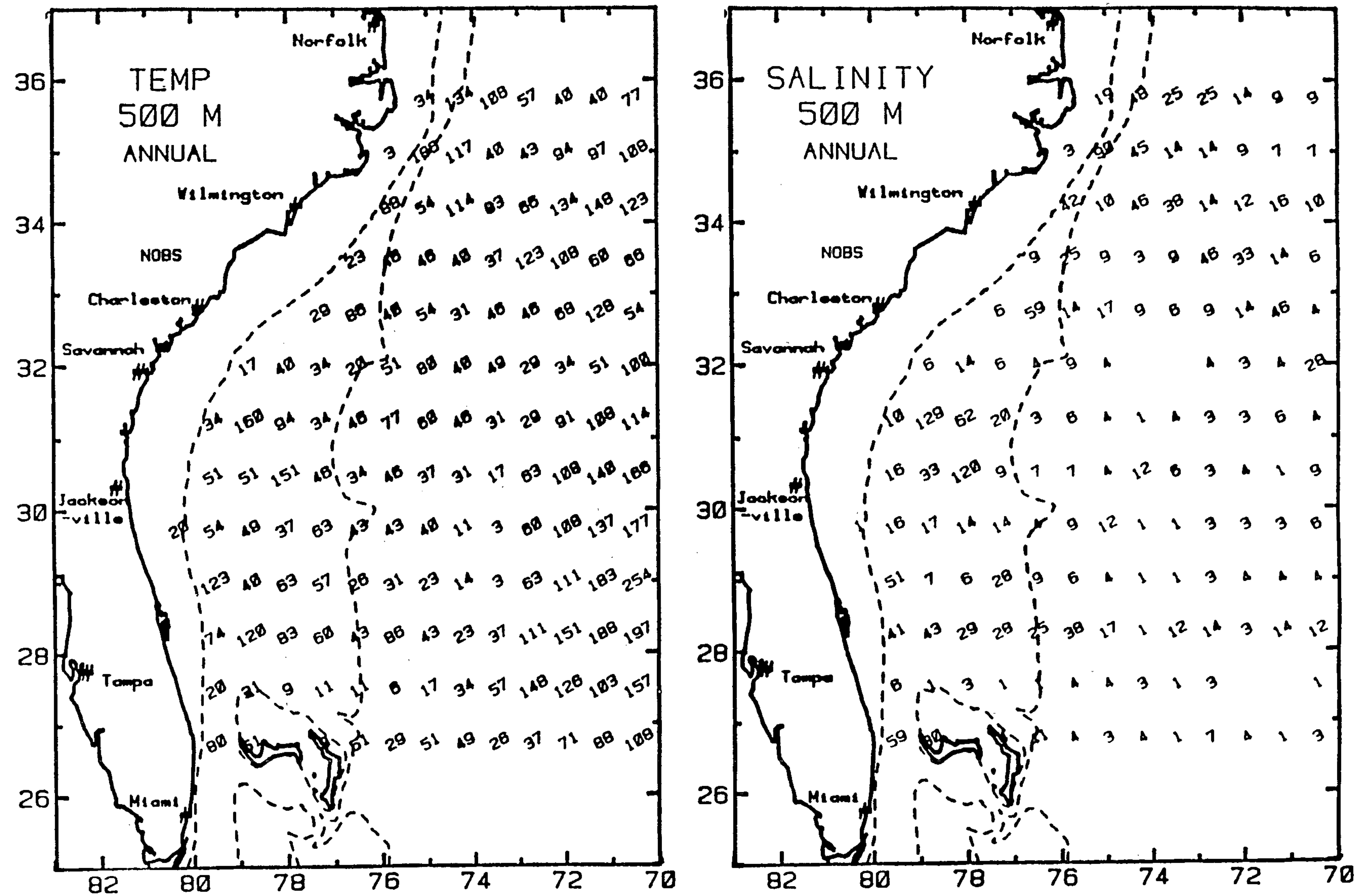


Figure VIII-2. Number of observations of temperature and salinity at 500 m depth.

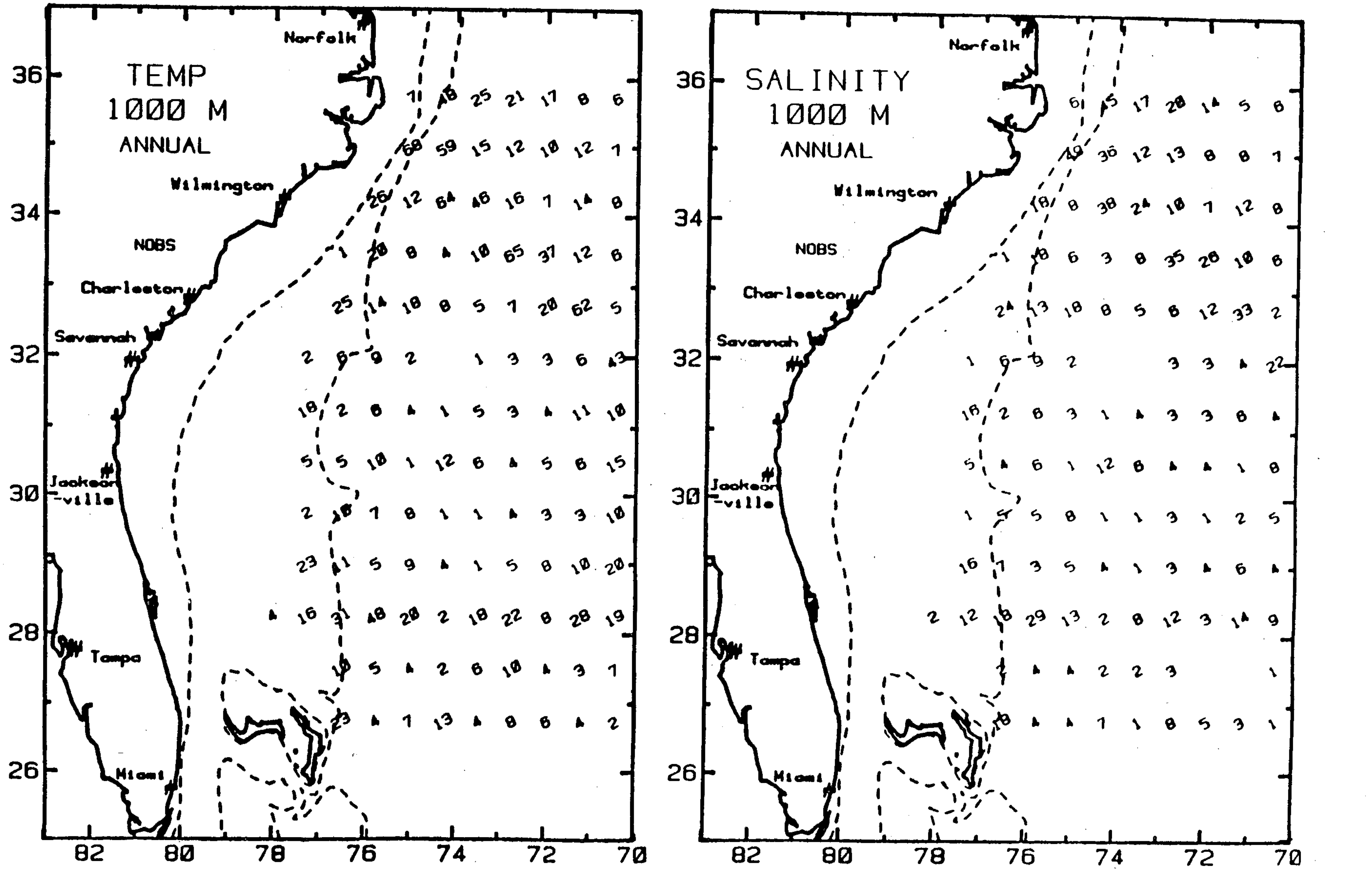


Figure VIII-3. Number of observations of temperature and salinity at 1000 m depth.

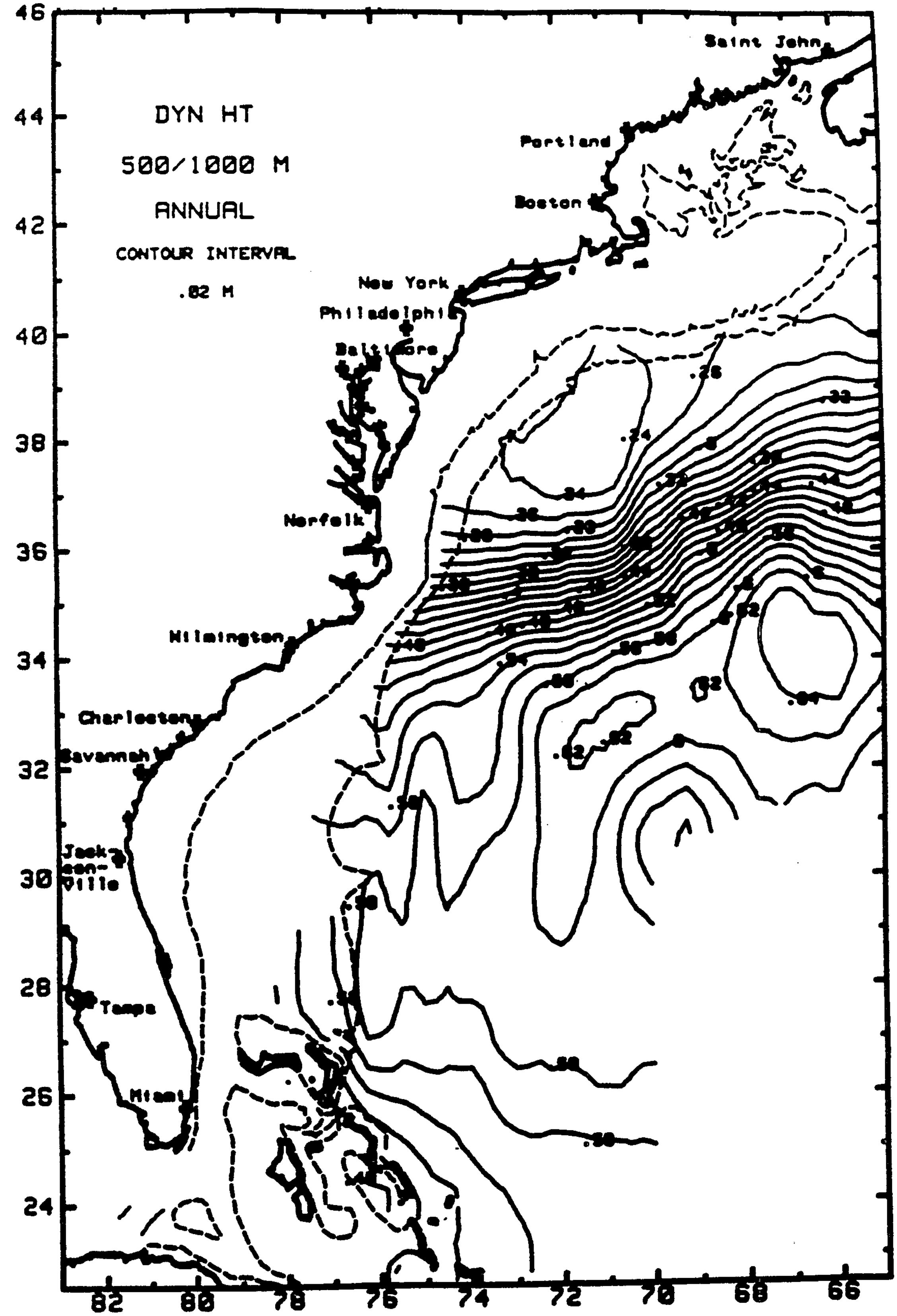


Figure VIII-4. 500/1000 m dynamic height distribution for the annual case.

(IX) GLOBAL MODELING EFFORT AT SANDIA NATIONAL LABORATORIES FOR DOE

By Mel Marietta
Sandia National Laboratories
Albuquerque, NM

Sandia National Laboratories has developed a box modeling approach, Mark A Model, for a preliminary overall assessment of the radiological effects of subseabed disposal of high-level radioactive waste (HLW) (see SAND 84-0646). This modeling approach is also applicable for assessing the global dispersion of long half-life isotopes of low-level radioactive waste (LLW). In Mark A model, the regional simulation, as proposed to use FLESCOT model, will be imbedded in and driven by General Circulation Model (GCM).

1. Problems to be Solved

Assess the impact of high-level radioactive waste disposal in the geologic formations beneath the deep oceans on the global population and environment.

2. Methodology Used

Used Mark A box model which integrates (1) General Circulation Model (GCM), (2) Regional Eddy-Resoliving Model (REMs), (3) Bottom Boundary Layer Model (BBLMs), and (4) Surface Boundary Layer Model (SBLMs). The specific objectives for each model are:

(a) General circulation model- spin-up ocean circulation current system used as initial condition, generate transport and geochemical distribution data which are used to precondition and drive the Mark A box model, and check their dispersion results. The GCM test problem configuration is shown in Figure IX-1.

(b) Regional Eddy-Resolving Model (REM)- resolves mesoscale motion of the proposed disposal site and simulates radiological release.

(c) Bottom Boundary Layer Model (BBLM)- focuses on the special dynamical processes that bring materials from the sea floor to the interior.

(d) Surface Boundary Layer Model (SBLM)- simulates realistic condition of the uppermost water.

A schematic view of a Regional-Resolving Model with Bottom Boundary Layer and Surface Boundary Model, embedded in and driven by the GCM test problem model is shown in Figure IX-2. Figures IX-3 and IX-4 show the nested box configuration and the geochemical component of the Mark A box Model respectively.

The iterative procedure for embedding a regional eddy-resolving model with numerically modeled BBLs and SBLs within a GCM utilizes real ocean data.

Note: in box modeling, the physical process is replaced by a prescribed bulk circulation which is based on either observation or a dynamical model simulation such as the GCM model.

3. Assumptions Made

Assumes all models can be interconnected in mass, momentum, and energy without loss of their continuity of constituents (i.e., conservation of mass, momentum and energy must be retained everywhere).

4. Results Expected

Mark A box model has been applied to the North Atlantic for the Nares Abyssal Plain (NAP) and Great Meteor East (GME) sites. For the Mark A box configuration, modified East Atlantic and West Atlantic box models were placed side by side to constitute a four-zone North Atlantic mode. This arrangement is motivated primarily by basin geometry, underlying topography, site location, and local mixing time. Integration of all models is still in progress.

REFERENCE:

SAND 84-0646, 1984. Report of The Second Annual Interim Meeting of The Seabed Working Group, Physical Oceanography Task Group. Fontainebleau, France, 9-12 January 1984. Edited by A. R. Robinson and M. G. Marietta.

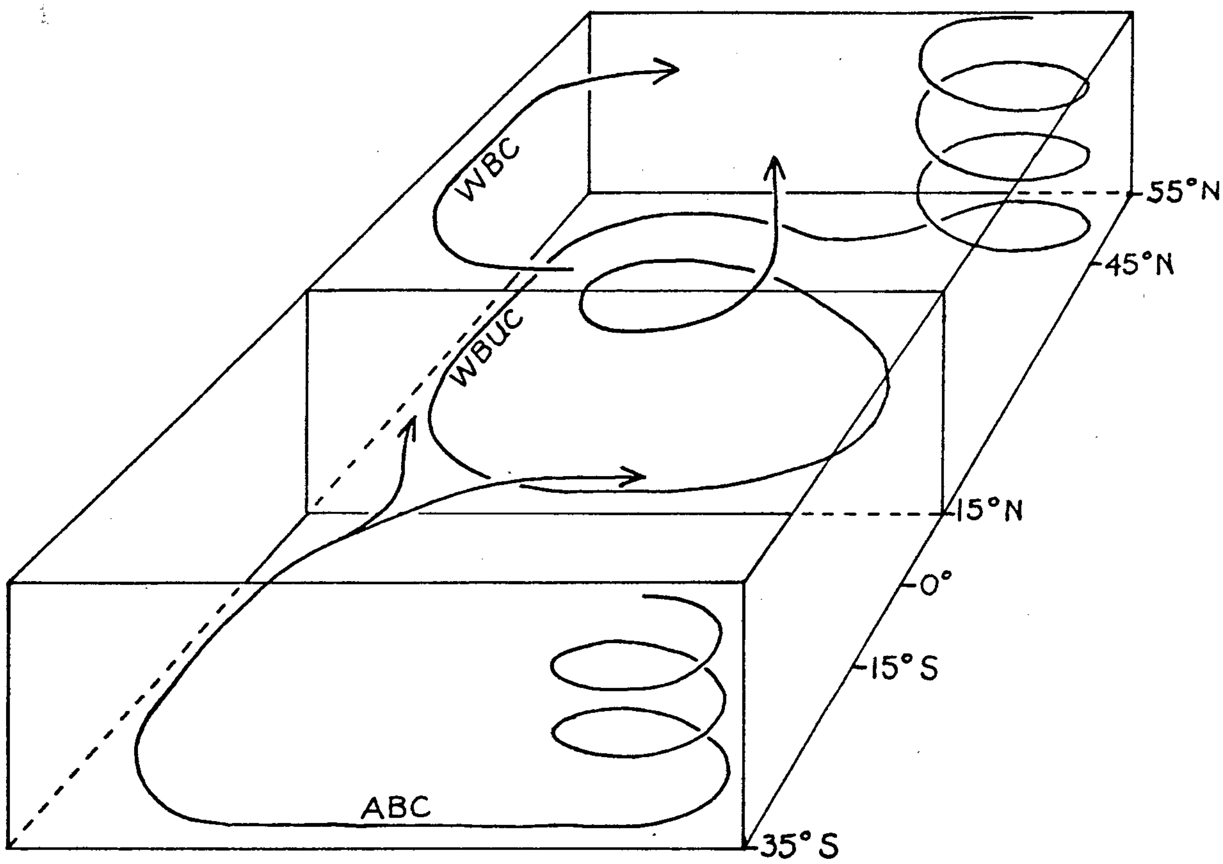


Figure IX-1. The POTG GCM test problem configuration as revised by the addition of the Equatorial and South Atlantic Oceans.

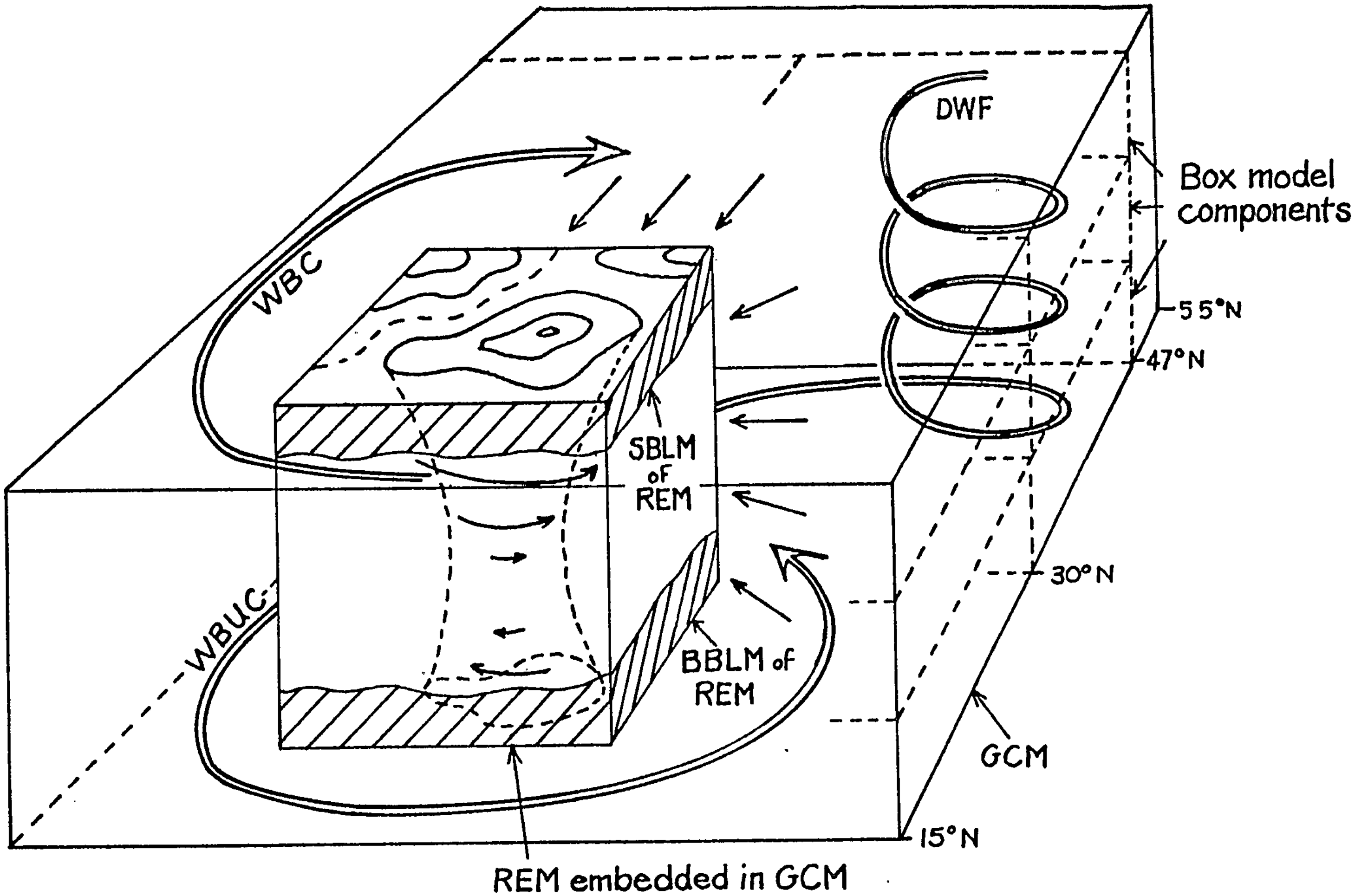


Figure IX-2. A schematic view of a Regional Eddy-resolving Model with Bottom Boundary Layer Model and Surface Boundary Layer Model, embedded in and driven by the GCM test problem model. Also indicated (dashed lines) are the boxes of the Mark A model, suggesting the three way interdependency that these models share.

NESTED BOX MODEL

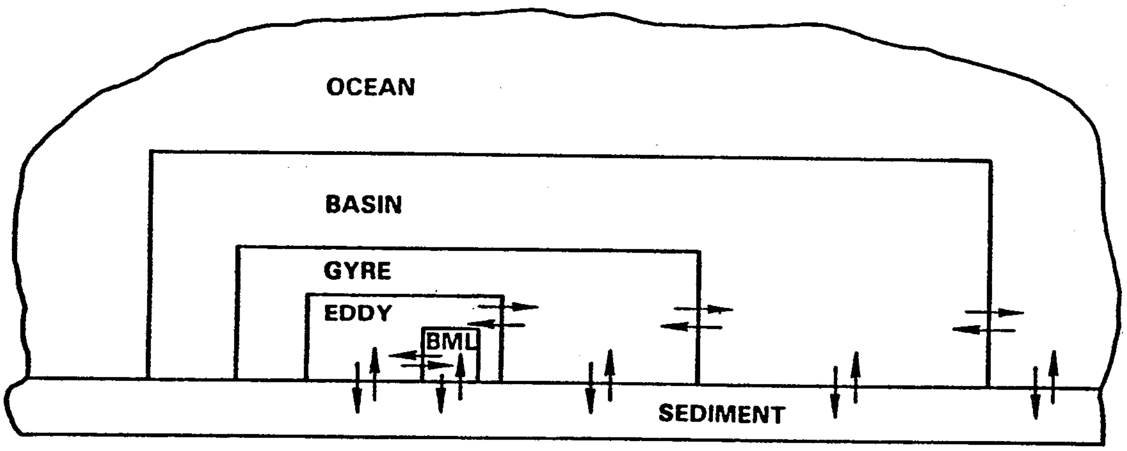


Figure IX-3. **The Nested Box Configuration used by TASC, Based Upon the Work of Kupferman and Moore (1981).**

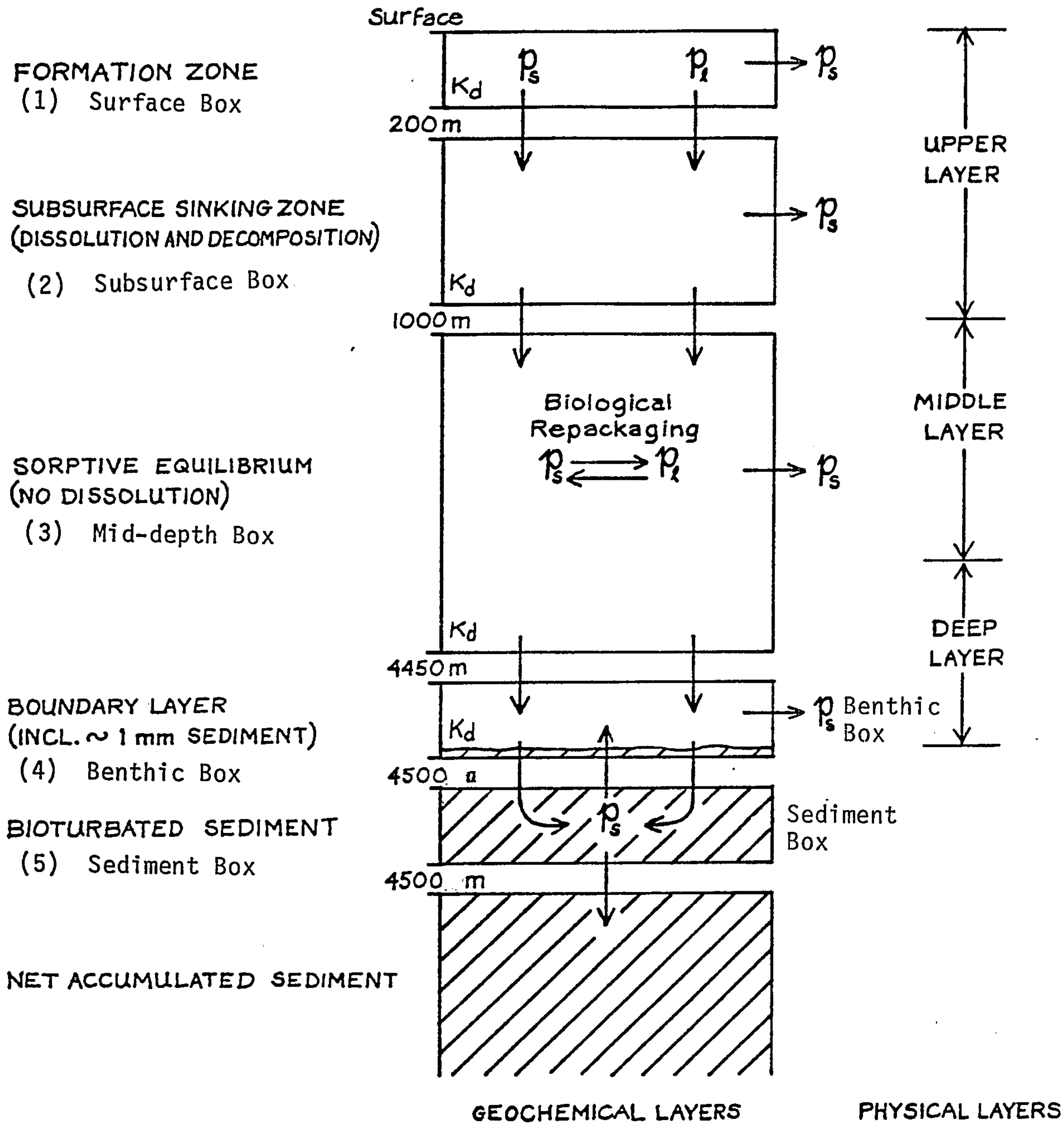


Figure IX-4. **Geochemical Component of the Mark A Box Model. Of the larger particles (≥ 50 µm) formed in the surface waters, about 10% survive below 1000-m depth, the other 90% being dissolved or decomposed in the upper 1000 m. Between 1000 m and 4450 m, processes that can both enhance and diminish particle size are encountered. Of the large particles reaching the BBL, about 90% are thought to dissolve in the lysocline. The remaining 10% are transmitted to the bioturbated sediment layer where they are broken up mechanically. Except for resuspension, small particles accumulate as sediment. Particle-solution interactions occur throughout the water column, indicated in the figure by a K_d in each box.**

(X) FIELD DATA COLLECTION AND ANALYSIS FOR MMS/DOI MASAR PROJECT

By Peter Hamilton
Science Applications International Corporation
Raleigh, NC

1. Overview of MASAR Program

In 1973, the Department of Interior (DOI) initiated the Outer Continental Shelf (OCS) Environmental Studies Program to support the department's OCS oil and gas leasing program. In September 1983, under the OCS program, the Minerals Management Service (MMS) of DOI contracted with Science Applications International Corporation (SAIC) to provide a study of the physical processes on the Mid-Atlantic Slope and Rise (MASAR). The MMS stated objectives for this study were to:

- Determine the broad scale, general circulation features on the continental slope and rise on a seasonal basis,
- Describe and quantify the variability in these areas in the vertical and horizontal planes,
- Determine the degree to which the slope/rise circulation features influence the physical oceanography of the Mid-Atlantic continental shelf.

To meet these objectives, the program focused on the following:

- Eddies, rings, streamers, and other Gulf Stream (GS) related events,
- Western Boundary Undercurrent (WBUC),
- Circulation in the surface layer above the main thermocline (less than 200 m),
- Shelf/slope front,
- Potential for waste transport at the EPA 3800-m dumpsite.

This report, derived from MMS/DOI 1987 preliminary final report submitted by SAIC, focuses on field data collection and analysis of the final results of a two-year field program designed to meet the above objectives.

2. Methodology

The methodology used to collect the field data addressing the physical processes of the MASAR study area relied primarily on an array of current meter moorings deployed over the slope and rise as shown in Figures VII-3 and X-2. The initial moorings were primarily located to intercept the southwestward passage of Warm Core Rings (WCRs), to determine the presence, extent and variability of the Western Slope Sea Gyre first inferred by Sverdrup in 1942, and to determine their interactions with the deeper Western Boundary Undercurrent (WBUC).

The current meter measurements were supplemented by hydrographic cruises, which identified the location of water masses associated with the shelf, slope, and GS regimes, thus providing data from which circulation was inferred implicitly from tracers and explicitly from geostrophic calculations. In addition, extensive use of remote sensing techniques provided daily infrared images, statistical data on Gulf Stream locations, and warm- and cold-core ring dimensions along with their life expectancy and speed.

In order to provide sufficient data to describe all the processes directly affecting the dynamics and circulation within the study area, the MASAR program drew on several associated programs conducted in the same region under the auspices of other agencies. These programs were:

- The Gulf Stream Meander Dynamics sponsored by National Science Foundation (NSF) and Office of Naval Research (ONR), designed to study the meandering processes in the GS, utilizing current meters and inverted echo sounders. The principal investigators were Drs. Randolph Watts of the University of Rhode Island (URI) and John Bane of the University of North Carolina (UNC).

- The Shelf-Edge Exchange Processes (SEEP), a program supported by the Department of Energy (DOE). The program's objectives were to describe and quantify the cross-shelf transport and subsequent deposition on the slope of organic carbon. The leader of the physical program was Dr. Gabriel T. Csanady (WHOI).

- Microbial Exchange and Coupling in Coastal Atlantic Systems (MECCAS), a program funded by NSF. This study undertaken by Dr. William Biocourt (UM) addresses the dynamics of estuarine plumes formed by the outflow of low salinity water onto the continental shelf. Only the observations concerned with the ambient shelf circulation and cross-shelf hydrographic transects were used in conjunction with other MASAR data to evaluate shelf-slope coupling features and variability.

- The Warm Core Rings Experiment (WCRE), funded by NSF and directed by Drs. Otis Brown and Robert Evans (RSMAS, University of Miami) provided much of the 10-year statistical information on WCRs presented in this report.

The locations of moorings and instrumentation provided by the associated programs are shown in Figure X-3.

Finally, a substantial, historical, regional data base was used in order to provide the comprehensive interpretation.

3. Slope Water

The water mass located between the edge of the continental shelf and the Gulf Stream, as shown in Figure X-4, is called slope water. This water mass plays an important role in the transport and dispersion of pollutants in the Mid-Atlantic Region. Iselin (1936) pointed out that slopewater was much like North Atlantic Central Water (NACW). The specific layers of slope water include those containing an admixture of Atlantic Intermediate Water (AAIW), except that each layer of given temperature and salinity was located at a depth some 500 m shallower than in the Sargasso Sea, and that salinity at constant temperature was less than in NACW by about 0.05 o/oo. An empirical scheme of slopewater circulation is shown in Figure X-5.

4. Data Products

Standard sets of hydrographic data products were supplied to each Principle Investigator (PI) of the programs. These included profiles of observed and derived variables in sequential format, grouped according to previously designated cross- and along-shelf transects. Each set consisted of:

- Contoured vertical fields of potential temperature, salinity, salinity anomaly, and density (sigma-t).

- Contoured vertical plots of oxygen, silicate, nitrate, and phosphate.
- Temperature-salinity mixing diagrams (Figure X-6).
- Oxygen- and nutrient-density mixing diagrams.
- Nutrient-temperature mixing diagrams.

Other products such as mixing diagrams for nitrate-phosphate were supplied when requested.

Most of the contour plots were generated using a National Center for Atmospheric Research (NCAR) graphics package called CONRAC which triangulates and contours through the data field.

Calibration checks were applied not only in the field during data acquisition but also during the in-house data reduction process. Comparisons of nitrates, phosphates, and silicates against each other, versus temperature and salinity, and versus historical data provided a check on data quality.

The steps used in processing and editing of the MASAR raw CTD data files were as follows:

- The raw data were read into sequential disk files created by storing the data scans as ASCII characters. These sequential disk files were then converted into separate temperature, conductivity, and pressure files ordered by cast number with checks for large spikes, data gaps, and the number of data scans.
- Cast header information required for NODC data files were stored in the individual cast file header records.
- Vertical profiles of temperature and conductivity were plotted and checked for spikes or obviously questionable data which were then removed.
- Data were converted to regular depth intervals. These regular depth interval data were then used to produce cast listings and final data plots. These final plots were checked against the vertical profiles produced earlier.
- Data tapes in National Oceanographic Data Center (NODC) format were then produced and submitted to NODC.

Data collected by the XBT acquisition system and thermosalinograph underwent similar procedures and were then cross-checked and calibrated as necessary. Table X-1 lists MASAR mooring cruises between February 1984 and May 1986.

The upper-level and near bottom currents from the MASAR array are shown in Figures X-7, X-8, and X-9. A transect of temperature, salinity, and density taken on MASAR cruise 2 is seen in Figure X-10a. In Figure X-10b, one saline tongue is intruding shoreward at 170-m depth, another, less regular one at 40-50 m. A pycnostad is visible between the two intrusions, centered at about 110 m (Figure X-10c). The surface mixed layer, about 25 m deep, is very fresh to a long distance from the shelf edge front.

The energy spectra for MASAR near-bottom current measurements are shown in Figure X-11. These deal with the alongshore (V) component of current. It is generally only this V component that has high coherence between neighboring pairs of deep site.

REFERENCES:

Iselin, C.O'D., 1936. A Study of The Circulation of The Western North Atlantic. PPOM4, No. 4, MIT-Woods Hole Oceanographic Inst., 101 pp.

MMS/DOI 1987. Study of Physical Processes on The U.S. Mid-Atlantic Continental Slope and Rise. SAIC preliminary final report, 1987.

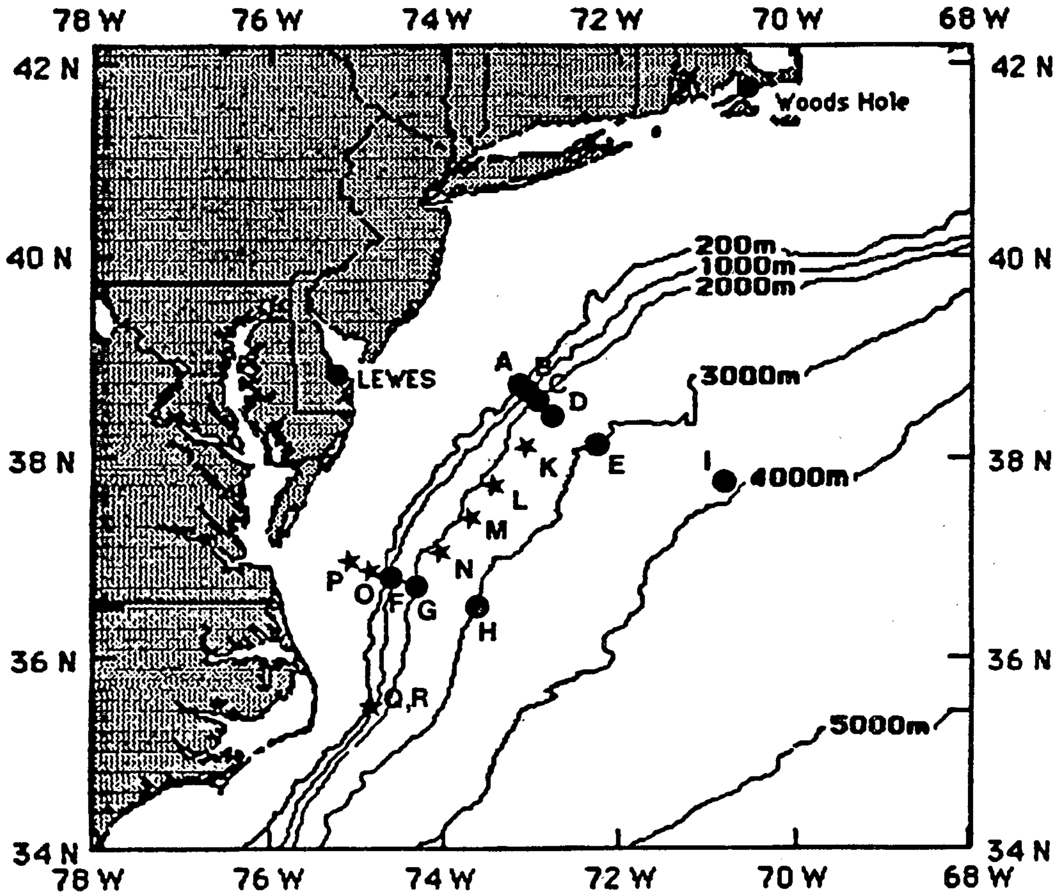


Figure X−1. Location of all MASAR moorings. The eight original moorings deployed in Feb. 1984 are designated by ● and those deployed in Sept. 1985 are shown by ★.

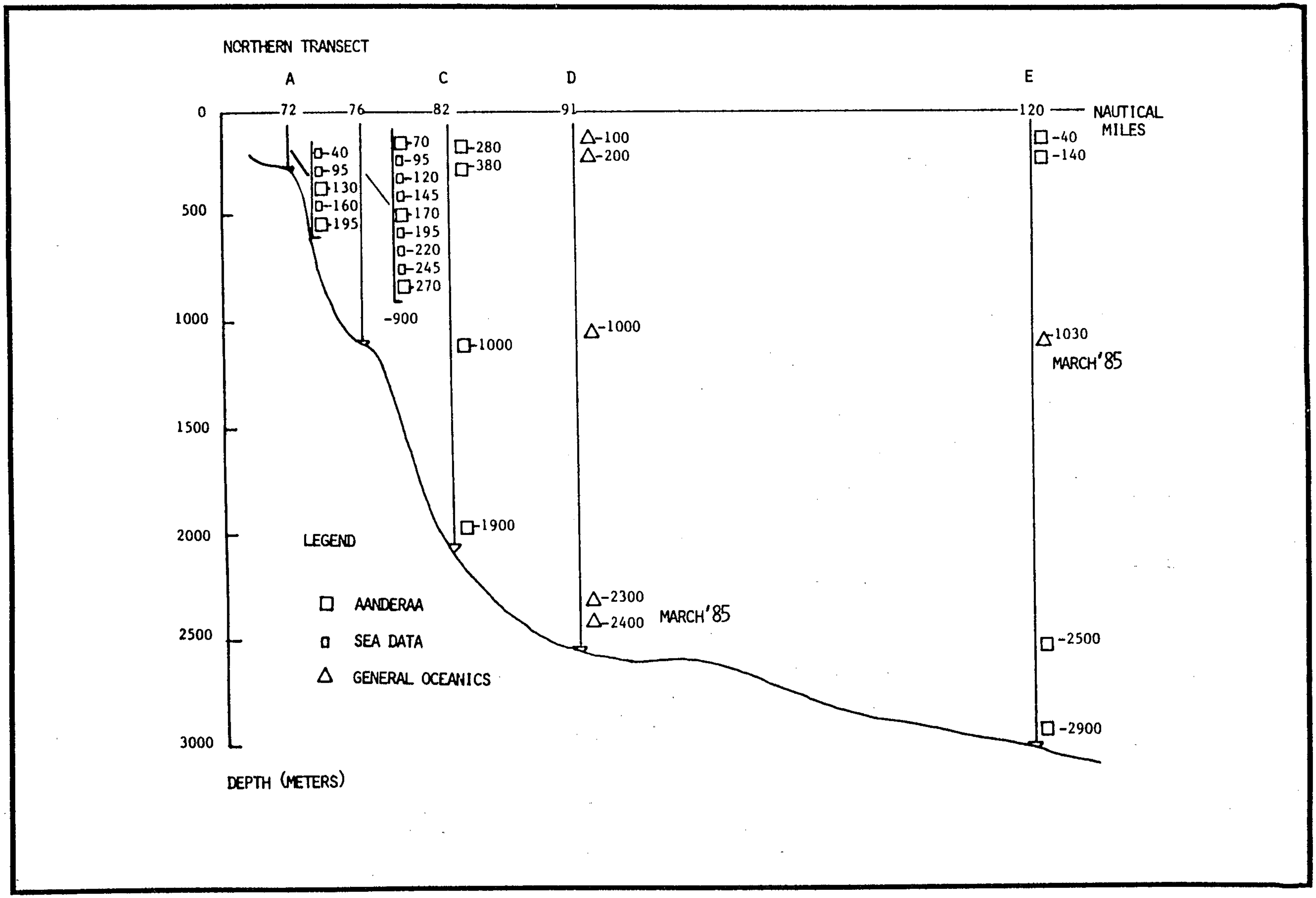


Figure X-2 . The northern mooring transect showing instrument locations. Note that a mid-depth current meter was added to mooring E in March 1985.

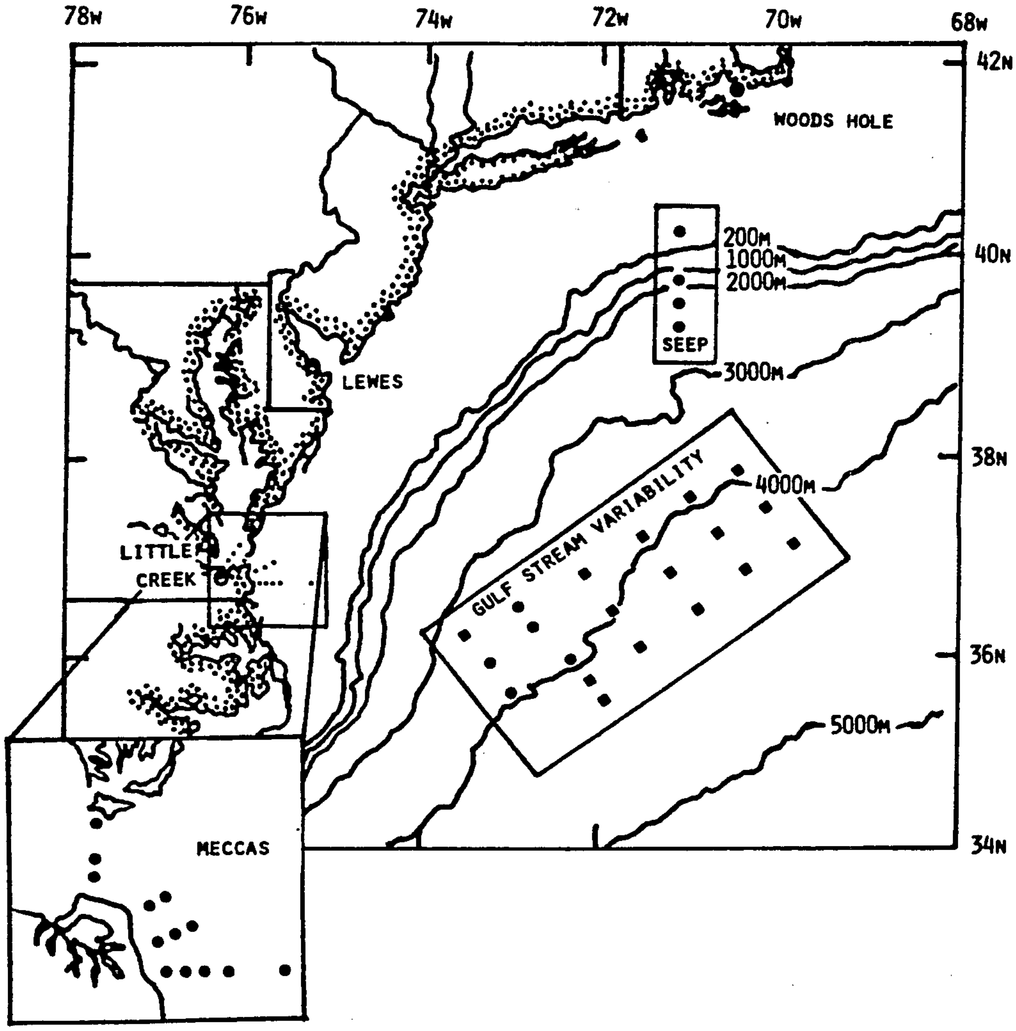


Figure X-3 . Mooring locations of the associated programs: SEEP, MECCAS, and Gulf Stream Variability, sharing data with MASAR.

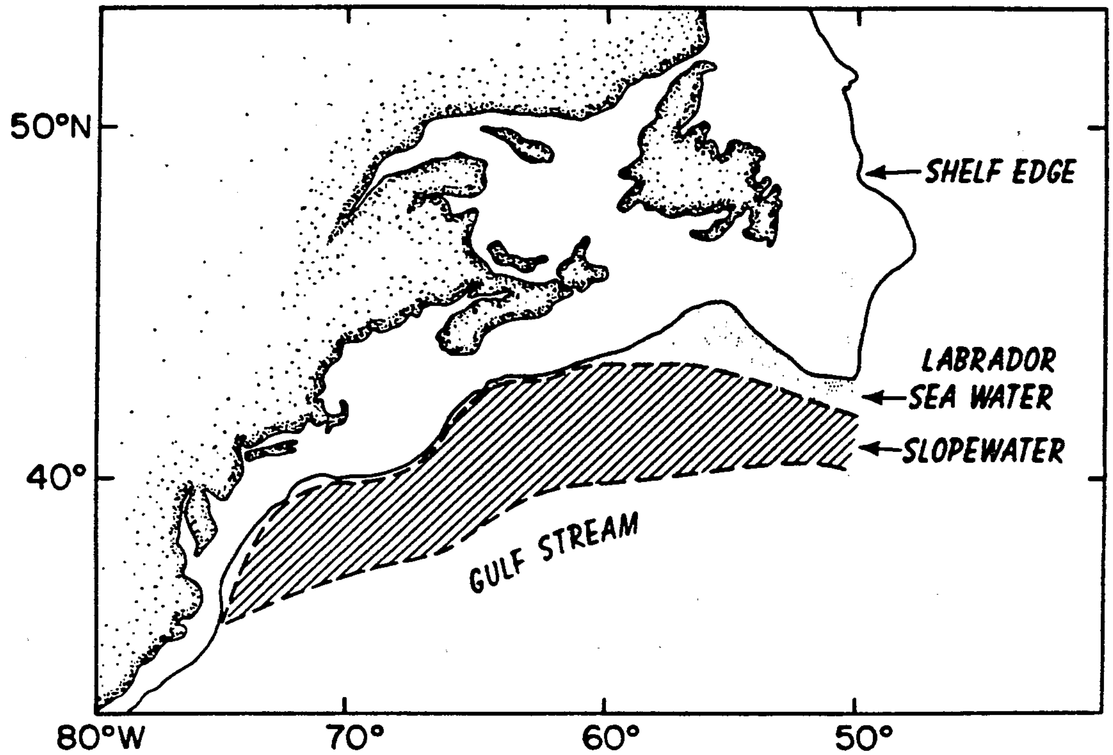


Figure X– 4 Location of slopewater between the edge of the continental shelf and the Gulf Stream, from Cape Hatteras to the Grand Banks. Most of the area is occupied by slopewater except in the northeast corner where coastal Labrador Sea water intrudes.

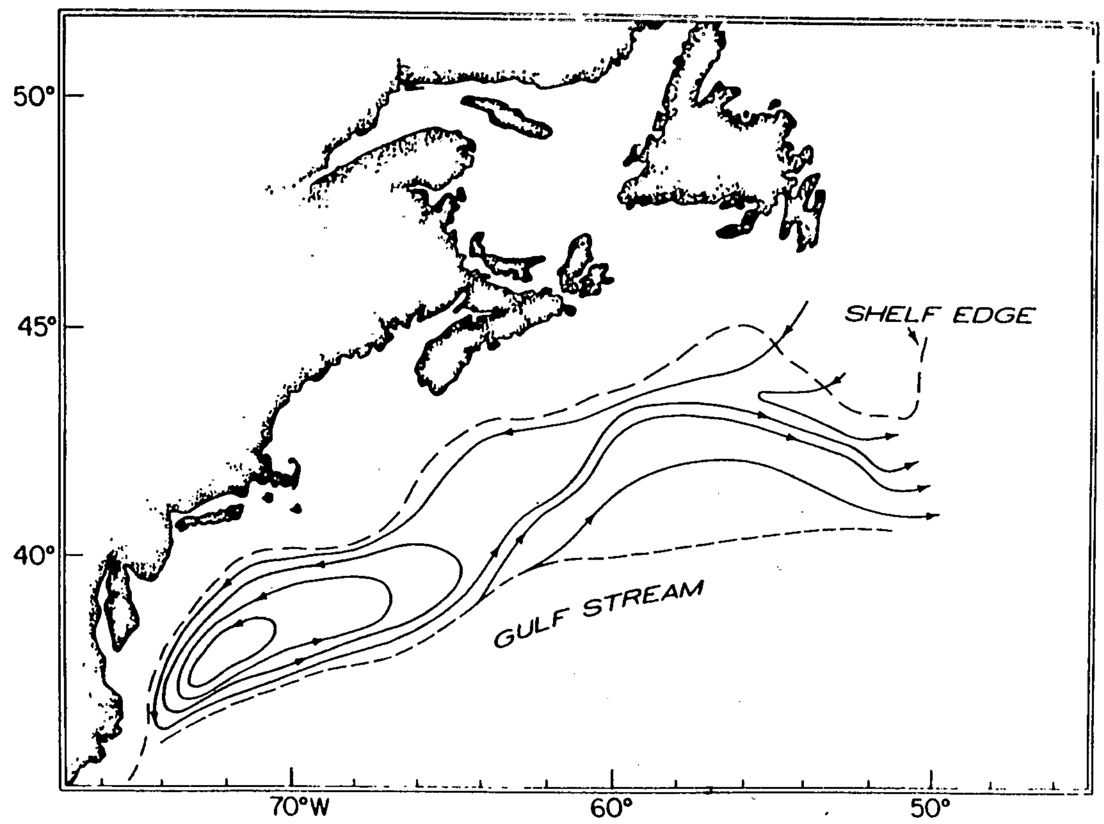


Figure X-5 . Empirical scheme of slopewater circulation, containing: CLSW inflow from the Grand Banks partly retroflecting, partly flowing southwestward along the continental margin; a western Slope Sea gyre; and inflow from the Gulf Stream thermocline. All inflows drain eastward.

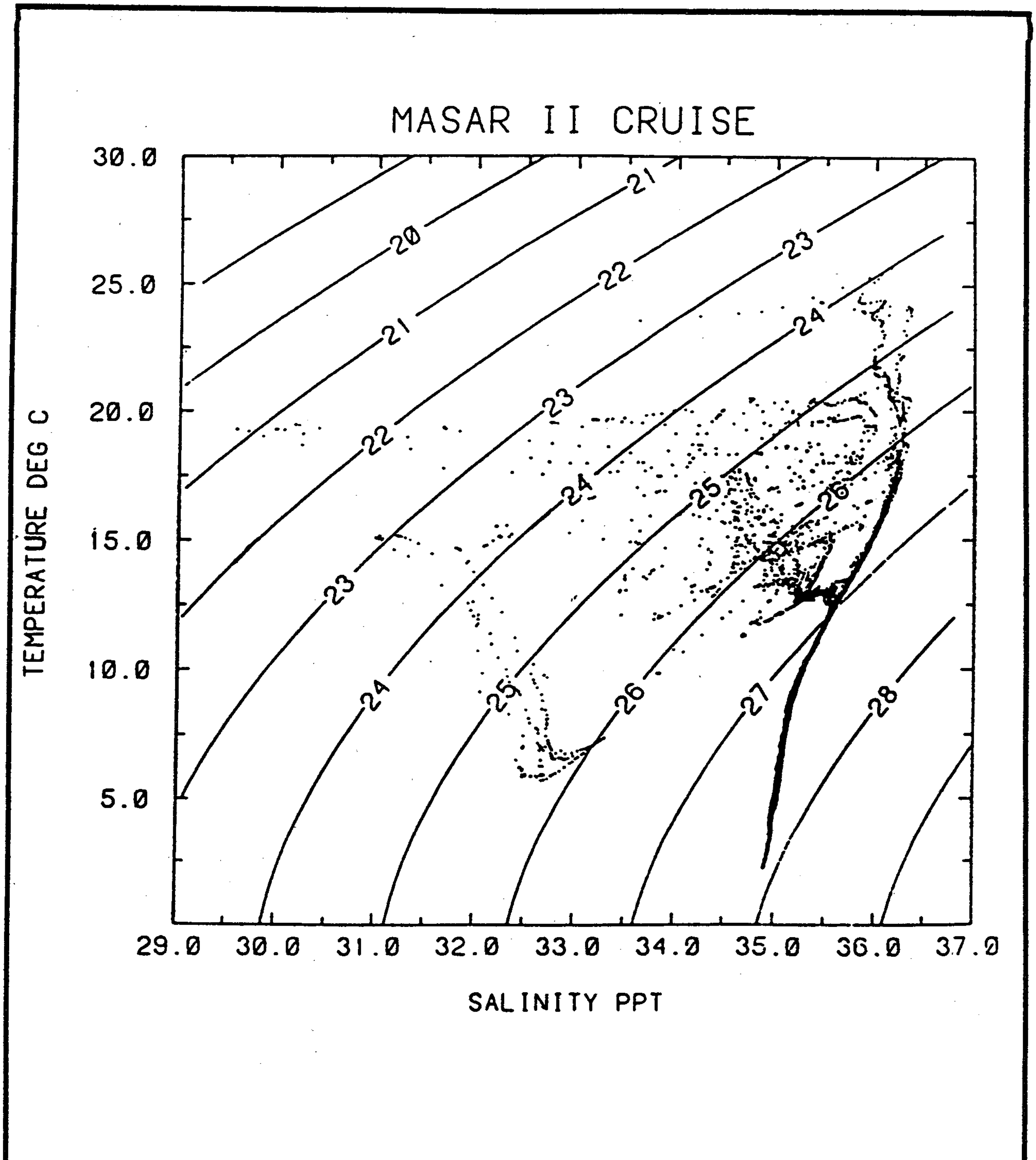


Figure X-6 . Temperature and salinity binary mixing diagrams from MASAR Cruise 2. The water masses sampled encompassed the Gulf Stream warm core (26°C maximum), the outer shelf cold pool (6°C minimum), as well as unusually fresh (< 30 °/oo salinity) surface shelf water. The slopewater pycnostad appears as an accumulation of dots at 13°C, 35.3 °/oo salinity. The nearly solid curve at densities greater than σ_t = 27.0 (and its upward extension) traces out the T-S relationship of NACW.

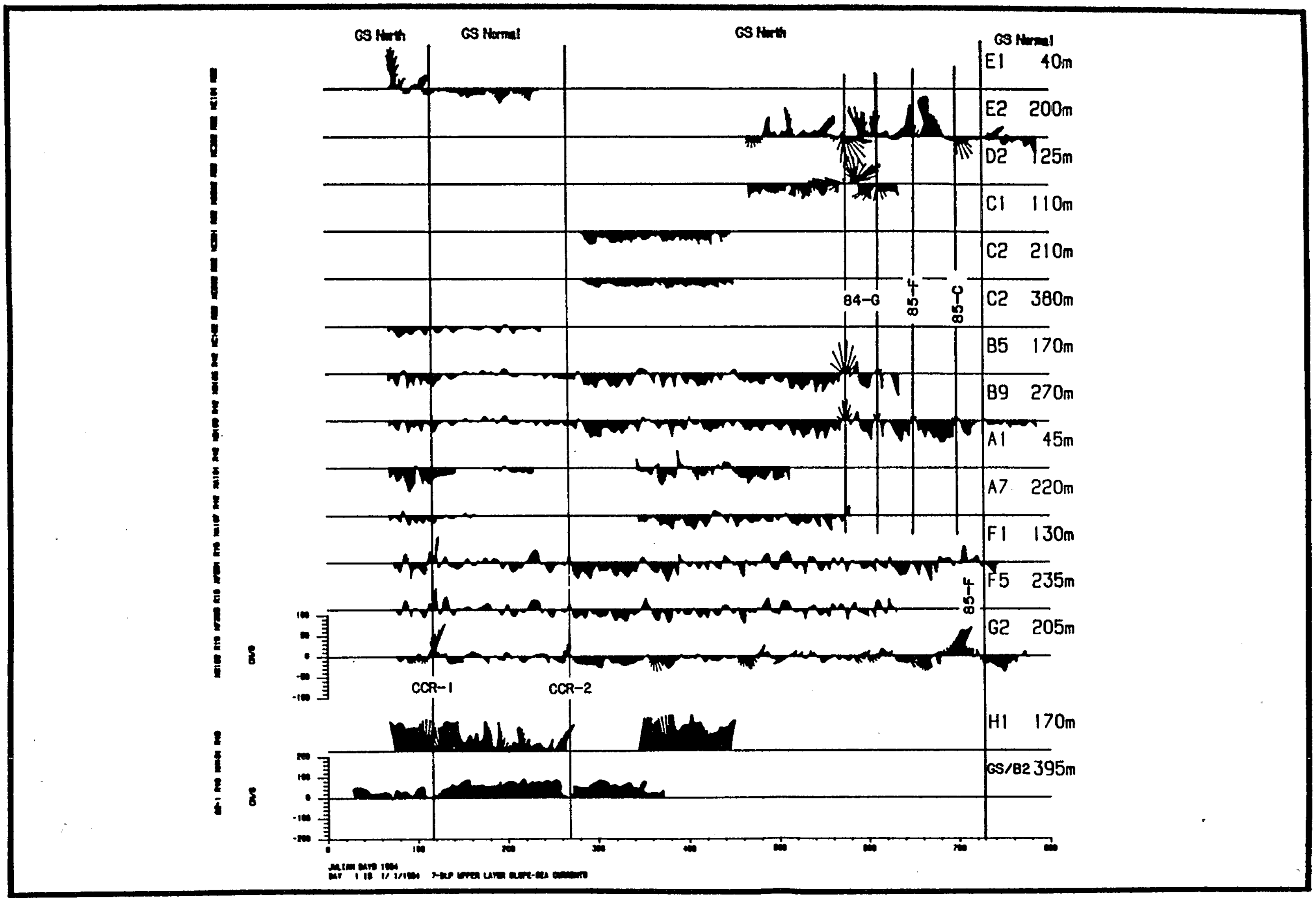


Figure X-7. Upper-level currents from the MASAR array. The Gulf Stream positions are denoted at the top.

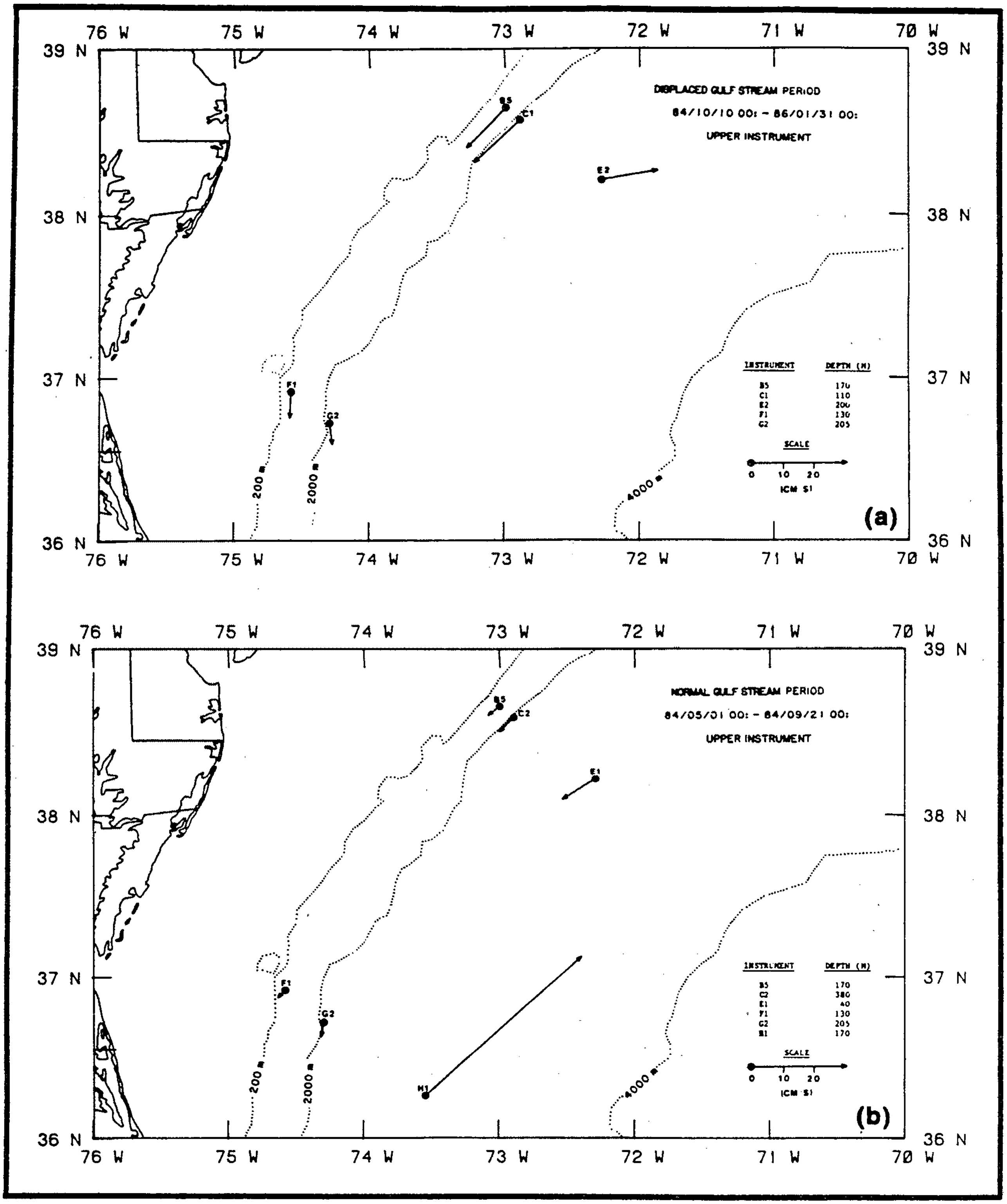


Figure X-8. (a) Upper-level currents averaged over the period of displaced Gulf Stream position, 10 Oct. 1984—31 Jan. 1986. (b) Upper-level currents averaged over the period of normal Gulf Stream path, 1 May—21 Sept., 1984.

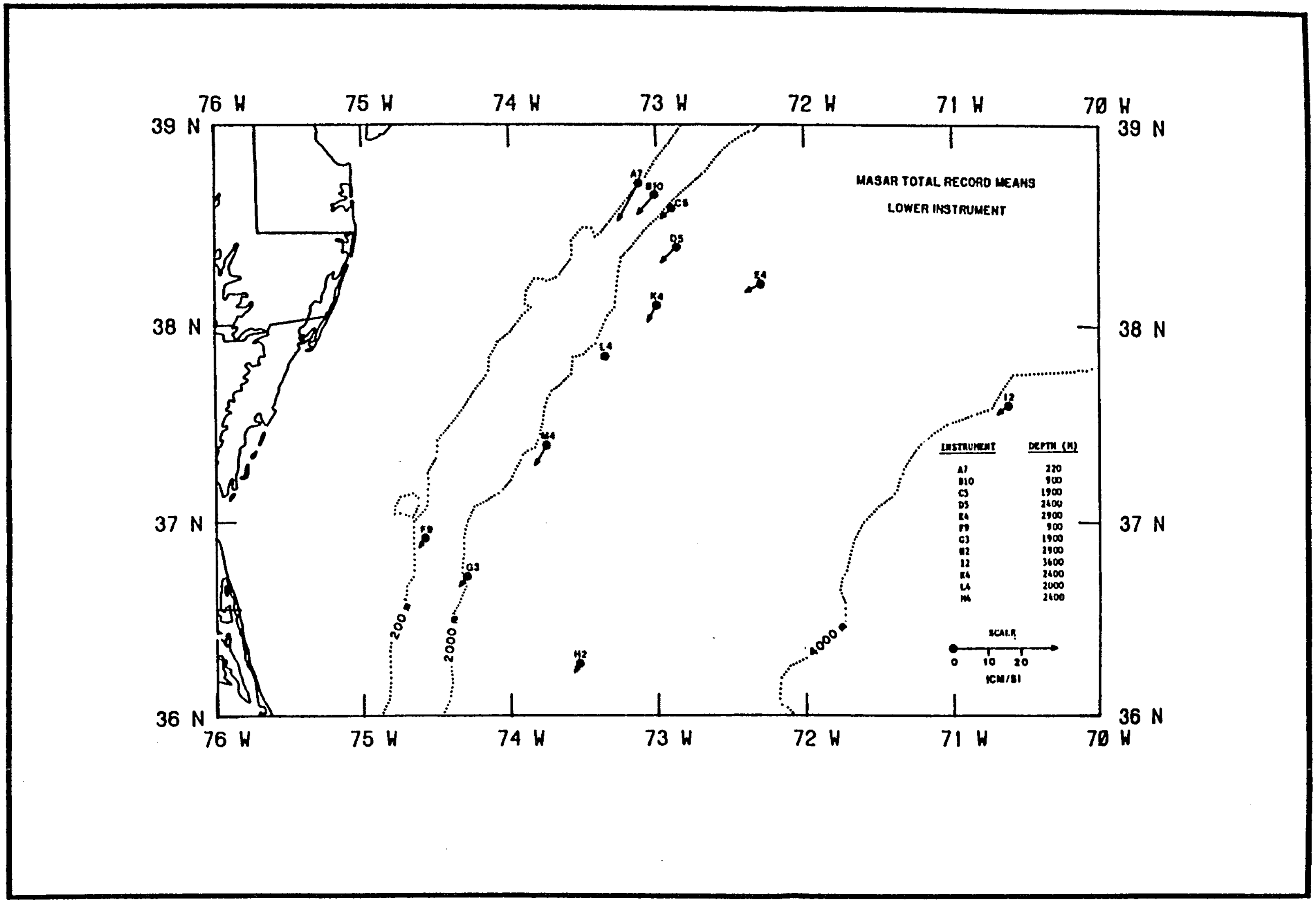


Figure X-9 . Near-bottom current measurements in the MASAR study area showing a pattern of consistent along-isobath southwestward flow.

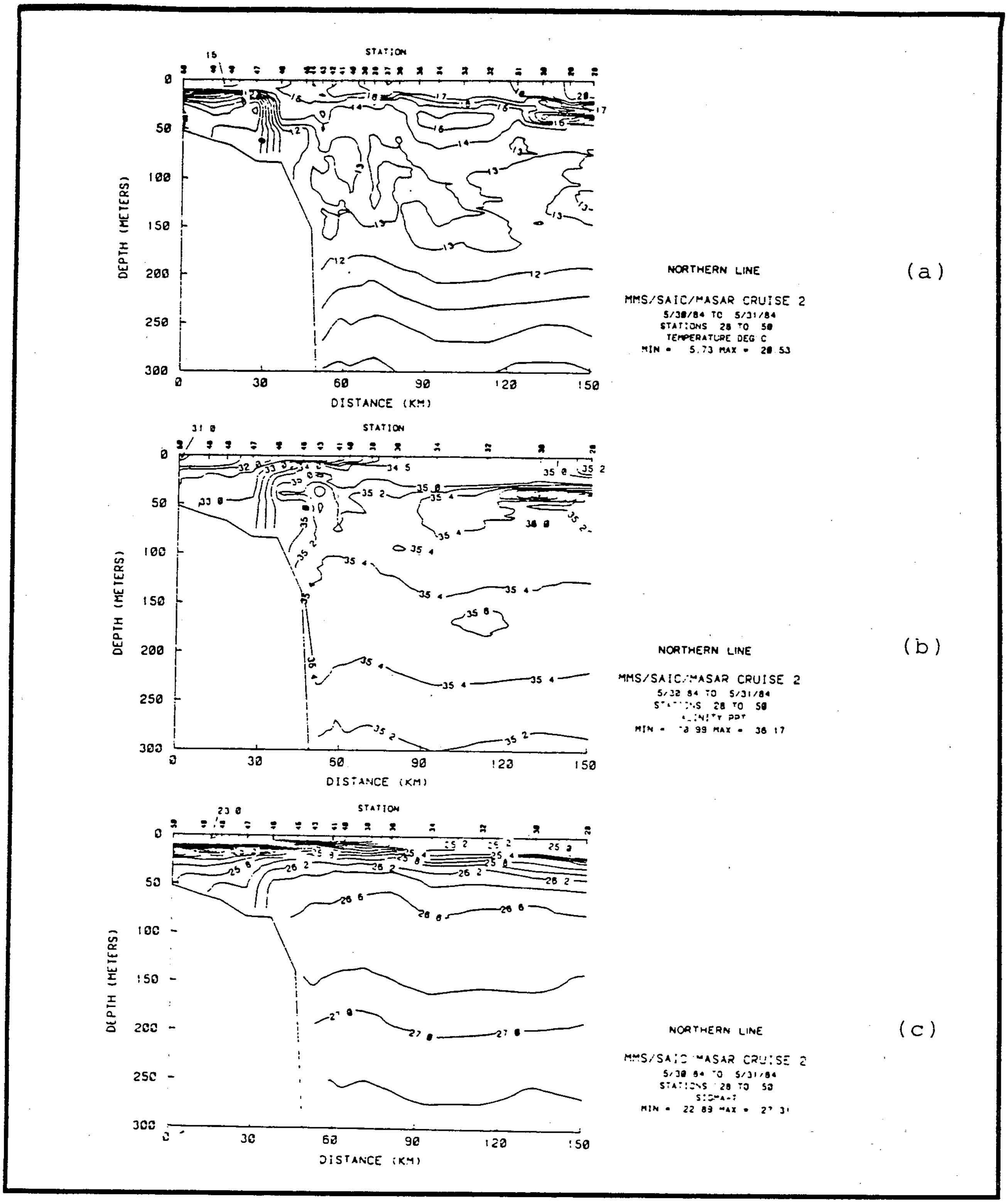


Figure X-10. MASAR Cruise 2 hydrographic transects: (a) temperatures, (b) salinity, (c) density (σ_t). Saline tongues are intruding at 40 and 150-m pth. Fresher water overrides slopewater at the surface and there is also a barely perceptible seaward intrusion of fresher water from the cold pool.

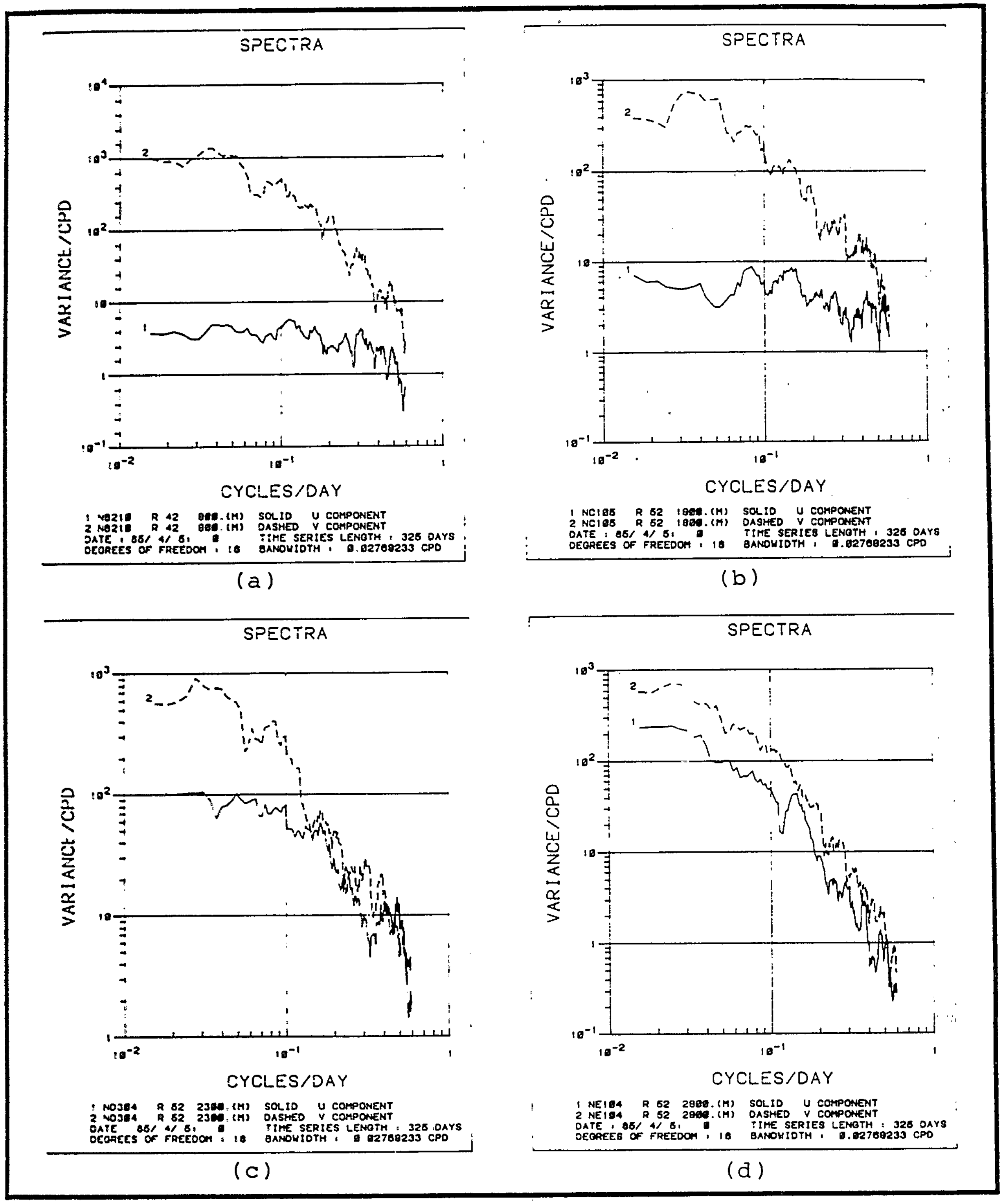


Figure X-11. Spectra of along-isobath (dashed line) and cross-isobath (solid line) components of current showing the pattern of variance for mooring (a) B, (b) C, (c) D, and (d) E.

Table X-1. MASAR Mooring Cruises between February 1984 and May 1986.

CRUISE NO.	DATES	MOORING SITES
1	24 February - 4 March 11984	A - H
2	27 - 31 May 1984	A, I
3	16 - 26 June 1984	A, J
4a	6 - 12 September 1984	A - D, G
4b	25 September - 2 October 1984	C - F, H, J
4c	26 - 30 November 1984	A, D, H
5	26 - 28 October 1984	I
6	27 March - 3 April 1985	A - H
7	29 April - 1 May 1985	I
8a	28 September - 5 October 1985	A-D, F, G, K-P
8b	29 October - 11 November 11985	E, H, I, Q, R
9	28 February - 12 March 1986	A - H, K - Q
10	5 - 10 May 1986	I

IV. CLOSING REMARKS

by Kung-Wei Yeh
Office of Radiation Programs
Environmental Protection Agency
Washington, DC

On behalf of the Office of Radiation Programs, Environmental Protection Agency, thank you all for attending the "Modeling Efforts at EPA" meeting in Washington, DC. We are particularly appreciative of our speakers for their excellent presentations. We hope this meeting will help us to get acquainted with all ongoing and/or completed efforts on ocean modeling and data collection at EPA in order to avoid redundancies in future work and to coordinate resources of various program offices. From this meeting, we hope that in the near future we may be able to identify areas of cooperation and collaboration on modeling and data collection efforts in support of Agency regulations development.

A proceedings of this meeting will be prepared and transmitted to you in the future.

LIST OF MEETING ATTENDEES AND SPEAKERS *

H. S. Bolton
Battelle Washington Operations
2030 M. St., NW
suite 606
Washington, DC 20036
(202)728-7107

Philip Cuny
Office of Radiation Programs, (ANR-461)
U.S. Environmental Protection Agency
401 M. St., SW
Washington, DC 20460
(202)475-9630

John Davidson
Office of Policy, Planning and Evaluation
U.S. Environmental Protection Agency
401 M. St., SW
Washington, DC 20460
(202)382-5484

Robert Dyer
Office of Radiation Programs
U.S. Environmental Protection Agency
401 M. St., SW
Washington, DC 20460
(202)475-9630

Richard Ecker *
Battelle Pacific Northwest Laboratories
Richland, WA 99352
(509)376-9681

J. William Gunter
Office of Radiation Programs
U.S. Environmental Protection Agency
401 M. St., SW
Washington, DC 20460
(202)475-9630

Cheng Hung
Office of Radiation Programs
U.S. Environmental Protection Agency
401 M. St., SW
Washington, DC 20460
(202)475-9633

David Janes *
Office of Radiation Programs
U.S. Environmental Protection Agency
401 M. St., SW
Washington, DC 20460
(202)475-9626

Joseph Karam *
ICF, Incorporated
1850 K. St., NW
Washington, DC 20006
(202)862-1100

Mel Marietta *
Sandia National Laboratories
Albuquerque, NM 87185
(505)844-7351

James Neiheisel
Office of Radiation Programs
U.S. Environmental Protection Agency
401 M. St., SW
Washington, DC 20460
(202)475-9644

Christopher Nelson
Office of Radiation Programs
U.S. Environmental Protection Agency
401 M. St., SW
Washington, DC 20460
(202)475-9640

Yasuo Onishi *
Battelle Pacific Northwest Laboratories
Richland, WA 99352
(509)376-8302

Martha Otto
Office of Solid Waste and Emergency Response
U.S. Environmental Protection Agency
401 M. St., SW
Washington, DC 20460
(202)382-2208

John F. Paul *
Environmental Research Laboratory-Narragansett
U.S. Environmental Protection Agency
Narragansett, RI 02882
(401)789-1071

Mashesh Podar
Office of Policy Analysis, OPPE
U.S. Environmental Protection Agency
401 M. St., SW
Washington, DC 20460
(202)382-2753

Mark Reed *
Applied Science Associates, Inc.
529 Main Street
Wakefield, RI 02879
(401)789-6224

Darcey Rosenblatt
Technical Resources, Inc.
Washington, DC
(202)231-5250

Malcolm Spaulding
Applied Science Associates, Inc.
529 Main Street
Wakefield, RI 02879
(401)789-6224

JoAnne Sulak
Office of Research and Development
U.S. Environmental Protection Agency
401 M. St., SW
Washington, DC 20460
(202)382-5979

Alexandra Tarnay
Office of Water Regulation and Standards
U.S. Environmental Protection Agency
401 M. St., SW
Washington, DC 20460
(202)382-7036

Marilyn Varela
Office of Radiation Programs
U.S. Environmental Protection Agency
401 M. St., SW
Washington, DC 20460
(202)475-9630

Joseph Yance
Office of Water Regulation and Standards
U.S. Environmental Protection Agency
401 M. St., SW
Washington, DC 20460
(202)382-5379

Kung-Wei Yeh *
Office of Radiation Programs
U.S. Environmental Protection Agency
401 M. St., SW
Washington, DC 20460
(202)475-9630

Bob Zeller *
Office of Marine and Estuarine Protection/OW
U.S. Environmental Protection Agency
401 M. St., SW
Washington, DC 20460
(202)475-8076

* Speakers

Appendix

CURRENT MEASUREMENTS AT THE FARALLON ISLANDS LOW-LEVEL RADIOACTIVE WASTE (LLW) DISPOSAL SITE, 1975 and 1977-78

William R. Curtis
Environmental Studies and Statistics Branch, ASD
Office of Radiation Programs

In 1975 and again in 1977-78, the Office of Radiation Programs (ORP) conducted current measurements at the Farallon Islands off the coast of San Francisco, CA. Figure A-1 shows the location of the Farallon Islands LLW site and the current meter mooring locations for the 1975 and 1977-78 deployments. Figure A-2 shows the topography in the LLW disposal site relative to current meter mooring arrays A-D in the 1977-78 study. The results of the two data collections and analysis efforts are briefly described.

I. In August 1975, four current meters were deployed by Scripps Institute of Oceanography for the Office of Radiation Programs. This study was designed to assess the current regime in the disposal site. The meters were recovered approximately one month later. Analyses of data included the generation of calibrated time history records and the extraction of tidal currents to produce tidal ellipses and progressive vector diagrams.

Two usable records (as indicated in Table A-1) were obtained:
(1) the speed for Meter 1009, point X, ranged between 0.0 and 20.61 cm/sec, with a mean magnitude of 5.54 cm/sec, and
(2) for Meter 1028, point Y, the range was 0.0 to 18.15 cm/sec, with a mean magnitude of 5.26 cm/sec. The vector-averaged currents for Meter 1028 were mostly northward, with an average vector magnitude of 1.33 cm/sec. The majority of the spectral energy for both meters was at the semi-diurnal tidal frequency. In addition to the diurnal and inertial peak, Meter 1028 also exhibited a significant spectral peak at about six hours, which could be attributed to internal waves.

The study was reported in the Environmental Protection Agency's (EPA) Report 520/1-83-019, titled "Analysis of Ocean Current Meter Records Obtained from a 1975 Deployment Off the Farallon Islands, California."

II. In October 1977, seven current meters, on four mooring arrays, were deployed. The study was designed to estimate the potential for sediment transport of radioactive waste materials from the disposal site. Recovery of the meters occurred in October 1978. Figure A-2 shows the locations of current meter deployments relative to the points B.C.D. in Figure A-1.

The general conclusions of the study were:

(1) In the deep western part of the site, current measurements exceeded 20 cm/sec no more than 3% of the time. This bottom current speed may be sufficient to suspend fine-grain sediments (silt and clay) from the bottom, providing a potential for transport in the water column;

(2) Long-term average near-bottom currents move north and eastward throughout the site. The average current speeds diminish from 1.7 cm/sec at the deep western end of the site to 0.17 cm/sec at the eastern end. Thus, it appears that this vector decreases with proximity to the shore.

The analysis of current, sediment, and bathymetric data, as well as an analysis of transport mechanisms related to these data, is presented in the 1982 Interstate Electronics Corporation 1982 final contract report to the ORP, entitled "Farallon Islands Oceanographic Data Analysis, Volumes I and II."

Table A-1, Current Data Obtained in 1975 Study

	METER NO.	START DATE/TIME	END DATE/TIME	NORTH LAT	WEST LONG	SITE DEPTH	METER DEPTH	DATA RECORDS
				(m)	(m)			
X	1009	8/21/75 21:00	9/17/75 15:30	37°37'30"	123°18'0"	1739	1737	1286
Y	1028	8/22/75 2:30	9/17/75 17:00	37°38'30"	123°18'0"	1851	1849	1278

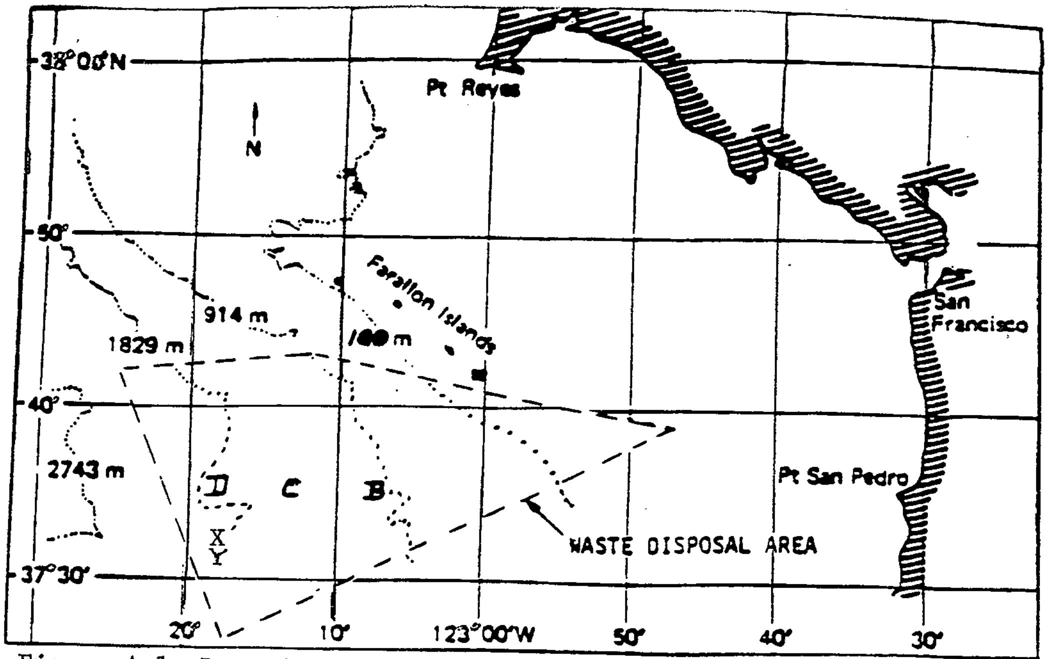


Figure A-1. Location of Farallon Islands low-level radioactive waste disposal site and 1975 & 1977-78 current meter mooring locations.

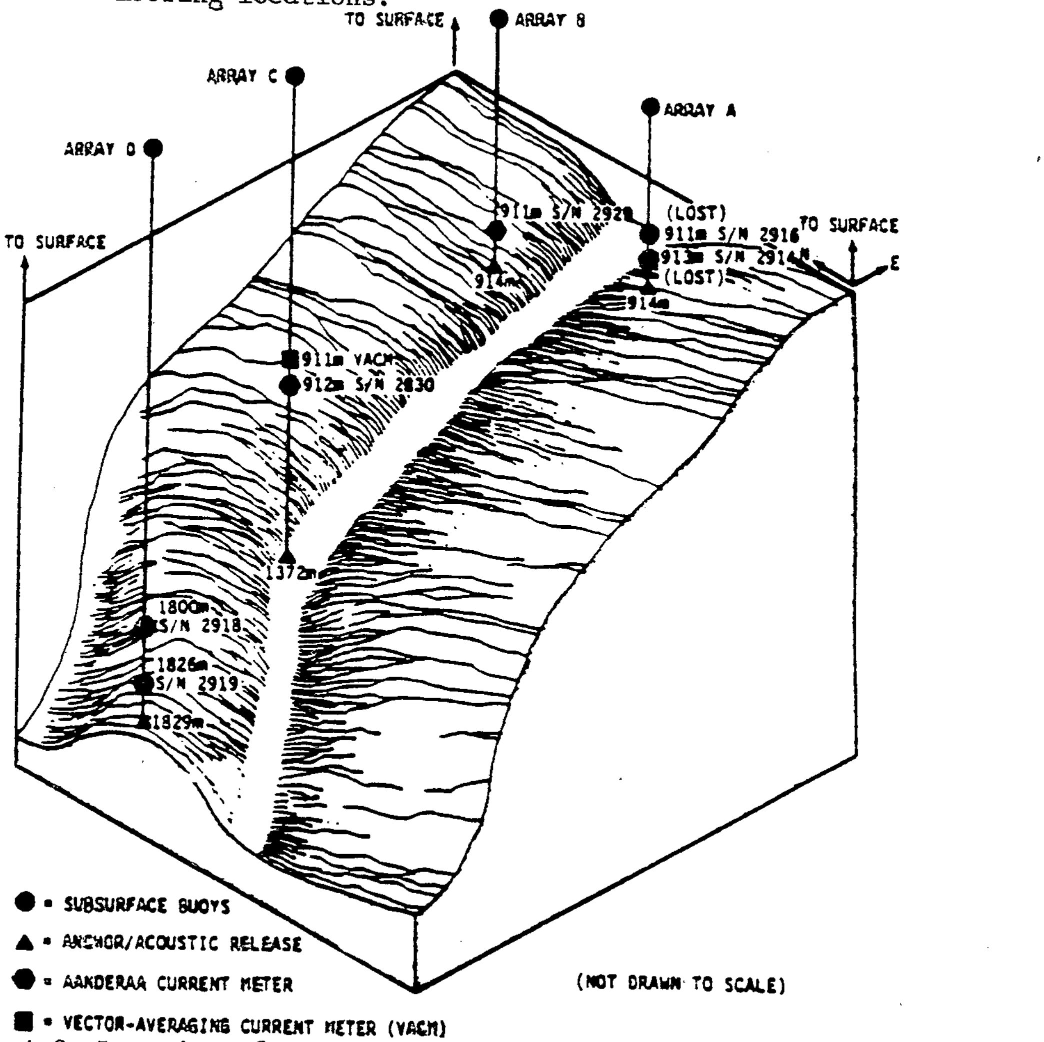


Figure A-2. Location of current meter deployments in the 1977-78 study relative to points B, C, and D on Figure. A-1.