

# **VI.**

## **The Galveston Bay Regional Monitoring Program**



# The Galveston Bay Regional Monitoring Program

## *The Galveston Bay Plan* Galveston Bay National Estuary Program

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The Regional Monitoring Program is designed to answer two different types of questions about Galveston Bay. The first type of question asks, "are the goals and objectives set forth in *The Galveston Bay Plan* being met?" Are the regulatory agencies and the regulated community fulfilling their commitments to *The Plan*? Are actions in *The Plan* having the desired impact? Does *The Plan* need to be changed? If the monitoring results indicate that *The Plan's* objectives are not being met, then the actions can be modified or the objectives can be changed to reflect a better scientific understanding about the bay.

The second type of question, which is much broader, asks, "is the health of the ecosystem changing, either for the better or the worse?" To answer this type of question, information from the monitoring program may be used to:

- Improve our understanding of the Galveston Bay system
- Assist in setting environmental standards
- Support the development of predictive tools

Two monitoring elements are needed to provide the information to answer these questions. These elements, programmatic and environmental monitoring, each provide information needed to evaluate *The Plan* at various levels. There are three identifiable levels at which we make use of monitoring information to assess *Plan* progress. These levels are administrative, symptomatic, and ecosystem (Figure RM-1) Programmatic monitoring can be accomplished at both administrative and symptomatic levels. Administrative monitoring establishes accountability of designated lead agencies for carrying out specific actions outlined in *The Plan*.

It is also necessary to measure non-environmental outcomes such as changes in opinion, knowledge, or behavior concerning a specific *Plan* action. These are examples of programmatic monitoring conducted at a symptomatic level. Examples of symptomatic level, programmatic monitoring would be a survey to determine if an educational outreach program has had the desired effect on a target community or monitoring changes in bay loadings from point or non-point sources. Environmental monitoring can also be thought of in terms of levels of information.

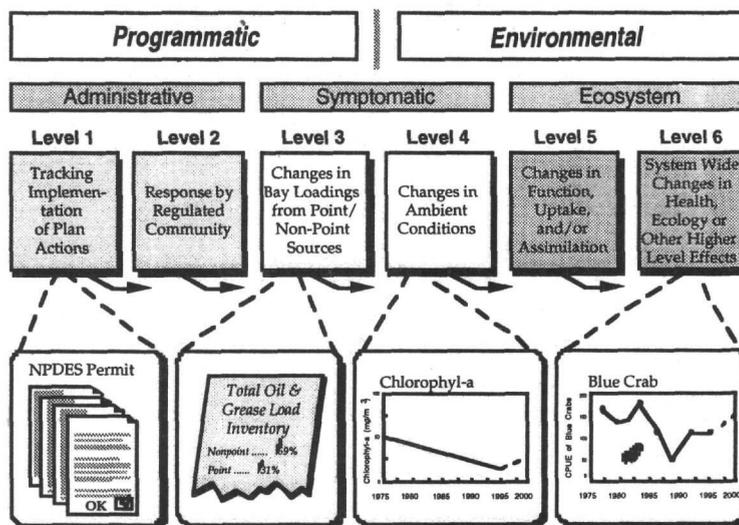


FIGURE RM-1. Hierarchy of Monitoring

While it can be argued that environmental monitoring measures outcomes, there are two different levels at which we can evaluate environmental monitoring. At one level, we measure certain parameters as an indicator of whether *Plan* actions are having an observable environmental impact. This we will call symptomatic monitoring. This level of measurement looks for such things as reductions in ambient conditions, changes in nutrient concentrations, or increased bird nesting habitat. At a higher level we want to be able to assess the impact of change in these indicators on the health of the ecosystem. Such indicators are measured as increases in nesting bird populations, changes in primary productivity, or reduced human health risk from bay fish and shellfish consumption. This hierarchy of indicators, shown in Figure RM-1, has been modified from the Chesapeake Bay program. Figure RM-2 shows how each component of *The Plan* fits into this hierarchy and how the levels of monitoring are integrated with the implementation strategies. We can see that all *Plan* actions contribute to the common goal of maintaining the ecosystem at an optimal health level.

**Programmatic Monitoring**

To effectively and completely measure the success of the program, it is necessary to establish a monitoring program which measures the success of the program in programmatic as well as environmental measures. *Plan* actions are usually specific activities designed to contribute to a

broader environmental objective and as such lend themselves to programmatic monitoring. As Figure RM-2 illustrates, it is the implementation of *Plan* actions which is the stimulus for anticipated changes in environmental health. Programmatic monitoring will have two goals. First is to monitor those activities which are established in *The Plan*. This is intended to keep managers informed on the implementation status of various programs. Secondly, the monitoring program must help identify which programs are or are not achieving their intended outcomes. Such monitoring improves the accountability of the program to the public and local governments. With this information, management can redirect resources or make necessary modifications to the actions to achieve the desired result.

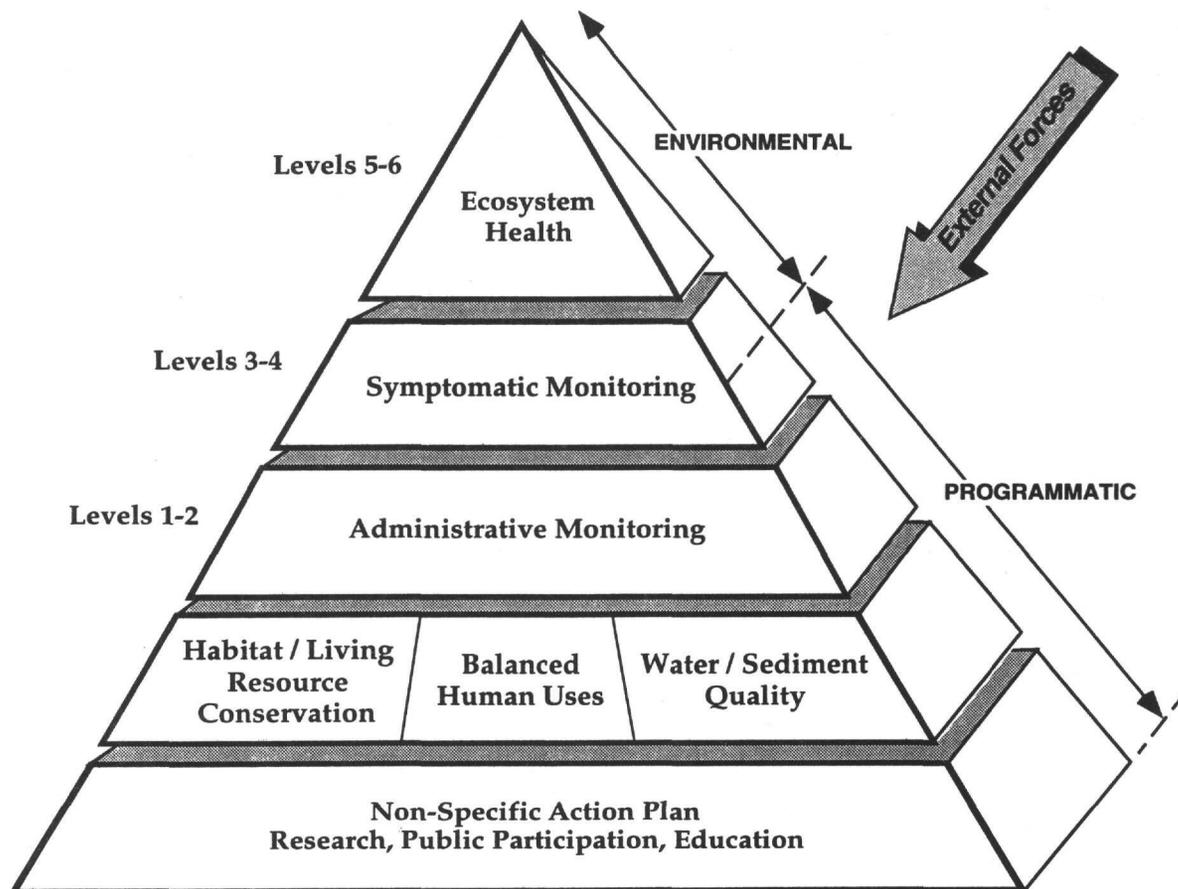


FIGURE RM-2. Integration of *Plan* Actions, Monitoring and Ecosystem Health

The programmatic element of the monitoring process will include an annual review of agency and local government implementation efforts. The Program will prepare an annual report outlining the specific actions taken toward achieving implementation goals. Biennial progress reports will be submitted to the Governor, the Texas Legislature and the public.

## **Environmental Monitoring**

Generally, environmental monitoring lends itself to assessment of *Plan* objectives rather than specific *Plan* actions. The environmental monitoring element of the Galveston Bay Regional Monitoring Program has been developed to provide these higher level assessments of *Plan* success. The Regional Monitoring Program is a statistically sound, holistic monitoring effort designed to provide environmental data of known quality and confidence. The Regional Monitoring Program is designed to collect data that can be compared to the quantifiable objectives in each action plan. It also has a larger goal of providing knowledge of bay-wide ecosystems, their variability, and societal impacts both environmental and ecological.

A lack of fundamental, long-term ambient information was identified by characterization reports and Task Force members as a critical concern (GBNEP-22). These and other concerns will be addressed by building on existing monitoring programs, coordinating them to eliminate duplication of effort, increasing their scope and resolution, improving timeliness of data analyses, eliminating information of dubious value, and making the results available to a diverse set of users in a timely fashion.

Understanding that no agency's mandate is broad enough for this undertaking, the Regional Monitoring Program seeks to promote a cooperative effort by all agencies who participate in bay monitoring activities. The Program attempts, wherever possible, to integrate and expand current monitoring activities into a comprehensive and unified monitoring plan. The plan was developed with full participation of all interested agencies to encourage cooperation, communication, and to maximize the potential for successful implementation. This chapter is a summary of a separate, more detailed report entitled "The Galveston Bay Regional Monitoring Program."

## **PRINCIPLES FOR BUILDING A REGIONAL MONITORING PROGRAM**

One of the early commitments of the Galveston Bay National Estuary Program (GBNEP) was the development of a sound regional monitoring program. The need for such a program was formalized at the GBNEP Regional Monitoring Conference held in Galveston, Texas, on July 8-9, 1992. The conference was widely attended by technical experts and managers of local, state, and federal programs administering monitoring activities in Galveston Bay. From this conference came the conceptual framework for the development of the regional monitoring program. Recommendations from this conference included the following points (Tetra Tech, 1994):

- A regional monitoring program is needed to improve our ability to effectively manage resources in the estuary
- Establishment and management of a technically sound regional monitoring program is feasible
- The details of the monitoring program should be designed by technical experts working with managers and decision makers

The Regional Monitoring Program is centered around five primary management topics:

- Water and sediment quality
- Species population protection
- Habitat protection
- Freshwater inflow
- Public health protection

A Task Force was established for each of the five management topics. Six rounds of meetings were held over a period of months. Each task force was charged with developing action plan items to address perceived threats and concerns. Once these action plans were incorporated into *The Plan*, monitoring objectives and information needs were developed by the Task Force.

**Key Elements in Development of the Regional Monitoring Program:**

- GBNEP Regional Monitoring Conference
- Management Topic Task Forces
- State of the Bay Symposia
- GBNEP Characterization Studies
- Monitoring Database Inventory
- Tetra Tech Monitoring Strategy Document
- Regional Monitoring Program Work Group Formation
- Final Regional Monitoring Program

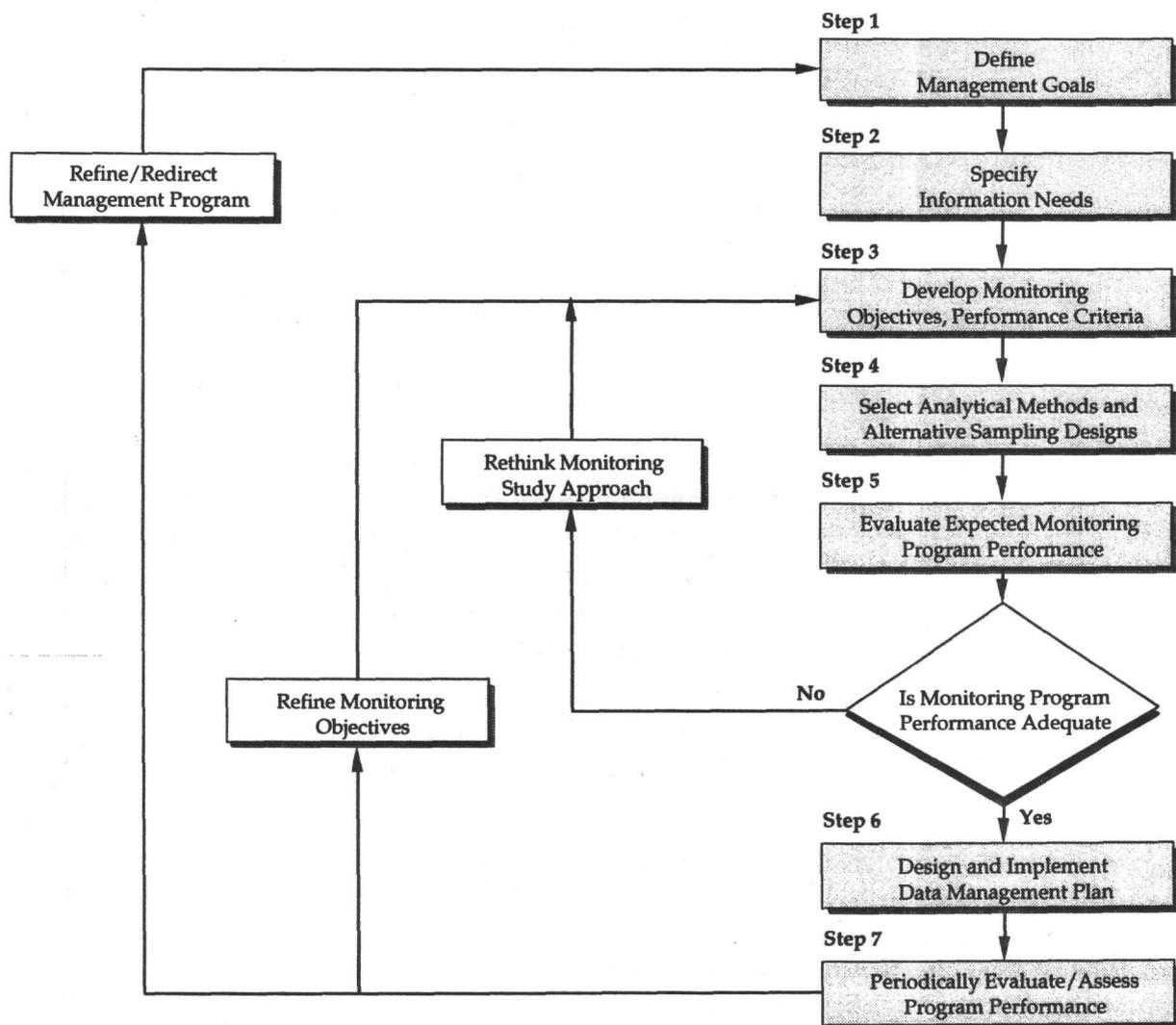
The Regional Monitoring Program has been designed to incorporate existing programs as its foundation. Goals were to reduce duplication of effort, expand the scope of the monitoring, and leverage resources by judicious selection of monitoring parameters. This was accomplished through the formation of the Galveston Bay Regional Monitoring Work Group. The Work Group membership was comprised of senior monitoring technical experts representing all agencies with ongoing monitoring activities in the bay area. The steps involved in development of the monitoring program are shown in Figure RM-3. The principles upon which the program was conceived are described below.

**Measuring the Status and Effectiveness of *Plan* Actions**

First and foremost, Galveston Bay's Regional Monitoring Program will provide information to measure the progress and effectiveness of implemented *Plan* actions. This will be accomplished through three types of monitoring efforts. These are programmatic monitoring, symptomatic monitoring, and environmental monitoring. Programmatic monitoring includes the tracking of *Plan* implementation. An important Galveston Bay Program staff function will be to coordinate and communicate regularly with agencies identified as lead agencies for specific initiatives. Symptomatic monitoring measures the effectiveness of *The Plan* actions in achieving the intermediate goals and objectives of *The Plan*. Environmental monitoring measures outcomes to determine improvements in environmental conditions relative to identified bay problems.

**Characterization of the Status and Trends of Conditions in the Bay**

Galveston Bay’s Regional Monitoring Program will provide information describing the status and long-term trends of specific biotic and abiotic resources to be managed. The monitoring effort will incorporate the regular and long-term collection of measurements of fundamental parameters. For each parameter, the measurements will be specifically defined and will relate directly to management objectives. Sampling efforts will be coordinated to facilitate testing for meaningful correlation among several parameters as well as trends in parameters measured over time. The Regional Monitoring Program will monitor parameters that will allow a direct comparison to the goals and objectives specified in *The Plan*. With this information, Bay managers, stakeholders, and the public can easily track the progress of *The Plan*.



**FIGURE RM-3. Galveston Bay Regional Monitoring Program Design**

### **Integration of Existing Monitoring Efforts**

Galveston Bay's Regional Monitoring Program will incorporate existing and planned monitoring efforts or elements from these programs to minimize duplication of effort, maximize the development of essential information, and reduce the cost of the monitoring effort. Where information gaps have been identified in existing monitoring programs, the appropriate agencies have been approached to supplement their existing monitoring or encouraged to develop the missing monitoring effort.

A key element in achieving this goal was the adoption of standard parameter sets and comparable protocols for field sampling, analytical, and Quality Assurance/Quality Control (QA/QC) methods. Performance-based standardized sampling, analytical, and QA/QC protocols will be employed to ensure that the data collected by different groups participating in the Regional Monitoring Program are directly comparable. Standardization and coordination of existing sampling efforts among local, state, and federal agencies will allow long-term sharing and use of all data collected as part of the Regional Monitoring Program.

An integral part of the Regional Monitoring Program is the development of a strong Quality Assurance program. This will be accomplished with the Galveston Bay Program office acting as a central figure in developing joint training programs and participation in laboratory quality assurance programs. An example of this is the Water Pollution Performance Evaluation Study available through the EPA. All laboratories in the program will participate in this nationwide quality assurance program.

### **Assessment of the Status and Trends of the Bay's Resources**

Measurement of all the variables of all the resources and all processes in the ecosystem is not feasible. The use of measurements that indicate the condition of valued habitats and resources, and the exposure to human stresses within habitats, will significantly reduce the cost of the monitoring effort. Galveston Bay's Regional Monitoring Program will measure indicator parameters to characterize:

- Condition
- Biological response
- Stress exposure
- Sources of stress

Analyses of these parameters will be used to assess the current status and trends in the condition of key estuarine habitats and resources.

### **Oversight and Coordination of the Regional Monitoring Program**

Participants in the Regional Monitoring Workshop held in June 1992, unanimously called for the formation of a multi-agency committee to coordinate regional monitoring and research efforts. The Regional Monitoring Work Group was formed in response to this call. The Work Group is comprised of senior technical representatives from each of the agencies currently

The second sampling program conducted by the Corps in Galveston Bay is the Open Bay Disposal Dredged Material Program. This is a three-year program now in its third year. Thirty stations were monitored two to four times per year. The monitoring is conducted by box corer and utilizes a sediment profiler for sediment profile imagery, benthos characterization, grain size, sediment carbon, redox potential, surface relief, and benthic succession. While not a true long-term monitoring effort, it will provide information on sediment characteristics which will be useful in assessment of our sediment data.

#### U. S. Fish and Wildlife Service

USFWS activities are generally limited to short-term special studies designed to address particular issues. USFWS does conduct the National Wetlands Inventory, which is a program of mapping wetlands nationwide using stereoscopic analysis of high altitude aerial photography. Areal changes in open-water, wetlands, and developed land are assessed and future changes projected. This survey is performed on a roughly 10-year interval. The USFWS also has plans for a larger monitoring effort focusing on wildlife refuges. This effort is expected to fall under the responsibility of the recently created National Biological Survey. At this time, no specific plans or schedules have been developed for Galveston Bay.

USFWS has also been involved in several bird surveys. The North American Breeding Bird Survey has been conducted continuously from 1986-1990 with intermittent coverage dating back to 1968. Another more significant study, the Mid-Winter Waterfowl Survey, is carried out in cooperation with the Texas Parks and Wildlife Department. This survey consists of a systematic scheme of sampling along transects and another less systematic scheme of counting birds in general locations. These data provide information on abundance of waterfowl by species and by transect, or by general location within the surrounding waters of the Galveston Bay System (GBNEP-19).

#### National Oceanic and Atmospheric Administration

NOAA has two programs that involve monitoring activities in Galveston Bay. NOAA's Mussel Watch Program monitors six stations in Galveston Bay. At each of these stations, oysters are sampled annually for trace elements, chlorinated pesticides, PCBs, PAHs, and tributyl tin (TBT). Sediments were also sampled during the period from 1986 to 1988.

The second NOAA monitoring program is the Benthic Surveillance Project which monitors nine sites in Galveston Bay. Fish livers are sampled from the sites every two years and are analyzed for chlorinated pesticides, PCBs, PAHs, TBT and pathology.

#### National Marine Fisheries Service

NMFS has two monitoring activities in Galveston Bay. The first is designed to monitor baseline production of fish and shellfish in West Bay marshes. This program includes a number of variable stations in the marshes. Fish, shrimp, and crab are sampled for the measurement of densities of target species and biomass. There are plans to expand the program to 30 sites covering the entire Galveston Bay. No cost or data management information is available at this time.

The second activity is the Brown Shrimp Catch program. During April-June each year, NMFS monitors sizes of brown shrimp and catch per unit effort (i.e., pounds per hour) using information provided by bait dealers and fishermen. A third activity, the Post Larval Shrimp program was discontinued in 1993.

### **State Agencies**

#### Texas Natural Resource Conservation Commission

The TNRCC conducts routine sampling at 68 stations in the Galveston Bay watershed to maintain a central database for monitoring water and sediment conditions. The stations are divided into groups of 55, 10, and 3 stations; the groups are sampled four, two, and one times per year, respectively, yielding a total of 243 sample collection events per year. Conventional water quality measurements including DO, Biochemical Oxygen Demand (BOD), Total Suspended Solids (TSS), pH, conductivity and salinity are conducted at all stations. Other water quality measurements include nutrients, fecal coliforms, chlorophyll *a* and pheophytin *a*, Total Organic Carbon (TOC), Total Dissolved Solids (TDS), and VSS. Additional parameters are monitored at selected stations and lower frequencies. These include benthos, plankton, metals, pesticides, other priority pollutants and toxicity in both water and sediment. Data are stored in the Surface Water Quality Monitoring database.

#### Texas Water Development Board

The objective of TWDB's monitoring program in Galveston Bay is to collect data to support calibration of TWDB's models of circulation and salinity, and to support analyses of the relationship between salinity and freshwater inflow. TWDB routinely samples five stations in Galveston Bay for water temperature, pH, DO, conductivity, and salinity. The measurements are conducted by probes fixed at the sites and are automatically recorded every 90 minutes.

#### Texas Department of Health

The TDH's monitoring program in Galveston Bay is designed to ensure compliance with the National Shellfish Sanitation Program (NSSP). NSSP requires use of bacteriological monitoring along with pollution source surveys to classify shellfish producing waters. TDH routinely monitors 104 stations in Galveston Bay at infrequent and variable intervals. These stations are located adjacent to actual or potential sources of fecal coliform pollution. Sample collections are timed to represent worst case conditions. The measurements conducted include air and water temperature, tide condition, rainfall, weather conditions, wind direction, velocity, DO, salinity, and fecal coliform (FC).

#### Texas Parks and Wildlife Department

The TPWD has three monitoring programs in Galveston Bay. The Resource Monitoring Program collects gill net samples at 45 sites twice annually during the spring and fall. On a monthly basis 20 trawl, 30 oyster dredge, and 20 bag seine samples are collected from Galveston Bay. Weather conditions, tide conditions, temperature, salinity, DO, and turbidity are measured when collecting samples. The collected samples are analyzed for species identification, number of specimens, size, weight (occasional), sex, and maturity. Large, live fishes are tagged to allow growth, mortality and movement estimates.

recreational waterfowl and wildlife. Habitat quality monitoring will provide information to characterize the condition of bay habitats, evaluate potential stresses to resident organisms, and track habitat recovery following adverse environmental impacts.

### Programmatic Monitoring

There are numerous specific *Plan* actions for which progress must be tracked and evaluated. Programmatic monitoring generally includes monitoring for implementation of key actions or milestones leading to such action and a broader evaluation of *Plan* objectives.

### *Acquiring and Protecting Quality Wetlands Habitat*

Actions HP-4, 5, and 6 address the objectives directed at acquisition and protection of wetland habitats. Wetland accounting systems will be implemented to monitor acquisitions of wetland habitat, habitat in public ownership, and to document wetland conversion. Effectiveness of tax incentives to discourage wetland development can be monitored through applications for special tax status. These will be tracked as administrative functions. Informational input will come from environmental wetland characterization monitoring and other ancillary data such as the Corps Section 404 permit program.

Another objective of the habitat protection action plan is directed at selectively moderating erosional impacts. To achieve this objective, a rating system will be implemented to identify areas of high erosion impact. These areas will be monitored for erosion rates and effectiveness of management practices implemented to reduce erosion.

Additional milestone events to track action implementation will include:

- Status and actions related to obtaining funding for habitat acquisition (HP-5)
- Prioritizing of wetland tracts for acquisition (HP-5)
- Status of state and local government efforts to create tax incentives for wetland protection (HP-6)
- Monitoring progress in beneficial use of dredged material for restoration and creation of wetland areas (HP-2 and 8)

### *Coordinating Wetland Regulatory Strategy*

Key elements for programmatic follow-up for this action are:

- Implementation of Memorandum of Understanding (MOU) to standardize mitigation criteria, policies and requirements (HP-4 and 9)
- Development of wetland water quality standards by TNRCC (HP-4)

### Environmental Monitoring

Task Force members adopted the following broad environmental monitoring objectives to be used in design of the Galveston Bay Regional Monitoring Program:

- Determine trends in the areal extent, quality, and distribution of selected habitats of concern (Actions HP-1, 3, 4, 5, and 6)
- Determine the extent of habitat quality, continuity, and fragmentation (Actions HP-1, 2, and 3)

- Determine trends in the abundance and distribution of species whose existence depends on wetland habitats (Actions HP-7,8)

Based on recommendations from Habitat Protection Task Force members, ecologically important and potentially threatened habitats within the estuary include:

- Submerged aquatic vegetation
- Freshwater, brackish, and salt marshes
- Colonial bird nesting habitat

Submerged vegetation and marshes were identified because they:

- Are important sources of nutrients and organic matter
- Furnish key nursery and adult habitat for bay biota
- Provide flood peak reduction, attenuation of storm water flows, and sediment and shoreline stabilization

Colonial bird nesting habitat was identified because bird populations have significant ecological and aesthetic value to users of the bay.

Based on *Plan* objectives and recommendations from Habitat Protection Task Force members, habitat indicators were developed and are given in Table RM-1. Because these habitat types differ significantly in their physical characteristics and location, different monitoring methods will be required for each.

#### *Extent, Change and Distribution*

Long-term measurements of area and location will be used to provide data on gains or losses of specific habitat types within the estuary as required by Actions HP-1, 3, 4, 5, and 6. Areal and distribution data will also be used to assess whether habitats are of sufficient size to perform hydrodynamic and water quality functions. Remote sensing techniques combined with ground truthing will be utilized to provide this information. Data on areal extent and change for the identified habitats and others will be obtained through the TPWD Resource Protection Division Coastal Habitat Group. This program utilizes satellite Landsat Thematic Mapper (TM), multi-spectral imagery from which land cover classifications are done. The program utilizes the NOAA Coast Watch-Change Analysis Program (C-CAP) classification protocols. In addition to development of baseline mapping, the program has a goal of monitoring changes in wetland and submerged habitat every 2-5 years. Mapping of the Galveston Bay system has been completed so baseline data are available. As reported by the TPWD, the primary advantages of landcover mapping with satellite imagery using C-CAP protocols are: 1) standardized mapping classification with other major wetland classification systems, 2) extensive coverage within a single satellite scene, 3) classification and mapping can be done over a relatively short period of time, and 4) the classified landcover information is in a format readily integrated into a Geographic Information System (GIS).

**TABLE RM-1. Candidate Indicators and Measurements for Habitat Protection**

<b>Candidate Indicators</b>	<b>Candidate Measurement</b>
<b>Marsh</b>	
• All marsh types	Areal extent and distribution % emergent vegetation % open water dominated by aquatic vegetation Marsh edge and interspersion Water duration Open water depth Salinity
• Brackish marsh	Aquatic organism access
• Salt marsh	Change in relative sea level - subsidence/erosion % <i>Spartina alterniflora</i>
<b>Submerged Vegetation</b>	
• Seagrasses	Areal extent and distribution Biomass Vegetation composition PAR Salinity
<b>Oyster Reefs</b>	Areal extent and distribution
<b>Colonial Waterbird Nesting Habitat</b>	Number of colonies and distribution Abundance of predators (e.g., fire ants) Elevation above sea level Accessible feeding habitat Connectivity to mainland Indications of human disturbance

*Habitat Quality and Function*

This monitoring element is directed at the goal of expanding areas and restoring quality of wetland habitat (HP-1, 2, and 3). In addition to monitoring habitat change using previously described methodology, various wetland habitat modification activities will be monitored to prioritize and target areas where potentially degraded wetlands may occur. Such activities would include humanly-induced subsidence, draining and filling, and isolation activities. Once targeted, assessments of wetland quality and function will be conducted using the Wetland Value Assessment (WVA) methodology. This methodology was developed by the US. Fish and Wildlife Service in Lafayette, LA. It was developed as a quantitative assessment tool intended for use in ranking projects for the Coastal Wetlands Planning, Protection, and

Restoration Act. It is a modification of the USFWS Habitat Evaluation Procedure (HEP). WVA utilizes a community-based approach in metric development as opposed to the species approach utilized by HEP. The assessment tool will be field tested for applicability to Galveston Bay wetland habitats and if necessary, appropriate modifications to the metrics will be made. Wetland restoration projects will be prioritized and evaluated utilizing WVA rankings.

#### *Colonial Waterbird Nesting Habitat*

The Texas Colonial Waterbird Census (TCWC) is a program for monitoring colonial waterbird nesting sites conducted in the Galveston Bay estuary. This program gives nesting site utilization data required to address Actions HP-7 and 8. This program does not include evaluation of habitat extent or condition so information from the project as currently conducted can not directly address the issue of the Habitat Objective. However, analyses of colony attributes can be made. Numerous possible factors may influence waterbird nesting habitats and each nesting habitat will be evaluated to determine the primary factor for abandonment as a nesting habitat. Some possible causes of nesting habitat loss are human disturbance, predation, loss of island area through subsidence or erosion and access to feeding habitats. Once specific factors can be identified, remediation measures can be recommended and implemented.

#### *Implementation*

As previously discussed, the information on habitat areal extent and distribution will be obtained from the TPWD Habitat Assessment Branch classification program. Assessment of the WVA approach for habitat quality will be headed by the USFWS along with members of the EPA, Corps and TPWD.

### **Species Population Distribution and Condition**

Galveston Bay's fish and wildlife provide some of the bay's greatest economic, recreational, and aesthetic values. Less recognized organisms play key roles in maintaining the diversity of the bay's biological resources. To protect and preserve Galveston Bay's biological resources, information on the condition of the bay's plants and animals is necessary. Species population monitoring will provide information to characterize the condition of bay biota, evaluate potential stresses to bay organisms, and track population responses following environmental interventions.

#### Programmatic Monitoring

The following are general programmatic areas for which progress will be tracked and evaluated:

- Creation of the Galveston Bay Species Advisory Committee (SP-1)
- Development and implementation of TPWD program for returning oyster shell to designated locations (SP-2)
- Progress in streamlining the current leasing process to encourage reef creation (SP-3)
- Legislative activity for creation of oyster reef research areas or preserves (SP-4)

- Identification of changes in gear and devices to reduce by-catch. Commercial fleets will be monitored for implementation of new devices as they are developed (SP-5)
- Educational programs for recreational fishermen will be developed by TPWD; effectiveness of these programs can be monitored through the TPWD Creel Surveys and surveys targeted at recreational fishermen to assess awareness of the program and its importance (SP-6)
- Adoption by TPWD of management plans for endangered species found in Galveston Bay (SP-8)
- Monitoring development of new legislative actions directed at the prohibition of introducing exotic species (SP-9)
- Progress in identification and implementation of effective means of controlling exotic species (SP-10)

Data information needs for the programmatic monitoring effort include:

- Numbers and locations of alternative material oyster reefs created (SP-3)
- Amounts of reef area designated as research or preserve areas (SP-4)
- Results of TPWD Coastal Resource Recreational Landings Program (SP-6)

### Environmental Monitoring

The stated goals of *The Plan* are to maintain and enhance populations of economically important species, ecologically important species, and threatened and endangered species, while reducing populations of introduced exotic species. Economically important species are ecological components having an economic or recreational value. Threatened and endangered species are listed by the US Fish and Wildlife Service. Of specific importance to Galveston Bay are the brown pelican, piping plover, and five species of sea turtles. Introduced exotic species include nutria, grass carp, and fire ants. Species of ecological importance are defined as ecological components mediating processes or interactions that affect the structure and function of existing bay habitats and communities. Because it is not feasible to measure all economic, threatened and endangered, introduced, and ecologically important species, a limited set of indicator species were identified based on recommendations by Species Population Protection Task Force members. The Regional Monitoring Program will determine the status and trends in the following.

- Abundance and distribution of dominant phytoplankton (SP-1).
- Abundance and distribution of dominant species of benthic invertebrates (SP-1).
- Relative abundance (i.e., catch per unit effort) and distribution of selected species of fin- and shellfish (SP-1,2).
- Abundance and distribution of selected species of birds and reptiles (SP-1).
- Abundance and distribution of endangered and threatened species (SP-8).
- Abundance and distribution of certain introduced exotic species (SP-9, 10).
- Impingement and entrainment and mortality of impinged organisms (SP-7).
- By-catch in commercial fisheries industry (SP-5).

From these broad objectives and a review of the data required to assess effectiveness of the defined action plans, a list of indicator species for environmental monitoring was developed. These species are outlined in Table RM-2.

**TABLE RM-2. Candidate Indicators and Measurements for Species Protection**

<u>Candidate Indicator</u>	<u>Candidate Measurement</u>
<b>Ecologically Important Species/Communities</b>	
• Plankton community	Chlorophyll-a (see Water Quality)
• Benthos	Community structure (see Sediment Quality)
• Invertebrates	
- white shrimp	Abundance and distribution
- brown shrimp	Abundance and distribution
- blue crabs	Abundance and distribution
• Finfish	
- Atlantic croaker	Abundance and distribution
- gulf menhaden	Abundance and distribution
- anchovy	Abundance and distribution
• Birds	
- Colonial waterbirds	Abundance and distribution
- Shorebirds	Abundance and distribution
- Wintering waterfowl	Abundance and distribution
• Alligator	Abundance and distribution; # nests
<b>Commercially and Recreationally Important Species</b>	
• Shellfish	
- eastern oyster	Areal extent of reefs; distribution; density; size
- white shrimp	Abundance and distribution; size; weight
- brown shrimp	Abundance and distribution; size; weight
- blue crabs	Abundance and distribution; size; weight
• Finfish	
- Atlantic croaker	Abundance and distribution; size; weight
- black drum	Abundance and distribution; size; weight
- red drum	Abundance and distribution; size; weight
- gulf menhaden	Abundance and distribution; size; weight
- sand seatrout	Abundance and distribution; size; weight
- spotted seatrout	Abundance and distribution; size; weight
- sheepshead	Abundance and distribution; size; weight
- southern flounder	Abundance and distribution; size; weight
<b>Commercial By-Catch</b>	<i>CPUE # and biomass; by-catch/shrimp biomass ratios</i>
<b>Impingement/Entrainment</b>	<i>Abundance</i>
<b>Introduced Exotic Species</b>	
• grass carp	Abundance and distribution
• nutria	Abundance and distribution

*continued*

*continued*

**Candidate Indicator**

**Candidate Measurement**

**Threatened and Endangered Species**

- brown pelican
- piping plover
- Kemps Ridley sea turtle
- Southeastern snowy plover
- Texas diamondback terrapin

Abundance and distribution  
Abundance and distribution  
Sightings

*Finfish and Shellfish*

Selected finfish and shellfish represent commercially important species, key intermediate consumers, and forage species in the estuary. Information describing the status and trends of economic species will be used to (1) characterize standing stocks of economic species, (2) provide early warning of potential impacts to bay fisheries, and (3) assist in identifying appropriate resource management actions. Information on abundance and distribution of ecologically important species will be used to assess the structure and function of the Galveston Bay System. Catch Per Unit Effort (CPUE), size, weight, and location of indicator finfish, shrimp, and crabs will be used to characterize abundance and distribution of fish and shellfish populations. The abundance of oysters will be determined from the areal extent, density, and distribution of oyster reefs as monitored through the TPWD Coastal Fisheries Program.

*Birds*

Several programs directed at the evaluation of bird populations are conducted in the Galveston Bay area. These include the previously discussed Texas Colonial Waterbird Survey, Mid-winter Waterfowl Survey and the Bolivar Shorebird Survey. The Regional Monitoring Program will work to promote, improve and increase utility of these programs.

*Reptiles*

Among locally important ecological species is the American alligator. TPWD conducts an helicopter survey of American alligator nests along established transects in the marshes adjacent to East Bay and Trinity Bay. This survey was conducted annually from 1980-1984 and on three-year intervals since 1985. In addition to nest counts, TPWD conducts night-count surveys on three selected navigable waterways within the Galveston Bay System. The Galveston Bay Program will work with TPWD to continue these surveys and to improve the quality of the data through improvements in standardized methods.

*Endangered and Threatened Species*

Listed threatened and endangered species will be directly and indirectly monitored. Long-term measurements of sightings and location data will be used to assess population levels and trend data will be used to identify potential population declines. In addition, it is recommended that the areal extent and distribution of required or preferred habitats of threatened and endangered species be used to assist in characterizing population abundance and providing early warnings of potential population declines.

### *Introduced Exotic Species*

Monitoring for introduced exotic species will be required to assess the effectiveness of techniques for controlling populations of these species. Species specifically named in *The Plan* are grass carp and nutria. Current monitoring efforts are not adequate to provide information needed to assess this plan objective. The Galveston Bay Program office will work with the appropriate agencies in developing methods for monitoring the effect of population management controls. An informal task force has met to discuss possible monitoring and control strategies for grass carp. A similar group will be convened to address the issue of nutria populations. Proposed population estimates include abundance and spatial distribution data.

### *Impingement/Entrainment*

One objective of *The Plan* is the reduction of impingement and entrainment and increased survival of impinged and entrained organisms at power generating stations. The TNRCC has collected impingement data for several years at one power plant location. This data collection effort will be continued to document any reductions seen in impingement from actions taken at the plant. In addition Houston Lighting and Power (HL&P) will be conducting mortality studies beginning in the fall of 1994 to measure the effectiveness in reducing mortality of recently installed pumping systems. Through these studies estimates of reductions that may be achieved through implementation of best available technology can be established.

### *Commercial By-Catch*

The NMFS works toward the development and implementation of gear and devices to reduce commercial by-catch. TPWD is currently conducting by-catch surveys in several Texas bays. The sampling protocols being used are comparable to those used in the GBNEP by-catch studies conducted by NMFS (GBNEP-25). Using the NMFS data as a baseline and implementing future by-catch studies in Galveston Bay, TPWD and NMFS will monitor trends in by-catch reductions.

### *Implementation*

As previously discussed most monitoring information on commercially important species will be provided from the TPWD Coastal Fisheries Program. The TNRCC also does limited collections in shallow water areas not generally sampled by the TPWD program. The Galveston Bay Program will work with volunteer, state, and federal agencies in the continuation and expansion of the bird surveys currently conducted within the Galveston Bay System. TPWD will be the lead agency for by-catch and endangered species monitoring

## **MONITORING ELEMENTS FOR BALANCED HUMAN USES**

### **Public Health**

The presence of contaminants in bay biota and pathogens in bay waters can have adverse human health effects. Concentrations of contaminants in bay fish and shellfish are used to assess risks to human health from the consumption of seafood. Levels of human pathogen indicators (fecal coliforms) in bay waters are used to regulate areas for shellfish harvesting and

may be used to develop a contact recreation advisory program. Maintenance of adequate public health standards within the estuary is critical for the protection of the general public and important for the long-term stability of the fishing and water recreation industries.

#### Programmatic Monitoring

Each of the public health plans are primarily environmental in nature. However, accomplishment of certain milestone activities can be administratively monitored. These are:

- Establishment of standards for selected toxics in tissue (PH-1)
- Adoption of an approved Risk Assessment Methodology for human consumption of seafood (PH-1)
- Increases in sampling frequency, in the Shellfish Sanitation Program (PH-3)
- Track trends in closures of oyster harvest areas (PH-3)
- Development of indicator organisms for the contact recreation program (PH-2)
- Tracking incidence of waterborne diseases resulting from contact recreation in Galveston Bay waters (PH-2)

#### Environmental Monitoring

The following broad monitoring objectives were used in developing the public health component of the regional monitoring program:

- Characterize the distribution and trends of selected toxics in fish and shellfish (PH-1)
- Characterize the distribution and trends of selected bacteriological indicators in estuarine waters and sediments (PH-3)

From these broad objectives and a review of the data required to assess effectiveness of the defined action plans, a list of indicator species for environmental monitoring for public health were developed. These species are outlined in Table RM-3.

#### *Concentrations of Contaminants in Tissues of Indicator Organisms.*

Concentrations of contaminants in edible portions of selected commercial fish and shellfish will be used to estimate contaminant exposures to humans through the consumption of seafood. Contaminant exposure levels will be used in health risk assessments to determine if seafood consumption poses unacceptable risks to human populations. Current tissue monitoring efforts are not adequate for development of human health risk assessments. Data are of an episodic nature, are many times single sampling events, and are generally limited to areas with known sources of contamination. Development of a seafood consumption safety program falls under the auspices of the TDH. Such a program will include establishing applicable standards, developing a periodic sampling and analysis program, and a public education program. The seafood monitoring program will be coordinated with the Regional Monitoring Program.

#### *Bacteriological Indicators*

Fecal coliform monitoring will be a Tier One element in the ambient water quality monitoring program. *The Plan* recommends development of a Contact Recreation Advisory program and designates the TDH as the lead agency. TDH is directed to utilize state TNRCC fecal coliform

standards for contact recreation, or other indicators if developed to create the advisory program. The ambient water quality program will collect fecal coliform samples according to TNRCC protocols. Development of an advisory program will require research to establish the relationship between water-borne illness, contact recreation and indicator organisms. Increased monitoring frequencies are scheduled to begin in 1999. The Monitoring Steering Committee will reassess monitoring frequencies and indicators for the purposes of this program once TDH has established the bacteriological indicator and monitoring needs.

*Shellfish Sanitation Program*

The TDH is the State Shellfish Control Authority responsible for administering the National Shellfish Sanitation Program (NSSP). Under this regulatory program TDH monitors 112 stations 12-30 times per year. From this monitoring data the Shellfish classification status of Texas estuarine areas is determined by TDH. Plan Action PH-3 addresses the need for increased sampling frequency.

*Implementation*

Current fecal coliform monitoring programs within the TNRCC, TDH, and GCHD will be coordinated through the Monitoring Steering Committee. The Galveston Bay Program will work with the TDH through the Monitoring Steering Committee, to implement a tissue monitoring program to meet the goals outlined by the Public Health Task Force. Upon development of the Contact Recreational Advisory Program by TDH, the Monitoring Steering Committee will assess current monitoring programs and make recommendations for modifications which meet the established monitoring needs.

**TABLE RM-3. Candidate Indicators and Measurements for Public Health Protection**

<u>Candidate Indicators</u>	<u>Candidate Measurements</u>
<b>Bacteriological Indicators:</b>	
<ul style="list-style-type: none"> <li>Fecal coliforms</li> <li>Enterococcus</li> <li>Escherichia coli</li> </ul>	<ul style="list-style-type: none"> <li>Colony counts</li> <li>Colony counts</li> <li>Colony counts</li> </ul>
<b>Weather:</b>	
<ul style="list-style-type: none"> <li>Precipitation</li> </ul>	<ul style="list-style-type: none"> <li>Amount and timing</li> </ul>
<b>Fish and Shellfish Tissue Contaminant Sampling:</b>	
<i>Shellfish</i>	
<ul style="list-style-type: none"> <li>Blue crab</li> <li>Oyster</li> </ul>	<ul style="list-style-type: none"> <li>Edible tissue COC concentrations</li> <li>Edible tissue COC concentrations</li> </ul>

*Fish*

- |                     |                                  |
|---------------------|----------------------------------|
| • Black drum        | Edible tissue COC concentrations |
| • Southern flounder | Edible tissue COC concentrations |
| • Atlantic croaker  | Edible tissue COC concentrations |
| • Seatrout          | Edible tissue COC concentrations |
| • Redfish           | Edible tissue COC concentrations |
- 

**Freshwater Inflow/Bay Hydrodynamics**

Information describing the quantity and timing of freshwater inflow is needed to determine annual and seasonal inflow needs to the bay and estimate contaminant and nutrient loadings to the bay. Information describing bay hydrodynamics is needed to determine circulation patterns in the bay and assist in determining the fate and transport of contaminants and weak-swimming or passively transported biological resources. Baseline information for these parameters is needed so that future projects which may impact circulation and salinity gradients can be assessed for their impact.

Programmatic Monitoring

Activities to be monitored for achievement of programmatic objectives are:

- Completion of TWDB/TPWD inflow study (FW-1)
- The development of freshwater inflow management plans (FW-3)
- Monitor changes in state legislation, Section 11.147, to expand water use permitting authority for TNRCC (FW-4)
- Track trends in water consumption rates (FW-6)
- Survey municipalities and local water utilities for implementation of programs to utilize low water-use devices(FW-6)

Environmental Monitoring

The Freshwater Inflow Task Force members adopted the following broad monitoring objectives to be used in development of the Regional Monitoring Program.

- Characterize the status and trends in the quantity and timing of freshwater inflows to the bay (FW-1)
- Characterize the water quality of freshwater inflows (FW-1)
- Characterize the distribution and trends of selected water quality parameters in the bay (FW-2)
- Determine bay-wide, as well as habitat-specific, circulation patterns (FW-7)

Data that will be collected and analyzed as part of the freshwater inflow/hydrodynamics component of the regional monitoring program are listed in Table RM-4.

*Timing, Volume, and Rates of Freshwater Inflow.*

Freshwater inflow data are needed to gain a fundamental understanding of what levels and timing of freshwater flow are necessary to maintain the productivity of the bay. The goals of

long-term measurements of freshwater inflow volumes are to:

- Estimate contaminant, nutrient, and sediment loadings
- Identify potential causes for observed changes in salinity regimes
- Calibrate and validate hydrodynamic models describing Bay circulation patterns
- Explain and identify potential causes for observed changes in the abundance and distribution of Bay biota

**TABLE RM-4. Parameters used as Indicators of Freshwater Inflow Quantity and Quality**

**Candidate Parameters**

**Inflows - In areas with gauging stations**

- Tidal flow
- Freshwater flow

**Inflows - In areas without gauging stations**

- Precipitation
- Runoff coefficients

**Inflow Water Quality**

*In situ Measures*

- Temperature
- Conductance
- pH
- Dissolved Oxygen
- Turbidity

*Analytical Samples:*

- Oxygen demand, BOD (5-day)
- TSS, VSS
- Nutrients:
  - Nitrogen - NH<sub>3</sub>-N, nitrate, nitrite,
  - Phosphorous - Total and ortho-
- Carbon - TOC
- Fecal coliform
- Total/dissolved metal COCs
- Organic toxic COCs
- Pesticide COCs
- Ambient toxicity

Timing, volume, and rates of freshwater inflow may be directly measured at stream gauging stations. However, in areas without gauging stations, freshwater inflow must be estimated from measurements of precipitation and watershed area. Run-off estimates will be made from tables relating runoff coefficients to land use or from watershed ratios. Efforts will be made to

establish flow gauging stations where feasible.

#### *Water Density.*

Descriptions of water density are needed to identify distinct water masses and predict circulation patterns. Water density will not be measured directly, but determined from measurements of salinity (conductance), temperature, and pressure (depth). Vertical measurements of salinity (conductance) and temperature can be collected by passing a CTD (Conductivity-Temperature-Depth) unit through the water column. Information for this indicator will be routinely collected as part of the water quality monitoring element.

#### *Current Speed and Direction*

Long-term measurements of current speed and direction will be used to:

- Characterize and predict circulation patterns in the bay
- Describe the transport of contaminants, sediments, and larvae in the bay
- Calibrate and validate Bay hydrodynamic models

Circulation and transport information will be used to assist in identifying and predicting potential causes for observed changes in the abundance and distribution of Bay habitats and biota. This monitoring element will be conducted to establish a baseline understanding of these systems in the bay.

#### *Implementation*

Existing and projected monitoring efforts of the TWDB, TNRCC and USGS will provide information for this element of the monitoring plan.

### **Spills and Dumping**

#### Programmatic Monitoring

Administrative tracking of action implementations is essential to the assessment of program success in this element. Most plan actions are administrative in nature. Examples of information to be used in tracking this element are:

- Establishment of MOU to delineate the roles of natural resource trustees (SD-1)
- Development of a compensation table for oil spills in Galveston Bay (SD-2)
- Identification of oil spill natural resource restoration needs (SD-3)
- Monitor local governments for ordinances requiring waste receptacles at shoreline facilities (SD-5)
- Surveys to track implementation of stormwater debris removal programs (SD-6)
- Maintain public hotline for reporting incidence of illegal dumping (SD-7)

Programmatic data needs for monitoring success of program objectives are:

- Records of environmental compensation
- Miles of shoreline evaluated under advanced shoreline characterizations
- Monitor numbers of shoreline waste receptacles put into service
- Conduct Galveston Bay debris survey every three years to monitor trends in debris characterization

### Environmental Monitoring

Monitoring for this element in *The Plan* is primarily programmatic in nature. There are no specific environmental monitoring actions for this element. However, several monitoring initiatives are linked to this element. For example, habitat identification procedures can provide baseline information for identification of sensitive wetland habitats in the advance shoreline characterization action (SD-4). Other such indirect involvement includes baseline information on habitat quality.

### **Shoreline Management**

Most actions under this plan element are programmatic in nature. Milestone achievements to be monitored under this element include:

- Designation of Galveston Bay as a Special Management Area under the CMP (SM-1)
- Create system to track development of local regulations consistent with CMP (SM-2, 3)
- Establish standards and guidelines for shoreline development (SM-2, 3)

Data information needs for assessing plan objectives include:

- Numbers of new recreational opportunities and access opportunities established around the bay (SM-5)
- Documentation of activities resulting in reduced negative environmental impacts to the bay (SM-4)
- Land use maps with adequate detail for shoreline planning (SM-1)

## **MONITORING ELEMENTS FOR WATER AND SEDIMENT QUALITY IMPROVEMENT**

### Programmatic Monitoring

The ultimate measure of success in this element will be measured in environmental terms. However, there are programmatic measures important to success of the Water Quality element. Examples of these measures are:

- Establishment of sediment quality criteria (WQS-3)
- Development of Total Maximum Daily Loads (TMDL) for toxics in Galveston Bay watersheds, (WQS-4)
- Incorporation of TMDLs for toxics into NPDES permit process (WQS-4)
- Monitor activities in support of Clean Texas 2000 (WQS-5)
- Track NPDES permit issuance (WQS-4, 6, & 7)
- Monitor TMDL studies for oxygen demand and nutrients (WQS-6 & 7)

Data information needs for programmatic monitoring include:

- Point and non-point nutrient and BOD loadings to Galveston Bay

### Environmental Monitoring

Integration of information from multiple sources on the various resources of Galveston Bay, especially water and sediment quality, was determined to be a critical function for successful system-wide sampling. The adoption of a common sampling design agreed to by all participants in the regional monitoring effort will greatly contribute to this integration effort. Several potential spatial strategies were evaluated by the Monitoring Work Group. These included randomized sampling, stratified random designs and a probabilistic sampling model such as the one used in the EPA Environmental Monitoring and Assessment Program (EMAP).

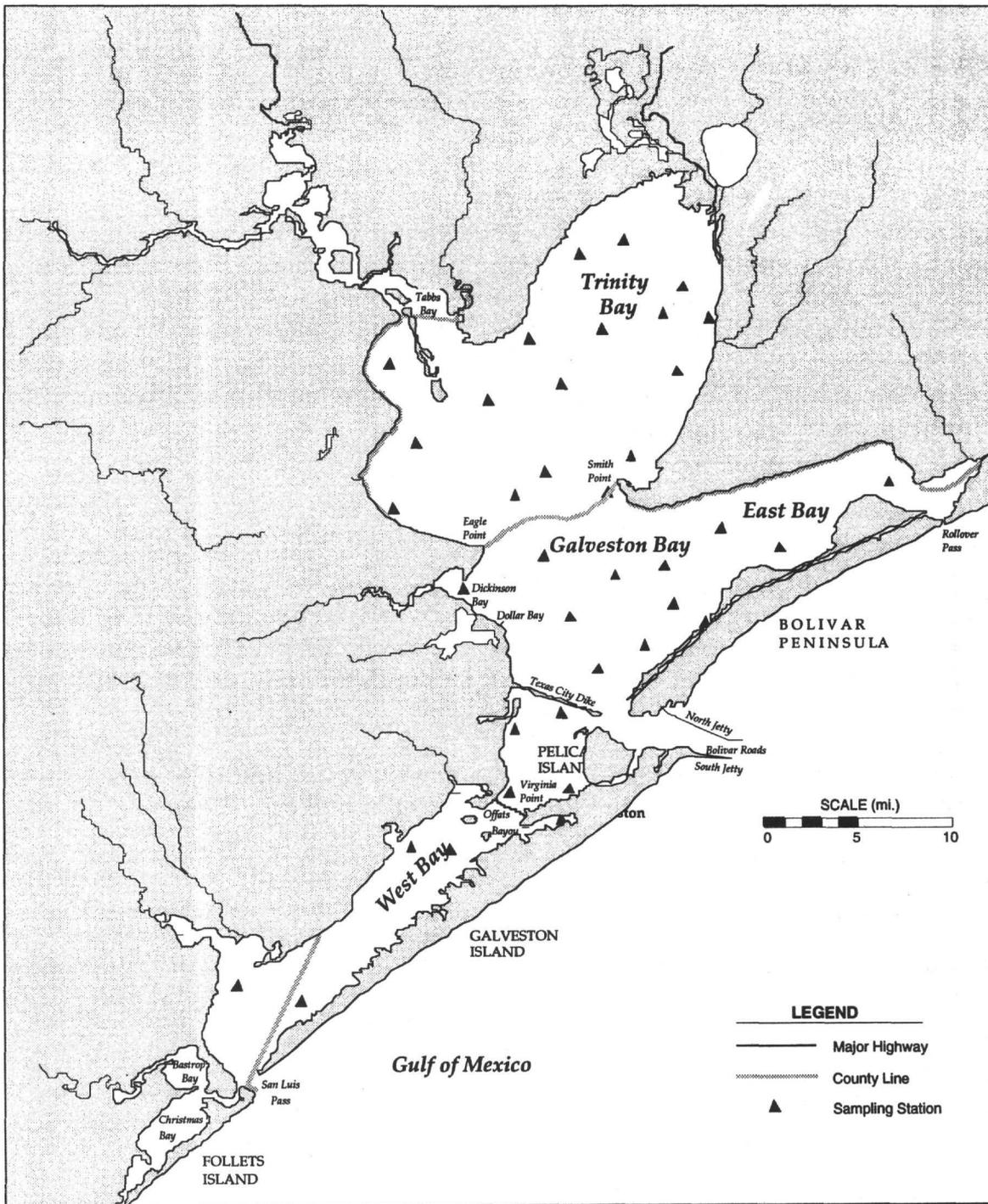
The spatial design model adopted for the open-bay water portions of the Regional Monitoring Program is the probability-based, hierarchical grid design utilized by EMAP. The design uses probability sampling theory to provide rigorous, unbiased estimates of environmental conditions. EMAP stated goals and objectives were determined to be consistent with our own:

- Estimate the current status and trends in the condition of ecological resources within a defined spatial scale, with known statistical confidence
- Seek associations among anthropocentric stress and ecological conditions
- Provide periodic statistical summaries and interpretive reports on ecological status and trends to resource managers and the public

Recently conducted R-EMAP projects, including one in Galveston Bay in 1993, have demonstrated the utility of the grid structure in addressing any spatially distributed and well defined ecological resource. In addition, this approach has been successfully applied to several estuary monitoring programs including the Delaware Bay, Tampa Bay and Sarasota Bay National Estuary Programs. In the opinion of the Work Group this design had numerous advantages over other considered designs.

Monitoring tidal stream segments is a second element in the Regional Monitoring Program. Tidal stream sampling design will coordinate current sampling efforts of monitoring entities. Adoption of comparable sampling and analytical methods will allow creation of a regional database incorporating data from all local and state agencies. This effort will be closely coordinated with the Texas Clean Rivers Program. Clean Rivers is a state program administered locally by the Houston-Galveston Area Council. Its goals are to provide coordinated river basin monitoring information utilizing a watershed management approach. Two major river basin watersheds for the Galveston Bay system are the San Jacinto and lower Trinity systems. The Monitoring Work Group is working closely with the regional Clean Rivers Program to ensure comparability with Galveston Bay Regional Monitoring Program sampling efforts. Close coordination with the Clean Rivers Program will assure a truly regional monitoring program which will include the entire Galveston Bay watershed.

The Monitoring Work Group adopted water and sediment quality assessment goals that would allow bay-wide determinations of estuarine conditions on an areal basis within ten percent annually. Sample site selection was made by randomly placing a 4-fold enhancement of the EMAP grid structure over the Galveston Bay area. The result is approximately 30-40 hexagons of approximately 70 km<sup>2</sup> with a 7.5 km distance between the grid centers. From these hexagons, random site selection procedures produced 34 sampling sites (Figure RM-4).



SOURCE: EPA, 1994

**FIGURE RM-4. Galveston Bay Regional Monitoring Program  
Ambient Water and Sediment Quality Sampling Stations**

The Regional Monitoring Work Group acknowledges Dr. Kevin Summers of the EMAP-Estuarines program in Gulf Breeze, Florida, who provided the technical assistance for enhancement of the EMAP sampling grid system.

In addition to the goal of determining trends within 10 percent on an areal basis, biennial assessments of the statistical resolving power of the sampling plan, for trend detection, will be conducted by the Galveston Bay Program staff. This will be accomplished using the Macintosh based JMP<sup>®</sup> statistical package developed by the SAS Institute Inc. Power analysis evaluations of selected parameters from the historical data set, compiled during the characterization phase of the program, have demonstrated that sample sizes required to meet recommended power criteria of 80 percent are highly variable. For example, sample sizes designed to detect a 25 percent change from the historical mean for NH<sub>3</sub> - N, at a power level of 0.8 would require approximately 25 samples. In contrast, similar evaluations for TOC and total zinc would require only 4 and 17 samples respectively. Based on these estimates, the chosen sampling scheme will enable program staff to make reliable estimations of trends in Galveston Bay.

### **Water Quality**

Estuarine waters represent an important habitat for many commercially, recreationally, and ecologically important organisms. These waters also represent a medium in which food, larvae, nutrients, and contaminants may be transported throughout the estuary. Water quality monitoring will provide information to characterize the condition of the aquatic environment, evaluate potential stresses to aquatic organisms, and track habitat recovery following adverse environmental impacts.

Broad water quality monitoring objectives aimed at providing information to assess action items were outlined by the Water and Sediment Quality Task Force. These are:

- Characterize the concentration and trends of selected toxics in Bay waters and sediments (WSQ-1)
- Characterize the magnitude and trends of toxicity in waters and sediments (WSQ-2)
- Characterize the magnitude, extent and trends of selected conventional water and sediment quality parameters (WSQ-1)

Based on these objectives and recommendations from Water and Sediment Quality Task Force members, the indicator parameters for water quality were selected and are outlined in Table RM-5. Tier One Water Quality parameters will be collected quarterly at a minimum and Tier Two parameters will be collected on an annual basis.

### *Contaminants of Concern*

Not all chemicals in the environment warrant equal attention. Contaminants of concern (COCs) are a limited set of chemicals that may adversely affect bay biota and human populations. Concentrations of COCs are needed to characterize the condition of aquatic habitats and evaluate effectiveness of management actions. A primary objective of the Regional Monitoring Program is to measure attainment with state water quality standards for

chemical toxics. COCs will be established from state Surface Water Quality Standards Criteria which establish numerical levels for both aquatic life and human health protection.

**TABLE RM-5. Parameters and Performance Criteria for Water and Sediment Quality**

**Ambient Water Column Tier One Monitoring:**

**Parameter**

***In situ Measures***

- Temperature
- Salinity
- Conductivity
- pH
- Dissolved Oxygen
- Turbidity, as Secchi depth
- Sample depth

***Analytical Samples:***

- TSS, VSS
- Oxygen demand, 5-day BOD (tributary monitoring only)
- Nutrients: Nitrogen - NH<sub>3</sub>-N, nitrate, nitrite,  
Phosphorous - Total and ortho-  
Carbon - TOC
- Chlorophyll-a
- Fecal coliforms

**Parameters for Ambient Water Column Tier Two Monitoring:**

- Water Hardness (for salinity < 2 ppt)
- Dissolved Metal COCs
- Organic toxic COCs
- Pesticide COCs
- Ambient toxicity

**Parameters for Sediment Quality Monitoring:**

- Grain size (to be developed)
- Sediment bound metals
- Sediment bound organics
- Benthic community assessments
- Sediment toxicity tests
- Acid Volatile Sulfides (to be developed)

### *Continuous Monitoring for Dissolved Oxygen*

Areas within the bay system, sensitive to variations in DO will be monitored with continuously recording instrumentation to supplement the DO measurements collected as part of Tier One sampling. This data will be used to evaluate diurnal patterns of DO and compliance with state water quality criteria. These probes will also provide data for conductivity, salinity, temperature and pH.

### *Concentration of Nutrients*

Nutrients in bay waters can affect plant growth and, in certain instances, can result in algal blooms and eutrophication of bay waters. Conversely, low levels of nutrients can become limiting factors in the bay's overall productivity. Ward and Armstrong (GBNEP-22) performed a quantitative assessment of water and sediment quality over time. This characterization report highlighted significant reductions in suspended solids and nutrient loadings to the bay over the last two decades. These trends are of concern as a potentially limiting factor of productivity in the bay. This study emphasizes the importance and provides the foundation for further scientific study of nutrients in Galveston Bay. To address this concern, nutrient evaluations have been included as a major component of the water quality program. Monitoring nutrients in bay waters and inflows will provide information needed to 1) characterize ambient nutrient levels, 2) help explain and identify potential causes for observed changes in plant species composition, growth and/or distribution, and 3) help in assessing the status of nutrient loadings to the bay.

### *Phytoplankton*

Phytoplankton provide a major direct food source for both the pelagic and benthic food chains in estuaries. Phytoplankton biomass is most frequently estimated through the measurement of chlorophyll-a concentration. As a potential enhancement to this program, evaluation of high-performance liquid chromatography (HPLC) methods of chlorophyll determination are recommended. HPLC provides the most accurate measurement of chlorophyll a, b, c and their degradation products. It can also provide information on relative proportions of pigments from which estimations of phytoplankton distributions can be based.

### *Ambient Toxicity*

Toxicity of bay waters will be evaluated using tests adopted from EPA toxicity methods. Both vertebrate and invertebrate species will be evaluated for their response to exposure to bay waters. Candidate freshwater tests are the seven-day chronic tests for *Ceriodaphnia dubia* and fathead minnow, *Pimephales promelas*, embryo larval and teratogenicity test. Candidate marine tests are the nine-day embryo-larval and teratogenicity chronic test for sheepshead minnow, *Cyprinodon variegatus*, and the 96-hour acute test for mysids, *Mysidopsis bahia*.

### *Physical Attributes*

Salinity and temperature data will be used to identify distinct water masses, determine the areal extent of the influence of freshwater and Gulf of Mexico water inflow, and assist in explaining and identifying potential causes for changes in the abundance and distribution of salinity and temperature dependent biota. Contaminants tend to sorb to particulates in the water column. Measurement of total and volatile suspended solids will be used to estimate

bioavailable COC concentrations in bay waters. Suspended substances increase both the scattering and absorption of photosynthetically active radiation (PAR). A reduction in the depth to which light penetrates can result in reduced growth of phytoplankton and submerged vegetation. Turbidity, as Secchi depth, will be used to estimate light penetration in water. In areas of submerged aquatic vegetation direct measurement of light (PAR) will be made.

#### *Implementation*

Numerous agencies including the TNRCC, GCHD, HCPCD, City of Houston, USGS and TPWD have ongoing monitoring programs which supply information for evaluation water quality. A well coordinated effort of station location and parameter selection will allow integration of data collected from all agencies for inclusion in the Regional Monitoring database. Volunteer monitoring data will also be incorporated into the regional database.

### **Sediment Quality**

Estuarine sediments represent an important habitat for many commercially, recreationally, and ecologically important organisms. Sediments also represent the ultimate sink for many chemical toxics in the estuarine environment. Sediment quality monitoring will provide information to characterize the condition of the aquatic environment, evaluate potential stresses to aquatic and sediment-dwelling organisms, and track habitat recovery following environmental interventions.

Based on *Plan* objectives and recommendations from Water and Sediment Quality Task Force members, the parameters listed in Table RM-5 will be collected as part of the sediment quality component of the regional monitoring program.

#### *Contaminants of Concern*

Concentrations of COCs are needed to characterize the condition of benthic habitats, provide early warnings of potential impacts to estuarine biota, and evaluate the effectiveness of management actions. Research strongly suggests that measurements of total organic carbon (TOC) and acid volatile sulfides (AVS) are needed to estimate bioavailable concentrations of selected organic compounds and metals, respectively. Development of these analytical capabilities by the TNRCC laboratory will be pursued. These parameters will be evaluated on a limited basis upon establishing analytical capabilities. Sampling and analysis of these parameters on a regular basis will be implemented upon adoption of sediment criteria requiring their use.

#### *Benthic Invertebrates*

The identification and enumeration of infaunal and epibenthic invertebrates will be used to characterize benthic communities, assess sediment quality, and assist in predicting potential impacts to bottom-feeding fish and birds. Number of species and dominance will be some of the metrics used to characterize the structure of the benthic communities. Functional characterizations of benthic communities will be based on dominant feeding types. Sediment quality will be assessed based on relative abundance of pollutant-resistant species, species richness, and dominance.

### *Depth of Aerobic Sediments*

The depth of aerobic sediments provides a direct measurement of the biologically active zone. This will be used to determine the depth to which sediment samples will be taken. It is also important in the evaluation of the presence of particular benthic assemblages. Shallow aerobic sediments are often dominated by small polychaetes; whereas deep aerobic sediments typically support more diverse benthic communities.

### *Grain Size*

The bioavailability of sediment contaminants are often correlated to sediment grain size. Grain size data are also needed to explain and identify potential causes for temporal and spatial variability in benthic communities: changes in grain size often affect an infaunal organism's ability to build tubes, capture food and escape predation.

### *Sediment Toxicity*

Toxicity of bay sediments will be evaluated using sediment elutriate tests adopted from EPA toxicity methods. Both a vertebrate and invertebrate species will be evaluated for their response to exposure to bay sediments. Candidate freshwater tests are the seven-day chronic tests for *Ceriodaphnia dubia* and fathead minnow, *Pimephales promelas*, embryo larval and teratogenicity test. Candidate marine tests are the nine-day embryo-larval and teratogenicity chronic test for sheepshead minnow, *Cyprinodon variegatus*, and the 96-hour acute test for mysids, *Mysidopsis bahia*. These tests, as conducted by the US EPA Regional Laboratory for the TNRCC, have been shown to produce valuable information on bay-area sediment quality, especially in tributary sediments. These methods will be assessed over a two year period to determine if valuable sediment information is being obtained. Tests will be evaluated for appropriate modifications or elimination as indicated from a review of the data.

### *Implementation*

The only current broad-based, long-term monitoring of bay sediments is conducted by the TNRCC. The Corps has a program which emphasizes sediment deposition in navigation channels. With sampling assistance to be provided by other monitoring agencies and increased resources within the TNRCC an expanded sediment monitoring effort will be implemented. This program will collect sediment samples from half of the water/sediment quality sites each year. Collections will be done during late summer months. Analyses will cover a wide range of organic and inorganic toxics and sediment toxicity testing.

## **Non-Point Sources of Pollution**

Control of non-point sources of pollution is one of the most difficult areas of environmental management. The bay is impacted by urban and rural area runoff carrying toxics, sediment, bacteria and nutrients. This problem is compounded by the fact that losses in wetland habitats reduce the natural cleansing ability provided by these habitats. The plan to reduce the harm caused by non-point sources (NPS) is addressed through both regulation and public education actions.

### Programmatic Monitoring

In response to *Plan* actions the following administrative monitoring actions will be implemented by the program office.

- The Program Office will develop a Galveston Bay Best Management Practices Performance Document for NPS control techniques (NPS-2)
- Success of public education programs directed at reducing NPS pollution will be evaluated (NPS-4 & 5)
- Submittal of the CMP Texas Coastal NPS Reduction Plan by CCC and GLO will be tracked (NPS-6)
- An NPDES stormwater permitting tracking programs will be implemented (NPS-8)

To properly assess these management program objectives data information needs:

- Local municipalities will be surveyed for progress in development of stormwater programs, shoreline septic tank ordinances, construction standards for NPS reductions (NPS-1, 4, 5, 6, 7, 12, & 13)
- Galveston Bay marinas will be monitored for implementation of sewage pumpout and storage facilities, and washdown activities at targeted marinas (NPS-14)
- Surveys targeted at boats will evaluate compliance with use of approved marine sanitary chemicals (NPS-15 & 16)

The first three goals (Actions NPS-1-13) of the NPS action plan call for reductions in NPS pollutant loads. Because of the diverse nature of NPS pollution it is not feasible to monitor every source of discharge. To address these objectives monitoring will focus on implementation of BMPs rather than onsite monitoring. Monitoring will be limited to BMP pilot studies from which projected loading reductions from implementation of BMPs will be determined.

### **Point Sources of Pollution**

This action plan outlines means of improving the control of point source discharges into Galveston Bay. The routine operations of larger point sources are heavily regulated and have shown considerable improvement over the last 20 years. For this reason, this action plan focus on non-routine operations such as elimination of wet-weather bypasses and overflows at larger facilities and elimination of operational problems smaller discharges.

### Programmatic Monitoring

The Program Office will implement tracking of the following activities related to point source action goals. These activities will include:

- Issuance of TNRCC administrative orders requiring studies to identify overflow and bypass problems (PS-1 & 2)
- Tracking submittals of corrective action plans of larger POTWs to address identified bypass and overflow problems (PS- 1 & 2)

- Monitoring of coordinated NPDES compliance and enforcement actions of small bay area dischargers (PS- 3 & 4)
- Tracking implementation of dry-weather illicit connection programs by local municipalities (PS-5)
- Monitoring issuance of permits to produced water discharges by EPA or Texas Railroad Commission (PS-6)

Data information needs to be utilized in assessing program success include:

- Records of reported by-pass or overflow events and amounts
- Number of POTWs with satisfactory or higher ratings from Compliance Evaluation Inspections, conducted by TNRCC and EPA
- Permit violations for limits exceedances

### Environmental Monitoring

Incidence of environmental degradation that can be associated with produced water discharges will be documented. This information may come from toxicity testing information, benthic survey data, sediment or water chemistry, and other sources.

## **IMPLEMENTING THE REGIONAL MONITORING PROGRAM**

### **Regional Monitoring Steering Committee**

The Galveston Bay Council will establish a Regional Monitoring Program Steering Committee whose purpose will be to 1) establish final design specifications for Galveston Bay's Regional Monitoring Program; 2) oversee implementation of the program; 3) ensure comparability of monitoring efforts; 4) direct and approve future monitoring design modifications; and 5) secure institutional support for the program.

The Regional Monitoring Program Steering Committee will be a consortium of agencies, institutions, and organizations. It is highly recommended that the institutional membership of the Regional Monitoring Work Group be considered for inclusion in this body. The Regional Monitoring Steering Committee will be a governing body composed of representatives from

- Participating local, state, and federal agencies
- Environmental, private industry, and public interest groups
- Academic institutions

The Galveston Bay Regional Monitoring Program will delineate a program which is dynamic and subject to periodic re-evaluation of design, procedures, and findings to ensure its continued scientific credibility and its usefulness to policy makers and the public. It will be the responsibility of the Steering Committee to ensure that this re-evaluation take place in a rigorous manner, and that changes are made to the program as necessary. Guiding principles for the Regional Monitoring Program Steering Committee include:

- The Steering Committee will have responsibility for 1) review and modifications to monitoring elements, 2) creating new monitoring program elements, as appropriate; 2) developing new protocols; and 3) managing, interpreting, and reporting regional monitoring data.
- The Steering Committee will work to involve all parties (federal, state, and local agencies, research institutes, and academic institutions) engaged in monitoring and research in the estuary to maximize the usefulness and efficiency of public moneys spent on monitoring, but it will not dictate changes in ongoing agency monitoring programs.
- The Steering Committee will not make policy recommendations on regulatory or management issues. The Steering Committee will, however, seek to provide relevant information to policymakers and bring identified problems to the attention of policymakers and the public. It will establish policy on monitoring and recommend research needs related to monitoring efforts.
- The Steering Committee will be responsible for effective translation of scientific data (its own and that of others) in terms that policymakers and the public can readily understand. A periodic report on conditions in the estuary will be produced and distributed.
- The Steering Committee will be accountable to the Galveston Bay Council.

### **Galveston Bay Program Office**

The Galveston Bay Program Office will have full-time staff responsible for monitoring action implementation and outcomes. The Galveston Bay Program Organization Plan will be structured to mirror initiatives found in *The Plan*. Every *Plan* Action will be managed by one of four organizational groups. These groups are Water/Sediment Quality, Natural Resources Uses, Monitoring and Research, and Public Participation. The Program will track implementation of *Plan* Actions, submit annual reports of these activities, implement any actions which *The Plan* delegates to the Program Office, and work with other lead agencies to develop assessment tools to measure the effectiveness of *Plan* actions.

### **COMMUNICATING RESULTS: DATA AND INFORMATION MANAGEMENT**

One of the limitations of estuary monitoring systems across the country, including Galveston Bay, is that results from different monitoring programs are not easy to compile for ecosystem analyses. Agencies maintain different data bases and report formats, acquisition of data can be time-consuming, and no centralized data management system is currently available to report on overall trends. To alleviate these problems, a Data and Information Management System (DIMS ) for Galveston Bay has been developed as an integral part of the Regional Monitoring Program.

#### **DIMS Objectives**

The Galveston Bay DIMS has been structured to meet the following objectives:

- Ensure the long-term integrity, storage, and accessibility of high-quality data collected by Galveston Bay's Regional Monitoring Program.
- Ensure data quality.
- Improve the access to information at various decision-making levels.
- Facilitate the integration and analysis of existing physical, chemical, and biological data to generate information useful to resource managers.
- Support statistical, graphical, spatial analysis and mapping of monitoring data, (e.g. power analyses, computer-compatible geographic information system (GIS) format).

### Summary of Agency Data Management Systems

There are 19 programs presently conducting monitoring in Galveston Bay. In most cases the data are stored 1) on in-house computers under a variety of formats, or 2) on paper. Although most data are made available to the public, access is often difficult. There is no central data storage system that would allow easier access for the public or the agencies presently concerned with monitoring Galveston Bay. Some duplication of effort is noted, particularly for point source monitoring. Most efforts are directed at fulfilling specific agency mandates and have not been geared to ecosystem scale assessments. Ward (GBNEP-22) cites numerous challenges encountered in compiling 26 data sets for such an analysis. Publications GBNEP-7 and 8 also document monitoring deficiencies encountered in obtaining and compiling historical data sets. To address some of these problems during the development of *The Plan*, several GBNEP projects were conducted to compile data sets from diverse sources and to allow easy exchange of existing bay information. For example, the Galveston Bay Information Center was developed to serve as a clearinghouse for all types of literature about the bay.

There are several existing database management systems (DBMS) and GIS systems running on various platforms at the local, state, and federal agency level. The diversity of existing and planned DBMS applications, GIS applications, and hardware platforms at the agency level reveals a determined use of best available technology. However, these conditions have made it difficult for agencies to access, query, transmit, and analyze resource data in an efficient and timely manner. Getting different DBMS on different hardware platforms to communicate is technically challenging. Currently, no statewide computer network system exists to quickly and easily share data among state and federal resource agencies.

In 1989 the Texas Legislature enacted legislation which requires that state agencies share information and information resources. In the same year, the Department of Information Resources (DIR) was established to provide the leadership role in this area. From this effort two planning groups important to the Galveston Bay DIMS have been formed. The GIS Planning Council was formed to make recommendations to DIR concerning GIS coordination. The GIS Standards Committee was formed to develop and/or recommend GIS technical standards to DIR. Statewide efforts have not specified the use of specific DBMS software or networking hardware products to agencies. Because no single existing system or network of systems currently exists to accommodate Galveston Bay's regional monitoring data, GBNEP has planned a regional DIM system that conforms to existing and planned statewide agency and information management plans wherever possible.

## **Design of Galveston Bay DIMS**

The Galveston Bay DIM system will be implemented in phases. In the first phase, Galveston Bay's DIM will emphasize standardized data file structures and implementing data storage and retrieval from a centralized system. Centralizing data to one database server will simplify the tasks of storing, maintaining, locating, querying, and retrieving regional monitoring data. Later phases will include modifying the system to include linking all participating agency database servers on a Wide Area Network (WAN).

Participating federal, state, and local agencies will be assigned primary responsibility for adapting standardized formats for data collected by their program. All water and sediment quality data collected will be submitted to the Houston-Galveston Area Council (HGAC). Additional roles to be performed by the HGAC include data quality assurance and handling data requests for regional monitoring data. A direct link will be established between the Galveston Bay Program Office and the HGAC. HGAC will serve as custodian and repository for all Galveston Bay regional monitoring data. HGAC has been named as a regional provider in the state data information system and is responsible for data management of the Texas Clean Rivers Program in the Galveston Bay area. Once this system is established the Program Office will be able to access all information through their HGAC link.

Future planning will allow all contributing agencies wide-area LAN access to this system for data input and on a read only basis through the HGAC Office. Base maps of interest to many agencies will be stored, managed, and accessed at a centralized location within the Galveston Bay Program Office as well as HGAC. Particular emphasis will be placed on keeping all agencies in the information management loop through establishment of a committee to help define data formats and data structure.

## **Network Architecture**

HGAC currently maintains a UNIX network with Hewlett-Packard workstations. This network is linked to a Novell network with approximately 100 personal computers (PCs). The UNIX workstations run Arc/Info GIS software and the PC's run in Windows environment.

In the future a WAN will connect database servers located at participating agencies. A network design that is inexpensively maintained and that allows individual users (i.e., workstations or dumb terminals) and local area networks (LANs) to be easily and inexpensively added to the system will be selected.

## **Data Types**

The DIMS system will support the following data types:

- Discrete and continuous numeric monitoring data
- Nonparametric monitoring data (e.g., presence/absence data)
- Text or memo formats
- Maps and charts, i.e., geographically referenced data

Galveston Bay's DIMS system will store core base maps in a central location in accordance with the state GIS Planning Council's recommendation. Participating agencies may request copies of specific core base maps and have them mailed on magnetic disks or optical CDs.

A standard file structure will be established for each data type (e.g., water quality data, population abundance data, toxicity testing data). The standard file structures will link QA/QC information and other data to their parametric and geographically referenced data. Directly linking meta- and monitoring data will ensure that information needed to assess the quality of monitoring data will not be lost.

### **Data Quality Assurance / Quality Control (QA/QC)**

Maintaining the integrity of data stored in the system is critical to ensuring user confidence in the system. Data stored in the central database can be queried, read, copied, and downloaded initially only through requests to HGAC or the Program Office. As direct access to the system is established users of the system will have read only access. Additions and updates to the data will only be made through standard quality control protocols.

Standardized procedures for checking submitted data will include: computerized code and range checking, technical data review, and preparation of a data QA abstract. The data abstract is for describing sampling and analytical methods, QA/QC information, and any other pertinent metadata information needed to assess data quality.

### **GIS**

GIS capabilities are viewed as an important tool for this program to complete and achieve its mission. However, it is not necessary that the Galveston Bay Program develop comprehensive GIS analytical capabilities at this time. Personnel and budgetary requirements to maintain such a system would be prohibitory. For this reason an ARC-INFO ARCVIEW system electronically linked to the main server at HGAC will be the level of entry into GIS. ARCVIEW allows the integration of intermediate and final GIS products needed for this program. Core GIS data sets will be kept and maintained at the Program Office or accessed through the direct link with HGAC. Most of these data are readily available from sources such as state and federal agencies. This system would allow GBNEP to integrate and maintain all of its data sets geographically.

### **DIMS Systems Administration**

Galveston Bay's DIMS Steering Committee will be responsible for overseeing the implementation of the DIMS, approving all DIMS system modifications, and securing future funding sources. The HGAC will be responsible for administration of the Regional Monitoring Data system. These responsibilities will include:

- Providing DBMS technical support to agency database managers and system users
- Designing and implementing user interfaces and/or other system applications

- Securing sources of financial support for the system

Additional specific responsibilities will include supervision of system quality assurance and implementation of system upgrades.

### **Communicating Monitoring Results**

The system will support the following user groups:

- Galveston Bay Council
- Technical and scientific staff of participating agencies
- Technical and scientific staff of non-participating agencies
- Private industry
- Public interest groups
- Schools
- General public

Technical staff of non-participating agencies, private industry, public interest groups, schools, and the public will have access to raw monitoring data. In addition there will exist the ability to retrieve selected summary statistics and display these data on core base maps. Requests for data will be handled through HGAC or the Program Office. In the future the Program Office will support evaluation programs for development of direct link data service centers at strategic locations. These would be established to support direct access to the system for non-participating agencies, private industry, public interest groups, schools, and the general public. Selected bay-wide summary statistics will be available to the public for downloading at the service centers. Requests for raw regional monitoring data will continue to be made through the HGAC or the Galveston Bay Program Office.

Information from The Galveston Bay Regional Monitoring Program will be available in two formats: technical reports for the scientific community and non-technical briefs for the lay public. Programs will be written to automatically conduct the appropriate data queries, data retrievals, data analyses, and data presentations (e.g., graphs, maps). Ad hoc analyses may be used, as needed, to supplement these fundamental data analyses. A set of most requested bay information may be published in an annual report as well as made available on-line in the system.

The Galveston Bay Program Office will be responsible for comparing the results from the monitoring program with the objectives listed in *The Plan*. The comparison will be conducted for both environmental objectives and management objectives in *The Plan*. The comparisons will be conducted on an annual basis and summarized in the DIMS system. In addition a more robust bay-wide analysis of the data will be conducted every two years, with Galveston Bay Program staff presenting evaluations of implementation findings through the State of the Bay Symposium.

### Bay Barometer

A potential tool for communicating the status of the health of the ecosystem is the development of a Galveston Bay barometer similar in approach to the one used in the Chesapeake Bay Program. For example, such a barometer could include several easily measured components of the Galveston Bay system, such as:

- Trends in species abundance ( key species sampled by TPWD)
- Water quality (index of key TNRCC parameters, such as DO and FC)
- Seafood consumption safety (based on planned risk assessments of seafood)
- Habitat (planned studies showing the change in wetland and reef areas)
- Areas opened to oyster harvest

Using these types of data, a simple index could be developed for each component, and a total number that indicates the general health of the ecosystem could be provided. This number could then be used as a simple, general yardstick to tell the public how the bay is doing. The Bay Barometer concept will be developed by the Galveston Bay Program Office.

### **Sources of Financial Support**

Several candidate sources of financial support for the implementation and maintenance of the DIMS system were identified by the Data and Information Management Task Force, including

- Corporate sponsors
- Other state-wide or gulf-wide data sharing projects
- Line-item support from the State

Private sector corporations and software/hardware vendors will be sought out to sponsor, in part, the cost of hardware and software needed to implement the DIMS system. Candidate corporate and vendor sponsors will be aggressively pursued by the chair of the Regional Data Management Steering Committee and the DIMS systems administrator.

Furthermore, the implementation of Galveston Bay's DIMS system may be partially supported through other statewide or gulfwide data management projects including the Coastal GIS Initiative, the Natural Resources Inventory, the Texas Clean Rivers Program, and the Gulf of Mexico Program (GMP).

The Chair of the Regional Data Management Steering Committee and the DIMS systems administrator will pursue all statewide and Gulf Coast financial sources. The Chair of the Regional Data Management Steering Committee and the DIMS Systems Administrator will aggressively approach the legislature to seek line-item status for Galveston Bay's DIMS system.

**TIMETABLE**

A detailed timetable for analyzing the data and assessing program performance will be developed at a later date.

*This chapter was based on material provided in the Regional Monitoring Program report prepared by Tetra Tech, Inc.*

