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NSY PORTSMOUTH
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DEPARTMENT OF THE NAVY
PORTSMOUTH NAVAL SHIPYARD
PORTSMOUTH, N.H. 03804-5000

IN REPLY REFER TO:

November 1, 1995

MEMORANDUM

FOR THE MEMBERS OF THE RESTORATION ADVISORY BOARD (RAB) CERCLA REMEDIAL ACTION PROGRAM, PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE

Please find enclosed the draft minutes from the October 19, 1995 RAB meeting for your review and comment. Comments are requested by November 13, 1995. You may provide your comments to me at 207-438-3830.

Sincerely,

Ken

Ken Plaisted
Navy Co-Chairman
Restoration Advisory Board

Distribution:

Juanita Bell
Doug Bogen
Jeff Clifford
Michele Dionne
Eileen Foley
Mary Marshall
Phil McCarthy
Jack McKenna
Guy Petty
Onil Roy
Cathy Wolff
EPA Region I (M. Cassidy)
NOAA (K. Finkelstein)
MEDMR (D. Card)
USFWS (K. Munney)
NHF&G (J. Nelson)
MEDEP (N. Beardsley)
North Div (J. Conroy)
COMSUBGRU TWO (R. Jones)
Brown & Root Environmental (B. Horne, L. Klink)
Portsmouth Naval Shipyard (Codes 120, 121, 121.10, 122.4, 100PAO, 105, 105.5, NRRO)

Draft

RESTORATION ADVISORY BOARD MEETING
PORTSMOUTH NAVAL SHIPYARD
PORTSMOUTH CITY HALL, PORTSMOUTH, NEW HAMPSHIRE
OCTOBER 19, 1995

The meeting began at 7:17 pm and ended at 9:30 pm. Attending were community members: Doug Bogen, Jeff Clifford, Eileen Foley, Mary Marshall, Phil McCarthy, Jack McKenna, Guy Petty, Onil Roy, and Cathy Wolff; regulatory members: Meghan Cassidy and Patty Whittemore (EPA) and Nancy Beardsley (MEDEP); Natural Resource Trustees Donald Card (MEDMR), Bruce Smith (NH F&G) and Ken Finkelstein (NOAA); and Navy members Lt. James Conroy and Ken Plaisted. Others attending were Jack Spillane (Portsmouth Herald); Patti Tyler (EPA); Fred Short (UNH-JEL), Dave Burdick (UNH-JEL), and Larry Ward (UNH-JEL); Bob Johnston (MESO); and Fran Endyke and Mary Anne Mascianica (PAO) from the Shipyard. Absent were community members Juanita Bell and Michele Dionne and Natural Resource Trustee Ken Munney (US F&W).

INTRODUCTION

Doug Bogen, the Community Co-Chair welcomed everyone and outlined the agenda. Agenda items are denoted by the underscored headings in these minutes.

STATUS OF WORK

Lt. Conroy indicated that until issues involving the feasibility study are resolved, he was not prepared to address the other studies' status. He anticipated this should be an agenda item at the next RAB meeting.

RESOLUTION OF COMMENTS FROM THE LAST RAB MEETING

Ken Plaisted, the Navy Co-Chair, referenced a letter from the Kittery Conservation Commission that was appended to the minutes of the September 21 RAB meeting, requesting that the Shipyard conduct additional testing in Spruce Creek. Ken indicated that the Navy was reviewing the data and he hoped to have a response to the request by the next RAB meeting.

PRESENTATION ON THE ECOLOGICAL RISK ASSESSMENT

Bob Johnston, who works for the Navy research laboratory in San Diego, has been on a detail to the EPA's Narragansett Laboratory. Under a memorandum of agreement between the federal agencies, Bob was assigned to perform the Shipyard's ecological risk assessment.

Bob's hour-long presentation generally followed a bound 32-page handout, explaining the steps taken in conducting this ecological risk assessment. The essence of an ecological risk assessment is to determine the degree of environmental impact and estimate the chance that that impact will occur on an identified ecological population. Bob stressed that this exercise cannot assess the human health impacts or determine what needs to be done to address the ecological impacts.

To determine the degree of environmental impact on the Portsmouth Harbor area ecological system, the study estimated the risk (determined the probability of a benchmark concentration being exceeded) of a contaminant being toxic to a particular set of Harbor-dwelling creatures. The study collected water (river water and seep water) and sediment (on the Harbor bottom surface and in cores) from a network of sampling stations established from Great Bay and the upper reaches of the Piscataqua River, down through the Kittery-Portsmouth stretch (particularly around Seavey Island and the Shipyard), out into the Gulf of Maine (including off-shore stations at the Isles of Shoals and a winter flounder station) and including areas of York Harbor (background areas) that are obviously not impacted by any possible effect from the Shipyard.

Water flow direction and strength measurements were taken (including a dye tracer test by the marine research vessel, ECOS, from the Navy's MESO facility in San Diego, which sailed the Harbor area for 20 days in July 1992. The flow information was used to calibrate a model developed to predict water flow in the river.

Chemicals sampled in off-shore media included heavy metals (lead, mercury, nickel, chromium, copper, zinc, and silver); arsenic; hydrocarbon compounds (polycyclic aromatic hydrocarbons - PAHs, and volatile aromatic hydrocarbons); chlorinated compounds such as PCBs and DDT; butyltin compounds; and methylmercury.

The types of ecosystems to be studied were identified. These included pelagic species (winter flounder); epibenthic (attached to or living on the bottom) species such as mussels, lobster, rockweed algae; benthic (living in the bottom) community such as worms; salt marsh community; eelgrass community; herbivorous waterfowl (ducks); avian predators (cormorants, osprey); and trophic transfer through the food chain.

The study evaluated risks to these ecosystems from exposure to the contaminants of concern, both where they lived and insome cases controlled laboratory experiments. Major findings:

- lead was discovered at elevated levels almost everywhere
- water - contains excess nutrients and traces of sewage; there is significant flushing in the estuary; and a transport model of lead was developed
- sediment - areas where high concentrations of contaminants of concern were deposited have been identified; sediment distribution was measured; toxicity in lab toxicity tests was detected; traces of sewage and evidence of oil were found
- pelagic community - productivity was within normal limits; flounder showed evidence of spleen disorders (area-wide)
- benthic community - within normal range of the Piscataqua River; evidence of community stress

- Epibenthic community - juvenile lobsters abundant; lobster nursery and reproductive habitat delineated; mussel and rockweed algae within normal range

- eelgrass community - abundance within normal range; habitat quality beneficial to lobster; absent from inner Clark Cove; inverse relationship between lead exposure and eelgrass root and rhizome biomass

- salt marsh community - good habitat community; indication of ecological stress

- herbivorous water fowl - no impact calculated

- avian predators - no impact calculated

- trophic transfer - bioaccumulation evident in juvenile lobster, mussels, and eelgrass

Major conclusions:

- no appreciable risks were detected for exposure to river water or dietary uptake by birds

- risks of exceeding benchmarks were calculated for exposure to sediment containing lead, nickel, copper, zinc, and mercury; phenanthrene, fluoranthene, and PCBs

- risks of exceeding benchmarks were calculated for exposure to lead and phenanthrene in mussel tissue accumulation

- healthy and productive estuarine habitats were observed

- indications of stress were present

Bob Johnston then entertained questions.

Question: Please define toxicity testing.

Answer: Toxicity tests determine if an impact occurs to the test organism exposed to water or sediment. Exposure can be for a specific duration to determine whether and when an effect occurs or to assess viability (such as the impact on a sea urchin to assess its sperm or egg count.) During the studies conducted at the Narragansett Laboratory, no adverse effects on growth were detected.

Question: What were the spleen disorders encountered in the flounder?

Answer: Spleens respond to infections. After the flounder were fileted, the spleen was sectioned to see if cells were deformed. If they are, it may be an indicator of physiological

problems.

Question: Please re-explain what exceeding benchmark probability levels are

Answer: A benchmark is a chemical concentration where some effect was observed. It can be considered as a threshold above which chemical levels may harm marine organisms. We calculate the probability of exceeding those levels.

Question: Where can I find all the data collected for this study?

Answer: They are located in the two-volume report now under review.

Question: Does the tidal information collected represent all the durations and seasons needed to draw accurate conclusions?

Answer: ECOS collected measurements over a 20-day period in July 1992. That information allowed us to calibrate a tidal model that can extrapolate to tidal effects in other seasons.

Question: How can you be sure the lobsters studied in the Harbor represent the lobster population?

Answer: Fred Short explained that once lobster habitats were identified, divers worked over a three month period in the October-December timeframe to tag, and mark. Some of the lobsters were recaptured in the spring and summer when the lobsters were sampled for chemistry analysis. They determined that if the lobsters were burrowed in the habitat in these months, they were natives and therefore exposed long term to whatever contamination was present in the sediment.

Question: Is there a link in the hydrodynamic regime to contaminant fate and transport?

Answer: The study resulted in a model of physical water movement and how contaminants move in the water. However, it could not identify any linkage with groundwater or other sources of contamination.

Question: Did the dye from the dye test move into Spruce Creek?

Answer: They were physically unable to take measurements in Spruce Creek. The dye was placed outside of Clark Cove; it sat there, then was caught by the tide and pushed into Back Channel. For the dye to get into Spruce Creek, it would have to go to the mouth of Portsmouth Harbor and then back in.

Question: Do you have an overhead graphic that includes chemical contaminants and their effects on biota?

Answer: No. The closest the study comes to that linkage is an analysis in the phase 1 report. We could not correlate toxicity and chemical concentrations. If we divide the

chemical concentration by the percentage of fine grained sediment material that describes the amount of chemical per unit mud. This procedure came the closest to explaining why sediments were toxic.

Question: Have you concluded any risk to birds? If lead was found in mussels and birds eat the mussels, is there no affect on the birds?

Answer: Even thought the lead level in mussels is high compared to the level one might expect in mussels, it still is not high enough to effect the birds that ingest those mussels.

Question: Is there no risk of contaminated surface water?

Answer: During each tidal cycle, about a billion gallons of sea water comes in and out of the Harbor. Based on sampling, there is no effect on water quality. Even if contaminant concentrations emerging from seep areas were high, that effect is rapidly diluted. However, the contaminants may become associated with particulate matter and settle out in nearby sediment.

Question: What do you know about sediment transport? Are contaminated sediments entering Spruce Creek?

Answer: Spruce Creek is a large area of sediment deposition. We can look at sediments over time but cannot be sure if there is linkage to the water column.

Question: Why hasn't this study resulted in more concrete information? We might have gotten more out of the ecological risk assessment if it had been based on evaluating the chemicals with a probability of exceeding Probable Effects Levels (ER-M).

Answer: The study provided information on the ecology of the estuary and identified the important habitat necessary to sustain marine resources in the Portsmouth Harbor area.

Question: What future studies are planned?

Answer: We need to reduce the uncertainty in the findings. The study so far is only a baseline representing "current" conditions, like a snapshot. We need more data, for instance, on whether sediment resuspension may be having an effect on eelgrass.

Question: What are the 2 most important conclusions you could draw from phases 1 and 2?

Answer: First, that this area is a healthy and productive estuary with some pockets of trouble, and second, that these depositional areas are important habitats to the local biota. Remedial steps undertaken need to ensure that these habitats are not destroyed.

Question: Why have you found so much lead?

Answer: Lead was used in Shipyard operations and is discharged from the sewage treatment plants. It is everywhere but we cannot tell where it comes from. Portsmouth Harbor has levels of leadin mussels that are nine times higher than the average found nationally in harbors. However, Portsmouth has lower than national levels of organic contaminants (because of the high tidal flushing). What stays are the contaminants that bind to sediments.

Question: What do you suspect has prevented the eelgrass from growing?

Answer: Part of the answer may be the lack of water clarity. The high rate of tidal flushing resuspends material on the bottom that clouds the water. Eelgrass needs light to flourish.

NEXT MEETING - AGENDA AND DATE

Please note that the November 16 RAB meeting has been rescheduled to Thursday, December 7, in Kittery (location to be announced). The agenda will feature a presentation on the OU-4 Off-Shore Media Protection Standards - Human Health, and an overview of groundwater flow. The January 18, 1996 meeting will include a presentation on the OU-4 Off-Shore Media Protection Standards - Ecological Risk, and discussions of study areas and the revised Community Relations Plan.

MISCELLANEOUS

Guy Petty and Cathy Wolff inquired about the status of EPA's approval of the RFP for SAPL to advertise for a consultant for their TAG grant. Meghan Cassidy stated that EPA's TAG coordinator met with Roger Cole on October 17 to discuss the matter. She did not know the outcome of those discussions. Guy and Cathy stressed the need for them to receive technical advice as soon as possible, particularly as presentations such as this ecological risk assessment are made. They would like a presentation to be added to the RAB agenda on TAG grants. Meghan suggested that EPA could conduct a TAG presentation but it would be generic and not be particularly relevant to what SAPL may do decide to do with the money. She suggested that SAPL might wish to give the presentation.

ECOLOGICAL RISK ASSESSMENT FOR PORTSMOUTH NAVAL SHIPYARD, KITTERY MAINE

Presentation for

The PNSY Restoration Advisory Board

October 19, 1995

Presented by

Robert K. Johnston

Marine Environmental Support Office of the US Navy Naval Command, Control and Ocean Surveillance Center, RDT&E Division.

KEY MESSAGES

1. Chemical Impacts from SWMUs on Ecological Resources of the Estuary were Assessed.
2. Indications of Stress were Present and Elevated Risks to Benthic Organisms Were Calculated.
3. Healthy and Productive Estuarine Habitats were Observed; No Severe Ecological Impacts were Detected.
4. Information will be used to Evaluate Need for Remedial Action

OVERVIEW

What is Ecological Risk Assessment?
Participants in Study
Conceptual Model
Exposure Assessment
Effects Assessment
Risk Characterization
Ecological Findings
Conclusions

WHAT IS ECOLOGICAL RISK ASSESSMENT?

"The process that evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors" - USEPA 1994

Determining the Degree of Environmental Impact

Estimating the Chance Environmental Impact will Occur

COMPONENTS OF ECOLOGICAL RISK ASSESSMENT

Define the Problem
(Problem Formulation)

Measure Pollution Levels
(Stress Characterization)

Determine Degree of Harm
(Effects Characterization)

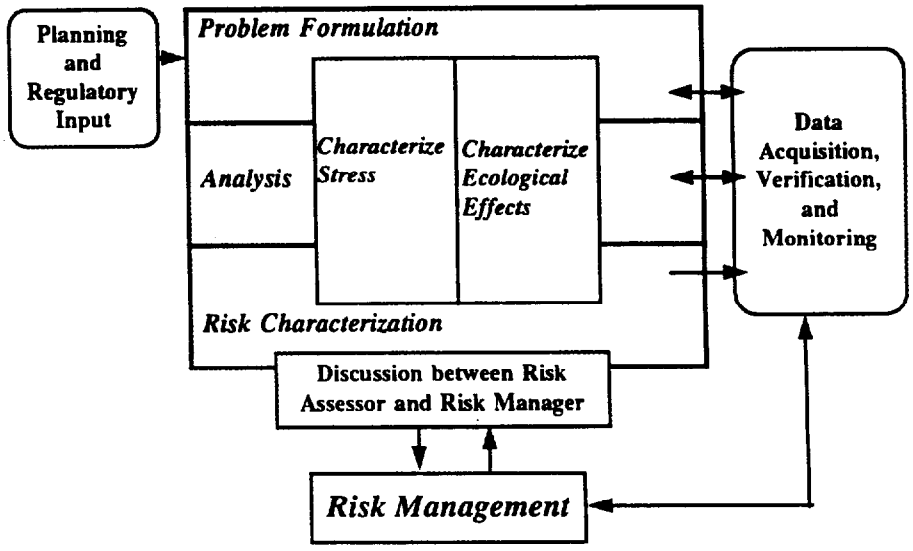
Calculate Risk Levels
(Risk Characterization)

Evaluate Ecological Health
(Verification and Monitoring)

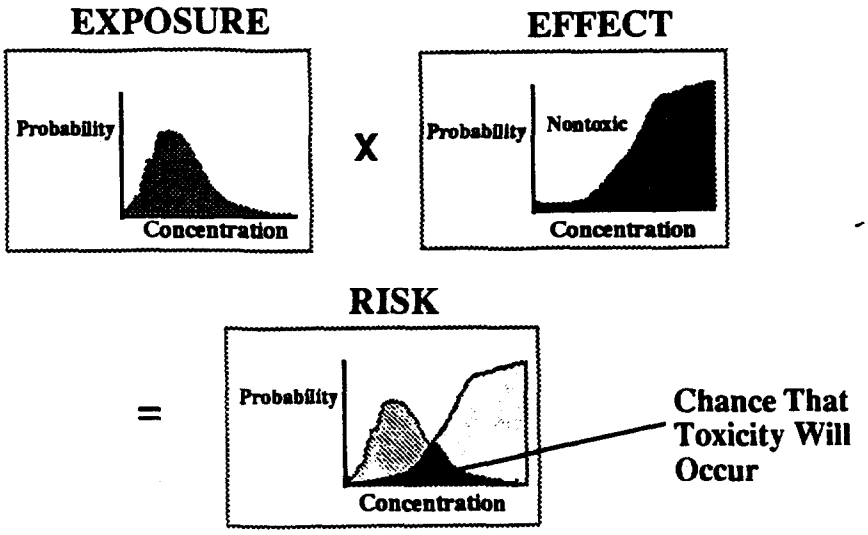
Uncertainty Analysis (Sources of Error)

ECORISK FRAMEWORK

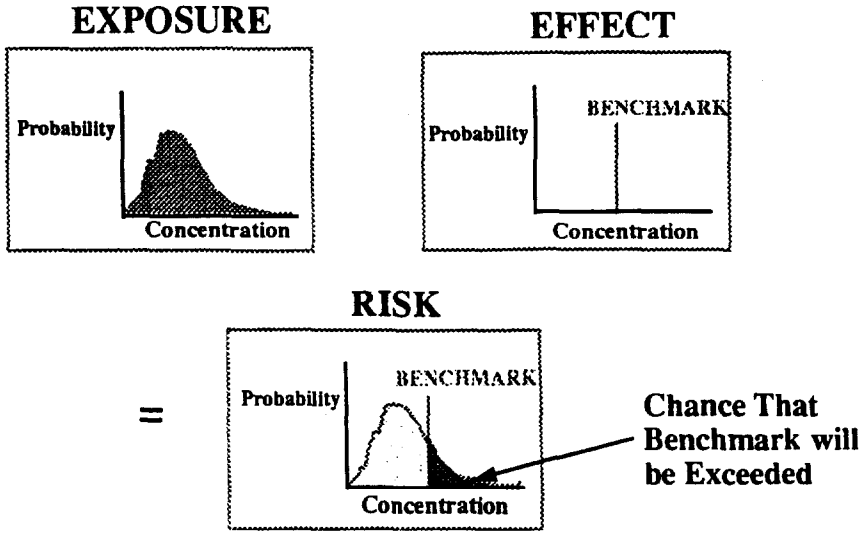
(USEPA Ecological Risk Assessment Forum 1992)



EXPOSURE x EFFECT = RISK



Probability of Exceeding Benchmark



STUDY PARTICIPANTS

MESO/NRaD	Coordination, ECOS Survey, Data Synthesis
EPA AED	Bioaccumulation, Exposure-Response, Analytical Chemistry
UNH-JEL	Field Sampling, Ecological Resource Studies, Sedimentology, Data Analysis
UNH-OEP	Modeling, Current Measurements
URI-GSO	Trace Metal Chemistry
SAIC	Toxicity Assessment
CEMIC	Analytical Chemistry (Phase I)
BMSL	Analytical Chemistry (Phase II)

STUDY PARTICIPANTS

Marine Environmental Support Office (MESO) of the US Navy Naval Command Control and Ocean Surveillance Center, Research Development, Test and Evaluation Division (NRaD), San Diego, CA (Formerly the Naval Ocean Systems Center)

US EPA National Health and Environmental Effects Research Laboratory, Atlantic Ecology Division (AED), Narragansett, RI. (Formerly USEPA Environmental Research Laboratory Narragansett)

University of New Hampshire Jackson Estuarine Laboratory (UNH-JEL), Durham, NH

University of New Hampshire Ocean Engineering Program (UNH-OEP), Durham, NH

University of Rhode Island Graduate School of Oceanography (URI-GSO), Narragansett, RI.

Science Applications International Corporation (SAIC), Narragansett, RI

Cemic Corporation, Narragansett, RI

Battelle Marine Sciences Laboratory (BMSL), Sequim, WA

DEFINE THE PROBLEM
(PROBLEM FORMULATION)

CONCEPTUAL MODEL

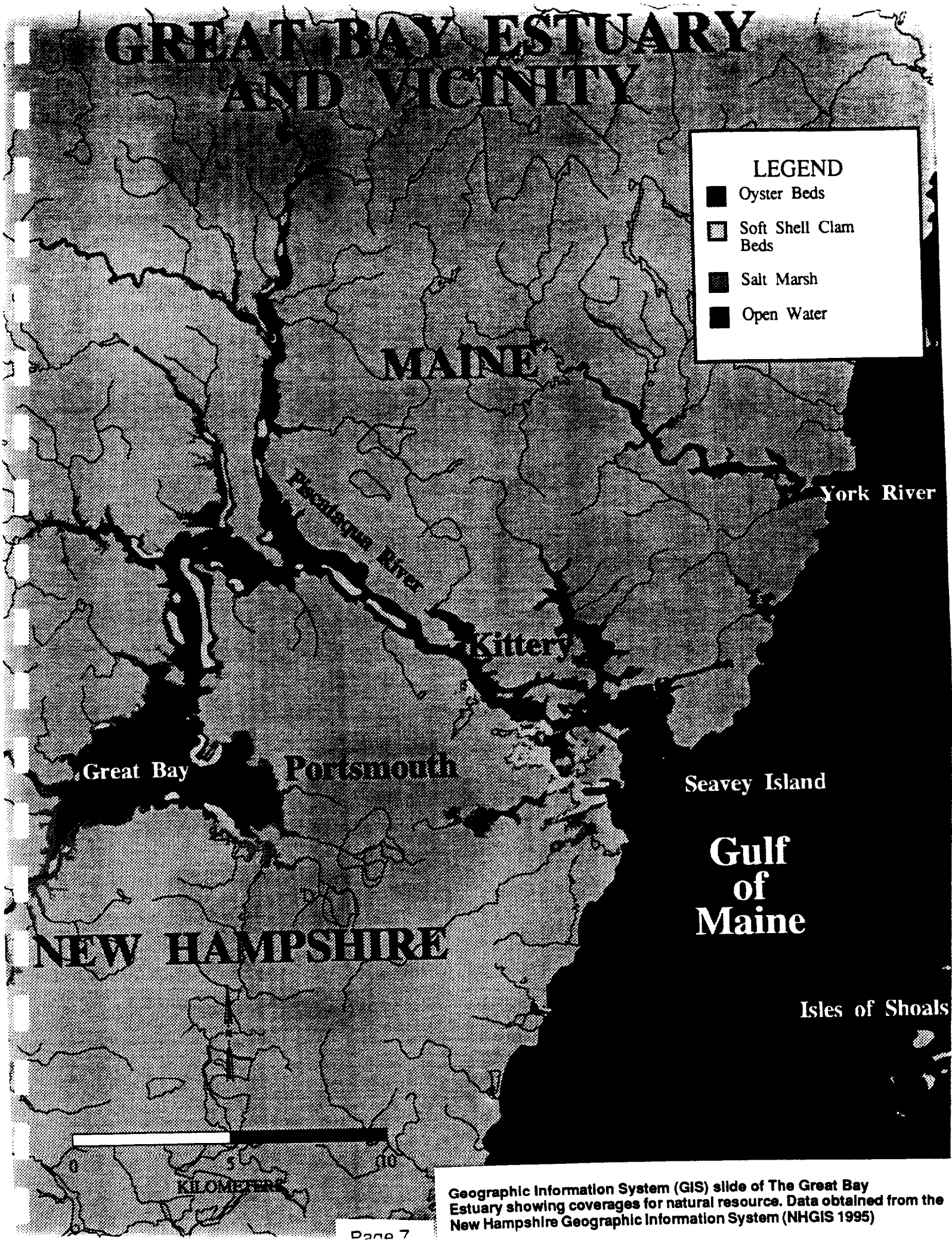
- Picture of our Understanding of How the Estuary Works
- Basis for Conducting the Investigation
- Framework of How Contaminants will Affect Ecosystem

ASSESSMENT AND MEASUREMENT ENDPOINTS

- What do we want to protect?

SITE DESCRIPTION

- Physical Description
- Hydrodynamics and Flushing
- Sediment Distribution
- Ecological Resources



Geographic Information System (GIS) slide of The Great Bay Estuary showing coverages for natural resource. Data obtained from the New Hampshire Geographic Information System (NHGIS 1995)

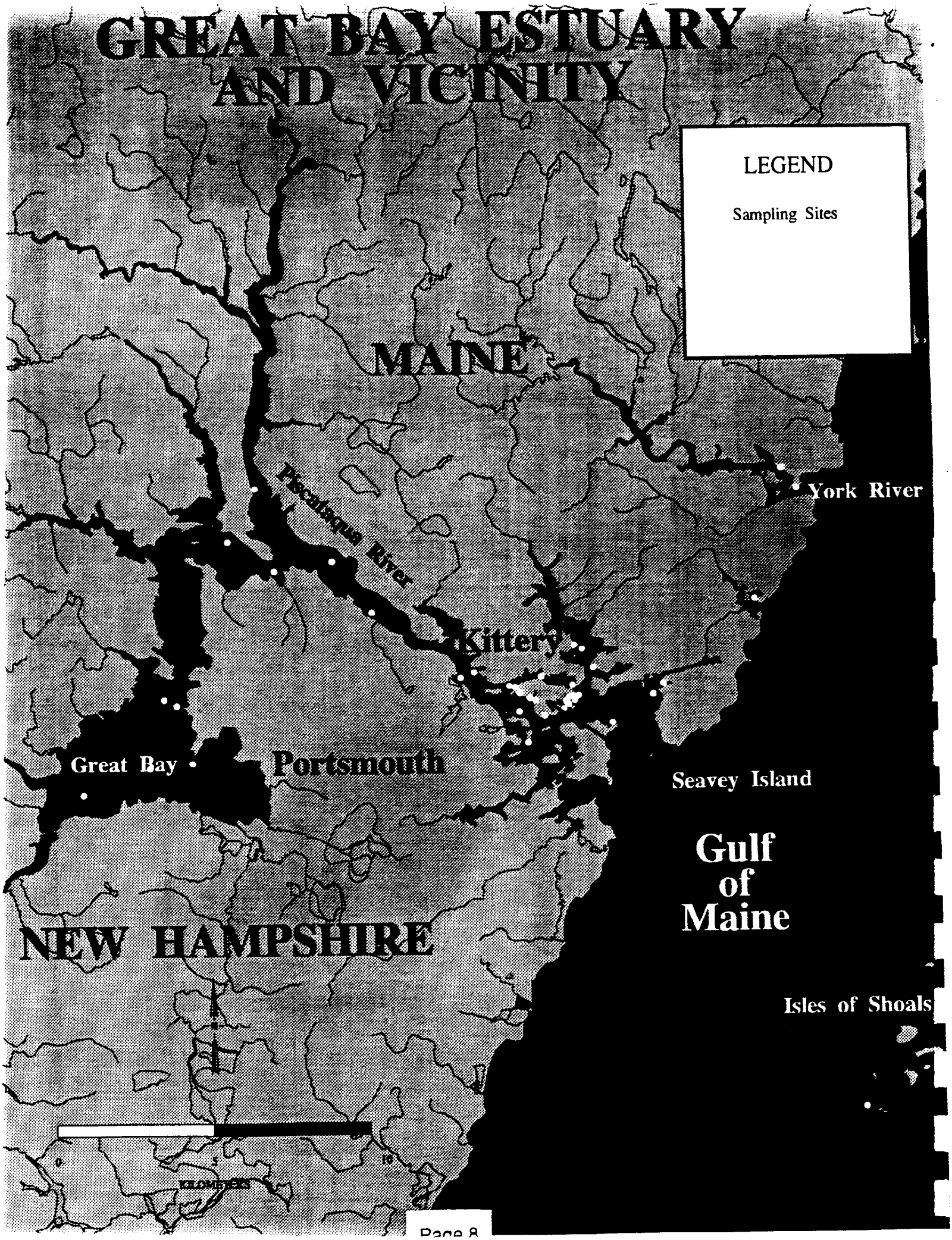

GREAT BAY ESTUARY
AND VICINITY
LEGEND
Sampling Sites
MAINE
Piscataqua River
York River
Kittery
Great Bay
Portsmouth
Seavey Island
Gulf
of
Maine
NEW HAMPSHIRE
Isles of Shoals
0
5
10
KILOMETERS

Figure 5-1. Depth averaged currents measured around Seavey Island during ebb tide (a), low slack tide (b), flood tide (c), and high slack tide (d) (from Chadwick *et al.* 1993).

(a)

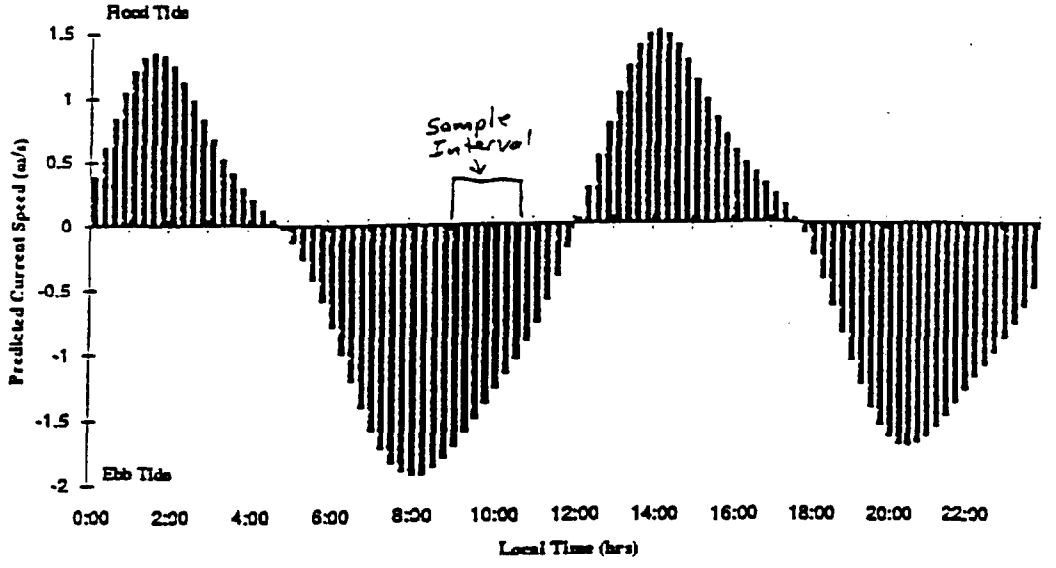


Figure 34. Predicted tide stage histogram, ebb tide.

Water currents measured in the lower estuary from acoustic doppler current profiler (ADCP) meter measurements made by the Research Vessel (R/V) ECOS July 1992. (Chadwick, Katz, and Paterson 1993.)

(1) Ebb tide surface currents.

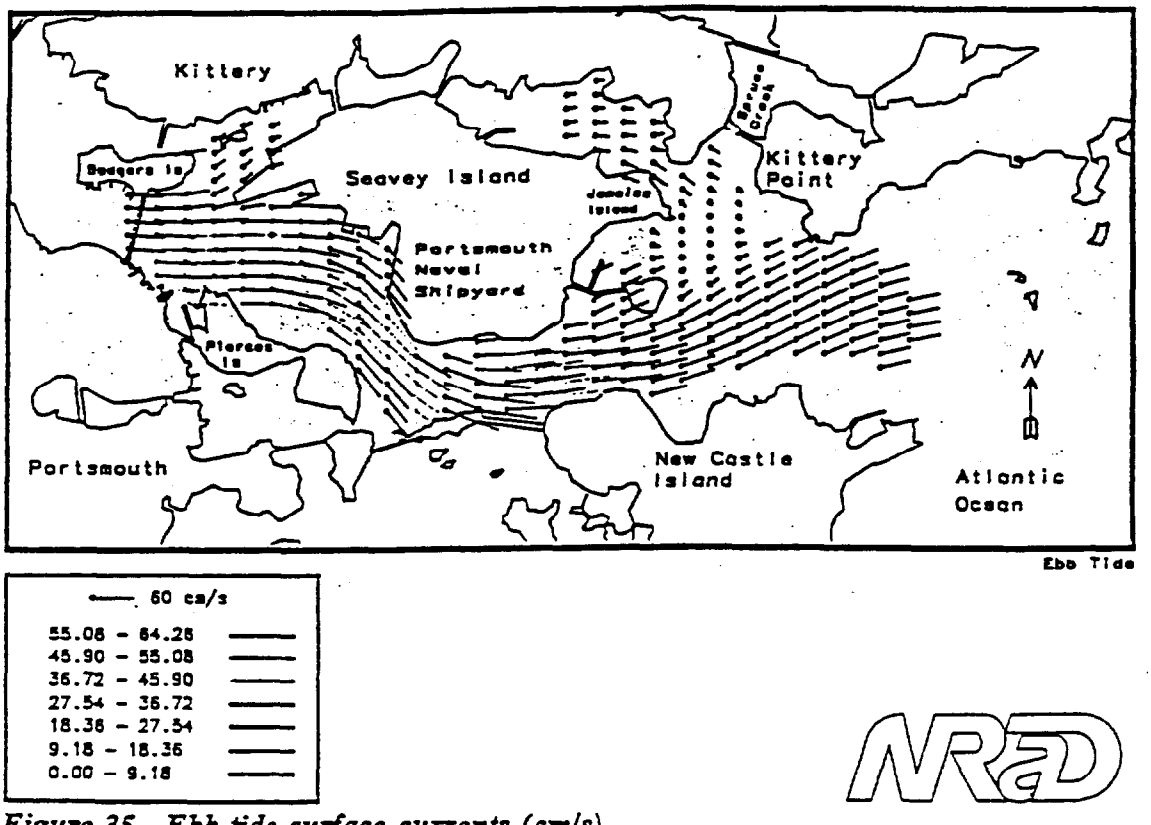


Figure 35. Ebb tide surface currents (cm/s).

Figure 5-1. Continued

(c)

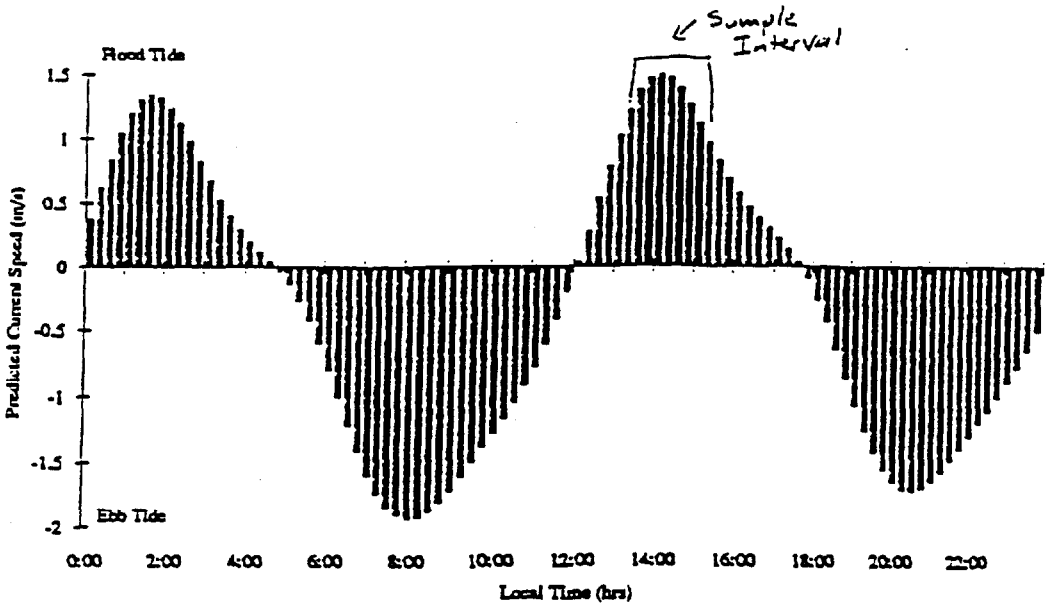


Figure 50. Predicted tide stage histogram, flood tide.

(2) Flood tide surface currents.

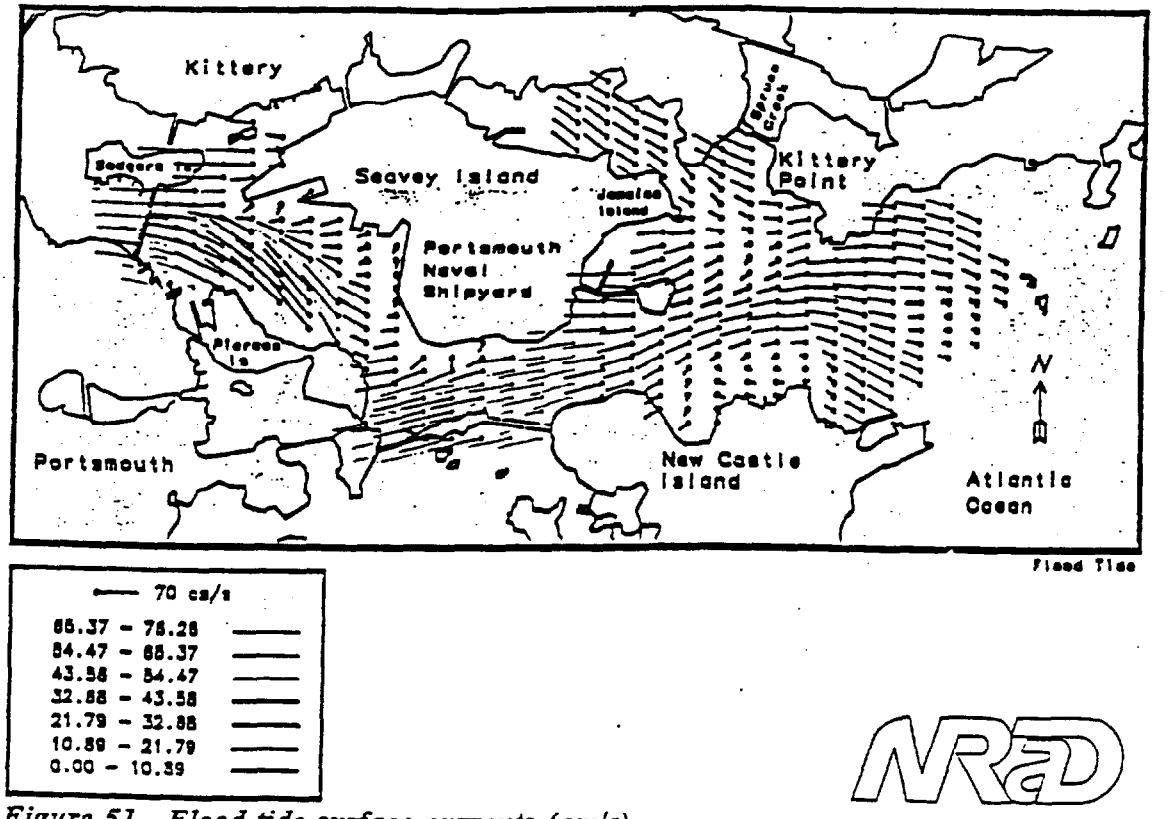
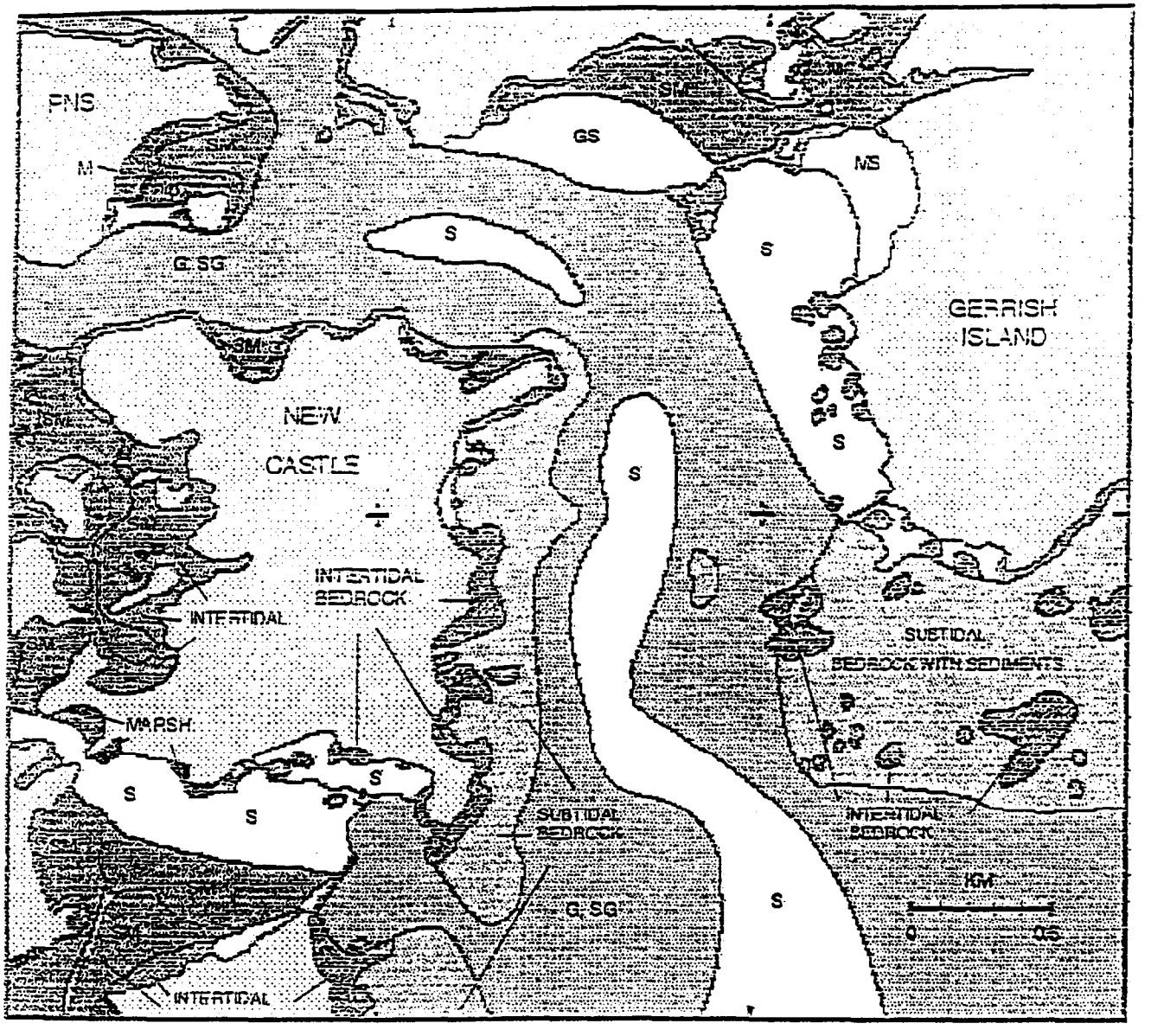
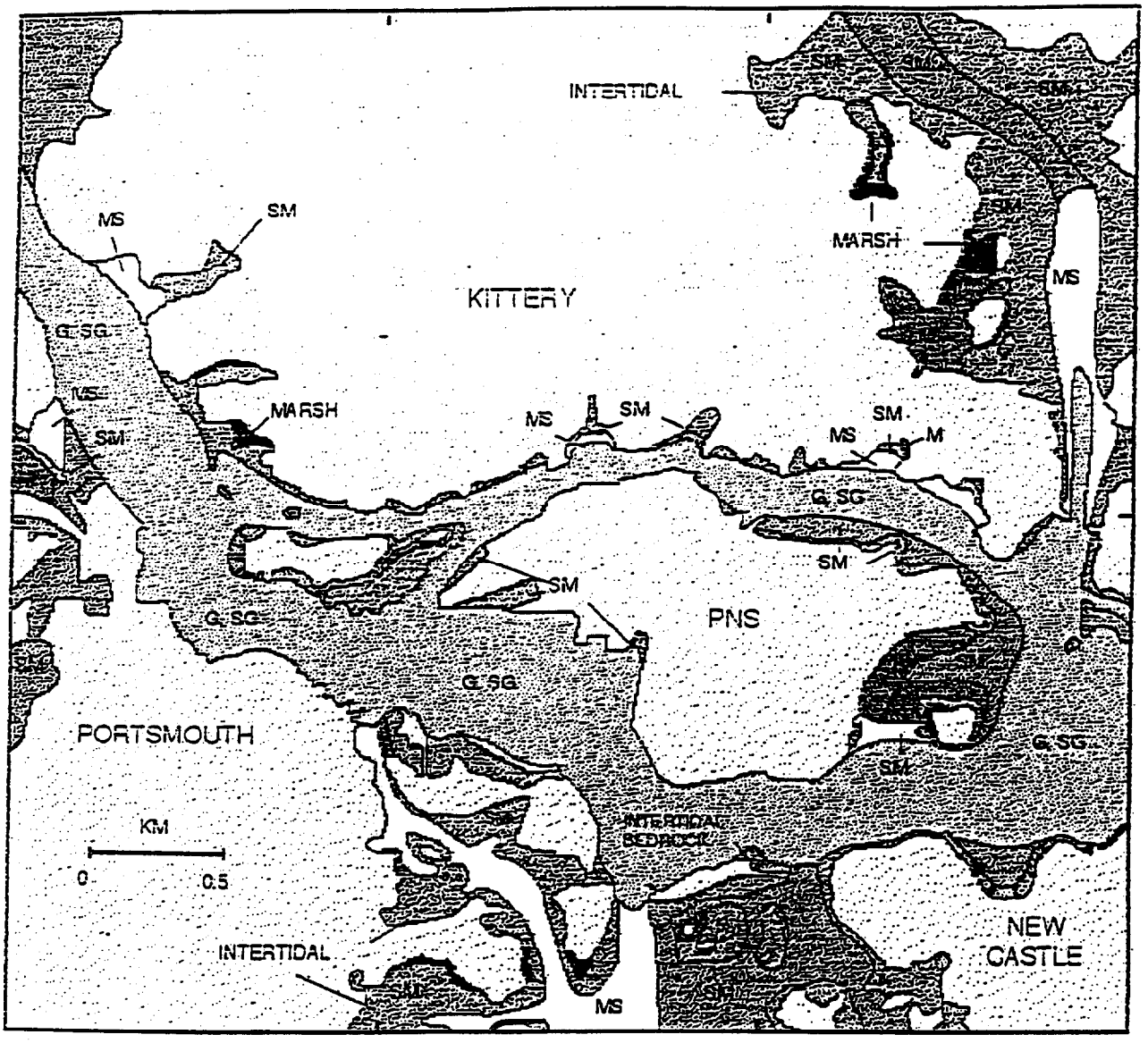


Figure 51. Flood tide surface currents (cm/s).



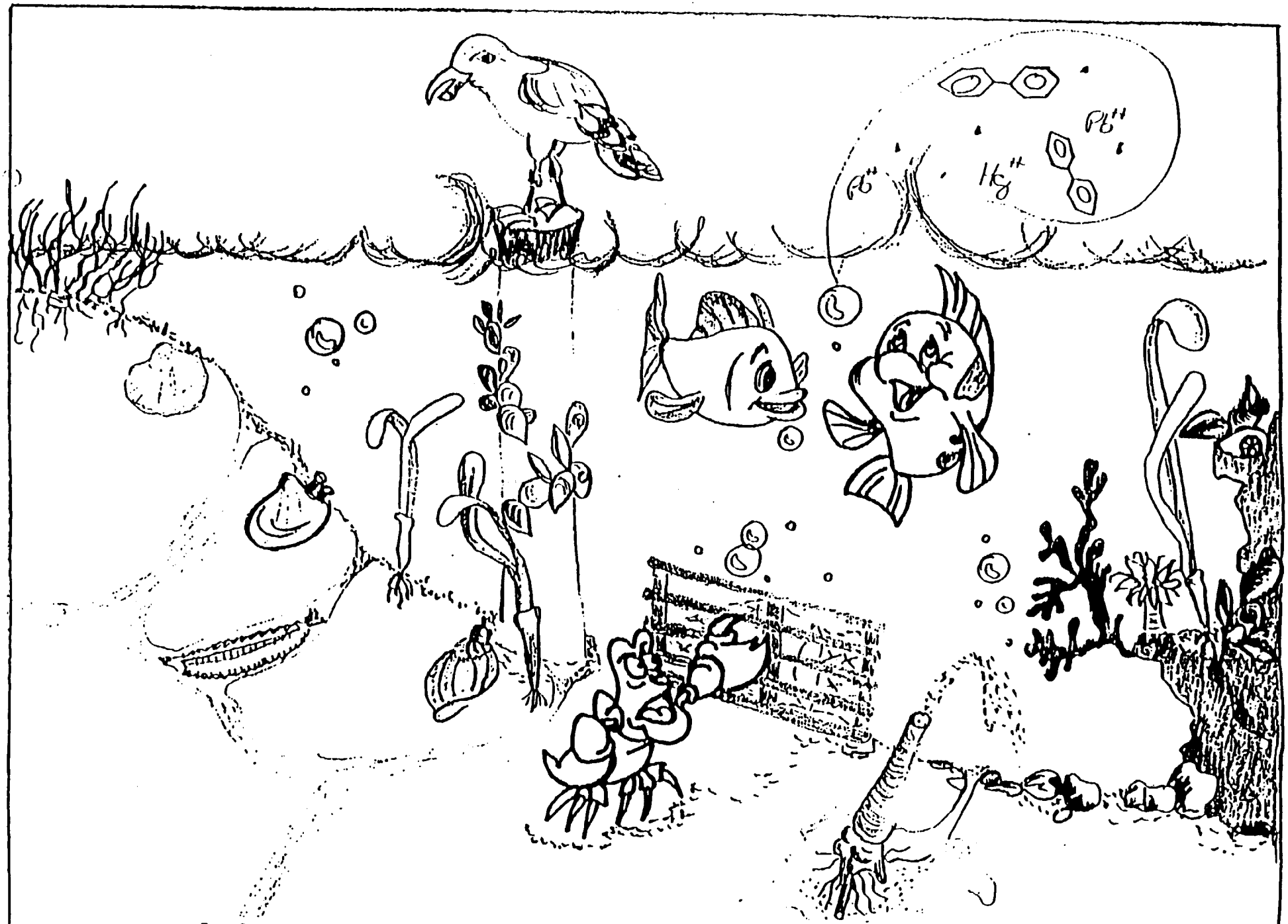
Sediment distribution map for lower estuary. (Ward 1995.)

(1) Mouth of Portsmouth Harbor.



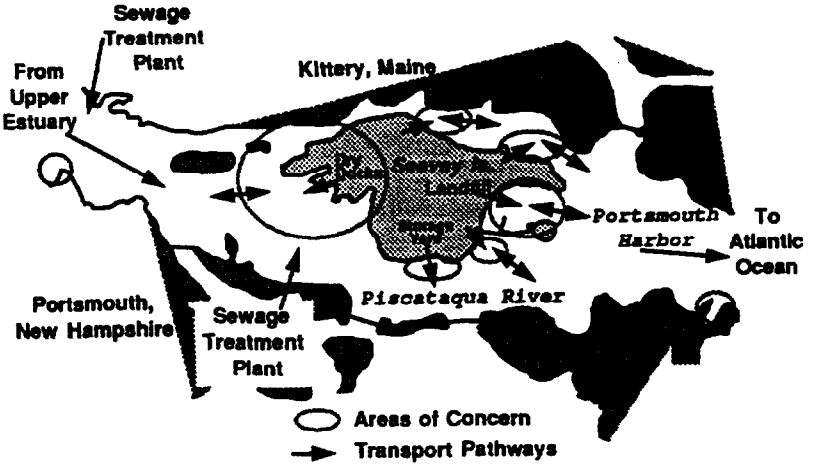
(2) Seavey Island and vicinity.

FIGURE 3-4. Distribution of sediment types in the lower Piscataqua River (from Ward 1994b). Abbreviations are G (gravel), SG (sandy gravel), MS (muddy sand), SM (sandy mud), and M (mud). See Ward 1994b for further detail.

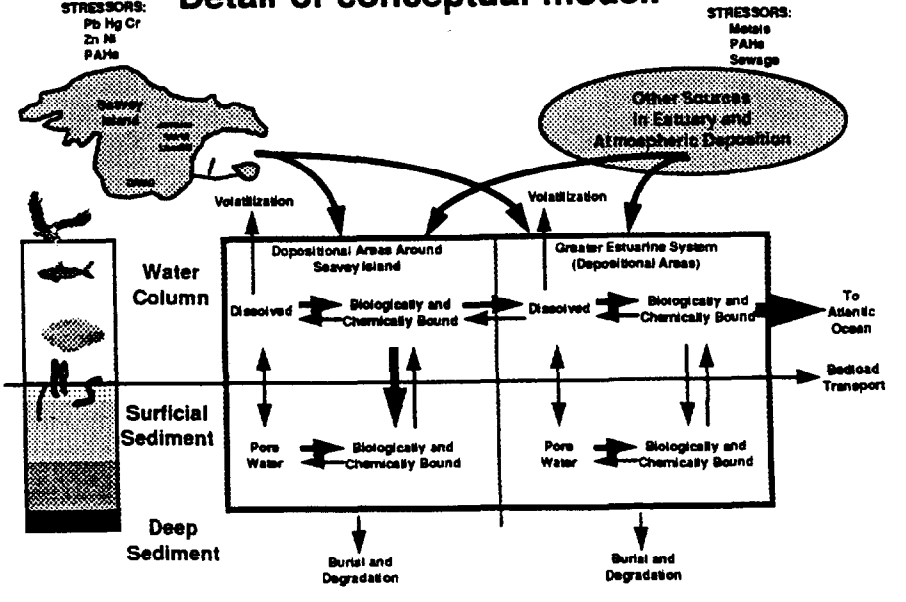


Artist's depiction of ecological resources in the Great Bay Estuary. (drawing by K.D. Johnston)

Areas of Concern from Conceptual Model



Detail of conceptual model.



DEFINE THE PROBLEM
CHEMICALS OF CONCERN (COCs)

- Evaluate Contamination Levels in the Estuary
- Screen Contamination Levels Above Conservative Benchmarks
- Determine Chemicals that could be Linked to SWMUs
- RESULT: COCs were selected for chemicals which exceeded benchmark levels and were associated with SWMUs

Chemicals Measured

Heavy Metals
- Lead (Pb)
- Mercury (Hg)
- Nickel (Ni)
- Chromium (Cr)
- Copper (Cu)
- Zinc (Zn)
- Silver (Ag)

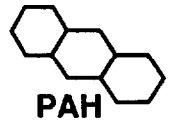
Arsenic (As)

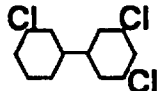
Hydrocarbon Compounds (HC)
- Polycyclic Aromatic HC (PAH)
- Volatile Aromatic HCs (VOC)

Chlorinated Compounds
- PolyChlorinated Biphenyls (PCB)
- Chlorinated Pesticides (DDT)

Butyltin Compounds (TBT)
Methyl Mercury (CH_3-Hg)

Pb^{++}	Dissolved
PbS	Solid (Bound to Sulfur)

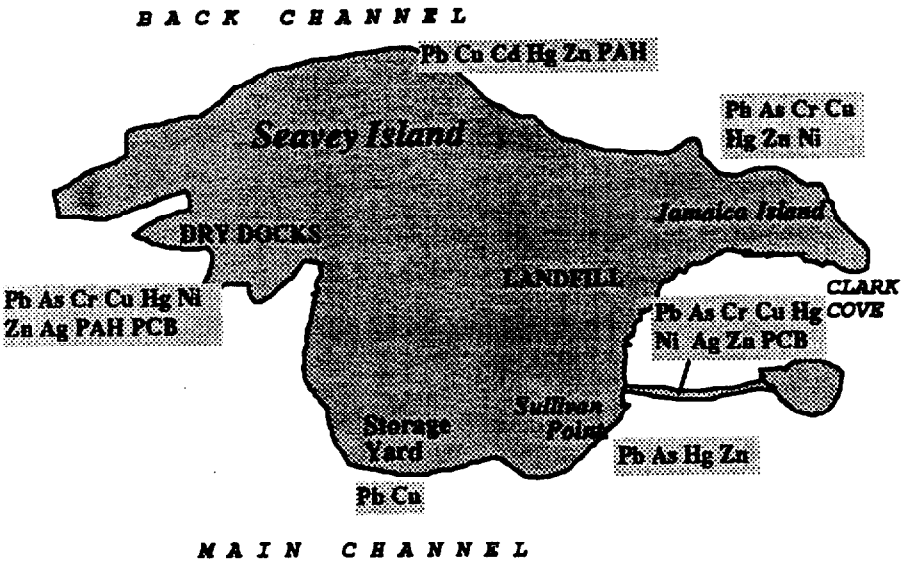

PAH



PCB

VOC (Benzene)

COCs and Areas of Concern



ECOSYSTEMS EVALUATED

Pelagic Species - Winter Flounder

Epibenthic Species - Mussels, Lobster, Winter Flounder, Rockweed Algae

Benthic Community - Invertebrates

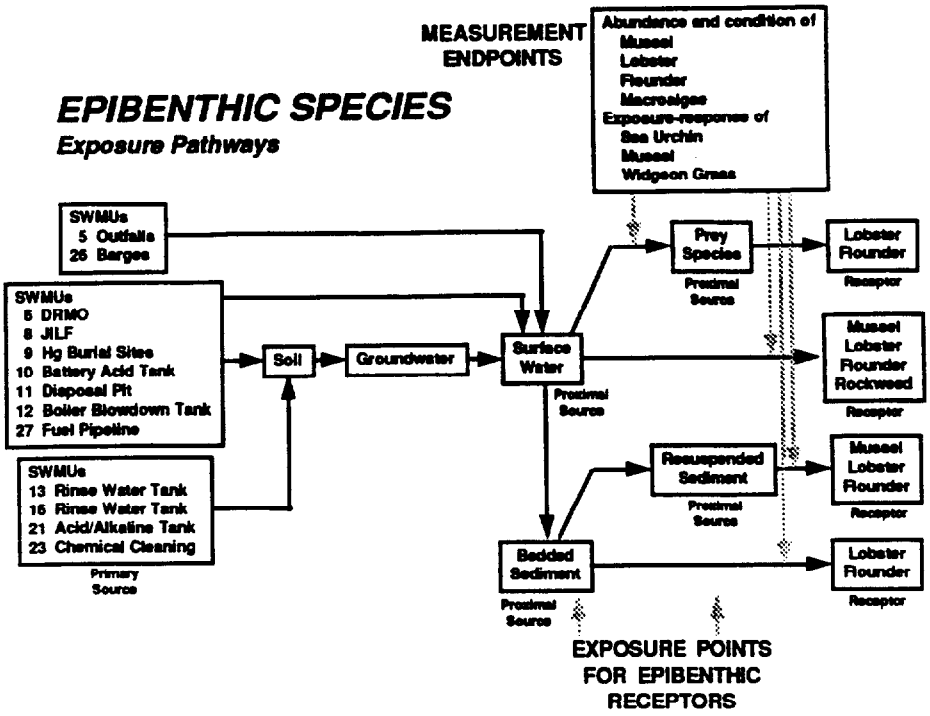
Salt Marsh Community - Plants, Animals

Eelgrass Community - Eelgrass

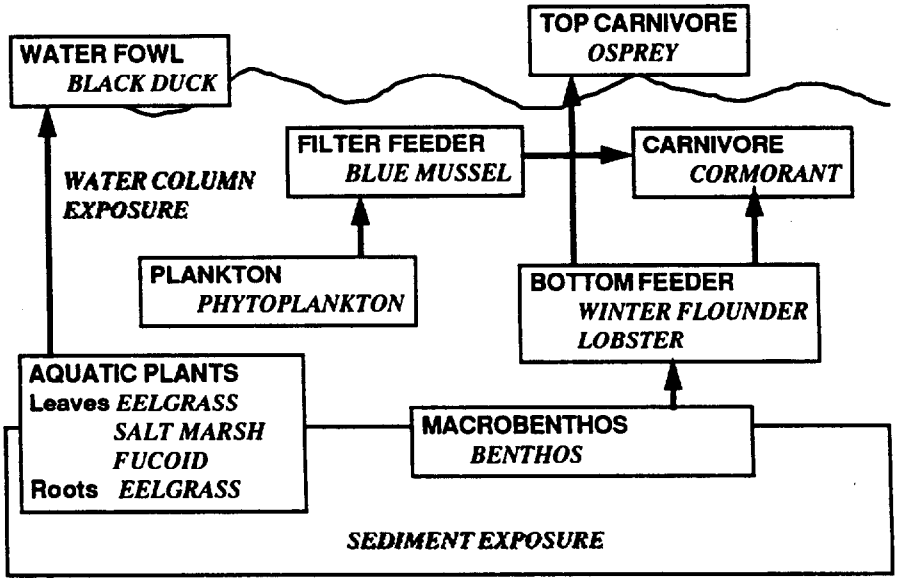
Herbivorous Waterfowl - Ducks

Avian Predators - Cormorant, Osprey

Trophic Transfer - Food Web



Simplified Food Web to Evaluate Chemical Accumulation in Food Chain



EXPOSURE ASSESSMENT
(STRESS CHARACTERIZATION)

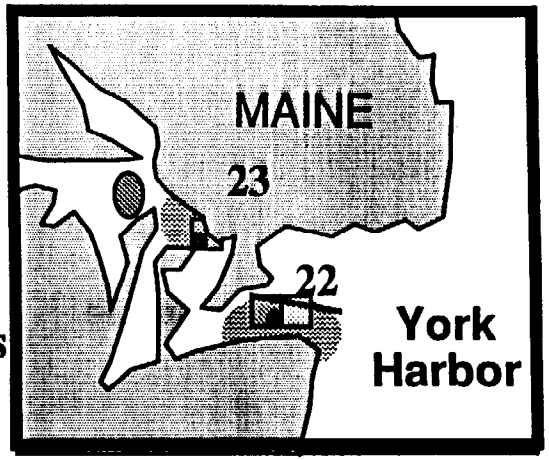
Measurement of Pollution Levels in:

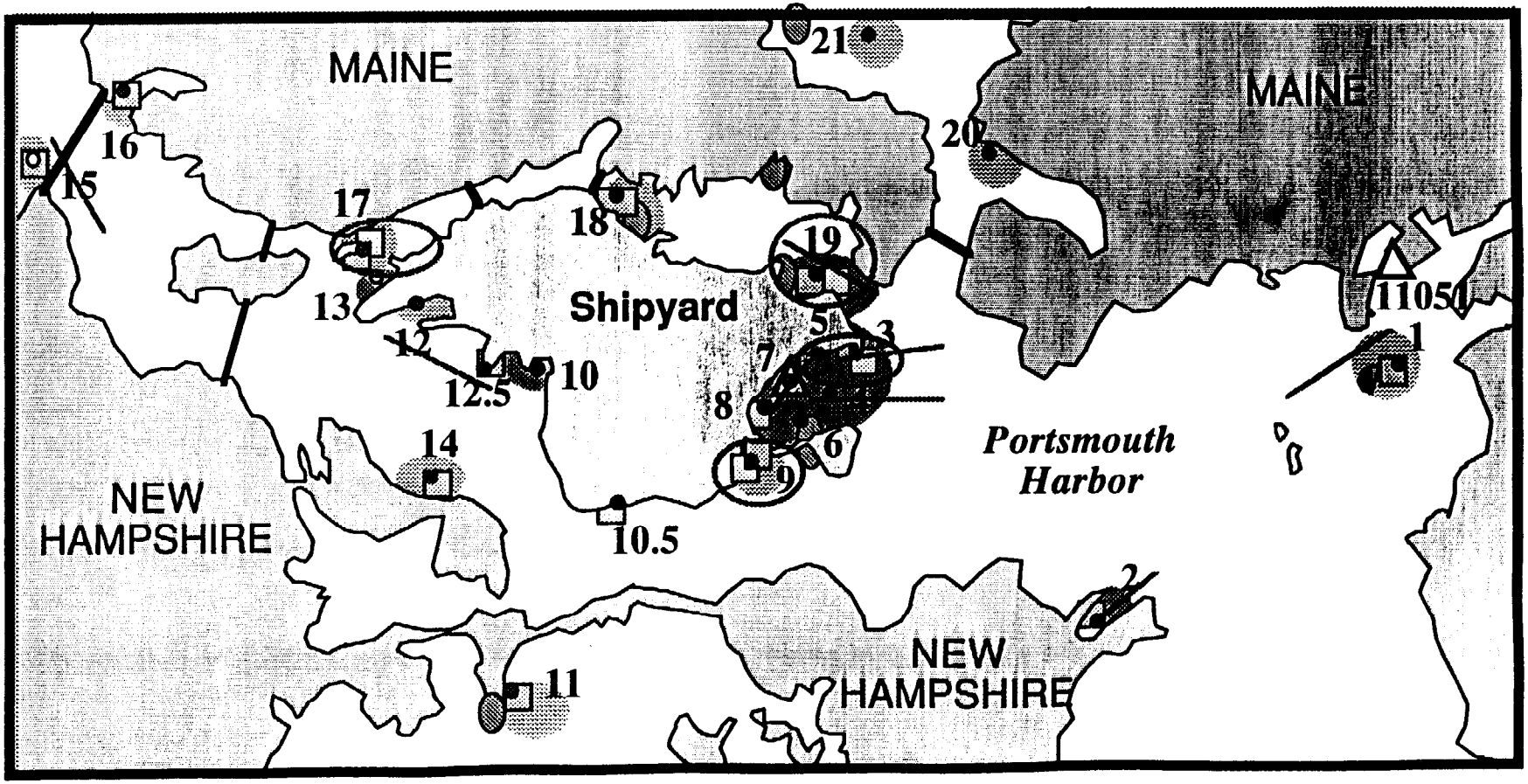
- **Water - River Water and Seeps**
- **Sediments - Grabs and Cores in Depositional Areas**
- **Biota - Flounder, Lobster, Mussels, Oysters, Eelgrass, Saltmarsh Plants, and Rock Weed**

Measurements Made In Reference Areas and Near the Shipyard

Station Locations and Habitat Types

- Station Location - Mussel Bed
- Eelgrass Bed
- Seaweed Algae
- Salt Marsh
- Sandy Sediment
- Silty Sediment
- Fish/Lobster Trawl
- Lobster Habitat Stations
- Sediment Exposure Stations





EFFECTS ASSESSMENT (EFFECTS CHARACTERIZATION)

- Known Effects of COCs from Literature
- Site-Specific Toxicity Evaluations
  - Sediment Toxicity
  - Water Toxicity
  - Laboratory Studies
    - Pb Toxicity to Sea Urchins, Mussels, Amphipods, and Widgeon Grass
    - Mussel Pb Bioaccumulation
- Criteria and Standards

EFFECTS ASSESSMENT (Cont.)

- Benchmarks Derived From:
  - Toxicity Values Derived from Effects Reported in the Literature
  - Developed for Each Chemical and Receptor for Which Data Were Available
  - Laboratory Studies of Site Specific Pb Toxicity

Example of the receptor-specific benchmark concentrations for Pb used in the risk assessment.

Table 6-1. Receptor-specific effects concentrations (μg/L) for Shipyard CoCs - lead.

Receptor	Acute	Chronic	Effect
BLUE MUSSEL	476		larva 96-h LC50
	>500,000		adult 96-h LC50
	100		96-h LC50 - tetraethyl Pb
		500	150-d LC50
WINTER FLOUNDER	180,000		plaice (*Pleuronectes platessa*) 96-h LC50
PHYTOPLANKTON	>5,000		diatom (*Phaeodactylum tricornutum*) 96-h LC50
	100		diatom (*Phaeodactylum tricornutum*) 96-hr LC5C
		10	12-d 100% growth inhabition of diatom (*Skeletor*
		207	reduced chlorophyl a in natural phytoplankton pc
		21	reduced biomass in natural phytoplankton popula
LOBSTER	575		Dungeness crab (*Cancer magister*) 96-h LC50
		50	reduced enzyme activity in antennal gland after 3
EELGRASS			
FUCOIDS		20.3	no sexual reproduction and reduced female grow
		810	45% growth inhabition in fucoid alga (*Fucus ser*
BENTHOS	547		amphipod (*Ampelisca abdita*) 96-h LC50
	1,200		polychaete (*Capitella capitata*) 96-h LC50
		1,000	suppressed reproduction in polychaete (*Ctenodri*
SALT MARSH			
BLACK DUCK		25,000 μg/Kg diet	no deaths, no pathologies in mallard (*Anas plat*)
CORMORANT		50,000 μg/Kg diet	no adverse effects on survival, egg laying, ferti: kestrel (*Falco sparverius*)
OSPREY		50,000 μg/Kg diet	no adverse effects on survival, egg laying, ferti: kestrel (*Falco sparverius*)

EFFECTS ASSESSMENT (Cont.)

Benchmarks Derived From:

- **Criteria and Standards:**
  - **Concentration Identified by Law, Regulation or Guidance**
- **Mussel Tissue Critical Values:**
  - **Estimated Mussel Tissue Level that Would Result from Exceeding Criteria, Standard, or Benchmark Water Concentration**

RISK CHARACTERIZATION

Observations of Ecological Effects

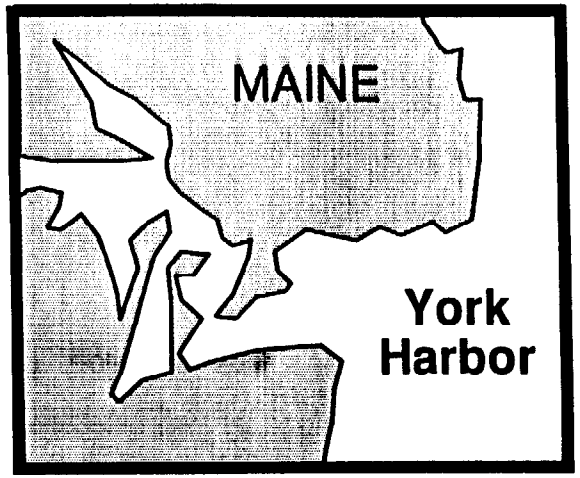
Bioaccumulation Levels

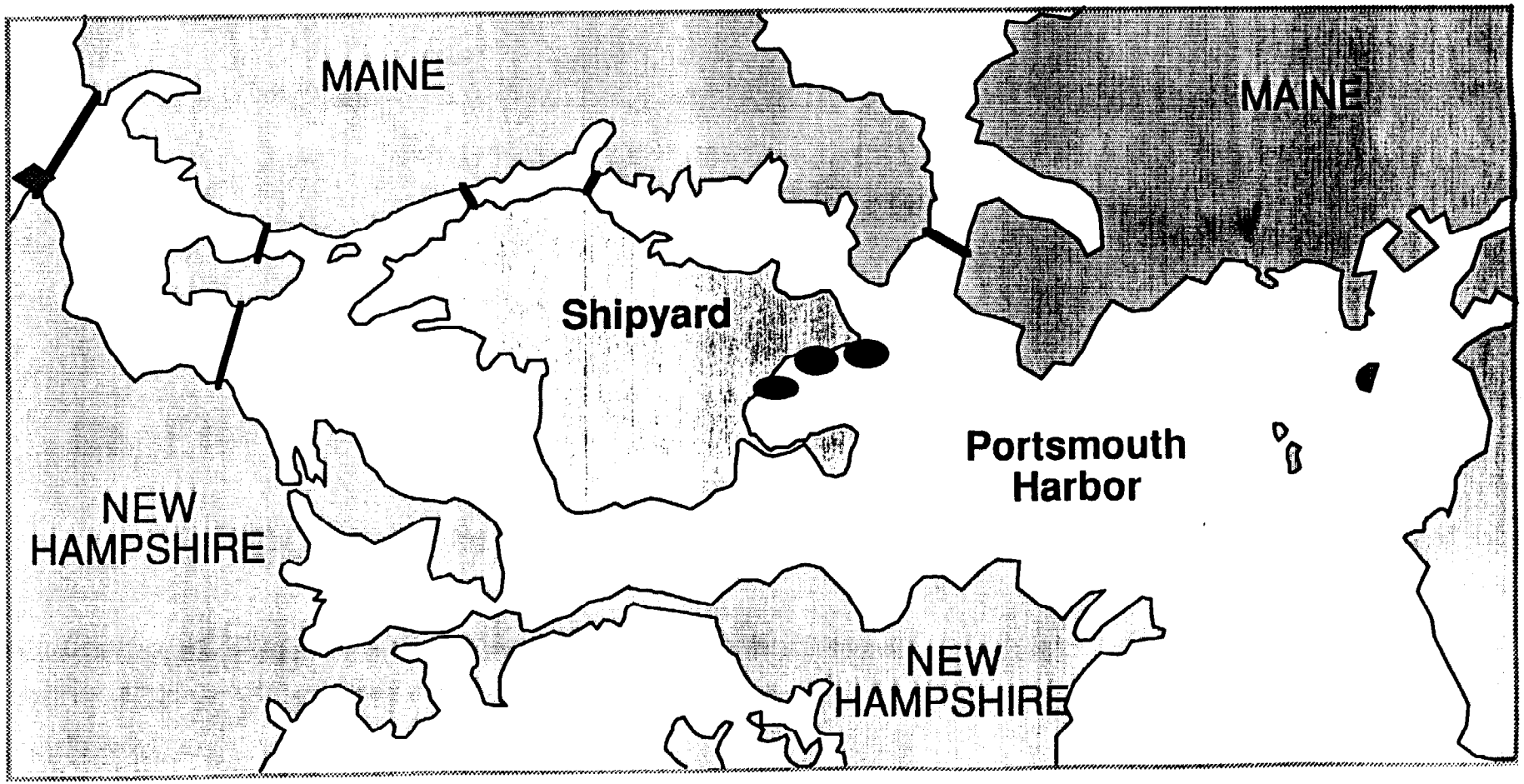
Probability of Exceeding Benchmarks Based On:

- **Direct Chemical Measurements**
- **Calculations of Sediment Pore Water Concentrations**
- **Mussel Tissue Critical Values**

ECOLOGICAL EFFECTS
Water Column Indicators

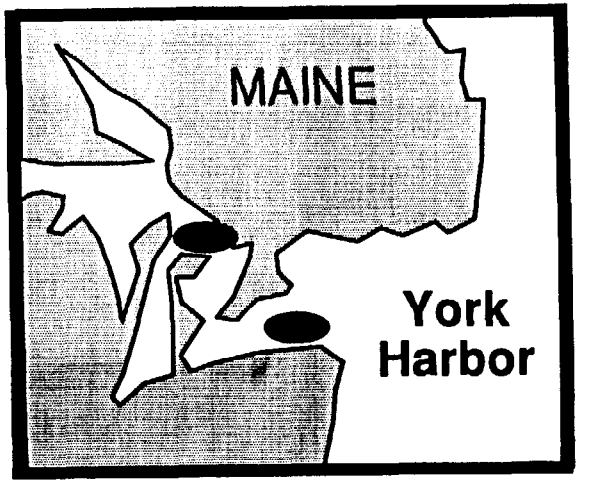
- ● Toxicity to Sea Urchin Sex Cells
- ◆ Stress on Mussel Growth

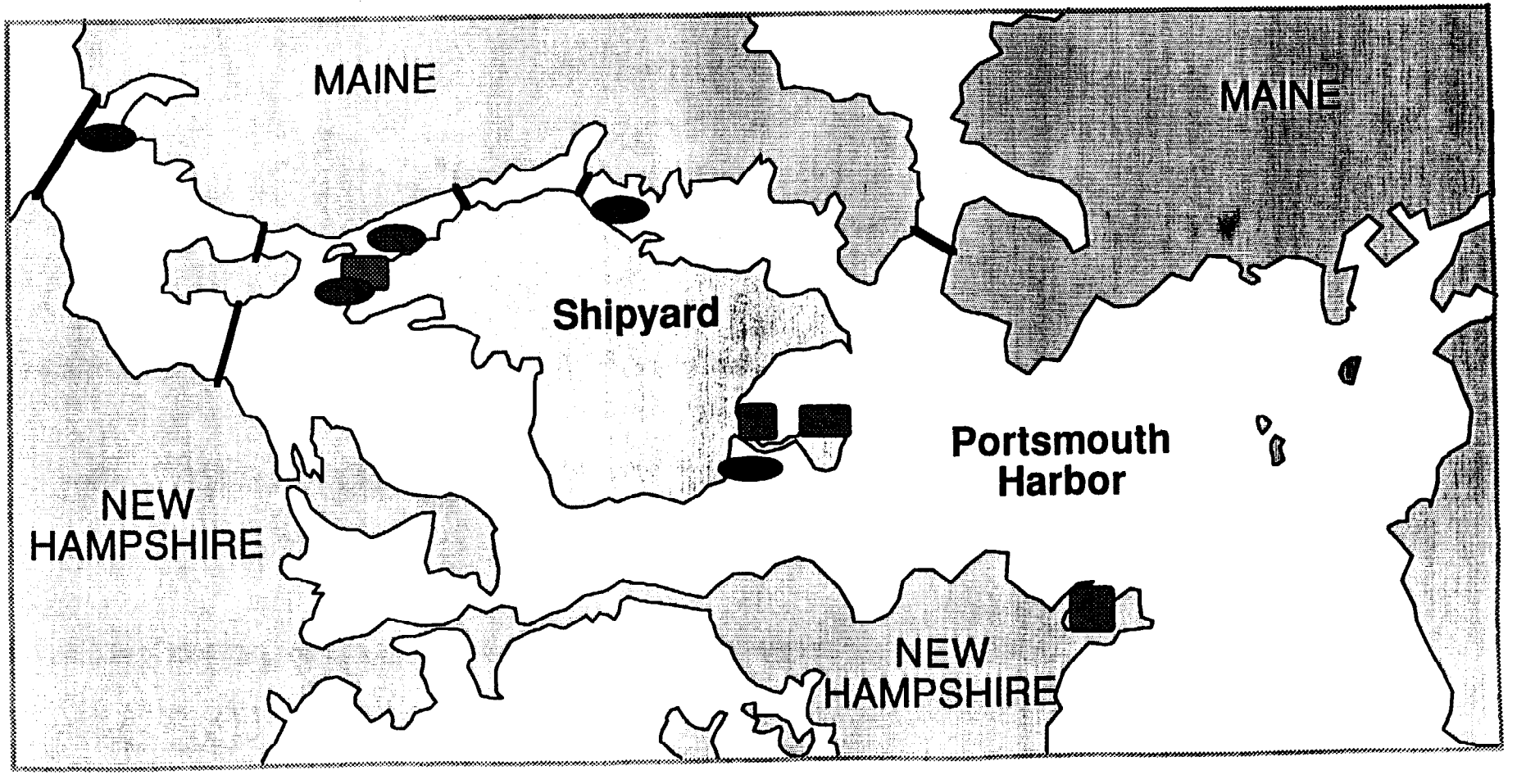




ECOLOGICAL EFFECTS
Sediment Indicators

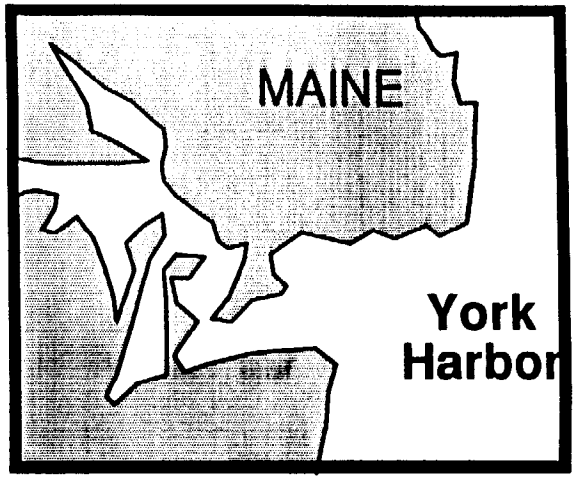
- Toxicity to Amphipods
- Effect on Bottom Organisms

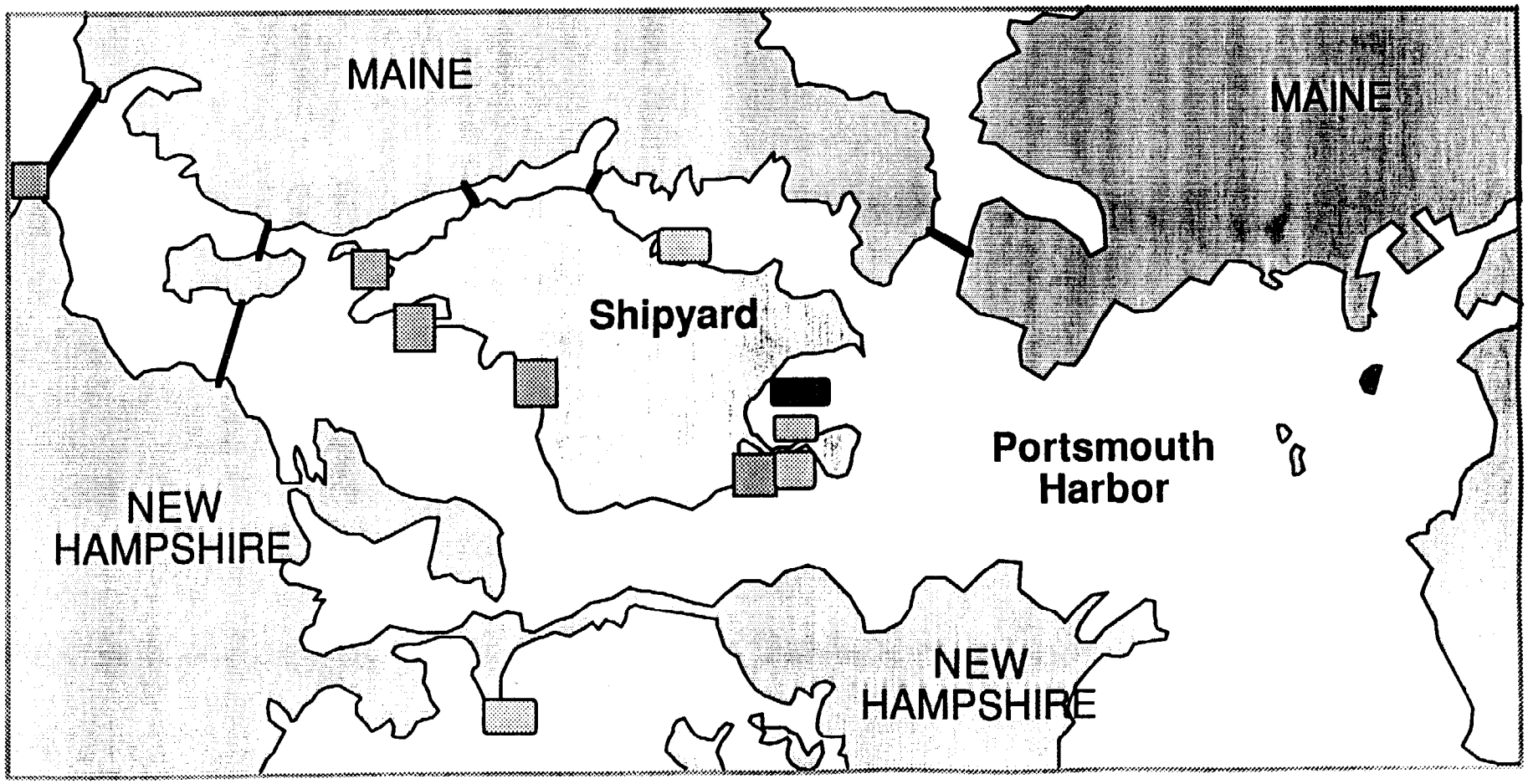




ECOLOGICAL EFFECTS
Ecological Indicators

- Salt Marsh Stress
- Eelgrass Absent
- High Microbial Contamination





SUMMARY OF SIGNIFICANT BIOACCUMULATION FINDINGS

Flounder	Chemical Levels Similar Between Gulf of Maine and Portsmouth Harbor;
	High Levels of Spleen Disorders
Lobster	Significant Differences between Age Classes (Juveniles Highest);
	No Difference between Isles of Shoals and Portsmouth Harbor Adults tail+claw
Mussel	Significantly Elevated Concentrations of Pb, Hg, and Cr
Eelgrass	Root Residues Proportional to Sediment for Hg, Pb, Cr, Ni, and Cu

PROBABILITY OF EXCEEDING BENCHMARKS

WATER COLUMN

No Appreciable Risks Detected for Exposure to Surface Waters

Seavey Island Seeps Had High Probability of Exceeding WQC

TROPHIC TRANSFER

No Risks Detected for Dietary Exposure to Osprey, Cormorants, or Ducks

PROBABILITY OF EXCEEDING BENCHMARKS (Cont.)

SEDIMENT: Chemicals With Probability of Exceeding Probable Effects Levels (ER-M):

PCB, Pb, Ni, Cu, Zn, Hg

MUSSEL: Chemicals with Probability of Exceeding Mussel Tissue Critical Values:

Pb and Phenanthrene

PROBABILITY OF EXCEEDING BENCHMARKS (Cont.)

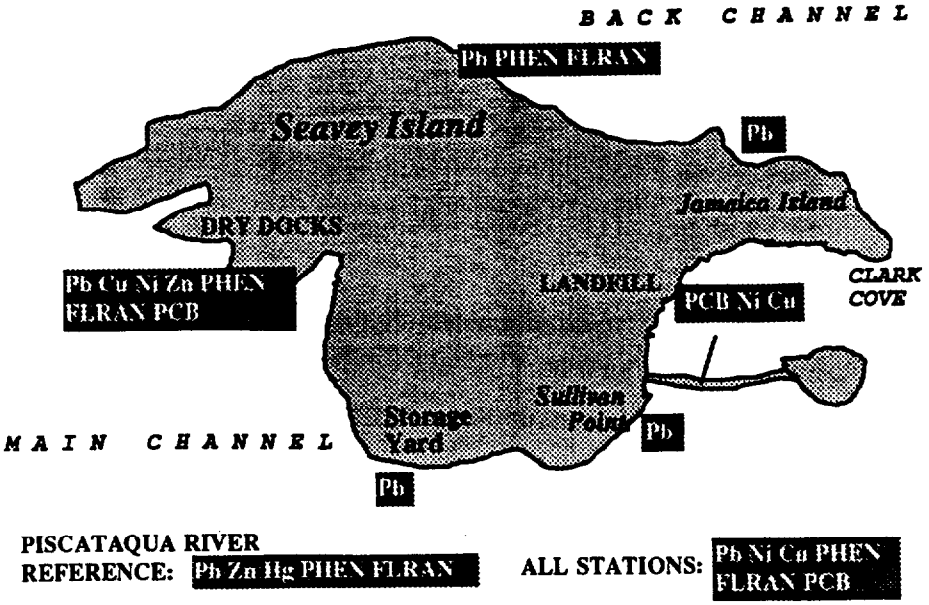
SEDIMENT PORE WATER:

Metals: Sulfide Binding Indicates Metals Not Available in Pore Water (Does not apply to As, Cr, and MeHg)

Organics: Compounds With Probability of Exceeding Water Quality Criteria:

Phenanthrene and Fluoranthene

CHEMICALS WITH PROBABILITY OF EXCEEDING BENCHMARKS

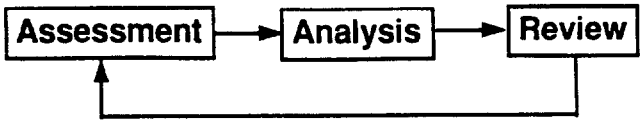


UNCERTAINTY ANALYSIS

SOURCES OF UNCERTAINTY

- Errors in Assumptions
- Errors in Analyses
- Errors in Measurements
- Natural Variation

ITERATIVE STUDY HAS SELF CORRECTING CAPABILITY



ECOLOGICAL FINDINGS

Water Quality
- Excess Nutrients
- Sewage Input
- Significant Flushing in Estuary
- Transport Model for Pb Developed

Sediment Quality
- Depositional Areas Identified
- Sediment Distribution Measured
- Toxicity Detected
- Sewage Input
- Evidence of Runoff, Atmospheric, and Oil Inputs

ECOLOGICAL FINDINGS (Cont.)

Pelagic Community
- Primary Productivity Within Normal Limits
- Flounder Residues Low But Evidence of Spleen Disorders

Benthic Community
- Within Normal Range for Piscataqua River
- Evidence of Community Stress

ECOLOGICAL FINDINGS (Cont.)

Epibenthic Community

- Juvenile Lobster Very Abundant
- Important Lobster Nursery and Reproductive Habitat Delineated
- Mussel Density and Abundance Within Normal Range
- Rockweed Algae Within Normal Range

ECOLOGICAL FINDINGS (Cont.)

Eelgrass Community

- Abundance/Morphology Within Normal Range
- Excellent Habitat Quality Beneficial to Lobster
- Eelgrass Absent from Inner Clark Cove
- Inverse Relationship Between Pb Exposure and Eelgrass Root+Rhizome Biomass

Salt Marsh Community

- Good Habitat Value
- Indications of Ecological Stress

ECOLOGICAL FINDINGS (Cont.)

Herbivorous Water Fowl

- No Impact Calculated

Avian Predators

- No Impact Calculated

Trophic Transfer

- Bioaccumulation Evident in Juvenile Lobster, Mussels, and Eelgrass

CONCLUSIONS

No Appreciable Risks Were Detected for:

- Exposure to River Water or
- Dietary Uptake by Birds

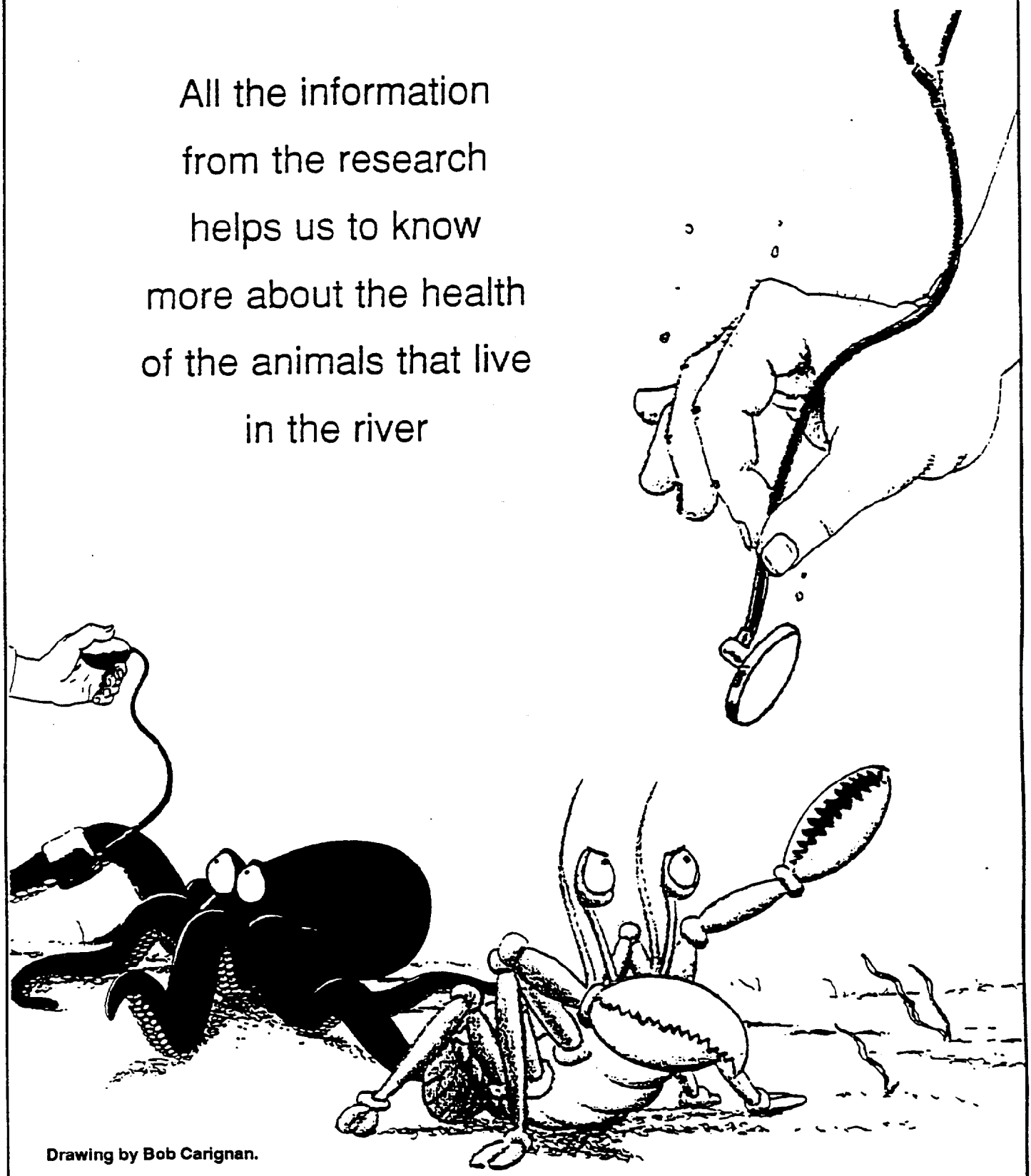
Risks of Exceeding Benchmarks Calculated for:

- Sediment Exposure - Pb, Ni, Cu, Zn, Hg, Phenanthrene, Fluoranthene, and PCB
- Mussel Tissue Accumulation- Pb, PHEN

Healthy and Productive Estuarine Habitats were Observed

Indications of Stress were Present.

All the information from the research helps us to know more about the health of the animals that live in the river



Drawing by Bob Carignan.

RECEPTOR SPECIFIC BENCHMARKS

Receptor	*Pb*	*Cu*	*As*	*Cr*	*Zn*	*Cd*	*Hg*	*Ni*	*Ag*	*PCB*	*PAH*
BLUE MUSSEL	●	●	●	●	●	●	●	●	●	●	
FLOUNDER	●	●	●	●	●	●	●	●	●	●	●
PHYTOPLANKTON	●	●	●	●	●	●	●	●	●		●
LOBSTER	●	●	●	●	●	●	●	●	●	●	●
EELGRASS											
FUCOIDS	●	●	●	●	●	●	●	●	●		
BENTHOS	●	●	●	●	●	●	●	●	●		●
SALT MARSH			□	●	□						
BLACK DUCK	○		○	○	○		○			○	○
CORMORANT	○						○				
OSPREY	○			○			○			○	

Benchmark Data Available for:

● Water Concentrations

□ Soil Concentrations

○ Dietary Concentrations

DEPARTMENT OF THE NAVY
NAVAL COMMAND, CONTROL, AND OCEAN SURVEILLANCE CENTER
RESEARCH, DEVELOPMENT, TEST AND EVALUATION DIVISION
MARINE ENVIRONMENTAL SUPPORT OFFICE - EAST DETACHMENT
CODE 5221, 27 TARZWELL DRIVE
NARRAGANSETT, RHODE ISLAND 02882-1154

Ser 5221/065-95
October 6, 1995

MEMORANDUM

From: R. K. Johnston, Marine Environmental Support Office, East Detachment (MESO-E)
To: Lt. James Conroy, Northern Division

Subj: PRESENTATION MATERIALS FOR PORTSMOUTH NAVAL SHIPYARD 19 OCT 1995 RAB MEETING

Encl: (1) Ecological Risk Assessment for Portsmouth Naval Shipyard, Presentation Materials

1. Enclosure (1) provides the presentation materials for the subject meeting.

2. Please provide any comments so that they can be incorporated into the presentation for the Restoration Advisory Board.

3. I can be reached at (401) 782-3128, FAX 401-782-3030, or email (rjohnston@narvax.nar.epa.gov). Thank you for your interest.

R. K. JOHNSTON

cc: w/encl.
PNSY (Endyke)
USEPA NHEERL-AED (Pesch, Munns)
NCCOSC RDTE DIV (Grovhoug)
UNH JEL (Short)

ECOLOGICAL RISK ASSESSMENT FOR PORTSMOUTH NAVAL SHIPYARD, KITTERY MAINE

Presentation for

The PNSY Restoration Advisory Board

October 19, 1995

Presented by

Robert K. Johnston

Marine Environmental Support Office of the US Navy
Naval Command, Control and Ocean Surveillance
Center, RDT&E Division.

KEY MESSAGES

1. Chemical Impacts from SWMUs on Ecological Resources of the Estuary were Assessed.
2. Indications of Stress were Present and Elevated Risks to Benthic Organisms Were Calculated.
3. Healthy and Productive Estuarine Habitats were Observed; No Severe Ecological Impacts were Detected.
4. Information will be used to Evaluate Need for Remedial Action

OVERVIEW

What is Ecological Risk Assessment?
Participants in Study
Conceptual Model
Exposure Assessment
Effects Assessment
Risk Characterization
Ecological Findings
Conclusions

WHAT IS ECOLOGICAL RISK ASSESSMENT?

"The process that evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors" - USEPA 1994

Determining the Degree of Environmental Harm

Estimating the Chance Environmental Harm will Occur

COMPONENTS OF ECOLOGICAL RISK ASSESSMENT

Define the Problem
(Problem Formulation)

Measure Pollution Levels
(Stress Characterization)

Determine Degree of Harm
(Effects Characterization)

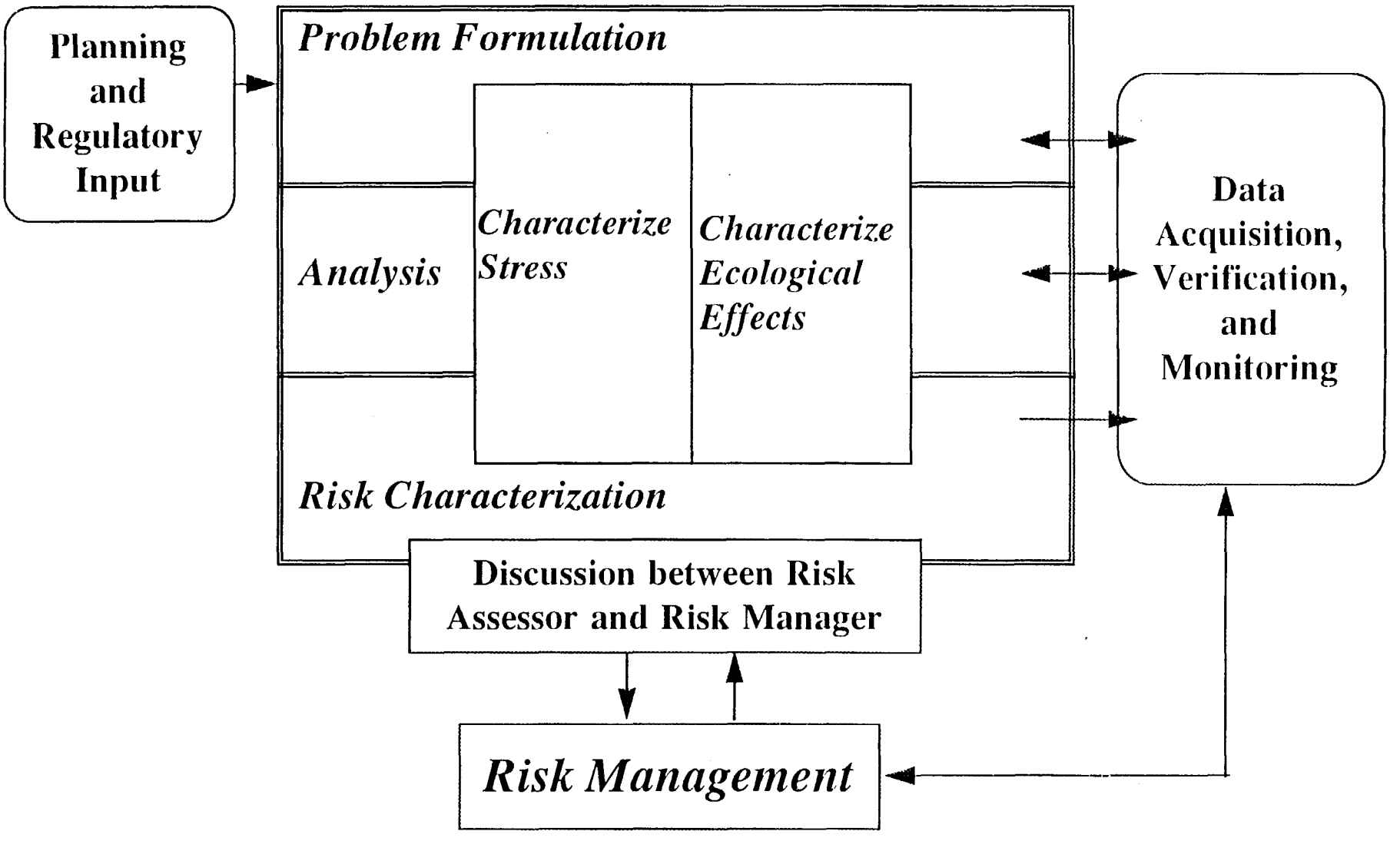
Calculate Risk Levels
(Risk Characterization)

Evaluate Ecological Health
(Verification and Monitoring)

Uncertainty Analysis (Sources of Error)

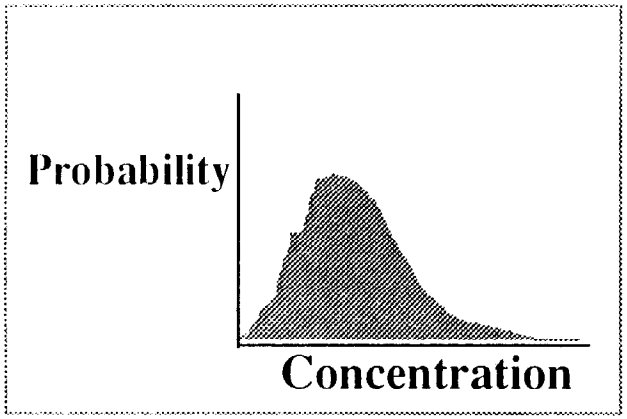
ECORISK FRAMEWORK

(USEPA Ecological Risk Assessment Forum 1992)



EXPOSURE x EFFECT = RISK

EXPOSURE



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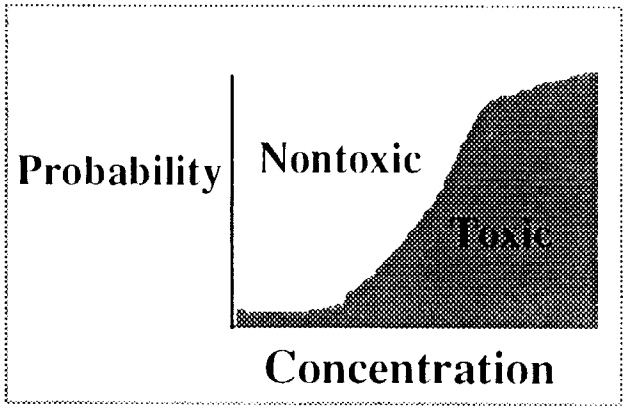
EFFECT



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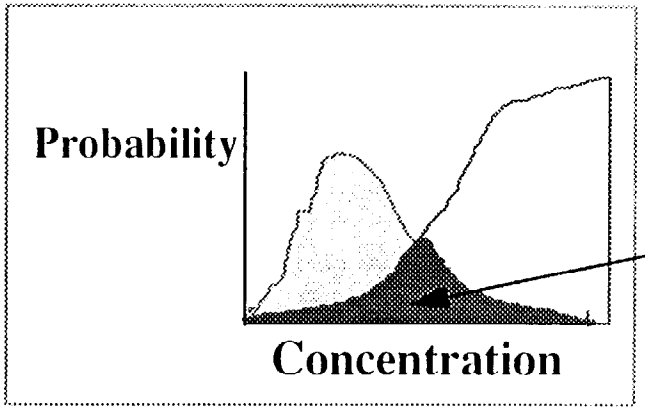
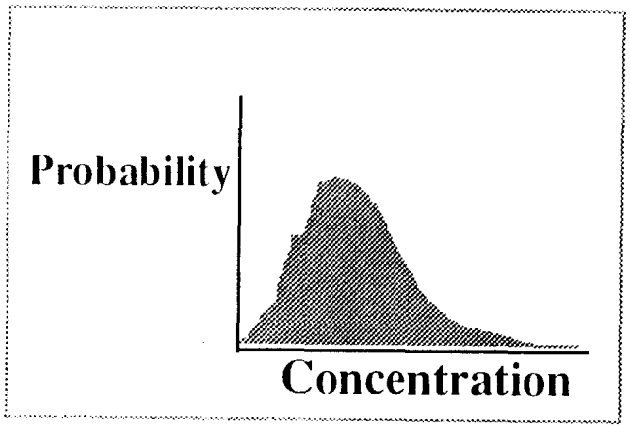
RISK



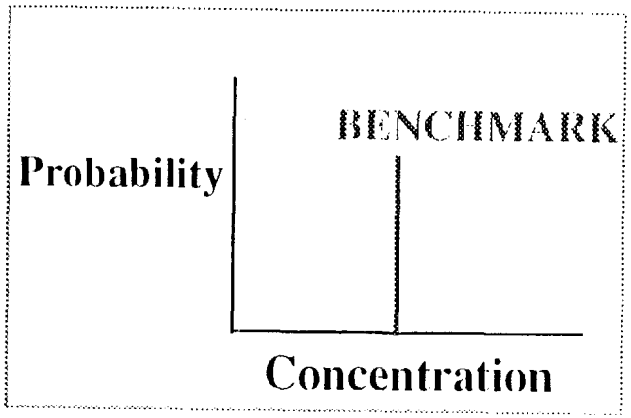
Chance That Toxicity Will Occur

Probability of Exceeding Benchmark

EXPOSURE

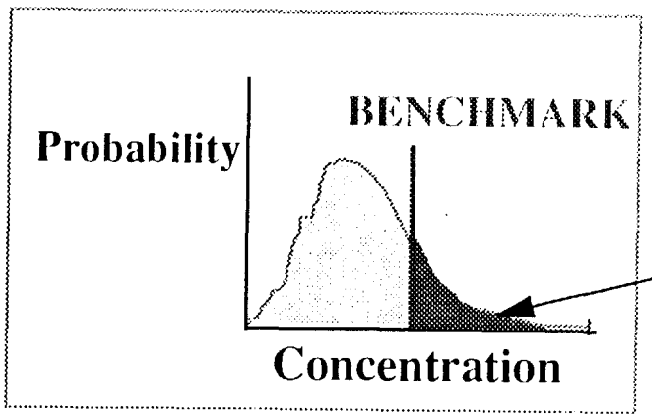


EFFECT



RISK

=



Chance That Benchmark will be Exceeded

STUDY PARTICIPANTS

MESO/NRaD	Coordination, ECOS Survey, Data Synthesis
EPA AED	Bioaccumulation, Exposure-Response, Analytical Chemistry
UNH-JEL	Field Sampling, Ecological Resource Studies, Sedimentology, Data Analysis
UNH-OEP	Modeling, Current Measurements
URI-GSO	Trace Metal Chemistry
SAIC	Toxicity Assessment
CEMIC	Analytical Chemistry (Phase I)
BMSL	Analytical Chemistry (Phase II)

STUDY PARTICIPANTS

Marine Environmental Support Office (MESO) of the US Navy Naval Command Control and Ocean Surveillance Center, Research Development, Test and Evaluation Division (NRaD), San Diego, CA (Formerly the Naval Ocean Systems Center)

US EPA National Health and Environmental Effects Research Laboratory, Atlantic Ecology Division (AED), Narragansett ,RI. (Formerly USEPA Environmental Research Laboratory Narragansett)

University of New Hampshire Jackson Estuarine Laboratory (UNH-JEL), Durham, NH

University of New Hampshire Ocean Engineering Program (UNH-OEP), Durham, NH

University of Rhode Island Graduate School of Oceanography (URI-GSO), Narragansett, RI.

Science Applications International Corporation (SAIC), Narragansett, RI

Cemic Corporation, Narragansett, RI

Battelle Marine Sciences Laboratory (BMSL), Sequim, WA

DEFINE THE PROBLEM
(PROBLEM FORMULATION)

CONCEPTUAL MODEL

- Picture of our Understanding of How the Estuary Works
- Basis for Conducting the Investigation
- Framework of How Contaminants will Affect Ecosystem

ASSESSMENT AND MEASUREMENT ENDPOINTS

- What do we want to protect?

SITE DESCRIPTION

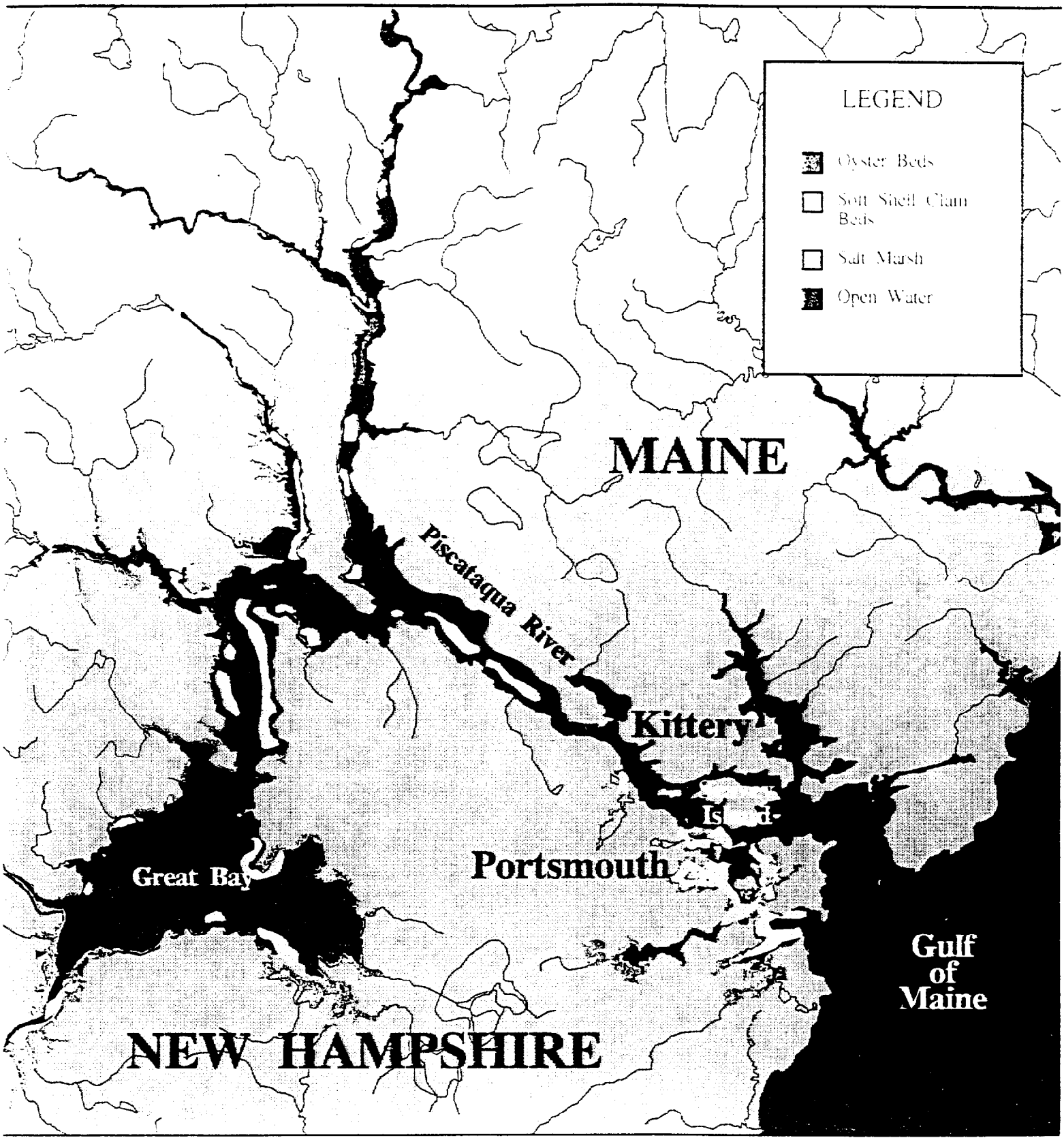
Physical Description

Hydrodynamics and Flushing

Sediment Distribution

Ecological Resources

Geographic Information System (GIS) slide of The Great Bay Eastuary showing coverages for natural resouces. Data obtained from the New Hampshire Geographic Information System (NHGIS 1995)


LEGEND
Oyster Beds
Soft Shell Clam Beds
Salt Marsh
Open Water
MAINE
Piscataqua River
Kittery
Portsmouth
Great Bay
Gulf of Maine
NEW HAMPSHIRE

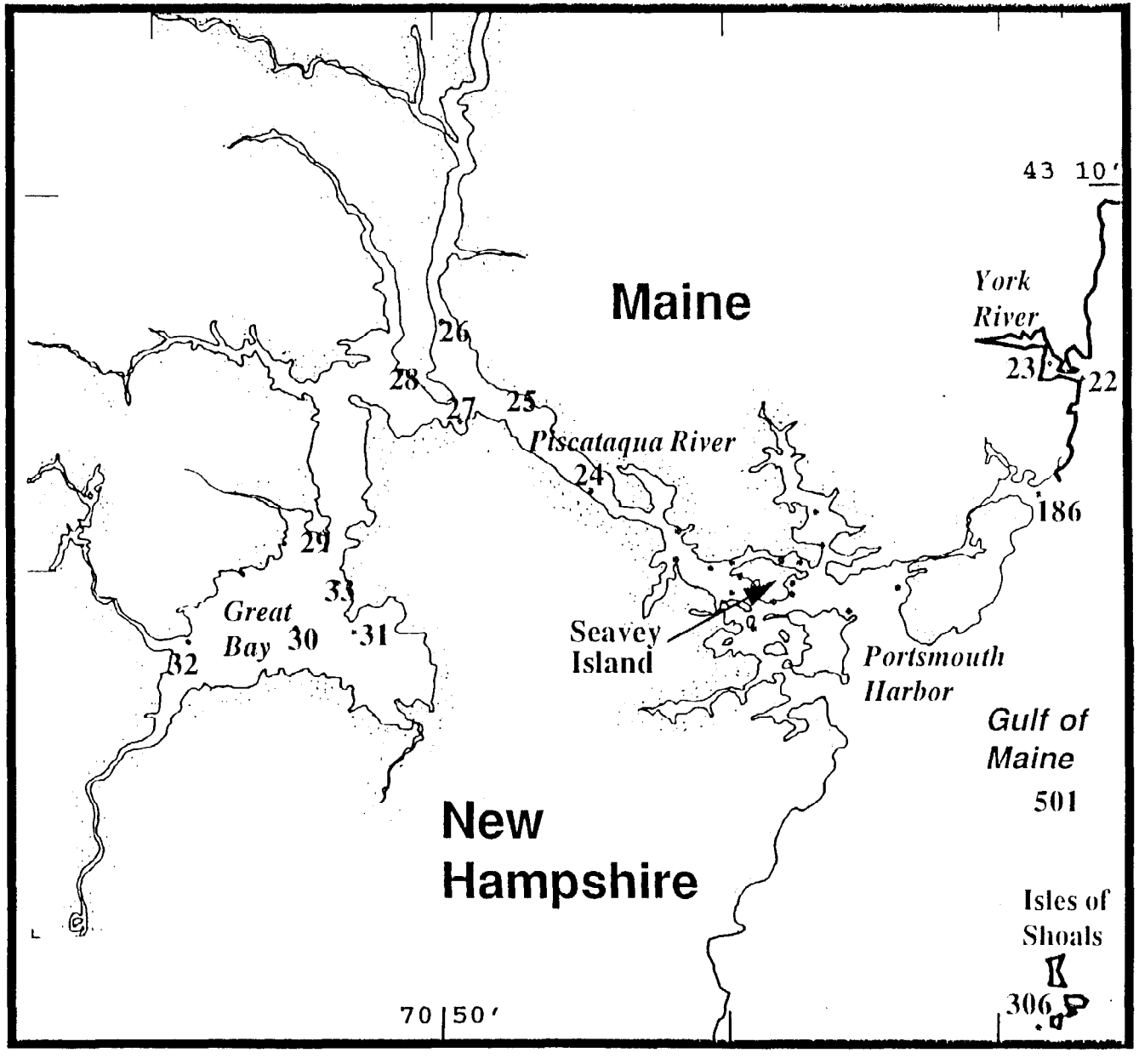


Figure 2-3. Station locations locations in the Great Bay Estuary and at reference locations in the York River, Isles of Shoals and the Gulf of Maine.

Water currents measured in the lower estuary from acoustic doppler current profiler (ADCP) meter measurements made by the Research Vessel (R/V) ECOS July 1992.

(1) Ebb tide surface currents.

(2) Flood tide surface currents.

(Chadwick, Katz, and Paterson 1993.)

Figure 5-1. Depth averaged currents measured around Seavey Island during ebb tide (a), low slack tide (b), flood tide (c), and high slack tide (d) (from Chadwick *et al.* 1993).

(a)

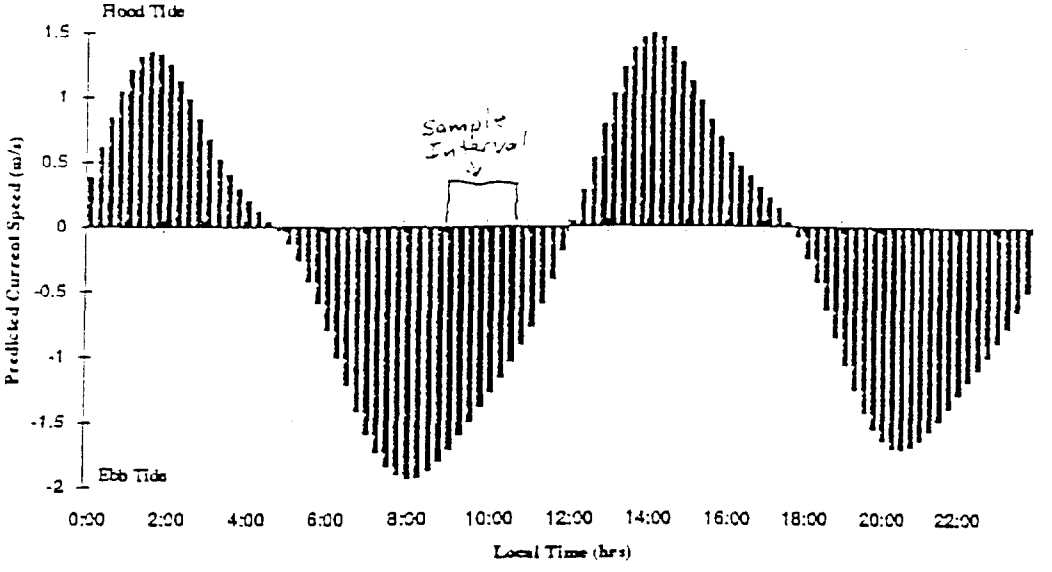


Figure 34. Predicted tide stage histogram, ebb tide.

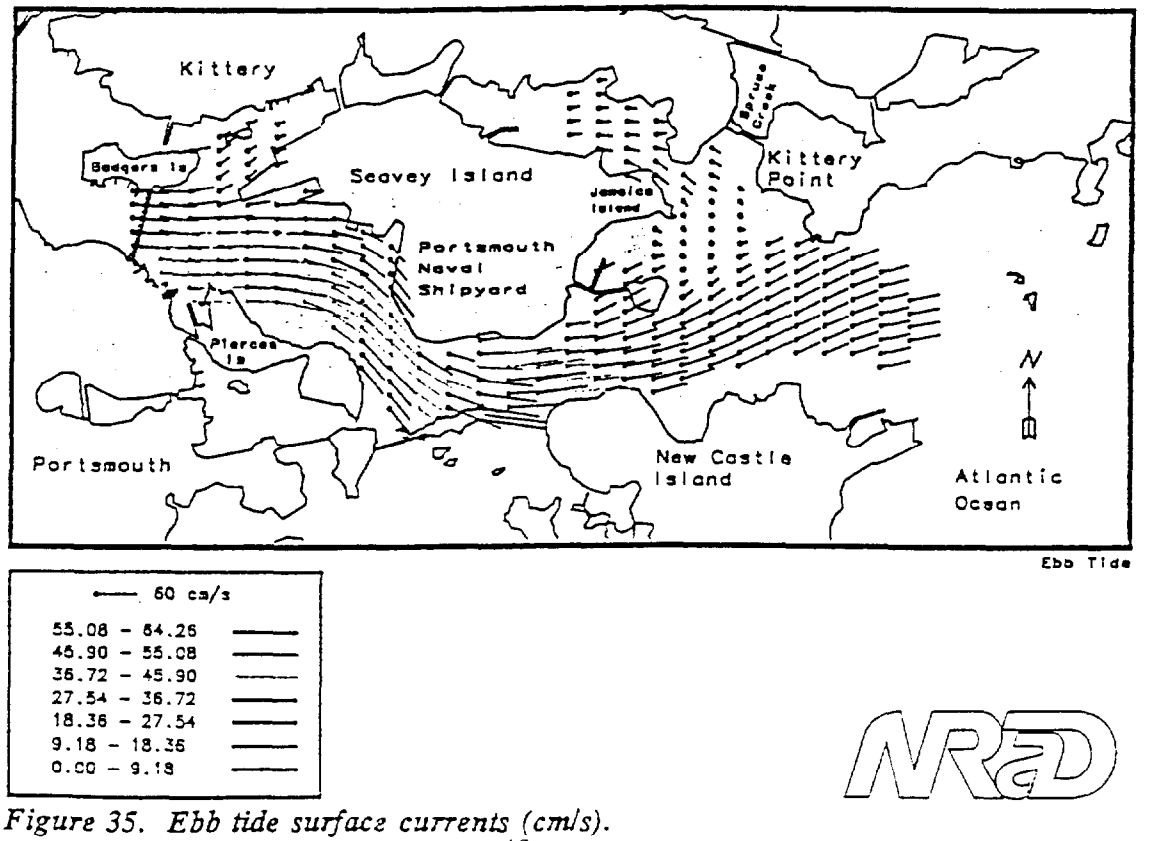


Figure 35. Ebb tide surface currents (cm/s).

Figure 5-1. Continued

(c)

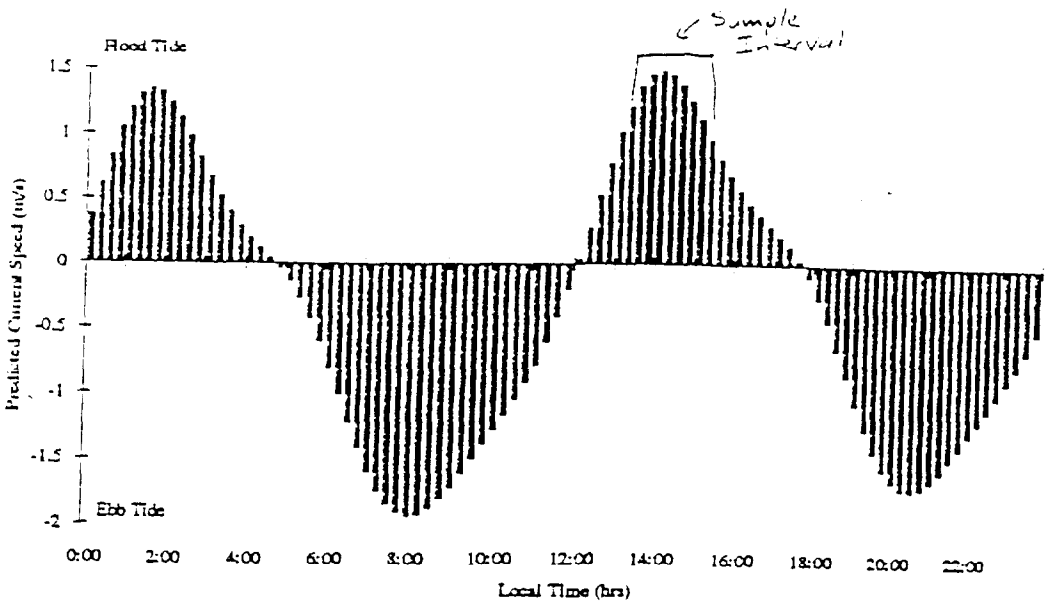


Figure 50. Predicted tide stage histogram, flood tide.

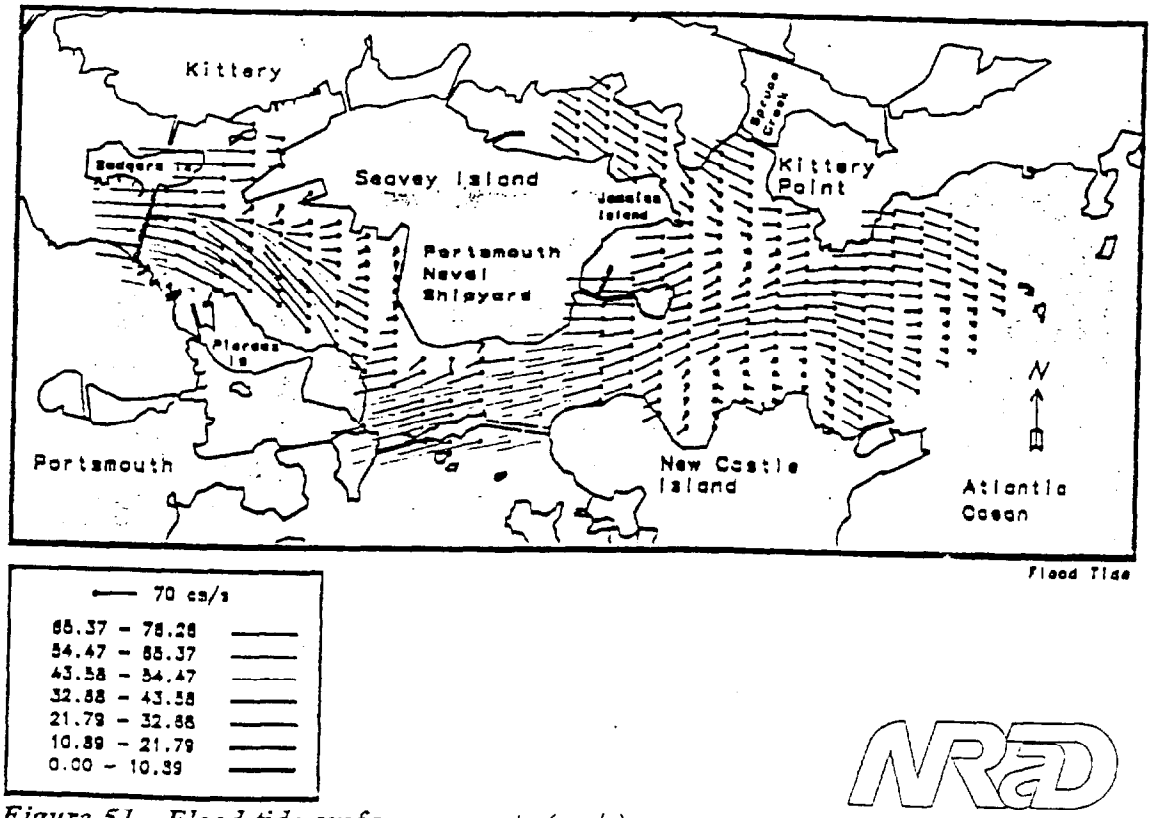


Figure 51. Flood tide surface currents (cm/s).

Sediment distribution map for lower estuary.

(1) Mouth of Portsmouth Harbor.

(2) Seavey Island and vicinity.

(Ward 1995.)

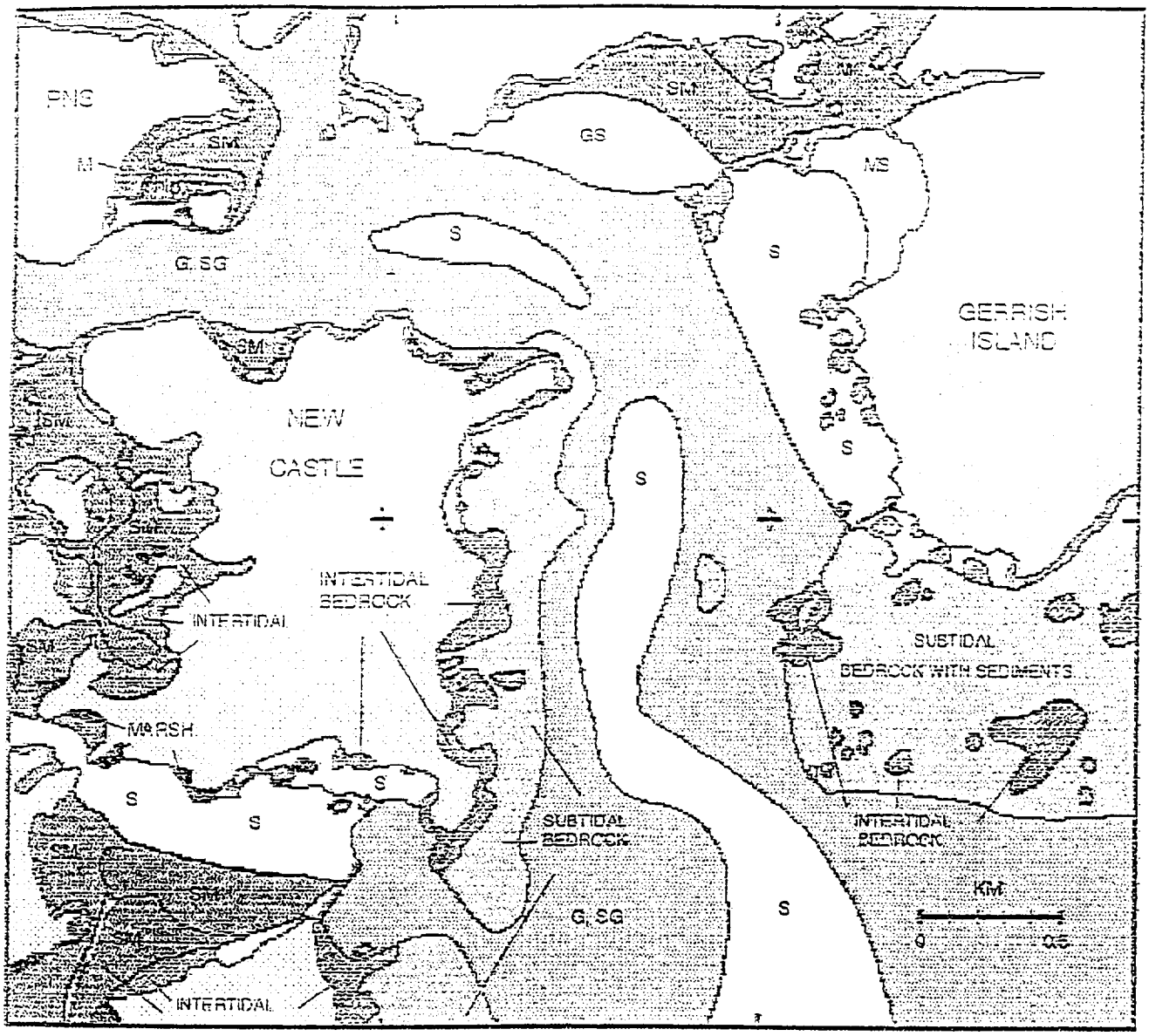


FIGURE 3-4 (continued).

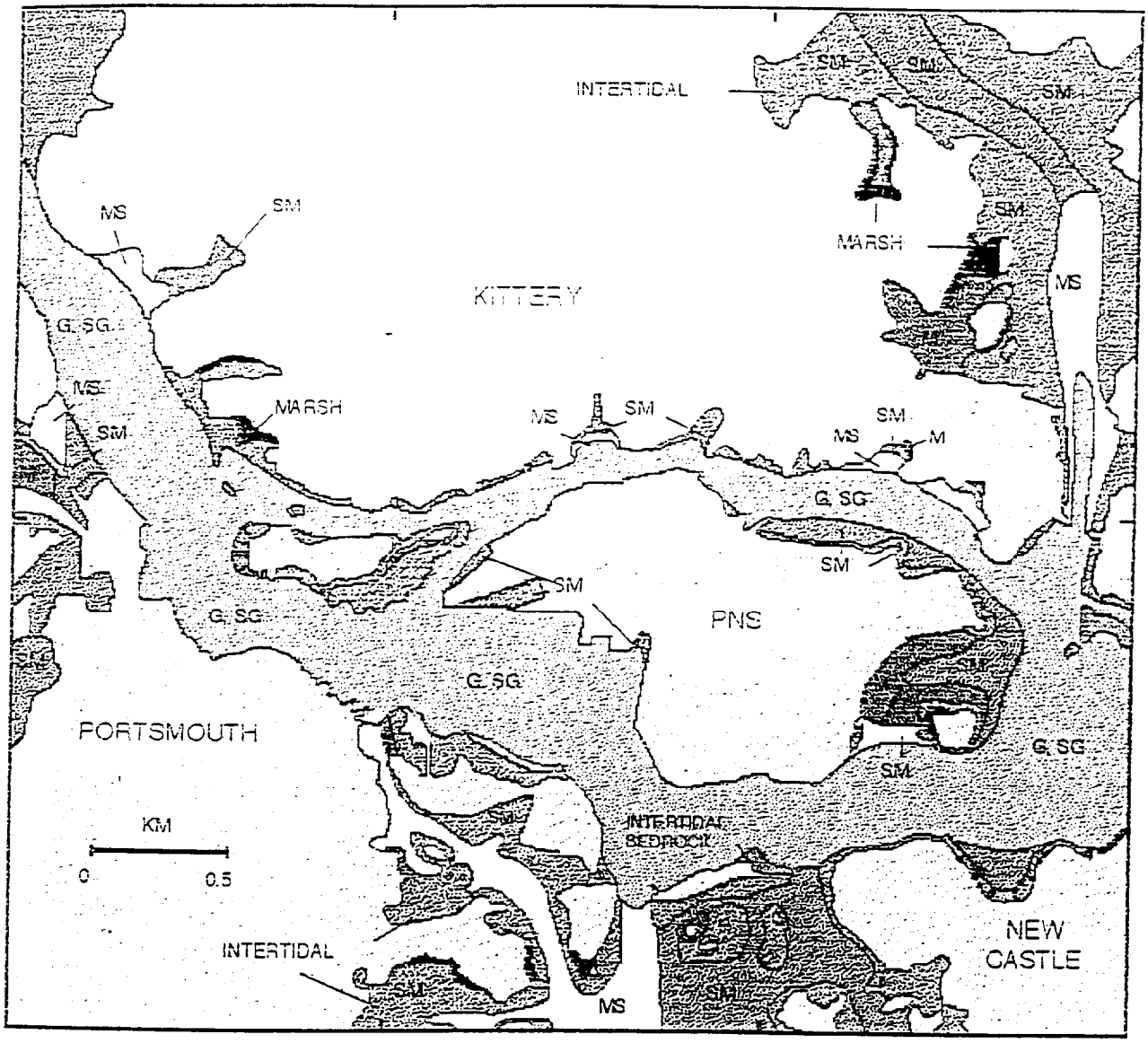
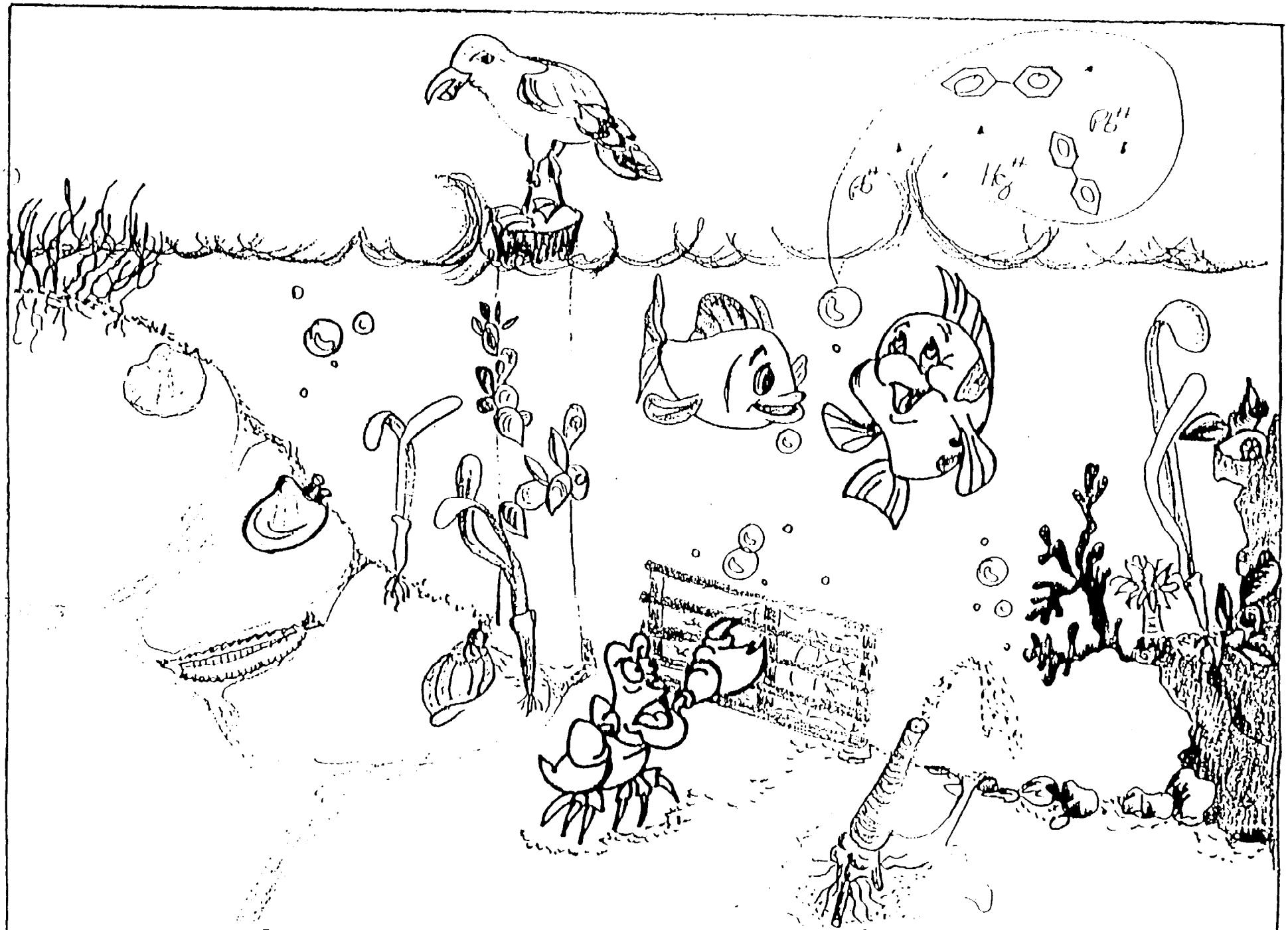
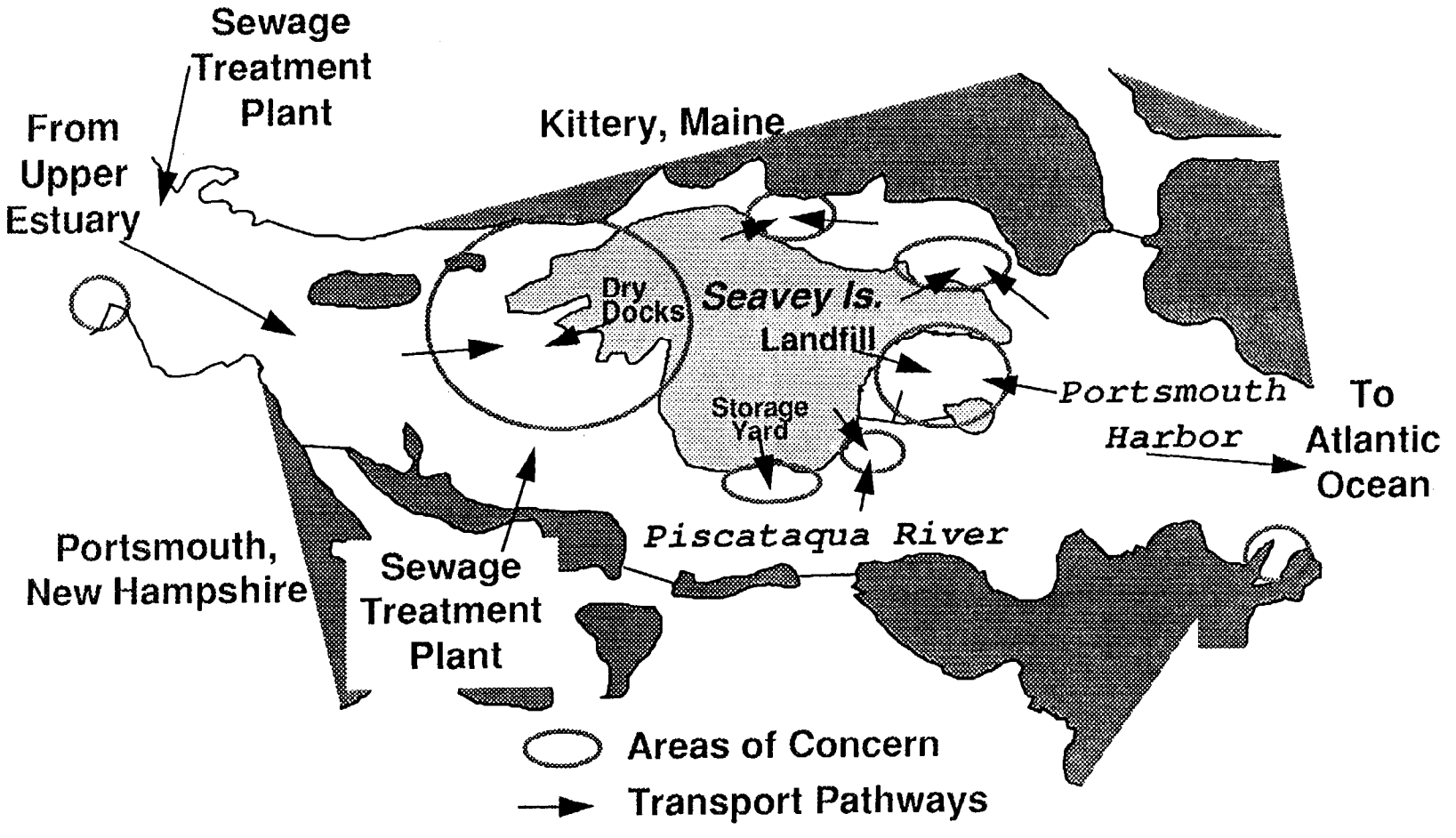


FIGURE 3-4. Distribution of sediment types in the lower Piscataqua River (from Ward 1994b). Abbreviations are G (gravel), SG (sandy gravel), MS (muddy sand), SM (sandy mud), and M (mud). See Ward 1994b for further detail.

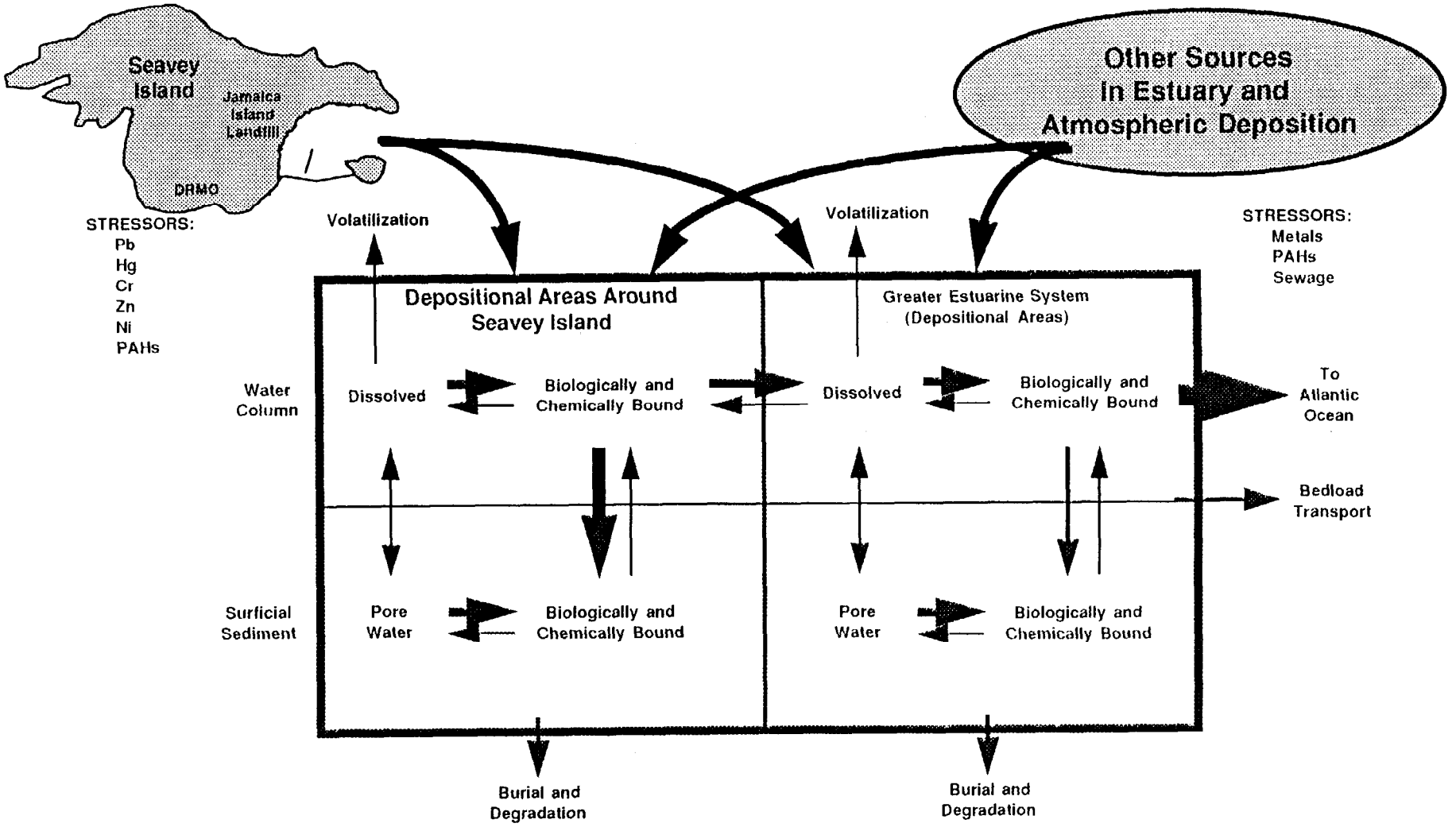


drawing of assessment endpoints

Areas of Concern from Conceptual Model



Detail of conceptual model.



DEFINE THE PROBLEM
CHEMICALS OF CONCERN (COCs)

Evaluate Contamination Levels in the Estuary

Determine Contamination Levels High Enough to Harm Estuarine Resources

Determine Chemicals that could be Linked to SWMUs

RESULT: COCs were selected for chemicals which showed an indication of being at harmful levels and were associated with SWMUs

Chemicals Measured

Heavy Metals
- Lead (Pb)
- Mercury (Hg)
- Nickel (Ni)
- Chromium (Cr)
- Copper (Cu)
- Zinc (Zn)
- Silver (Ag)

Arsenic (As)

Hydrocarbon Compounds (HC)
- Polycyclic Aromatic HC (PAH)
- Volatile Aromatic HCs (VOC)

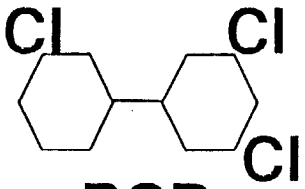
Chlorinated Compounds
- PolyChlorinated Biphenyls (PCB)
- Chlorinated Pesticides (DDT)

Butyltin Compounds (TBT)

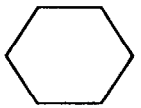
Methyl Mercury (CH_3-Hg)

Pb^{++}	Dissolved
PbS	Solid (Bound to Sulfur)

PAH

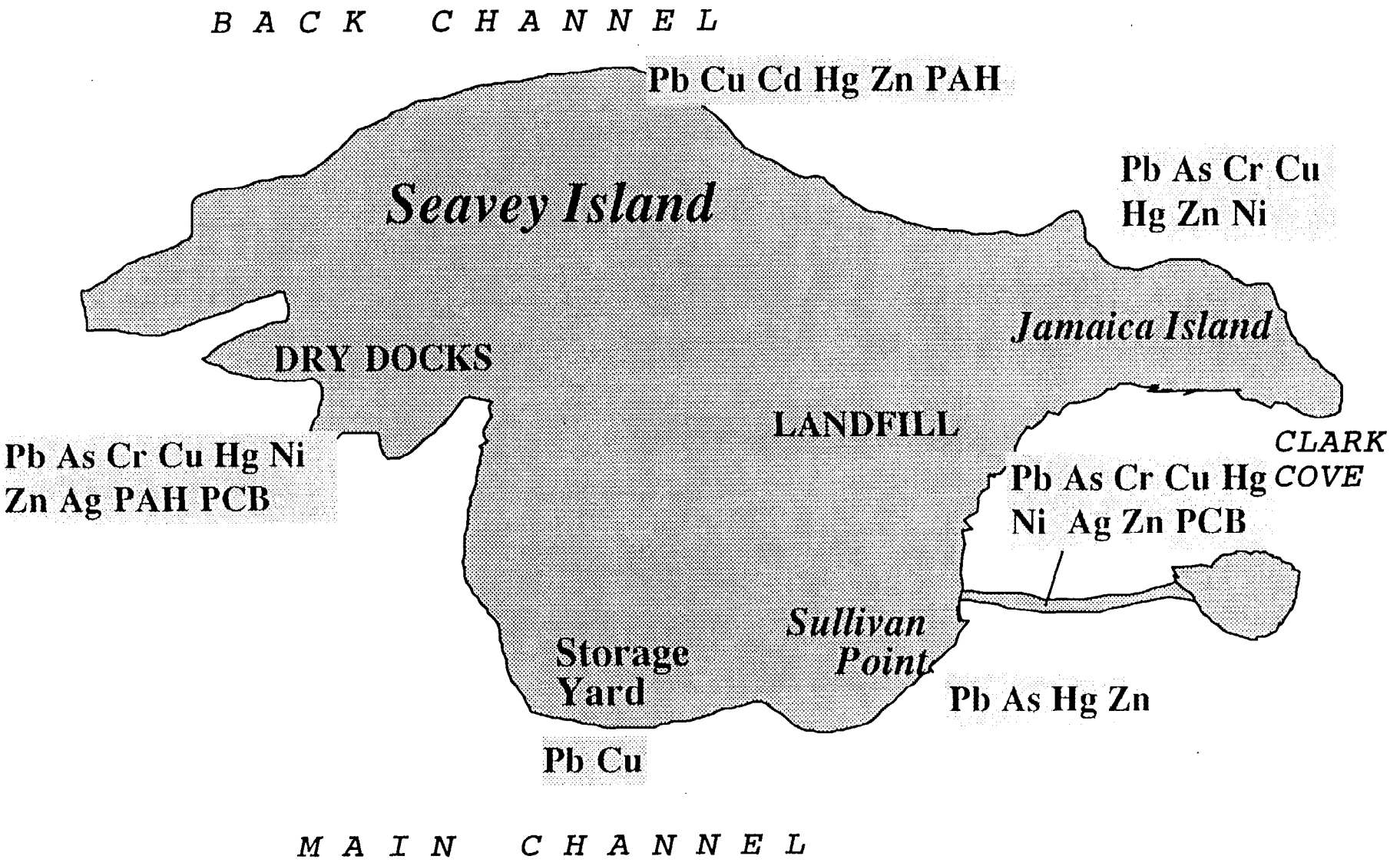


PCB



VOC (Benzene)

COCs and Areas of Concern



ECOSYSTEMS EVALUATED

Pelagic Species - Winter Flounder

Epibenthic Species - Mussels, Lobster, Winter Flounder, Rockweed Algae

Benthic Community - Invertebrates

Salt Marsh Community - Plants, Animals

Eelgrass Community - Eelgrass

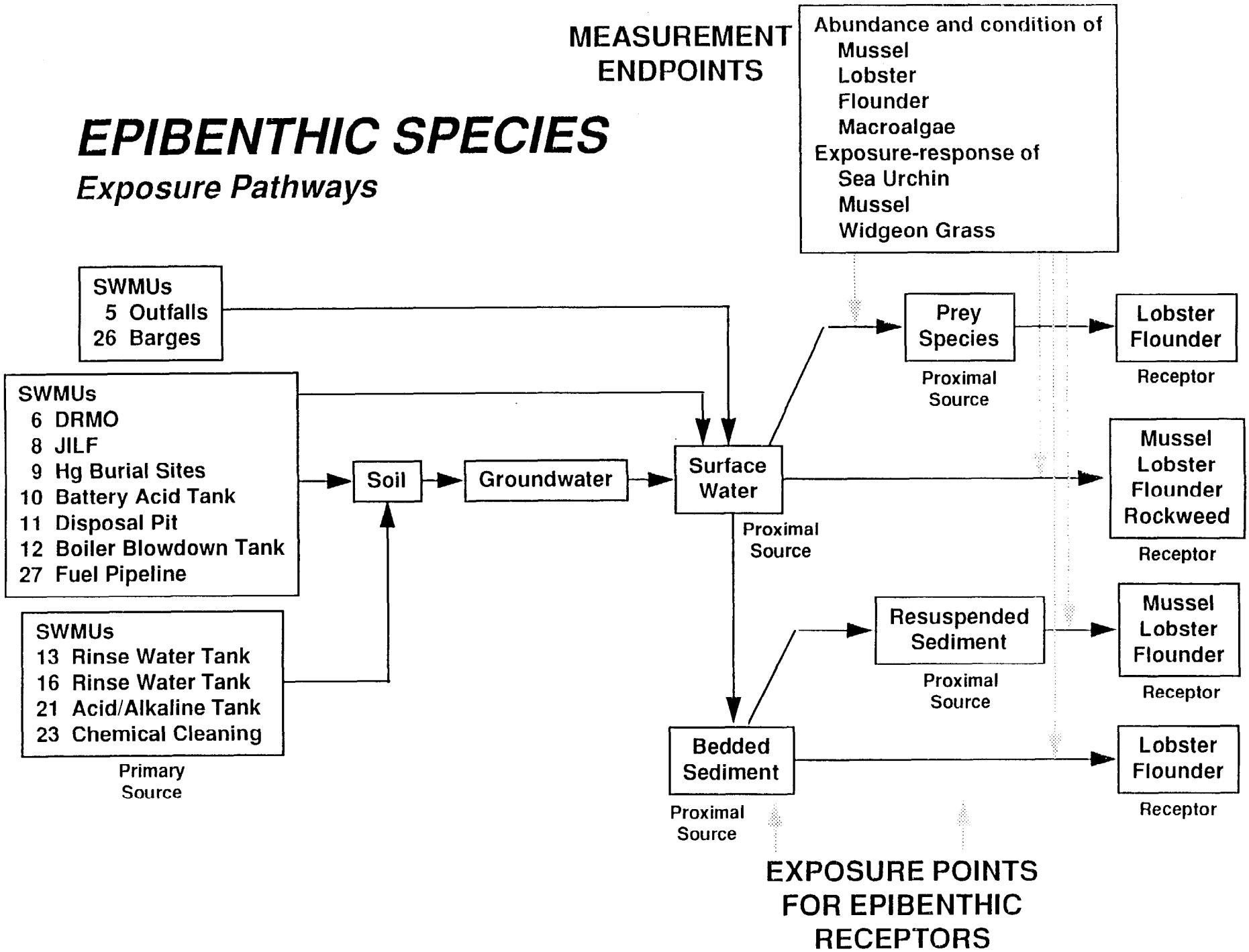
Herbivorous Waterfowl - Ducks

Avian Predators - Cormorant, Osprey

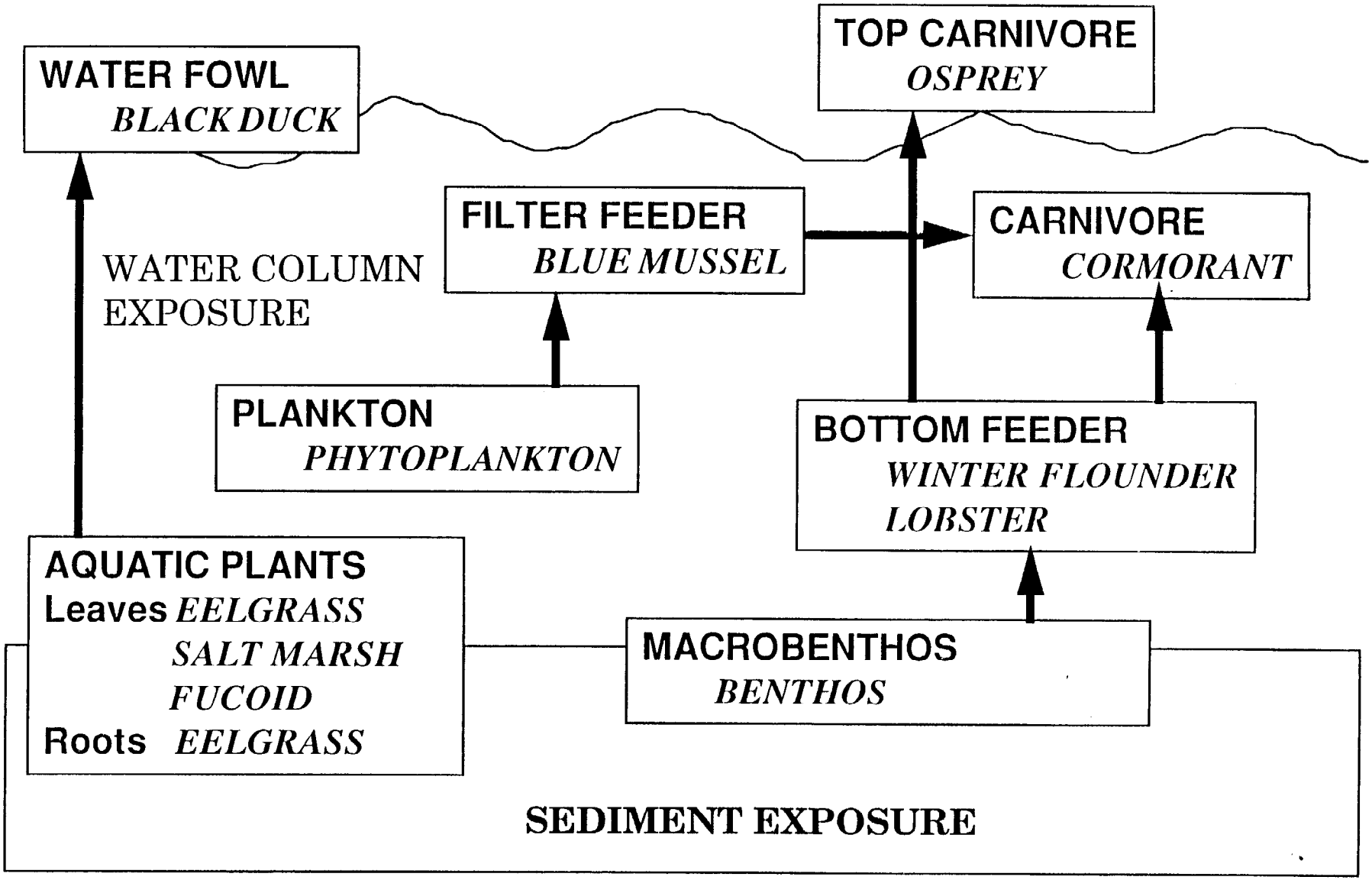
Trophic Transfer - Food Web

EPIBENTHIC SPECIES

Exposure Pathways



Simplified Food Web to Evaluate Chemical Accumulation in Food Chain



EXPOSURE ASSESSMENT (STRESS CHARACTERIZATION)

Measurement of Pollution Levels in:

- Water - River Water and Seeps
- Sediments - Grabs and Cores in Depositional Areas
- Biota - Flounder, Lobster, Mussels, Oysters, Eelgrass, Saltmarsh Plants, and Rock Weed

Measurements Made In Reference Areas and Near the Shipyard

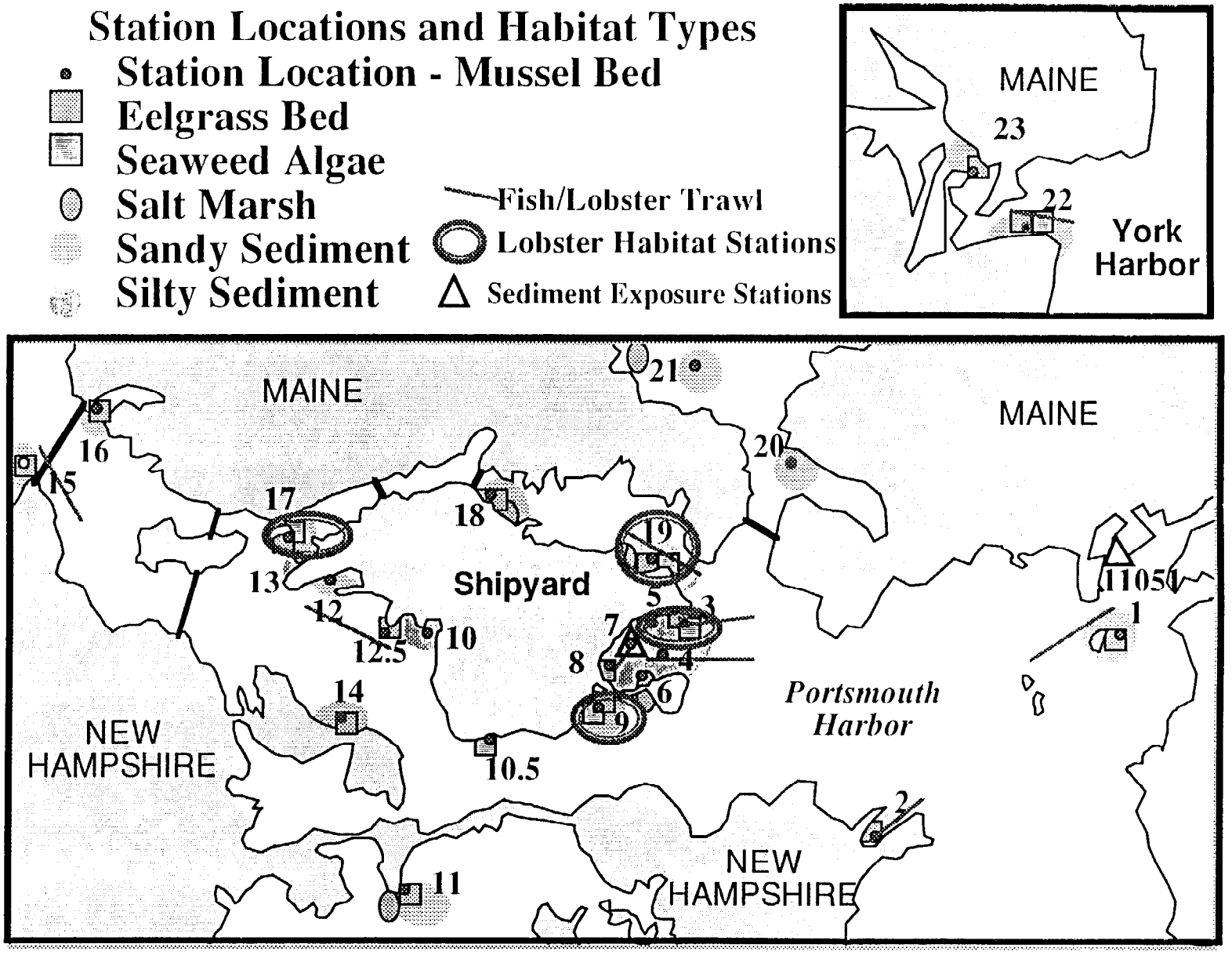


Figure 2-4. Station locations and habitat types in the lower Piscataqua River and York River.

EFFECTS ASSESSMENT
(EFFECTS CHARACTERIZATION)

- Known Effects of COCs from Literature
- Site-Specific Toxicity Evaluations
  - Sediment Toxicity
  - Water Toxicity
  - Laboratory Studies
    - Pb Toxicity to Sea Urchins, Mussels, Amphipods, and Widgeon Grass
    - Mussel Pb Bioaccumulation
- Criteria and Standards

EFFECTS ASSESSMENT (Cont.)

Benchmarks Derived From:

- Toxicity Values Derived from Effects Reported in the Literature
- Developed for Each Chemical and Receptor for Which Data Were Available
- Laboratory Studies of Site Specific Pb Toxicity

Example of the receptor-specific benchmark concentrations for Pb used in the risk assessment.

(MESO 1995)

Table 6-1. Receptor-specific effects concentrations (μg/L) for Shipyard CoCs - lead.

Receptor	Acute	Chronic	Effect
BLUE MUSSEL	476		larva 96-h LC50
	>500,000		adult 96-h LC50
	100		96-h LC50 - tetraethyl Pb
		500	150-d LC50
WINTER FLOUNDER	180,000		plaice (*Pleuronectes platessa*) 96-h LC50
PHYTOPLANKTON	>5,000		diatom (*Phaeodactylum tricornutum*) 96-h LC50
	100		diatom (*Phaeodactylum tricornutum*) 96-hr LC50
		10	12-d 100% growth inhabition of diatom (*Skeleton*
		207	reduced chlorophyl a in natural phytoplankton po
		21	reduced biomass in natural phytoplankton popula
LOBSTER	575		Dungeness crab (*Cancer magister*) 96-h LC50
		50	reduced enzyme activity in antennal gland after 3
EELGRASS			
FUCOIDS		20.3	no sexual reproduction and reduced female growt
		810	45% growth inhabition in fucoid alga (*Fucus ser*
BENTHOS	547		amphipod (*Ampelisca abdita*) 96-h LC50
	1,200		polychaete (*Capitella capitata*) 96-h LC50
		1,000	suppressed reproduction in polychaete (*Ctenodril.*
SALT MARSH			
BLACK DUCK		25,000 μg/Kg diet	no deaths, no pathologies in mallard (*Anas platy*
CORMORANT		50,000 μg/Kg diet	no adverse effects on survival, egg laying, fertiz kestrel (*Falco sparverius*)
OSPREY		50,000 μg/Kg diet	no adverse effects on survival, egg laying, fertiz kestrel (*Falco sparverius*)

EFFECTS ASSESSMENT (Cont.)

Benchmarks Derived From:

- Criteria and Standards:
  - Concentration Identified by Law, Regulation or Guidance
- Mussel Tissue Critical Values:
  - Estimated Mussel Tissue Level that Would Result from Exceeding Criteria, Standard, or Benchmark Water Concentration

RISK CHARACTERIZATION

Observations of Ecological Problems

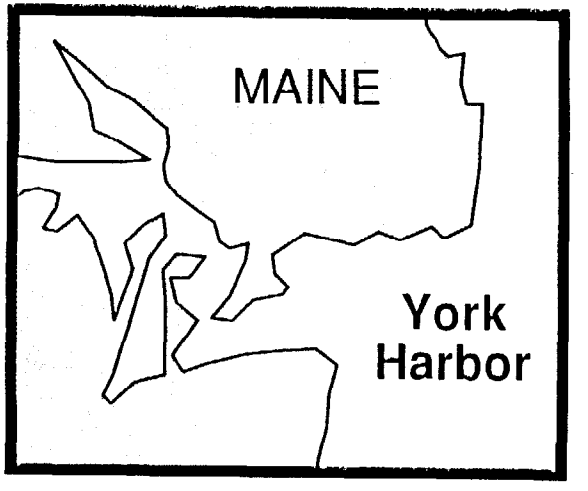
Bioaccumulation Levels

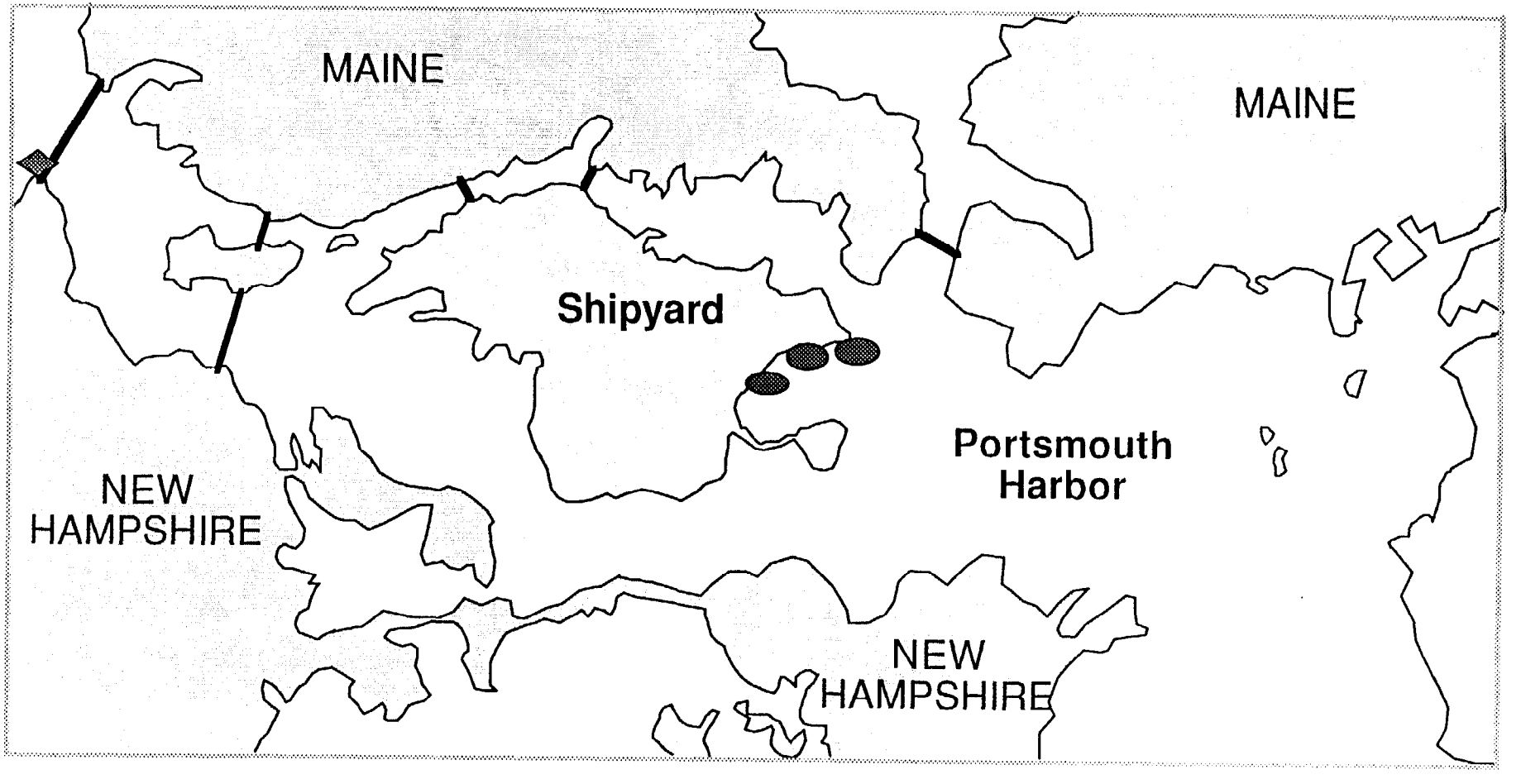
Probability of Exceeding Harmful Levels Based On:

- Direct Chemical Measurements
- Calculations of Sediment Pore Water Concentrations
- Mussel Tissue Critical Values

ECOLOGICAL PROBLEMS
Water Column Effects

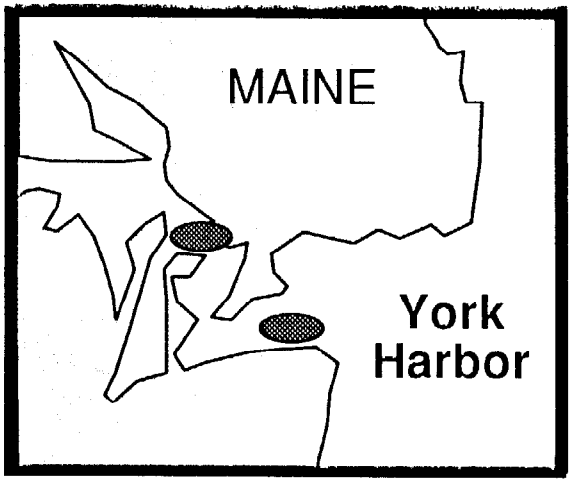
- Toxicity to Sea Urchin Sex Cells
- Stress on Mussel Growth

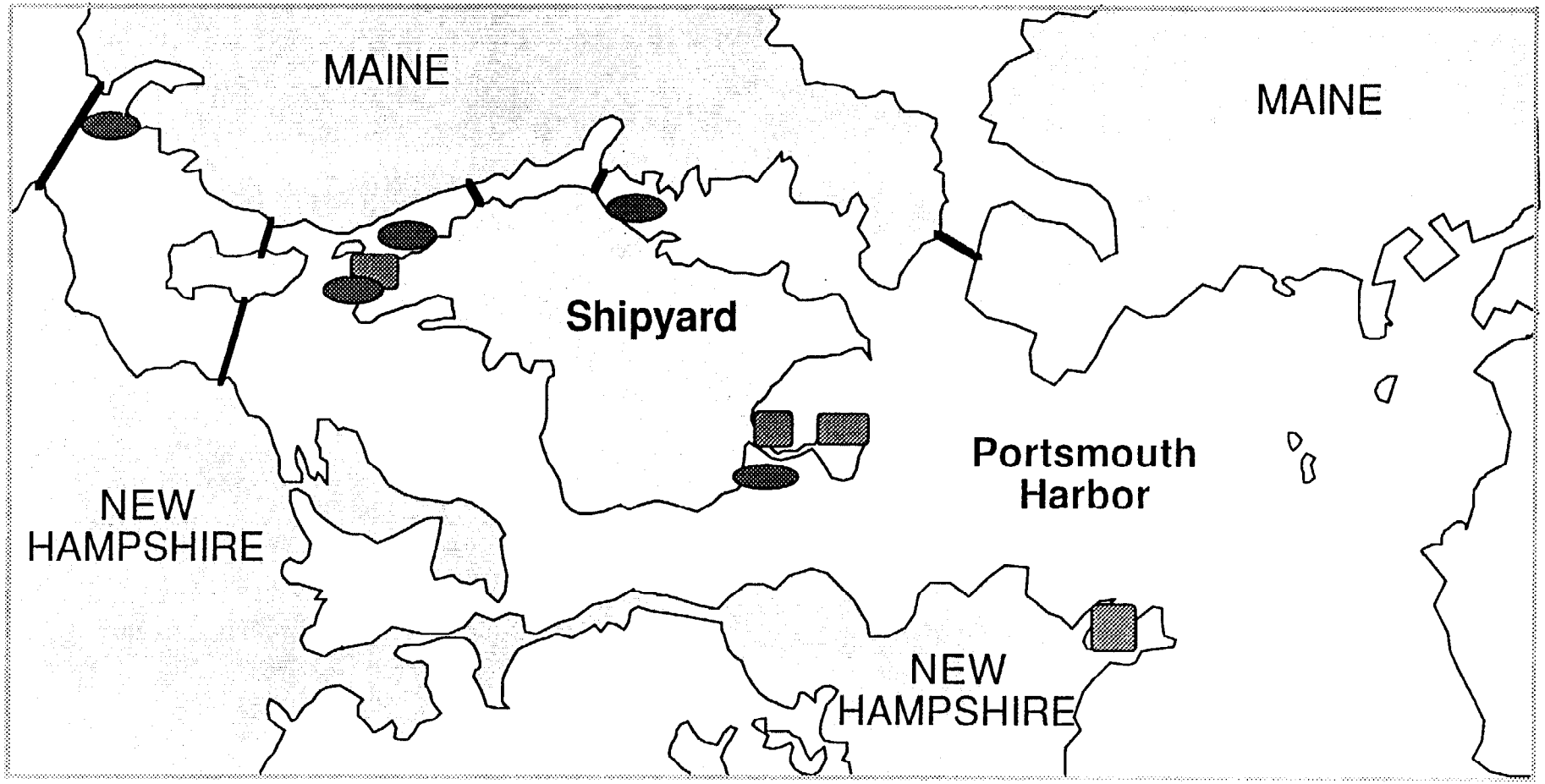




ECOLOGICAL PROBLEMS
Sediment Effects

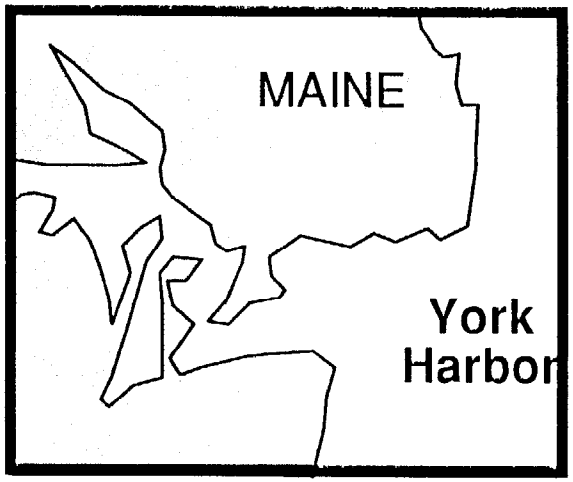
- Toxicity to Amphipods
- Effect on Bottom Organisms

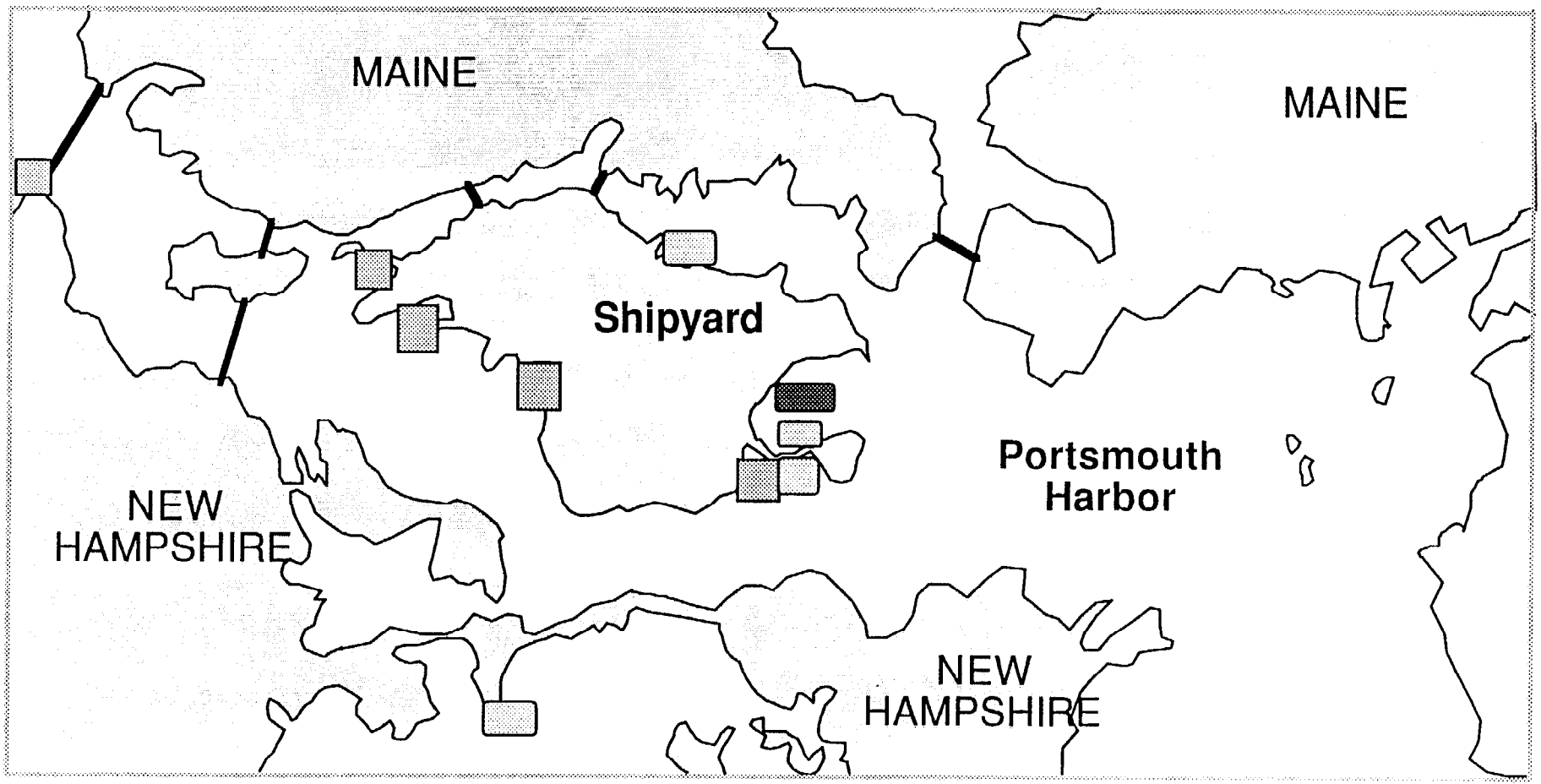




ECOLOGICAL PROBLEMS
Indication of Ecological Stress

- Salt Marsh Stress
- Eelgrass Absent
- High Microbial Contamination





SUMMARY OF SIGNIFICANT BIOACCUMULATION FINDINGS

Flounder	Chemical Levels Similar Between Gulf of Maine and Portsmouth Harbor;
	High Levels of Spleen Disorders
Lobster	Significant Differences between Age Classes (Juveniles Highest);
	No Difference between Isles of Shoals and Portsmouth Harbor Adults tail+claw
Mussel	Significantly Elevated Concentrations of Pb, Hg, and Cr
Eelgrass	Root Residues Proportional to Sediment for Hg, Pb, Cr, Ni, and Cu

PROBABILITY OF EXCEEDING BENCHMARKS

WATER COLUMN

- No Appreciable Risks Detected for Exposure to Surface Waters
- Seavey Island Seeps Had High Probability of Exceeding WQC

TROPHIC TRANSFER

- No Risks Detected for Dietary Exposure to Osprey, Cormorants, or Ducks

PROBABILITY OF EXCEEDING BENCHMARKS (Cont.)

SEDIMENT: Chemicals With Probability of Exceeding Probable Effects Levels (ER-M):

PCB, Pb, Ni, Cu, Zn, Hg

MUSSEL: Chemicals with Probability of Exceeding Mussel Tissue Critical Values:

Pb and Phenanthrene

PROBABILITY OF EXCEEDING BENCHMARKS (Cont.)

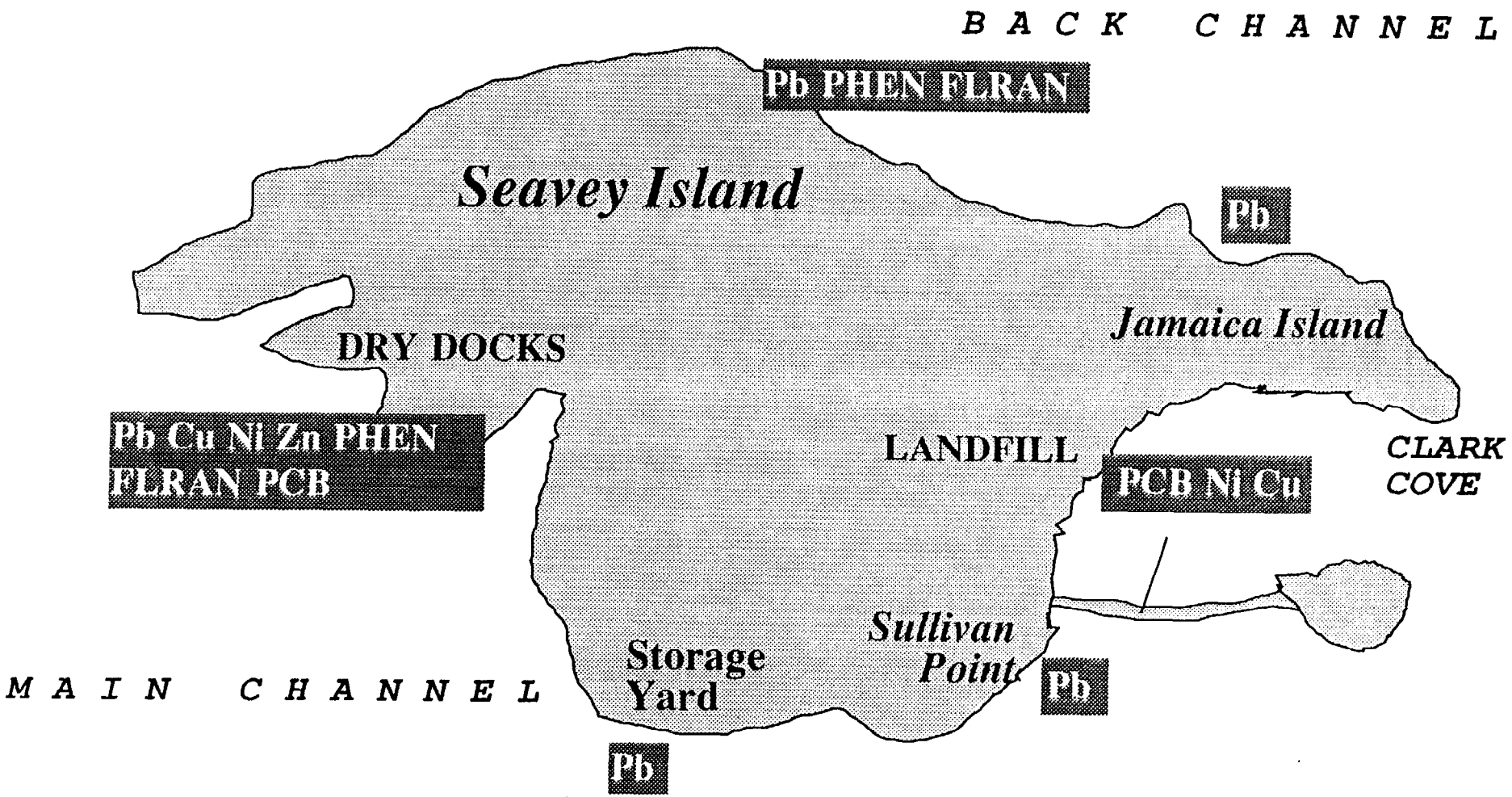
SEDIMENT PORE WATER:

<u>Metals:</u> Sulfide Binding Indicates Metals Not Available in Pore Water (Does not apply to As, Cr, and MeHg)

<u>Organics:</u> Compounds With Probability of Exceeding Water Quality Criteria:

Phenanthrene and Fluoranthene

CHEMICALS WITH PROBABILITY OF EXCEEDING BENCHMARKS



PISCATAQUA RIVER REFERENCE: Pb Zn Hg PHEN FLRAN

ALL STATIONS: Pb Ni Cu PHEN FLRAN PCB

ECOLOGICAL STATUS

Water Quality
- Excess Nutrients
- Sewage Input
- Significant Flushing in Estuary
- Transport Model for Pb Developed

Sediment Quality
- Depositional Areas Identified
- Sediment Distribution Measured
- Toxicity Detected
- Sewage Input
- Evidence of Runoff, Atmospheric, and Oil Inputs

ECOLOGICAL STATUS (Cont.)

- Pelagic Community
  - Primary Productivity Within Normal Limits
  - Flounder Residues Low But Evidence of Spleen Disorders
- Benthic Community
  - Within Normal Range for Piscataqua River
  - Evidence of Community Stress

ECOLOGICAL STATUS (Cont.)

Epibenthic Community

- Juvenile Lobster Very Abundant
- Important Lobster Nursery and Reproductive Habitat Delineated
- Mussel Density and Abundance Within Normal Range
- Rockweed Algae Within Normal Range

ECOLOGICAL STATUS (Cont.)

Eelgrass Community

- Abundance/Morphology Within Normal Range
- Excellent Habitat Quality Beneficial to Lobster
- Eelgrass Absent from Inner Clark Cove
- Inverse Relationship Between Pb Exposure and Eelgrass Root+Rhizome Biomass

Salt Marsh Community

- Good Habitat Value
- Indications of Ecological Stress

ECOLOGICAL STATUS (Cont.)

Herbivorous Water Fowl

- No Impact Calculated

Avian Predators

- No Impact Calculated

Trophic Transfer

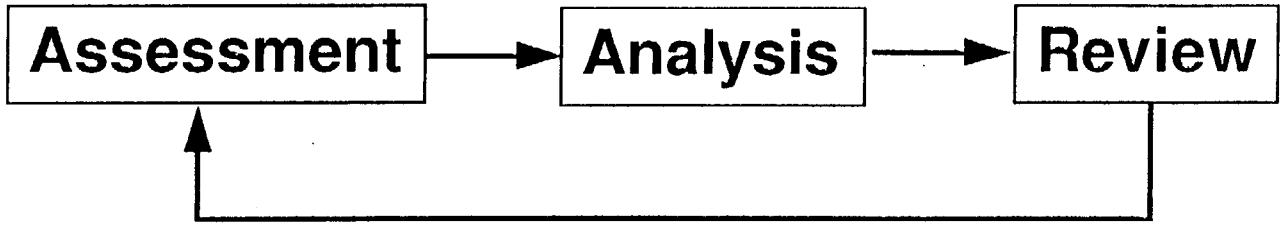
- Bioaccumulation Evident in Juvenile Lobster, Mussels, and Eelgrass

UNCERTAINTY ANALYSIS

SOURCES OF UNCERTAINTY

- Errors in Assumptions
- Errors in Analyses
- Errors in Measurements
- Natural Variation

ITERATIVE STUDY HAS SELF CORRECTING CAPABILITY



CONCLUSIONS

No Appreciable Risks Were Detected for:

- Exposure to River Water or
- Dietary Uptake by Birds

Risks of Exceeding Benchmarks Calculated for:

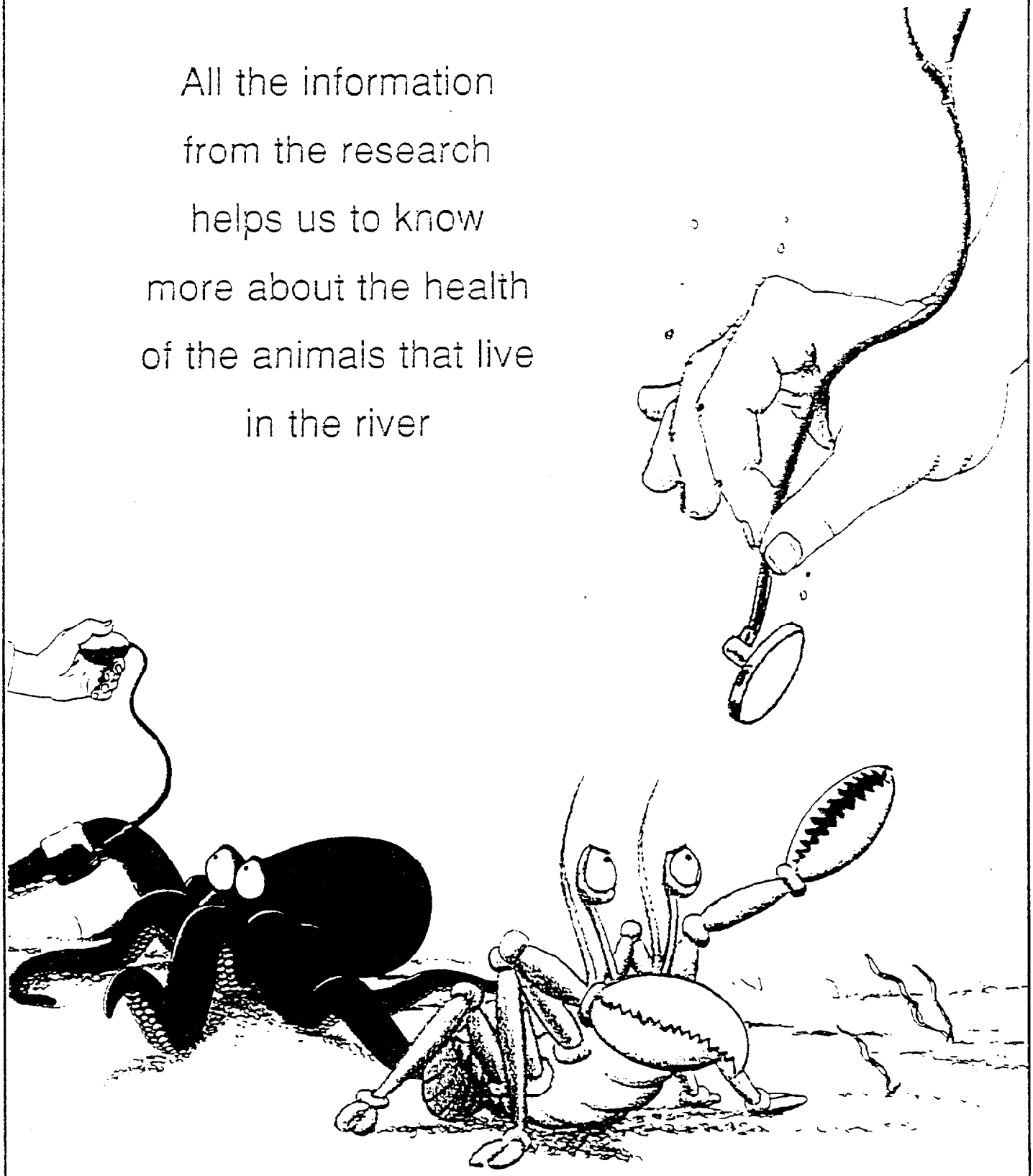
- Sediment Exposure - Pb, Ni, Cu, Zn, Hg, Phenanthrene, Fluoranthene, and PCB
- Mussel Tissue Accumulation- Pb, PHEN

Healthy and Productive Estuarine Habitats were Observed

Indications of Stress were Present.

Drawing by Bob Carignan.

All the information
from the research
helps us to know
more about the health
of the animals that live
in the river



DEPARTMENT OF THE NAVY
PORTSMOUTH NAVAL SHIPYARD
PORTSMOUTH, N.H. 03804-5000

IN REPLY REFER TO:

October 11, 1995

MEMORANDUM

FOR THE MEMBERS OF THE RESTORATION ADVISORY BOARD (RAB) CERCLA REMEDIAL ACTION PROGRAM, PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE

The next RAB meeting will be held on Thursday October 19, 1995 at Portsmouth City Hall in Portsmouth, NH. We will be presenting the Estuarine Ecological Risk Assessment. Your participation is greatly appreciated. If you cannot attend the meeting please call me at 207-438-3830. I look forward to seeing you again.

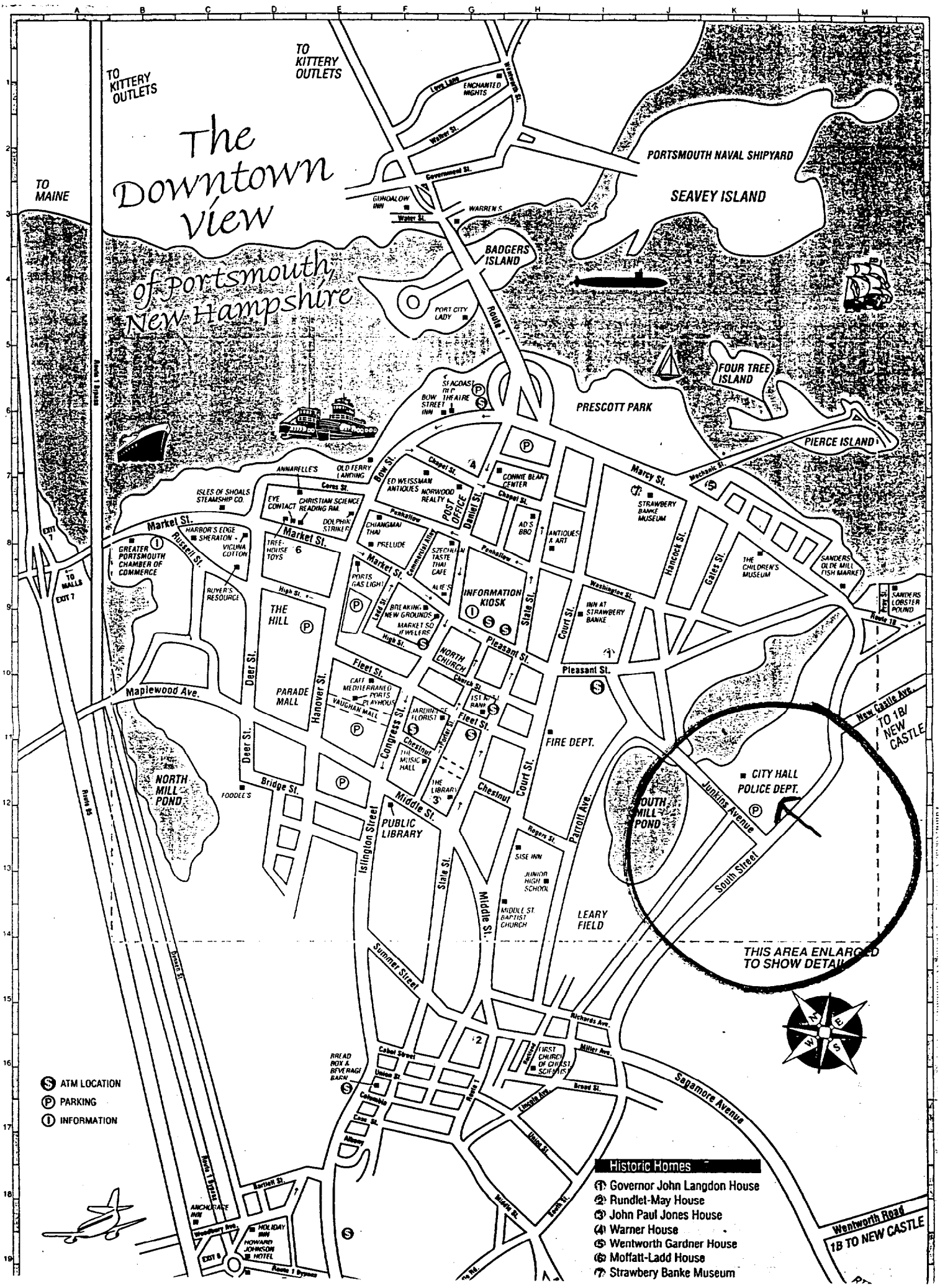
Sincerely,

Ken

Ken Plaisted
Navy Co-Chairman
Restoration Advisory Board

Distribution:

Juanita Bell
Doug Bogen
Jeff Clifford
Michele Dionne
Eileen Foley
Mary Marshall
Phil McCarthy
Jack McKenna
John Nelson
Guy Petty
Onil Roy
Cathy Wolff
EPA Region I (M. Cassidy)
MEDEP (N. Beardsley)
NOAA (K. Finkelstein)
MEDMR (D. Card)
USFWS (K. Munney)
North Div (J. Conroy)
COMSUBGRU TWO (R. Jones)
Portsmouth Naval Shipyard (Codes 120, 121, 121.10, 122.4, 100PAO, 105, 105.5, NRRO)
Brown and Root (B. Horne, L. Klink)


The Downtown View of Portsmouth, New Hampshire
TO KITTERY OUTLETS
TO KITTERY OUTLETS
TO MAINE
PORTSMOUTH NAVAL SHIPYARD
SEAVEY ISLAND
BADGERS ISLAND
FOUR TREE ISLAND
PRESCOTT PARK
PIERCE ISLAND
ENCHANTED NIGHTS
GUNDALOW INN
WARREN'S
PORT CITY LADY
SEACOAST OLD THEATRE
BOW STREET INN
ANNABELLE'S
OLD FERRY LANDING
ISLES OF SHOALS STEAMSHIP CO.
EYE CONTACT
CHRISTIAN SCIENCE READING RM.
DOLPHIN STRIKER
ED WEISSMAN ANTIQUES
NORWOOD REALTY
POST OFFICE
CONNIE BEAR CENTER
AD'S BBQ
ANTIQUES & ART
STRAWBERY BANKE MUSEUM
THE CHILDREN'S MUSEUM
SANDERS OLDE MILL FISH MARKET
SANDERS LOBSTER POUND
GREATER PORTSMOUTH CHAMBER OF COMMERCE
HARBOR'S EDGE
SHERATON
VICUNA COTTON
TREE-HOUSE TOYS
CHIANGMAI THAI
PRELUDE
SZECHUAN TASTE THAI CAFE
ALIE'S
PORTS GAS LIGHT
BREAKING NEW GROUNDS
MARKET SQ. JEWELERS
INFORMATION KIOSK
INN AT STRAWBERY BANKE
NORTH CHURCH
THE HILL
PARADE MALL
CAFE MEDITERRANEO
PORTS PLAYHOUSE
VAUGHAN MALL
JARDINIERE FLORIST
1ST NAT'L BANK
FIRE DEPT.
THE MUSIC HALL
THE LIBRARY
PUBLIC LIBRARY
NORTH MILL POND
FOODEE'S
SOUTH MILL POND
CITY HALL
POLICE DEPT.
SISE INN
JUNIOR HIGH SCHOOL
MIDDLE ST. BAPTIST CHURCH
LEARY FIELD
THIS AREA ENLARGED TO SHOW DETAIL
TO 1B/ NEW CASTLE
BREAD BOX & BEVERAGE BARN
FIRST CHURCH OF CHRIST SCIENTIST
ANCHORAGE INN
HOLIDAY INN
HOWARD JOHNSON HOTEL
Market St.
Russell St.
Deer St.
Hanover St.
Maplewood Ave.
Bridge St.
Islington Street
Congress St.
Middle St.
State St.
Court St.
Pleasant St.
Fleet St.
Chestnut
Summer Street
Parrott Ave.
Junkins Avenue
South Street
New Castle Ave.
Sagamore Avenue
Wentworth Road
1B TO NEW CASTLE
Route 1
Route 1 Bypass
Route 95
Route 1B
Route 1 Bypass
Route 1 Bypass
Route 1
Route 1
Route 1B
Marcy St.
Mechanic St.
Hancock St.
Gates St.
Washington St.
Pleasant St.
Chapel St.
Daniel St.
Penhallow
Commercial Alley
Bow St.
Cores St.
Lewis Lane
Walker St.
Government St.
Water St.
Wentworth St.
Dennett St.
Bartlett St.
Woodbury Ave.
Cabot Street
Union St.
Columbia
Cass St.
Albany
Richards Ave.
Miller Ave.
Broad St.
Lincoln Ave.
Rogers St.
Church St.
Porter St.
Lady St.
High St.
Chestnut
Middle St.
South St.
Union St.
Middle St.
EXIT 7
EXIT 8
TO MALLS
ATM LOCATION
PARKING
INFORMATION
Historic Homes
1 Governor John Langdon House
2 Rundlet-May House
3 John Paul Jones House
4 Warner House
5 Wentworth Gardner House
6 Moffatt-Ladd House
7 Strawbery Banke Museum