BUZZARDS BAY

Comprehensive Conservation and Management Plan

Volume III

Monitoring Plan

BUZZARDS BAY PROJECT

U. S . Environmental Protection Agency

Massachusetts Executive Office of Environmental Affairs

Final 8/91

Acknowledgements

Most of this volume was prepared for the Buzzards Bay Project by Science Applications International Corporation (SAIC) through a contract with the Massachusetts Executive Office of Environmental Affairs (EOEA). Mention of trade names or products does not represent an endorsement by the Commonwealth of Massachusetts or the U.S. Environmental Protection Agency.

SAIC would like to acknowledge input and helpful information on monitoring activities provided by the Buzzards Bay Project, Massachusetts Division of Marine Fisheries, Massachusetts Department of Environmental Protection, the U.S. EPA (Region 1), the U.S. Army Corps of Engineers New England Division, various citizen's groups, and Dr. Jefferson T. Turner of Southeastern Massachusetts University.

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The Buzzards Bay Project modified or supplemented the contents of the original monitoring plan developed by SAIC to make it consistent with Volume I and the goals of the Buzzards Bay Project.

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List of Acronyms

BBP	Buzzards Bay Project
CCMP	Comprehensive Conservation and Management Plan
CHN	Carbon, hydrogen, nitrogen
CVAAS	Cold Vapor Atomic Absorption Spectrometry
DAMOS	Disposal Area Monitoring System
DEP	Massachusetts Department of Environmental Protection
DIN	Dissolved inorganic nitrogen
DMF	Massachusetts Division of Marine Fisheries
DO	Dissolved oxygen
DWPC	DEP, Division of Water Pollution Control
EOEA	Massachusetts Executive Office of Environmental Affairs
EMAP	Environmental Monitoring and Assessment Program
EPA	U.S. Environmental Protection Agency
GFAAS	Graphite Furnace Atomic Absorption Spectrometry
GIS	Geographic Information System
ICPES	Inductively Coupled Plasma Emission Spectrometry
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
PCB	Polychlorinated biphenyls
PON	Particulate organic nitrogen
RPD	Redox Potential Discontinuity
SAIC	Science Applications International Corporation
TBT	Tributyl tin
TOC	Total organic carbon
USACE	U.S. Army Corps of Engineers
WHOI	Woods Hole Oceanographic Institution

Monitoring Buzzards Bay: A Framework for Action

Buzzards Bay, located between Cape Cod and southeastern Massachusetts, serves as a transportation corridor for ships and barges, a vacationland for tourists, a site for businesses and industries, and a home for the more than 230,000 residents of the 17 municipalities within the watershed.

Residential, commercial, and industrial use of Buzzards Bay and its watershed have put pressures upon the region—pressures that left unchecked may threaten the marine environment and public health. Consequently, the Buzzards Bay Project (BBP), under joint management of the U.S. Environmental Protection Agency (EPA) and the Massachusetts Executive Office of Environmental Affairs (EOEA), has identified and researched priority water quality problems in Buzzards Bay. The BBP has developed the Buzzards Bay Comprehensive Conservation and Management Plan (CCMP) for the future protection of resources and human health. Management recommendations are contained in Volume 1 of the CCMP. A Financial Plan is contained in Volume 2 and this Monitoring Plan is the third volume of the CCMP.

Priority Issues

The Management Plan identified three priority pollution problems:

- Health risks and closure of shellfish beds due to pathogen and fecal coliform contamination associated with the improper treatment or disposal of human wastes and other coliform and pathogen sources.
- Excessive nutrient inputs to the bay and their potential for causing water quality degradation and loss of habitat.
- Contamination of fish, lobster, and shellfish by toxic substances and the effects of this contamination on human health and the environment.

The Management Plan also identifies loss of habitat through physical disturbances as a major concern for Buzzards Bay.

Various action plans have been developed to mitigate these problems. Actions included in the plan are listed in Figure 1. Some of the problems and actions identified and presented are not addressed by this Monitoring Plan. Monitoring the effectiveness of management actions on some of these issues, for example, planning for a shifting shoreline or evaluating utilization of boat pump-out facilities, are best addressed by documenting the adoption of new regulations or documenting changes in public behavior rather than monitoring water quality or living resources. For example, it is too costly to document site- specific improvements due to construction and use of boat pump-out facilities. We have found sufficient studies conducted elsewhere that have involved continuous monitoring that show such water quality improvements can occur. We believe that implementing these kinds of costly monitoring efforts as part of a routine monitoring program is unwise. Instead, it is sufficient to merely document the amount of pollution which is prevented from entering the environment. For the most part, this monitoring plan focuses on monitoring of water quality, habitat, and living resources which is appropriate to evaluate specific management actions.

Monitoring in Coastal Embayments and the Open Bay

Because the problems in Buzzards Bay often are different in local embayments from those in the open bay, this monitoring plan includes monitoring strategies specific to coastal embayments as well as the open bay. Embayments, such as the Westport River, Mattapoisett Harbor, Wareham River, and Buttermilk Bay are already adversely affected by pollutants. Closure of shellfish beds, high fecal coliform counts, and excessive nitrogen loading are of special management concern in many Buzzards Bay embayments. Figure 1 outlines the CCMP Action Recommendations for Buzzards Bay.

High levels of polychlorinated biphenyls (PCBs) and metals in the inner portions of New Bedford Harbor appear to be the greatest threat to water and sediment quality (and potentially to public health) from toxic

MANAGING NITROGEN-SENSITIVE EMBAYMENTS

Municipalities should adopt nitrogen loading bylaws or health regulations to implement nitrogen management program.
DEP should regulate cumulative impacts of nitrogen from nonpoint sources by developing nitrogen-specific criteria for state water quality standards.
DEP should actively promote the development and acceptance of alternative, cost-effective technologies for denitrification.

PROTECTION AND ENHANCEMENT OF SHELLFISH RESOURCES

Local municipalities should correct identified sources of coliforms and pathogens entering the Bay.
EOEA should increase funding to carry out the Shellfish Sanitation Program.
Local communities should designate an individual with public health responsibility to assist DMF in classifying shellfish areas within their respective jurisdictions.
DMF and the municipalities should work together to increase the number of conditionally approved shellfish areas.
EPA and FDA should develop a new indicator or suite of indicators to replace fecal coliforms as an indicator of human-health risk.
The Legislature should pass House 1755 to improve financial assistance at the local level.
DMF should develop standard methods for towns to report commercial and recreational catch data as a first step in monitoring resource utilization or losses.

STORMWATER RUNOFF

Each Buzzards Bay community should adopt subdivision bylaws that require that best management practices for stormwater runoff be incorporated into any new development plans.
Each Buzzards Bay community should implement best management practices for storm drains that are currently contributing to shellfish bed closures.
EOEA should provide funding for local stormwater remediation projects.
The State DPW should eliminate the exemption for bridge work and road widening from review by local conservation commissions.

MANAGING BOAT WASTE

Boards of Health should require the installation of pumpout facilities at all marinas.
DEP and CZM should ensure that all marinas have adequate pumpout facilities.
EOEA should implement a policy assuring adequate treatment for sewage pumped from boats.
CZM should develop a policy to eliminate toxic additives in marine sanitation devices.
CZM should petition EPA to designate Buzzards Bay as a no-discharge zone.

MANAGEMENT OF ON-SITE SYSTEMS

DEP should amend the Title 5 Code so that it becomes a more comprehensive environmental regulation.
DEP should elevate the priority of the Title 5 program.
All boards of health should employ a full-time qualified health agent.
All boards of health should adopt a series of regulations that address the placement of septic systems in special resource areas.
All boards of health should amend their regulations to increase the septic system setback distances from resource areas to account for virus transport.

OIL POLLUTION PREVENTION

CZM should provide technical assistance to Buzzards Bay communities to develop contingency plans in each municipality.
BBAC should develop a regional strategy for responding to oil spills and ensure its adoption by all towns.
All levels of government should adopt a policy to minimize or reduce oil entering the Bay.
The State should develop a policy for the use of dispersants in Buzzards Bay during oil spill events.
DEP should adopt a policy for treating stormwater by requiring oil and gas traps, absorbent pads, and regular catch basin maintenance programs.
Buzzards Bay communities should adopt regulations requiring booms around any vessel during fuel loading.

WETLANDS AND MARINE-HABITAT PROTECTION

DEP should amend the regulations to the Wetlands Protection Act to better protect wetlands.
Conservation commissions should upgrade their ability to protect wetlands.
All town boards as well as local environmental organizations should assist in protecting wetlands.
DEP should expand implementation of the Wetlands Restriction Program.
Communities should fully utilize nonregulatory wetlands protection techniques wherever possible.
DEP should prohibit the issuance of permits to chronic violators of the Wetlands Protection Act.

PLANNING FOR A SHIFTING SHORELINE

CZM should sponsor public education and awareness programs at the local level and provide technical assistance.
Buzzards Bay communities should pass bylaws increasing the required setback for septic systems from groundwater, waterbodies, and vegetated wetlands for areas subject to sea-level rise, erosion, or flooding.
Buzzards Bay communities should establish coastal construction setbacks and regulate construction activities more stringently for areas predicted to be subject to sea-level rise, erosion, or flooding.
Buzzards Bay communities should establish higher flood elevations that exceed the minimum elevations mapped by FEMA.
DEP should amend its wetlands regulations and adopt performance standards for the resource area "land subject to coastal storm flowage" (100-year floodplain).

SEWAGE TREATMENT FACILITIES MANAGEMENT

The State management framework for protecting surface water quality should be made more comprehensive to address nitrogen from existing and future sewage treatment facilities.
Communities should develop and implement plans to reduce effluent volume.
Communities should develop and implement industrial pretreatment and industrial and household hazardous waste reduction programs where appropriate.
Future sewage treatment facilities and outfalls should be sited so that they minimize pathogen contamination, nitrogen impacts, and threats to human health and marine ecosystems.

TOXIC POLLUTION REDUCTION

Municipalities should establish and implement a toxic waste reduction program for industries that discharge directly into receiving waters or sewage treatment facilities.
DEP should reduce oil entering the environment through enforcement of adequate collection regulations.
Buzzards Bay municipalities should collect and properly dispose of household hazardous waste on a continuous basis.
SCS and the Cooperative Extension Service should develop a pesticide reduction program.
EOEA should establish sediment level criteria that are protective of the ecosystem and of human health for selected contaminants.
EOEA should coordinate with DPH to review our current seafood testing program and to develop recommendations for future actions.

DREDGING AND DREDGED-MATERIAL DISPOSAL

An interagency disposal committee of local, regional, State, and Federal authorities, should meet to develop a dredged material disposal plan for Buzzards Bay.
EOEA and BBP should cooperate with CE and compile data in an accessible database for relevant users.
EOEA should develop appropriate sediment criteria that are protective of the environment.

Figure 1. Action Items for Buzzards Bay summarized from Volume I.

compounds in Buzzards Bay.

In contrast, the open bay appears to be spatially uniform in water quality. Its waters are more like offshore waters than the waters of the coastal embayments (Turner *et al.*, 1989). Nitrogen loading rates to the open bay are estimated as approximately 30 mmol/m^3/year (SAIC, 1991), which is low compared to many other estuaries (Nixon and Pilson, 1987).

The 28 embayments considered in this Monitoring Plan are listed in Table 1. The open bay is defined as that part of the bay located seaward of a line that connects the headlands at the mouths of harbors. Figure 2 shows the position of the demarcation line as well as subdivisions of the major embayments as segmented by the BBP. These embayment subdivisions--which correspond to major sub-drainage basins of the Buzzards Bay drainage basin--were made to locate sampling locations and define analysis units within harbors.

Principles of Monitoring

The design and conduct of this Monitoring Plan incorporates principles recommended by the National Academy of Sciences (NRC, 1990), the EPA Monitoring Guidance Document (1990), and the management goals contained in the CCMP. Among these recommendations is the articulation of management goals and questions followed by development of tiered monitoring structures to ensure that each datum collected addresses these goals and hypotheses (see also Section 8). Data generated by this monitoring program will enable the success of implementation of CCMP actions to be documented and identify where new action is needed.

We have attempted to identify the location and frequency of sampling along with the appropriate institutions and agencies to carry out this work. We have also estimated the cost of each work element to assist the BBP in estimating funding needs.

The monitoring program will be coordinated with existing programs from other state and federal agencies. The BBP will not duplicate or substitute for any ongoing effort but will incorporate those efforts into this plan.

Table 1. List and features of major Buzzards Bay embayments and their drainage basins.

BUZZARDS BAY EMBAYMENT	WATER AREA(km2)	Depth MLW (m)	Vol MLW m3x10^6	Basin land area(km2)	Predicted BASIN POPUL.
Acushnet River (New Bedford inner	4.27	3.19	13.60	69.5	8861
Acushnet River (N.B. inner+outer)	10.73	3.61	38.70		ERR
Allens Pond	0.77	0.50	0.39	9.1	ERR
Apponagansett Bay, inner	1.54	0.70	1.08	19.9	11223
" " , inner & outer	2.93	1.74	5.10	21.6	13062
Aucoot Cove	1.29	2.22	2.86	10.5	671
Brant Island Cove	0.34	0.81	0.27	1.7	ERR
Buttermilk Bay	2.15	0.90	1.94	24.1	9150
	2.17	1.18	2.55	26.0	9144
Clarks Cove	2.86	3.57	10.20	7.6	ERR
Hen's Cove	0.26	0.83	0.22	2.7	2266
Marks Cove	0.46	0.78	0.36	2.9	1167
Mattapoisett upper Harbor	1.59	2.84	4.52	NA	ERR
Mattapoisett upper+lower	4.32	3.82	16.50	80.2	7854
Inner Nasketucket Bay	2.05	1.59	3.25	14.2	3340
Onset Bay	2.39	1.29	3.09	12.6	6438
Phinney's Harbor	2.17	2.00	4.35	9.8	3996
Pocaseet River	0.80	0.93	0.74	19.6	2599
Quisset Harbor	0.47	1.57	0.74	1.3	343
Red Brook Harbor	0.61	1.74	1.06	6.3	663
Sippican Harbor upper harbor	1.70	1.44	2.45		
Sippican Harbor upper and lower	7.45	2.51	18.70	10.1	3496
Slocums River	1.97	0.74	1.45	95.7	15580
Squeteague Harbor	0.30	0.81	0.24	9.5	1831
Wareham River	2.49	0.96	2.40	114.4	12317
West Falmouth Harbor	0.80	0.58	0.47	10.7	2031
Westport River, East Branch	8.02	0.77	6.21	154.8	14926
Westport River, West Branch	5.32	0.78	4.17	44.0	2987
Weweantic River	2.38	1.14	2.72	217.3	20500
Widows Cove	0.54	0.94	0.51	1.4	55
Wild Harbor	0.49	1.17	0.57	2.6	1716
Wings Cove	0.88	1.39	1.22	4.6	521

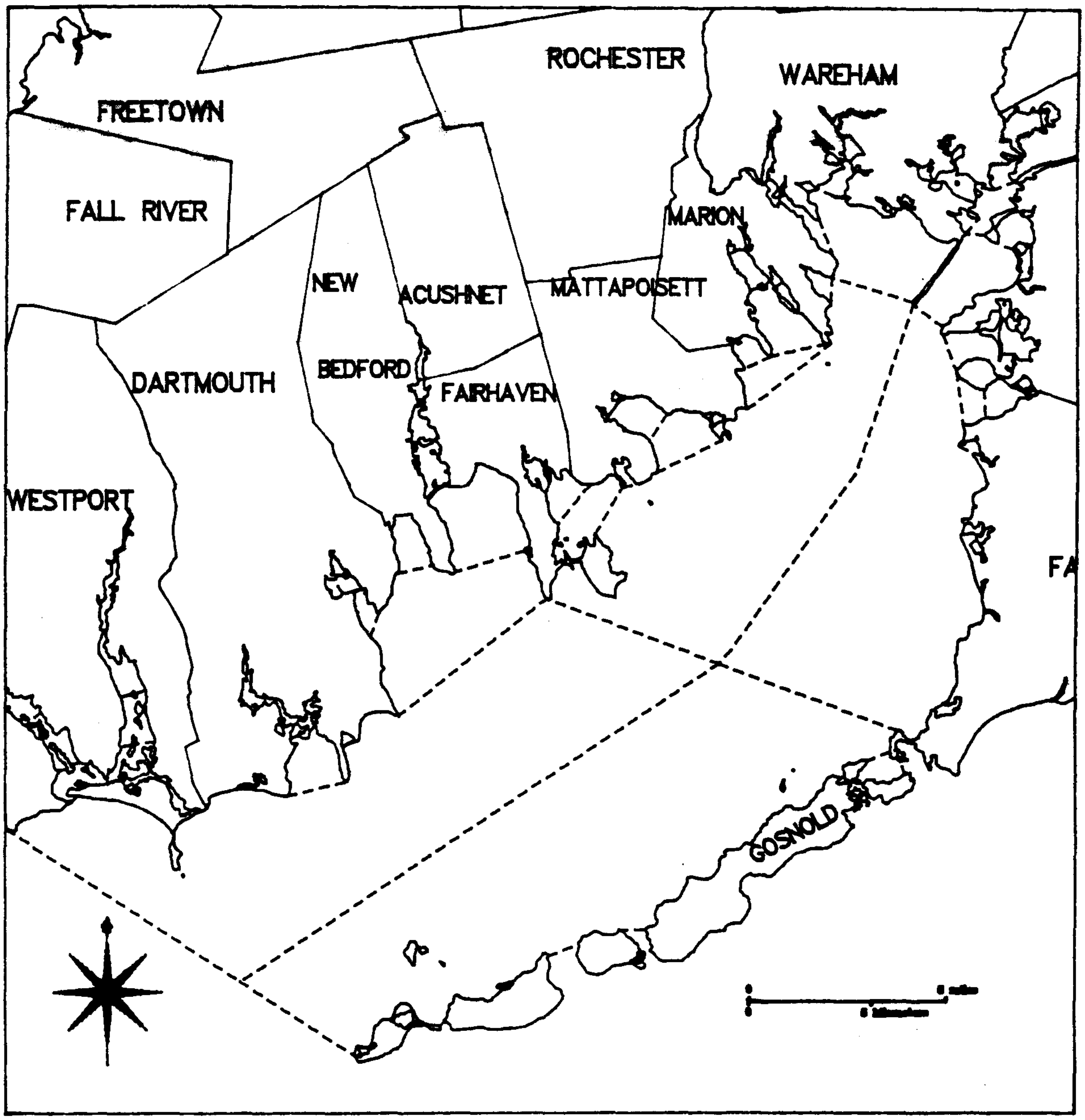


Figure 2. Map of Buzzards Bay showing segmentation of the Bay into study units.

The program will incorporate citizens' monitoring components as well as monitoring by federal and state agencies and their contractors.

The Monitoring Plan has been reviewed by scientists, managers, state and federal agencies and interested citizens and has been approved by BBP Management Committee and Technical Advisory Committee. Upon initiation of the monitoring program, committees will need to meet at least biannually for reviewing and evaluating the results of the monitoring. The decision to terminate or limit monitoring, or extend monitoring to a lower tier, resides with these management committees. In the event that insufficient monies are available for implementing the entire monitoring program outlined here, these committees will need to establish priorities.

Implementation of the monitoring program will require quality assurance plans from participants that include written protocols for collecting and analyzing data. Protocols will be standardized throughout the program.

Objectives of the Monitoring Plan

The objectives of the Monitoring Plan are:

- To assess the effectiveness of management actions specified by the CCMP.
- To document environmental trends and the need for new actions.

Baseline information is necessary for both monitoring objectives—it will be obtained from existing information and from limited additional data collection. All of the tiered monitoring protocols outlined in this plan rely on the baseline for detecting future change in the Buzzards Bay system. Many studies have already been conducted in Buzzards Bay as part of the BBP, and ongoing State, Federal, and municipal programs, as well as various academic research programs. Reviews and literature compilations of research conducted in Buzzards Bay are provided by Tripp (1985), SAIC (1986), Farrington and McDowell Capuzzo (1991), Grimes and Heufelder (1991), and Kelley et al. (1991). Reviews and summaries of historical data sets were developed by Brown and Gale (1986a-b) and

Brown et al. (1987).

Data from these studies will provide some of the baseline information necessary for monitoring Buzzards Bay, but new data must be collected. Although past research and synthesis efforts have characterized the overall nature of problems facing the bay as a whole, individual embayments have not been adequately assessed for site-specific problems. Thus, for most embayments, there is lack of knowledge concerning sources of coliforms contributing to closure, the environmental effects of excess nitrogen loading, or even the preexisting condition of each embayment due to historical degradation. Because the Buzzards Bay CCMP focuses many of its management actions on embayments, additional data must be gathered for the first time by research or characterization studies. Ongoing programs and new baseline or characterization studies will also provide much of the monitoring necessary to assess the effects of management actions and trends (Appendix A).

To ensure that the monitoring program evolves and improves technically, research on the effectiveness of the monitoring strategy is needed as well. Projected research activities will enhance the ability of the BBP to assess the effects of management actions and trends and therefore are included in this plan. Specific, directed research projects will assess and improve the monitoring strategy and its implementation. Therefore, four types of monitoring are considered here:

- Baseline monitoring
- Mitigation monitoring
- Trend monitoring
- Research

In some cases, specific monitoring activities will need to be conducted to demonstrate the effectiveness of specific management actions. These specific projects will be described in separate plans and reports issued by the BBP as the need arises. In this Monitoring Plan we describe generic approaches that are needed to implement a monitoring program.

The management actions proposed in the CCMP comprise a wide variety of far-reaching activities that will not easily be linked with specific effects in the marine environment. Rather, continued long-term success of the assembly of management actions will be judged by the trends in parameters that are likely to be affected by those actions.

Monitoring Questions

For each of the issues identified by the BBP, there are two basic questions:

- What are the anthropogenic perturbations (physical disturbances and/or pollution inputs) affecting Buzzards Bay?
- What are the effects of these perturbations?
- What are the effects of management actions that are implemented?

These basic questions can be stated for each type of perturbation or pollutant of concern for both the coastal embayments and the open bay. They may be posed for each type of monitoring (mitigation, trend, or research) described in this plan. The detection of perturbations and effects is to be measured against baseline data (either existing data or data that will need to be collected).

In most instances, we have not identified specific decision endpoints or criteria for determining whether data exceeds baseline levels or trends. This reflects the complexity of marine ecosystems, where environmental conditions are often largely determined by local, site-specific parameters. There is often no "objective" standard for documenting healthy vs. unhealthy ecosystems. Such an assessment needs to be determined on a case- and site-specific basis by qualified experts until additional research clarifies the role and nature of all components of marine ecosystems. Nonetheless, wherever possible, specific criteria and standards for determining the health of a specific ecosystem should be developed and used. A discussion of decision thresholds is presented in section titled "Testing Hypotheses and Setting Action Thresholds".

The monitoring questions are organized into four major areas of concern:

pathogen contamination, nutrient enrichment, toxic contamination, and loss of habitat and living resources. In addition to identifying the salient monitoring questions, we have summarized the work tasks required to address the monitoring, listed methods, listed monitoring agencies and institutions, and estimated the cost per task. Detailed information on the work tasks and methods are found in the appropriate sections of this plan.

Pathogen Contamination

Pathogen contamination, resulting primarily from human and other animal wastes, enters Buzzards Bay from stormwater runoff, improperly designed or malfunctioning on-site sewage treatment systems, boats, and natural sources. Human pathogens comprise both bacteria and viruses, however only fecal coliform bacteria are now routinely monitored as indicators of potential pathogen contamination. Indication of potential pathogen contamination can result in closure of bathing beaches and shellfish beds.

The monitoring questions relating to pathogen and coliform pollution, observations required to answer these monitoring questions, collectors of the data, and estimated costs to answer these questions are summarized in Table 2.

Because pathogen contamination is largely a problem only in the coastal embayments, no routine monitoring of pathogens in the open bay is planned. Necessary research includes determining whether there are better indicators of pathogen contamination than the fecal coliform test currently used.

Nutrient Enrichment

The principal anthrpogenic sources of nutrients entering Buzzards Bay are sewage outfalls, septic systems, and fertilizer runoff. Nitrogen is the nutrient of greatest concern in marine waters. Excessive nitrogen inputs stimulate growth of algal species, which can clog coastal embayments, deplete water of dissolved oxygen, and affect shellfish and fisheries resources.

How excess nitrogen affects ecosystem health is a complex question. Ecosystems are diverse, and do not always follow predictable patterns. However, high nitrogen inputs are known to stimulate both planktonic and benthic algal production. Algal blooms can result in decreased water clarity, cause a net loss of oxygen in the water column, kill submerged aquatic vegetation, and eliminate benthic habitats for commercial species. These effects may take years to develop. The possibility of such patterns occurring can be estimated using a variety of parameters, that are discussed in the following section on monitoring activities and parameters.

Recent data have indicated that increased nutrient loadings have not affected water quality in the open bay (Turner et al., 1989). However, there is some evidence that concentrations of chlorophyll *a* have increased (Kelly et al., 1991). These results, while not definitive, may provide an indication of a parameter that will be sensitive to future changes. Table 3 is a summary of the major management questions regarding nutrient enrichment.

Research issues that may benefit the monitoring program include (1) determining the relationship of ecosystem response to nitrogen inputs and flushing rates, (2) developing a better understanding of lags in ecosystem responses following increased inputs of nutrients, and (3)determine losses and attenuation of nitrogen from various sources. Better predictive models will aid in interpreting the complex responses of populations and communities to increased nutrient levels.

Toxic Contamination

Toxic contaminants, including petroleum products, PCBs, and heavy metals, enter Buzzards Bay from a variety of sources, including oil spills, discharges from sewage treatment plants, and mooring areas. Toxic contaminants may affect marine populations and communities. Through ingestion of seafood, toxic contaminants may also affect human health although establishment of this linkage is technically difficult. Because of this difficulty, the human health issue is to be addressed in a conservative way. Tissue concentrations that approach or exceed FDA regulatory limits will be assumed to be a potential human health hazard. As such, the

Table 2. Pathogen contamination monitoring.

Table 2. Pathogen Contamination Monitoring

Monitoring Code: M = Mitigation T = Trend R = Research

Questions	Code	Observations	By	Methods	Annualized Est. Cost
1) Do management actions lessen levels of fecal coliform bacteria or other indicator organisms in water and/or shellfish?	M,T	Monitor new mitigation projects, receiving waters and shellfish tissues biweekly from April to Nov. (Table 6, fig. 3-4).	DMF	MPN or MF method	100K
2) Do management actions lessen the number of shellfish areas closed and duration of closure due to contamination?	M,T	Ongoing shellfish resources area water quality monitoring	DMF	Comparison of areas (acres) closed and duration of closure.	Funded
3) Are boat pump-out facilities contributing to decreased loading?	M	Monitor volume of septage being collected.	Local boards of health	Maintenance of records on pump-out volumes.	None
4) Do management actions decrease the number of beaches closed and duration of closure due to pathogen contamination?	M,T	Monitor fecal coliforms before and after remediation. Compare closure data before and after mitigation based on fecal coliform and *Enterococcus* counts performed biweekly from April to Nov. (Table 6, fig. 3-4).	Local boards of health	MPN or MF method	Funded
5) What are upstream sources of coliforms contributing to shellfish bed closures?	M,T	Map upstream coliform gradients. (Table 6, fig. 4) and monitor individual coliform sources	DMF/DEP	MPN or MF method	100K
6) Is there a better indicator or suite of indicators to replace fecal coliforms as a more direct indicator of human health risks?	R	Analysis of candidate microbial/viral pathogens in embayments receiving sewage/septage.	EPA/FDA/ Universities	Develop new assay techniques for pathogens.	National Research Funding
7) What is the relationship between surface runoff and bacterial levels in embayments?	R	Analysis of coliforms during runoff and post-runoff events.	DMF	Time-series analysis of water.	Funded

Table 3. Nutrient Enrichment Monitoring

Monitoring Code: M = Mitigation T = Trend R = Research

Questions	Code	Observations	By	Methods	Annualized Est. Cost
1) Do management strategies affect nitrogen loads and eutrophication parameters in coastal embayments?	M,T	Tier 1: 1) DO, 2) water transparency, 3) periphyton deployments, 4) frequency of fish kills, 5) drift algae, 6) benthic infaunal indicators (Aug. only), 7) eelgrass cover, 8) fish, shellfish. See Tables 6, 7, & Fig. 6. Tier 2: Biweekly measurements of DIN, PON, & Chl from April to Nov. at DO stations (5 embayments/yr). See Tables 6, 7 & Fig. 6.	Tier 1: Citizens monitoring 1-4. Contractors 5-7. DMF 8. Tier 2: Contractors &/or DWPC.	Tier 1: Analyze water, sediments. Collect living marine resources by trawling, benthic sampling. Tier 2: Analysis of surface water samples.	Tier 1: 60K Tier 2: 125K
2) Does the STP upgrade in New Bedford Harbor affect nitrogen loads and ecological response in the open bay?	M,T	Tier 1: Monitor nitrogen in New Bedford outfall discharge weekly. Measure DIN, PON, chl a during July & August at 12 stations every 3 yrs (Fig.5; Table 8; Fig.7). Tier 2 (min. every 5 to 10 yrs): 1) benthos, 2) periphyton deployments, 3) chl a (water, sed.), 4) DIN, 5) phyto-& zooplankton, 6) sed. CHN.	Tier 1: City of New Bedford. Contractors &/or DWPC. Tier 2: Outside contractors.	Tier 1: Analysis of surface water samples. Tier 2: Analysis of water, sediments, benthos, plankton.	Tier 1: 30K Tier 2: 50K
3) What is relationship between nutrients & plankton communities?	R	Weekly measurements of nutrients, phytoplankton, & zooplankton at several stations off New Bedford and in open Bay (e.g., SMU program).	Universities &/or research institutions	Water column sampling of phytoplankton, zooplankton.	50K
4) Can areal thematic mapper data be used to synoptically characterize primary production in the Bay?	R	Weekly comparison of remote sensing data with ground truth data (#3). 1 field study + annual remote sensed images.	NOAA, EPA, Contractors	GIS overlays	20K + 50K initial cost
5) What are loads & losses of nitrogen from individual septic systems via groundwater, under different hydrologic conditions?	R	Groundwater monitoring of selected systems.	Universities &/or research institutions	Test well water samples	75K

conservative practice will be to close the affected area to fishing. Management actions related to inputs of toxic materials include reduction of oil from major and chronic spills and reduction of inputs of contaminants from sewage treatment plants, other discharges, and runoff. The toxic contamination questions are outlined in Table 4.

Habitat and Living Resources

Freshwater and marine wetlands, such as salt marshes, eelgrass beds, shellfish beds, spawning and nesting areas, and important coastal plant communities are recognized by the state as fundamental to maintaining a diverse ecosystem. In Massachusetts, an estimated 40% of fresh- and saltwater wetlands have been destroyed by human activity, and wetlands continue to be lost. Although the state protects wetlands, the continued cumulative impact of small projects threatens habitats and living resources. Table 5 gives the major monitoring questions related to habitat and living resources loss.

Monitoring Activities & Parameters

A variety of activities must be conducted and parameters measured to address the monitoring questions that have been posed. To the extent practicable, activities and parameters have been selected that (1) are socially, economically, and environmentally meaningful; (2) are sensitive to the impacts of interest; (3) are relatively invariant in a non-impacted environment; (4) are cost effective to measure, and (5) are already being monitored.

Pathogen Contamination

The test used to evaluate pathogen contamination to determine the status of swimming areas and shellfish resource areas is the presence of fecal coliform bacteria, or *E. coli*, a specific fecal coliform, or other indicator

Table 4. Toxic Contamination Monitoring

Monitoring Code: M = Mitigation T = Trend R = Research

Questions	Code	Observations	By	Methods	Annualized Est. Cost
1) Do management actions decrease oil inputs from spills? A) Catastrophic B) Chronic	M,T	A) Document catastrophic spills. B) Monitor petroleum residues in effluent discharges and sediments once a year.	EPA, NOAA, DWPC	A) Sediment sampling. B) Sediment sampling and evaluation of NPDES permits.	A) In place B) 50K
2) Do management actions reduce contributions of toxic substances to the bay from NPDES discharges?	M,T	Evaluate new technologies employed for reduction. Annual monitoring.	DWPC, Municipal officials	Maintenance & monitoring industrial discharges relative to NPDES permits.	35K
3) Do management actions reduce discharges of toxic substances from sewage treatment plants (STP's) and other permitted sources?	M,T	Sampling effluent waters & associated sediments annually.	DWPC	Comparison of water and sediment samples along contaminant gradients over time.	30K
4) Do management actions decrease contaminants in storm runoff?	M	Oil trap maintenance. Annual evaluation of maintenance program at selected traps, using best management practices.	DWPC, Municipal officials	Monitoring & maintenance of oil/grease traps.	25K
5) Do management actions in New Bedford Harbor increase or decrease PCB levels in resource species baywide?	M,T	Measurements of PCBs in living resources (clams, mussels, lobsters, flounder) and bottom sediments. Evaluation every 5 years.	DMF, DWPC	Analysis of edible tissue, water and sediment.	Ongoing + 20K
6) Do management actions increase or decrease PAH levels in resource species?	M,T	Measurements of PAHs in living resources (clams, mussels, lobsters, flounder), water column (suspended sed.) and bottom sediments. Evaluation every 5 years in selected harbors and/or after a major oil spill.	DMF, DWPC	Analysis of edible tissue, water and sediment.	Ongoing + 20K

Table 5. Habitat Loss Monitoring

Monitoring Code: M = Mitigation T = Trend R = Research

Questions	Code	Observations	By	Methods	Annualized Est. Cost
1) Do management actions slow the rate of loss of habitat?	M,T	Distribution of eelgrass beds; mapped distribution of marshes, nesting areas, spawning areas, shellfish beds, tidal flats and important coastal plant communities. Comparison & correlation of changes in these distributions with adjacent land use information and control measures for nutrient/contaminant loading. Mapping to be done every 4-8 years. Monitoring permits issued by ConComs and DEP to document frequency and area of wetlands allowed to be altered or destroyed.	BBP office, MASS GIS, DEP (wetlands division), conservation committees (ConComs)	GIS mapping & overlay analysis of aerial photographs.	5K
2) Can one detect early signs of habitat "stress" from the GIS data?	R	Analysis of above data using GIS map overlays.	BBP office, MASS GIS, DEP.	Time-series analysis of GIS map overlays with appropriate ground-truth data.	5K
3) What is the relationship between dock construction, mooring areas, and boat traffic (sediment resuspension), on nearshore habitats?	R	Map docks and other structures and relate them to specific habitat changes.	Universities and/or research institutions.	GIS mapping and overlay analysis.	75K

organisms such as *Enterococcus* in the water column. Other indicators such as the long-lived spores of *Clostridium perfringens* in sediments can also be used as a time-integrator of fecal contamination (Krieger, Mulsow, and Rhoads 1990). None of these indicators are pathogenic themselves, but they are associated with fecal matter and hence indicate that pathogenic bacteria or viruses may be present. The effectiveness of management action to reduce pathogen contamination can be documented by measuring these indicators. The effectiveness of management action to open resource areas can be documented simply by changes in the frequency and/or duration of closures and by measurements of fecal coliforms in water.

Nitrogen Enrichment

A wide variety of parameters must be measured to address the question of nutrient loading and its effects on coastal embayments and the open bay. These parameters include dissolved inorganic nitrogen (DIN), particulate organic nitrogen (PON), orthophosphate, dissolved oxygen (DO), transparency, chlorophyll *a*, periphyton growth (fouling microalgae) and macroalgal abundance. Information on benthic communities and fish and shellfish populations may be difficult to link directly to nutrient levels, but they may be useful in monitoring trends in the overall effects of pollutants. Auxiliary information necessary to interpret these data include flushing rates of the coastal embayments, temperature, and salinity.

DIN and PON in streams and groundwater provide direct measures of nitrogen loading in marine waters. Water column levels (especially PON) are related to enrichment. Dissolved oxygen is a frequently measured parameter to indicate excessive nitrogen loads. When increased nitrogen levels stimulate photosynthesis, they also stimulate respiration. Daily oxygen minima, which occur early in the morning, can be a measure of increased respiration due to nitrogen additions. Water transparency can be an indicator of excessive nitrogen loading. When phytoplankton growth is stimulated by nutrients, transparency decreases.

Measurements of chlorophyll *a* provide a simple measurement of phytoplankton biomass. Stimulated phytoplankton productivity, caused by increased nitrogen loads, can be inferred from an increase in chlorophyll *a* levels.

Monitoring Plan: Activities and Paramaters

Periphyton growth has been found to be a simple effective method for assessing productivity in coastal waters. Periphyton are microalgae that attach to the leaves of rooted plants, rocks, and other surfaces in the water. Blank strips of settlement substratum can be deployed to quantify colonization and subsequent growth of periphyton on the strips by measuring chlorophyll *a*.

Macroalgae, especially 'drift algae,' are abundant in many of the coastal embayments within Buzzards Bay. There is growing evidence that macroalgal abundance is linked to eutrophication and that macroalgae respond rapidly to nitrogen loading. Macroalgal abundance is difficult to measure, but aerial extent can be estimated using sediment profile images, grabs, or diver collection. Data from these kinds of surveys can be used to select areas for measurement of biomass.

Benthic infaunal community parameters have often been used to monitor environmental conditions because the infauna are sedentary and generally unable to migrate away from a pollution source and as such offer a resident biota for the study of effects. The generation times of benthic organisms are such that some species can reproduce rapidly and produce new generations within weeks or months, thus providing the potential of building dense populations under certain conditions. These conditions may arise when their habitats are organically enriched either from natural processes such as seasonal die-offs of phytoplankton, marsh grasses, and eelgrass beds, or from anthropogenic sources such as sewage outfalls, or dredged material disposal. Typical responses to organic enrichment by benthic populations include rapid colonization by opportunistic or stress tolerant surface dwelling species (usually spionid and capitellid polychaetes). Resident benthic populations tend to integrate the effects of all environmental conditions over their life spans. Specific parameters measured may include information obtained through sediment profile images or more traditional ones obtained from the identification and enumeration of species. A disadvantage to monitoring the benthos is that effects of nitrogen loading cannot be easily distinguished from those of toxic contaminants or natural temperature or salinity changes. However, such monitoring does provide an overall picture of the health of the ecosystem.

Shellfish abundance and density may also provide integrated measures of environmental trends. These measures also provide direct information about the health of resources of interest. Although quahogs, soft-shell clams, oysters, scallops, and mussels are commercially and recreationally harvested throughout the bay, the status of the populations of these organisms have not generally been measured in the region.

Finfish population characteristics are also integrated measures that provide direct information about resource species. Although fishing by seine, trap, or trawl for finfish has been prohibited in Buzzards Bay since the late 1880s, recreational and commercial hook-and-line fishing is widespread and important to the region.

Toxic Contamination

Measurements of toxic compounds in contaminant sources, sediments, and tissues of lobsters, shellfish, and fishes provide direct information about the fate of contaminants in the marine systems. These data can also be used to discern potential public health effects. These issues are focused on New Bedford Harbor, a significant source area for toxics. New Bedford Harbor is an EPA Superfund site and, as such, a program to clean-up and monitor contaminants within the harbor is underway. It is not the intention of the BBP to duplicate these efforts but rather to determine if the clean-up efforts result in an improvement in open Bay sediment and animal tissue quality.

Benthic community parameters and fish and shellfish population parameters may also provide information about the ecosystem-level effects of toxic contaminants in Buzzards Bay. Such measurements will assess the overall effects of pollutant inputs and other permutations to the environment.

Habitat Loss

Although all types of marine habitat may be affected by man's activities, beaches, emergent vegetated wetlands (marshes), and submerged aquatic vegetation communities are the most sensitive habitats in Buzzards Bay. Direct measurements of loss of these habitats can be made through the analysis of aerial photographs coupled with some field verification.

Tiered Sampling and Analysis Plans

Extensive sampling and analysis have already been done in Buzzards Bay, and those activities have been integrated into the plans described in this section. Plans for ongoing sampling and analysis will evolve throughout the duration of the monitoring program. These plans are 'tiered,' that is, results of each stage of monitoring will determine the nature and extent of future monitoring. After the first two years, the entire program will be reevaluated to determine whether (1) fewer parameters or samples should be taken, and/or (2) if more or different parameters or samples are appropriate.

Our initial recommendations are that trend monitoring involve revisiting embayments every 5-6 years and the open bay every 3 years. These frequencies are justified on the basis of the high costs of annual monitoring and the fact that changes in the coastal ecosystem are gradual. Trends and changes monitored over smaller sampling intervals are not necessary. When sampling does take place, we have recommended sampling during spring, summer and early fall. This is justified as it is during these seasons that the ecosystem is metabolically the most active. Adverse biological/ecological effects are most efficiently monitored during this period.

The tiered approach is recommended as an important tool by the NRC (1990). Tiered plans incorporate the statement of questions and hypotheses intended to focus the objectives of the monitoring plan. The monitoring plan is then presented as sequential components that are implemented only if data from a previous component (tier level) indicate the necessity of advancing to the next level. This approach results in a more cost-effective monitoring program than would an approach where all monitoring activities are implemented without integration. The on-going analysis and evaluation implied by the tiered approach allows management decisions to be a part of the monitoring program. The stated objective of each tier of the program should focus on regulatory or environmental protection endpoints against which measured effects can be compared. The outcome of the activities in each tier provide a technically sound basis for deciding whether specific types of monitoring activities are needed for the next tier.

Implementation of the recommended tiered programs outlined in the following plans will require the Buzzards Bay Project Management Committee and Technical Advisory Committee to meet at least once a year to evaluate monitoring results. As results are submitted to the BBP office, an initial evaluation will be made. More frequent meetings may be required if the data appear to warrant higher tiered monitoring efforts. Such a decision has both fiscal and technical implications. It is the responsibility of the BBP office and technical advisors to decide if the monitoring results are to trigger higher-tiered monitoring. In some cases, this decision may be based on a change in the system that causes rejection of the null hypothesis (observation is greater or less than baseline condition). The basis for rejecting a "loose" null hypothesis (sensu Bakan, 1966) may be set at 0.05 or 0.01 depending on how conservative the BBP managers wish to be regarding a particular problem. We strongly urge that one should not use test results alone to assert "significance" of an outcome but rather to prompt a decision or risk-evaluation (Carver, 1978 and Bakan, 1966). Decisions should be based on several tier factors, consideration of alternative hypotheses, priority of the problem, and fiscal constraints. If tier one results show consistent qualitative trends away from baseline conditions, it may be prudent to investigate these trends even if the null hypothesis is not rejected at the preselected level. One of the reasons why tier one levels consist of several observations or variables is so that evaluations do not rest on only one variable.

Pathogen Indicators

Baseline Monitoring. The detection of future change in pathogen indicators will depend on historical data for defining baseline conditions. Currently, the Massachusetts Division of Marine Fisheries (DMF) monitors fecal coliform bacteria in waters and shellfish of coastal Massachusetts, including Buzzards Bay. Auxiliary parameters monitored concurrently with coliform bacteria monitoring include salinity, temperature, and wind speed and direction, and time since last rainfall. Monitoring is carried out by a team of workers who sample locations throughout Buzzards Bay five times per year. Some stations in critical areas are visited more frequently, usually following heavy storms. Shellfish resource areas that have been permanently closed are not routinely monitored by this program. Station locations for this program are shown in Figure 3. The DMF also maintains records of resource area and beach closings.

The Massachusetts Department of Environmental Protection (DEP) Division of Water Pollution Control (DWPC) conducts periodic surveys of water quality conditions in Massachusetts waters. During 1985-1986, they monitored 95 stations within the tidal reaches of the Buzzards Bay Basin for as many as 24 parameters (DEP, 1989a-b). No routine monitoring of water quality is currently being conducted by DEP, however, the surveys provide a baseline for answering critical questions necessary for long-term trend and mitigation monitoring.

Mitigation and Trend Monitoring. Existing programs provide an adequate basis for monitoring the effects of mitigation measures and for continuing to assess trends (Figure 4). Minimally, fecal coliform measurements will be made by the DMF biweekly during April through November. We suggest that as a research investigation, *Clostridium perfringens* spores should be measured in sediments taken for monitoring of the effects of nitrogen enrichment (Section 5.2) in selected embayments. These measurements, comprising Tier 1 monitoring, will be made in each embayment, at least once every four years. These data will be used to determine whether *C. perfringens* is a cost-effective alternative indicator to fecal coliform counts for long term trend assessment.

Should pathogen levels increase, additional or Tier 2 monitoring will be conducted. This monitoring will not include new parameters but will focus on identification of new or increased point or nonpoint sources of contaminants. Depending upon the results of Tier 2 measurements, mitigation and further monitoring may be required.

These data may not provide sufficient information to assess the effects of all specific management actions related to pathogen contamination. These actions will be assessed by conducting special projects that will be presented in separate documents.

Research. One management action listed in the CCMP Management Plan is that EPA and FDA develop a new indicator or suite of indicators to replace fecal coliforms as an indicator of risks to human health. When that action has been completed, then the state monitoring program for pathogen contamination will be reevaluated. Another research need is a better definition of the relationship between precipitation and bacterial levels. This research should consider factors such as rainfall, surface runoff, temperature, fecal coliforms in runoff, and other variables affecting fecal coliform survival and abundance outside their animal hosts.

Nitrogen Enrichment

Baseline Monitoring. Nitrogen inputs to the bay from point and nonpoint sources have already been estimated (SAIC, 1991 and Kelly et al. (1991). Inputs from groundwater were calculated from land-use data, and inputs from sewage treatment facilities were estimated from data on flow and nitrogen concentrations from the New Bedford sewage treatment facility. Nutrient data were not available from all STP's (Sewage Treatment Plants) in the watershed, however, and these should be collected in order to improve the accuracy of the estimate.

Our estimates of nitrogen loadings were for the entire Bay (SAIC, 1991 and Kelly et al. (1991). To manage nitrogen loading in embayments, estimates of nitrogen loading and flushing time for specific embayments are needed; preliminary estimates are being prepared by the BBP. Groundwater nitrogen inputs can be modelled from the watershed land use pattern for each embayment, as was done for the whole Bay. The BBP and the United States Geological Survey (USGS) have delineated subdrainage basin boundaries, but more detailed assessments are required in some instances.

In embayments with surface water discharge, river and streams will be sampled using flow integrated automatic samplers. Measurements will be made during the spring through the fall.

In the open bay, an excellent database on water column parameters exists for the period 1988-1990, based on research monitoring of nutrients and components of the planktonic food chain (Turner *et al.*, 1989). The results of those studies can be incorporated into the monitoring program, and with some modifications, monitoring by DWPC can form the backbone for monitoring the bay for the effects of nitrogen enrichment.

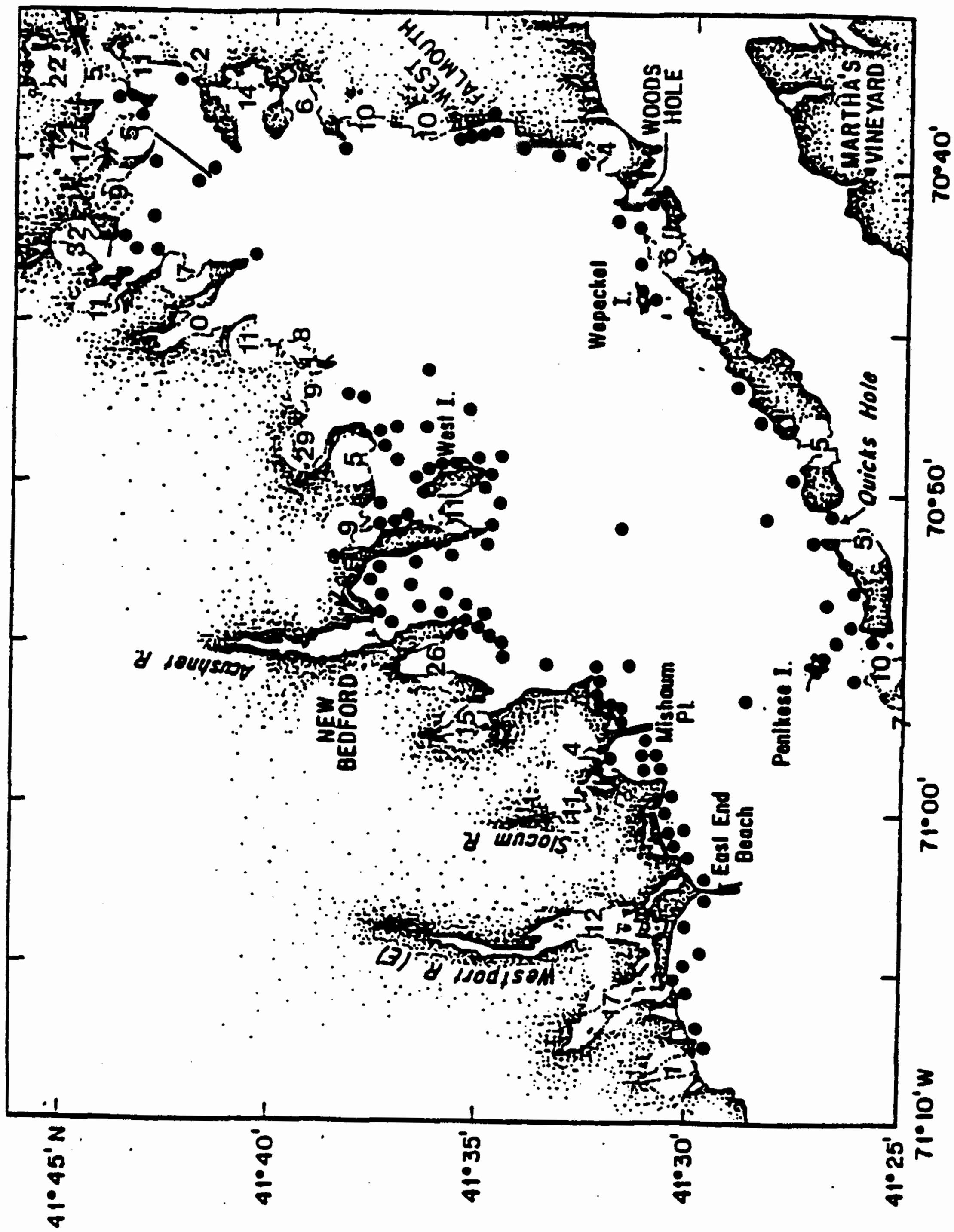


Figure 3. Map of Buzzards Bay Showing Location of DMF Pathogen Monitoring Stations.

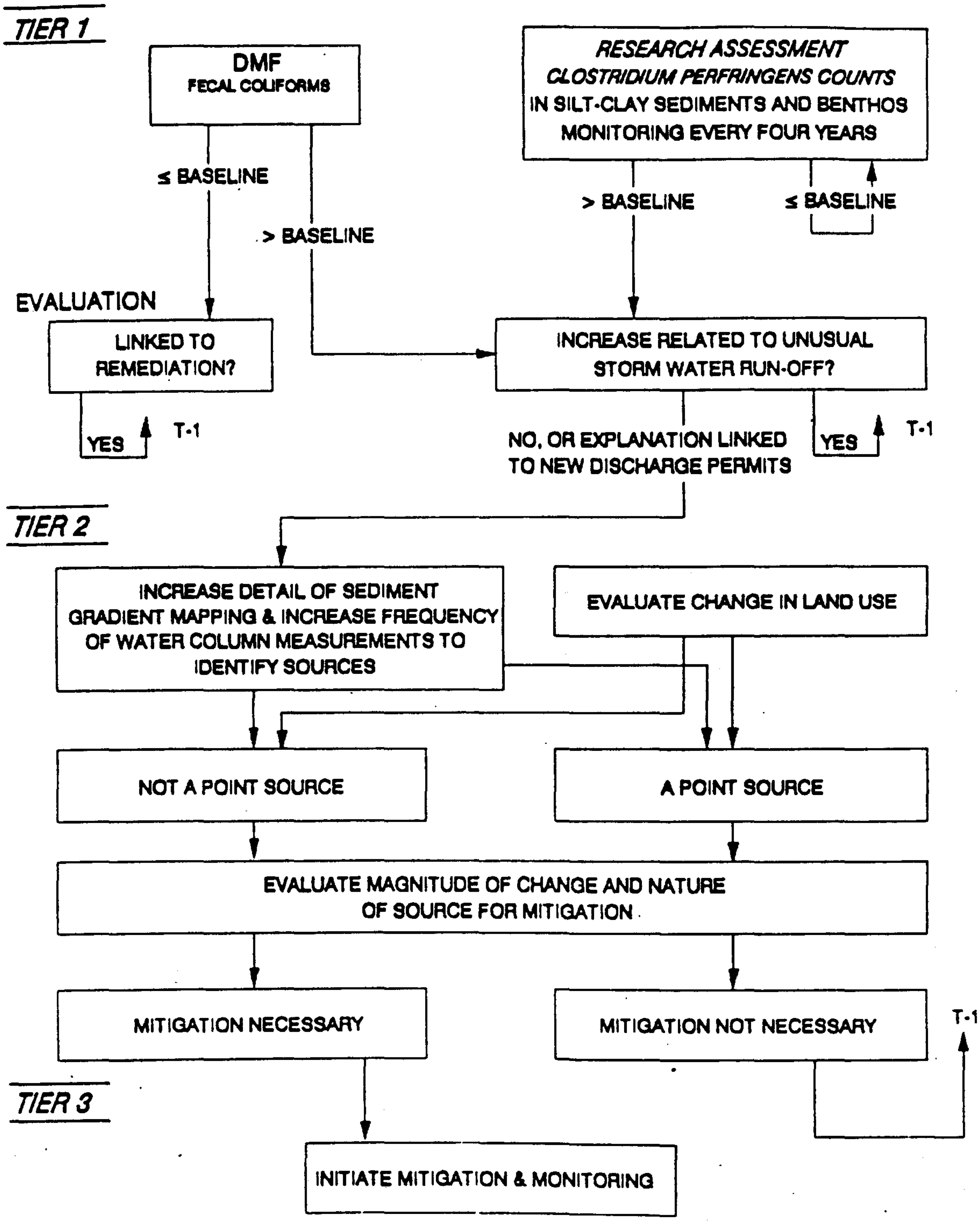


Figure 4. Tiered Trend Monitoring for Pathogens in Buzzards Bay Embayments.

These changes included adopting analytical methods and protocols suggested here, and implementing any monitoring programs in a way that is consistent with the nitrogen monitoring program described here. Monitoring by DWPC will be supplemented by monitoring conducted by citizens.

A complete study of water quality and biological parameters that may be affected by nitrogen loading has not yet been completed for each of the 28 embayments included in Buzzards Bay. Therefore, the first step of the monitoring program will be to conduct a comprehensive, initial or 'baseline' study. (Note that this monitoring is not a true baseline study, because excess nitrogens have already been released into the bay.) Each year, for 5 to 6 years, 5 to 6 embayments (totalling about 30 embayments) will be studied during July-August, the period during which effects of eutrophication are expected to be most apparent.

Monitoring of embayments can be costly in resources and manpower, and no more than 5 to 6 embayments can be monitored intensively in any one year. Ecosystem changes and trends resulting from nitrogen loading can be gradual and may not be statistically demonstrated by year-to-year changes, but may be more evident over several years. Hence the 5-6 year study periods are advisable, over which conditions in 5-6 embayments can be followed on an individual basis.

Measurements of DIN, PON, DO, transparency, chlorophyll *a*, periphyton growth, macroalgae abundance, flushing rates, temperature, and salinity will be made by State agencies and citizen volunteers (Tables 6 and 7). Oxygen and water transparency will be monitored by citizen volunteers for a period of six weeks (last week of July through the first week in September). Ideally, these measurements will be made on the same day of the week for all stations throughout the bay. Samples will be taken between 6-9 AM, as close to 8 AM as possible. In each embayment, at least five stations will be established along a transect running from the head to the mouth of the embayment. Total number of stations will vary depending upon the size of the embayment and may range between 5 and 20. Both near-surface and near-bottom samples will be taken for oxygen. Concurrent measurements of water transparency will be made at each station. Citizen volunteers will deploy and collect periphyton strips at the same stations. Nitex® strips will be deployed on buoys at the near surface and near bottom and left in place for 2 to 4 weeks. The volunteers will collect the strips, place them in plastic bags, and freeze them for analysis of chlorophyll *a* by DWPC.

For a portion of the time that the citizen volunteers are monitoring the embayments, DWPC or another state agency will deploy continuous-recording O_2 and light meters. The DWPC will also obtain baseline information for DIN, PON, and chlorophyll *a* in the embayments. For the first two years of monitoring, samples will be taken biweekly from April through November from the same stations where oxygen is measured. Temperature and salinity will be measured at the same time.

Baseline information about macroalgae abundance and the benthic communities of the coastal embayments and the open bay can be most efficiently and cost-effectively assessed by first conducting a reconnaissance sediment-profile camera survey of the embayments. These surveys will include mapping of benthic gradients in sediment type, drift algal cover, biological mixing depths, and estimation of the successional status of the bottom. Based on this 'quick-look' survey, stations can be chosen for more extensive sampling and subsequent identification and enumeration of the fauna. Stations will also be selected to avoid areas with large fluctuations in salinity and to correspond with stations where water quality is being measured.

If macroalgae are abundant, 0.1 m^2 areas in 3 to 5 stations will be harvested. The algae will be sorted by species, dried, and weighed to estimate biomass.

Also based on the results of the sediment profile camera survey, benthic communities will be monitored at minimally five stations within each embayment. Triplicate grabs will be taken, sorted, and preserved from each station. Samples will be taken in August, the time of year when oxygen levels are expected to be lowest. These samples will then be archived and only analyzed if benthic infauna are included in the mitigation and trend portion of the monitoring program.

In the open bay, additional, necessary baseline data include additional DO measurements, periphyton growth measurements, and benthic community parameters (Table 8). Parameters such as these, which integrate effects

Table 6. Parameters to be Measured by Government and Contractual Monitoring Efforts. (These parameters are included in the tiered approaches outlined in Figs. 4, 6, 7 and 9)

Parameter	Description
Flushing rates	Calculated from the tidal prism and hydrologic modeling. Done once unless the tidal basin is modified.
Dissolved Oxygen & Attenuation	Deployment of continuous recording light attenuation meters and dissolved oxygen meters on moorings near the head and mouth of selected harbors. These are to be one week-long deployments with hourly sampling rates.
DIN, PON, POC, Chl. *a*, Total N, elemental P, N	Biweekly measurements from April through November at stations being monitored for oxygen.
Eelgrass Cover	Enter existing data into GIS. Update once every four to eight years.
Drift Algae	Distribution to be mapped in July-August by means of sediment-profile imaging or diver surveys. Quantification of cover and species composition to be documented at stations selected from the profile-image maps or diver transects. Repeated once every four years.
Infaunal benthos	Reconnaissance mapping of successional seres. Results to be used to locate 'sentinel' stations for traditional sampling and archiving of grab samples.
Epifauna/demersal fish	Evaluate scallop/hardclam resources and winter flounder.
Pathogen indicators	Enumeration of *Enterococcus*, *E. coli*, fecal coliforms at low tide during the summer. *Clostridium perfringens* to be measured in silt-clay sediments during same period.
Contaminants	PCBs in outer New Bedford Harbor and PAHs in the open bay.

Table 7. Parameters to be Measured by the Citizens' Monitoring Efforts.

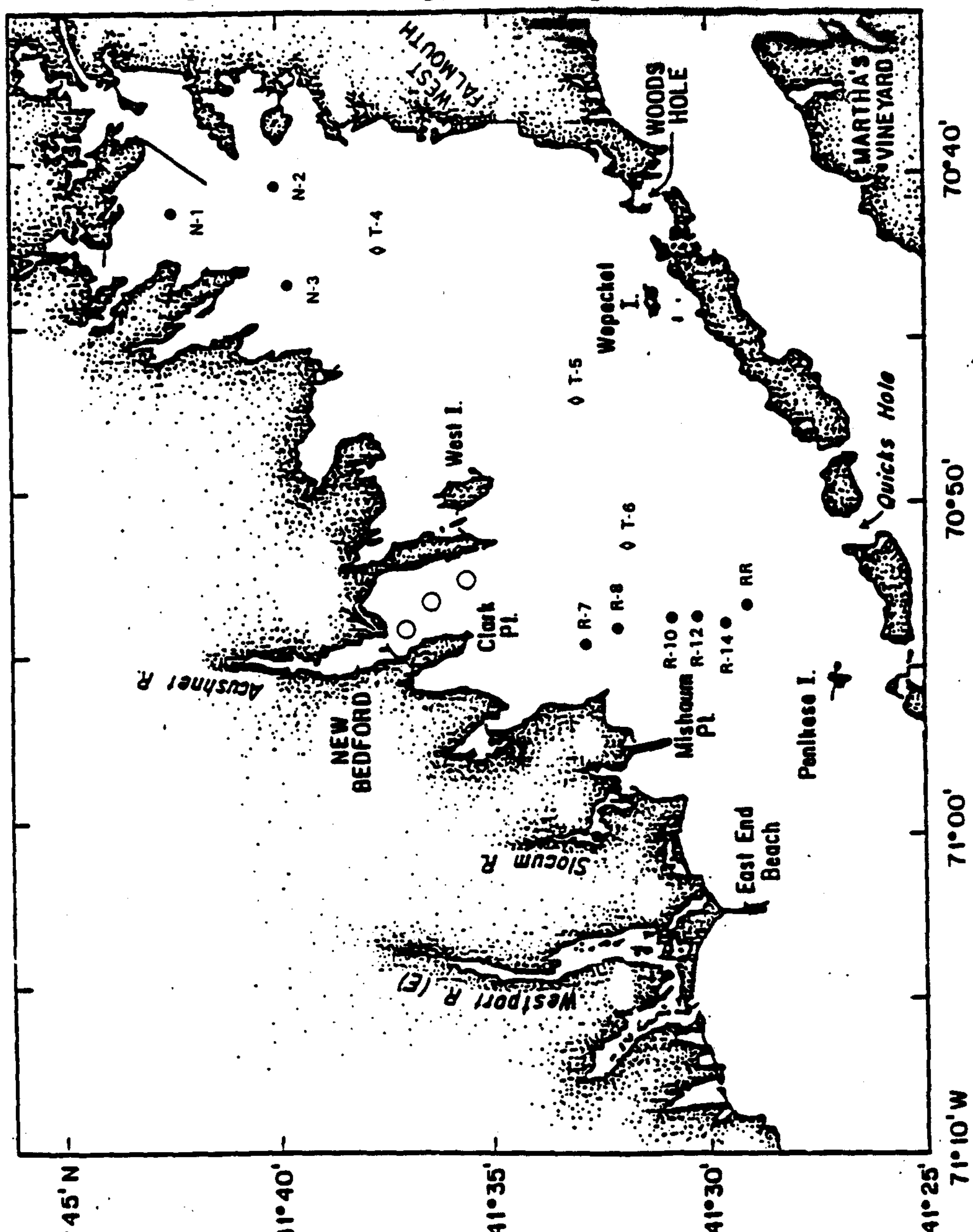
(These parameters are included in the tiered approach outlined in Fig. 6)

Parameter	Description
Dissolved Oxygen	Surface and near bottom at 0800 in the morning to characterize the 'worst-case' conditions when net system respiration exceeds photosynthesis. Last week of June through first week in September.
Water Transparency	Secchi disc readings and extinction coefficient readings at DO stations.
Salinity/Temperature	Surface and bottom at DO stations.
Periphyton Substrates	Deployment and time-series collection (once every two to four weeks).
Fish Kills	Records of time, place, magnitude, species, and duration of kills.
Other parameters	As needed to assist government agencies and research investigators in collection of relevant data

Table 8. Open Bay Baseline Monitoring.
(These parameters are included in the tiered approach outlined in Fig. 7)

Parameter	**Description**
Flushing rate	Obtained from NOAA (NEI) database and other studies (once).
Dissolved Oxygen	Vertical profiles a one meter increments from surface to within 0.5 meters from the bottom at 0800 in the morning at Axial Stations RR, T4, T5, T6 in Late July-August.
DIN, PON, Chl. *a*	Data from SMU's ongoing water column work in late July-August.
Sediment Chl. *a* & CHN	Homogenized sample of the upper 2 cm of sediment column at 12 stations
Living Resources	Sediment-Profile imaging and traditional infaunal analysis at 12 stations in August
Periphyton strips	Monthly deployment of strips at three buoy-marked stations extending from the mouth of New Bedford Harbor to Station T-6 in July and August.
Organics/inorganics	From NOAA Status and Trends Program (Table 9) and EPA EMAP Program (3 stations; Fig. 8).

Figure 5. Map Showing Location of Proposed Open Bay Stations for Monitoring Nutrients and Living Resources. Three outer New Bedford Harbor stations are also located on this map for monitoring PCB's (open circles).



over time, were not included in the earlier program. These will be sampled at 12 stations (Figure 5). Eight of these stations are along a transect extending outward from New Bedford, the greatest source of nutrients to the open bay.

The biological resources in the open bay that best integrate the potential effects of organic enrichment and hypoxia are the benthic infauna. An extensive baseline exists (Sanders, 1956; unpublished data in Whitlatch et al., (unpublished ms.) at Station R; Banta (1992), including annual data from one station and a survey of 12 stations throughout the bay). Earlier benthic reconnaissance along a transect extending from New Bedford Harbor to Station RR (Figure 5) showed some indication of nutrient enrichment (Hampson, 1987; SAIC, 1987). The six stations (with a prefix of 'R') sampled during these studies will be resampled during baseline monitoring. During this period, sediment-profile imaging will be used to characterize the stations. Stations T-4, T-5, and T-6 are parts of the open bay baseline for water column properties (Turner et al., 1989). Stations N-1, N-2 and N-3 are new stations to be added to the upper Bay for surveillance of conditions where the ratio of shoreline to open water is greatly increased. Some information on shellfish abundance is available from commercial and recreational catch statistics, but those data are not considered to be reliable (Alber, 1987). Currently, there is no plan to institute monitoring of shellfish abundance, growth, or other population parameters, but this plan may be reevaluated. The DMF should work with shellfish officers to improve the reliability of data collection. In towns where there is extensive shellfishing, the DMF and local officers will be encouraged to develop programs to monitor shellfish growth.

DMF conducts finfish surveys in Massachusetts territorial waters, including the open part of Buzzards Bay. No surveys are routinely carried out in the embayments. These surveys are conducted twice each year and are designed to monitor the abundance of juvenile winter flounder. Data for Buzzards Bay have typically been lumped with those from Vineyard Sound and the coastal waters south of Martha's Vineyard, but they can be separated. These data should be reanalyzed, and plans for additional measurements should be made. If embayment monitoring shows that certain embayments are experiencing summer hypoxia, these finfish surveys could extend into these problem embayments to assess the effect of hypoxia on the distribution of demersal fish.

Mitigation and Trend Monitoring. Direct inputs from sewage treatment plants should always be measured under their permits. Other studies of inputs will be conducted if special projects to monitor effects of management actions are conducted. These studies, if they are conducted, will be described in separate documents.

Following the 5 to 6 years of initial comprehensive monitoring of nitrogen loads and effects of nitrogen inputs, nitrogen loading and eelgrass cover will be assessed in the 28 embayments. This regular monitoring, Tier 1, will be repeated once during every 4 to 8 years for each embayment. Only embayments where there is 20% or more change in total nitrogen loading, calculated from land use data (using the Buzzards Bay Project's approach) or where eelgrass cover changes significantly will receive more intensive, Tier 2, monitoring (Figure 6). In those embayments where significant changes are observed, the comprehensive suite of water quality parameters included in the baseline monitoring will be repeated as Tier 2 monitoring. These parameters will include DIN, PON, chlorophyll *a*, macroalgae, and benthic community parameters. Should there be significant changes in these parameters, Tier 3 monitoring will be conducted. DO and transparency will be monitored continuously over a summer, and fish and shellfish resources will be evaluated.

In the open bay, Tier 1 monitoring will continue the measurements of periphyton growth and benthic community assessments, using sediment profile cameras and conventional methods. Should significant changes in Tier 1 parameters occur, Tier 2 monitoring will be conducted. Depending on the results from Tier 1, Tier 2 monitoring may include measurements of DO in bottom waters, carbon, hydrogen, and nitrogen (CHN[1]) in sediments, chlorophyll *a* and DIN at all open bay stations, or chlorophyll *a* and DIN along the gradient from New Bedford (Figure 7). If results from Tier 2 indicate effects from nitrogen enrichment, Tier 3 monitoring may be conducted. Tier 3 would include analysis of phytoplankton and zooplankton communities and/or assessment of specific sources of nitrogen, using mapping techniques (Figure 7).

Research. In the open bay, research is necessary to discern linkages

[1] CHN data include the parameter usually called total organic carbon (TOC).

between nutrients and planktonic communities. Because variability in nutrient levels and planktonic population and community parameters is great, intensive weekly sampling would be necessary to determine linkages (R. Turner, personal communication). One method for extending the spatial coverage of water-column data is overflight imagery. This technique would allow extrapolation and interpolation of ground-truth data over the entire surface of the bay. It would also allow identification of extraordinary bloom events or circulation anomalies.

Further discussions of monitoring needed to support nitrogen management action in Buzzards Bay are contained in Costa (in press).

Toxic Contamination

Baseline Monitoring. Permits to discharge sewage effluent or other wastes require monitoring of discharges, including toxic compounds. However, these measurements provide incomplete information about the sources of contaminants to Buzzards Bay, and specific projects to assess the effects of management actions on inputs to the bay may be to be undertaken. These projects will be described in separate documents.

Other measurements can be used to assess the potential impacts of toxic contaminants on public health. DMF monitors metals and PCBs in commercial species. Ten years of data have been collected on PCB's in edible tissues of lobsters, winter flounder, and quahogs from Area 3 in New Bedford Harbor. These data form a firm baseline against which future changes can be measured relative to future mitigation projects. DWPC also periodically checks metals and PCB levels as part of their water quality surveys. None of these programs, however, are comprehensive nor designed to provide managers with regular inputs. As part of this baseline, there is a need to add PAHs to the list of contaminants measured by the DMF.

Federal programs also provide some information. The National Oceanic and Atmospheric Administration (NOAA) National Status and Trends (Mussel Watch) currently maintains three stations—Round Hill, Angelica Rock, and Gooseberry Neck—in Buzzards Bay (NOAA, 1989; Figure 8). Mussels collected annually at the stations are analyzed for a wide variety of toxic contaminants and for pathological conditions that may be

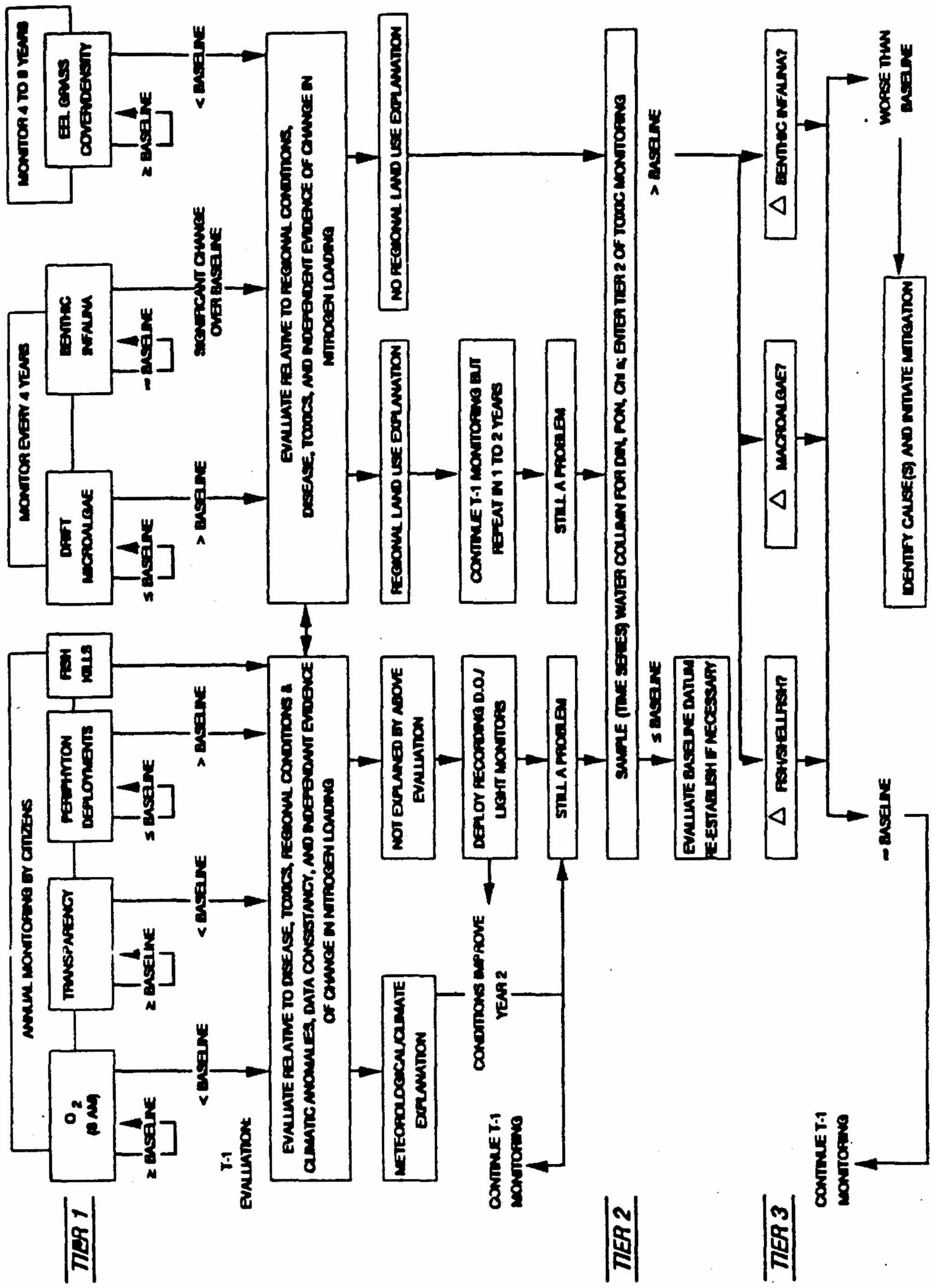


Figure 6. Tiered monitoring plan for nutrients and habitat status in embayments.

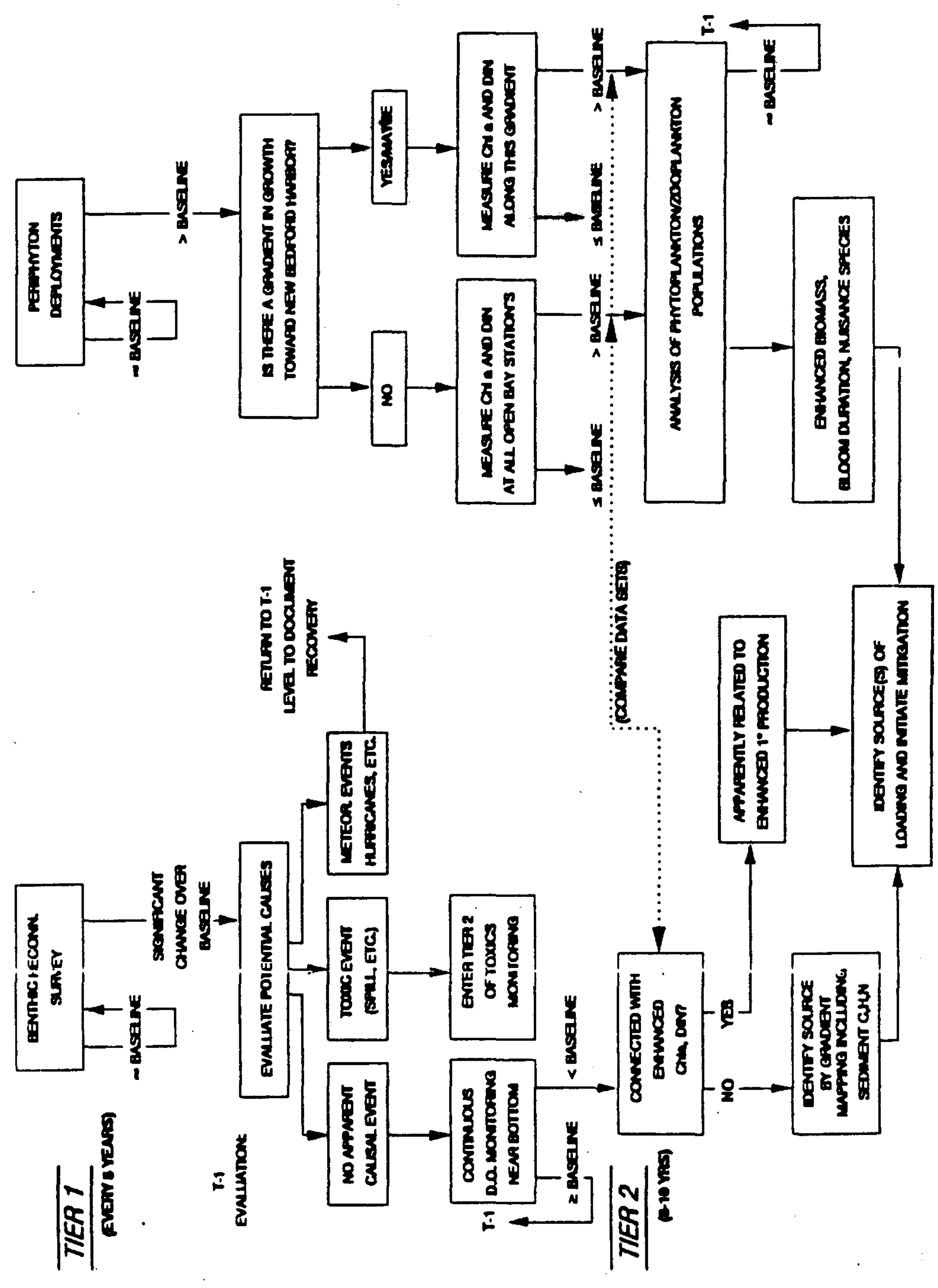


Figure 7. Tiered trend monitoring for nutrients and habitat status in the open bay.

correlated with pollutant levels (Table 9). Sediment samples are also taken at the stations. They are periodically analyzed for contaminants and parameters that aid in interpreting data on contaminants: sediment grain-size distribution and total organic carbon (TOC).

Additional measurements of contaminants in the open bay are available through EPA Office of Research and Development's Environmental Monitoring and Assessment Program (EMAP). EMAP was initiated in 1990 to monitor the health of the nation's ecosystems and is intended to extend over decades. One station is located in Buzzards Bay and one in New Bedford Harbor (Figure 8). Sediments and fish samples are expected to be regularly monitored for toxic contaminants, at least once every 5 years. In the future, additional EMAP stations will be established in the bay and over time, the EMAP data may accumulate sufficient data to be of use in detecting trends in Buzzards Bay (EPA, 1990), but as now designed, EMAP will be unable to answer some of the most basic questions for Buzzards Bay management.

Periodic data may also be available from the U.S. Army Corps of Engineers (USACE) program to monitor the Buzzards Bay Disposal Site, a site used for disposal of dredged material (SAIC, 1990). Monitoring of the site is periodic, although not regular (SAIC, 1990). A control site located approximately 0.25 mi from the disposal site may provide data on toxic contaminants in sediments. The USACE may also survey the quality of sediments within embayments that require dredging. These data should also be included in the baseline program.

If sufficient funds are available, the BBP will conduct additional baseline monitoring at the 12 stations sampled for parameters related to nitrogen loads and the three outer New Bedford Harbor stations (Figure 5). Sediment samples will be analyzed for metals and organic compounds, using the same methods employed by the Mussel Watch Program.

Mitigation and Trend Monitoring. Mitigation and trend monitoring will focus on the effects of cleanup efforts in New Bedford Harbor and on petroleum hydrocarbons and PCBs. The PCB aspect of this monitoring will not duplicate the EPA Superfund monitoring efforts which are focused within New Bedford Harbor. Rather, the effectiveness of the clean-up on

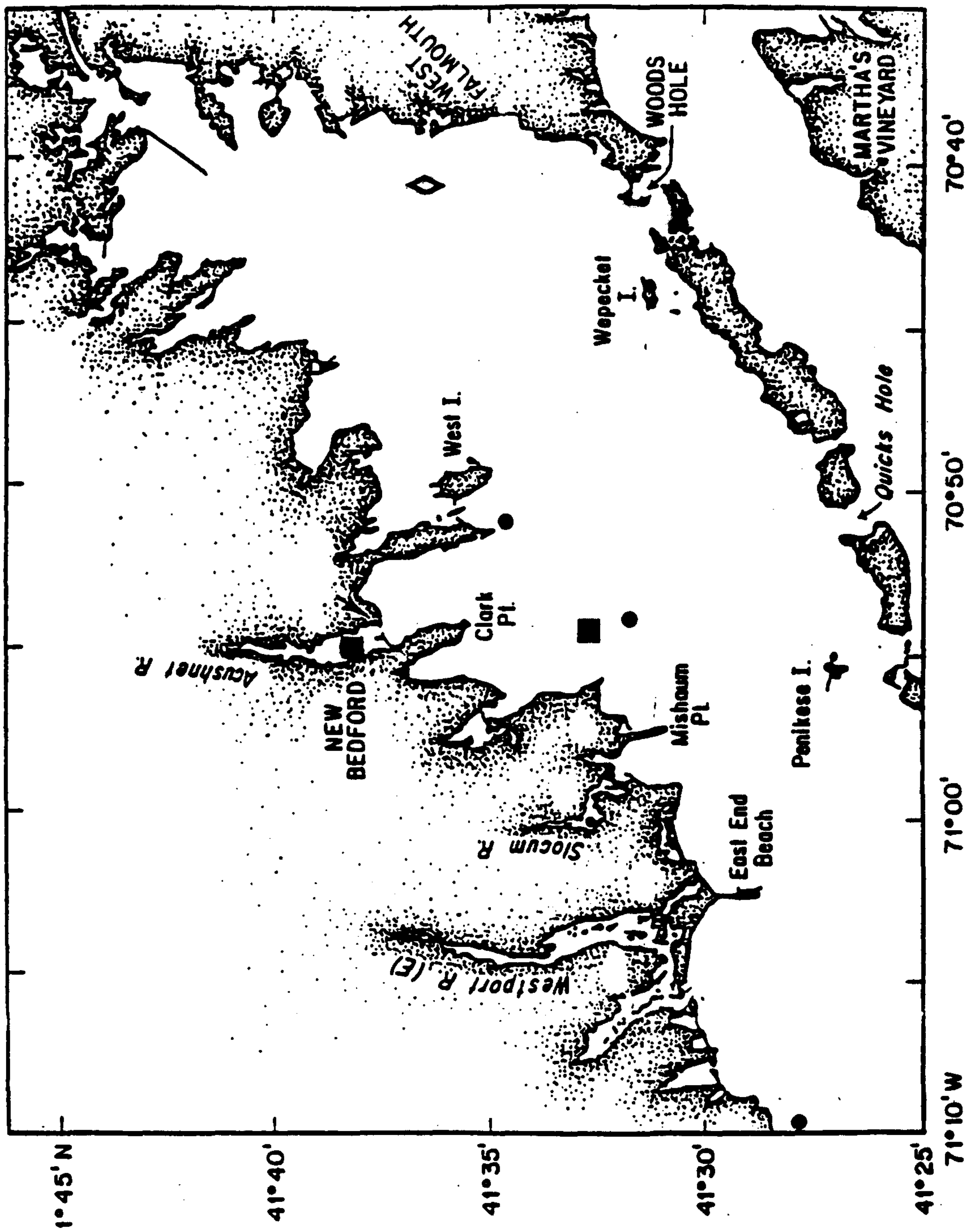


Figure 8. Location of Toxic Contamination Sampling by Federal Agencies (EPA/EMAP: Solid Squares, NOAA/Status and Trends: Closed Circles) and Location of DAMOS Buzzards Bay Disposal Site Monitoring Stations (USACE: Diamond).

Table 9. Chemicals Measured in the National Status and Trends Program.

DDT and Metabolites[a]

o,p'-DDD
p,p'-DDD
o,p'-~~DDE~~
p,p'-DDE
o,p'-DDT
p,p'-DDT

Chlorinated Pesticides Other than DDT[b]

Aldrin
Alpha-Chlordane
Trans-Nonachlor
Dieldrin
Heptachlor
Heptachlor epoxide
Hexachlorobenzene
Lindane (gamma-BHC)
Mirex

Polyaromatic Hydrocarbons[d]

2-ring
Biphenyl
~~Naphthalene~~
1-~~Methyl~~naphthalene
2-Methylnaphthalene
2,6-Dimethylnaphthalene
Acenaphthalene

3-ring
Fluorene
Phenanthrene
1-Methylphenanthrene
Anthracene

4-ring
Fluoranthene
Pyrene
Benz(a)anthracene

5-ring
Chrysene
Benzo(a)pyrene
Benzo(e)pyrene
Perylene
Dibenz(a,h)anthracene

Major Elements

Al	Aluminum
Fe	Iron
~~Mn~~	~~Manganese~~
Si	Silicon

Trace Elements

Sb	Antimony
As	Arsenic
Cd	Cadmium
Cr	Chromium
Cu	Copper
Pb	Lead
Hg	Mercury
Ni	Nickel
Se	Selenium
Ag	Silver
Sn	Tin
Zn	Zinc

Polychlorinated Biphenyls[c]

Dichlorobiphenyls
Trichlorobiphenyls
Tetrachlorobiphenyls
Pentachlorobiphenyls
Hexachlorobiphenyls
Heptachlorobiphenyls
Octachlorobiphenyls
Nonachlorobiphenyls

Other Parameters

Total organic carbon
Grain size
Coprostanol
Clostridium perfringens spores

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[a] Reported as total DDT (tDDT). The dominant compounds are generally p,p'DDE and p,p'DDD.

[b] Reported as total chlorinated pesticides other than DDT (tChlP). Generally this fraction is dominated by dieldrin and the chlodanes.

[c] Reported as total polychlorinated biphenyls (tPCB).

[d] Combined and reported as total polyaromatic hydrocarbons (tPAH). In 70% of the samples, more than 75% of the tPAH was comprised of 4- and 5-ring compounds.

the open bay will be undertaken in the BBP plan. The New Bedford Harbor Superfund Site, and acute and chronic inputs of petroleum hydrocarbons from major and minor spills and runoff, clearly pose the greatest threats from toxic contamination to the open bay.

Ongoing monitoring will include continued evaluation of data generated by the programs already in progress (Figure 9). To facilitate a toxics monitoring program, sediment and tissue samples could be taken during monitoring of nutrients or fecal indicators in the New Bedford area. These could be archived at low temperature (-20° C) and would be available for later analysis of toxic compounds (see Figure 7). Material collected during that monitoring will be archived in the event that future monitoring requires the baseline information. Success of monitoring will depend upon close coordination between monitoring program efforts being conducted by governmental, research and contractual groups, in both data exchange and evaluation of monitoring as discussed later in this Plan.

Tier 1 monitoring will include analysis of surface sediments from areas consisting of organic-rich, silt-clay mixtures (Figure 7). These conditions favor the deposition and retention of toxic compounds. This should be done once every five years or triggered by spill events. If contaminant levels in these samples are higher than predicted, Tier 2 monitoring—analysis of additional sediment samples and/or tissue samples—will document the aerial extent of increased contamination. Tier 2 monitoring will also provide information on contaminant levels in resource species that can be used to estimate public health risks. Higher than expected levels of contaminants could trigger Tier 3, market-basket surveys of contaminants in fishes available for consumption and public health studies.

A separate PCB monitoring module has been developed to provide additional guidance for monitoring this category of toxic compounds in the outer reaches of New Bedford Harbor (Figure 10). Sampling efforts at three stations (Figure 5) are to be used to collect sediments and market basket species (lobsters and flounder, clams, and mussels) for further establishing baseline concentrations that have already been established by the DMF and NOAA Mussel Watch Program (Farrington and McDowell Capuzzo, 1991). We recommend that PCB measurements be repeated every 5 years in the outer harbor following remediation. Because New

Bedford Harbor is the point source for PCBs, any change in the concentration in PCBs in the outer harbor are most likely to be identified from concentration gradients extending along these 3 stations (Figure 5).

An observed decrease in PCBs in the outer harbor may mean that the rate of supply has been reduced by remediation and/or that PCB laden particles are being diluted by burial in the fine-grained sediments of the bay. Tier 1 evaluation may terminate at this point, or the BBP may wish to explore a variety of mechanisms that might explain the observed decrease.

If subsequent surveys show an increase in PCB concentrations following remediation, the first level of evaluation is to determine if this is related to processes that can remobilize these contaminants nearshore. The mechanisms of remobilization and vectors of transport offshore may require a higher level of spatial mapping to identify sources and transport routes (Tier 2). If the remobilization appears to be a one-time event related to remediation, immediate mitigation/remediation might not be necessary. However, if the higher frequency monitoring in Tier 2 shows a chronic release of PCBs extending far beyond the remediation period, management actions may be required to prevent further releases.

Research. Farrington and McDowell Capuzzo (1991), in a summary of sources, fate, and effects of toxic contaminants in Buzzards Bay, noted that the effects of contaminants in the coastal environment depend upon understanding conditions that foster the persistence of contaminants, bioavailability, impacts of sublethal effects of contaminants, and the effects of synergistic effects of complex mixtures of contaminants. They noted that none of these parameters is well understood and that a Buzzards Bay monitoring program must be linked to ongoing research.

One specific research issue that may prove important to Buzzards Bay will be to determine the sources, fate, and effects of herbicides and the newer types of pesticides in Buzzards Bay. Organophosphorus pesticides which are currently used on cranberry bogs, other agricultural crops, golf courses, and home gardens, were developed to degrade quickly, thereby posing minimal problems in the environment. Little research has been conducted to verify these intents. When initial assessments have been made, those data will be used to determine whether ongoing, routine

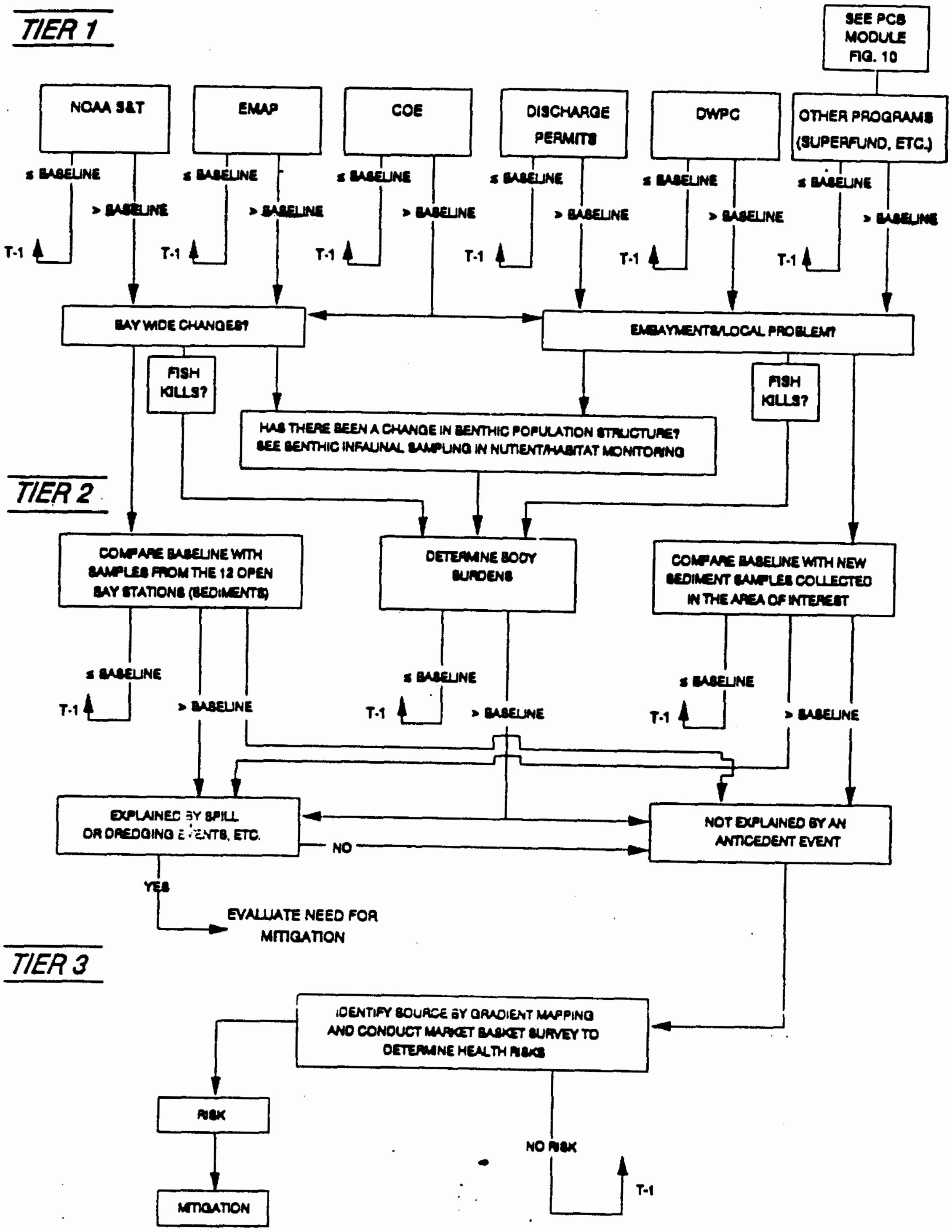

Figure 9. Tiered Trend Monitoring for Toxics. See also Fig. 10 for PCB's.

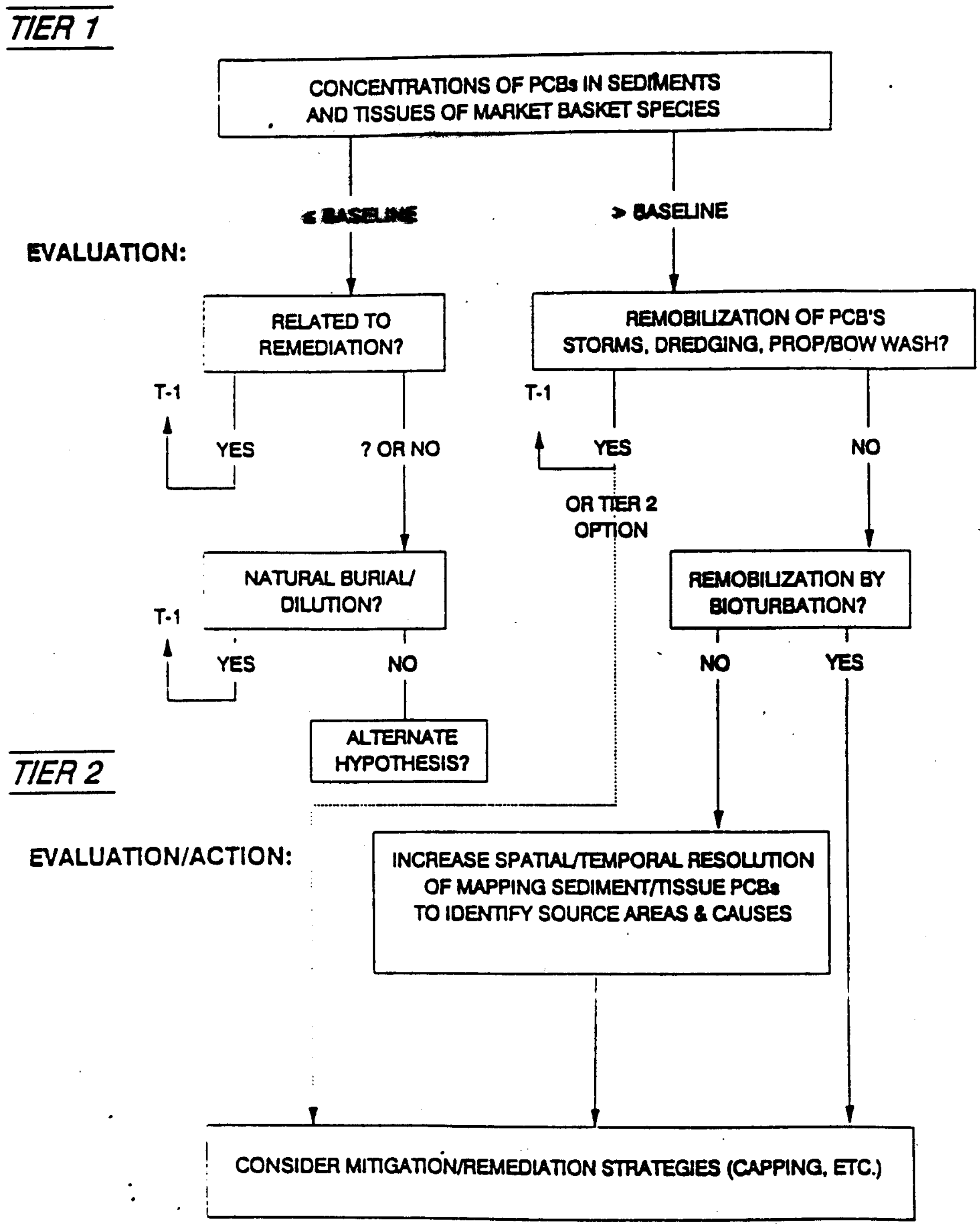

Figure 10. PCB Tiered Module for the Open Bay.

monitoring of herbicides or pesticides should be added to the monitoring program.

Additional studies on bottom paints, especially those containing tributyl tin (TBT), may also be important. The extent of use, fate, and effects of these paints are not well known for Buzzards Bay.

Another research project recommended by Farrington and McDowell Capuzzo (1991) is to use indigenous bivalve or fish populations to define seasonal patterns in contaminant concentrations and their relations to reproductive activity and/or aberrations in physiological conditions. Nonmigratory fish species would be used. This information would provide a basis for evaluating routine measurements of contaminants in resource species.

Habitat Loss

Baseline Monitoring. Baseline data on eelgrass cover are already available for almost all the embayments in Buzzards Bay (Costa, 1988). These data were obtained from aerial photographs taken during 1978-1981.

Mitigation and Trend Monitoring. Continued monitoring will include reevaluation of eelgrass cover and aerial extent of salt marshes and beaches. These assessments will be made every 4 to 8 years, by examination of aerial photographs or satellite data. Should results indicate that loss rates are increasing, assessments will be made at more frequent intervals, and additional monitoring may be planned. This task does not lend itself to a tiered monitoring structure for habitat loss assessment. Rather, the threshold for management concern will need to be established by the BBP once the GIS overlay analysis reveals the extent of aerial change in the systems of interest.

Research. New research may indicate that there are early warning signs that can be used to predict habitat losses. Results of studies of the effects of boat traffic, docks, and moorings on habitat loss, and studies of the interactions between nutrient loads may be used to modify the monitoring program.

Living Resources

Selected commercial and recreational species can be monitored. For example, shellfish, herring, flounder and herring are indicators of water quality. The DMF finfish surveys do not presently include the embayments but this might take place if embayment monitoring shows summer hypoxia to be a potential threat to demersal fish habitats. The catch statistics on spring herring runs that are collected by the DMF from the towns and runs monitored directly by the DMF may be used to assess upstream water quality in the watershed feeding the runs. Although there is a lot of year-to-year variability in such data, runs that have a long temporal database (Bournedale) may be particularly useful for assessing habitat health through living resource monitoring.

Citizens' Roles in Monitoring

Trend monitoring in the 28 embayments around Buzzards Bay is an ambitious and potentially very expensive task. It is critical to obtain as much of these data as possible at low cost. Citizens' monitoring can provide a substantial amount of these data while, at the same time, serving to build civic pride, grass-roots involvement, and a sense of achievement.

Although the data collected by citizens cannot be submitted as evidence to affect official closure or re-opening of shellfish beds or swimming beaches, the information can serve to supplement existing state and local health department monitoring.

Many citizens' monitoring efforts are already underway, including programs in the Buzzards Bay region (Figure 11). The purpose and goals for establishing a citizens' monitoring program in Buzzards Bay are similar to those that have already been initiated in Chesapeake Bay. The Chesapeake Bay citizen's monitoring program serves as an excellent model and should be adopted for incorporation into the Buzzards Bay monitoring program with appropriate modifications to cover only those parameters to be monitored by citizens (Table 3). The Chesapeake Bay Citizen's Monitoring Manual (Alliance for the Chesapeake Bay, 1986) and the

Coordinator's Handbook (Elliott and Mountford, 1988) are informative sources developed to guide program coordinators and volunteers. The 'How and Why' of sampling is covered in detail in the training section and standardized methods and equipment are covered in the handbook along with data management, fund raising, volunteer recruitment, quality assurance, and group motivation.

Citizens monitoring groups listed in Appendix B represent Buzzards Bay organizations that are actively involved in coastal marine water quality monitoring and have expressed interest in becoming more involved in a citizens' monitoring effort. Certain harbors around the bay (e.g., Onset) are populated by citizens who belong to several civic-minded groups. All are interested in preserving water quality and avoiding water use conflicts yet none of these organizations have a water quality monitoring program in place. It appears that there is considerable, but untapped interest in participating in a formal Buzzards Bay citizen monitoring program.

The most successful ongoing citizens' monitoring programs are those sponsored by academic, municipal, or research institutions. Grant or in-kind support such as providing sample analysis, equipment loans, and data management are all important assurances to keep the citizen's network operating. Most citizens' organizations are sustained by feelings of civic pride and making a contribution toward keeping the environment clean. However, this goodwill can be compromised or destroyed if the data generated are not properly stored in a central file, and the findings do not lead to remedial action, due to lack of follow-through by the state or town officials.

Besides being included in the general monitoring described in Section 5, citizens' groups may be able to undertake some special projects such as the following two programs:

Citizen Involvement in Remote Sensing

Table 6 includes aerial remote sensing for periodic mapping of eelgrass beds. Aerial surveillance may also be used to monitor open Bay fronts related to intense bloom conditions. While Table 6 refers to parameters that may be provided by government agencies or outside contractors.

CITIZENS MONITORING GROUPS • BUZZARDS BAY	COLIFORM	DISSOLVED O 2	TEMPERATURE	NUTRIENTS	WATER CLARITY/COLOR SECCHI	SALINITY	PH	DEPTH	ANADROMOUS-FISH CENSUS	EDUCATION/WATER PROTECTION	LAND ACQUISITION AND MANAGEMENT	OTHERS-COMMENTS
AM. LITTORAL SOCIETY									(X)	X		
BOURNE/POLLUTION TASK FORCE												Hazard Waste Census-Street Non-Point
CATAUMET CIVIC ASSOC.	X	X	X	X		X	X	X		X		
COALITION BUZZARDS BAY										X		Land Use Monitoring
LLOYD CENTER										X		Bird Census
MASS. DIV. MAR. FISH.										X		Watchdog Fish, Shellfish Abnormalities
MATTAPOISETT R. PROJECT					X					X	X	
MONUMENT BEACH ASSOC.										X		
ONSET PROTECTIVE LEAGUE										X		
SAVE OUR SEAS	X		X	(X)								Bird Census
SAVE WEST ISLAND										X	X	

(X) = Proposed

Figure 11. Environmental Variables Measured by Citizen's Monitoring Groups.

CITIZENS MONITORING GROUPS BUZZARDS BAY	COLIFORM	DISSOLVED O_2	TEMPERATURE	NUTRIENTS	WATER CLARITY/COLOR SECCHI	SALINITY	PH	DEPTH	ANADROMUS-FISH CENSUS	EDUCATION/WATER PROTECTION	LAND ACQUISITION AND MANAGEMENT	OTHERS-COMMENTS
WESTPORT POLLUTION ADVISORY COMMITTEE	X								X	X		
WESTPORT R. WATERSHED ALLIANCE	X									X		
WHOI/SEA GRANT/ POND STUDY	X	X	X	X		X	X	X		X		
CZM/ADVISORY COMM. (County Planning)										X		
SRPEDD (County Planning)										X		
CITIZENS MONITORING GROUPS OTHER EXAMPLES												
CHESAPEAKE BAY CITIZENS MONITORING PROGRAM		X	X		X	X	X	X		X		Nitrogen/General Observations
NORTH SHORE HARBOR MONITORING PROGRAM: MASS AUDUBON	(X)	X	X		X	X				X	X	Waterfowl Management
RIVERWAY PROJECT-BOSTON-ADOPT-A-STREAM	X	X	X			X	X			X		
PUGET SOUND AMBIENT MONITORING PROGRAM										X		Paralytic Shellfish Poisoning Toxins in Fish
BOSTON HARBOR MONITORING PROGRAM		X	X		X	X				X		
NORTH AND SOUTH RIVERS WATERSHED ASSOCIATION		X								X		Biological Monitoring

(X) = Proposed

Figure 11 continued. Citizen Involvement.

Nevertheless, citizens may be able to provide low level overflight information for part of the remote sensing tasks. For example, R. Buchsbaum (Massachusetts Audubon Society) and F. Short (Jackson Estuarine Laboratory) have documented the existence of eelgrass meadows in coastal waters off the north shore and in Plymouth/Duxbury Bays using a combination of aerial photography and surveys by boat. This technique could be adopted for Buzzards Bay utilizing assistance of local civilian flying clubs within the New Bedford, Hyannis, Falmouth, and Plymouth areas. Guidance for how this type of work should be conducted is given in Costa (1988).

Alewives Restoration Program

Herring are an important component of the Buzzards Bay food web, and are a natural indicator of healthy waters, as well as a good teaching aid for the coastal environment. Donald Bourne, Regional Director of the American Littoral Society of New England, has offered to be the central coordinating agency to organize any re-establishment of volunteer alewives census program within the Buzzards Bay watershed. Alewives Anonymous and representatives of the towns of Marion, Rochester and Mattapoisett are interested in improving herring stocks in this tri-town region. The Buzzards Bay citizen monitoring program can assist the towns and DMF in their spring herring census as well as help maintain or improving herring runs and river habitat.

Vessel and Other Support

Members of the U.S. Coast Guard Auxiliary Flotilla from Marion, Fairhaven, and Westport have expressed interest in participating in the Citizens Monitoring Program and are prepared to collect samples in open waters of the bay, using their vessels.

Other projects may also be developed and added to the program. Coordination and success will require a team effort.

Testing Hypotheses and Setting "Action" Thresholds

This monitoring plan outlines several management questions (listed in Tables 2 through 5) and hypotheses about differences between the current observational data set and baseline conditions (within each tiered approach). While this plan can serve as a general "roadmap" for answering these questions and hypotheses, the Buzzards Bay Project and its Technical Advisory Committee (TAC) will have to revisit each of the monitoring questions and tiered approaches to see if all of the goals and expectations can be realized with available resources. If resources are very limiting, priorities will have to be made. Our program design has gone as far as possible in outlining a general approach that follows guidelines outlined in the National Academy of Science book: **Managing Troubled Waters; The Role of Marine Environmental Monitoring (NRC, 1990)**. Further implementation of our general plan will require the Buzzards Bay Project office and TAC to prioritize work tasks, set "action" thresholds for measured changes in water quality, and to develop specific statistical designs for detecting these thresholds.

Once the prioritized objectives have been listed, criteria for determining "action" thresholds will have to established. For example, in the Tiered Trend Monitoring Program for nutrients and habitat status in embayments (Figure 6), how much of a change in water transparency over baseline conditions will be required to move from tier one monitoring to tier two monitoring? Such management "action" thresholds are often subjective as absolute values for delimiting the boundaries of a "healthy" environment generally are not agreed upon and such baseline data do not exist for Buzzards Bay embayments. Let's say that in this example the TAC initially suggests that a 10% change is sufficient to move from tier one to tier two. This initial decision will involve development of a statistical design for detecting such a change. For example, power analysis (Cohen, 1988) can be used to assure that the sampling design has a reasonable chance of detecting a desired level of change. The sensitivity of a test will depend on the number of samples taken, the variability of the parameter being tested, and the desired level of change to be detected (in this case 10%). The variability can be estimated from available data, or in cases where data are lacking, a subjective estimate may be necessary. Often, the power analysis can show that an unreasonable number of samples are needed to detect the desired level of change, and the original hypothesis or "action" level must be altered. It is important that valuable resources not be wasted on testing hypotheses that have low sensitivity. In our example above, tests for a 10% change in water transparency over baseline may require too many samples for the program budget. Lowering the "action" threshold to 20% may prove to be an affordable compromise for detecting change. In contrast, for fecal coliform monitoring, a change in the closure status of a shellfish resource area may be an adequate threshold criterion for moving from a tier one to a tier two level. Threshold decisions are seldom based on a single criterion but are also influenced by the results of the tier one evaluation including an assessment of how other tier one parameters have changed along with independent information about apparent causal agents.

Several techniques are available for testing hypotheses and relating observed changes to baseline or reference station conditions. A general discussion of these techniques follows (text modified from EcoAnalysis, Inc.).

Summarization

In some cases, it may be important to know the average level of a parameter. For example, one might want to know the average concentration of a toxic chemical (e.g. PCB's) within a critical area. Typically, the average concentration with some measure of variability within the area would be obtained. When the area of interest is not relatively homogeneous, much more precise estimates of the mean can usually be obtained with a random stratified sampling design (Cochran, 1977; Gilbert, 1987). With this technique, the area is subdivided into relatively homogeneous strata or subareas, and random samples are obtained within the strata.

Three steps are involved in an efficient stratified random sampling design. First, optimization analysis (Sokal and Rohlf, 1981, pp. 309-317) should be used to determine the number of replicates to be taken at each random position within the strata. This analysis is based on cost and estimates of the relative magnitudes of the between- and within-replicate variabilities of the parameter(s) of interest. One method of rapidly assessing heterogeneity of benthic environments in the field is with a "quick-look" survey. For this reason, we have recommended such rapid assessment methods (Table 6) for selecting 'sentinel' monitoring stations in embayments by either employing diver reconnaissance transects or sediment-profile imaging surveys. Second, the proportions of the total number of samples to be allocated to the different strata must be determined. The variability of the overall mean value is minimized if the samples are allocated to a stratum in relative proportion to the size of the stratum (or other measure of stratum importance) and the variability of the parameter of interest within the stratum (Neyman allocation, Cochran, 1977, pp.98-99). Third, the number of samples to be taken in the overall study should be determined. Knowing the number of samples per location within strata (first step), the estimated variances within the strata, and the proportions of the total samples to be placed within each strata (second step), the size of the confidence limits around the mean can be estimated for different numbers of total samples (Cochran, 1977, pp.95-96). The number of total samples that gives the desired confidence limits would be chosen. Often, this number of samples is too large given the available resources, and the desired standards of precision need to be lowered. Alternately, one could instead use other less variable (but equally useful) parameters in the study.

If a non-stratified design is used, the same procedure described above should be used as if there were only a single stratum. Here, the second step would be simplified since all samples would obviously be allocated to the one stratum.

Cochran (1977) and Gilbert (1987) give formulae for computing the means and confidence limits once the data are obtained. Alternately, when it is felt that some of the parametric assumptions of this method are seriously violated, bootstrap techniques can be used to compute the confidence limits (Efron and Tibshirani, 1986).

Patterns

Spatial gradients in biological processes or structure or concentration gradients of contaminants can develop in response to known source inputs to the Bay or embayments. Such information is important in defining and refining our conceptual models of how the Buzzards Bay system responds to perturbations. A good general rule for designing surveys to observe spatial patterns is to "put your samples where you want to obtain information." Randomly placed samples can lead to an uneven spatial pattern consisting of undersampled and oversampled subareas. Often, some systematic sampling approach (e.g., grid, transect) will be best for the study of patterns. Other information can be used to modify a completely systematic sampling pattern. For example, one may want to sample less in a relatively homogeneous subarea, and more intensely in an area of rapid directional change. These sampling principles have been observed in our recommendations to sample along a transect extending from New Bedford Harbor out into the open bay. We know that the major long-term threat to the open bay is from toxics and nitrogen additions from New Bedford and so most of the sampling effort is focused on this transect (Figure 5). This same strategy should be employed in other embayments once the summarization phase of reconnaissance sampling is completed.

If the survey data is also to be used for other purposes that require random sampling, the overall area could be subdivided into strata and random sampling within the strata could be used. This approach would at least assure a more even distribution of samples throughout the area (compared to a completely random approach).

The results from such a survey can most often be conveyed with simple graphics or mapping techniques. For example, contours overlaid on a map are often a very useful analytical tool. When there are many measured parameters that contain redundancy, the results can sometimes be more efficiently displayed using summary variables derived from multivariate techniques. For example, principal component analysis (PCA) can be used to summarize environmental data, and other ordination techniques are useful for summarizing biological community patterns (Smith et al., 1988). Note that we have recommended GIS (ARCinfo) for mapping patterns of habitat change (Table 5) for the above reasons. An example of how multiple map (parameter) layers can be used to evaluate habitat status is given in Krieger, Mulsow, and Rhoads (1990).

Correlations

Correlation studies addressing relationships between different patterns (in time or space) can be useful in testing hypotheses concerning cause and effect mechanisms and links within the system. Note that results from a tiered observational program involve an evaluation that requires either a qualitative or quantitative assessment between (for example) periphyton growth and nitrogen loading from changes in land use patterns (Figure 6- tier 1 evaluation). Often, a correlation analysis will involve studying the relationships between patterns defined in the previous category (patterns). Such correlation analyses will often involve the use of regression techniques. When there are multiple independent variables, it is more appropriate to include the independent variables in a single multiple regression analysis than to perform separate analyses for each independent variable (e.g., examine several correlation coefficients, Smith et al., 1988). Discriminant (or canonical variates) analysis can also be useful when studying the correlates associated with differences between groups of observations (Smith et al., 1988).

Experimental Studies

In some cases, it will be important to know some specific information that can only be obtained with an experimental study. Such a study will most often be set up to evaluate a very specific null hypothesis (for example, what is the linkage between observed nutrients and planktonic communities- Table 3 (item 3)). It is important that the sampling and statistical designs control for extraneous factors that may invalidate the test of the null hypothesis.

Analysis of variance (ANOVA) is a valuable analytical technique which can be used to test specific null hypotheses by partitioning the total variability into components due to the various independent variables in the model. Thus, the effects of the separate independent variables (or interactions between combinations of independent variables) can be evaluated. There are assumptions associated with this method that must be considered (Glass et al., 1972). Randomization techniques are variations of the ANOVA approach with less restrictive assumptions but comparable sensitivity (Edington, 1987; Noreen, 1989; Manly, 1991).

A monitoring program designed to test for impact of some external change is an example of such a study. In this type of study, one must distinguish between random error, naturally occurring changes, changes from other impacting agents, and an impact from the external change of interest. To do this, the positioning of sampling locations in time and space must be carefully considered. Replication at the appropriate scales of time and space can provide estimates of the random error, while control sampling locations can give estimates of the natural changes. Samples should be placed to avoid other impacting agents that my confound our results. Other important issues associated with the experimental approach include development and refinement of underlying conceptual models, tiering of observations, power of statistical tests, optimization of sampling design, and pseudoreplication.

Coordinating Efforts

Many of the management questions outlined in Tables 2-5 depend on data collection efforts of the DMF, DEP, EPA, NOAA, FDA, local boards of health, universities, private research organizations, contractors, and citizens. The level of coordination required for efficient data transfer, QA/QC, and storage of data in the ORACLE/ARCinfo data base will be considerable and will form a major responsibility of the Buzzards Bay Project office. The BBP will focus primarily on coordinating state and local activities as federal monitoring programs are designed to answer regional or provincial questions, rather than questions specific to Buzzards Bay.

Cost of Monitoring

The annualized cost of monitoring has been estimated in 1991 dollars from an evaluation of new work tasks and scaling these projected efforts to comparable scopes-of-work in past or ongoing programs. Our evaluation also included a consideration of "no cost" data that can be provided by ongoing funded studies or redirection of existing programs. The costs of each major monitoring task are summarized below:

- Mitigation and trend monitoring for pathogens (Table 2) amount to 200K/yr and research is estimated to be about 60K/yr.
- Nitrogen enrichment trend and mitigation monitoring (Table 3) is estimated to cost 265k/yr and research studies cost 145K/yr with the addition of a one-time start-up (item 4) of 50K.
- Toxic contamination trend and mitigation monitoring (Table 4) is estimated to be 185K/yr. No research efforts are proposed.
- Habitat loss (Table 5) trend and mitigation monitoring is estimated to be 5K/yr with 80K applied to research questions.

The total estimated annualized cost for the program of trend and mitigation monitoring is 650K. Research tasks are estimated to cost 285K (plus an initial 50K start-up for item 4 in nitrogen enrichment). The research programs will have relatively short lives compared with the trend and mitigation monitoring. Therefore, the annualized research funding should be expected to decline over time.

Data Management, QA/QC, and Use of Data

The monitoring project must adopt common and appropriate standardized methods and procedures for all organizations participating in data collection (see Section 13). This is important for data comparability. With the large and diverse volume of data to be collected in the Buzzards Bay monitoring program, a major effort will be required to archive, manage, and interpret these data. The Buzzards Bay Project office will archive and manage a central data repository. The Buzzards Bay Project must see to the timely synthesis of these data to produce information transfer to the scientific community, governmental agencies, as well as the public. This is particularly true of data collected in the citizens monitoring program, where the Project must insure that the data are of sufficient quality that they may be used by mangers and scientists. In Chesapeake Bay, a monthly newsletter on environmental monitoring not only helps to educate a wide range of users of the bay, but also created a lot of public support for the monitoring program. A similar effort needs to be made by the Buzzards Bay Project.

Data collected or obtained by the Buzzards Bay Project will be stored in a relational data base (ORACLE) linked to a geographic informational system (ARCinfo). By using this data management structure, the Buzzards Bay Project can retrieve specified data sets that meet specific information needs (e.g. by parameter, spatial or temporal distributions, or analytical method). These data can be analyzed by project staff or transferred to appropriate regulatory agencies, research investigators, or the Technical Advisory Committee for further investigations. These entities would then be able to analyze these data using existing commercial statistical, analytical or graphical software. For example, the Buzzards Bay Project could map water quality or living resource data together with related parameters or other GIS overlays such as land use or stormwater discharges. This will be a powerful analytical tool for documenting trends and directing management action.

The Project will establish QA guidelines for data entered into the data management system.

Data submission requirements

Transferring data to the Buzzards Bay Project's database requires that data files be in one of several formats. The intent of these requirements is not to constrain those collecting data but to ensure easy transfer of data. If data is to be transferred to the Buzzards Bay Project data base, it is important that the investigators communicate with the Project about data file format and data entry before the files are created. In many instances deviations from the requirements below are possible, but these should be discussed with the Project's Data Manager before data are submitted. Any questions about these requirements or special problems not covered below should also be directed to the Project.

File Formats

Data should be delivered on 3-1/2" or 5-1/4" floppy disks formatted under MS-DOS. Files should be in one of the formats listed below (order of preference indicated).

1) ORACLE export (.DMP) file (version 2.0 of SQL*PLUS)

2) dBase III or III+ file or compatible.

3) QuatroPro file or compatible.

4) Lotus 1-2-3 (version 1 or 2) file or compatible.

5) ASCII files.

If ASCII files are submitted they can be either variable or fixed format, but if variable field format files are submitted, they must be comma delimited. Other ASCII file formats may also acceptable.

File Structure

Table 10 shows the preferred formats for fields in data files. This format is particularly suitable for water column data; for formats for other data types (e.g., sediments, tissues) contact the Project. Where appropriate, it is preferable to leave empty fields blank and to place greater than (>) or less than (<) signs in their own character field when part of an analytical result.

Table 10. Preferred data file format for entry into Buzzards Bay Project data base.

Field Name (comments)	Field Type	Field Width
Station_No	numeric	4
(all stations must have numeric id's)		
Sample_Date	date	8
[Use MM/DD/YY or DD-MMM-YY format for dates (e.g., 02/06/91 or 06-FEB-91 for February 6, 1991)]		
Sample_Time	numeric	4
(times to be entered in "military" time, e.g., 5:15pm is 1715)		
Sample_Replicate, if appl.	numeric	2
Tide_Stage	character	6
(enter as ebbing,flooding, high slack, low slack; project will also record tide table times)		
Tide_Height, if known	numeric	4,2
(4,2 intended to mean total width 4 bytes, with 2 bytes to the right of the decimal)		
Wind_Dir	character	4
(enter as N,E,S,W,NE,NW,SE,SW,or CALM)		
Wind_Speed, if knw (mph)	numeric	2
Analytical Results	numeric	as appropriate

11.3 Documentation

A data dictionary must accompany data submittals. This dictionary need not be voluminous, but should contain the information needed to understand the data file. The data dictionary should include brief explanations of each data field. If database management software is used, the data dictionary must include the structure of the database.

Data documentation should also record:

- The name and phone number of the person who prepared the data file
- The units for each substance sampled
- The analytical methods used
- The equipment used to collect samples
- A synopsis of quality assurance and quality control procedures
- An explanation of any special codes in the data files

All data files should be accompanied by a paper copy. Where a complete copy is impractical, a representative sample may be substituted.

Station Locations

A lookup table for station locations should be included with each data submittal. The file should have three columns, one each for station id, the 'x' coordinate, and the 'y' coordinate. The station id in the lookup table must, of course, be the same as the station id used in the data file. The coordinates should be reported in one of the following geographic projections (ordered in preference):

- State plane coordinates
- UTM coordinates
- Longitude and latitude, as decimal degrees

A map showing locations of sampling stations must be included. This requirement holds whether or not a station coordinates file is included. This map should show the correct location of each station and its unique identifier. Original USGS 7.5' 1:25000 scale topographic quad sheets are preferred but other maps may be substituted if they are first approved by the Data Manager. Photocopies of the relevant portions of quadrangle maps are acceptable, provided the photocopy is labelled with the gradrangle name.

Evaluation of the Monitoring Program

One of the attributes of a responsive monitoring program is that it reexamine itself periodically for the purpose of improving the program's efficiency and responsiveness (NRC, 1990). This review should be the major role of the TAC once the program gets underway. A meeting every two years would serve to review all elements of the program, including the priority management questions, "action" thresholds, hypotheses and logic flows within the tiered protocols, management options for remediation, and resolve logistical and communication problems. New methods and technologies should also be reviewed for their potential to reduce monitoring costs. Normally TAC workshops are highly technical and are therefore not open to the general public. However, the results of such workshops should be made public either through subsequent public presentations or in a widely circulated news letter (or both). The monitoring program results must be made available for public scrutiny and comment. This will go far to maintain local support for the monitoring efforts and provide a positive feedback to citizens who participate in data collection.

Standard Methods and Practices

The BBP supports EPA policy that requires formal quality assurance plans for all monitoring efforts. Quality assurance includes defined standards for personnel, facilities, equipment, and services; data generation and record keeping; data processing; data quality assessments; and corrective actions.

The BBP requires that all monitoring be conducted according to standardized procedures, or if other procedures are used, that their comparability with standard procedures be demonstrated. For the most part, we have discussed what new programs can be implemented and what existing State efforts can be redirected. Most Federal programs, such as EMAP or the Status and Trends Monitoring Program, have been designed to answer questions of national scale, or at the scale of biological provinces. This section provides information on the procedures to be used for the Buzzards Bay monitoring program. The techniques to be used in the Buzzards Bay Program are outlined alphabetically below:

Benthic Infaunal Analysis. Sediment for benthic infauna can be collected with a 0.1 or 0.05 m^2 Ted Young grab. This sampler is similar in biting profile to the Ponar grab, but has been modified with a frame that contains weight to provide stability and consistency in sample collection. This grab is now used by all three federal agencies (NOAA, EPA-EMAP, USACE-DAMOS) conducting monitoring in Buzzards Bay as well as by most of the local research institutions such as WHOI.

For monitoring programs in Buzzards Bay, the smaller grab (0.05-m^2) will be used. At least three replicates will be taken at each site. Upon collection, they will be sieved through screens having mesh openings of 0.5 mm. In some cases a finer mesh of 0.3 mm may be used. These fine mesh screens are necessary in order to retain the smaller benthic infauna that responds to organic enrichment. The samples will be fixed in 10% formalin in prelabeled jars, and transported to the laboratory for analysis. Techniques are described in Hampson (1987).

In the laboratory, each sample will be processed in such a way that all organisms are removed from the sediment, identified to the lowest possible taxon (i.e., species), and counted. These data will be recorded by taxonomists and coded for computer entry and analysis.

Chlorophyll *a* (and Phaeopigments). Samples to be analyzed for chlorophyll *a* will be extracted with cold, 90% buffered acetone in the dark and then analyzed with a spectrophotometer using GF "A" filters. Samples will be acidified and remeasured, following the method of Lorenzen (1967). This analysis is to be carried out by the DWPC and/or outside contractors.

CHN (Carbon, Hydrogen, Nitrogen). Total carbon, hydrogen, and nitrogen in sediment samples will be analyzed using a high-temperature combustion elemental analyzer. In the laboratory the sample is dried, placed into a container where water is added. Next the wet sample is placed in a desiccator where it is then redried to drive off the water and HCl, after which a correction is made for weight changes. This analysis is part of the Tier 2 observational program for the open Bay.

***Clostridium perfringens*.** Sediment concentrations of the enteric bacterium, *C. perfringens* can be used as an independent indicator of organic loading linked to sewage discharges. This bacterium produces endospores when it is discharged into the environment. These spores are highly resistent to die-off during wastewater disinfection and survive for long periods of time in terrestrial and aquatic environments (Bisson and Cabelli, 1980). The concentration of colony forming units (CFUs), as cultured from sediments, is therefore a time-integrated record of fecal input from sewage.

DIN. Separate analyses of filtered samples will be conducted for (1) ammonium and (2) nitrate and nitrite. For ammonium analyses, the samples will be reacted with alkaline hypochlorite and phenol to form indophenol blue (Solarzano, 1969 and Parsons et al., 1984), with adjustments depending upon sample matrix and the autoanalyzer used).

A common alternate method for analysis of ammonium, the salicylate-hypochlorite method (Bower and Holm-Hansen, 1980) is not recommended. Although this method eliminates the need for phenol and therefore offers some advantages for routine use, results are affected by salinity. The authors of the method also have noted that results may be photosensitive. Therefore, the method is not appropriate for outdoor, estuarine work. To measure nitrate and nitrite, a Cd column will be used to reduce the nitrate to nitrite. Nitrite will be measured colorimetrically (autoanalyzer method, modified from Parsons *et al.*, 1984.) Frequent checks of column efficiency will be made to ensure good results.

Dissolved Oxygen. DO can be measured using the Winkler titration method (e.g. Lamott kits), as described in Parsons *et al.* (1984). Brian Howes (Woods Hole Oceanographic Institution, pers. comm., 1990) has developed some modifications of the Winkler method that make it suitable for use by citizens' groups. In addition to the Winkler method, dissolved oxygen may be measured with a polarigraphic electrode. It is advisable to periodically check polarigraphic measurements with Winkler titration results. During part of the time that baseline information is being obtained, DEP will deploy a continuous recording O_2 and light meter in the embayments. It will not be possible to monitor all the embayments at once.

Eelgrass. Eelgrass distributions, as well as other forms of coastal vegetation can be mapped from aerial photographs in areas of concern. This should be done in October (peak growth) followed-up by ground-truth verification of imaged beds. The aerial coverage of vegetation can be quantified with the aid of a computer image analysis system by density slicing of imaged beds. These data should be stored in a GIS for future reference and time-series comparison. Additional descriptions of the methodology can be found in Costa (1988).

Fish Monitoring Methods. The DMF uses a 39' headrope and 51' footrope otter trawl with a 1/2" mesh liner as part of their coastal biannual fishery assessment. These tows are of a 20-minute duration.

Macroalgae Biomass and Composition. Protocols for describing drift algae (unattached algae such as *Ulva* that drift over, and sometimes smother, the bottom have been developed in the NOAA Waquoit Program. These sampling methods include preselection of sites known to be vulnerable to collection of these algae. Low kinetic energy areas, especially depressions or areas of grass beds are candidate areas for accumulation. A 10 x 10 cm Eckman grab is used to collect samples. a sieve is used to remove sand and mud from the sample. The algal reside is then dried at 60° F and dry weights are determined. About 10 stations per embayment are recommended to obtain stable mean to variance ratios.

Particulate Organic Nitrogen. PON will be measured by high-temperature combustion with a commercially available elemental CHN analyzer. Glass "A" filters are to be used. Several firms, including Perkin Elmer, Carlo Erba, and LECO, make instruments that would perform satisfactorily.

Total Nitrogen (TN). Total nitrogen is defined as the sum of particulate organic nitrogen (see above) and nitrogen from persulfate digestion of filtrate. This method of TN is recommended rather than the TKW method.

Pathogens. Pathogens are not directly measured. Instead, fecal indicators are measured and, if they are high in concentration, the assumption is that pathogenic bacteria and viruses may also be elevated. There are currently two standard methods in use to monitor fecal coliform bacteria in the water column: the membrane-filter technique (MF) and the multiple-tube-fermentation technique (MPN). The MF technique consists of passing a defined volume of water through a filter membrane, transferring the filter onto culturing medium, and counting the resulting bacterial colonies after a certain incubation time. The MPN technique includes incubation of a series of dilutions of the water sample in tubes, documenting gas production (metabolic activity) in the dilution series and treating the numbers statistically to estimate numbers of coliforms present. The latter technique is required by the Commonwealth of Massachusetts for closure of shellfish beds and is employed by the Department of Marine Fisheries, Sagamore (M. Hickey, pers. comm.). MPN is therefore the recommended method for fecal coliform counts for purposes of management classification. Coliform counts are also checked in shellfish tissues by the DMF prior to reopening a shellfish bed. Values greater than or equal to 14 cells/100 ml of water may result in closure of shellfish beds. The fecal indicator *E. coli*, which is usually the principal organism measured by the fecal coliform assay, can be quantified by modifying the MPN technique.

Polyaromatic Hydrocarbons (PAHs). PAHs classified as EPA Priority Pollutants will be measured, including both low and high molecular weight aromatics (total of 16 compounds). PAHs in sediments and tissues will be sampled according to standard methods (USEPA 1981) and measured by high-resolution glass capillary GCMS (Gas Chromatography/Mass Spectrometry) for positive identification and measurement of specific organic compounds (USEPA 1979, 1986a; Farrington et al., 1986). Sediments and organisms will be separated and stored frozen until the analysis is carried out, to minimize loss of volatile organic compounds. Storage in a freezer has proved best for determinations of PAHs in tissue samples (Farrington et al., 1986). Sediments and tissues will be extracted with methylene chloride extraction and glass capillary column chromatography (which will allow for analysis of both PCBs and PAHs), followed by GCMS for measurement and identification of PAHs.

Polychlorinated Biphenyls (PCB). PCBs in homogenized sediments and tissues will be measured using high-resolution glass capillary chromatography followed by gas chromatography/electron capture detection (glass capillary GC/ECD). The use of capillary column chromatography (using silica gel) to separate out PCB mixtures, followed by gas chromatography/electron capture detection (GCECD) is essential if high-resolution PCB data are desired--the use of the mass spectrometer (MS) for PCB determination may not be as sensitive as the electron capture detector (ECD) (USEPA 1979, 1981, 1986a). Sediment and tissue samples are stored frozen until the analysis can be carried out. Methylene chloride is used to extract the sample (both sediment and tissue alike) and the extract is run through the capillary column. Isotopically-labelled compounds are added to the concentrate to serve as internal standards.

In fish tissues, the FDA action level for PCBs is 5 ppm (5.0 micrograms of PCB in 1 gram of tissue), and the FDA has proposed lowering this level to 2 ppm (FR, 1979). No levels have been established for benthic invertebrates or algal materials. Since PCBs in tissue have been correlated with lipid content (Mayer et al., 1979; Veith and Kiwus, 1976; Skea et al., 1979), we recommend that a lipid extraction of one homogenized subsample of tissue (if sufficient tissue is available, as from larger benthic invertebrates, macroalgae or fish) be extracted with ether, dried to remove water, and weighed after removal of solvent by sodium sulfate.

Periphyton. Nitex strips will be collected, wrapped in aluminum foil, and frozen. Samples will then be extracted in acetone and analyzed for chlorophyll *a* as described above (Costa, 1988).

Salinity. Salinity will be measured using a refractometer or conductivity meter. The BBP will maintain a set of salinometers which can be loaned to citizens' groups.

Sediment Profile Imaging. The system that will be used obtains images of the top 20 cm of the seafloor in profile (Rhoads and Germano, 1982). Sediment profile imaging is able to assess the gross physical and biological features of near-surface boundary roughness, apparent redox potential discontinuity (RPD) depths, infaunal successional status, and various erosional/depositional features such as mud clasts, sand over mud layering, and the presence/absence of voids in the sediments caused by deepburrowing benthic organisms. The operating procedure for sediment profile imaging in presented in Rhoads and Germano (1982).

Shellfish. Tissue samples are taken from clams and oysters only when a formerly closed shellfishing area is about to be re-opened. The Division of Marine Fisheries (DMF) conducts these investigations. The tissues are checked for coliform levels (see Pathogens above).

Temperature. Temperature will be measured using mercury or electronic thermometers. The BBP will maintain a supply of thermometers and unbreakable cases that may be loaned to citizen volunteers.

Trace Metals and Organic Compounds. Sediment samples for analysis of metals will be collected using acid-cleaned, deionized water-rinsed Teflon sampling tools and Teflon-coated sample bottles which can be tightly sealed. Plastic disposable gloves (free from powder which can introduce particle contamination) and clean handling techniques and facilities on the part of the collecting parties will be used. All sampling instruments used will be cleaned between different samples, using an acid-wash followed by a deionized water rinse.

Sediment samples for organic compounds will be collected in the same manner, taking care to avoid sources of contamination such as oil, ship exhaust fumes, cigarette smoke, food, skin contact, etc. All samples will be frozen immediately, at a recommended temperature of -20 to -30° C (Forstner and Wittman, 1983). Samples for organic analyses will be sent for analysis immediately upon freezing, and will be shipped frozen with freezer-packs in appropriate insulated containers.[2]

Upon thawing in the respective analytical laboratories, samples will be homogenized and subsamples will be taken using the same precautions to avoid contamination described above. Teflon labware and digestion vessels are recommended to minimize contamination during the analysis itself. Extraction and analysis techniques are derived from EPA recommended protocols (EPA, 1982, 1986a-b).

[2]For Monitoring Plan, the samples will be archived. Therefore, it will not be possible to develop data on volatile organic compounds.

Subsamples for metals will be acid-digested, using a combination of hydrochloric and nitric acids, which are often considered to have the highest recovery rates for more volatile metals such as mercury, cadmium and arsenic (Lewis et al., 1989; Forstner and Wittman, 1983). For extraction of organic contaminants from sediments, the methylene chloride-acetone solvent mixture used in 1986 is the recommended method. It does not require a sodium sulfate drying step, as other extraction methods do, processing time is decreased, with lower risk of contamination (Lewis et al., 1989; Brown et al., 1979; EPA, 1986a). Subsequent fractionation of organic compounds can be accomplished using either activated copper/florisil or silica/activated copper/alumina (Lewis et al., 1989; EPA, 1986a), as these both effectively remove interfering compounds containing sulfur or lipids.

Instrumental analysis for metals will vary according to the metals being measured. When metal concentrations are expected to be in the high-to-moderate range, as might be expected for Fe, Al, Cu, Cr, Zn and Ni, Inductively Coupled Plasma Emission Spectrometry (ICPES) will be used. For samples where metal concentrations may be low, as for As, Cd, Pb, Se, and Ag, Graphite Furnace Atomic Absorption Spectrometry (GFAAS) is desirable, as it has a very high precision. For Hg, Cold Vapor Atomic Absorption Spectrometry (CVAAS) is appropriate (Lewis et al., 1989; Forstner and Wittman, 1983). For organic compounds, GCMS would probably be used according to protocols established by the National Status and Trends Program (Mussel Watch).

Transparency. Transparency will be measured concurrently with DO measurements. Measurements will be made by citizens groups using a Secchi disk and/or a PAR (Photosensitive Active Radiation) meter.

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Appendix A: Inventory of On-going Monitoring Programs

There have been numerous research efforts directed toward understanding biological and physical processes in Buzzards Bay. Most of the literature dealing with these programs has been compiled and reviewed in varying degrees by Tripp (1985) and SAIC (1986). Important data sets have been compiled by Brown and Gale (1989a-b) and Brown et al. (1987). In this Appendix, we summarize those on-going monitoring efforts in Buzzards Bay.

Federal Programs

National Status and Trends (Mussel Watch). (National Oceanic and Atmospheric Administration, NOAA).

Mussel Watch is a long-term status and trends program designed to monitor the health of the nation's coastal waters. Data are provided on metal and organic contamination in bivalve molluscs, incidence of disease in bivalve molluscs, and chemical contamination of sediments. Sediment grain-size and TOC are also measured. Three permanent stations are monitored annually in Buzzards Bay.

Environmental Monitoring and Assessment Program (EMAP). (U.S. EPA, Office of Research & Development, Environmental Research Laboratory, Narragansett, Rhode Island)

EMAP is a new federally funded program that is intended to monitor the health of the nation's ecosystems. The first of the ecosystems to be monitored is the Near Coastal Environment. The first of the Near Coastal systems to be sampled was the Virginian Province between Cape Cod and the entrance to Chesapeake Bay during the summer of the 1990.

Buzzards Bay and other near coastal embayments in the Virginian Province were included in the sampling plan. The types of samples that were taken include:

- Long-term dissolved oxygen measurements using moorings equipped with Hydrolabs;
- Profiles of temperature, salinity, dissolved oxygen, turbidity, and Chlorophyll *a* using SeaBird CTDs, fluorometers, and transmissometers;
- Grabs for benthic biology, sediment grain-size and chemical constituents;
- Grabs for sediments to be used in bioassay tests;
- Water samples to be used for calibration and others for bioassay testing;
- Fish trawls for tissue chemical analysis, pathological assessment, and population structure;
- Dredge samples for large bivalve molluscs.

In addition, several research indicators, including sediment profile imaging using a new light weight camera system were used at selected sites. One station off New Bedford will be monitored periodically over the next five years. The data will be used to assess regional trends in sediment quality, but will be available for local users.

Monitoring of the Buzzards Bay Dredged Material Disposal Site near Cleveland Ledge. (U.S. Army Corps of Engineers (USACE), New England District, Disposal Area Monitoring Program (DAMOS)).

This site is located off West Falmouth in 10-12 m of water on a relatively level bottom. Approximately 600 cubic meters of dredged material was dumped in 1989 and 1990. Continued use of site is anticipated for routine maintenance dredging required for the Cape Cod Canal.

A literature report for the site was completed (SAIC, 1986) and a field survey was conducted at the site in March 1990. A bathymetric survey revealed a distinct disposal mound at the center of the site indicating recent disposal activity. Surveys of the biological and sedimentary environment were made using sediment profile imaging and benthic infaunal analysis. Samples were also taken for sediment grain-size determination and chemistry. The results are reported in SAIC (1990) and indicate a relatively healthy uncontaminated area, both at the disposal site and control locations. The USACE plans to conduct limited monitoring at the site as part of the DAMOS program.

State and Locally Funded Programs

The Commonwealth of Massachusetts has supported a variety of monitoring efforts in the past, but at present is only supporting pathogen monitoring. The DEP has conducted extensive surveys of water quality in order to establish baseline conditions of water quality in Buzzards Bay (DEP, 1989a-b), but at present does not conduct routine monitoring. The EPA requires a biannual status report on the water quality of Massachusetts streams, lakes, and estuaries. The DEP polls the relevant state agencies to prepare this Section 305B report. The DEP also carries out an EPA 319 program to assess non-point pollution in the streams, lakes, and estuaries of the state. The BBP anticipates that DEP will ultimately be responsible for a great deal of water quality monitoring as recommended in this monitoring plan.

Seasonal Monitoring of Plankton, Larval Fish, and Water Quality in Buzzards Bay.

An important data set exists for New Bedford Harbor and the open bay over the period October 1987 to the present time. These data are collected on a monthly basis. Biweekly sampling was done from June through September, 1988. Eight stations are sampled for temperature, salinity, water transparency, inorganic nutrients ammonium, nitrite, nitrate, phosphate, silicate), chlorophyll *a* and phaeopigments, total bacterioplankton abundance, and numbers and species composition of phytoplankton, microzooplankton (>20 μm), net-zooplankton (> 102 μm), and ichthyoplankton.

This water column program, directed by Dr. Jefferson Turner, was supported until recently by the Massachusetts Division of Water Pollution Control, the Department of Environmental Protection (DEP). Southern Massachusetts University (SMU) is now supporting these monitoring efforts to assure the continuity of data collection.

Results of the October 1987-September 1988 study have been submitted to the DEP (Turner et al., 1989). The two additional years of data (1988-1989 and 1989-1990) are presently being prepared. These data represent the most detailed and continuous record of water quality for the open Bay. For this reason, we have incorporated several of these stations into the long-term trend monitoring of Buzzards Bay.

Coastwide Fishery Resource Assessment (Resource Assessment Program) (Massachusetts Division of Marine Fisheries, DMF).

The DMF carries out a semi-annual (spring and autumn) standardized bottom trawling program to monitor the relative abundance of fish stocks in Massachusetts territorial waters. This encompasses a 3 nautical mile wide border than extends from Rhode Island to New Hampshire, including Cape Cod and Nantucket Sound. The entire Massachusetts territorial water is divided into five regions, that are in turn subdivided into stations that are defined by depth. Three stations are located in Buzzards Bay. Twenty-minute tows are made along depth contours using a 39/51 otter trawl with a 1/2" mesh liner. Data are collected on the species composition, abundance, and weight of the catch at each of the stations in spring and autumn.

Anadromous Fish Program (Massachusetts Division of Marine Fisheries, DMF).

Statistics on spring herring catches are obtained from town catch reports and from herring runs monitored by the DMF. For those runs that have a long temporal data base (e.g. Bournedale), trends in year-to-year catches provide a baseline for future trend monitoring.

PCB Monitoring in Marine Resources (Massachusetts Division of Marine Fisheries, DMF).

Ten years of data have been collected on edible tissue concentrations of PCB's in lobsters, winter flounder, and quahogs from Area 3 in New Bedford Harbor. Sampling has been done twice a year in spring and fall. These data form a baseline against which future trends can be assessed following mitigation action.

Monitoring of Coliform Levels in Water and Shellfish. (Massachusetts Division of Marine Fisheries, DMF)

The DMF conducts a major program in Buzzards Bay that is directed toward monitoring the health of water in nearshore embayments and shellfish resources. The following activities are carried out:

- monitoring of water at more than 300 stations in 58 or 59 shellfishing areas around Buzzards Bay; each station is sampled 5 times per year; parameters are: temperature, salinity, pH, and fecal coliforms; also noted are weather conditions such as air temperature and precipitation

- collection of additional samples on rainy days in areas where stormwater runoff is a concern, e.g., in Westport

- collection of tissue samples only when a formerly closed shellfishing area is about to be re-opened

- performance of a complete sanitary survey (including an assessment of all potential and actual pollution sources along the entire shoreline) once every 12 years; an evaluation of the shellfish beds is published as a report once every year

Appendix B: Addresses for Citizens Monitoring Organizations

American Littoral Society
New England Regional Office
3 Water Street, P.O. Box 301
Woods Hole, MA 02543
(508)457-1499
Attention: Dr. Donald Bourne

Bourne Pollution Task Force
Town of Bourne
24 Perry Avenue
Buzzards Bay, MA 02532
(508)759-3441
(508)759-5301
Attention: Mr. Steven Kain, Mr. Carl Wirsen

Cataumet Civic Association
Cataumet
P.O. Box 277
(508)564-4404
Attention: Mr. George Seaver

The Coalition for Buzzards Bay
P.O. Box 268
Buzzards Bay, MA 02532
(508)759-5761
Attention: Ms. Marion McConnell

Committee to Save Onset Beaches
P.O. Box 1727
Onset, MA 02558
(508)295-2460
Attention: Ms. Marilyn Knowlton
Ms. Cathleen McFadden

Lloyd Center for Environmental Studies
430 Potomska Road
South Dartmouth, MA 02748
(508)990-0505
Attention: Mr. Mark Mello

Massachusetts Division Marine Fisheries
18, Route 6A
East Sandwich, MA 02537
(508)888-1155
Attention: Mr. Mike Hickey, Mr. Frank Germano

Monument Beach Civic Association
P.O. Box 483
Monument Beach, MA 02553
(508)759-3449
Attention: Mr. & Mrs. Richard Prince

Onset Protective League
P.O. Box 81
Onset, MA 02558
(508)295-8159
Attention: Mr. Albert Fisher, President

Save Our Seas (SOS)
Box 71
Marion, MA 02738
(508)748-2265
Attention: Ms. Georgia McDonald

Save West Island
P.O. Box 757
Fairhaven, MA 02719

Westport Pollution Advisory Committee
Westport Board of Health
816 Main Street
Westport, MA 02790
(508)636-8168
Attention: Mr. Dale Thomas

Westport River Watershed Alliance
Wing Carriage House
1151 Main Road
P.O. Box 3103
Westport, MA 02790
(508)636-3016
Attention: Ms. Betsey McEvoy

Citizens Monitoring of Water Quality in Coastal Ponds
WHOI Sea Grant Program
Woods Hole Oceanographic Institution
Woods Hole, MA 02543
(508)540-4382
Attention: Mr. Alan W. White

CZM/Advisory Committee
Cape Cod Regional Office
Box 226
3225 Main Street
Barnstable, MA 02630
(508)362-3828
Attention: Ms. Pam Rubinoff

Southeastern Regional Planning and Economic Development District
88 Broadway
Taunton, MA 02780
(508)824-1367

Boston Harbor Monitoring Program
Massachusetts Audubon: Boston
3 Joy Street
Boston, MA 02108
(617)367-1026
Attention: Betsey Johnson

Chesapeake Bay Citizens Monitoring Program
Alliance for the Chesapeake Bay
410 Severn Avenue, Suite 110
Annapolis, MD 21403
(301) 266-6873
Attention: Ms. Kathy Ellet

North Shore Harbor Monitoring Program
Massachusetts Audubon-North Shore
159 Main Street
Gloucester, MA 01930
(617)-283-0598
Attention: Ms. Lesley Rowse

North and South Rivers Watershed Association
Scituate, MA
Attention: Ms. Maria Van Dousen, Riverways Program

Puget Sound Ambient Monitoring Program
Puget Sound Water Quality Authority
217 Pine Street, Suite 1100
Seattle, WA 98101
(206)464-7320
Attention: Ms. Susan Handley

Riverways Programs - Adopt A Stream
Department of Fisheries, Wildlife and Environment Enforcement
100 Cambridge Street, Room 1902
Boston, MA
(617)727-1614
(617)727-6278
Attention: Ms. Maria Van Deusen