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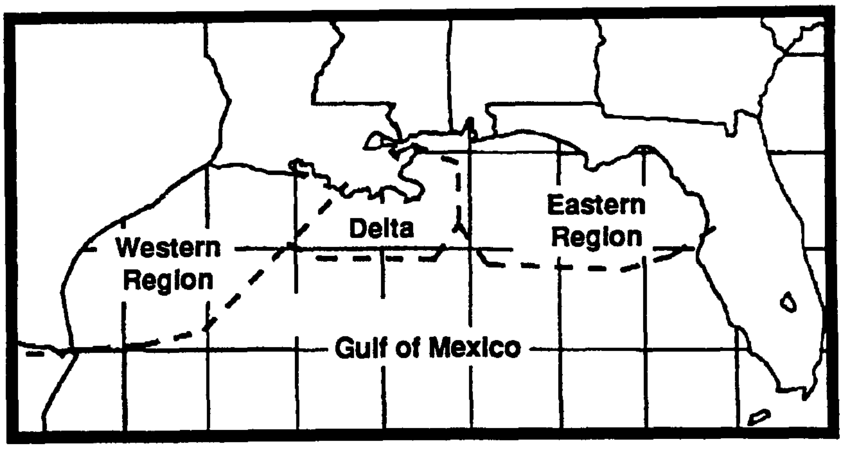
IMPLEMENTATION PLAN FOR MONITORING THE ESTUARINE WATERS OF THE LOUISIANIAN PROVINCE - 1991 DEMONSTRATION



Environmental Monitoring and Assessment Program

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IMPLEMENTATION PLAN FOR MONITORING THE ESTUARINE WATERS OF THE LOUISIANIAN PROVINCE - 1991 DEMONSTRATION

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PREFACE

Environmental regulatory programs in the United States have been estimated to cost more than $70 billion annually. Most of these programs address specific local pollution problems and appear to be effective for the specific purpose for which they were designed. However, the means to assess the effectiveness of these programs in protecting the environment at national and regional scales and over the long-term do not exist. The U.S. Environmental Protection Agency (EPA) considers it critical to establish monitoring and assessment programs to confirm effectiveness of pollution control strategies and corroborate the science on which they are based.

The Environmental Monitoring and Assessment Program (EMAP) is a nationwide initiative by EPA's Office of Research and Development (ORD). It was developed in response to the demand for information on the condition of the nation's ecological resources. The near coastal element of EMAP (EMAP-NC) presently represents one such ecological resource--estuaries. This document specifically addresses the development of an implementation plan for a demonstration of the efficacy and utility of EMAP-NC in the Louisianian Province (i.e., estuaries of the Gulf of Mexico) in 1991.

Although EMAP is funded by ORD, it is designed as an integrated federal program. Throughout the planning of EMAP-NC in the Louisianian Province, ORD worked with other federal agencies, including the National Oceanic and Atmospheric Administration (NOAA), U.S. Fish and Wildlife Service (FWS), the resources and water quality agencies of the five Gulf states (Florida, Alabama, Mississippi, Louisiana, and Texas), as well as other offices within EPA (e.g., Gulf of Mexico Program, Regions IV and VI). These agencies and other offices will participate in the collection and use of EMAP data.

Information obtained in the 1991 EMAP-NC Louisianian Province Demonstration will be used to: (1) demonstrate the value of integrated, multiagency monitoring programs for planning, setting priorities, and evaluating the condition of the estuarine resources in the Gulf of Mexico; (2) define a sampling approach for quantifying the extent and magnitude of pollution problems in Gulf of Mexico estuaries; (3) develop standardized monitoring methods that can be transferred to other programs and agencies for sampling the near coastal environment; (4) identify and resolve logistical issues associated with implementing a multiagency national status and trends ecological monitoring program.

The sampling design used by EMAP-NC for the 1991 Louisianian Province Demonstration combines the strengths of systematic sampling designs with an understanding of estuarine systems to provide unbiased estimates of the condition of estuarine resources. Information from individual sample sites will be used for regional estimates for three classes of estuarine resources: (1) large estuaries (e.g., Apalachee Bay, Mobile Bay, Mississippi Sound, Lake Pontchartrain, Galveston Bay); large tidal rivers (i.e., Mississippi River); (3) small estuaries, bays, inlets, tidal creeks, and tidal rivers (e.g., Cedar Bayou, East Bay Bayou, Withlacoochie River, Little Lake Pelican Bay). Design modifications appropriate for representing the condition and trends in the extent and magnitude of ecological problems will be used when the Louisianian Province Program is implemented.

NOTICE

This document is the final revision of the implementation plan for the Louisianian Province of the Near Coastal component of the Environmental Monitoring and Assessment Program (EMAP).

The report should be cited as follows:

Summers, J.K., J.M. Macauley, and P.T. Heitmuller. 1991. Implementation Plan for Monitoring the Estuarine Waters of the Louisianian Province - 1991 Demonstration. EPA/600/5-91/228. U.S. Environmental Protection Agency, Office of Research and Development, Environmental Research Laboratory, Gulf Breeze, FL.

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1.0 INTRODUCTION

The Environmental Monitoring and Assessment Program / Near Coastal Program (EMAP-NC) is designed to provide a quantitative assessment of the regional extent of coastal environmental problems by measuring status and change in selected ecological condition indicators. The Near Coastal monitoring program began in 1990 with a demonstration in the Virginian Province (Cape Cod, MA to Cape Henry, VA). EMAP-NC proposes to continue the development of the monitoring program with the implementation of a demonstration project in the estuaries of the Louisianian Province (Gulf of Mexico) beginning in the summer of 1991.

Sampling to be conducted in 1991 represents the second year of base monitoring demonstrations for EMAP-NC. As described in the 1990 Research Plan for the Virginian Province (US EPA, 1990), 1991 sampling activities will include further monitoring demonstrations in the Virginian and Louisianian Provinces. The implementation plan presented below describes the sampling and logistical activities planned for the monitoring demonstration in the Louisianian Province to be conducted in July-August 1991 and the analytical activities planned for the collected data during July 1991-January 1992. A data summary report will be available in June 1992.

The basic strategies to be employed in the Louisianian Province (e.g., long-term probability-based sampling, early emphasis on estuarine waters, measurement of indicators with known interpretability) are identical to those described for the 1990 sampling in the Virginian Province (US EPA, 1990). The key issues regarding the near coastal strategy for implementation in the Louisianian Province are described in subsequent chapters.

This document is organized into sections that describe the major elements of the proposed monitoring program for the Louisianian Province. These elements are:

- o <u>Coordination</u> (Chapter 2.0) lists the primary groups involved in environmental management of the Gulf of Mexico resources with whom EMAP-NC will have interaction and describes planned activities.

- o Sampling Design (Chapter 3.0) provides a detailed description of the proposed sampling approach for base-level monitoring as well as details concerning special studies conducted to assess indicator sensitivity and spatial variability.

- o Indicator Selection and Evaluation (Chapter 4.0) describes the strategy used to select the parameters to be measured (i.e., indicators of environmental quality) and describes the activities that will evaluate the sensitivity of the indicators. In addition, this chapter details retrospective data collection and analysis activities completed for key elements of the proposed plan (e.g., optimal sampling times for DO characterization, selection of target species).

- o Logistics Plan (Chapter 5.0) details the sampling activities, communications procedures, training, and the contingency plans for unexpected events. Plans for the reconnaissance of all "planned" sampling locations are described. The project management structure that will be used to monitor the status of all program sampling, laboratory processing, and shipping activities is detailed.

- o Information Management (Chapter 6.0) provides a general description of the data management procedures that will be used to store and manipulate the monitoring data.

- o Quality Assurance (Chapter 7.0) details the procedures that will be used to ensure that the quality of the data collected is sufficient to meet program objectives and the steps that will be followed in subsequent monitoring years to prepare data quality objectives for the Louisianian Province Monitoring.

- o References (Chapter 8.0)

2.0 COORDINATION

To meet the objectives of the EMAP-Near Coastal program in the Louisianian Province will require close cooperation with other federal agencies, state resource and water quality agencies, interested groups, and many other offices within EPA involved in environmental management of Gulf of Mexico resources. Many of these parties are listed below and the following text describes our planned activities to ensure cooperative interaction with these groups. Of major concern to the success of monitoring efforts in the Louisianian Province are:

- The Gulf Of Mexico Program (GOMP)
- EPA Regions IV and VI
- NOAA's Status and Trends, Strategic Assessments, and Coastwatch Programs
- EPA's Office of Marine and Estuarine Protection
- Fish and Wildlife Service
- State Resource and Water Quality Agencies
- Gulf Coast Estuarine Research Institutions.

Estuarine systems are recognized as a National resource and there are many Federal, State, and local agencies concerned with their health, regulation, or management. The Louisianian Province component of EMAP-Near Coastal will coordinate its activities with each of these groups and work jointly with several of these groups in the execution of the monitoring demonstration.

The Louisianian Province Team is actively working with the Gulf of Mexico Program (GOMP). GOMP views its mission as the coordinator and facilitator of environmental activities in the Gulf of Mexico. This program has the longer term responsibility of developing a comprehensive action plan for the management of Gulf resources. As such, the program has a definite need for the type of information that will be generated by the Louisianian Province monitoring effort. GOMP has assisted EMAP-Near Coastal by reviewing earlier versions of this implementation plan. EMAP-Near Coastal has updated the GOMP steering committee at its regularly scheduled sessions. GOMP, EMAP-NC, and the EPA Environmental Research Laboratory at Gulf Breeze, FL signed a memorandum of understanding to cooperate in the execution of EMAP-NC in the Louisianian Province. In addition, EMAP-NC continues to work closely with members of the Toxic Substances and Pesticides Subcommittee in the review of our sediment and tissue contaminants analyte list, in the selection of Indicator Testing and Evaluation sites (ITEs), and in the development of local monitoring plans. Finally, EMAP-Near Coastal was a co-sponsor of the GOMP workshop convened to address problems associated with local monitoring of small estuarine systems. (One of the issues addressed at this workshop was the potential use of EMAP information, designs, and strategies at the local level.)

EPA Regions IV and VI have regulatory jurisdiction over the coastal environments comprising the Louisianian Province. EMAP representatives (e.g., GOMP Director, EMAP-NC Associate Director, Louisianian Province Technical Director) have met with representatives of the Regions IV and VI to update them on the progress of EMAP-Near Coastal. Regional representatives for Regions IV and VI are also members of the GOMP Steering Committee and the Louisianian Province Peer Review Panel and, thus, might fulfill dual roles in the dissemination of information concerning EMAP activities in the Louisianian Province. In addition, EMAP-NC briefings included ORD Regional Scientists, ESD Directors, and other regional personnel. Finally, the EMAP Associate Director/Near Coastal will notify the Regional Administrator, Deputy Regional Administrator, and the ESD Director prior to the initiation of the sampling program in the Louisianian Province. These actions should assist the Regions in tracking all activities in their Region and should provide notice so that the Regions can contribute to our efforts.

EMAP-Near Coastal is currently working closely with NOAA's National Status and Trends Program, Coastal Oceans Program, the Strategic Assessments Branch, and several of its research personnel. The joint NOAA/EPA committee on near coastal monitoring activities has been briefed concerning planned 1991 activities in the Gulf of Mexico and is considering a proposed joint research effort to further develop biological and ecological indicators of ecosystem status. In 1991, NOAA's Coastal Oceans Program (COP) will play an important role in a cooperative EMAP, USFWS, Gulf of Mexico States, and NOAA-COP project to map submerged aquatic vegetation in the Gulf of Mexico. This cooperative effort will help develop and will implement a protocol consistent with NOAA's effort to construct a national SAV inventory. In this cooperative project, SAV habitat will be: 1) photographed, 2) interpreted, 3) verified by surface level sampling, 4) compiled on a base map, 5) reviewed, and 6) digitized. NOAA will provide in kind support, technical expertise, and coordination for groundtruthing, map review, and quality control. In addition, NOAA may extend the planned coverage of SAV habitats by extending coverage seaward of EMAP's near-coastal focus in areas such as the Big Bend area of Florida.

The Louisianian Province includes two National Estuary Programs (i.e., Galveston Bay and Barataria Bay). While the emphases of these NEP, the development of a Comprehensive Conservation and Management Plan for their respective estuaries, have a somewhat different perspective than the regional and national assessments proposed by EMAP, we will interact with the Galveston and Barataria NEPs by providing briefings concerning EMAP-Near Coastal's activities and will strive to develop joint activities where feasible.

The Louisianian Province Team is interacting with the U.S. Fish and Wildlife's (USFWS) National Wetlands Research Center (in conjunction with NOAA's Coastal Oceans Program) in the development of the submerged aquatic vegetation (SAV) monitoring activities of the Louisianian Province. In 1991, USFWS/NOAA will be an integral part of the SAV mapping program in the Louisianian Province and in the development of a sampling and indicator strategy for the assessment of the ecological status of these resources. The Louisianian Province Team is currently interacting with representatives from each of the five Gulf States resource agencies, through USFWS/NOAA, for the ground-truthing of the SAV mapping activities that will be initiated in 1991.

The ultimate goal of EMAP-Near Coastal is to develop a program to monitor the condition of the Nation's coastal resources on a National scale. Recognizing that knowledge on the condition of estuarine resources is as important locally as it is nationally, state and local agencies will undoubtedly be interested in expanding the EMAP program/strategy to meet local and site-specific needs. The Louisianian Province Team is currently interacting with representatives of many of the state resource agencies in the Louisianian Province; including Florida Department of Natural Resources, Florida Department of Environmental Regulation, Alabama Department of Environmental Management, Mississippi Bureau of Marine Resources, Mississippi Office of Pollution Control, Louisiana Department of Natural Resources, Louisiana Department of Water Quality and Texas Department of Parks and Wildlife, Texas Water Commission, and Texas Water Development Board. This interaction spans a number of activities including briefings concerning progress, cooperative efforts within the Toxic Substances and Pesticides Subcommittee of the GOMP, discussions to help state agencies with responsibilities for monitoring to use the EMAP strategy and approach, the use of state personnel to augment sampling crews, and eventually the training of state resource personnel in EMAP-NC's protocols and methods. This early interaction is important to secure cooperation and develop an understanding of EMAP's goals and objectives; particularly, if these state agencies may be involved in the execution of EMAP components at some future time.

The success of the Louisianian Province implementation depends to a large extent upon the cooperation of the state agencies and research facilities of the Gulf community. We have made a concerted effort to brief many of the major estuarine research centers concerning the progress of EMAP-Near Coastal. In addition, EMAP-NC's implementation is a cooperative effort involving five Gulf Coast research centers to implement key aspects of the program. These activities include environmental sampling, benthic sample processing and evaluation, analytical chemistry support, biomarker evaluation, and SAV mapping. As a result, the Gulf Coast Research Laboratory, Ocean Springs, MS; the University of Mississippi, Oxford, MS; Texas A&M University's Geochemical and Environmental Research Group, College Station, TX; Louisiana State University, Baton Rouge, LA; the University of West Florida, Pensacola, FL; and Dauphin Island Sea Laboratory, Dauphin Island, AL will be partners with EPA in the implementation of EMAP in the Louisianian Province.

The peer review process has been an important aspect of the development of the implementation of the monitoring demonstration in the Louisianian Province. This process has consisted of two levels of review: (1) a national peer panel that has reviewed the EMAP-NC Program of which the Louisianian Province Demonstration is a part, and (2) a regional peer panel that has reviewed the specifics of the Louisianian Province Demonstration. The regional peer panel is comprised of members of the Gulf research and regulatory community including academia, federal and state research facilities, and EPA Regions IV and VI. The regional peer panel will remain as a review group for EMAP-NC Louisianian Province activities.

3.0 SAMPLING DESIGN

To accomplish its objectives, EMAP-NC must collect information on the following:

- o The current quantity, extent (e.g., square kilometers, hectares), and geographic distribution of each near coastal ecosystem class of interest;

- o The proportion of each ecosystem class that is currently in "acceptable" condition;

- o The proportions that are degrading or improving, in what regions, and at what rate; and

- o The likely causes of degradation or improvement.

The above issues are important to environmental decision makers for two reasons: (1) decision makers are concerned with the outright loss of ecosystems, as is currently the case with wetlands, and (2) degradation of a portion of an ecosystem resource that is abundant (e.g., high-salinity estuarine waters) is generally more acceptable than degradation of a resource that is limited (e.g., spawning and nursery habitats for shrimp species or productive oyster habitat).

Because EMAP-NC seeks to make statistically unbiased estimates of ecological condition with known confidence, sampling sites cannot be selected subjectively. Rather, they must be selected by a process that ensures the validity of future analyses. Therefore, the sampling network must be probability-based. If the sampling points represent a statistically valid probability sample, the estimates of ecosystem extent and status can be expanded, with quantifiable confidence, to yield estimates for an entire region or nation.

This chapter provides the details for the sampling design to be used in the 1991 Louisianian Province Monitoring Demonstration. Monitoring in the Louisianian Province is being initiated with a demonstration project rather than by full-scale implementation because sufficient information is not presently available to accomplish the following:

- o Determine the appropriate sampling scale to represent resource condition;
- o Estimate the uncertainty associated with many indicators;
- o Define nominal-subnominal boundaries for many indicators;
- o Evaluate the reliability of many indicator responses; and
- o Develop Data Quality Objectives (DQOs).

The objectives of the 1991 Louisianian Province Monitoring Demonstration are to obtain the information needed to: (1) demonstrate the usefulness and ease of presentation of the data resulting from applying the EMAP monitoring approach, (2) develop a logistically feasible sampling design that will define the status and trends of estuaries in the Louisianian Province and will be flexible enough to address alternative objectives, and (3) evaluate trade-offs between cost and uncertainty, allowing DQOs to be developed before full-scale implementation occurs. The data collected during the 1991 Louisianian Province Monitoring Demonstration will contribute to the establishment of baseline determinations of environmental conditions. However, if the scale of sampling (i.e., grid density) and the measured uncertainty levels are acceptable, the results of the 1991 Louisianian Province Monitoring Demonstration can be used as year 1 of a four year monitoring cycle.

The 1991 Louisianian Province Monitoring Demonstration sampling design is different from a full-scale implementation design because it includes sampling strategies that will address important design questions, such as:

- o Intensive sampling to evaluate the influence of spatial scale on the assessment of status, to define a spatial scale that is adequate for full-scale implementation in later years, and to assess the value of information collected from index sampling sites relative to information collected at randomly located sites.

- o Testing and evaluation of indicators to determine the validity, reliability, sensitivity, specificity, and repeatability of indicator responses to discriminate between known environmentally "good" and "poor" conditions.

Much of the information collected from the intensive sampling programs listed above will be applicable to the design of sampling programs in other provinces (e.g., reliability of indicator responses, value of information from index sample locations). EMAP-NC plans to conduct intensive sampling prior to implementing field programs in new provinces or when incorporating new resource types (i.e., coastal waters). The amount of intensive sampling that will be required is expected to decline substantially as additional regions are incorporated into the program and more information becomes available on the scale of regional variation. The design presented in this chapter is modeled after the successes of the Virginian Province Demonstration Project in 1990 and represents a model that could be used each time new provinces or resource types are incorporated into the program.

The remainder of this chapter is presented in two parts:

- o Classification -- the organization of estuarine resources within a region into classes to facilitate sampling and interpretation of findings; and

- o Sampling Design -- the detailed statistical sampling design for the 1991 Louisianian Province Monitoring Demonstration.

3.1 Region and Estuarine Classification

The region to be sampled in the 1991 Louisianian Province Monitoring Demonstration includes the majority of the United States' coastline of the Gulf of Mexico. The Louisianian Province (Fig. 3-1) extends from Anclote Key, Florida, to the United States-Mexico border at the Rio Grande.

The region has a subtropical climate and is characterized by extensive sandy beaches (e.g., Pensacola region), extensive marsh and swamp areas (e.g, Atchafalaya/Vermilion Bays), barrier island systems (e.g., Texas barrier islands), broad hypersaline lagoons (e.g., Laguna Madre), and an expansive deltaic system (e.g., Mississippi Delta).

EMAP-NC proposes to classify near coastal ecosystems (e.g., estuaries) within the Louisianian Province in a manner that defines groups of systems as follows:

- Systems for which a common sampling design can be used.

- Systems where the variability of indicators within a group (i.e., class) is less than that which occurs among groups, thereby reducing the number of samples necessary to represent ecological conditions accurately.

- Systems which allow inferences about systems that are not sampled to be made with a high degree of confidence.

The classification scheme presented in this section is applicable to estuaries; however, the approach used and the principles developed are applicable to all near coastal ecosystem types. The scheme will be applied to other ecosystem types as they are incorporated into EMAP-NC.

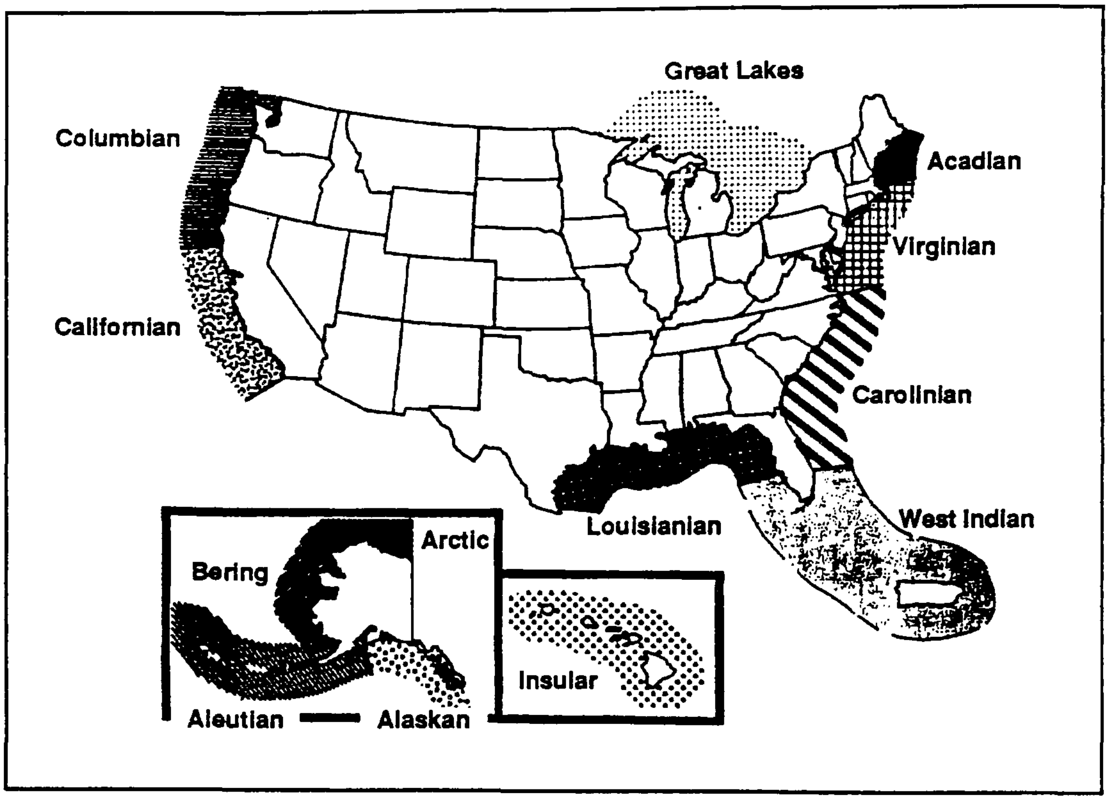

Figure 3-1. EMAP-NC Biogeographical Provinces.

EMAP-NC has given a high priority to classification variables and schemes that define geographic units. The formulation of these classes, especially those that have boundaries that are variable and difficult to define, can severely limit the usefulness of the data for addressing alternative or "new" objectives. In addition, because classes are the smallest sampling units for which data will be summarized, it is important that EMAP-NC class boundaries be delineated in a manner that is meaningful to a broad range of audiences, from the public to scientists. Geographic units are meaningful to all interested parties. It is essential that the boundaries of the classes be defined on the basis of geographic units meaningful for resource management and regulatory action. If class boundaries vary on short time scales (e.g., years or less) or cannot be accurately delineated in a manner for which enforceable decisions can be made, then the value of the EMAP Near Coastal data to environmental decision makers will be reduced greatly.

A review of the literature identified potential classification variables that reduced within-class variance in indicators as salinity, sediment type, pollutant loadings and variables used to infer pollutant loadings (e.g., human population density), and physical dimensions. Use of salinity, sediment type, and pollutant loadings as classification variables would result in the definition of classes for which the areal extent could vary dramatically from year-to-year or over the time period of EMAP-NC.

A classification scheme based upon physical dimensions (surface area, length/average width) was chosen because physical data have the following advantages:

- o Physical dimensions change minimally over the time scale of concern and do not adversely influence the value of resulting data to address alternative or "new" objectives;

- o Surface Areas can be used to aggregate or segregate the data into geographic units that are meaningful from a regulatory and general interest perspective; and

- o Physical dimensions define groups of systems that can be sampled with a common design and for which data can be aggregated to make meaningful regional and national statements about ecological status and trends.

Although salinity, sediment characteristics, and pollutant loadings are not appropriate a priori classification variables, they can be used as post-classification variables during the analysis phase because they have dramatic effects on the ecological aspects of the ecosystem. These system parameters will be used to define subpopulations that will facilitate interpretation and synthesis of the data. EMAP-NC will use subpopulations defined by these variables for making inter-regional and intra-regional comparisons of specific indicators and, eventually, comparisons of trends in indicators. The major constraint associated with using salinity, sediment characteristics, and pollution loading variables in a post-classification mode is that the number of samples comprising subpopulations will vary. The effect of varying sample sizes will be an uncontrollable variation in the uncertainty levels associated with findings.

A total of 30,146 km^2 of estuarine waters is present in the Louisianian Province (i.e., estuarine systems > 2.6 km^2 and with tidal ranges > 2.5 cm). Table 3-1 provides a list of the estuarine resources of the Louisianian Province with surface areas greater than or equal to 2.6 km^2 (~1 mi^2). Resources with surface areas less than 2.6 km^2 were not included in the base sampling frame. However, small bayou systems (i.e., surface areas from 1 to 2.6 km^2) comprise a large number of estuarine systems in the Mississippi Delta region of Louisiana. A sampling frame of the 418 small bayou systems in lower Louisiana was compiled (Table 3-2) to assess the similarity of bayou-systems to the estuaries in the EMAP-NC small estuary category, based on available data. Using information about physical dimensions, estuarine waters of the Louisianian Province were classified into three base sampling categories: large estuarine systems, large tidal rivers, and small estuarine systems. Large estuarine systems were defined to have surface areas greater than 260 km^2 and aspect ratios (length/average width) less than 20. Large tidal rivers were defined as having surface areas greater than 260 km^2 and aspect ratios greater than 20. Small estuarine systems were defined to have surface areas less than 260 km^2 but greater than or equal to 2.6 km^2. In addition, an experimental class comprised of small bayou systems was defined to have surface areas greater than 1 km^2 but less than 2.6 km^2. This experimental class was defined only for the lower Louisiana area and, due to fiscal constraints, will not be evaluated until 1992.

These classes represent estuaries with potentially different behaviors in relation to pollution and other stressors because of different dilution capacities, flushing characteristics, and other factors. The boundaries of these classes can be delineated accurately from available NOAA maps and are not likely to change within the time frame of EMAP. In addition, the classes of small estuaries, large tidal rivers, and large estuaries are meaningful to environmental managers, Congress, scientists, and the public. These classes also form categories for the development and implementation of regional and national management actions.

Application of the classification scheme to the Louisianian Province results in the identification of:

- o Twenty-eight (28) large estuarine systems with a total surface area of 23,773 km2 (79% of the total base area to be sampled);

- o One (1) large tidal river (i.e., Mississippi River) with a total surface area of 307 km2 (1% of the total base area to be sampled); and

- o One hundred fifty-six (156) small estuarine systems with a total surface area of 6,066 km2 (20% of the total base area to be sampled).

- o Four hundred eighteen (418) small bayou systems with a total surface area of 878 km^2 (not included in total base area).

3.3 Sampling Design

EMAP-NC in the Louisianan Province will focus on collecting data for indicators of environmental quality during an index period, when some estuarine responses to anthropogenic and climatic stresses are anticipated to be most severe. The proposed sampling design combines the strengths of systematic and random sampling with an understanding of estuarine systems to collect data that will provide unbiased estimates of the status of the Nation's estuarine resources. This design also will provide reasonable approximations of the variability associated with such estimates.

The following characteristics distinguish the EMAP-NC sampling design from most other monitoring program designs:

- The scale of sampling is regional. The spatial scale of most other monitoring programs is smaller (i.e., individual estuarine systems or portions of systems) (Wolfe et al. 1987; NRC 1991a, 1991b).

- Standardized sampling methods are used across broad geographical regions. Methods used by most monitoring programs are generally standardized across regions; therefore, available data rarely can be combined to perform regional assessments (NRC 1991a, 1991b).

- Sampling is limited to an index period when environmental stress is expected to be most severe; however, sampling effort in the index period is intense. Most other monitoring programs sample throughout the year resulting in the inability to make rigorous statements about any particular time period.

- Measurements are focused on categories of indicators that are linked to major environmental concerns and to each other, allowing the definition of the extent and magnitude of impacts associated with potential causes. Most other monitoring programs are specific to one pollution problem and sample only a few parameters directly related to that problem. Frequently, different programs monitor the effects of the same pollution problem, in the same system, using different parameters (NRC 1991b). Consequently, data from ongoing programs rarely can be combined to estimate the regional extent of even one pollution problem (NRC 1991a).

- A combination of random and systematic components is used in the EMAP-NC design to obtain broad, complete geographic coverage of resource distributions and unbiased estimates of status and trends. Most other monitoring programs sample at fixed stations, do not have complete coverage of resource distributions, and do not include both random and systematic elements (NRC 1991a; Wolfe et al. 1987). In most cases, locations where problems are perceived to be small are not sampled. Unfortunately, these perceptions of the lack of any problems generally cannot be supported.

Table 3-1. List frame of estuarine systems within the Louisianian Province with surface areas greater than 2.6 km^2 (Class refers to estuarine class type: S=Small estuary or tidal river; R=Large tidal river; and L=Large estuary).

State	Estuary	Class	Surface Area (km^2)	Aspect
Alabama	Dauphin Bay	S	2.9	3.2
	Heron Bay	S	2.9	3.2
	Tensaw River	S	5.1	200.0
	Wolf Bay	S	5.4	5.8
	Perdido River	S	6.4	40.0
	Weeks Bay	S	7.0	2.3
	Little Lagoon	S	8.3	13.0
	Mobile River	S	12.8	125.0
	Pelican Bay	S	30.2	1.2
	Grand Bay	S	37.3	2.0
	Bon Secour Bay	L	274.2	1.3
	Mobile Bay	L	895.8	3.0
Florida	St. Martins River	S	2.6	25.0
	Escambia River	S	2.6	25.0
	Withlacoochee River	S	2.7	26.5
	Waccasassa River	S	2.7	26.4
	Steinhatchee River	S	2.7	26.6
	Ecofina River	S	2.8	26.5
	Crystal River	S	3.1	30.0
	Blackwater River	S	3.1	30.1
	Old River	S	3.2	20.0
	Indian Bay	S	3.8	1.5
	Bayou Grande	S	3.8	24.0
	Homosassa River	S	4.1	40.0
	Chassahowitza River	S	4.2	40.0
	Carabelle River	S	4.2	40.3
	Ochlockonee River	S	5.4	53.0
	Goose Creek Bay	S	6.7	1.5
	Choctawhatchee River	S	8.5	83.0
	Big Lagoon	S	9.0	7.1
	Bayou St. John	S	9.0	14.0
	Ochlockonee Bay	S	10.2	4.0
	Oyster Bay	S	11.0	2.5
	Suwannee River	S	13.6	33.3
	Grand Lagoon	S	15.4	6.0
	St. Andrew Sound	S	21.2	8.3
	Horseshoe Cove	S	24.1	2.4
	Apalachicola River	S	25.6	250.0
	Deadman Bay	S	27.1	2.7
	Anclote Anchorage	S	33.8	2.7
	Lake Wimico	S	35.8	3.5
	Withlacoochee Bay	S	36.6	2.0
	Crystal Bay	S	38.4	1.7
	Chassahowitza Bay	S	40.3	1.3

Table 3-1. List frame of estuarine systems within the Louisianian Province with surface areas greater than 2.6 km^2 (Class refers to estuarine class type: S = Small estuary or tidal river; R = Large tidal river; and L = Large estuary).

State	Estuary	Class	Surface Area (km^2)	Aspect
Florida (Cont'd)	St. Vincent Sound	S	43.8	6.7
	Homosassa Bay	S	44.8	2.8
	East Bay (Apalachicola)	S	55.3	3.0
	Waccasassa Bay	S	69.0	3.2
	Perdido Bay	S	80.1	7.1
	Suwannee Sound	S	95.2	2.3
	Cedar Keys	S	126.2	1.8
	St. Josephs Bay	S	157.4	2.5
	Santa Rosa Sound	S	189.2	16.8
	Apalachicola Bay	S	204.3	2.2
	St. George Sound	L	327.7	8.0
	Choctawhatchee Bay	L	398.1	6.2
	Pensacola Bay	L	412.0	3.9
	St. Andrews Bay	L	419.8	6.6
	Apalachee Bay	L	2223.9	3.0
Louisiana	Sabine River	S	2.6	100.0
	Amite River	S	4.1	160.0
	Pearl River	S	5.1	200.0
	Bayou Terrebone	S	5.1	200.0
	Wax Lake Outlet	S	5.1	50.0
	Bayou Teche	S	5.1	200.0
	The Rigolets	S	7.7	12.0
	Mermentau River	S	10.2	100.0
	Calcasieu River	S	10.6	103.5
	Vermilion River	S	11.5	200.0
	Mississippi River Gulf Outlet Canal	S	12.7	220.0
	SW Louisiana Lakes	S	12.8	1.0
	Belle River	S	12.8	125.0
	Lost Lake	S	20.5	2.0
	Grand Bay	S	23.0	4.0
	Lake De Cade	S	25.6	2.5
	Lake St. Catherine	S	28.7	1.1
	Blind Bay	S	30.7	3.0
	Atchafalaya River	S	31.2	305.0
	Caillou Lake	S	38.4	1.7
	Wax Lake	S	41.0	4.0
	Bayou LaFourche	S	43.5	425.0
	Lake Mercant	S	51.2	1.3
	West Bay	S	53.8	2.3
	Lake Plourde	S	61.4	1.5
	Lake Felicity	S	76.8	1.2
	Lake Verret	S	76.9	3.3

Table 3-1. List frame of estuarine systems within the Louisianian Province with surface areas greater than 2.6 km^2 (Class refers to estuarine class type: S=Small estuary or tidal river; R=Large tidal river; and L=Large estuary).

State	Estuary	Class	Surface Area (km^2)	Aspect
Louisiana (Cont'd)	Garden Island Bay	S	81.9	2.0
	Lake Barre	S	82.0	2.0
	Lac des Allemands	S	122.9	1.3
	Fourleague Bay	S	123.1	3.0
	Little Lake	S	125.9	1.4
	Bay Boudreau	S	129.0	1.4
	Caminada Bay	S	133.6	1.5
	Lake Cataouatche	S	133.9	1.5
	Lake Raccourci	S	134.0	1.5
	East Bay	S	153.6	1.7
	Lake Pelto	S	153.6	1.7
	Timbalier Bay	S	204.8	1.3
	Sabine Lake	S	211.2	2.7
	White Lake	S	212.0	2.3
	Grand Lake	S	222.2	1.8
	Lake Salvador	S	245.8	1.5
	Lake Maurepas	L	276.5	1.3
	Calcasieu Lake	L	294.2	4.3
	Mississippi River	R	307.2	187.5
	Caillou Bay	L	356.3	1.8
	Terrebone Bay	L	358.4	1.4
	Barataria Bay	L	368.6	1.0
	Vermilion Bay	L	460.8	2.2
	Atchafalaya Bay	L	491.5	3.3
	Lake Borgne	L	819.2	1.3
	Cote Blance (E&W)	L	1126.4	1.1
	Breton Sound	L	1474.6	1.8
	Lake Pontchartrain	L	2580.5	3.1
	Chandeleur Sound	L	3686.4	2.5
Mississippi				
	Pascagoula River	S	2.6	100.0
	Bernard Bayou	S	2.6	125.0
	West Pascagoula River	S	2.6	25.0
	Heron Bay	S	4.6	1.3
	Portersville Bay	S	6.4	2.5
	Point Aux Chenes Bay	S	7.7	1.3
	Little Lake	S	7.7	1.3
	Pascagoula Bay	S	14.3	1.4
	Biloxi Bay	S	38.7	7.7
	St. Louis Bay	S	49.8	1.5
	Mississippi Sound	L	2587.9	8.7
Texas	Clam Lake	S	2.6	1.0
	Star Lake	S	2.6	1.0

Table 3-1. List frame of estuarine systems within the Louisianian Province with surface areas greater than 2.6 km^2 (Class refers to estuarine class type: S = Small estuary or tidal river; R = Large tidal river; and L = Large estuary).

State	Estuary	Class	Surface Area (km^2)	Aspect
Texas	Lake Austin	S	2.6	1.0
(Cont'd)	Oyster Lake	S	2.6	1.0
	Lavaca River	S	2.6	100.0
	Chocolate Bayou	S	2.6	25.0
	Highland Bayou	S	2.6	100.0
	Guadalupe River	S	2.6	100.0
	Offatts Bayou	S	2.8	27.5
	San Jacinto Bay	S	3.1	3.3
	Scott Bay	S	3.1	1.0
	Colorado Arroyo	S	3.8	66.7
	Neches River	S	4.0	155.0
	Dickinson Bayou	S	4.1	40.0
	Brazos River	S	4.1	160.0
	San Bernard River	S	4.1	160.0
	Galveston Channel	S	4.3	18.7
	Dickinson Bay	S	4.3	1.0
	Burnett Bay	S	4.5	2.8
	Oso Creek	S	4.6	20.0
	Tule Lake Channel	S	4.7	45.5
	Freeport Harbor	S	5.1	12.5
	Rio Grande	S	5.1	200.0
	Aransas Passes	S	5.8	100.0
	Bastrop Bay	S	5.8	1.0
	Moses Lake/Dollar Bay	S	7.7	3.0
	Drum Bay	S	7.7	1.3
	Jones Bay	S	7.7	1.5
	Pringle Lake	S	7.7	3.0
	Sabine-Neches Canal	S	10.0	97.5
	Laguna Madre Bays	S	10.2	2.0
	Cedar Lakes	S	10.2	4.0
	South Bay (Laguna Madre)	S	10.3	1.0
	Houston Ship Canal	S	10.4	102.0
	Powderhorn Lake	S	11.5	4.5
	Shoalwater Bay	S	11.5	18.0
	Oso Bay	S	12.8	5.0
	Chocolate Bay	S	19.2	3.3
	Bolivar Roads	S	22.0	2.2
	Christmas Bay	S	23.0	1.0
	Caracahua Bay	S	26.9	4.7
	Hynes Bay	S	30.7	3.0
	St. Charles Bay	S	34.6	6.0
	Tres Palacios Bay	S	35.8	3.5
	Redfish Bay	S	38.4	1.7
	Mesquite Bay	S	41.0	1.0

Table 3-1. List frame of estuarine systems within the Louisianian Province with surface areas greater than 2.6 km^2 (Class refers to estuarine class type: S=Small estuary or tidal river; R=Large tidal river; and L=Large estuary).

State	Estuary	Class	Surface Area (km^2)	Aspect
Texas (Cont'd)	Copano Bay	S	102.4	2.5
	East Matagorda Bay	S	115.2	7.2
	Lavaca Bay	S	117.8	2.9
	Espiritu Santo Bay	S	112.9	3.0
	Aransas Bay	S	161.3	5.1
	San Antonio Bay	L	266.2	2.5
	Baffin Bay	L	266.4	2.5
	East Bay (Galveston)	L	268.8	2.1
	West Bay (Galveston)	L	269.1	2.2
	Corpus Christi Bay	L	286.7	1.8
	Matagorda Bay	L	399.4	3.7
	Galveston Bay	L	860.2	1.7
	Laguna Madre	L	1323.5	17.1

Table 3-2. Small Louisiana bayous greater than 1 km^2 but less than 2.6 km^2 in surface area. Systems shown are associated with the larger estuarine system indicated.

Timbalier Bay System:

1. Devils Bay
2. Bay Champagne
3. Bay Marchand
4. Pierle Bay
5. Bayou Moreau
6. Laurier Bay
7. Lake Billiot
8. Bayou Blue
9. Catfish Lake
10. Grand Bayou
11. Deep Lake
12. Bay Courant
13. Bayou Pointe au Chien
14. Bayou Moreau

Barataria Bay System:

1. Lake Laurier
2. Lake Pelourde
3. South Lake
4. Southwest Louisiana Canal
5. Caminada Bay
6. Bay Tambour
7. Bay des Iletes
8. West Champagne
9. Fishermans Bay
10. North Lake
11. Bayou Ferblanc
12. Round Lake
13. Bayou Casse Tete
14. Creole Bay
15. Briste Lake
16. Pound Lake
17. Hackberry Bay
18. Grand Bayou
19. Mud Lake
20. Bay Dosaris
21. Bayou St Denis
22. Bayou Rigolettes
23. Bayou Perot
24. Bayou Dupont
25. Dupre Cut
26. Bayou Barataria
27. Raquette Bay
28. Lake Hermitage
29. Bayou Grand Chenier
30. Wilkinson Canal

Terrebone Bay System:

1. Old Lady Lake
2. Bayou Jean Lacroix
3. Lake Chien
4. Lake Tambour
5. Wonder Lake
6. Bayou Barre
7. Bayou La Cache
8. Bayou Terrebone
9. Lake St Jean Baptiste
10. Bay Lost Reef
11. Lake la Graisse
12. Bay Welsh
13. Tambour Bay
14. Bay Blanc
15. Jacko Bay
16. Coupe Nouvelle
17. Bay Round
18. Pelican Lake
19. Bayou Sale
20. Bay Sale
21. Deer Bay
22. Bayou Petit Caillou
23. Deep Saline
24. Houma Navigation Canal
25. Bayou Grand Caillou
26. Bay Chaland
27. Bay la Peur
28. Sweetwater Pond
29. Four Point Bayou
30. Quitman Lake
31. Lake Cero
32. Long Lake
33. Lake Fields
34. Bayou L'Eau Bleu

Caillou Bay System:

1. Dog Lake
2. Bay Voison
3. Charleys Bay
4. Bayou Colyell
5. Bayou Plat
6. Felix Lake
7. Bayou Grand Caillou
8. Grand Bayou du Large
9. Moncleuse Bay
10. Bayou Sauyeur

Table 3-2. Small Louisiana bayous greater than 1 km^2 but less than 2.6 km^2 in surface area. Systems shown are associated with the larger estuarine system indicated.

Barataria Bay System (Cont'd):

31. Upper Wilkinson Bay
32. Wilkinson Bay
33. Bay Chene Fleur
34. Bay Sansbois
35. Freeport Sulfur Canal
36. Lake Grand Ecaille
37. Cat Bay
38. Bayou Fifi
39. Bay Melville
40. Bay Long
41. Bay Ronquille
42. Robinson Canal
43. Billet Bay
44. Lake Washington
45. Lake Robinson
46. Pipe Bay
47. Garden Bay
48. Bay Lanaux

Mississippi Delta Bays:

1. Bay Joe Wise
2. Bastian Bay
3. Adams Bay
4. Grand Bayou
5. Bay de la Cheniere
6. Bayou Long
7. English Bay
8. Drakes Bay
9. Bayou Huertes
10. Bay Pomme d'Or
11. Big Cypress Bayou
12. Cyprien Bay
13. Bay Coquette
14. Skipjack Bay
15. Bay Jacques
16. Chicharas Bay
17. Bayou Grand Laird
18. Hospital Bay
19. Yellow Cotton Bay
20. Spanish Pass
21. Bay Tambour
22. Sandy Point Bay
23. Fleur Pond
24. Red Pass
25. Tiger Pass
26. Bayou Tony
27. Pass de Wharf

Caillou Bay System (Cont'd):

11. Bay Long
12. Bayou du Large
13. King Lake
14. Mud Lake
15. Mudhole Bay
16. Bay Junop
17. Fiddlers Lake
18. Blue Hammock Bayou
19. Oyster Bayou
20. Bay Castagnier
21. Mosquito Bay
22. Lake Chapeau
23. Big Carencro Bayou
24. Carencro Lake
25. Small Bayou LaPointe
26. Lac Pagie
27. Bayou Mauvais Bois
28. Lake Penchant
29. Lake Theriot
30. Bayou Penchant
31. Lake Hatch
32. Bayou Copasaw
33. Bayou Cocodrie

Atchafalaya Bay System:

1. Creole Bayou
2. Bayou Penchant
3. Plumb Lake
4. Plumb Bayou
5. Palmetto Bayou
6. Crooked Bayou
7. Deer Island Bayou
8. Sweetbay Lake
9. Avoca Island Cutoff
10. Little Horn Bayou
11. Lake Cascha
12. Turtle Bayou
13. Piquant Bayou
14. Bayou L'Ourse
15. Big Wax Bayou
16. Grassy Lake
17. Flat Lake
18. Little Bay
19. East Bay
20. Little Hog Bayou
21. Big Hog Bayou

Table 3-2. Small Louisiana bayous greater than 1 km^2 but less than 2.6 km^2 in surface area. Systems shown are associated with the larger estuarine system indicated.

Mississippi Delta Bays(Cont'd):

28. Pass Tante Phine
29. Grand Pass
30. Chawee Bay
31. Jaquines Pass
32. Williams Pass
33. Felice Bayou
34. Riverside Bay
35. Zinzin Bay
36. Dixon Bay
37. Scott Bay
38. Cockler Bay
39. Whale Bay
40. Southwest Pass
41. South Pass
42. Cheniere Pass
43. Redfish Bay
44. Southeast Pass
45. Pass a Loutre
46. Jackass Bay
47. North Pass
48. Customhouse Bay
49. Bull Bay
50. Raphael Pass
51. Horse Shoe Pond
52. Bucket Bend
53. Main Pass
54. Woodyard Pond

55-83. 29 Unnamed South Pass Bays
84-130. 47 Unnamed Delta National Wildlife Refuge Bays

Breton Sound System:

1. Alexis Bay
2. Carencro Bay
3. Grand Bay
4. Grand Couqille Bay
5. Little Couquille Bay
6. Bay Denesse
7. Quarantine Bay
8. Cuselich Bay
9. California Bay
10. Bay la Mer
11. Allen Bay
12. Auguste Bay
13. Long Bayou
14. American Bay

Atchafalaya Bay System (Cont'd):

22. Belle Isle Lake
23. Little Wax Bayou
24. New Pass Bay
25. Wax Lake Outlet
26. Six Mile Lake
27. Pierre Bay
28. Bayou Long
29. Hog Bayou
30. Bayou Blue

Cote Blanche Bay System:

1. Bayou Sale Bay
2. Bayou Sale
3. Fresh Water Lake
4. Mud Lake
5. Franklin Canal
6. Pipeline Canal
7. Charenton Canal
8. Bayou Choupique
9. Lake Sand
10. Bayou Blanc
11. Lake Ferme
12. Oyster Lake
13. Lake Blanc
14. Lake Micheal
15. Lake Tom
16. Lucien Lake
17. Bayou Lucien
18. Hackberry Lake
19. Hummock Lake
20. Bayou Cypremort

Vermilion Bay System:

1. Weeks Bay
2. Weeks Bayou
3. Wilkins Canal
4. New Iberia Drainage Canal
5. Tigre Lagoon
6. Lake Peigneur

Chandeleur Sound System:

1. Lake Anathasio
2. Twilight Harbor
3. Eloi Bay

Table 3-2. Small Louisiana bayous greater than 1 km^2 but less than 2.6 km^2 in surface area. Systems shown are associated with the larger estuarine system indicated.

Breton Sound System (Cont'd):

15. Bay Crabe
16. Black Bay
17. Bay Gardene
18. Bay La Fourche
19. Third Bay
20. Grand Point Bay
21. Back Levee Canal
22. River Aux Chenes
23. Bay of River Aux Chenes
24. Bakers Bay
25. Bayou La Croix
26. Forty Arpent Canal
27. Big Mar
28. Delacroix Canal
29. Reggio Canal
30. Spanish Lake
31. Grand Lake
32. Lake Batola
33. Sun Lagoon
34. Lost Lake
35. Lake Lery
36. Reggio Canal #2
37. Bayou la Change
38. Hopedale Lagoon
39. Middle Bayou
40. Bayou Terre au Poeuts
41. Lake Amedee
42. Bay Shallow
43. False Bayou
44. Lost Flat Bayou
45. Lake Campo
46. Dead Duck Pass
47. Lake Pato Caballo
48. Round Lake
49. Lake Batola
50. Bottle Lagoon
51. Lake Calebasse
52. Lake Jean Louis Robin
53. Mississippi River Gulf Outlet
54. Lake Couquille
55. Pisana Lagoon
56. Lake of Second Trees
57. Lake Machias
58. Lake Fortuna
59. Drum Bay
60. Saint Helena Bay

Chandeleur Sound System (Cont'd):

4. Lake Eliot
5. Bayou Pointe-en-Pointe
6. Bayou la Loutre
7. Halfmoon Lake
8. Christmas Camp Lake
9. Treasure Bay #1
10. Morgan Harbor
11. White Log Lake #1
12. White Log Lake #2
13. Skiff Lake
14. Lake of the Mound
15. Blind Lagoon
16. Long Lagoon
17. Engineers Canal
18. Halfmoon Pass Bay
19. Bayou Cuyago
20. Padre Bayou
21. Grand Bayou
22. Magill Lagoon
23. Lakes of Bayou Merron
24. Bobs Lake
25. Cutoff Lagoon
26. Bayou Biloxi
27. Muscle Bay
28. Stump Lagoon
29. Drum Lake
30. Lake Eugenie
31. Lawson Bay
32. Drum Bay
33. Keelboat Pass
34. Live Oak Bay
35. Conkey Cove
36. Fishing Smack Bay
37. Fox Bay
38. Redfish Bend
39. Cranetown Bay
40. Kerchimbo Bay
41. Shell Island Lake
42. Indian Mound Bay
43. Treasure Bay #2

- Index samples will be collected to facilitate and enhance the interpretation of the data from randomly selected sites. Most other monitoring programs include only index samples. Consequently, these programs cannot be used to describe, in a probabilistic sense, the degree to which the data are representative of conditions throughout the resource (NRC 1991a).

- The intended time frame of sampling is long-term (decades), and trend evaluations will be based on multi-year baselines. Most other monitoring programs are limited in duration (several years), with baselines based on one or two years of data; therefore, trend evaluation relies on differences among years (Wolfe et al. 1987; NRC 1991a). This approach is clearly flawed because of the high year-to-year variation characteristic of near coastal resources (e.g., Holland et al. 1987).

3.3.1 Base Sample Selection for Large Estuarine Systems

Sampling sites in large estuarine systems were selected using a randomly placed systematic grid. The distance between the systematically spaced grid points is approximately 18 km. This grid is an extension of the grid proposed for generic use by EMAP (Overton 1989). It is hierarchical, consisting of a series of grids representing increasing spatial densities, that are appropriate for sampling at national, regional, subregional, and local scales. An hexagonal space or cell was identified surrounding each grid point and a randomly placed sample site was selected for each hexagon.

For the 1991 Louisianian Province Monitoring Demonstration, 625 grid sample locations were identified within an area designated as the Gulf Coast extending from 50 km inland to 50 km offshore. The 625 potential sampling sites were plotted on NOAA nautical charts, and 55 were found to be within the boundaries of large estuarine systems. The remaining potential sites were located primarily on land, and in the Gulf of Mexico, while some were located in large tidal rivers or in small estuaries. According to available NOAA charts, seven (7) of these 55 base locations for large estuarine systems were found to occupy areas with restricted access or depths less than 1 m (i.e., Mobile Bay, Mississippi Sound, Laguna Madre, Choctawhatchee Bay). The 55 potential sites for large estuarine monitoring are listed in Table 3-3 and shown in Fig. 3-2. All of these sites, with the exception of the seven shallow water sites, will be sampled in the 1991 Louisianian Province Monitoring Demonstration.

3.3.2 Base Sample Selection for Large Tidal River Systems

The selection of sampling sites for the large tidal rivers class was based on a linear analog of the design for the large estuarine systems. A systematic linear grid was used to characterize the spine of the Mississippi River to a point 150 km upstream from the mouth (i.e., approximately head of tide). The spine is located systematically on the river, placing the start-point of the spine at the mouths of the tidal river (i.e., the Missississippi River has four primary outlets). The spine was broken into segments every 15 km. The first four segments occurred between river-kilometer 0 and 15 as delineated by the four separate passes and subsequent segments were determined every 15 km along the upstream course of the river resulting in a total of ten (10) segments. A random location was selected within each tidal river segment. In addition, an index site was located in each tidal river segment along the downstream margin of the segment; index sampling sites were located in a deep, muddy portion of the transect, usually near the channel. The design for large tidal rivers results in 20 locations (10 index samples and 10 random samples). The 20 sample locations (index and random) for the Mississippi River are listed in Table 3-4 and are shown in Fig. 3-2.

3.3.3 Base Sample Selection for Small Estuarine Systems

The small estuarine systems class was composed of 156 systems. For the 1991 Louisianian Province Monitoring Demonstration, 47 (i.e., ~ 30 percent) of the available small estuarine systems were selected randomly. These systems were geographically dispersed from east to west by combining adjacent small estuaries into groups of four and taking a systematic random sample from each group. Both an index sampling site and a randomly selected sampling site deeper than 1 m, where possible, were identified within

Table 3-3. 1991 base sampling locations for large estuary class.

Estuary	Location			
	Latitude (N)		Longitude (W)	
Apalachee Bay, FL	30	0.76'	83	59.47'
	29	54.23'	84	12.56'
	30	1.56'	84	16.22'
Choctawhatchee Bay, FL	30	24.54'*	86	26.55'*
Bon Secour Bay, AL	30	18.13'	87	57.94'
Mobile Bay, AL	30	35.43'	88	3.22'
	30	25.93'*	88	6.21'*
Mississippi Sound, MS	30	18.66'	88	12.65'
	30	15.26'	88	26.05'
	30	12.86'	88	29.47'
	30	20.63'	88	54.22'
	30	14.48'	88	57.49'
	30	22.66'*	89	1.76'*
	30	16.46	89	3.44'
	30	15.48	89	9.64'
	30	7.63'	89	21.10'
	30	8.13'	89	28.62'
Chandeleur Sound, LA	29	58.24'	88	51.08'
	29	59.23'	88	58.21'
	29	41.68'	89	0.45'
	29	53.20'	89	4.90'
	29	56.69'	89	6.47'
	29	44.61'	89	13.97'
Breton Sound, LA	29	30.84'	89	6.09'
	29	31.06'	89	11.78'
	29	39.03'	89	12.24'
Lake Borgne, LA	30	5.30'	89	38.82'
	29	56.71'	89	42.88'
	29	59.56'	89	46.38'
Lake Ponchartrain, LA	30	10.30'	89	49.18'
	30	14.22'	90	2.14'
	30	20.02'	90	9.98'
	30	2.74'	90	10.01'
	30	10.03'	90	10.04'
	30	9.97'	90	19.99'
Lake Maurepas, LA	30	15.00'	90	30.00'

Table 3-3. Continued.

Estuary	Location			
	Latitude (N)		Longitude (W)	
Lake Salvador, LA	29	45.00'	90	14.99'
Barataria Bay, LA	29	24.54'	89	55.67'
	29	21.55'	89	57.74'
Terrebone Bay, LA	29	7.32'	90	28.47'
Caillou Bay, LA	29	8.84'	91	3.69'
Cote Blance Bays, LA	29	34.69'	91	34.18'
	29	36.88'	91	41.99'
Vermilion Bay, LA	29	48.94'	91	52.28'
	29	37.85'	92	1.70'
Galveston Bay, TX	29	20.71'	94	44.47'
	29	39.18'	94	49.32'
Matagorda Bay, TX	28	34.38'	96	16.76'
	28	35.58'	96	25.46'
San Antonio Bay, TX	28	16.85'	96	47.22'
Laguna Madre, TX	26	21.78'*	97	16.03'*
	26	36.19'*	97	21.27'*
	27	20.35'*	97	22.17'*
	26	55.44'*	97	26.89'*
	26	59.49'	97	26.98'

* Depth of site is anticipated to be less than 1 meter.

Table 3-4. 1991 base sampling locations (random and index) for the large tidal river class.

Tidal River	Segment Number	Sample Type	Location Latitude (N)		Longitude (W)	
Mississippi River	1	R	28	57.09'	89	23.80'
		I	28	54.90'	89	25.40'
	2	R	29	8.50'	89	14.91'
		I	28	59.11'	89	8.50'
	3	R	29	12.29'	89	2.20'
		I	29	12.88'	89	1.20'
	4	R	29	12.50'	89	16.98'
		I	29	9.00'	89	15.17'
	5	R	29	21.00'	89	25.12'
		I	29	16.85'	89	21.02'
	6	R	29	20.60'	89	29.60'
		I	29	20.88'	89	28.24'
	7	R	29	35.11'	89	49.22'
		I	29	27.41'	89	37.30'
	8	R	29	44.04'	89	59.89'
		I	29	35.43'	89	49.60'
	9	R	29	46.80'	90	1.30'
		I	29	44.50'	90	0.51'
	10	R	29	57.41'	90	2.30'
		I	29	52.80'	89	54.21'

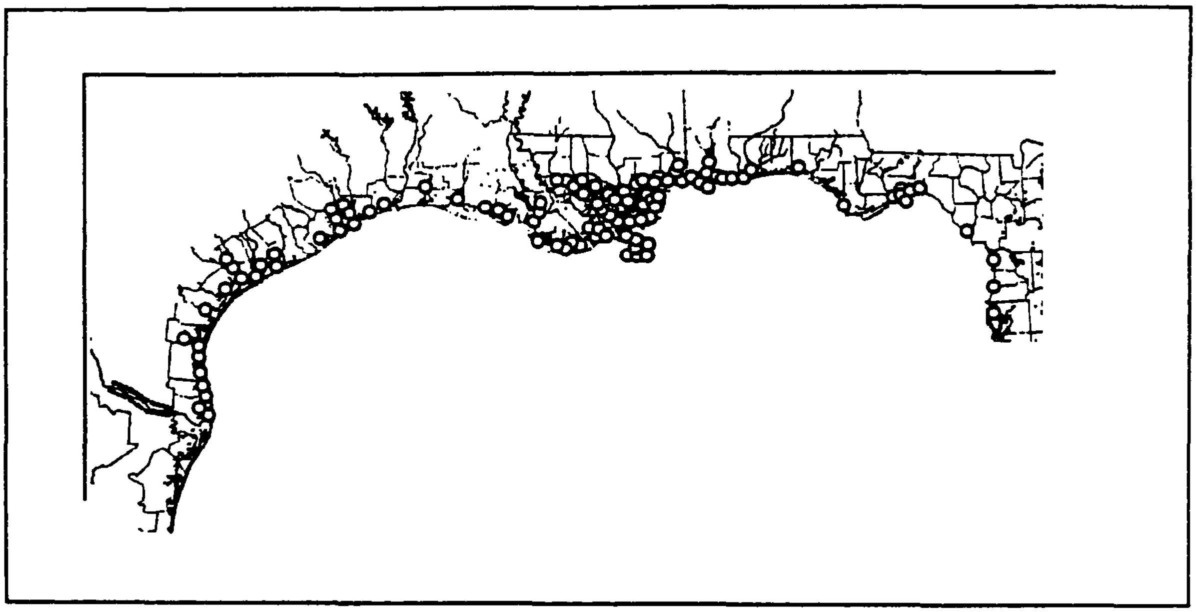

Figure 3-2. Base Sampling Stations For 1991 Louisianian Province Monitoring.

the boundaries of these 47 small estuaries. The index site was selected by using available information on sediment type, depth, and geometry to identify a net depositional environment. In small tidal rivers, the index site was located at the mouth of the river in a muddy sediment (e.g., Old River, FL). In small estuaries, the index site was located at the deep central portion (spine) of the estuary. The 94 sampling sites (index and random) for small estuarine systems are listed in Table 3-5 and shown in Fig. 3-2.

3.3.4 Definition of the Index Period

Many of the proposed indicators (see Table 3.2) exhibit large intra-annual variability (e.g., Oviatt and Nixon 1973; Jeffries and Terceiro 1985; Crassle et al. 1985; Holland et al. 1987). EMAP-NC does not have the resources to characterize this variability or to assess status in all seasons. Therefore, sampling will be limited to a confined portion of the year (i.e., an index period) when indicators are expected to show the greatest response to anthropogenic and climatic stress.

For most near coastal ecosystems in the Northern Hemisphere, mid-summer (July-August) is the period when ecological responses to pollution exposure are likely to be most severe. During this period, dissolved oxygen concentrations are most likely to approach stressful, low values (Holland et al. 1977; USEPA 1984; Oviatt 1981; Officer et al. 1984). Moreover, the cycling and adverse effects of sediment contaminant exposure are generally greatest at the low dilution flows and high temperatures that occur in mid-summer (Connell and Miller 1984; Sprague 1985, Mayer et al. 1989). Water concentrations of contaminants may be highest during late spring-early summer runoff events from agricultural fields in specific locales. However, most information points to the use of summer as the appropriate index period for EMAP-NC. This index period is characterized by a slightly protracted time span in The Louisianian Province, generally July-September.

The definition of the boundaries of the summer index period is a critical element of the sampling design. This is particularly true for indicators that have a high degree of variation within the summer period (e.g., dissolved oxygen concentration) and for indicators for which little is known about variation over the summer

Table 3-5. 1991 base sampling locations (random and index) for small estuary/tidal river class.

Tidal River or Estuary	Sample Type	Location Latitude (N)		Longitude (W)	
Florida					
Anclote Anchorage	R	28	11.21'	82	48.49'
	I	28	10.21'	82	49.72'
Homosassa River	R	28	46.59'	82	39.42'
	I	28	46.36'	82	42.10'
Crystal Bay	R	28	53.96'	82	42.52'
	I	28	53.24'	82	44.41'
Withlacoochee River	R	29	0.19'	82	45.26'
	I	29	0.12'	82	45.74'
Suwannee Sound	R	29	16.78'	83	9.00'
	I	29	14.89'	83	7.55'
Ecofina River	R	30	2.27'	83	55.39'*
	I	30	2.18'	83	55.61'*
Oyster Bay	R	30	3.43'	84	18.02'
	I	30	2.61'	84	18.83'
Ochlockonee River	R	29	59.25'	84	29.57'
	I	29	58.92'	84	26.61'
St. Josephs Bay	R	29	51.86'	85	22.27'
	I	29	48.80'	85	22.89'
Bayou Grande	R	30	22.21'	87	17.62'
	I	30	22.50'	87	15.98'
Big Lagoon	R	30	19.23'	87	19.82'
	I	30	19.25'	87	21.52'
Old River	R	30	17.26'	87	30.00'
	I	30	16.79'	87	32.40'
Alabama					
Bay La Launch	R	30	18.43'	87	33.05'
	I	30	18.43'	87	33.41'
Bon Secour River	R	30	17.22'	87	45.28'
	I	30	17.09'	87	45.70'
Tensaw River	R	30	48.49'	87	55.20'
	I	30	41.35'	88	0.00'

Table 3-5. 1991 base sampling locations (random and index) for small estuary/tidal river class.

Tidal River or Estuary	Sample Type	Location Latitude (N)		Longitude (W)	
<u>Alabama (Cont'd)</u>					
Pelican Bay	R	30	12.85'	88	3.23'
	I	30	14.00'	88	5.69'
Grand Bay	R	30	22.30'	88	22.12'
	I	30	22.89'	88	20.33'
<u>Mississippi</u>					
West Pascagoula River	R	30	22.13'	88	36.48'
	I	30	22.38'	88	36.13'
Bernard Bayou	R	30	25.30'	88	57.40'
	I	30	24.90'	88	53.12'
St. Louis Bay	R	30	21.81'	89	20.09'
	I	30	19.30'	89	18.41'
<u>Louisiana</u>					
Garden Island Bay	R	29	2.51'	89	6.35'
	I	29	1.69'	89	6.50'
Mississippi River Gulf Outlet Canal	R	29	50.48'	89	37.42'
	I	29	41.27'	89	24.19'
Lake St. Catherine	R	30	7.71'	89	43.06'*
	I	30	7.71'	89	44.31'*
Little Lake	R	29	28.75'	90	8.60'
	I	29	27.70'	90	5.40'
Lake Raccourci	R	29	13.97'	90	20.31'
	I	29	12.38'	90	18.60'
Amite River	R	30	17.97'	90	36.00'
	I	30	17.84'	90	33.60'
Lake Pelto	R	29	4.92'	90	47.70'
	I	29	4.13'	90	44.41'
Lake Plourde	R	29	43.60'	91	10.00'
	I	29	42.20'	91	7.35'
Belle River	R	29	53.40'	91	12.48'
	I	29	50.25'	91	9.05'

Table 3-5. 1991 base sampling locations (random and index) for small estuary/tidal river class.

Tidal River or Estuary	Sample Type	Location Latitude (N)		Longitude (W)	
Louisiana (Cont'd)					
Grand Lake	R	29	56.40'	92	45.85'
	I	29	53.65'	92	45.00'
Calcasieu River	R	30	7.30'	93	20.30'
	I	30	3.40'	93	19.00'
Texas					
Star Lake	R	29	40.64'	94	10.71'*
	I	29	40.45'	94	10.00'*
East Bay Bayou	R	29	33.83'	94	26.00'
	I	29	33.44'	94	28.44'
Moses Lake/Dollar Bay	R	29	25.53'	94	54.61'
	I	29	26.57'	94	55.32'
Cedar Bayou	R	29	42.43'	94	56.08'
	I	29	41.85'	94	56.92'
San Jacinto Bay	R	29	42.39'	95	2.60'
	I	29	42.35'	95	1.37'
Highland Bayou	R	29	18.62	94	57.08*
	I	29	19.78	94	56.32*
Bastrop Bay	R	29	5.79'	95	10.00'
	I	29	5.50'	95	11.00'
Cedar Lakes	R	28	49.60'	95	31.91'*
	I	28	50.50'	95	30.45'*
Caracahua Bay	R	28	41.60'	96	24.11'
	I	28	37.55'	96	22.52'
Powderhorn Lake	R	28	29.07'	96	31.48'*
	I	28	30.00'	96	30.00'*
Lavaca River	R	28	45.00'	96	34.84'
	I	28	41.55'	96	34.60'
Hynes Bay	R	28	23.71'	96	47.28'
	I	28	20.00'	96	44.80'
Copano Bay	R	28	4.79'	97	8.88e
	I	28	7.35'	97	1.60'

Table 3-5. 1991 base sampling locations (random and index) for small estuary/tidal river class.

Tidal River or Estuary	Sample Type	Location Latitude (N)		Longitude (W)	
Texas (Cont'd)					
Tule Lake Channel	R	27	49.21'	97	26.94'
	I	27	48.71'	97	23.41'
South Bay	R	26	1.60'	97	11.98'
	I	26	1.60'	97	11.44'
Rio Grande	R	25	57.37'	97	11.35'
	I	25	57.37'	97	8.72'

* Depth of site is anticipated to be less than 1 m.

(e.g., contaminants in fish flesh, gross pathology of fish).

Because of the importance of establishing a reasonable and appropriate index period, a special sampling program was conducted in 1990 in Northern Gulf of Mexico estuaries to assess the variability of the index period. Measurements were made at 8 locations in the Louisianian Province characterizing a variety of continuous dissolved oxygen and contaminant conditions. Continuous dissolved oxygen monitoring was not initiated at a larger number of stations because it was not logistically possible. The eight selected locations were located predominately in small estuarine systems. Four of these sites were selected because available information and expert opinion suggested that they were all likely to exhibit low dissolved oxygen conditions (i.e., < 2 ppm) for some period. The dissolved oxygen criteria of consistently greater than 2.0 mg/l was selected because this condition has little impact upon biota (Vernberg 1972; Renand 1986; Coutant 1985; Chittenden 1971) in absence of other stressors. Dissolved oxygen concentrations that are consistently less than 2.0 mg/l may have substantial impact upon estuarine and marine biota (e.g., Vernberg 1972). Data from the 1990 stations and retrospective water quality information confirmed that the period from July 1 through September 30 has low dissolved oxygen concentrations for long continuous periods of time at those Gulf sites experiencing oxygen stress, while many "low" dissolved oxygen sites could be expected to continue to exhibit oxygen stress through September. The anticipated sampling index period for the Louisianian Province will be July 15 through September 15.

3.3.5 Indicator Testing and Evaluation

Sufficient information to verify the reliability of indicator responses throughout the Louisianian Province is not available. Therefore, testing and evaluation of indicators will be conducted at 16 locations (Table 3-6; Fig. 3-3) to determine the reliability of indicators to discriminate between polluted and unpolluted environments. These 16 locations include two geographic subregions (Eastern and Western Gulf of Mexico). Eight sites, with varying combinations of expected pollution stress were selected within each geographic subregion based on the knowledge of regional/local experts. For example, the eastern region of the Louisianian Province will be represented by samples from Perdido Bay, Alabama (expected low industrial and agricultural contaminants and low dissolved oxygen); Bayou Casotte, Mississippi (expected low

Table 3-6. Indicator testing and evaluation sites for 1991 based on a priori judgements concerning the degree of sediment contamination due to agricultural (AG) and industrial (IN) sources and the anticipated dissolved oxygen concentration (DO). (L= Low levels; H= High Levels).

Tidal River or Estuary	Sample Type DO	AG	IN	Location Latitude (N)		Longitude (W)	
East Gulf of Mexico							
Perdido Bay, FL/AL	L	L	L	30	27.08'	87	22.60'
Bayou Casotte, MS	L	L	H	30	20.00'	88	30.71'
Wolf Bay, AL	L	H	L	30	19.71'	87	35.72'
Mobile Bay, AL	L	H	H	30	37.00'	88	0.00'
Apalachicola Bay, FL	H	L	L	29	40.00'	84	56.65'
Watsons Bayou, FL	H	L	H	30	8.59'	85	38.00'
Choctawhatchee River, FL	H	H	L	30	24.00'	86	8.00'
Escambia Bay, FL	H	H	H	30	31.70'	87	10.00'
West Gulf of Mexico							
Calcasieu Lake, LA	L	L	L	29	59.38'	93	20.03'
Houston Ship Canal, TX	L	L	H	29	44.09'	95	8.00'
Arroyo Colorado, TX	L	H	L	26	20.03'	97	25.76'
Brazos River, TX	L	H	H	28	57.61'	95	22.60'
San Antonio Bay, TX	H	L	L	28	18.30'	96	39.90'
Galveston Bay, TX	H	L	H	29	31.66'	94	56.90'
Laguna Madre, TX	H	H	L	27	8.00'	97	16.00'
Lavaca Bay, TX	H	H	H	28	38.30'	96	32.41'

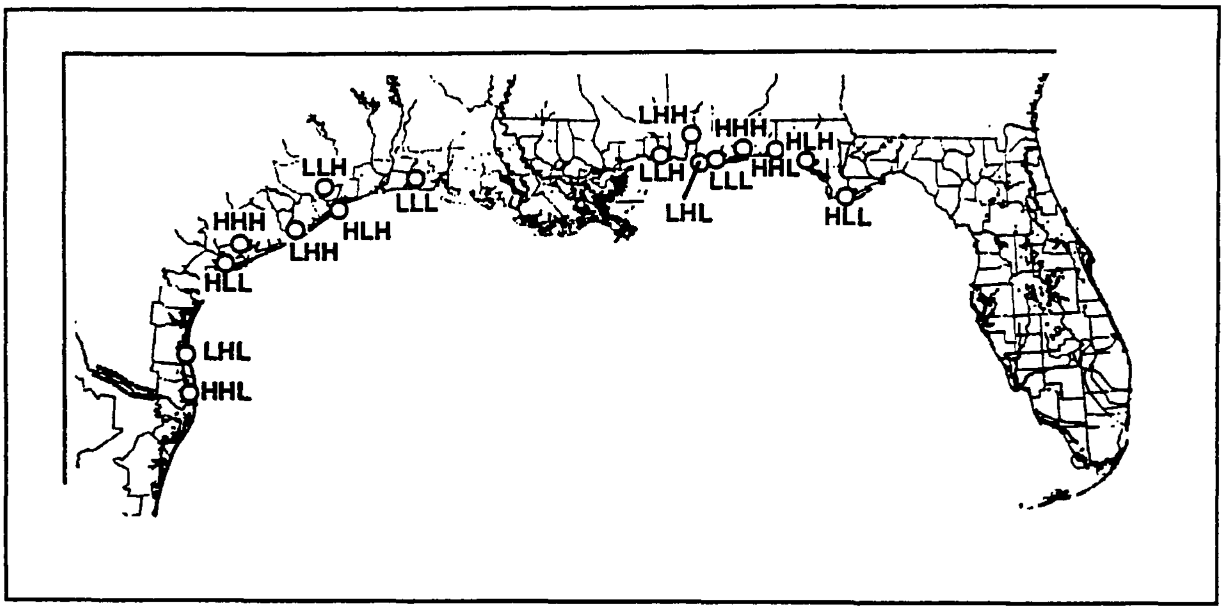

Figure 3-3. Indicator Testing and Evaluation Stations for Louisianian Province Monitoring.

agricultural contaminants, high industrial contaminants, and low dissolved oxygen); Wolf Bay, Alabama (expected high agricultural contaminants, low industrial contaminants, and low dissolved oxygen); Mobile Bay, Alabama (expected high agricultural contaminants, high industrial contaminants, and low dissolved oxygen); Apalachicola Bay Florida (expected low agricultural contaminants, low industrial contaminants, and high dissolved oxygen); Watson's Bayou, Florida (expected low agricultural contaminants, high industrial contaminants, and high dissolved oxygen); Choctawhatchee River, Florida (expected high agricultural contaminants, low industrial contaminants, and high dissolved oxygen); and, Escambia Bay, Florida (expected high agricultural contaminants, high industrial contaminants, and high dissolved oxygen).

Indicator testing and evaluation sites will be sampled during the index period (July 15-September 15). The entire suite of exposure and response indicators, including research indicators (see Table 4-2), will be measured at these sites.

3.3.6 Supplemental Sampling

Sufficient data are not available to ascertain if the spatial sampling scale used in the Virginian Province to represent the ecological condition (i.e., cells of 280 km^2) will adequately represent large estuarine systems in the Louisianian Province, using the selected indicators. To address this problem, Mobile Bay will be sampled at a density four times greater (i.e., sample points approximately 9 km apart; 13 additional sampling sites) than that of the other large estuaries (Table 3-7). This spatially intensive data set will be used to evaluate the benefits of an enhanced grid for the assessment of ecological condition.

The information resulting from the supplemental sampling program in Mobile Bay has the added benefit of providing information that will assist the Gulf of Mexico Program's Demonstration Project to identify environmental concerns, design future monitoring activities, and formulate the Comprehensive Management Action Plan for the Gulf of Mexico. The information will also facilitate the evaluation of the effect of spatial scale on DQOs.

Table 3-7. Supplementary sampling stations in 1991 to evaluate the effect of sampling scale on parameter estimation.

Tidal River or Estuary	Sample Type	Location Latitude (N)		Longitude (W)	
Mobile Bay	L	30	14.45'*	87	50.88'*
		30	19.51'	87	51.71'
		30	16.57'	87	55.88'
		30	28.92'	87	59.21'
		30	29.79'	88	0.46'
		30	45.19'	88	0.59'
		30	19.90'	88	1.25'
		30	33.96'	88	1.61'
		30	22.28'	88	2.79'
		30	39.36'*	88	3.04'*
		30	26.17'	88	3.99'
		30	20.55'	88	5.81'
		30	18.21'	88	7.69'

*Depth at site anticipated to be less than 1 m.

3.4 Overview of Sampling Activities

The 1991 Louisianian Province Monitoring Demonstration sampling activities will be conducted during a summer index period, extending from July 15 through September 15. A total of 198 sites will be sampled in 1991 as follows:

- 112 base sampling sites;
- 16 indicator testing and evaluation sites
- 57 index sampling sites in small estuaries and large tidal rivers
- 13 supplemental sampling sites.

Based on the analysis of the information obtained from these samples, a detailed sampling design for future years will be developed. The total sampling effort in future years probably will be about 75 percent of the 1991 effort. In subsequent monitoring years, only an array of base stations will be sampled in each year, although during the initial years of the Louisianian Province Monitoring some additional index monitoring and indicator testing may be completed. Tables 3-8 through 3-10 delineate the estuarine systems and the number of samples from each system that would be expected if the 1991 design were implemented for the remainder of the four-year cycle (1992-1994).

Table 3-8. Anticipated 1992 Estuarine Systems to be sampled and the projected number of samples from each system (L=Large Estuary Class; R=Large Tidal River Class; S= Small Estuary and Tidal River Class).

Estuarine System	Sample Type	Number of Samples
<u>Alabama</u>		
Dauphin Bay	S	2
Wolf Bay	S	2
Mobile Bay	L	3
<u>Florida</u>		
Waccasassa River	S	2
Indian Bay	S	2
Chassahowitza River	S	2
Carabelle River	S	2
Bayou St. John	S	2
St. Andrew Sound	S	2
Horseshoe Cove	S	2
Lake Wimico	S	2
Withlacoochee Bay	S	2
Apalachicola Bay	S	2
St. George Sound	L	1
Choctawhatchee Bay	L	2
Pensacola Bay	L	3
St. Andrews Bay	L	1
Apalachee Bay	L	5
<u>Louisiana</u>		
Sabine River	S	2
Bayou Terrebone	S	2
Bayou Teche	S	2
Lake De Cade	S	2
Lake Mercant	S	2
Lake Felicity	S	2
Lake Verret	S	2
Bay Boudreau	S	2
Lake Cataoatche	S	2
East Bay	S	2
Sabine Lake	L	1
Calcasieu Lake	L	1
Caillou Bay	L	1
Terrebone Bay	L	3
Barataria Bay	L	2
Vermilion Bay	L	1
Atchafalaya Bay	L	1
Lake Borgne	L	3
Cote Blanc Bays	L	3

Table 3-8. Anticipated 1992 Estuarine Systems to be sampled and the projected number of samples from each system (L=Large Estuary Class; R=Large Tidal River Class; S= Small Estuary and Tidal River Class).

Estuarine System	Sample Type	Number of Samples
Louisiana (Cont'd)		
Breton Sound	L	6
Lake Pontchartrain	L	5
Chandeleur Sound	L	8
Mississippi River	R	20
Mississippi		
Heron Bay	S	2
Point Aux Chenes Bay	S	2
Mississippi Sound	L	7
Texas		
Lake Austin	S	2
Scott Bay	S	2
Offatts Bayou	S	2
Dickinson Bay	S	2
Drum Bay	S	2
Houston Ship Canal	S	2
Chocolate Bayou	S	2
Christmas Bay	S	2
Redfish Bay	S	2
Mesquite Bay	S	2
Lavaca Bay	S	2
Espiritu Santo Bay	S	2
San Antonio Bay	L	1
Baffin Bay	L	1
East Bay (Galveston Bay)	L	1
West Bay (Galveston Bay)	L	1
Corpus Christi Bay	L	2
Matagorda Bay	L	3
Galveston Bay	L	5
Laguna Madre	L	2

Table 3-9. Anticipated 1993 Estuarine Systems to be sampled and the projected number of samples from each system (L=Large Estuary Class; R=Large Tidal River Class; S= Small Estuary and Tidal River Class).

Estuarine System	Sample Type	Number of Samples
Alabama		
Little Lagoon	S	2
Heron Bay	S	2
Perdido River	S	2
Mobile Bay	L	3
Florida		
Chassahowitza Bay	S	2
St. Martins River	S	2
Waccasassa Bay	S	2
Santa Rosa Sound	S	2
Suwannee River	S	2
Deadman Bay	S	2
Ochlockonee Bay	S	2
Apalachicola River	S	2
East Bay (Apalachicola)	S	2
Blackwater River	S	2
St. George Sound	L	1
Choctawhatchee Bay	L	1
Pensacola Bay	L	4
St. Andrews Bay	L	1
Apalachee Bay	L	3
Louisiana		
Grand Bay	S	2
West Bay	S	2
Wax Lake Outlet	S	2
Lac Des Allemands	S	2
Caillou Lake	S	2
Lost Lake	S	2
Fourleague Bay	S	2
Sabine Lake	L	1
Calcasieu Lake	L	1
Caillou Bay	L	1
Terrebone Bay	L	2
Barataria Bay	L	1
Vermilion Bay	L	2
Atchafalaya Bay	L	1
Lake Borgne	L	2
Cote Blanc Bays	L	2

Table 3-9. Anticipated 1993 Estuarine Systems to be sampled and the projected number of samples from each system (L=Large Estuary Class; R=Large Tidal River Class; S= Small Estuary and Tidal River Class).

Estuarine System	Sample Type	Number of Samples
Louisiana (Cont'd)		
Breton Sound	L	8
Lake Pontchartrain	L	7
Chandeleur Sound	L	7
Mississippi River	R	20
Mississippi		
Little Lake	S	2
Pascagoula Bay	S	2
Mississippi Sound	L	6
Texas		
Galveston Channel	S	2
Oyster Lake	S	2
Brazos River	S	2
Aransas Passes	S	2
Oso Creek	S	2
East Matagorda Bay	S	2
Chocolate Bay	S	2
Shoalwater Bay	S	2
Aransas Bay	S	2
Nueces Bay	S	2
San Antonio Bay	L	1
Baffin Bay	L	1
East Bay (Galveston Bay)	L	1
West Bay (Galveston Bay)	L	1
Corpus Christi Bay	L	2
Matagorda Bay	L	2
Galveston Bay	L	7
Laguna Madre	L	1

Table 3-10. Anticipated 1994 Estuarine Systems to be sampled and the projected number of samples from each system (L=Large Estuary Class; R=Large Tidal River Class; S= Small Estuary and Tidal River Class).

Estuarine System	Sample Type	Number of Samples
Alabama		
Mobile River	S	2
Weeks Bay	S	2
Mobile Bay	L	4
Florida		
Homosassa Bay	S	2
Crystal River	S	2
Cedar Keys Bays	S	2
Steinhatchee River	S	2
Goose Creek Bay	S	2
Grand Lagoon	S	2
Choctawhatchee River	S	2
St. Vincent Sound	S	2
Escambia River	S	2
Perdido Bay	S	2
St. George Sound	L	1
Choctawhatchee Bay	L	1
Pensacola Bay	L	1
St. Andrews Bay	L	1
Apalachee Bay	L	2
Louisiana		
Timbalier Bay	S	2
White Lake	S	2
The Rigolets	S	2
Pearl River	S	2
Blind Bay	S	2
Bayou LaFourche	S	2
Caminada Bay	S	2
Atchafalaya River	S	2
Lake Barre	S	2
Mermenteau River	S	2
Wax Lake	S	2
Sabine Lake	L	1
Calcasieu Lake	L	1
Caillou Bay	L	1
Terrebone Bay	L	2
Barataria Bay	L	2
Vermilion Bay	L	1
Atchafalaya Bay	L	1
Lake Borgne	L	3

Table 3-10. Anticipated 1994 Estuarine Systems to be sampled and the projected number of samples from each system (L=Large Estuary Class; R=Large Tidal River Class; S= Small Estuary and Tidal River Class).

Estuarine System	Sample Type	Number of Samples
Louisiana (Cont'd)		
Cote Blanc Bays	L	2
Breton Sound	L	7
Lake Pontchartrain	L	5
Chandeleur Sound	L	5
Mississippi River	R	20
Mississippi		
Portersville Bay	S	2
Pascagoula River	S	2
Biloxi Bay	S	2
Mississippi Sound	L	6
Texas		
Neches River	S	2
Dickinson Bayou	S	2
Clam Lake	S	2
Bolivar Roads	S	2
San Bernard River	S	2
Guadalupe River	S	2
Burnett Bay	S	2
Colorado Arroyo	S	2
Freeport Harbor	S	2
Tres Palacios Bay	S	2
Jones Bay	S	2
Pringle Lake	S	2
St. Charles Bay	S	2
Oso Bay	S	2
San Antonio Bay	L	1
Baffin Bay	L	1
East Bay (Galveston Bay)	L	1
West Bay (Galveston Bay)	L	1
Corpus Christi Bay	L	1
Matagorda Bay	L	2
Galveston Bay	L	7
Laguna Madre	L	4

4.0 INDICATOR DEVELOPMENT AND EVALUATION

EMAP-NC does not have the resources to monitor all of the ecological parameters of concern to the public, Congress, scientists, and environmental managers. Therefore, the limited resources available must be focused on the system attributes that are of greatest concern, ecologically, and best address program objectives. The purpose of this chapter is to describe and explain the strategy used to identify and select indicators generically for EMAP-NC and, by extension, for the Louisianian Province. In the first section of the chapter, we describe in abbreviated form, the generic approach to indicator selection that is being used by all resource groups within EMAP; this process is explained fully in EMAP-Near Coastal Program Plan for 1990 (U.S. EPA, 1990). In the remaining sections of the chapter, we describe the application of that approach to identify indicators to be measured for the 1991 Louisianian Province Monitoring Demonstration.

4.1 EMAP-NC Framework for Indicator Selection

To function within the constraints of limited resources, a defined set of efficient, yet effective, parameters that serve as indicators of environmental quality will be measured. EMAP-NC indicators will be selected to be:

- o Related to ecological condition in a way that can be quantified and interpreted
- o Applicable across a range of habitats and biogeographical provinces
- o Valued by, and of concern to, society
- o Quantifiable in a standardized manner with a high degree of repeatability.

The selection of indicators that will be used by EMAP-NC is an ongoing process. It is anticipated that a number of years will be required before a relatively complete list of indicators is developed that is applicable across geographic regions. The selection process consists of the following steps:

- Identification of valued ecosystem attributes and stressors that affect them;

- Development of a conceptual source-receptor model that links valued ecosystem attributes to stressors;

- Using the conceptual model to identify all possible candidate indicators;

- Evaluation and classification of candidate indicators into categories (core, developmental, research) using evaluation criteria that are generic to all EMAP resource groups (e.g., forests, arid lands, agroecosytems);

- Testing and evaluation of indicators to assess their ability to discriminate between polluted and unpolluted sites;

- Conducting regional scale demonstration projects to show the feasibility and value of indicator data; and,

- Periodic re-evaluation of indicators.

While the first three steps of the indicator selection process are targeted towards inclusion of all relevant possible indicators, the next three phases of the EMAP indicator development strategy focus on exclusion of indicators that currently cannot be measured within EMAP constraints, as well as identifying a subset of the indicators to be designated as research or developmental indicators. The process of establishing priorities is guided both by a set of criteria for indicator selection and by peer reviews of research plans. As an indicator advances through the indicator development process, different criteria are emphasized (Fig. 4-1). At each step the criteria become more focused on the value of the data.

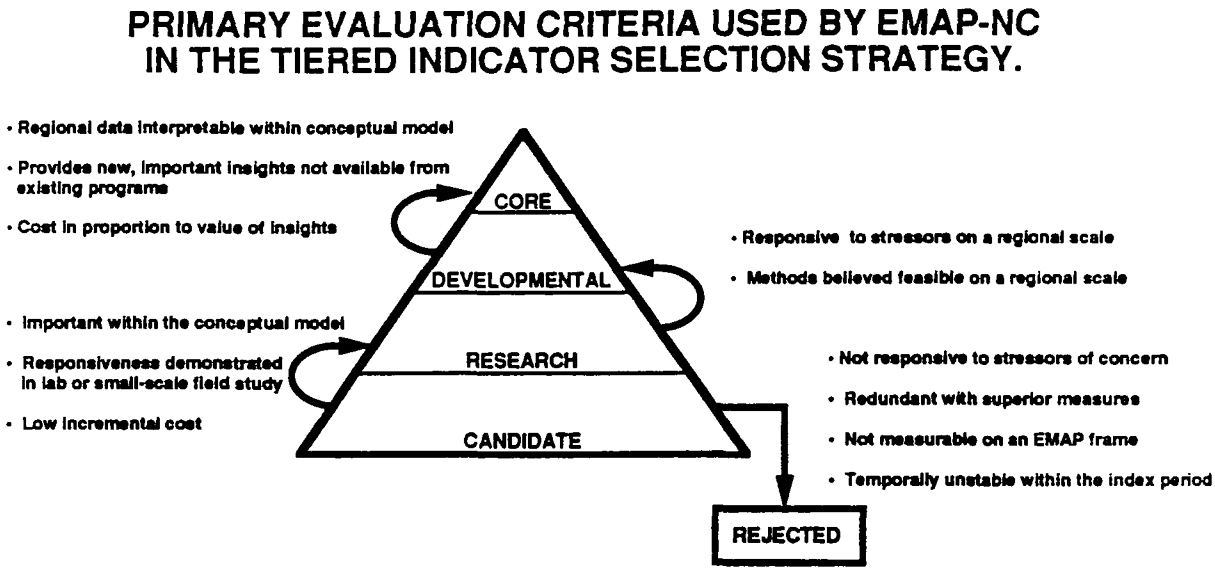

Figure 4-1. Primary evaluation criteria used by EMAP-NC in the tiered indicator selection strategy.

Categories of indicators that were identified and will be sampled by EMAP-NC include the following:

- Response Indicators -- Measurements that quantify the integrated response of ecological resources to individual or multiple stressors. Examples include measures of the condition of individuals (e.g., frequency of tumors or other pathological disorders in fish), populations (e.g., abundance, biomass), and communities (e.g., species composition, diversity).

- Exposure Indicators -- Physical, chemical, and biological measurements that quantify pollutant exposure, habitat degradation, or other facets of degraded ecological condition. Examples include contaminant concentrations in the water, sediments, and biological media; the acute toxicity of sediments to indigenous or sensitive biota; and dissolved oxygen concentration.

- Habitat Indicators -- Physical, chemical, and biological measurements that provide basic information about the natural environmental setting. Examples include acreage of submerged aquatic vegetation, water depth, salinity, sediment characteristics, and temperature. Habitat indicators will be used to normalize values for exposure and response indicators across environmental gradients. Habitat indicators may also be used as a basis for defining subpopulations of interest for assessments.

- Stressor Indicators -- Economic, social, or engineering measures that can be used to identify the sources of environmental problems and poor ecological condition. Examples include human demographics, land-use patterns, discharge records from manufacturing and sewage treatment facilities, freshwater inflows, and pesticide usage on the watershed. Stressor data will be gathered primarily from existing federal and state programs (e.g., NOAA's National Coastal Pollution Discharge Inventory-NCPDI; wetland acreage and extent from FWS's National Wetland Inventory, NOAA, and State wetland inventories and maps), from other EMAP task groups (e.g., the extent and distribution of forests), as well as from local permitting/planning agencies.

The relationships among indicator categories are summarized in Fig. 4-2. Information on exposure, habitat, and stressor indicators will be used to identify potential factors that contribute to the status and trends of response indicators. A list of indicators that were used in the first year of the program in the Virginian Province is provided in Table 4-1.

4.2 Estuarine Candidate Indicators

Approximately 150 candidate indicators were identified from the conceptual model of near coastal systems. Following preliminary selection and categorization of candidate indicators, a series of workshops to identify, evaluate, and discuss potential indicators of ecological condition and environmental quality was held in December 1989. Participants were requested to identify, evaluate, and establish priorities for indicators for the 1990 Demonstration Project and to recommend measurement and analysis methods for potential indicators. Conclusions and findings of the workshops were used to refine the list of indicators that were measured in the 1990 Demonstration Program.

As pointed out in the previous section, indicator selection is an ongoing process. The 1991 Louisianian Province Monitoring Demonstration reviewed the data from the initial 1990 Demonstration in the Virginian Province to finalize the selection of indicators and to elevate some candidate indicators to research status (Table 4-2). This section of the chapter identifies which indicators were placed into each category for the 1991 Louisianian Province Monitoring Demonstration, provides the rationale for these placements and gives an overview of the methodology to be used for measurement of those indicators that were selected for use in the 1991 Louisianian Province Monitoring Demonstration. Although the tiered selection process for indicators was conducted from candidate upwards to core, indicators are presented here from core downward to place emphasis on those measurements most important to the program.

EMAP-NC INDICATOR STRATEGY

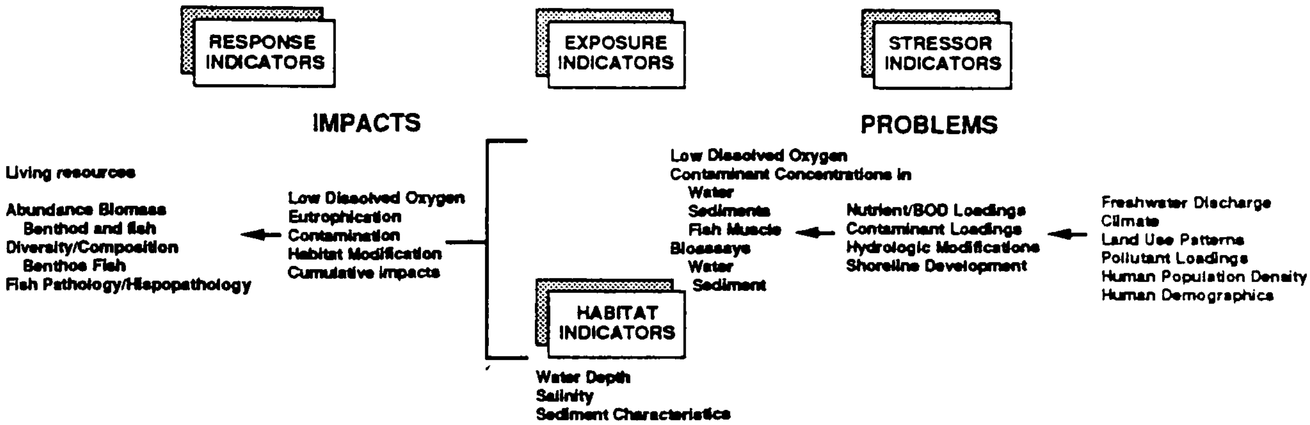

Figure 4-2. Overview of the indicator strategy for the EMAP near coastal program. The manner in which indicators are related to the major environmental problems, and impacts is also shown.

Table 4-1. List of EMAP-NC indicators (by major category) used in The Virginian Province in 1990.

Category	Proposed Indicator
Core	Benthic species composition and biomass
	Salinity
	Sediment characteristics
	Water depth
	Apparent redox potential discontinuity
Developmental	Sediment contaminant concentration
	Sediment toxicity
	Contaminants in fish flesh
	Contaminants in large bivalves
	Relative abundance of large burrowing bivalues
	Gross pathology of fish
	Continuous and point measurements of dissolved oxygen concentration
Research	Water column toxicity
	Fish community composition
	Histopathology of fish

Table 4-2. Indicators selected for measurement in the 1991 Louisianian Province Monitoring Demonstration

CATEGORY	PROPOSED INDICATOR
Core	Benthic Species Composition and Biomass
	Habitat Indicators (Apparent Redox Potential Discontinuity, Salinity, Temperature, pH, Sediment Characteristics, Water Depth)
Developmental	Sediment Contaminant Concentration
	Sediment Toxicity
	Dissolved Oxygen Concentration (Continuous and Instantaneous)
	Contaminants in Fish and Shellfish Tissue
	Gross Pathology of Fish
	Relative Abundance of Large Burrowing Bivalves
	Aesthetic Indicators (flotsam, jetsam, odor, water clarity)
	Acreage of Submerged Aquatic Vegetation
Research	Fish Community Composition
	Histopathology of Fish
	Blood Chemistry
	Stable Isotope Ratios
	Bile Florescence
	Liver Lesions
	Fish Condition Index
	Liver Contaminant Concentrations
	Whole Fish Contaminant Concentrations

4.2.1 Core Indicators

4.2.1.1 Benthic Species Composition and Biomass

Macrobenthic organisms play an important role in the estuarine and coastal waters conceptual model. As major secondary consumers in coastal marine ecosystems, benthos represents an important linkage between primary producers and higher trophic levels for both planktonic and detritus-based food webs (Frithsen 1989, Holland et al. 1989). Benthos are a particularly important food source for juvenile fish and crustaceans (Chao and Musick 1977, Bell and Coull 1978, Homer et al. 1980, Holland et al. 1989). Macrobenthic feeding activities can also remove large amounts of particulate material from the water, especially in shallow (< 10 m) environments, improving water quality by increasing water clarity and limiting phytoplankton production (Cloern 1982, Officer et al. 1982; Holland et al. 1989).

The benthic macroinvertebrate species composition and abundance indicator has been placed in the core group not only because of its importance, but also because of its responsiveness to the kinds of environmental stress gradients of interest to EMAP-NC. Benthic assemblages are composed of diverse taxa with a variety of reproductive modes, feeding guilds, life-history characteristics, and physiological tolerances to environmental conditions (Warwick 1980; Frithsen 1989; Bilyard 1987). As a result, benthic populations respond to changes in environmental quality, both natural and anthropogenic, in a variety of ways (Pearson and Rosenberg 1978, Rhoads et al. 1978; Boesch and Rosenberg 1981). Responses of some species (e.g., filter feeders and species with pelagic life stages) are indicative of water-quality changes, while responses of others (e.g., organisms that burrow in or feed on sediments) may be indicative of changes in sediment quality.

Furthermore, most benthic species have limited mobility and cannot avoid stressful environmental conditions. Thus, benthic assemblages are likely to respond to many of the problems that will be emphasized by EMAP-NC, including toxic pollution, eutrophication, sediment quality, habitat modification, multiple pollution stresses, and climate change (Sanders et al. 1980, Elmgren and Frithsen 1982, Rhoads et al. 1978, Frithsen et al. 1985, Holland et al. 1987). Macrobenthos abundance, composition, and biomass have a history of use in regional estuarine monitoring programs and have served as an effective indicator for describing the extent and magnitude of pollution impacts in near coastal ecosystems, as well as for assessing the effectiveness of management actions.

Natural benthic species composition, abundance, and biomass are determined largely by naturally occurring habitat conditions including salinity and sediment type (Sanders et al. 1965, Carriker 1967, Boesch 1977, Dauer et al. 1984, Holland et al. 1987, 1989). The distributions of some benthic organisms are remarkably predictable along estuarine gradients, and, in the absence of antropogenic stressors, can be characterized by similar groups of species over broad latitudinal ranges (Thorson 1957; Holland et al. 1987). Information on changes in benthic population and community parameters due to habitat characteristics can be useful for separating natural variation from changes associated with human activities (Holland et al. 1987).

Data for the benthic species composition and biomass indicator will be obtained by collecting three replicate 413-cm^2 samples with a Young-modified Van Veen grab. The Young grab was selected as the appropriate sampling gear because it is easily deployed from small boats and adequately samples both mud and sand habitats. Other gear choices did not sample such a broad range of sediment types adequately (e.g., Wildco Box Corer, Ponar grab, Van Veen grab) or could not be deployed as easily from the small boats proposed for use by EMAP-NC (e.g., spade box corer, Smith-McIntyre grab). Hard sediments (e.g., rock) that cannot be sampled adequately by the Young-modified Van Veen grab will not be sampled by EMAP-NC. Sediments with dense submerged aquatic vegetation or oyster shell will be sampled using a modified small-scale box cover. However, the proportion of these habitat types that are not sampleable by our conventional gear will be estimated and will not be included in condition estimates of the province.

Benthic samples will be sieved in the field through a 0.5-mm screen and preserved in a 10% buffered formalin solution to which rose bengal has been added. In the laboratory, organisms will be identified to the lowest taxonomic level practical and counted. The dry-weight biomass of major taxa will be measured.

4.2.1.2 Habitat Indicators -- Salinity, Temperature, pH, Sediment Characteristics RPD, Water Clarity, and Water Depth

Habitat indicators provide important information about the environmental setting of a sample site. Salinity and temperature are among the most important environmental factors controlling the distribution of biota and ecological processes in estuaries (Remane and Schlieper 1971). Organic content, grain-size distribution, and depth of the redox potential discontinuity (RPD) layer are some of the major sediment characteristics that influence benthic invertebrate distributions. Water depth itself has little direct effect on estuarine biota because most U.S. estuaries are relatively shallow, and the pressure changes that occur are minor. However, in almost all estuaries, changes in water depth are associated with changes in sediment characteristics, dissolved oxygen concentration, and temperature.

Cumulatively, the above parameters define the major habitats sampled by EMAP-NC, and information on these habitat indicators will be essential for normalizing changes of exposure and response indicators to environmental gradients. They also will be used to define subpopulations for analysis and integration activities.

These indicators have been advanced to core status because they are essential to interpretation of response and exposure indicators, because regional sampling is feasible, and because it can be accomplished at little incremental cost. Some of the measures, notably salinity and temperature, are variable within the index period, but they vary in a predictable manner with respect to known factors such as tide, time, and freshwater flow. The single measurements taken at the time of sample collection will provide a reference point for post-classifying the site into a stratum with a known range for these variables.

Point-in-time salinity, temperature, pH, and water depth measurements will be taken using a Hydrolab Surveyor II, at each sampling site. Sediment characteristics (e.g., water content, grain size distribution, organic carbon content) will be determined for all sampling sites by using the procedures of Plumb (1981). The RPD will be assessed by visually measuring the depth of the color change in sediments in clear plastic cores extracted from each sample collected for benthic species composition and biomass. In addition, a grain-size analysis of each sediment subsample collected for benthic community analyses will be determined.

Water clarity will be measured by determination of Photosynthetically Active Radiation (RAR). PAR will be measured using a LI-COR irradiometer to indicate the degree to which turbidity can inhibit photosynthetic activity. In addition, measurement of the 1% irradiance depth will be measured using a Seechi disk.

4.2.2 Developmental Indicators

Table 4-2 lists developmental indicators proposed for use in the 1991 Louisianian Province Monitoring Demonstration. A brief justification for the selection of each indicator, and a summary of the measurement methods that will be used for each indicator, is provided below.

4.2.2.1 Sediment Contaminant Concentrations

Metals, organic chemicals, and fine-grained particulates entering estuaries from freshwater inflows, point sources of pollution, and various nonpoint sources, including atmospheric deposition, generally accumulate within the sediments and are retained within estuaries (Turekian 1977; Forstner and Wittman 1981; Nixon et al. 1986; Hinga 1988; Schubel and Carter 1984). This is because different contaminants have specific affinities for adsorption onto particles (Hinga 1988; Honeyman and Santschi 1988). Chemical and microbial contaminants generally adsorb to fine-grained materials in the water and are deposited on the bottom, accumulating at deposition sites such as regions of low current velocity, deep basins, and the zone of maximum turbidity. Contaminant concentration in sediments is dependent upon interactions between natural (e.g., physical sediment characteristics) and anthropogenic factors (e.g., type and volume of contaminant loadings) (Sharpe et al. 1984).

Bottom sediments in some harbors near urban areas and industrial centers are so contaminated that they represent a threat to both human and ecological health (OTA 1987; NRC 1989; Weaver 1984). Contaminated sediments are not limited to harbors near industrial centers and urban areas; they are also associated with pollutant runoff from agricultural areas and may be an important source of contaminant input to estuaries (Boynton et al. 1988; Pait et al. 1989).

Sediment contamination meets three criteria for elevation to developmental status. It is feasible to sample on a regional scale; it is clearly important to assessment endpoints; and the expected variability within the index period is expected to be minimal.

The geographic extent of contaminated sediments and the ecological effects of exposure to them are poorly defined (NRC 1989, NOAA 1988). Even in highly contaminated bays and harbors (e.g., Bayou Casotte, Houston Ship Canal, Freeport Harbor, the extent and magnitude of contamination often is not known (NRC 1989). Because high quality regional information on the extent and magnitude of sediment contamination does not exist, environmental managers do not know whether the pollution abatement measures that have been taken to reduce contaminant loadings are having the desired effect, nor do they have the information to establish priorities for future cleanup efforts. The sediment contamination indicator addresses these needs.

Sediment samples for determination of contaminant concentrations will be collected by using a Young-modified Van Veen grab. The surface sediment (top 2-3 cm) will be removed from three or more grab samples and composited. During collection, care will be taken to use only samples that have undisturbed sediment surfaces. The composite sample will be homogenized, and a subsample measured for contaminant concentrations.

Initially, the NOAA National Status and Trends suite of contaminants will be measured in the homogenized subsample (Table 3-3). The NOAA suite includes chlorinated pesticides, polychlorinated biphenyls (PCBs), polyaromatic hydrocarbons (PAHs), major elements, and toxic metals. The NOAA Status and Trends and EMAP quality assurance programs have developed measurement methods jointly that will provide data of sufficient quality to meet the objectives of both Agencies. Several contaminants of special interest in the Louisianian Province have been added to the list of analytes for the 1991 Monitoring Demonstation to provide a further characterization of sediments exposed to petrochemical effluents and intensive agricultural runoff (Table 4-3). These new analytes include: aliphatic hydrocarbons to assess sediment contaminants due to petrochemical refining, selected polycyclic aromatic hydrocarbons to assess contaminantion from estuarine oil drilling, and selected pesticides (i.e., endosulfan and toxaphene) used in agricultural practices in Gulf states. In addition, the frequency of "produced" waters in the estuarine habitats of the Gulf will be assessed through the use of selected PAH isomers (R. Albritton, Louisiana Department of Water Quality, pers. comm.) that occur frequently only at "produced" water sites; namely, 1,2,3, -c naphthalene; 1,2,3, -c phenanthrene; and 1,2,3, -c pyrene-dibenzopyathene.

The pesticides list provided in Table 4-3 primarily addresses contaminants that have been banned. We will investigate, in 1992, the efficacy of analyzing for classes of pesticides that are commonly used in Gulf states but generally exhibit poor persistence in sediments (e.g., pyrethroids, triazinines, carbamates).

4.2.2.2 Sediment Toxicity

Sediment toxicity tests are the most direct measure available for determining the toxicity of contaminants in sediments. These tests provide information that is independent of chemical characterizations and ecological surveys (Chapman 1988), and they improve upon the direct measure of the effects of contaminants in sediments because many contaminants are tightly bound to sediment particles or are chemically complexed and are not biologically available (USEPA 1989). However, sediment toxicity can not be used entirely in replacement of direct measurement of sediment contaminant concentrations, because the latter may be an important part of interpreting the causes for observed mortality in the toxicity test.

Sediment toxicity testing has had many applications in both marine and freshwater environments (Swartz 1987; Chapman 1988) and has become an integral part of many benthic assessment programs (Swartz 1989). A particularly important application is in programs seeking to establish contaminant-specific effects.

Sediment toxicity represents a developmental indicator based on the same criteria as sediment contaminants: (1) regional scale sampling is feasible, (2) it is important to the assessment endpoint, and (3) variability within the index period is expected to be minimal.

EMAP-NC proposes to measure acute toxicity of surface sediments as an estimate of contaminant bioavailability and toxicity. The sediments used for the toxicity tests will be subsampled from the same composite from which sediment contaminant concentrations and sediment physical/chemical properties are determined. Data on the physical and chemical characteristics of sediments (e.g., grain size, acid volatile sulfides, and organic carbon content) will be used to determine whether such sediment properties are associated with the degree of toxicity.

The sediment toxicity tests proposed for the Louisianian Province will employ standard methods (Swartz et al. 1985) but will use the East Coast amphipod, Ampelisca abdita. This species has been shown to be both acutely and chronically sensitive to contaminated sediments (Breteler et al. 1989; Scott and Redmond 1989; DiToro et al. in press). Because Ampelisca is a tube dweller, it is tolerant of a wider range of sediment types than the West Coast species, Rhepoxynius (Long and Buchman 1989) and Ampelisa can be easily cultured. In addition, sediment toxicity tests using the mysid, Mysidopsis bahia, will be conducted as a surrogate of the toxicity of collected sediments to the commercially important penaeid shrimps. Mysids will not burrow into sediments but will come in contact with sediments and have been used to assess the contaminant toxicity of sediment samples. Penaeid shrimp did interact directly with the sediment but it is not feasible, presently, to test penaeid shrimp with sediments from all sampling sites. Toxicity tests will be conducted with penaeid shrimp with sediment collected from the 16 ITE sampling sites to evaluate the logistical difficulties of using this test organism for future monitoring years. In addition, we will evaluate the use of a polychacte as a test organism at the 16 ITE sites.

For a typical bioassay, a 200-ml aliquot of sediment from the homogenized, composited 2-3 cm, top layer of grab samples collected at a sampling site will be placed in a 1-l beaker and covered with 700 ml of water.

Table 4-3. Chemicals to be measured in sediments at base stations during the 1991 Louisianian Province Monitoring Demonstration

Polycylic Aromatic Hydrocarbons (PAHs)

Acenaphthene
Acenaphthylene
Anthracene
Benz(a)anthracene
Benzo(b)fluoranthene
Benzo(k)fluoranthene
Benzo(g,h,i)perylene
Benzo(a)pyrene
Benzo(e)pyrene
Biphenyl
Chrysene
Diben(a,h)anthracene
2,6 dimethylnaphthalene
Fluoranthene
Fluorene
2-methylnaphthalene
1-methylnapthalene
1-methylphenanthrene
Naphthalene
1,2,3,-c naphthalene
Perylene
Phenanthrene
1,2,3,-c phenanthene
1,2,3,-c,d pyrene
Pyrene
1,2,3-c pyrene-dibenzopyathene

Aliphatic Hydrocarbons

n-dodecane
n-heptadecane
n-hexadecane
n-nonadecane
n-octadecane
n-pentadecane
Phytane
Pristane

Major Elements

Aluminum
Iron
Manganese

Trace Elements

Arsenic
Cadmium
Chromium
Copper
Lead
Mercury
Nickel
Selenium
Silver
Tin
Zinc

DDT and its metabolities

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

Pesticides

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

Table 4-3. Chemicals to be measured in sediments during the 1991 Louisianian Province Monitoring Demonstration

PCB Congeners

Congener #	Location of Cl's
8	2 4'
18	2 2'5
28	2 4 4'
52	2 2'5 5'
44	2 2'3 5'
66	2 3'4 4'
74	2 4 4'5
77	3 3'4 4'
99	2 2'4 4'5
101	2 2'4 5 5'
118	2 3'4 4'5
153	2 2'4 4'5 5'
105	2 3 3'4 4'
126	3 3'4 4'5
138	2 2'3 4 4'5'
187	2 2'3 4'5 5'6
128	2 2'3 3'4 4'
180	2 2'3 4 4'5 5'
170	2 2'3 3'4 4'5
195	2 2'3 3'4 4'5 6
206	2 2'3 3'4 4'5 5'6
209	2 2'3 3'4 4'5 5'6 6'

Other Measurements

Butyltins
Acid Volatile Sulfide
Total Organic Carbon

Bioassays will be conducted for 10 days for Ampelisca and 4 days for mysids, penaeid shrimps, and polychaetes under static conditions with aeration; temperature will be maintained at 20°C for all tests; there will be five replicated test containers of Ampelisca for each test sediment and three for mysids, penaeid shrimp, and polychaetes.

4.2.2.3 Dissolved Oxygen Concentration

Adequate dissolved oxygen (DO) is required for the maintenance of populations of fish, shellfish, and other aquatic biota. Most estuarine populations can tolerate dissolved oxygen concentrations below 100% of saturation without apparent adverse effects. Prolonged exposures to less than 60% oxygen saturation, however, may result in altered behavior, reduced growth, adverse reproductive effects, and/or mortality (Vernberg 1972; Reish and Barnard 1960). Exposure to less than 2 ppm for extended periods of time (hours to days) causes mortality to most biota, especially during summer months, when metabolic rates and ambient temperatures are high. Additional stresses that occur in conjunction with low dissolved oxygen (e.g., exposure to hydrogen sulfide) may cause as much, if not more, harm to aquatic biota than exposure to low dissolved oxygen concentrations alone (Brongersma-Sanders 1957; Brown 1964; Theede 1973). In addition, aquatic populations exposed to low dissolved oxygen concentrations may be more susceptible to the adverse effects of other stressors (e.g., disease, metals, pH, toxic chemicals).

Dissolved oxygen concentration is potentially both an exposure and response indicator. As a response indicator, it can reflect the cumulative system-level effects of eutrophication from nutrient or sewage loading. As an exposure indicator, it reflects the potential biological stresses of low dissolved oxygen concentrations on biota. However, dissolved oxygen concentrations, even in bottom waters, can fluctuate greatly with tide, wind patterns, and biological activity. Before dissolved oxygen can be used as a core indicator, the following questions concerning its stability and variability at a site must be answered:

- Is the dynamic frequency distribution of dissolved oxygen concentration stable over the summer period?

- o Is there sufficient predictability in dissolved oxygen patterns so that the degree of low dissolved oxygen can be predicted by using an instantaneous or short-term continuous measurement record?

These questions must be addressed in order to quantify the "low" dissolved oxygen stress (magnitude and duration of extreme events) to which biota might be exposured during the summer. The reliability of the dissolved oxygen indicator was examined in the Virginian Province Demonstration in 1990 at roughly 30 locations throughout the region and at 8 ITE sites in the northern Gulf of Mexico. Complete information is not available for the 30 continuous DO monitoring sites in the Virginian Province. However, 30-day records of continuous bottom DO concentrations (every 15 minutes) are available for 4, a priori, low-dissolved oxygen stations and 4, a priori, high-dissolved oxygen stations in Gulf of Mexico esturaries (criterion for low dissolved oxygen was > 15% of observations being < 2 ppm) (Summers and Engle 1991) for the period August 1-31, 1991.

EMAP-Near Coastal cannot afford, fiscally or logistically, to monitor all 198 base and index stations continuously for 30 days. Therefore, subsampling of the 8 temporal records collected in 1990 was used to evaluate the effect of shorter time-interval sampling upon the accuracy of the classification of the sites.

Monte Carlo subsampling of the full record of dissolved oxygen measurements at each site was used to construct data sets for each of the following continuous scenarios: 24-hour, 48-hour, 72-hour, and 96-hour. Because the logistical problems associated with continuous measures at all base stations prohibit measurement for greater than 4 days, alternative metrics to continuous distributions were investigated that utilized short-term measurements (i.e., 12-24 hour) to characterize an instantaneous measure or set of measures of dissolved oxygen. These "instantaneous" classification measures were the minimum DO concentration for a 24-hour period, the DO concentration at dawn (i.e., roughly 0500), and the nighttime mean DO concentration. Sites experiencing high frequencies of hypoxia were poorly characterized using a 24-96 hour continuous distribution (i.e., success rate < 60%). Neither the nighttime mean nor the dawn DO concentrations correctly classified "poor" sites at a rate greater than 75% while the 24-hour minimum DO concentration correctly classified "good" and "poor" sites more than 85% of time.

The reliability of dissolved oxygen as an indicator will be examined further in the 1991 Louisianian Province Monitoring Demonstration. Two types of dissolved oxygen measurements will be made: (1) continuous bottom water measurements (approximately every 15 minutes) for 12-24 hours but over nighttime hours and (2) point-in-time water column profiles to characterize dissolved oxygen conditions at the time of other sample collections.

Continuous measurements of bottom water dissolved oxygen concentration will be made at all monitoring sites over a 12-24 hour period inclusive of nighttime hours. Based on available data, these sites are anticipated to have highly variable dissolved oxygen concentrations within the 24-hour period. As a result, the combination of the minimum, dawn, and mean nighttime concentrations of dissolved oxygen will be used to classify the site based on the established DO criterion. A Hydrolab DataSonde III, equipped with a polarographic dissolved oxygen electrode and a digital datalogger, will be used to make these measurements. In addition to DO concentrations, the DataSonde III will be programmed to take measurements of conductivity, temperature, salinity, depth and pH about 0.5 m off the bottom every 15 minutes. The unit will be deployed between 6 AM and 6 PM and retrieved between the hours of 6 AM and 6 PM the following day. The retrieved DataSonde III will be returned to the mobile laboratory where the stored data will be retrieved, the instrument calibrated, and reinitiated for subsequent deployment. Immediately after deployment and prior to retrieval of the DataSonde III, point-in-time measures of dissolved oxygen concentration and other parameters will be taken with the HydroLab Surveyor II. These measurements will be used as a quality assurance check of the DataSonde III.

Point-in-time water column profiles of dissolved oxygen concentration will be made each time a sampling site is visited by using a HydroLab Surveyor II equipped with a polarographic dissolved oxygen electrode. The point-in-times measure will be used as a response indicator to estimate the extent of low dissolved oxygen conditions at the time of sampling.

4.2.2.4 Contaminants in Fish Flesh

One of the questions that the concerned public most frequently asks environmental managers is "Do fish contain contaminants?" This question is one of the assessment endpoints of EMAP. The indicator of contaminants in fish flesh is of overwhelming importance to the assessment endpoint and is intended to answer this question on a regional scale. It is a critical component of the Near Coastal conceptual model, and analytical methods for analyzing contaminants are well-established. The largest concern with the indicator is that we may be unable to catch fish at a sufficient number of the sites to warrant inclusion of this measure in the program. Fish samples will be archived initially, and the decision to proceed with chemical analysis will be conditioned upon achieving sufficient numbers.

In addition to serving as a response indicator for human usage of estuaries, contaminants in fish tissue also will provide a measure of ecological exposure of valued biota to contaminants in the environment. As previously noted, the presence of contaminants in sediments does not mean that they are available for uptake into the food web. Contaminants present in fish tissue obviously have made their way into the food web and are available to higher trophic levels. In addition, long-term, region-wide changes in the average concentration of a particular contaminant in fish flesh over a number of years provides useful information about contaminant input, bioavailability, or both (NOAA 1989). This information, however, must be normalized for the influence of size, species-specific physiological differences, and other factors that are known to influence contaminant concentrations in fish flesh (Sloan et al. 1988).

While the presence of contaminants in tissue implies exposure to bioavailable contaminants, the absence of contaminants in fish flesh, without regard to other measures of impact, does not necessarily indicate the absence of available contaminants. The reasons for this are:

- Many contaminants are taken up and metabolized by fish; consequently, even when fish are constantly exposed to a contaminant, that contaminant may not accumulate in their flesh.

- o Contaminants may cause mortality before they accumulate in the flesh.

Many of the factors that influence contaminant concentration in fish flesh are species-, and compound-specific. The indicator testing and evaluation program is designed to define the relative importance of these factors to EMAP-NC.

Fish for tissue analysis will be collected at each sampling location by using a 16-ft otter trawl. Trawls will be towed for 10 minutes against the tide, at a boat speed of approximately 1 m/s. Up to five individuals from each of 10 target species will be retained from each trawl and frozen for tissue analysis. The list of target species is based on: (1) the expectation of capture at a high percentage of sampling stations, (2) commercial/recreational value, and (3) use by one or more coastal states in tissue toxics monitoring programs. Catch expectations were estimated by conducting a retrospective analysis of available finfish and shellfish monitoring data collected by resource agencies in each of the Gulf States. Frequencies of collection within each state's estuarine waters were estimated and then these frequencies were weighted by the expected number of EMAP sampling stations within the state's waters to calculated the expected frequencies of catch during the 1991 Louisianian Province Monitoring Demonstration. These frequencies are shown in Table 4-4, with the anticipated target species delineated.

Not all of the target species collected and frozen will be processed for chemical analysis. Selection of taxa for processing will depend largely on the frequency of capture of selected species at sampling sites; more broadly distributed species will be favored. Bottom-dwelling fish will be processed preferentially because: (1) they tend to be more stationary than pelagic fish, and (2) they generally accumulate contaminants associated with bottom sediments at a faster rate and have a higher incidence of pathologic abnormalities than pelagic fish. Four species, all benthic or epifaunal feeders, are expected in high frequency (i.e., brown shrimp, Atlantic croaker, spot, and hardhead catfish) and contaminant analysis will begin upon receipt of shipment of these species.

The selection of additional target fish and shellfish species for chemical analyses will not be made until after all collections have been completed and an evaluation of the target species collected at the greatest number of stations by estuarine class, sediment type, and geographic subregion has been completed. A species will have to be collected at $\geq$ 50% of the sampling site within an estuarine class to be of use in the program.

Generally, five individuals from each of the target species will be composited for analysis; however, the final decision on the number of fish to composite will be delayed until the number of each target species collected at sampling sites and the size of the individuals is known. Muscle tissue will be dissected from the dorsal region of the fish by using titanium blades, with care being taken not to incorporate skin, scales, or bone into the sample. The chemicals measured and analytical procedures to be used are similar to those used in the NOAA Status and Trends Program (Table 4-5).

The ingestion of contaminated tissues is also a source of these contaminants of wildlife (e.g., wading birds, ospreys). Fillets could underestimate the levels of potential ingestion by only evaluating contaminant loads in muscle tissue. Therefore, at the 16 ITE stations, we will assess the magnitude of this underestimate by analyzing the contaminants (Table 4-5) found in fillet, whole body, and livers of the target species.

4.2.2.5 <u>Gross Pathology of Fish</u>

The incidence of gross pathological disorders in fish such as fin erosion, somatic ulcers, cataracts, and axial skeletal "aesthetic" abnormalities is an important set of criteria used by the public to judge the quality of a water body. The indicator was advanced to developmental status because it is clearly important to assessment endpoints, it is responsive, and there is a small incremental cost for testing the indicator, given that trawling activity is already taking place at each site to capture fish for tissue analysis.

Gross pathological disorders have a scientific base; severely polluted habitats have a higher frequency of gross pathological disorders than similar, less polluted habitats (Sinderman 1979; O'Connor et al. 1987;

Buhler and Williams 1988; Malins et al. 1984, 1988). Laboratory exposures to contaminants such as PCBs, petroleum products, and pesticides, suggest that many gross pathological disorders are associated with long-term contaminant exposure (Sinderman 1979; Capuzzo et al. 1988; Middaugh and Hemmer 1988). Fish pathology is not ready for core status because several questions remain to be answered, including the following:

- o Can sufficient numbers and kinds of target species be collected within the EMAP-NC sampling design and logistical constraints to provide meaningful data on the incidence of gross pathological disorders?

- o Is the incidence of pathological defects sufficiently high at polluted sites to be distinguished from "clean" sites, given the level of sampling effort (i.e., previous studies at severely polluted sites have found incidences of 10% or less, and it is likely that we will collect fewer than 100 fish at most sites).

Answers to these questions should provide the information needed to determine whether the fish gross pathology indicator should be added to the core indicator suite during full implementation of EMAP-NC.

All individuals of each target species from each trawl sample will be examined externally for gross pathological disorders including skin ulcers, fin erosion, gill abnormalities, visible tumors, cataracts, or spinal abnormalities. Fish found to have pathological defects will be preserved for detailed histopathological examination. Results of the detailed examination will be used to identify possible causes of aberrations and to ensure that the conditions noted were not ones that could result from abrasion and physical damage during collection.

In addition, we will evaluate the development of a health condition index for estuarine fish using the methodology described by Goede (1989). This autopsy-based method combines information concerning

Table 4-4. Catch frequencies (> 1.0%) of Gulf finfish based on available trawl data from Gulf States (1980-1989) and anticipated catch frequencies (overall) during the 1991 Louisianian Province Monitoring Demonstration.

Species	FL	AL	MS	LA	TX	Overall
Trawl (ft)	16	16	16	16	20	16.80
Stretch Mesh (in)	2.00	1.50	1.25	1.50	1.50	1.55
Lined	No	Yes	Yes	Yes	No	—
Mesh Liner	—	—	0.25	0.25	—	—
No. of Trawls	24	140	71	4445	400	5080
No. of Stations	8	10	6	20	10	54
No. EMAP Stations	34	24	19	73	48	198
Brown Shrimp*	80.00	59.29	25.35	75.59	85.00	71.83
Atlantic Croaker*	66.70	60.71	36.62	34.80	95.00	58.19
White Shrimp*	0.00	49.29	29.58	64.57	85.00	53.23
Hardhead Catfish*	53.30	37.86	35.21	28.64	92.50	50.11
Blue Crab*	26.70	60.71	23.94	34.81	95.00	50.11
Spot*	46.70	45.00	23.94	23.24	92.50	46.76
Pinfish*	60.00	8.57	4.22	75.75	95.00	48.14
Southern Flounder*	20.00	34.29	29.58	74.00	67.50	40.64
Sand Seatrout*	0.00	58.57	36.62	33.84	70.00	40.06
Bay Anchovy**	6.70	74.29	94.37	45.22	0.00	35.88
Gafftopsail Cat*	0.00	22.14	16.90	21.46	67.50	28.58
Gulf Menhaden	13.30	9.29	18.31	16.27	72.50	28.74
Bay Whiff	0.00	46.43	32.39	38.87	10.00	25.49
Striped Anchovy**	6.70	20.71	40.85	28.50	0.00	18.09
Striped Mullet	0.00	0.00	0.00	11.50	32.50	12.12
Atlantic bumper	0.00	20.71	23.94	12.00	10.00	11.66
Spotted Seatrout	0.00	0.00	0.00	10.00	32.50	11.57
Lizardfish	13.30	31.43	9.86	7.70	5.00	11.09
B. Tonguefish	0.00	35.71	28.17	4.90	5.00	10.05
Pink Shrimp	0.00	15.00	1.41	11.50	12.50	9.22
Hogchoker	0.00	22.14	22.53	10.10	0.00	8.57
Threadfin Shad	0.00	13.47	23.94	11.56	0.00	8.20
Least Puffer	0.00	29.29	23.94	2.20	5.00	7.87
Squid	6.70	11.10	23.94	2.20	5.00	6.82
Sheepshead	0.00	0.00	0.00	0.00	27.50	6.67
Gulf Butterfish	20.00	2.86	1.41	3.30	0.00	5.13
Gulf crab	0.00	11.10	33.80	0.00	0.00	4.59
Silver Perch	0.00	9.52	35.21	0.00	0.00	4.53
Red Drum	0.00	0.00	0.00	0.00	15.00	3.64
Harvestfish	0.00	11.68	18.31	1.20	0.00	3.62
Crevalle Jack	13.30	5.71	1.41	1.13	0.00	3.53
Sp. Mackerel	0.00	2.14	4.22	3.33	5.00	3.10
Black Drum	0.00	0.00	0.00	0.00	10.00	2.42
Atlantic Threadfin	0.00	17.14	0.00	0.00	0.00	2.08
Bighead Searobin	0.00	12.86	4.23	0.00	0.00	1.96
Southern Kingfish	0.00	12.14	2.82	0.00	0.00	1.74

* Target Species
** Poorly collected unless net is lined

Table 4-5 Chemicals to be measured in tissues during the 1991 Louisianian Province Monitoring Demonstration

DDT and its Metabolites

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

Pesticides

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

PCB Congeners

(#)	Location of Cl's
8	2 4'
18	2 2'5
28	2 4 4'
52	2 2'5 5'
44	2 2'3 5'
66	2 3'4 4'
74	2 4 4'5
77	3 3'4 4'
99	2 2'4 4'5
101	2 2'3 5 5'
118	2 3'4 4'5
153	2 2'4 4'5 5'
105	2 3 3'4 4'
126	3 3'4 4'5
138	2 2'3 4 4'5'
187	2 2'3 4'5 5'6
128	2 2'3 3'4 4'
180	2 2'3 4 4'5 5'
170	2 2'3 3'4 4'5
195	2 2'3 3'4 4'5 6
206	2 2'3 3'4 4'5 5'6
209	2 2'3 3'4 4'5 5'6 6'

Trace Elements

Aluminum
Arsenic
Cadmium
Chromium
Copper
Iron
Lead
Mercury
Nickel
Selenium
Silver
Tin
Zinc

basic blood parameters, length and weight, external pathology, and internal pathology to calculate an index of health. We will employ this method at the 16 ITE sites to evaluate the efficacy of using the health condition index as a future part of the base sampling effort.

4.2.2.6 Relative Abundance and Tissue Contaminant Concentrations of Large Shellfish

Estuarine waters continue to produce large quantities of economically important shellfish even though substantial portions of shellfish-producing areas in virtually every coastal state are closed because of pollution impacts (Broutman and Leonard 1986; Leonard et al. 1989). The large shellfish indicators (i.e., abundance of large shellfish and tissue contaminant concentrations) were given developmental status because of their importance to the assessment endpoint of human use, a small incremental cost, the availablity of proven methods to analyze contaminants, and the likely success of index site samples.

Problems that threaten shellfish include low dissolved oxygen concentration, toxic contamination of sediments and tissues, and microbial and viral contamination of tissues. These insults reduce growth and survival, adversely affecting production. They also reduce the value and quality of shellfish meats for human consumption. The relative immobility of shellfish makes them good integrators of long-term environmental conditions at the site where they were collected. The burrowing life style of many shellfish places them at a location where exposure to hazards, such as low dissolved oxygen stress and contaminants, is likely to be high. The occurrence of large-sized (i.e., older) shellfish at a site generally is considered to be an indicator that environmental conditions at that site have been biologically acceptable over time.

Filter feeding bivalves pump large quantities of water across the surface of their gills and remove large amounts of particulate material from the water (Galtsoff 1964; Dame et al. 1980; Cloern 1982; Jorgensen et al. 1986; Doering et al. 1986). A substantial portion of the captured material is ingested, and the associated contaminants may be accumulated in tissues to concentrations many times higher than those in the water. Tissue contamination increases or decreases with respect to ambient concentrations (Roesijadi et al. 1987; Pruell et al. 1987). Bivalve tissue contaminant concentrations are influenced by many factors including: species, size, season, sexual maturity, and environmental setting. If variation attributable to these factors can be partitioned, and sufficient numbers of individuals can be collected, contaminant concentration in the tissues of bivalves is a potentially useful core indicator of contamination.

The NOAA Status and Trends Program has been measuring contaminant concentrations in tissues of bivalves (oysters and mussels) of higher salinity estuarine waters (> 10 ppt) since 1986. NOAA, however, does not collect data on burrowing shellfish or shellfish from low salinity areas. As a part of the 1991 Louisianian Province Monitoring Demonstration, EMAP-NC will determine whether sufficient numbers of large, easily collected filter-feeding bivalves occur in lower salinity waters to justify their inclusion in the NOAA Status and Trends Program. Such a program would provide useful information on the extent and magnitude of contaminant exposure in habitats that are particularly vulnerable to contaminant impacts (Schubel and Carter 1984; Sharpe et al. 1984).

Large infaunal shellfish will be collected from each site by using a bivalve rake equipped with a 2.5 cm mesh liner. The duration of the dredge tows will be five minutes, which will allow the dredge to sample as much sediment as possible without becoming clogged. All large shellfish collected in each sample will be counted and identified to species level. Shell length of target species will be measured to provide an indication of the age structure of the population.

Up to 20 individuals of each target species will be scrubbed of sediment and other material by using a nylon or natural fiber brush, frozen, and shipped to the analytical laboratory on dry ice. These 20 individuals will represent the largest specimens available in the collection. In the laboratory, composited whole-body tissue samples will be made by homogenizing soft parts, and the NOAA National Status and Trends suite of bivalve tissue contaminants will be measured on homogenized tissue subsamples (Table 4-5). As with fish, the decision to proceed with chemical analysis, and the species which will actually be analyzed, will be determined by the number of sites at which bivalves are collected.

4.2.2.7 Aesthetic Indicators (Flotsam, Jetsam, Odor, Water Clarity)

One of the human-use endpoints is visual aesthetics of an environment. A habitat is degraded for human use if floating and deposited garbage and trash are abundant, if there are noxious odors, or if the water is not clean in appearance. Because of their importance to assessment endpoints and low incremental cost for observation, these parameters were included as developmental indicators.

Although easy to observe and measure, flotsam, jetsam, and odor generally are not measured, and almost nothing is known of their variability and stability as indicators. Flotsam is likely to be highly variable, because it is subject to movement by wind and tides, and its input rate may not be stable. Presence of flotsam and odors will be noted at each EMAP-NC sampling site during the 1991 Louisianian Province Monitoring Demonstration.

Water clarity will be measured by determination of Photosynthetically Active Radiation (PAR). Photosynthetically active radiation (PAR) will be measured to indicate the degree to which turbidity can inhibit photosynthetic activity. PAR will be measured with a LI-COR irradiometer.

4.2.2.8. Extent of Submerged Aquatic Vegetation Beds

During the 1991 Louisianian Province Monitoring Demonstration, EMAP-NC will begin to map the location and extent of the submersed aquatic vegetation (SAV) beds throughout the coastal region of the Gulf of Mexico (exclusive of the region south of Tampa, FL). Review of available information (CSA and Martel Labs, 1985; Eleuterius, 1987; Dunton, 1990; Onuf and Quammen, 1990) provide some characterization of the distribution of SAV beds in the "Big Bend" region of Florida; western Mississippi Sound, Mississippi; and, southern Laguna Madre, Texas. However, much of the Louisianian Province remains unstudied or characterization of the existence of SAV beds is anecdotal. In addition, although similar methodologies have been used in numerous SAV remote sensing studies, significant differences in methodology makes combined use of the available information very difficult. This indicator is designed to address two major issues:

- o Development of a baseline for the extent and distribution of SAV beds in the Louisianian Province

- o Development of a list frame of SAV beds for the development of a monitoring program to ascertain the status and trends of these habitats.

The SAV mapping effort will consist of two parts; namely, (1) remote sensing overflights of coastal regions of the Louisianian Province (including Chandeleur Sound, Breton Sound, and Apalachee Bay), and (2) ground-truthing to verify the remotely sensed data. Overflights will be conducted in late summer/ early fall and the overflight data will be used to produce maps, over a 4-year period, delineating the presence and extent of SAV beds (minimal detection size of a bed will be 0.25 hecture). In 1991, the region between Pensacola Bay, FL, and Apalachee Bay, FL, (inclusive) will be mapped and ground-truthed. Ground-truthing will consist of visitation to a randomly selected number of beds to confirm existence and physical dimensions as well as to measure dominant species, biomass, and density.

An effort will be made in Year 1 to determine appropriate indicators of SAV bed condition for employment in Year 2 of the monitoring in the Louisianian Province by holding a SAV Indicator Workshop. Candidate indicators include available underwater photosynthetically active radiation or PAR (Dunton 1990), photosynthate reserve (Dawes and Lawrence 1979), and biomass and density of submersed seagrasses.

4.2.2.9. <u>Coastal Wetlands</u>

Because of the prominence of the "no net loss" national policy concerning loss of wetlands habitat and the importance of wetlands as a land margin ecosystem pressured by multiple anthropogenic stresses, EMAP-NC is working cooperatively with the EMAP Wetlands Resource Group to develop a pilot wetlands project in coastal wetlands within the Louisianian Province. This pilot will be conducted by the EMAP-Wetlands Group in September 1991 and the content of this pilot will be described in a subsequent document compiled by the EMAP-Wetlands Resource Group.

4.2.3 Research Indicators

Table 4-2 includes the list of the research indicators that will be used for the 1991 Louisianian Province Monitoring Demonstration. A brief justification for the selection of each of these indicators, and a summary of the measurement methods that will be used is provided below. The general purpose of sampling these indicators during the 1991 Monitoring Demonstration is to obtain the information required to determine whether they should be evaluated further, should be removed from the list of potential indicators because of some deficiency, or should be incorporated into the developmental indicator suite.

4.2.3.1 Fish Community Composition

Estuarine fish have economic, recreational, and ecological value. Some are harvested; others serve as forage for predators that have great aesthetic value (birds, mammals). Many fish species hold a position in the top 30% to 50% of the estuarine food chain. Therefore, fish community indicators were advanced to research status because of their importance to assessment endpoints and their role in the conceptual model of estuarine resources.

Factors controlling species composition and abundance of estuarine fish communities are complex and not well understood. However, most fish ecologists agree that the assemblages of fishes that occurs at a sampling site are controlled by water quality parameters, contaminant concentrations and inputs, and habitat conditions (Weinstein et al. 1980). For example, stressed areas may have depauperate fish communities or be dominated by pollution-tolerant species such as mummichogs or carp (Haedrich and Haedrich 1974; Jeffries and Terceiro 1985; Weinstein et al. 1980; Livingston 1987). Polluted sites are thought to contain less diverse and less stable fish assemblages than unpolluted sites. The degree to which information on fish community composition can be used to assess the status of estuarine environments on regional scales is unknown. A major purpose of evaluating fish community composition as part of the Louisianian Province Monitoring Demonstration is to determine whether regional scale information on fish community characteristics can be used as an indicator of environmental quality. If fish community data could be used in this manner, it would be particularly meaningful to a broad range of audiences.

4.2.3.2 Histopathology of Fish Populations

While gross fish pathology is a potential response indicator of environmental status (O'Connor et al. 1987) that is easy and economical to measure, it may not provide insight into the potential cause of the pathology. To address this concern, EMAP-NC will perform detailed histopathological examinations of randomly selected individuals of target and non-target fish species at the indicator testing and evaluation sites. All individuals of each target species that "fail" the field gross pathology examination and up to 25 randomly selected individuals of each target species that "pass" the field examination at the indicator testing and evaluation sites will undergo a detailed histopathological examination. In addition, up to 10 randomly selected individuals from non-target species collected at these sites will be examined similarly. Histopathology advanced to research indicator status on the same criteria as gross pathology; however, it is not being implemented on a regional basis until it can be shown to enhance our ability to discriminate between polluted and unpolluted sites.

Representative tissue samples will be taken from specimens and processed for histological analysis. Tissue samples will be dehydrated in an ethanol gradient, cleared in a xylene substitute, infiltrated, and embedded in paraffin. Sections will be cut at 6 μm on a rotary microtome, stained with Harris' hematoxylin and eosin, and examined microscopically by a trained pathologist. The results of this microscopic examination will be used to assess the relationship between the incidence of external abnormalities and internal histopathological abnormalities, to characterize the types of external/internal pathologies, and to create a baseline of histopathological information for the Louisianian Province. Based on these findings, a determination will be made regarding whether histopathological examination warrants further consideration by EMAP-NC.

4.2.3.3. Suborganismal Bioindicators

Considerable basic research effort is being conducted on a wide range of suborganismal bioindicators (e.g., genetic, biochemical, physiological) that will represent precursors to major changes in organismal condition (e.g., mortality, growth, reproduction) and/or population condition (e.g., abundance, production, reproductive success). The major advantage of bioindicators is that they may be an early warning indicator of exposure to environmental stress. Monitoring in the Louisianian Province in 1991 will concentrate on testing the applicability of selected bioindicators to assess their reliability and sensitivity as ecological indicators in the context of regional and national monitoring.

EMAP-NC is interacting with the EPA Research Laboratories at Gulf Breeze, FL; Narragansett, RI; and Duluth, MN, the EPA Monitoring Support Laboratory at Cincinnati, OH, and the National Marine Fisheries Service Laboratory in Seattle, WA, to develop a basic strategy that will help to incorporate suborganismal indicators into the developmental stage of EMAP indicators. An advisory group, comprised of representatives from these laboratories, has been formed to develop a short list of bioindicators that could be evaluated by EMAP-NC. This advisory group developed a list of 30 potential bioindicators of exposure and effects (Table 4-6) along with their judgement concerning the readiness of these parameters for field usage. As a result of this effort, the monitoring demonstration in the Louisianian province will examine the efficacy of several bioindicators: bile flourescence, blood chemistry, stable isotopes, detailed histopathology including hepatic lesions, and skeletal development. During the 1991 monitoring in the Louisianian Province, these four bioindicators will be examined for selected target finfish species from the 16 ITE sites (i.e., good and poor quality sites based on best judgement). The results of these analyses will provide information concerning the ability of the selected bioindicators to discriminate between sites characterized by "good" environmental quality and "poor" environmental quality.

Table 4-6. Priority ecological indicators selected as applicable for EMAP-NC monitoring.

Indicator **Organism of**
Availability for Testing

Interest

Exposure			
Base	ITE		
Stable C&N Isotopes	Microorganisms	No	Yes
Tissue Hydrocarbons	Crustaceans/Molluscs	Yes	Yes
Hepatopancreas Glutathione	Crustaceans	No	No
Stress Proteins	Fish	No	Yes
Bile Flourescence	Fish	Yes	Yes*
Hepatic Hydrocarbons	Fish	Yes	Yes*
Hepatic P-450	Fish	Yes	Yes*
Hepatic Glutathione	Fish	No	Yes
Effects			
DNA Adducts	Crustaceans/Molluscs Fish	No Yes	Yes Yes
DNA Strand Breaks	Molluscs	No	Yes
Genetic Diversity	Fish	No	No
Blood Chemistry	Fish	No	Yes
Blood Protein Adducts	Fish	No	No
Plasma Chemistry	Fish	No	Yes
Nitroblue Tetrazolium	Molluscs	No	Yes
Hemocyte Salinity Regulation	Molluscs	No	Yes
PIKA	Molluscs	No	No
Brown Cells	Molluscs	No	No
Neoplastic Lesions	Molluscs	Yes	Yes
Detailed Histopathology	Fish	Yes	Yes
Early Hepatic Lesions	Fish	Yes	Yes

* Parameter already field validated to limited extent

Table 4-6. Continued

Indicator	**Organism of Interest**	**Availability for Testing**	
Condition Indices		Base	ITE
RNA:DNA Ratios	Molluscs	No	Yes
Protein Synthesis	Molluscs	No	No
Sperm Motility	Fish	No	Yes
Germ Cell Analysis	Fish	No	Yes
Organosomatic Index	Fish	No	Yes
Skeletal Development	Fish	Yes	Yes

4.2.4 Stressor Indicators

The stressor indicators, including an overview of the specific parameters to be estimated and their sources, are defined in Table 4-7. This list of stressors includes factors associated with natural climatic and hydrographic data (e.g., river discharge), basic land use patterns and utilization rates (e.g., population density), commercial and regulatory information (e.g., shellfish bed classification), point source loadings (e.g., industrial effluents), and non-point source loadings (e.g., agricultural runoff). Most of the information on stressor indicators relating to pollutant loadings will be obtained from an update of NOAA's National Coastal Pollution Discharge Inventory (NCPDI). The data sources NOAA includes in the NCPDI are extensive; a partial list of these sources is presented in Table 4-8. These stressor indicators will not be sampled concurrently in the field with other indicators by the Louisianian Province sampling teams.

4.2.5 Future Indicators

In a long-term status and trends monitoring program, it is important to maintain continuity in the indicators that are measured. However, it is also important to continually re-evaluate whether the techniques used to measure those indicators remain the most cost-effective and precise, particularly as technology improves (NRC 1990a). In addition, candidate indicators must be examined continually to determine whether their addition to the program would improve our ability to characterize environmental conditions and identify factors contributing to that condition.

EMAP-NC will maintain two types of indicator development activities as the program progresses. One will concentrate on development of new candidate indicators, or studies to advance candidate indicators to research indicator status. This program will emphasize basic research, will be conducted primarily through extramural research, and will be funded through ORD or the EPA grants program that is administered independently of, and integrated across, resource groups. In contrast, studies conducted within EMAP-NC will be more applied and will concentrate on tests to advance research indicators to developmental or core status. EMAP-NC efforts will build upon basic research conducted in laboratory settings or at local scales by testing and evaluating promising indicators on a regional or national scale. While it is difficult to

Table 4-7. Synposis of potential data sources for stressor indicators

Stressor Indicator	Specific Parameters	Source(s)
Freshwater Discharge	Volume of inflow	o U.S. Geological Survey (USGS) - National Stream Quality Accounting Network (NASQAN) - Water Data Reports - National Water Data Exchange (NAWDEX) o National Oceanic and Atmospheric Administration (NOAA) - National Coastal Pollution Discharge Inventory (NCPD)
Atmospheric Temperature	Daily mean, median, and range at the earth's surface for key locations within each region	o National Climate Center Archives (NCCA)
Wind Speed and Direction	Wind speed and direction at the earth's surface for key locations within each region	o National Climate Center Archives (NCCA) o National Oceanic and Atmospheric Administration (NOAA) - Local Climatological Data
Atmospheric Deposition	Rainfall in cms, loading of atmospheric pollutants	o National Climate Center Archives (NCCA) o Natinal Atmospheric Deposition Program (NADP) o Multi-state Atmospheric Power Production Pollution Study (MAP3S) o Utility Acid Precipitation Program (UAPSP)

Table 4-7. (Continued)

Stressor Indicator	Specific Parameters	Source(s)
Pollutant Loadings by Categories including: o Point Sources - Industrial Discharge by Category - Municipal Sewage o Non-Point Sources - Urban Runoff - Non-Urban Runoff (i.e., agriculture, forests, etc.) - Irrigation Return Flows	Flow, biological oxygen demand, organic pollutants, number of wastewater treatment plants, number of industrial dischargers, number of power plants	o National Oceanic and Atmospheric Administration (NOAA) - National Coastal Pollution Discharge Inventory (NCPDI)
Land Use Patterns	Area, % urban, % agriculture, % forest, % wetland, % water, % barrier, number of major and minor urban areas	o National Oceanic and Atmospheric Administration (NOAA) - National Coastal Pollution Discharge Inventory (NCPDI)
Human Population Density	Density, density by occupation and industrial category	o U.S. Census of Population o United Nations Demographic Yearbook o U.S. Census of Manufacturing o U.S. Agriculture Census
Fishery Landings	Commercial and Recreational catch statistics	o National Oceanic and Atmospheric Administration (NOAA) o National Marine Fisheries Service (NMFS)
Shellfish Bed Classification	Area, % approved for harvesting	o National Shellfish Register of Classified Estuarine Waters

Table 4-8. Major data sources for the National coastal Pollution Discharge Inventory (modified from Basta et al, 1985)

Source Category	Institutions	Major Data Sources
Pollutants in Streamflow Entering the Coastal Zone	• U.S. Geological Survey • State Water Quality Agencies	• USGS National Stream Quality Accounting Network (NASQAN) • USGS Water Data Reports
Point Sources	• EPA Regional Offices • State Water quality Agencies • Section 208 and Regional Planning Offices • Industry organizations	• EPA Data Bases, Reports, and Regulations - NPDES Discharge Monitoring Reports (DMR) - Permit Compliance System (PCS) - 1982 Needs Survey - Industrial Facilities Discharge (IFD) File - Section 201, 208, and 303e Basin Plans - Effluent Limitations Guidelines and Standards • State Water Quality Reports • Regional Basin Planning Reports
Urban Nonpoint Runoff	• U.S. Geological Survey • National Weather Survey • Bureau of the Census • State Water Quality Agencies • Section 208 and Regional Planning Offices	• EPA National Urban Runoff Program (NURP) • EPA Nationwide Evaluation of Combined Sewer Overflows and Urban Stormwater Runoff • USGS Land Use Data and Analysis Program (LUDA) • 1982 Census of Population • 1983 and 1983 County and City Data Book • 1982 EPA Needs Survey • NOAA Local Climatological Data
Non-urban Nonpoint Runoff	• US Geological Survey • National Weather Service • US Department of Agriculture • Soil Conservation Service • State Water Quality Agencies • Agricutural Extension Officies • Section 208 and Regional Planning Offices	• USGS LUDA Program • SCS 1982 National Resource Inventory (NRI) • SCS SOILS-5 Data Base • Cornell Nutrient Simulation Model • USGS Study, "Elemental Concentration in Soils" • Agricultural Extension Office Records for fertilizer and Pesticide Use • NOAA Local Climatological Data • County Soils and Surveys Maps • Section 208 and Regional Planning Studies
Irrigation Return Flows	•U.S. Department of Agriculture • Soil Conservation Service • EPA Regional Offices • USGS Regional Offices • Local Water Management Districts	• USGS, State, and Regional Water Quality Management Studies
Oil and Gas Operators	• US Geological Services • EPA Regional Offices • US Coast Guard • State Oil and Gas Programs • American Petroleum Institute • Environmental Subcommittee of the Offshore Operators Committee	• USCG Pollutant Incident Reporting System (PIRS) • USGS Conservation Division Accident File and Production and Drilling File • EPA Drilling Platform Permits and Platform Discharge Characterization Studies • API Inventory of Wells and Drilling Statistics • State Oil and Gas Program Files • OOC Pollutant Discharge Characterization Studies
Marine Transportation	• U.S. Department of Commerce Marine Administration • U.S. Army Corps of Engineers • U.S. Coast Guard • UN International Maritime Organization • Port Authorities in U.S. and Mexico • Industry Organizations	• MARAD Vessel Movement Monthly Master Data File • USGS Documented Vessel File • COE, "Waterborne Commerce Statistics"
Dredging Operators	• U.S. Army Corps of Engineers • EPA Regional Offices • UN International Maritime Organization	• EPA Ocean Dumping Permit Files • COE Report to Congress, "Administration of Ocean Dumping Activities" • IMO Dredge Material Disposal Reports

Abbreviations: SCS, U.S. Department of Agriculture Soil Conservation Service; API, American Petroleum Institute; OOC, Offshore Operators Committee; USCG, U.S. Coast Guard; MARAD, U.S. Department of Commerce Maritime Administration; COE, U.S. Army Corps of Engineers; IMO, UN International Maritime Organization (formerly IMCO, Intergovernmental Maritime Consultative Organization).

be precise about future plans, it appears likely that indicator development within EMAP-NC will focus on four areas during the next few years: (1) suborganismal measures such as biomarkers, (2) remote sensing of primary producers, and (3) measurement of status and trends for wetlands and SAV, (4) evaluation of additional contaminants.

Although suborganismal measures (e.g., blood chemistry and bile contaminants) will be introduced as a indicator during the 1991 Louisianian Province Monitoring Demonstration, the scope will be limited in the initial year. Considerable basic research effort is being conducted on a wide range of suborganismal measures, that includes genetic, biochemical and tissue biomarkers, and many of these have been found to be promising indicators of environmental stress. However, many of these bioindicators are general biological responses to many types of stress. Research into diagnostic specificity is needed to provide useful insight into the types of stress (exposure) causing the response. The major advantage of biomarkers is that they may provide early warning indicator of exposure to environmental stress. At present, EMAP-NC is using measures that provide a reliable indication that an impact has occurred. In the future, however, we undoubtedly will need to incorporate more sensitive measures to identify which sites presently unimpacted are likely to be impacted by further stress and to evaluate the sensitivity of individual bioindicators along stress/contaminant gradient. EMAP-NC is interacting with the EPA Research Laboratories in Gulf Breeze, FL, Cincinnati, OH, and Narragansett, RI, and the NMFS Research Laboratory in Seattle, WA, to develop a basic research strategy that will help to incorporate suborganismal indicators into the program in future years.

Primary production is an important component of the estuarine conceptual model but is not being measured in the Louisianian Province Monitoring Demonstration because of large temporal variability in conventional measures that could be used to estimate the status and trends for primary producers. However, there appear to be two feasible methods that might be used to overcome this problem: (1) remote sensing techniques for estimating status and trends in chlorophyll stocks (a measure of algal biomass), and (2) automated in situ fluorometers with digitizing capability. Remote sensing of chlorophyll by satellite has the advantage of allowing multiple estimates of a site over a season without having to visit the site once initial ground-truthing was completed. This would permit integration over time at a reasonable cost. The technique has been tested to a limited degree, with mixed success. The principal problem appears to be one of turbidity. Automated fluorometers would solve the temporal variability problem for primary production in the same way that the deployed dissolved oxygen meters solve this problem for dissolved oxygen. Analogous instrumentation for fluorescence that includes data logging capability is just becoming available on the market, and EMAP-NC is working with several potential manufacturers to examine the feasibility of such an instrument.

The EMAP-NC Louisianian Province Team will be working with NOAA's Coastwatch Program and the U.S. Fish and Wildlife Service's Wetlands Research Laboratory to identify core, developmental, and research indicators for submersed aquatic vegetation communities. Our intent is to implement necessary indicators of SAV in 1992 once we have delineated the extent and locations of the SAV beds in the Louisianian Province in 1991.

EMAP-NC in the Louisianian Province will be evaluating the need for the assessment of additional contaminants beyond those listed in Table 4-3. Additional contaminants would focus primarily on pesticides, insecticides, and herbicides widely used in the Gulf States. However, some industrial contaminants of special interest (e.g., dioxin) could be evaluated by joint efforts between EMAP-NC and the entity requesting information on that contaminant. In this case, EMAP-NC would collect the samples and the requesting organization would provide the laboratory analysis.

5.0 LOGISTICS

5.1 Sampling Sub-regions

The Louisianian Province sampling will be conducted from July 8 through September 15, 1991. Three sampling regions (Fig. 5-1) have been established within the Louisianian Province which include only the estuarine and tidal river portions of the near coastal resources. These sub-regions are: (1) Eastern Gulf of Mexico, (2) Delta, and (3) Western Gulf of Mexico.

- The East Gulf Region extends from Anclote Key, FL to the western boundary of the Mississippi Sound

- The Delta Region includes the Lake Borgne/Lake Pontchartrain complex and continues around southern Louisiana to Terrebone Bay, LA including Chandeleur and Breton sounds.

- The West Gulf Region starts at Terrebone Bay, LA and follows the coastline of the Gulf of Mexico to the Rio Grande, TX.

5.2 Sampling Logistics

5.2.1 Crew Composition

There will be two sampling teams operating in the Louisianian Province in 1991. Team #1 (comprised of personnel from ERL/GB, the Gulf Coast Research Lab, and the University of Mississippi) will be responsible for the East Gulf Region; Team #2 (comprised of personnel from Texas A&M University and Louisiana State University) will be responsible for the Delta and West Gulf Regions. The East Region team will consist of two 5-member crews, each alternating on 6-day sampling schedules. There will be a Crew Chief in each crew who will be responsible for the overall performance of the crew with one Crew Chief (i.e., the Team Leader) having overall responsibility for the team. The West Region will also have two teams but

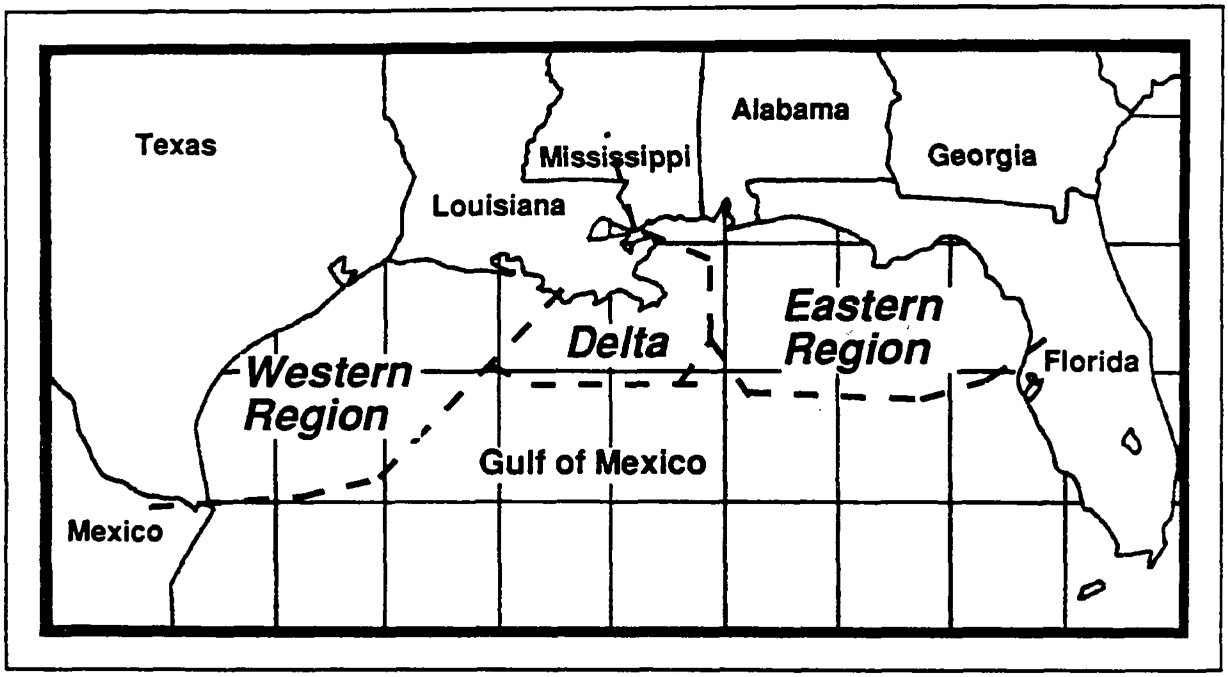

Figure 5-1. Regional divisions of the Louisianian Province.

these teams will operate simultaneously for 8-12 day periods within a common sampling area. For example, both vessels used in the West Region could sample the 16 stations in the Lake Pontchartrain area over a four day sampling window. The west regions will have two Crew Chiefs and two Team Leaders. The Crew Chiefs will be stationed on the two vessels in the Delta/West Region while the Team Leaders may be stationed in either the mobile laboratory associated with the two vessels, or on the vessels themselves.

At a minimum each will consist of: a Crew Chief (who may also be the Team Leader), 2 boat crew members and 2 shore crew members. The Crew Chief has the responsibilities of boat captain, specifically, the safety and performance of the crew, boat operation and navigation, adherence to sampling protocols, maintenance of the boat, vehicles, and assigned field equipment during field operations. At least one member of the boat crew will be familiar with finfish and shellfish taxonomy so that he/she can readily identify these species in the field. The boat crew, under the supervision of the Crew Chief will deploy and retrieve gear to collect samples and hydrographic data, process and store samples for the interim period after collection and before release to the shore crew, and perform maintenance on the boat, vehicle, and field equipment.

The shore crew will be responsible for: computer entry of previously collected field data, transmission of data files to ERL/GB, preparation and shipment of samples that have been previously collected, preparation of data sheets and sample containers for subsequent field activities and delivery of samples to overnight shippers. The qualifications of all crew members may be mixed so that back-up capabilities are available for each skill position. All crew members will have basic first aid/CPR training skills.

5.2.2 Equipment

Each team will be supplied by ERL/GB with all equipment and supplies required to perform the sampling. This will include:

- 26 ft sampling vessel (SeaArk aluminum workboat) equipped with a heavy duty hydraulic winch assembly (astern)

- Loran navigation, with backup
- 2 VHF radios, 1 of which is handheld
- Bottom depth and profile recorder
- 7.4 L (330 HP) V8 engine
- Bravo II outdrive with 20" propeller
- All required safety equipment and lines
- Corrosion resistant drive-on trailer with brakes

o Heavy duty 4-wheel drive pickup truck equipped with:

- 454 V8 engine
- Dual rear wheels
- Towing package for up to 12,000 lbs
- Camper shell for equipment storage

o Passenger van for transport and exchange of field crews

o Truck set up as a mobile preparation lab and shipping/receiving site. The truck will be equipped with

- VHF radio for communication with the boat
- Grid 386 portable computer
- Maintenance tools
- Calibration kits and spare parts
- Nautical charts
- Coolers
- Reagents
- Sample and shipping containers
- Safety equipment

o Sampling gear

- (2) 16' otter trawls
- Modified Van Veen sediment sampler
- Bivalve rake/dredge
- Hydrolab Surveyor II
- Multiple Hydrolab Data Sonde 3
- Licor Quantum Irradiometer

ERL/GB will maintain a backup sampling vessel to be provided to the teams as necessary. Spares for selected pieces of sampling gear will be provided to each team with additional spares to be kept at ERL/GB. In the event of equipment failure the replacement equipment will either be shipped overnight or delivered to the team in the field. The repair of the disabled equipment can then be expedited.

5.3 Sampling Activities

5.3.1 Station Types

Within each of the sampling subregions, there are 4 types of stations to be sampled: (1) Base Sampling Stations, (2) Indicator Testing and Evaluation (ITE) Stations, (3) Index Stations, and (4) Supplemental Spatial Stations. The distribution of samples in the 1991 Louisianian Province Monitoring Demonstration among these station types is shown in Table 5-1.

Each of the base stations has been selected according to the sampling strategy described in Chapter 3.0. The base stations provide the basis for the analysis to be performed to quantify the ecological status of the estuarine waters of the Louisianian Province. Ten sampling locations for the base characterization lie in water < 1.0 m in depth. As a result, these sites cannot be sampled using the proposed techniques. These sites will provide an estimate of the "unsampleable" area of a province. ITE stations are intended to represent extremes (i.e., "good" and "poor" condition) in both dissolved oxygen and contaminant

Table 5-1. Distribution of 1991 Louisianian Province Monitoring Demonstration samples among station types and sampling sub-regions.

	Number of Samples			
Station Type	East Gulf	Delta	West Gulf	Total
Base	37[a]	40	35[c]	112
Indicator Testing & Evaluation	8	1	0	16
Index	20	17	20[d]	57
Spatial Supplements	13[b]	0	0	13
TOTAL	78	57	63	198

[a] 3 stations are too shallow to sample

[b] 3 stations are too shallow to sample

[c] 7 stations are too shallow to sample

[d] 3 stations are too shallow to sample

concentrations due to industrial contamination and/or agricultural runoff. The ITE will be sampled for all of the same monitoring parameters as the base sampling sites, as well as for several "research" indicators. Index stations are judgementally determined locations (i.e., non-random) chosen in each tidal river segment and small estuary sampled. They were selected to represent the locations in these systems most likely to display "poor" environmental condition based on local geomorphometry (i.e., sediment type and depth). Three index sites are located in estuarine systems that are very shallow (i.e., < 1m) over their entire surface. These sites will represent the proportions of systems in the Louisianian Province that cannot be sampled by the present program.

Supplemental Spatial Stations consist of 13 locations in Mobile Bay, AL. These samples will be taken to evaluate the effect of the selected sampling grid density on the estimation of regional conditions. The monitoring parameters sampled at the spatial supplement stations will be the same as the base stations. This information will be used to identify appropriate sample density for systematic sampling for the Louisianian Province. Three sampling sites for spatial supplements are located in less than 1 m of water and, thus, represent unsampleable areas.

5.3.2 Sample Types

Seven different sampling activities will be performed during the 1991 Louisianian Province Monitoring Demonstration. The specific activities performed depend upon the type of station sampled (Table 5-2). Hydrographic profiles, include vertical water column profiles of salinity, temperature, dissolved oxygen, pH, and light energy and will be taken at all 198 sampling sites. Continuous "24-hour" monitoring of bottom dissolved oxygen concentration will be completed at all sampling sites. Deployed continuous monitors will be placed at a site prior to 6 pm and retrieved after 6 AM on the following day. Fish trawling will be performed at all sites and will collect pelagic fish and invertebrates to determine composition and abundance, perform gross pathology screening on individual fish and shellfish, select specimens for subsequent histopathological analysis, collect tissue for contaminant analysis, and collect specimens for suborganismal bioindicator assessment. Sediment grabs will be taken at all sites. These grabs will provide

Table 5-2. Activity performed at each station type to be sampled in the Louisianian Province.

Activity	Station at Which Activity is Performed			
Hydrographic Profile	Base	Indicator	Index	LSS[1]
Continuous DO	Base	Indicator	Index	LSS
Fish Trawling	Base	Indicator	Index	LSS
Sediment Grabs	Base	Indicator	Index	LSS
Bivalve Sample	Base	Indicator	Index	LSS
Additional sediment		Indicator		
Research Indicators		Indicator		

[1] Large Supplemental Stations

material for benthic identification of organisms to determine abundance, community composition, and biomass; contaminant analysis; sediment characterization; and, toxicity testing of sediment with mysids and amphipods. Large bivalve sampling will be conducted at all sites. An oyster dredge will be used to collect bivalves from the site to assess abundance and composition as well as to collect tissue for subsequent contaminant analysis. Additional sediment grabs will be taken at ITE sites toprovide sediment to perform toxicity tests with penaeid shrimp species and polychaetes. This collection is in addition to the sediment collected for the mysid and amphipod testing performed at all base and ITE sites. Additional samples from target fish and shellfish species (i.e., blood, bile) will be taken for analysis of suborganismal bioindicators which may provide an indication of the sub-lethal effects on the target populations. In addition, some research and developmental indicator measures will be collected by personnel not associated with the Louisianian Province sampling teams. These include: (1) aerial mapping of submerged aquatic vegetation beds (samples collected by NOAA/NMFS and Fish and Wildlife Service personnel), and (2) ground-truthing of submerged aquatic vegetation beds (samples collected by NOAA/NMFS, USFWS, and resource agencies of Florida, Alabama, Mississippi, Louisiana, and Texas).

5.3.3 Field Sample Handling

Specific handling and processing procedures must be followed for each sample type. The actual methodologies for the collection of the different samples will be described in the field manual for The Louisianian Province (Macauley et al. 1991a). Some samples may require immediate attention while others may be held for a period of time. A homogenized benthic sediment sample comprised of several sediment grabs will be split for shipment for subsequent toxicity testing and contaminant analysis. These sediment samples will be kept on ice, returned to the mobile laboratory where they will be frozen and shipped within 24 hours for overnight delivery to the appropriate processing laboratory. Fish and shellfish tissue for contaminant analysis must be quick-frozen and shipped for overnight delivery.

It seems reasonable that each crew, at the end of its 6-day rotation should be responsible for shipping the remainder of the samples they have accumulated during the week. These samples, shipped weekly, consist of: histopathology samples which had been preserved immediately following collection by opening the gut and placing in Dietrich's Solution; benthic samples for faunal identification which were immediately preserved in formalin/ rose bengal; and benthic samples for sediment characterization which have been kept on ice. Each crew should ship these samples, along with the backup data diskettes and sheets, using overnight delivery on the last day of their rotation.

5.4 Field QA/QC

During sampling activities, the boat crew will receive a check sheet provided to them daily by the shore crew. This sheet will include (1) the stations to be sampled, (2) type of sampling to be performed, (3) number of samples to be taken, and (4) the navigational information on the station. Prelabeled sample containers and data sheets will also be provided. These containers and data sheets will correspond to the data on the check sheet. It is the responsibility of the Crew Chief to see that the proper jars are filled with the correct samples and that they are correctly preserved. This check sheet may also serve as a daily log of the sampling activities with spaces for comments and other pertinent information. Once the samples have been turned over to the shore crew, a hard-copy chain of custody / shipping form will be completed for each sample or batch of samples as they are shipped. This chain of custody form will document the location of the sample and its condition at the sample's destination. One copy of the form will be retained by the shipper another by the recipient; both, in turn, will forward a copy to the operations center at ERL/GB.

All equipment will be maintained and calibrated according to the procedures identified in the Louisianian Province field manual (Macauley et al. 1991a). A log for the maintenance and calibration of the equipment will be established. The calibration log will document all of the information regarding how, when, and why the standardization was performed.

Independent checks by EMAP-Louisianian Province QA personnel will be performed periodically on each team during sampling activities; upon initiation of the sampling activities, each team will be visited and spot checks will be performed during the remainder of the sampling period. QA personnel will generate blind duplicate samples to be sent to each of the analytical labs for analysis.

Data entered into the computer in the field and electronically transmitted to ERL/GB will be spot checked in the field by another team member. Once the data are at the laboratory they will be checked against the original data sheets that were sent in from the field. The Louisianian Province Information Management System (LPIMS) data manager at ERL/GB will be responsible for performing this check.

5.5 Communication

There has been a toll-free commercial telephone number established at the field operation center (FOC) located at ERL/GB (1-800-321-3968). This will be backed up with a standard commercial number (904-934-9200). The toll free line will allow field teams to contact the operations center from any telephone. Field teams will be required to check-in daily with the field coordinator or designee upon the initiation and termination of sampling activities. The Crew Chief will report on the progress of the days activities and any problems encountered. Communications with the operations support staff, to help the field teams to resolve any problems they encounter, will also be facilitated by the toll-free line.

The Field Coordinator, or his designee, will be available after normal hours of operation via a paging system or a portable phone system by contacting the operations center's number (1-800-321-3968) which will be automatically forwarded to the paging service. This will allow the Field Coordinator to receive urgent or emergency communications during the period in which sampling activities are performed. In order to maintain the rigid sampling schedule, decisions concerning altering sampling stations or changing the schedule must be made in a timely manner.

At the end of each crew's 6-day rotation, the Crew Chief will check in with the Field Coordinator to discuss the progress of the stations sampled. The Crew Chief will also submit a weekly status report covering the stations sampled, problems that were encountered and the solutions used to resolve them, and the condition of the boat and crew.

ERL/GB operations center will maintain a toll free communications line to the VAX 11-785 for data communications. Shore crews will use this line to transfer data electronically to the mainframe data base at LPIMS on a daily basis. In the event of the VAX being down there will also be a commercial number which they may use and communicate the data to a backup PC.

Data collected in the field will be tracked and identified according to Province - Year - Station Number - Station Class - Type of Sample - and replicate number. There may be times when individual organisms collected in the trawl or dredge may need to be tracked. Each of these individuals will be given a unique sample number in addition to the standard identification. This sample identification information will be used to track samples from time of collection where the samples will be placed into prelabeled containers, through shipping and receiving reports, data entry, and reporting of final results.

The Crew Chief is responsible for all data collected and entered on board the boat, along with assuring that the samples are in the correct containers. Once ashore, the data and samples are transferred to the shore crew which is then responsible for entering the data into the computer and storing/shipping the samples. A chain of custody form will be established for each set of samples shipped, this chain of custody form may also be used as a shipping report. The report must contain airbill information, sample information, condition at shipment, and signature of shipper.

Laboratories receiving samples will report the condition of the samples upon receipt by entering the data, in specified formats, into the computerized sample tracking system and by returning a copy of the chain of custody form to ERL/GB. The processing laboratories will be required to maintain the established sample identification with the samples and report their results using the same identification. Problems with the shipping or receiving of samples will be recorded and reported to the Field Coordinator.

ERL/GB will receive copies of all reports and data both electronically and by hard copy. In this manner the status of each sample or station data will be tracked using two methods to minimize the loss of information should one of the systems prove unreliable.

5.6 Equipment Inventory and Maintenance

A full equipment inventory will be maintained by the operations staff at ERL/GB. Equipment that is required to perform the sampling activities will be assigned to the sampling teams. The Team Leader will sign for the issued equipment and maintain an inventory of the issue along with the Field Coordinator. Team Leaders and their respective institutions are responsible for the issued equipment and they will maintain the equipment in a serviceable condition during the period of issue. The Field Coordinator will be responsible for replacement and major repairs of equipment, as needed. The Crew Chiefs are responsible for reporting maintenance problems to the Field Coordinator. A maintenance log will be furnished with each piece of major equipment and it is the responsibility of the Crew Chief to maintain the equipment and update the log while the equipment is assigned to the team. The operations staff at ERL/GB will schedule all annual maintenance of the major equipment. All equipment will be returned to ERL/GB at the completion of sampling and will be stored at ERL/GB until the equipment is needed for subsequent sampling periods.

The Field Coordinator will be responsible for issuing supplies of consumables (sampling containers, shipping containers, data diskettes and sheets) to each team. He will maintain an inventory of consumables adequate to replenish the sampling teams while they are in the field.

5.7 Reconnaissance

Suspected problem sites in each of the regions were visited prior to April 1991. Access to the sample sites will be evaluated by field operations staff to determine the availability of adequate boat launching facilities, fuel availability, a usable route to travel to the site, and availability of unrestricted access. The adequacy of the area for remote staging will be evaluated in terms of availability of acceptable communications, lodging, suppliers of ice and dry ice, access to overnight delivery services, and mechanical repair services.

A mock sampling was performed during the reconnaissance by operations center personnel to evaluate whether the proposed sampling schedule can be accomplished. Ten stations in the eastern Gulf were successfully sampled over a six-day period by a boat crew of three with a land-support crew of two.

5.8 Training

Training will be performed in two segments at ERL/GB. Crew Chiefs will undergo 2 weeks of training from May 20 - 31, followed by 3 weeks of crew training from June 1 - 21. Training manuals have been prepared (Macauley et al. 1991b) and there is some overlap in the material covered at both training sessions. Because of earlier training, the Crew Chiefs will be able to help guide their the crew members through some of the training material and begin building team identities and expertise. The emphasis during the training will be on "hands on" field activities with the actual gear to be used (e.g., boat handling, use of the Van Veen grabs, shipping).

5.9 Contingency Plan

The Crew Chiefs will implement all decisions about alterations to the sampling schedule made by the Field Operations Center staff. Crew Chiefs will have final word on determining whether sampling at a particular site on a particular day can be accomplished within an acceptable margin of safety. A problem leading to possible cancellation of a sampling event is severe weather. Unless small craft advisories have been issued, Crew Chiefs generally will proceed with scheduled sampling activities. If inclement weather is anticipated, Crew Chiefs will be encouraged to sample only at sites that are sheltered or close to shore. Decision to proceed in inclement weather will be at the individual Crew Chief's discretion. The sampling period in the Louisianian Province coincides with the occurrence of hurricane season in the Gulf of Mexico. In small craft advisories and/or gale warnings, the Crew Chief will assess the situation and determine the feasibility of sampling. If sampling cannot be done, the team will contact the FOC as soon as possible. If a hurricane warning is posted for a scheduled sampling area, all sampling activities will cease and the crews will pack up and evacuate to a safe area.

The other likely reasons for cancellation of sampling are site inaccessibility and/or equipment malfunction. Site inaccessibility problems have been minimized by site reconnaissance activities conducted by Field Operations personnel during the 2 - 4 months before crew training. Any navigational hazards or other potential problems noted during the field reconnaissance were entered into the field log for reference by the Crew Chiefs. If the station location was unacceptable for sampling (e.g., too shallow, located in a busy navigational channel), the information was transmitted to the Province Manager, who made a decision regarding whether the station was discarded and whether an alternate site was selected.

Crew Chiefs will advise the Field Coordinator via phone prior to making any decisions which alter the sampling schedule. The Province Manager or the Field Coordinator will be available to respond to telephone communications at all times during the data collection phase of the project. During nonworking hours, either the Project Manager or his designee will be assigned a pager to receive incoming calls from the field crews.

Despite these precautions, unforeseen circumstances, such as Coast Guard restrictions due to an accident or other regulations that close an area to boat traffic, may cause field crews to cancel sampling at a specific location. If this should occur, the Crew Chief should contact the Field Coordinator immediately for instructions. The Province Manager will have determined, in advance, the types of sites that can be moved without adversely affecting the sampling design, as well as the protocol for choosing an alternative site. If the site is one that can be moved, the Operations Center will inform the Crew Chief of the location of the "new" site. If the site cannot be moved, the Province Manager will contact the Technical Director, who will decide on appropriate actions.

Most equipment malfunctions will be handled by Crew Chiefs, using repair facilities within the sampling area. Crew Chiefs will coordinate this activity with their Team Leader and the Field Coordinator. At least one spare for each piece of equipment will be located at ERL/GB. In the event that a piece of field equipment fails and requires extensive repair beyond what can be provided locally within one day, the Operations Center should be notified immediately. Arrangements will be made for the transport of the needed replacement equipment to the crew as quickly as possible to avoid interrupting the sampling schedule. The Project Manager or the Field Coordinator will assume responsibility for the rapid repair of damaged or malfunctioning equipment.

The Province Manager is responsible for the day-to-day operation of the project. He will be supported by a Field Coordinator and the staff of the Operation Center as shown in the province organization chart (Fig. 5-2). The Field Coordinator will be the major point of contact between field crews and other individuals within EMAP-NC.

The Province Manager will prepare weekly progress reports for the Technical Director that will include the following:

- A list of the sites successfully sampled;
- A list of sites not sampled, the reason why, and what plans have been made for obtaining these samples at a later time;
- Status of supplies and equipment;
- A general overview of the data collected; and a brief evaluation of the quality of the data which were collected.

When logistical problems threaten the integrity of the project, the Technical Director will convene a meeting of the Contingency Committee, who will advise the director on potential alternative sampling designs or strategies. He will be responsible for making decisions that alter the sampling design or the field/laboratory/QC procedures manuals. The committee will be composed of experts who are familiar

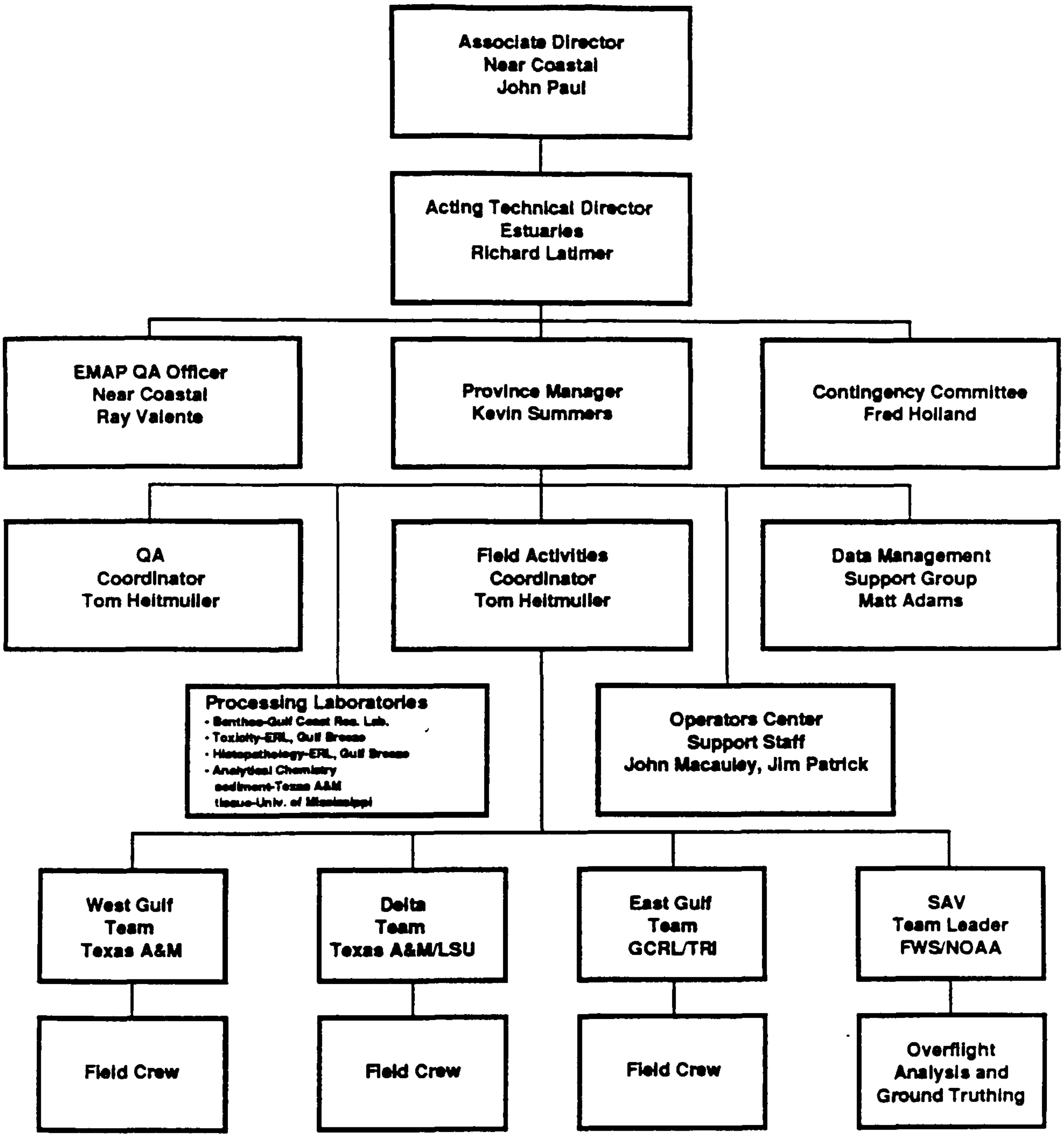

Figure 5-2. Management structure for the 1991 Louisianian Province Monitoring. Demonstration.

with the sampling design, analysis scheme, indicators, sampling methodologies, and logistics and will advise the Technical Director on topics related to their respective areas of expertise. Decisions of the Contingency Committee will be relayed to sampling crews by the Field Coordinator.

5.10 Crew Assignments

Sampling for each sub-region is presently scheduled to occur in blocks of sites randomly distributed during the index period. The identification of the sampling blocks was based on their proximity to common staging areas. The Eastern Region crew will follow a 6-day-on, 6-day-off cycle, with travel occurring on the 1st and 6th day of the off cycle. Crews should be able to sample at least 2 stations per day on the average.Areas with higher station density may facilitate daily sampling of 3 stations while travel distance may limit daily sampling to a single station. The West Region crews will operate on schedules of varying length and should sample a combined 4 stations per day on the average. A Hydrolab Datasonde III will be deployed overnight at each station to perform automated monitoring.

At present, all of the sampling sites and potential staging areas have been selected (Table 5-3). All staging areas currently under consideration are serviced by Federal Express with a minimum of next day service. Complete logistics plans for the implementation of EMAP-NC in the Louisianian Province have been completed for the East Region (Macauley, 1991) and for the Delta and West Regions (Phifer 1991).

5.11 Example Six-Day Sampling Scenario - (East Gulf)

Day 1

A sampling crew sets up staging out of Tarpon Springs, FL. The Field Coordinator at the Operations Center is notified that sampling activities are about to begin and any communications relevant to the Center or the crew are exchanged. The boat crew receives a check sheet and two, initialized, quality-checked, and calibrated, Datasonde III continuous recorders with their associated deployment systems for stations LA91

Table 5-3. Station locations with associated staging areas for the 1991 Louisianian Province Monitoring Demonstration.

East Gulf Region

Number Stations	Location	Staging Area
2	Anclote Anchorage	Tarpon Springs, FL
2	Homasassa River	Crystal River, FL
2	Crystal Bay	Crystal River, FL
2	Withalacoochie River	Crystal River, FL
2	Suwanee River	Suwanee River, FL/Hwy13
2	Ecofina River	St. Marks, FL
3	Apalachee River	St. Marks, FL
2	Oyster Bay	St. Marks, FL
2	Ochlocknee River	St. Marks, FL
1	Apalachicola Bay	Apalachicola, FL
2	St. Josephs Bay	Port St. Joe, FL
1	Watson Bayou	Panama City, FL
1	St. Andrews Bay	Panama City, FL
2	Choctawhatchee Bay	Ft. Walton Bch., FL
1	Escambia Bay	Gulf Breeze, FL
2	Bayou Grande	Gulf Breeze, FL
2	Big Lagoon	Gulf Breeze, FL
1	Perdido Bay	Gulf Breeze, FL
2	Old River	Gulf Breeze, FL
2	Bay La Launch	Gulf Shores, AL
2	Bon Secour River	Gulf Shores, AL
1	Bon Secour Bay	Gulf Shores, AL
3	Lower Mobile Bay	Gulf Shores, AL
2	Pelican Bay	Gulf Shores, AL
2	Tensaw River	Mobile, AL
8	Mobile Bay	Mobile, AL
4	Lower Mobile Bay	Dauphin Island, AL
1	Mississippi Sound	Dauphin Island, AL
2	Grand Bay	Pascagoula, MS
2	Mississippi Sound	Pascagoula, MS
2	Pascagoula River	Pascagoula, MS
1	Bayou Cassotte	Pascagoula, MS
2	Biloxi Bay/ Bernard Bayou	Biloxi, MS
4	Mississippi Sound	Biloxi, MS
2	Bay St. Louis	Gulfport, MS
3	Mississippi Sound	Gulfport, MS
3	North Chandeleur Sound	Gulfport, MS

Delta Region

Number Stations	Location	Staging Area
5	Lake Ponchartrain	New Orleans, LA
1	Lake Maurepas	New Orleans, LA
2	Amite River	New Orleans, LA

Table 5-3. (continued)

Delta Region

Number Stations	Location	Staging Area
1	Lake Salvador	New Orleans, LA
3	Lake Borgne	Slidell, LA
2	Lake St. Catherine	Slidell, LA
2	East Lake Ponchartrain	Slidell, LA
3	Upper Mississippi River	New Orleans, LA
2	Miss. River Gulf Outlet	Chalmette, LA
5	Chandeleur Sound	Chalmette, LA
8	Mid Mississippi River	Buras/Empire, LA
3	Breton Sound	Venice, LA
8	Lower Miss. River	Venice, LA
2	Garden Isle Bay	Venice, LA
2	Little Lake	Grande Isle, LA
2	Barataria Bay	Grande Isle, LA
2	Lake Raccourci	Houma, LA
1	Terrebone Bay	Houma, LA
2	Lake Pelto	Houma, LA

West Gulf Region

Number Stations	Location	Staging Area
2	Belle River	Houma, LA
2	Lake Palourde	Houma, LA
1	Caillou Bay	Morgan City, LA
1	Atchafalaya Bay	Morgan City, LA
2	East Cote Blanche Bay	Franklin, LA
1	Vermillion Bay	Abbeville/ New Iberia, LA
1	Weeks Bay	Abbeville/ New Iberia, LA
2	Grande Lake	Lake Arthur, LA
1	Calcasieu Channel	Lake Charles, LA
2	Calcasieu River	Lake Charles, LA
2	East Bay	High Island, TX
2	Star Lake	High Island, TX
2	Highland Bayou	Galveston, TX
2	Galveston Bay	Galveston, TX
2	Cedar Bayou	Galveston, TX
1	Galveston Ship Channel	Galveston, TX
2	Cedar Lake	Galveston, TX
2	San Juacinto Bay	Galveston, TX
2	Moses Vay/Dollar Lake	Galveston, TX
1	Brazos River	Freeport, TX
2	Bastrop Bay	Freeport, TX
2	Matagorda Bay	Port Lavaca/ Port O'Conner, TX
2	Carancahua Bay	Port Lavaca/ Port O/Conner, TX

Table 5-3. (continued)

West Gulf Region

Number Stations	Location	Staging Area
2	Lavaca River	Port Lavaca/ Port O/Conner, TX
1	Lavaca Bay	Port Lavaca/ Port O/Conner, TX
2	Powderhorn Lake	Port Lavaca/ Port O/Conner, TX
2	San Antonio Bay	Port Lavaca/ Port O/Conner, TX
2	Hynes Bay	Port Lavaca/ Port O/Conner, TX
2	Campano Bay	Fulton/Rockport, TX
2	Tule Lake Channel	Corpus Christi, TX
1	Corpus Christi Bay	Corpus Christi, TX
3	Laguna Madre (S. Baffin Bay)	Loyola Bch./ Kingsville, TX
3	Laguna Madre	Port Mansfield, TX
2	South Bay	Brownsville, TX
2	Rio Grande	Brownsville, TX

S4 and LA91-S4I (Homasassa River) from the shore-based crew prior to launch. The boat is launched at the Homasassa River at about 0630. The boat crew travels to station LA91-S4 (located by LORAN), deploys a continuous meter, and takes a manual bottom profile of temperature, salinity, depth, pH, and dissolved oxygen using the Surveyor II (afterward, this procedure will simply be referred to as deployment). After securing the meter, the boat crew travels to LA91-S4I and deploys an other continuous meter at that location. At the same time, the shore-based crew is organizing all sample containers, sampling gear, and performing shore-based functions for the continuous meters for Stations LA91-S1 and LA91-S1I (Anclote Anchorage). The boat crew returns to the Homasassa River launch point, trailer the boat, and the boat crew and shore crew proceed to the Anclote River (approximately one hour travel time).

The boat is launched at the Anclote River after being loaded with all the appropriate sampling gear, pre-labeled sample containers, processing gear, and two continuous monitors prepared in the morning by the shore crew. The boat crew has received a check sheet and appropriate quantities of ice and dry ice prior to launch. (A six-day supply of dry ice has been brought with the crew from the base of operations.) The boat crew travels to station LA91-S1 and deploys a continuous meter. They then anchor and perform the water column profiles followed by sediment sampling. Once the three replicate benthic samples have been collected and stored in the appropriate pre-labeled containers, additional sediment grabs are taken to secure enough sediment for toxicology and contaminant analysis. These samples are placed in the appropriate pre-labeled containers. The crew sets up and performs the fish trawl and properly counts, identifies, measures, and examines all specified fish for gross pathologies. Target fish are selected for contaminant analysis and prepared as required and placed in sample containers. All fish failing the gross pathology screen are prepared (i.e., opening the body cavity) and placed in Dietrich's solution. The bivalve dredge sample is taken and all samples are counted, identified, measured, and selected individuals are retained for preparation and storage in prelabelled containers. The crew proceeds to station LA91-S1I and deploys a continuous meter before 6 PM. The same sequence of sampling events is performed. Once the samples are collected, they are stowed and the boat returns to the staging area. The boat is moored at the Anclote River. All samples and data sheets are transferred to the shore crew for storage and processing.

Earlier in the day, as the boat crews worked on the Homasassa River, the shore crew prepared all pre-labeled sample containers and data sheets for the next day's sampling sites (LA91-S4 and LA91-S4I). The boat and shore crews leave the Anclote River and travel to lodging in Tarpon Springs, FL. The Team Leader/Crew Chief notifies the Field Coordinator that sampling has ceased for Day 1 and conveys any necessary information.

Day 2

The sampling vessel and gear are prepared for the morning's activities. The crew chief notifies the Field Coordinator that sampling operations are about to commence. If there is sufficient time, the shore crew, who will be in radio contact with the boat, will begin processing the samples from the previous day and perform the data entry into the PC. Processing the samples involves preparing them for shipment to the analytical and processing labs as well as the shipping reports and airbills. Samples which require overnight delivery will be taken to the express delivery office and shipped. The remaining samples will be properly stored until there is sufficient quantity to warrant shipping or until the end of the 6-day rotation.

The boat is launched at the Anclote River after being loaded with all the appropriate sampling gear, pre-labeled sample containers, and processing gear prepared by the shore crew the previous day. The boat crew has received a check sheet and appropriate quantities of ice and dry ice prior to launch. The boat crew travels to station LA91-S1. They then anchor, retrieve the continuous monitor and its deployment hardware, and take a bottom profile of temperature, salinity, dissolved oxygen, pH, and depth (afterward referred to as retrieval). They then perform the standard field activities described in Day 1. All samples are stored in pre-labeled containers as directed by the Field Operations Manual. The crew proceeds to station LA91-S1I and retrieves the continuous meter. The same sequence of sampling events is performed. Once the samples are collected, they are stowed and the boat returns to the staging area on the Anclote River. All samples and data sheets are transferred to the shore crew for storage and processing. The boat is trailered to the Homasassa River.

The boat is launched from the Homasassa River and the boat crew proceeds to LA91-S4, retrieves the continuous monitor. The boat proceeds to LA91-S4I and retrieves the continuous monitor located there. The boat returns to the Homasassa River launch point, trailers the boat, and transfers the Homasassa continuous monitors to the shore crew.

Earlier in the day, as the boat crews worked in the Anclote Anchorage, the shore crew began preparation of samples for shipment and data entry. After the launch of the boat crew in the Homasassa River, the shore crew completes the processing of the previous day's samples and data, debriefs the 2 continuous monitors from the Anclote Anchorage, and prepares all pre-labeled sample containers and data sheets for the next day's sampling sites (LA91-S8 and LA91-S8I, Withlacoochie River). Finally, the shore crew prepares four continuous monitors for deployment at the next day's sampling stations. The boat and shore crews leave the Homasassa River and travel to lodging in Crystal River, FL. The Team Leader/Crew Chief notifies the Field Coordinator that sampling has ceased for Day 2 and conveys any necessary information. All data are transferred to the Louisianian Province Information Management System (LPIMS).

Day 3

The sampling crew sets up staging out of Crystal River, FL. The Field Coordinator at the Operations Center is notified that sampling activities are about to begin and any communications relevant to the Center or the crew are exchanged. The boat and shore crew proceed out of Crystal River, north to the Withlacoochie River. The sampling vessel and gear are prepared and the boat crew receives a check sheet and two initialized, quality-checked, and two calibrated Datasonde III continuous recorders with their associated deployment systems for stations LA91-S8 and LA91-S8I (Withlacoochie River) from the shore-based crew prior to launch. The boat is launched at the Withlacoochie River. The boat crew travels to station LA91-S8 (located by LORAN) and deploys a continuous meter. After securing the meter, the boat crew travels to LA91-S8I and deploys the continuous meter at that location. At the same time, the shore-based crew is organizing all sample containers, sampling gear, and performing shore-based functions for the continuous meters for Stations LA91-S5 and LA91-S5I (Crystal Bay). The boat crew returns to the

Withlacoochie River launch point, trailers the boat, and the boat crew and shore crew proceed to the Crystal River (approximately one hour travel time).

The boat is launched at the Crystal River after being loaded with all the appropriate sampling gear, prelabelled sample containers, processing gear, and two continuous monitors prepared in the morning by the shore crew. The boat crew has received a check sheet and appropriate quantities of ice and dry ice. The boat crew travels to station LA91-S5 and deploys a continuous meter. They then anchor and perform all sampling activities. All samples are stored in pre-labeled containers as directed by the Field Operations Manual.The crew proceeds to station LA91-S5I and deploys a continuous meter before 6 PM. The same sequence of sampling events is performed. Once the samples are collected, they are stowed and the boat returns to the staging area. The boat is moored at the Crystal River. All samples and data sheets are transferred to the shore crew for storage and processing.

Earlier in the day, as the boat crews worked on the Withlacoochie River, the shore crew prepared all pre-labeled sample containers and data sheets for the next day's sampling site and debriefed the Homasassa continuous meters. While the boat crew is sampling Crystal Bay, the shore crew is preparing the previous day's samples for shipment and data entry. The boat and shore crews travel to lodging in Crystal River, FL. The Team Leader/Crew Chief notifies the Field Coordinator that sampling has ceased for Day 3 and conveys any necessary information. All data are transferred to LPIMS.

Day 4

The sampling vessel and gear are prepared for the morning's activities. The crew chief notifies the Field Coordinator that sampling operations are about to commence. The shore crew begins processing the samples from the previous day and perform the data entry into the PC.

The boat is launched at the Crystal River after being loaded with all the appropriate sampling gear, pre-labeled sample containers, and processing gear prepared by the shore crew the previous day. The boat crew has received a check sheet and appropriate quantities of ice and dry ice prior to launch. The boat crew travels to station LA91-S5. They then anchor, retrieve the continuous monitor. They then perform the standard field activities. All samples are stored in pre-labeled containers as directed by the Field Operations Manual. The crew proceeds to station LA91-S5I and retrieves the continuous meter. The same sequence of sampling events is performed. Once the samples are collected, they are stowed and the boat returns to the staging area on the Crystal River. All samples and data sheets are transferred to the shore crew for storage and processing. The boat is trailered to the Withlacoochie River.

The boat is launched from the Withlacoochie River and the boat crew proceeds to LA91-S8, retrieves the continuous monitor. The boat proceeds to LA91-S8I and retrieves the continuous monitor located there. The boat returns to the Homasassa River launch point, trailers the boat, and transfers the Homasassa continuous monitors to the shore crew. The crews travel to lodging in Crystal River, FL. The Team Leader/Crew Chief notifies the Field Coordinator that sampling has ceased for Day 4 and conveys any necessary information. All data are transferred to LPIMS.

Day 5

The Field Coordinator at the Operations Center is notified that sampling activities are about to begin and any communications relevant to the Center or the crew are exchanged. The boat and shore crew proceed out of Crystal River, north to the Suwanee River (about 2.5 hours). The sampling vessel and gear are prepared and the boat crew receives a check sheet and two initialized, quality-checked, and calibrated Datasonde III continuous recorders with their associated deployment systems for stations LA91-S10 and LA91-S10I (Suwanee River) from the shore-based crew prior to launch. The boat is launched at the Suwanee River. The boat crew travels to station LA91-S10 (located by LORAN), deploys a continuous meter. After securing the meter, the boat crew travels to LA91-S10I and deploys the continuous meter at that location. They then anchor and perform all sampling activities. All samples are stored in pre-labeled containers as directed by the Field Operations Manual. Once the samples are collected, they are stowed and the boat returns to the staging area. The boat is moored at the Suwanee River. All samples and data sheets are transferred to the shore crew for storage and processing.

Earlier in the day, the shore crew prepared all pre-labeled sample containers and data sheets for the next day's sampling site, debriefed the Crystal Bay continuous meters, and prepared the previous day's samples for shipment and data entry. The boat and shore crews travel to lodging in Suwanee River/ Highway 13, FL. The Team Leader/Crew Chief notifies the Field Coordinator that sampling has ceased for Day 5 and conveys any necessary information. All data are transferred to LPIMS.

Day 6

The sampling vessel and gear are prepared for the morning's activities. The Crew Chief notifies the Field Coordinator that sampling operations are about to commence. The shore crew begins processing the samples from the previous day and perform the data entry into the PC.

The boat is launched at the Suwanee River after being loaded with all the appropriate sampling gear, pre-labeled sample containers, and processing gear prepared by the shore crew the previous day. The boat crew has received a check sheet and appropriate quantities of ice and dry ice prior to launch. The boat crew travels to station LA91-S10 where they anchor, retrieve the continuous monitor, and then perform the standard field activities. All samples are stored in pre-labeled containers as directed by the Field Operations Manual. The crew proceeds to station LA91-S10I and retrieves the continuous meter. The boat returns to the staging area on the Suwanee River. All samples and data sheets are transferred to the shore crew for storage and processing. The Team Leader/Crew Chief notifies the Field Coordinator that sampling has ceased for Day 6 and conveys any necessary information. The crew prepares the boat and vehicles for the return trip to the FOC at Gulf Breeze, FL.

Post-Sampling

This crew will meet its follow-up crew at the FOC in Gulf Breeze, FL on the evening of Day 6. All vehicles and equipment, as well as the samples collected on Day 6, will be transferred to the oncoming crew to be sampling and sample processing the following day.

This scenario does not include sampling other types of stations than base and index. Some stations may take longer to sample than others depending on the station type. On days when research indicator samples are to be taken, an additional technician will be provided to take the samples.

6.0 INFORMATION MANAGEMENT

During the course of sample collection in the Louisianian Province, thousands of samples will be collected from the 198 stations. Many of the indicators (e.g., dissolved oxygen, contaminants in sediments or tissue) will produce hundreds of data points for each station. The ability of the Louisianian Province Information Management Team (Fig. 6-1) to manage, collate, quality-check, and transfer this large amount of data to the Near Coastal Information Management Center will have a significant influence on the success of the program. Major portions of the Near Coastal Information Management System have been developed and are described elsewhere (Near Coastal Team 1990, Rosen et al., 1990). To the extent possible, the Louisianian Province Information Management System (LPIMS) will utilize data management tools and protocols developed and tested by the Near Coastal Information Management Center at Narragansett, RI. In outline, the strategy for information management within the Louisianian Province is straightforward – data are collected in the field or samples are processed in laboratories; transmitted to LPIMS at Gulf Breeze, FL; screened, quality-assured and composed into data sets by LPIMS; and transmitted to the Near Coastal Information Management Center while retaining copies of the data for subsequent analysis. In practice, data management schemes rarely are straightforward and multiple contingencies will be "built" into the system to address potential sources of error and miscommunication.

Monitoring activities in the Louisianian Province will include a range of functions (e.g., sample collection, laboratory processing, statistical analysis) over a period of 9-10 months. In order to manage the flow of information in the Province effectively, the Province Manager must have the ability to identify problems, develop alternative plans, control costs, and modify schedules. The key to successfully attaining this ability is to review the flow of information in as close to a real-time mode as possible. The generation of computerized and/or hand-generated daily and weekly reports on the status of each element in the monitoring program will provide the information necessary to oversee and control the combined efforts of numerous field and laboratory personnel and to trace effectively the progress of sample collection, shipping and processing.

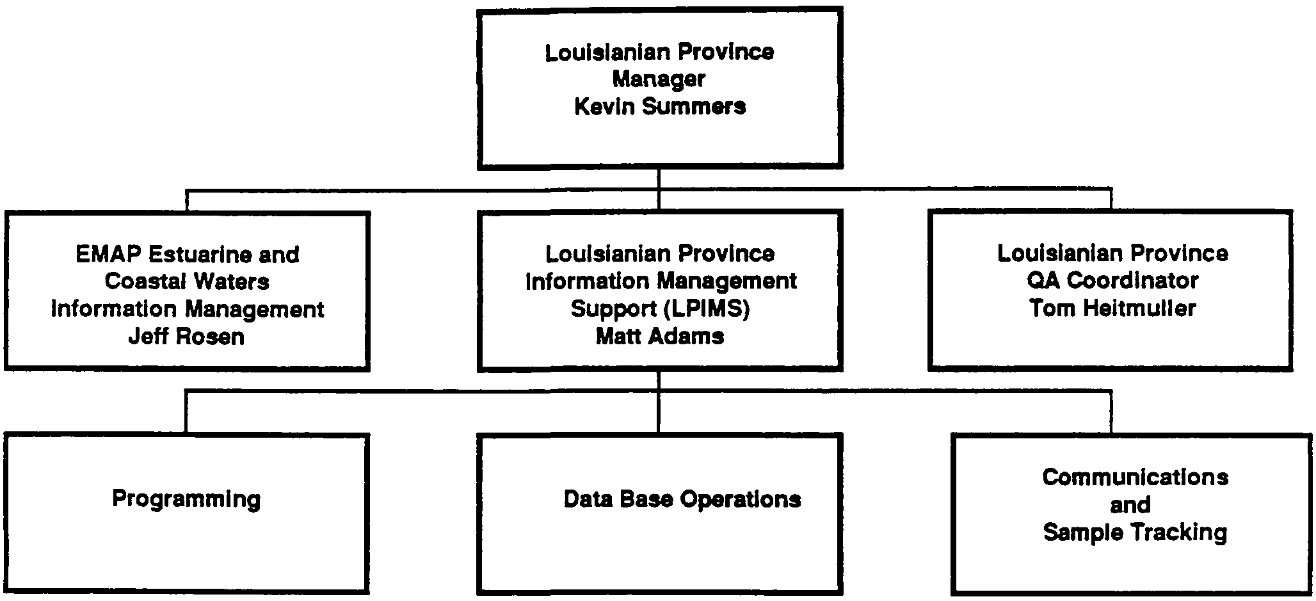

Figure 6-1. 1991 Louisianian Province Iformational Management Team.

The remainder of this chapter is organized into three sections that parallel the general types of information management activities to be completed by LPIMS: (1) Communications and Sample Tracking, (2) Data Management and Storage, and (3) Data Transmittal.

6.1 Communications and Sample Tracking

The Louisianian Province Manager will require frequent and accurate information concerning the status of field operations, laboratory processing activities, sample shipping, and "in-field" data transmittal. The Louisianian Province Information Management Team will use, and modify if necessary, a Project Management Information System developed for the 1990 Virginian Province Demonstration to conduct all activities with the exception of the field communications and "in field" data transmittal. An electronic bulletin board and field communications package will be developed by LPIMS for use in the Louisianian Province in 1991. "In field" transmittal will be facilitated by software developed by the LPIMS to simplify data entry in the field and its subsequent electronic transmittal to the Gulf Breeze facility. The elements of the Project Management Information System, the communications package, the data entry and "in field" transmittal packages and the sample tracking system are discussed below.

6.1.1. Communications

Daily communications with the field crews and laboratory processing centers will be facilitated by an electronic bulletin board that will store messages from, and to, the field crews and laboratory processing facilities. Field crews (land-based component) will access the bulletin board twice daily (early morning and late evening) to retrieve and send messages of general and specific use. In addition, field crews will communicate with operation center personnel by telephone on a daily basis. The bulletin board will be used to provide back-up information concerning the day's sampling locations; including, latitude and longitude, sample identification numbers, and expected field collection activities. The bulletin board will provide a system for recording logistical events and problems as well as observations made by the field crews concerning ramp facilities, shipping agents, and operational facilities (e.g., motels, ice houses) for future refinement of logistics in subsequent years. In addition, the bulletin board will provide access to a database of information concerning ramp locations, motels, restaurants, hospitals, emergency personnel and telephone numbers, boat repair facilities, and shipping agents.

6.1.2. "In Field" Data Entry and Transfer

LPIMS has facilitated the "in field" entry of data into computer-compatible form by devising on-screen forms identical to the hand-written field data sheets. These "forms" will be used by the land-based support team for entry of the previous day's data. Thus, the field crews will be submitting data to LPIMS in established formats within 24 hours of collection. These data include:

- o Instantaneous water quality data
- o 24-hour continuous dissolved oxygen data
- o Logistical and operational data (e.g., coordinates, weather conditions)
- o Fish trawl data (i.e., abundance, composition, lengths, gross pathology)
- o Benthic dredge data (i.e., abundance, composition)
- o Shipping data for sediments (i.e., analytical chemistry, sediment toxicity, and benthos), tissues (i.e., analytical chemistry), blood (i.e., bioindicators), and fish (i.e., pathology).

Once data have been entered at the land-based site, the information files will be transferred electronically to the VAX located at Gulf Breeze, FL via a toll-free number. Transferred data will be extracted daily by LPIMS personnel, then data clean-up and quality checking will commence.

6.1.3. Sample Tracking System

The sample tracking system will track the history of samples from their initial collection, through sample shipping, and to final completion of all laboratory analyses and/or processing. To accomplish this, each sampling event and sample type will be assigned a unique identification number. These numbers will be entered into the LPIMS system prior to sample collection. Sample numbers will be bar-coded to facilitate data entry by the field crews.

Information entered for each sample in the sample tracking system that will be available for retrieval and review will include:

- o Sampling site name
- o Time of sample collection and duration, if applicable
- o Type of sample
- o Identification of sampling team responsible for collection
- o List of projected activities for that sample (e.g., shipment, sieving, sorting, data processing, analyses for any of fifty analytes) and the status of each of these activities (e.g., completed, received broken, etc.)
- o Names of "raw" data files for continuous data (i.e., continuous dissolved oxygen records)
- o Names of textual files containing descriptive information about the sampling event (e.g., field team comments).

When the samples are transferred from the field crews to analytical laboratories, a record of the exchange will be entered into the sample tracking system, both upon release to the shipper and receipt by the laboratory, as to time of exchange and sample condition. The identity and disposition of any sample can be established, through the sample tracking system, by checking the sample status. The status of all samples and results will be available through the sample tracking system.

6.2 Data Management and Storage

Data management of concern to the 1991 monitoring activities in the Louisianian Province involves the management of regional information for subsequent transfer to the Near Coastal Information Management System (NCIMS) early in 1992. The LPIMS will work with and cooperate with NCIMS personnel to facilitate the subsequent transfer of information. This activity will include prior confirmation of data formats and a determination of compatibility with the overall Near Coastal data base system. As it is the responsibility of the Near Coastal Program (i.e., NCIMS) to archive near coastal data and respond to data inquiries, LPIMS has not been constructed to address data requests outside the immediate user-group associated with province activities.

6.2.1 Data Storage

EMAP-NC uses a distributed data base system that consists of a central site and multiple regional remote nodes. LPIMS represents one of these remote nodes. In addition, LPIMS acts as a central site for several province-level remote nodes: (1) sub-regional coordination nodes (i.e., operational centers for field teams), (2) field teams (i.e., in situ data entry and communications), and (3) processing laboratories (e.g., benthic lab, analytical chemistry labs). Field and laboratory nodes will transfer data and preliminary analytical results to the LPIMS for subsequent data clean-up and processing. Communication messages and selected data outputs will be provided to the sub-regional operation centers by LPIMS. Specific data management activities that will occur at the LPIMS include:

- Incorporation of field data into database
- Initial calculation of parameter values
- Preliminary data screening and quality control
- Preliminary data analysis and summarization
- Quality assurance for sample tracking, sample preparation, and analytical techniques
- Transfer of appropriate data, in specified electronic formats, to NCIMS at the conclusion of the 1991 sampling program.

The central repository of all Near Coastal data generated within EMAP is the Near Coastal Information Processing Center (NCIMS) located at Narragansett, RI. Personnel at this facility are responsible for the long-term storage of near coastal data which includes maintaining a comprehensive data inventory, a data set index, code libraries, and a data dictionary. The remote facility, the Louisianian Province Information Management System (LPIMS), is located at Gulf Breeze, FL and is responsible for the collection, collation, quality assurance, and transfer of all near coastal data collected in the Louisianian Province.

At a minimum, LPIMS will collect, organize, quality assure, and subsequently transfer to NCIMS the following information for all base, index, and supplemental monitoring stations:

- Complete logistical records of each sampling event
- Complete data for vertical profiles for instantaneous salinity, temperature, water depth, dissolved oxygen concentration, pH, and photosynthetically active radiation (PAR)
- Complete data for 24-hour continuous measurements of bottom salinity, temperature, water depth, pH, and dissolved oxygen
- Complete data on concentrations of selected contaminants, organic content, and grain size of sediments
- Complete data on the abundance, composition, and biomass of benthic organisms
- Complete data on the abundance, composition, and length of large bivalves
- Complete data on the abundance and size of fish and shellfish species taken by otter trawl (i.e., only base, spatial supplemental, and index stations with water depths > 1 m), concentrations of selected contaminants in fish and shellfish flesh of targeted species, and gross pathological disorders for targeted fish species
- Complete data for standard toxicity test results using two benthic species exposed to sediment samples collected from the base stations.

In addition, LPIMS will augment this information with data collected from Indicator Test and Evaluation (ITE) sites as follows:

- Detailed histopathology information for target fish species observed to have gross external pathological abnormalities

- o Detailed histopathology for non-target fish species observed to have no external abnormalities
- o Complete data for standard toxicity test results using shrimp exposed to sediment samples collected from the ITE stations
- o Complete data for selected physiological bioindicators for target fish and shellfish species and black crown night heron nestlings at selected ITE sites
- o Complete data on concentrations and uptake rates of selected contaminants in black-crown night heron nestlings from selected ITE sites

All data received by LPIMS will be quality assured by using procedures described in Chapter 7.0 and converted into SAS data sets. All data will be stored in SAS data libraries by indicator and topical area (e.g., benthic species composition and biomass, estuarine class, contaminants in nestling flesh). Following initial data processing, required data analyses will be completed to produce summary data reports.

6.3 Data Transmittal

Upon completion of data library and data set construction, as well as quality assurance on those data, LPIMS will transmit all data collected during the 1991 Louisianian Province Monitoring Demonstration and its subsequent processing by laboratories to the central Near Coastal data repository located in Narragansett, RI. This transfer will be completed using predetermined electronic formats compatible with the existing formats developed for the 1990 Virginian Province Demonstration. We anticipate these transfers will take place in early 1992.

All data requests for near coastal information from outside the province-specific synthesis and integration team, regardless of province, will be handled by the NCIMS (e.g., requests from non-EMAP personnel, requests from EMAP administrative personnel). The protocols for these requests are described in Rosen et al. (1990).

7.0 QUALITY ASSURANCE

The 1991 Louisianian Province Monitoring Demonstration will use 30 to 40 staff members to collect samples and four different laboratories to process samples. Monitoring programs that involve multiple field crews and laboratories frequently encounter problems in obtaining data that are comparable among the many individuals and laboratories involved (Taylor 1978, 1985; Martin Marietta Environmental Systems 1987; NRC 1990a). Such problems usually result because in the haste to initiate the data collection program, the field crews are not adequately trained in applying standardized collection methods and the comparability of the laboratory processing methods and capabilities are not evaluated (Taylor 1985).

The Louisianian Province will implement a quality assurance (QA) program (Heitmuller and Valente 1991) to ensure that the data produced are comparable, known and acceptable quality. This program will consist of two distinct but related sets of activities: quality control and quality assessment.

Quality control includes design, planning, and management actions to ensure that the types and amounts of data are collected in the manner required to address study objectives. Examples of some quality control activities that will be employed by the Louisianian Province are the employment of EMAP-NC standardized sample collection and processing protocols and the requirement for specific levels of training for field crews and technicians who will collect and process samples. The goals of quality control procedures are to ensure that collection, processing, and analysis techniques are accomplished consistently and correctly; the number of lost, damaged, and uncollected samples is minimized; the integrity of the data record is maintained and documented from sample collection to entry into the data record; data are comparable with similar data collected elsewhere and that study results are reproducable.

Quality assessment activities will be implemented to quantify the effectiveness of the quality control procedures. These activities ensure that measurement error and bias are identified, quantified, and accounted for or eliminated (if practical). Quality assessment consists of both internal and external checks including repetitive measurements, internal test samples, interchange of technicians and equipment, use of independent methods to verify findings, exchange of samples among laboratories, use of standard reference materials, and audits (Taylor 1985; USEPA 1984).

7.1 Data Quality Objectives

While quality assurance (QA) is a necessary part of any sampling program, defining the proper level of QA is difficult. If QA is defined too rigorously, it can consume a disproportionate share of program resources; if QA is defined too loosely, the ability to quantify the quality of the data collected may be insufficient to meet program objectives. Within EMAP, the balance between cost and uncertainty will be established by using the Data Quality Objective (DQO) process (Fig. 7-1).

Developing DQOs is a multistage, iterative process that involves individuals at all levels of the project (Fig. 7-1). The first stage is initiated by the manager or decision maker, who identifies the central question to be addressed and the degree of acceptable uncertainty associated with the answer. In identifying acceptable uncertainty, the manager must weigh the cost of collecting samples against the "cost" of reaching incorrect decisions based on the sampling effort. The second stage is conducted by the project scientific staff, who formulate a sampling strategy for addressing the question and then estimate the cost of developing an answer with the satisfactory level of accuracy, precision, representativeness, comparability, and completeness. If the cost estimates are acceptable to the decision maker, then the project proceeds to the third stage, where the technical staff develops quality control and quality assessment procedures for each aspect of the program (e.g., field collection, laboratory analysis and processing, data management analysis) that are consistent with the defined level of quality. If cost estimates are too high, then the scientific staff and the decision makers jointly modify the design and expectations of the proposed program until an acceptable balance of cost and uncertainty is achieved.

Two sources of error are considered in establishing DQOs: sampling error and measurement error. Sampling error is the difference between a sampled value and the true value and is a function of natural spatial and temporal variability and sampling design. The temporal variability relevant to EMAP-NC is that

STAGE	1		2		3
Purpose	Develop Major Questions	Refine Questions	Establish Design Constraints	Refine Questions	Design Program to Meet Constraints
Personnel With Lead Role	Data User (decision maker)		Project Management Staff		Technical Staff

Figure 7-1. The three stages of developing Data Quality objectives.

which occurs within the index period. Measurement error is the difference between the true sample values and the reported values, and can occur during the act of sampling, data entry, data base manipulation, etc. While "good" data are available to estimate measurement error for all of the parameters that will be measured by EMAP-NC, data for estimating sampling error are either unavailable or unaccessible for many, if not most, of the indicators to be measured. Acceptable estimates of variability at the appropriate regional scale are unavailable because EMAP is the first program to measure most of these parameters on a regional scale, using standardized methods and a probability-based sampling design.

Reliable estimates of temporal and spatial variability are essential to the DQO process because they are required for quantifying the degree of uncertainty that will be produced by the sampling design. Without them, the scientific staff cannot provide the decision makers with an estimate of cost for a desired level of uncertainty (Fig. 7-1). For this reason, DQOs will not be implemented in the 1991 Demonstration Project. Rather, a major goal of the Demonstration Project will be to gather the necessary data to establish DQOs as the program continues in subsequent years. The Demonstration Project will be implemented by using Measurement Quality Objectives (MQOs). MQOs establish acceptable levels of uncertainty for each measurement process but differ from DQOs in that they are not combined with sampling error to estimate programmatic uncertainty. In subsequent years, DQOs will be developed to replace the MQOs. MQOs were established by obtaining estimates of achievable data quality based on manufacturer specifications, the judgment of knowledgeable experts, and available literature information. Each measured parameter will have an associated MQO for each of the attributes of data quality: representativeness, comparability, completeness, accuracy, and precision. Data quality attributes are defined below, along with the MQO established for each measured parameter within EMAP-NC.

- o Representativeness is the degree to which the data represent a characteristic of a population parameter. In EMAP-NC, representativeness is most germane to the proper siting of a sampling location, and the MQO will be to ensure that all samples, with the exception of fish trawling, are within 100 meters of the planned sampling site. Fish trawling should occur within 500 meters of the designated sampling site.

- o Completeness is a measure of the amount of valid data (i.e., data not associated with some criterion of potential unacceptability) collected from a measurement process compared to the amount that was expected to be obtained. The MQO completeness criteria for EMAP-NC will range from 75 to 90 percent, depending on the measurement process. The specific completeness criterion for each measured variable is presented in Table 7-1.

- o Comparability is defined as "the confidence with which one data set can be compared to another" (Stanley and Verner 1985). Comparability of reporting units and calculations, data base management processes, and interpretative procedures must be ensured if the overall goals of EMAP are to be realized. The MQO for the 1991 Louisianian Province Demonstration Project is to apply accepted methods in a standardized way and to generate a high level of documentation so that future EMAP efforts will be comparable to baseline collections.

- o Accuracy is defined as the difference between a measured value and the true or expected value and represents an estimate of systematic error or net bias (Kirchner 1983; Hunt and Wilson 1986; Taylor 1985).

- o Precision is defined as the degree of mutual agreement among individual measurements and represents an estimate of random error (Kirchner 1983; Hunt and Wilson 1986; Taylor 1987).

Together, accuracy and precision provide an estimate of the total error or uncertainty associated with measured value. Accuracy and precision goals for the indicators to be measured are provided in Table 7-1. Accuracy and precision cannot be defined for all parameters because of the nature of the measurement type. For example, accuracy measurements are not possible for toxicity testing, sample collection activities, and fish pathology measurements. In addition, accuracy and precision goals are not established for stressor indicators. Control of the data quality attributes of stressor indicators is beyond the scope of EMAP-NC.

Table 7-1. **Measurement Quality Objectives for EMAP-NC indicators and associated data as they will be implemented in the Louisianian Province**

Indicator/Data Type	Accuracy Goal	Precision Goal	Completeness Goal
Sediment Contaminant Concentration			
Organics	30%	30%	90%
Inorganics	15%	15%	90%
Sediment Toxicity	NA	NA	NA
Benthic Species Composition and Biomass			
Sample collection	NA	NA	90%
Sorting	10%	NA	90%
Counting	10%	NA	90%
Taxonomic identifications	10%	NA	90%
Biomass	NA	10%	90%
Sediment Characteristics			
Grain size	10%	10% (most abundant size class)	90%
Total organic carbon	10%	10%	90%
% water	NA	20%	90%
Acid volatile sulfides	10%	10%	90%
Apparent RPD	± 5 mm	NA	90%
Water Column Characterization			
Dissolved Oxygen Concentration	± 0.5 mg/l	NA	90%
Salinity	± 1 ppt	NA	90%
Temperature	± 1 °C	NA	90%
Depth	0.5 m	NA	90%
pH	± 0.2 pH units	NA	90%
Contaminants in Fish and Bivalve, Tissue			
Organics	30%	30%	90%
Inorganics	15%	15%	90%
Gross Pathology of Fish	NA	NA	90%

Table 7-1. Continued.

Indicator/Data Type	Accuracy Goal	Precision Goal	Completeness Goal
Fish Community Compositoin			
Sample collection	NA	NA	75%
Counting	10%	NA	90%
Taxonomic identifications	10%	NA	90%
Length determinations	± 5 mm	NA	90%
Relative Abundance of Large Burrowing Bivalves			
Sample collection	NA	NA	75%
Counting	10%	NA	90%
Taxonomic identifications	10%	NA	90%
Histopathology of Fish	NA	NA	NA

7.2 Quality Control

Establishing MQOs is of little value if the proper quality control activities are not undertaken to ensure that program objectives are met. Quality control in EMAP-NC will be achieved in three ways:

- o Developing standardized sampling protocols for all sampling activities that are consistent with MQOs and the associated data quality attributes

- o Documenting those procedures in a manner that allows for easy reference and evaluation by all personnel involved in the project

- o Training personnel responsible for each protocol to ensure that they are qualified to conduct assigned tasks using the specified method.

Most of the indicators that will be measured during the Demonstration Project are those for which standardized protocols, with known and acceptable levels of error, already exist. The first year (or more) of the program will be used to develop, refine, and standardize the measurement methods for indicators for which standard methods presently do not exist.

Although standard protocols are being used for many of the measurements that will be made, an essential aspect of the EMAP-NC QC program is written documentation of all sampling, laboratory, and quality assurance protocols. EMAP-NC has produced three documents to accomplish this objective:

- o Laboratory Operations Manual -- A document containing detailed instructions for laboratory and instrument operations, including all procedures designed to ensure quality control of the measurement process (US EPA, 1991).

- o <u>Field Operations Manual</u> – A document containing detailed instructions for all field activities (Macauley and Summers, 1991).

- o <u>Quality Assurance Project Plan</u> – A document that specifies the policies, organization, objectives, and functional activities for the project. The plan will also describe the quality assurance and quality control activities and measures that will be implemented to ensure that the data produced will meet the MQOs established for the project (Heitmuller and Valente, 1991).

Copies of these documents are available upon request.

A critical aspect of quality control is to ensure that the individuals involved in each activity are properly trained to conduct the activity. Laboratory personnel involved in the Demonstration Project do not require extensive training, since most of the samples will be processed by established laboratories, using the standard protocols presently employed on a production basis. The field sampling personnel, who are being assembled specifically for this project and who are being asked to conduct a wide variety of activities in the same consistent manner, will receive approximately one month of training.

Training of the sampling teams will be accomplished in two sessions, one for the Team Leaders/Crew Chiefs and one for the remaining crew members; both sessions will be based out of the U.S. EPA Environmental Research Laboratory, Gulf Breeze, FL (ERL/GB). Training of Crew Chiefs will begin in mid-May. Qualifications for the Crew Chiefs include experience in small boat handling and familiarity with the use of most of the required sampling equipment (trawls, dredges, sediment samplers, etc.). Training of Crew Chiefs will emphasize project objectives and design, sampling protocols, computer use, and navigation protocols required to locate sites. In addition, the Crew Chiefs will be instructed in public relations and policy issues relating to EMAP-NC.

Once the Crew Chiefs have completed training, they will help to train the remaining crew members in boat operations, navigation, use of sampling gear, and general sampling protocols. The first part of this crew training, to be held June 1-21, will be oriented toward classroom and laboratory work. The final week of training will involve "hands-on/in-field" application of sampling methods.

Training at ERL/GB will place the Louisianian Crews in direct contact with leading authorities in several of the specialized areas of particular interest to the EMAP-NC Program (e.g., EMAP-NC conceptual and design aspects - Dr. Kevin Summers, Louisianian Province Manager; fish pathology, Dr. Jack Fournie). Other staff members of ERL/GB and selected experts will instruct the crews in routine sampling procedures, boat and equipment operation, navigation, computer use, and sample preparation.

All EMAP equipment (e.g., boats, sampling gear, computers) will be used during the training sessions, and by the end of the course, all crews members must demonstrate proficiency in the following areas:

- o Towing and launching the boat
- o Boat operation
- o Making predeployment checks of all sampling equipment
- o Locating stations using the navigation system
- o Entering data into and retrieving data from the lap-top computers
- o Using all the sampling gear
- o Administering first aid, including CPR
- o Using general safety practices.

In addition, all field crew members must be able to swim and will be required to demonstrate that ability.

Some sampling activities (e.g., fish taxonomy, gross pathology, net repair, etc.) require specialized knowledge. All crew members will be exposed to these topics during the training sessions but it is beyond the scope of the training program to develop proficiency for each crew member in all of these areas. Thus, two members of each team (one per crew) will have been selected (prior to training) for their specific expertise in the identification of Gulf fish and shellfish.

All phases of field operations will be detailed in the Field Operations Manual for the Louisianian Province (Macauley et al. 1991a). Copies of this manual will be distributed to all trainees prior to the training period. The manual will include an equipment checklist, instructions on the use of all equipment, and procedures for sample collection. In addition, the manual will include a schedule of activities to be conducted at each sampling location. It will also contain a list of potential hazards associated with each sampling site.

7.3 Quality Assessment

The effectiveness of quality control efforts will be measured by quality assessment activities, including quality assessment samples and audits. The goal of these activities will be to quantify accuracy and precision, but most importantly, they will be used to identify problems that need to be corrected as data sets are generated and assembled. Details of the quality assessment activities that will be conducted during the 1991 Demonstration Project can be found in the Quality Assurance Project Plan (Heitmuller and Valente, 1991). A brief overview of these activities is provided below.

Quality assessment procedures will include using standards and check samples to verify instrument calibrations in the field, as well as collecting duplicate samples, field blanks, and performance evaluation samples. Quality assessment samples generally will be blind or double-blind. The expected values of blind samples are not known to the analyst, while double-blind samples cannot even be identified by the analyst

Table 7-2. Quality Assurance Sample Types, Frequency of Use, and Types of Data Generated for the EMAP-Near Coastal Louisianian Province Monitoring Demonstration.

Variable	QA Sample Type or Measurement Procedure	Frequency of Use	Data Generated for Measurement Quality Definition
Sediment toxicity tests	Reference toxicant tests	2 wk intervals	Variance of replicated tests over time
Benthic Species Composition and Biomass:			
Sorting	Resort of complete sample including debris	10% of each tech's work	No. animals resorted
Sample counting and ID	Recount and ID of sorted animals	10% of each tech's work	No. of count and ID errors
Biomass	Duplicate weights	10% of samples	Duplicate results
Sed. grain size	Splits of a sample	10% of each tech's work	Duplicate results
Organic carbon and acid volatile sulfide	Sample splits and analysis of standards	10% of samples	Duplicate results

Table 7-2. (Continued)

Variable	QA Sample Type or Measurement Procedure	Frequency of Use	Data Generated for Measurement Quality Definition
Dissolved Oxygen Conc.			
Hydrolab Surveyor II	Air-saturated water measurement following water saturated air calibration	Daily	Difference between probe and saturation table
Hydrolab DataSonde 3	Side-by-side measurement against calibrated Hydrolab Surveyor II	At deployment and retrieval of unit	Difference between DataSonde 3 and Surveyor II (based on saturation table)
Salinity	Refractometer reading	Daily	Difference between probe and refractometer
Temperature	Thermometer check	Daily	Difference between probe and thermometer
Depth	Check bottom depth against depth finder on boat	One at each sampling location	Replicated difference from actual
pH	QC check with buffer solution standard	Daily	Difference from standard

Table 7-2. Continued

Variable	QA Sample Type or Measurement Procedure	Frequency of Use	Data Generated for Measurement Quality Definition
Fish community composition	Duplicate counts	10% of trawls (or 1 trawl/crew change)	Replicated difference between determinations
Fish gross pathology	Field audits	Regular intervals or as needed	Number of mis-identifications
Fish histopathology	NA	NA	NA
Abundance of large bivalves	Random recount and identification	10% of collection	Duplicate results
Apparent RPD depth	Duplicate measurements	10% of samples	Duplicate results

Table 7-3. Warning and control limits for quality control samples

Analysis Type	Recommended Warning Limit	Recommended Control Limit
Method Blanks (organic and inorganic)	-	Less than detection limit
Matrix Spikes	50%[a]	Not specified
Laboratory Control Sample		
Organic	80% - 120%[b]	70% - 130%
Inorganic	90% - 110%	85% - 115%
Laboratory Duplicate (organic and inorganic)	-	± 30% relative percent difference
Ongoing Calibration Check (organic and inorganic)	-	± 15% of the initial calibration
Standard Reference Material[b]		
Organic	80% - 120%	70% - 130%
Inorganic	90% - 110%	85% - 115%

[a] Units are percent recovery
[b] Units are percent of true value

Table 7-4. Recommended detection limits (ppm) for EMAP-NC chemical analyses in the Louisianian Province

Analyte	Tissue Sample	Sediment Sample
Inorganics (concentrations in ppm, dry weight)		
Al	10.0	1500.0
Cr	0.1	5.0
Mn	5.0*	1.0
Fe	50.0	500.0
Ni	0.5	1.0
Cu	5.0	5.0
Zn	50.0	2.0
As	2.0	1.5
Se	1.0	0.1
Ag	0.01	0.01
Cd	0.2	0.05
Sn	0.05	0.1
Sb	0.2*	0.2
Hg	0.01	0.01
Pb	0.1	1.0
Organics (concentrations in ppb, dry weight)		
Hydrocarbons	20.0*	5.0
PCB congeners	1.0	0.1
DDD, DDE, DDT species	1.0	0.1
Pesticides	1.0	0.1

*Not measured in fish tissues

as a control sample (Taylor 1985). The type and frequency of quality assessment activities that will be performed for each sampling activity are summarized in Table 7-2.

Field/laboratory technicians and analysts will be apprised routinely of their performance on quality assessment samples. Actions taken, upon failing an assessment sample, will depend on the magnitude of the problem. Criteria will be established for both warning and control limits. Exceeding warning limits will require only rechecking of calculations or measurement processes, but exceeding control limits will require that all samples processed since the last assessment sample be reanalyzed. Field/ laboratory technicians and analysts who repeatedly fail criteria will be removed from their positions and/or retrained. Examples of the warning and control limits that will be used in conducting chemical analyses of sediments and tissue samples collected during the Demonstration Project are shown in Table 6-4. Recommended detection limits for chemical analyses are shown in Table 7-5.

Field and laboratory aspects of the 1991 Louisianian Province Monitoring Demonstration will be subjected to audits. Initial review of the field team will be performed during the training program. Following training, a site assessment audit will be performed by a combination of QA, training personnel, the Province Manager, and the Technical Director. This audit will be considered a "shakedown" procedure to assist field teams in obtaining a consistent approach to collection of samples and generation of data. At least once during the field sampling program, a formal site audit will be performed by QA personnel to determine compliance with the Quality Assurance Project Plan, the Field Operations Manual, and the Laboratory Methods Manual. Checklists and audit procedures will be developed for this audit that are similar to those presented in USEPA (1985).

EMAP-QA personnel will conduct a performance audit of all laboratory operations at the outset of the project to determine whether each laboratory effort is in compliance with the procedures described in the Quality Assurance Project Plan. Additionally, once during the study, a formal laboratory audit will be conducted following protocols similar to those presented in USEPA, 1985. Checklists that are appropriate for each laboratory operation will be developed and approved by the EMAP-NC QA Officer prior to the audits.

7.4 Quality Assurance of Data Management Activities

EMAP-NC must ensure and maintain the integrity of the large number of values that eventually will be entered into the data management system (NRC 1990; Risser and Treworgy 1986; Packard et al. 1989). EMAP-NC will use the procedures highlighted below to ensure the quality of the data in the EMAP Near Coastal Information Management System (NCIMS).

To the extent possible, data will be captured electronically to minimize the errors associated with entry and transcription of data from one medium to another. When manual entry is required, a hard copy of the entered data will be checked against the original by a second data entry operator to identify non-matches and correct keypunching errors. When data are transferred, the transfer will be done electronically, if possible, using communications protocols (e.g., Kermit software) that check on the completeness and accuracy of the transfer. When data are transferred using floppy disks or tapes, the group sending the information will specify the number of bytes and the file names of the transferred files. These data characteristics will be verified upon receipt of the data. If the file can be verified, it will be incorporated into the data base. Otherwise, new files will be requested. Whenever feasible, a hard copy of all data will be provided.

Erroneous numeric data will be identified using range checks, filtering algorithms, and comparisons to lists of valid values established by experts for specific data types (i.e., lookup tables). When data fall outside an acceptable range, they will be flagged and reported to the Louisianian Province Quality Assurance Officer (LP/QAO). Similarly, when a code cannot be verified in the appropriate lookup table, the observation will be flagged and reported to the LP/QAO.

All identified discrepancies and errors will be documented. This documentation will be a permanent part of the NCIMS. Data will not be incorporated into the LPIMS until all discrepancies have been resolved. The near coastal LP/QAO will be responsible for resolving all errors. Data sets for which discrepancies have been resolved will be added to the appropriate data base. A record of the addition will be entered into the Data Set Index and kept in hard copy. Once data have been entered into the LPIMS, changes will not be made without the written consent of the LP/QAO.

To ensure that complete records of all field activities are maintained, the field computer system will not allow modification of the data files. Instead, correction values will be entered into the data file and associated with the incorrect entry. Corrections will be made then and a record of the original data and the correction will become a permanent part of the file.

7.5 Quality Assurance Reports to Management

Control charts (see example shown in Fig. 7-2) will be used extensively to document measurement process control. Control charts will be used with the following: (1) QC check standards for controlling instrument drift, (2) matrix spike or surrogate recoveries to measure extraction efficiency or matrix interference, (3) certified performance evaluation samples to control overall laboratory performance, and (4) blank samples. Control charts will be maintained at each participating laboratory and reported with the data.

The first Annual Statistical Summary for the Louisianian Province is scheduled for June 1992, after completion of the 1991 Louisianian Province Monitoring Demonstration. Precision, accuracy, comparability, completeness, and representativeness of the data collected during the Demonstration will be summarized in this document, and detection limits reported. Interpretive Assessment Reports will be prepared every four years by the program element of EMAP-NC and Special Scientific Reports will be produced periodically to address concerns raised about the program, such as the ability of the sampling design to detect trends. The data quality attributes of precision, accuracy, comparability, completeness, and representativeness will also be provided for each of the reports.

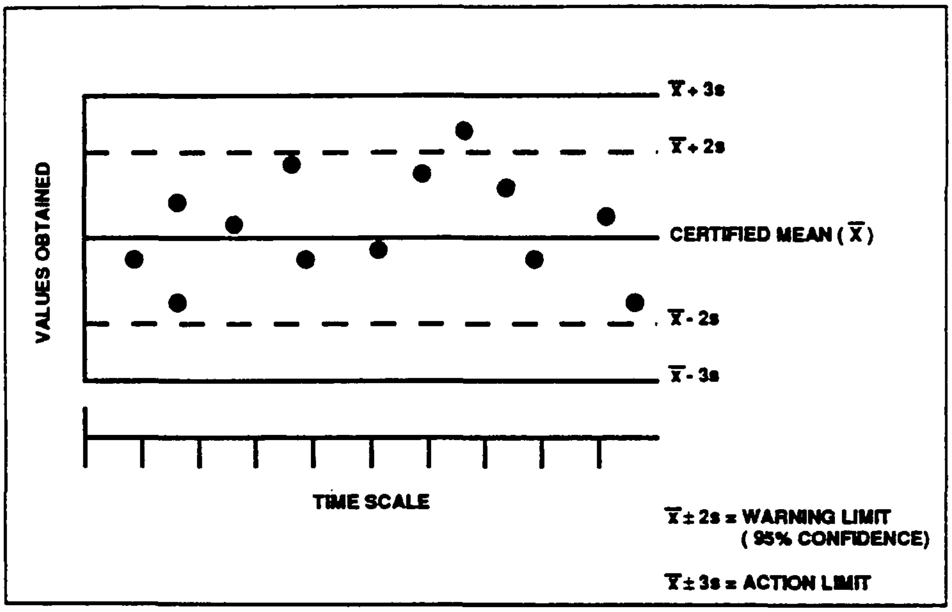

Figure 7-2. Example of a control chart.

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