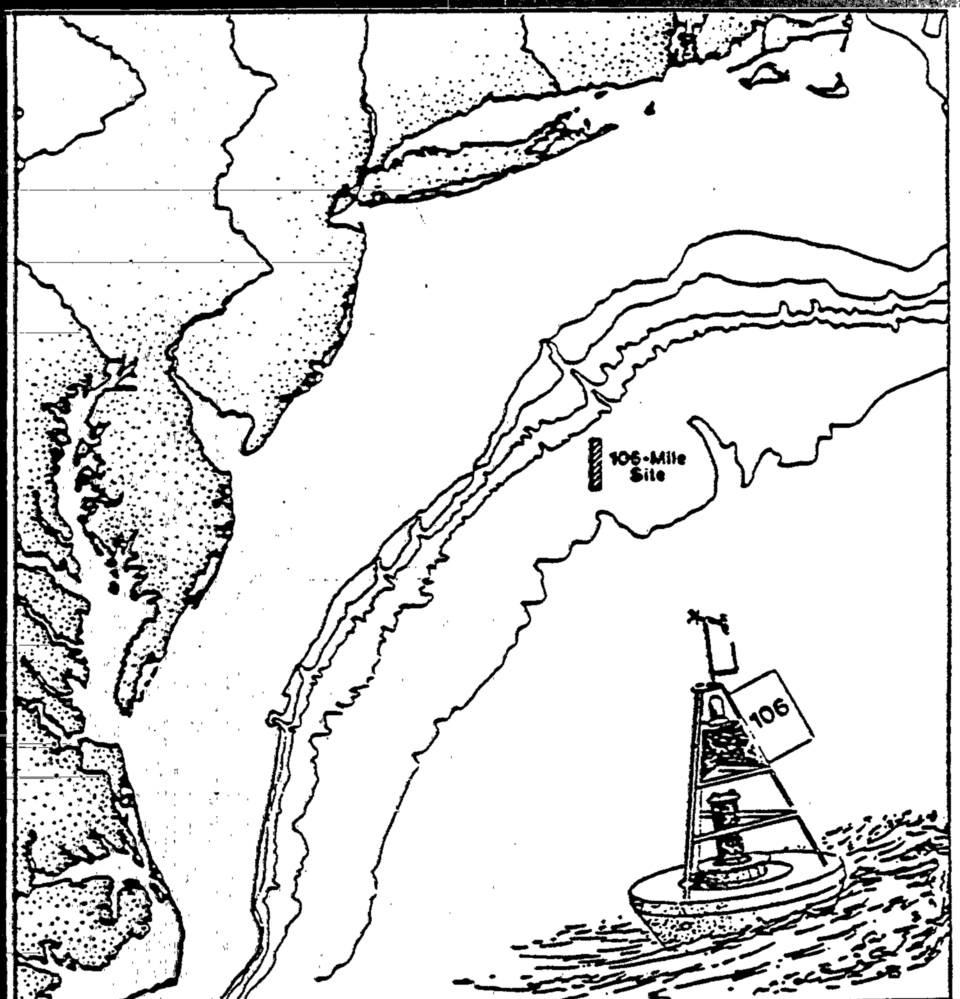
United States Environmental Protection Agency | Office of Water (WH-556F) | EPA 842-S-92-009 June 1992

EPA

Final Draft Monitoring Plan for the 106-Mile Deepwater Municipal Sludge Site



Recycled/Recyclable
Printed on paper that contains at least 50% recycled fiber

FINAL DRAFT

MONITORING PLAN
FOR THE
106-MILE DEEPWATER
MUNICIPAL SLUDGE SITE

March 11, 1988

U.S. ENVIRONMENTAL PROTECTION AGENCY
Region II
New York, New York
and
Office of Marine and Estuarine Protection
Washington, DC

Prepared Under Contract No. 68-03-3319

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

1. INTRODUCTION

The U.S. Environmental Protection Agency (EPA), under the Marine Protection, Research, and Sanctuaries Act of 1972 (MPRSA, PL 92-532), is responsible for regulating disposal of sewage sludge in ocean waters. This responsibility includes developing and maintaining effective monitoring programs for ocean disposal sites designated by EPA. The basis and structure of the monitoring program for the 106-Mile Deepwater Municipal Sludge Site (106-Mile Site), designated in 1984 for disposal of municipal sludges, is described in this document. A separate plan for implementing the monitoring program discussed here is presented in a companion document (EPA , 1992).

EPA's responsibilities for regulating disposal of sewage sludge into marine waters encompass not only monitoring, but also designation of appropriate sites for disposal and issuance of ocean dumping permits. The site designation process is designed to provide suitable sites for ocean dumping, based on need for a site and on indications that unacceptable impacts to human health and the environment will not occur. The permitting process further restricts disposal activities to those that allow only limited environmental effects of individual dumping operations, as well as limited cumulative effects from multiple or con inuing activities. In designating sites and issuing permits, EPA assumes that criteria for site designation and permitting are sufficient to protect the marine environment as prescribed by the MPRSA. Monitoring programs such as the one described in this document are designed 1) to verify compliance with permit requirements and 2) to verify that compliance with permit requirements does in fact to protect the environment (Zeller and Wastler, 1986).

Development of EPA's plan for monitoring sludge disposal at the 106-Mile Site has benefited from the work of many others who have also proposed monitoring plans for the site or who have used the 106-Mile Site as a case study in works describing effective approaches to ocean monitoring. Several authors have suggested that a step-wise approach to monitoring provides for the most effective use of resources and results in the most useful information (e.g., EG&G, 1983; Segar et al., 1984; Segar and Stammen, 1985; Zeller and Wastler, 1986). Plans have also been developed based on review of other long-term oceanic monitoring activities and previously proposed monitoring plans for deepwater dumpsites (CDM, 1984). A plan based on an iterative series of measurements suggested from models of sludge dispersion has been proposed (O'Connor et al., 1985). The sludge dispersion models were based on the characteristics of the 106-Mile Site and on the sludges to be disposed there.

This monitoring plan for the 106-Mile Site has built on those previous plans. It has been developed using an approach based on the current ocean dumping regulations and designed to provide for efficient and effective monitoring results that can be used in making management decisions. In its entirety, this approach has the following steps:

1) Development of a conceptual framework for the program.

2) Statement of objectives of the program.

3) Development of null hypotheses.

4) Grouping the hypotheses into "tiers."

5) Selection of parameters and the associated methods to collect data on those parameters.

6) Description of the variability of those parameters within the natural system.

7) Generation of a sampling and analysis design that will allow detection of changes in parameter values of significance to site managers.

This document is the result of Steps 1 through 4 of the approach, those steps that provide the theoretical structure to the overall monitoring program. The document introduces the activities that may be included under Step 5, which is to select the specific measurements that are included in the program. The implementation plan that accompanies this document elaborates on Step 5 and describes the remaining steps for implementing the monitoring program.

The conceptual framework of the monitoring program (Step 1) for the 106-Mile Site (Figure 1-1) is grounded in the provision of the ocean dumping regulations that monitoring programs include assessment of compliance with permit conditions and assessment of potential impacts of disposal of wastes. For the 106-Mile Site, existing information about characteristics of the site and of the sludges to be disposed has been used in determining specific conditions of the waste disposal permits and making a first determination of what sort of impacts may occur. Because of the great depths and dispersive nature of the 106-Mile Site, it is especially important that the monitoring program consider site characteristics when assessing the potential for impacts associated with sludge disposal. (Note that setting permit conditions is not part of the monitoring program. However, because monitoring compliance with those conditions is one important part of the overall monitoring program, determination of permit conditions is part of the overall conceptual framework.)

These permit conditions and potential impacts are used in formulating the null hypotheses to be tested in a program that monitors permit compliance and impact assessment. Null hypotheses are predictions presented as statements that can be

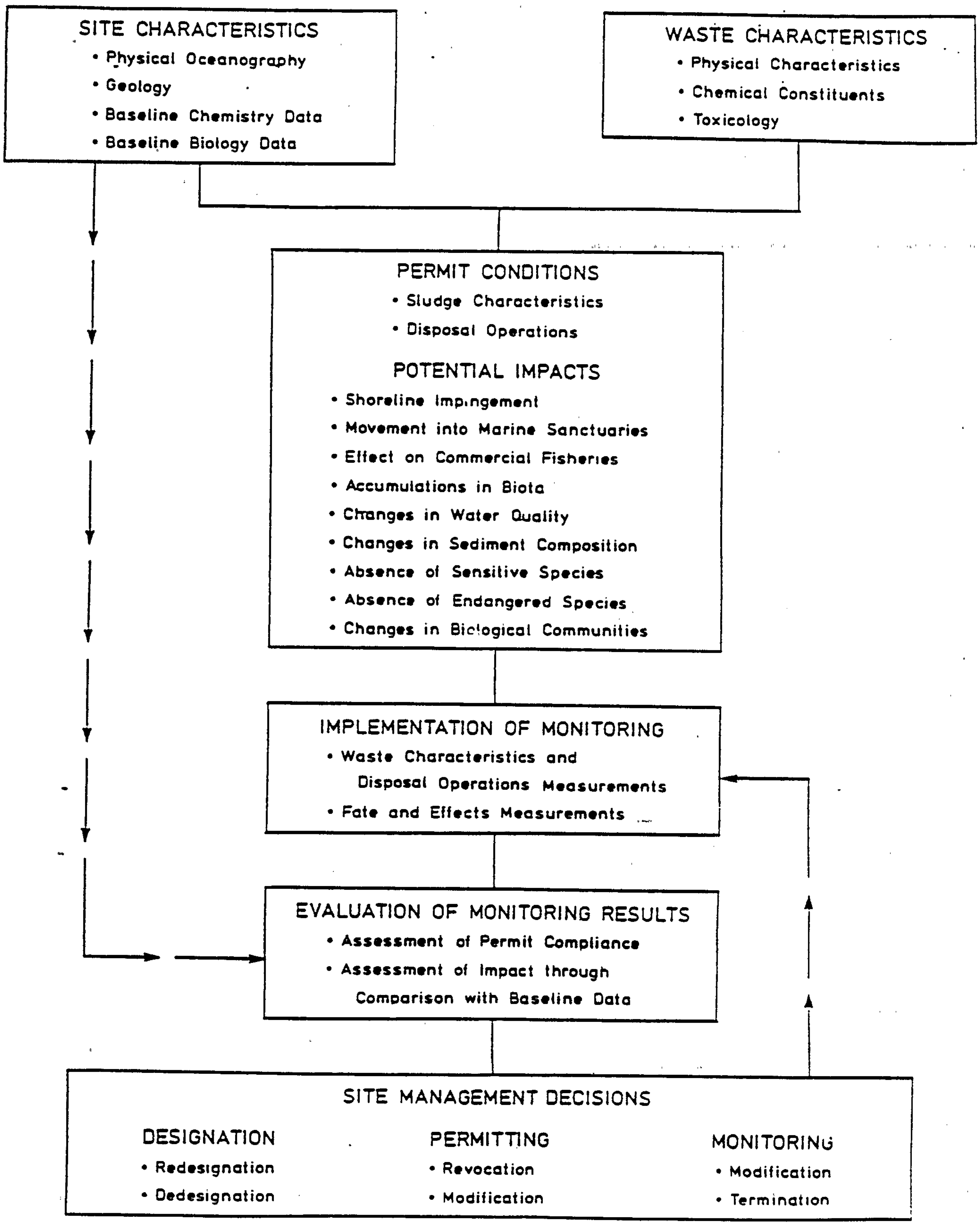


FIGURE 1-1. FRAMEWORK OF THE 106-MILE SITE MONITORING PROGRAM: CHARACTERISTICS OF THE SITE AND THE WASTE GUIDE THE PROGRAM.

disproven. Results from testing the null hypotheses are compared to permit conditions to assess compliance. Results may also be compared to baseline information to determine whether impacts have or have not occurred. These evaluations may then be used in decisions about site redesignation or dedesignation and permit continuation, modification, or revocation. They may also be used to make decisions about continuing, changing, or terminating the monitoring program itself.

The remainder of this document describes the monitoring program for the 106-Mile Site following the first steps of the general approach described above and using the framework introduced in Figure 1-1. Chapter 2 describes the regulatory basis for the program, the objectives of monitoring that are founded in those regulations, and the ultimate uses of data generated by the program. Chapter 3 describes the current understanding of the characteristics of the 106-Mile Site and of the sludge to be disposed there. Chapter 4 describes how this regulatory basis and the site and waste characteristics have been used to develop predictions of possible impacts that could occur from the disposal process and presents the null hypotheses that these predictions suggest. Chapter 5 presents an overview of the implementation of this approach to monitoring, including a description of how questions about impacts of waste disposal have been organized into tiers. Chapter 5 also briefly presents the activities that may be included in the monitoring program and describes the provisions for quality assurance and data management that are being implemented.

2. REGULATION OF OCEAN DUMPING AND THE OBJECTIVES OF MONITORING

EPA's responsibilities under the MPRSA (33 USC §§ 1401-1445) include the development and maintenance of effective monitoring programs for ocean dumpsites. In 1977, EPA published final regulations and criteria for transportation of materials for the purpose of ocean dumping (40 CFR Parts 220-229). These regulations provide a framework for the development of ocean dumpsite monitoring programs. The monitoring program described in this document for the 106-Mile Site is consistent with the management authority provided to EPA under the ocean dumping regulations and is driven by the guidelines presented therein.

2.1 MARINE PROTECTION, RESEARCH, AND SANCTUARIES ACT

Under the MPRSA, it is U.S. policy to "regulate the dumping of all types of materials into ocean waters and to prevent or strictly limit the dumping into ocean waters of any material which would adversely affect human health, welfare, or amenities, or the marine environment, ecological systems, or economic potentialities" (33 USC §1401[b]). The MPRSA gives the Administrator of EPA the authority to establish specific criteria and regulations governing the ocean disposal of nondredged materials. In establishing these regulations, EPA is directed to consider the nine factors presented in Figure 2-1 (33 USC §1412[a]).

When establishing regulations and criteria for ocean dumping, the MPRSA also requires EPA to consider applicable water quality standards and the standards binding upon the United States under the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (the London Dumping

FACTORS IN ESTABLISHING OCEAN DUMPING REGULATIONS

(A) The need for the proposed dumping

(B) The effect of such dumping on human health and welfare, including economic, aesthetic, and recreational values

(C) The effect of such dumping on fisheries resources, plankton, fish, shellfish, wildlife, shorelines, and beaches

(D) The effect of such dumping on marine ecosystems

(E) The persistence and permanence of the effects of the dumping

(F) The effect of dumping particular volumes and concentrations of such materials

(G) Appropriate locations and methods of disposal or recycling, including land—based alternatives and the probable impact of requiring use of such alternative locations or methods upon considerations affecting the public.

(H) The effect of such dumping on alternate uses of oceans, such as scientific study, fishing and other living resource exploitations, and nonliving resource exploitations

(I) In designating recommended sites, the Administrator shall utilize wherever feasible locations beyond the edge of the continental shelf.

FIGURE 2-1. THE MPRSA DIRECTS EPA TO CONSIDER SPECIFIC FACTORS IN ESTABLISHING OCEAN DUMPING REGULATIONS.

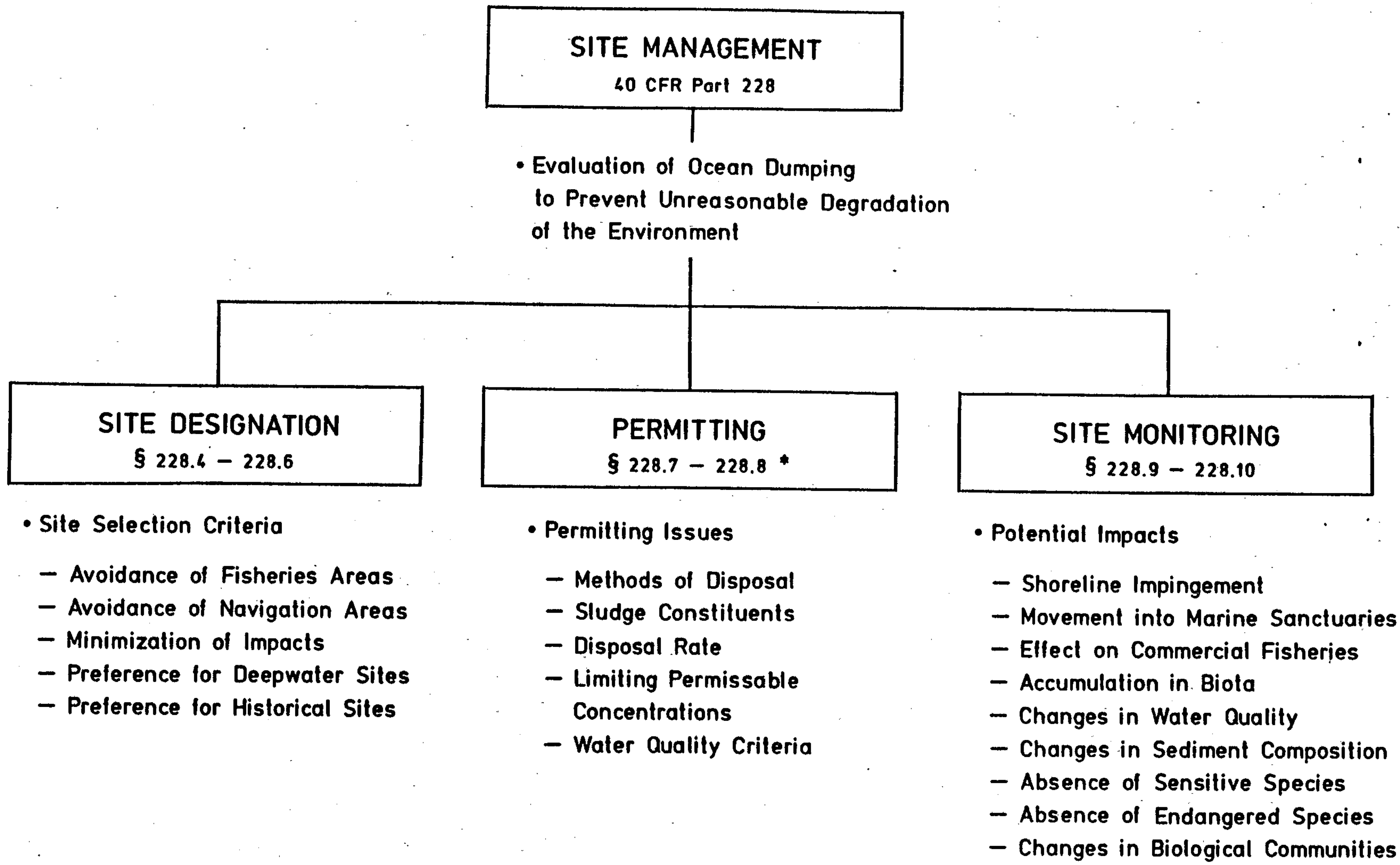
Convention). In this respect, the MPRSA is the enabling domestic legislation for the London Dumping Convention, which was ratified by the United States in 1974 (EPA, 1977).

2.2 OCEAN DUMPING REGULATIONS AND CRITERIA

On October 15, 1973 under the authority granted by the MPRSA, EPA published regulations and criteria for ocean disposal of wastes (38 FR 28610). Revised regulations (hereafter referred to as the existing regulations) were published on January 11, 1977 (40 CFR Parts 220-229, 42 FR 2462). EPA is currently revising the existing regulations in response to statutory amendments, public comment, operating experience, and advances in scientific understanding of the impact of ocean dumping on the marine environment.

The existing ocean dumping regulations address the three site management functions presented in Figure 2-2 (40 CFR §228.3). These functions consist of conducting disposal site evaluation and designation studies and recommending modifications in site use and/or designation (site designation); regulating times, rates, and methods of disposal and quantities and types of materials that can be disposed (permitting); and developing and maintaining effective monitoring programs for dumpsites (site monitoring). Although this document deals with site monitoring, it should be emphasized that the three management functions are interdependent and are intended to prevent unreasonable degradation of the marine environment by wastes being dumped in the ocean (40 CFR §228.1).

The dumping of wastes into the ocean is permitted only at sites selected to minimize interference of disposal activities with other activities in the marine environment. Particular consideration is given to avoiding areas with existing fisheries or shellfisheries areas and regions of heavy commercial or



* Permitting is also discussed in 40 CFR Parts 222–224, 227

FIGURE 2-2. FEDERAL REGULATIONS SPECIFY SITE MANAGEMENT REQUIREMENTS, INCLUDING SITE DESIGNATION, PERMITTING, AND SITE MONITORING.

recreational navigation (40 CFR §228.5[a]). Once a site is designated as an approved ocean dumpsite, permits must be issued by the proper EPA authority before dumping can begin. Permit application review and approval proceeds according to the guidelines in Parts 220-224 and 227 of the existing ocean dumping regulations. The times and quantities of materials dumped at a particular site are regulated by denying permits for the disposal of certain materials and by imposing specific disposal conditions on approved materials. In addition to setting limitations on times and rates of dumping by permits, EPA regulates dumpsite use through the establishment of site monitoring programs. Such programs evaluate the impact of dumping on the marine environment by comparing the monitoring results to a set of baseline conditions (40 CFR §228.9[a]).

2.3 OBJECTIVES OF MONITORING: APPLICATION OF THE REGULATIONS TO THE 106-MILE SITE

The ocean dumping regulations were developed with the goal of preventing unreasonable degradation of the marine environment by ocean dumping activities. A management tool provided by the regulations for achieving this goal is site monitoring. Therefore, the overall objective of the monitoring program developed for the 106-Mile Site is to protect the marine environment b, ensuring that the regulations are being met. This objective will be attained by

- Assessing whether ocean dumping permit conditions are being met.
- Assessing whether dumping of sludge adversely impacts resources or other aspects of the marine environment.

An underlying assumption made by the ocean dumping permit program is that compliance with permit conditions and dumpsite management requirements is sufficient to protect the marine environment (Zeller and Wastler, 1986). However, predictions of no adverse impacts implicit in the permitting process are based on best estimates involving site and waste characteristics and toxicity of sludges or sludge constituents. Changes in these variables over time or uncertainty in the predictions might affect the predicted impacts. Therefore, the monitoring program developed for the 106-Mile Site is intended to test the compliance assumption using data directed at determining 1) if dumping operations are being conducted in compliance with conditions stated in the permits, and 2) if dumping under these permit conditions results in an adverse impact on the marine environment.

Data generated during the monitoring program will primarily be used to address the three site management functions (Figure 2-3). Monitoring results will be used to make permitting decisions (continuation of, changes to, or revocation of permits), site designation decisions (redesignation or dedesignation) and monitoring decisions (continuation of, changes to, or termination of monitoring). In addition, the results of the monitoring program will be useful in verifying the various models available for predicting transport and fate of dumped materials in the ocean. Although model testing is not an objective of the program, verification of models could result in their increased use for site management.

The 106-Mile Site monitoring program is designed to produce results that are directly applicable to regulatory and site management questions. The program avoids research activities that do not provide necessary information to site managers. The program does consider, however, that certain directed research activities will be important for ensuring that predictions of potential impacts and subsequent management decisions are based on appropriate scientific theory.

USES OF MONITORING DATA
FROM THE
106—MILE MONITORING PROGRAM
IN
SITE MANAGEMENT

Permitting Decisions

- Continuation of Permits
- Changes to Permit Conditions
- Revocation of Permits

Site Designation Decisions

- Site Redesignation
- Site Dedesignation

Monitoring Program Decisions

- Continuation of Monitoring
- Changes to the Monitoring Program
- Termination of Monitoring

FIGURE 2-3. DATA GENERATED BY THE 106-MILE SITE MONITORING PROGRAM WILL BE USED IN MAKING SITE MANAGEMENT DECISIONS.

3. CHARACTERISTICS OF THE 106-MILE SITE AND THE SLUDGE DISPOSAL OPERATION

A wealth of information on chemical and physical characteristics and baseline biological conditions at the 106-Mile Site is available from studies performed during the past decade. This information has been considered in the development of the monitoring program and will be considered as the baseline against which monitoring results will be compared. Potential impacts will be predicted using information on site and waste characteristics and on the expected behavior of the sludges (Figure 3-1). The monitoring program will determine if and where impacts are likely to occur (i.e., where sludge is transported) and then will assess the magnitude of these impacts.

3.1 SITE CHARACTERISTICS

The following sections briefly summarize the information available on the physiography, physical oceanography, and baseline chemical and biological characteristics of the 106-Mile Site and surrounding regions.

3.1.1 Physiography of the 106-Mile Site

The 106-Mile Site is located approximately 120 nautical miles southeast of Ambrose Light, New York, and 115 nautical miles from the nearest coastline (Figure 3-2). The site is approximately 100 square nautical miles and is bounded by 38°40'00" to 39°00'00" north latitude and 72°00'00" to 72°05'00" west longitude. The site is seaward of the continental shelf, covering portions of both the continental slope and rise, in water depths that range from 2250 to 2750 meters. When designating the site, the significant dispersive forces, deep permanent stratification, and

SITE CHARACTERISTICS

- Physical Oceanography
  - Hydrography
  - Currents
  - Water Masses
- Bottom Characteristics
  - Sediment Grain Size
  - Sediment Composition
- Baseline Chemistry Data
  - Sediments
  - Water Column
    - Water Quality
    - Metals
    - Organic Compounds
    - Microbiology
- Baseline Biology Data
  - Plankton
  - Endangered Species
  - Benthic Communities

WASTE CHARACTERISTICS

- Physical Characteristics
  - Settling Data
- Chemical Characteristics
  - Priority Pollutants
  - Conventional Pollutants
- Toxicology
  - Bioassays
- Disposal Operations
  - Quantity of Material
  - Method of Release
  - Frequency and Duration

CONSIDERATION OF POTENTIAL IMPACTS

- Shoreline Impingement
- Movement into Marine Sanctuaries
- Effect on Commercial Fisheries
- Accumulation in Biota
- Changes in Water Quality
- Changes in Sediment Composition
- Effects on Sensitive Species
- Effects on Endangered Species
- Effects on Biological Communities

FIGURE 3-1. INFORMATION ON CHARACTERISTICS OF THE SITE AND OF THE SLUDGES WILL BE USED TO PREDICT POTENTIAL IMPACTS OF SLUDGE DISPOSAL AT THE SITE.

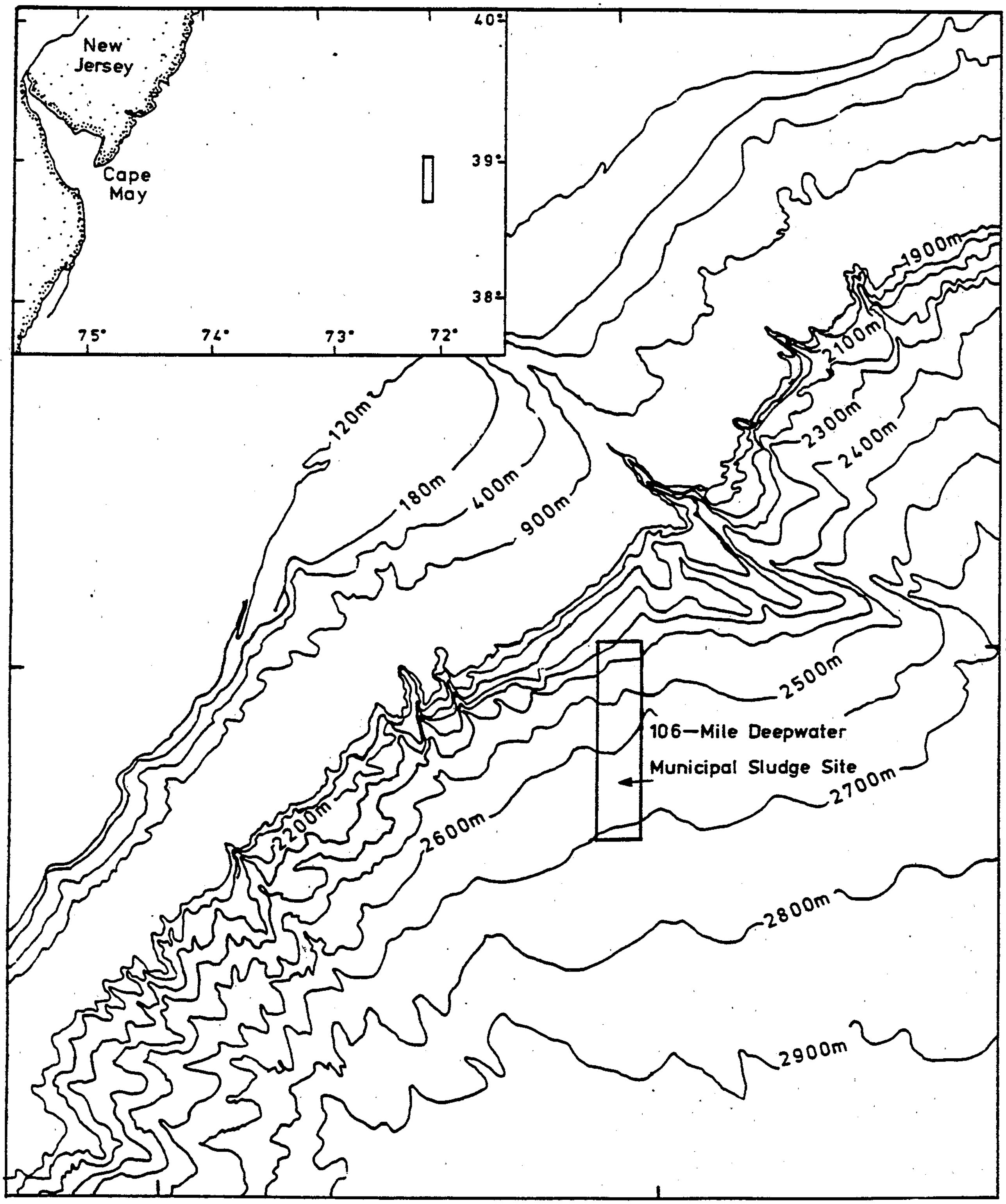


FIGURE 3-2. THE 106-MILE SITE IS SITUATED OFF THE COAST OF NEW JERSEY, BEYOND THE CONTINENTAL SHELF.

great distance of the site from shore were considered to ensure that potential impacts associated with dumping would be minimal (49 FR 19005).

Sediments within the site are predominantly silt and clay, which are characteristic of the Mid-Atlantic continental slope and rise (NOAA, 1983). Sediments found on the slope in the vicinity of the site are fine-grained, suggesting weak near-bottom currents (NOAA, 1977). At the slope-rise boundary, however, the paucity of fine-grained sediments implies that currents are sufficiently high to transport recently accumulated sediments out of the area.

3.1.2 Physical Oceanographic Conditions

The physical oceanographic environment at the 106-Mile Site will play a major role in the transport and fate of sewage sludge dumped at the site. A variety of physical processes, having time scales from hours to seasons and length scales from meters to hundreds of kilometers, govern the advection and mixing of regional water masses and consequently, the motion of any pollutants discharged at the site. Because the density of sewage sludge is close to that of seawater, the sludge constituents may take several weeks or longer to reach the seafloor, during which time they may be horizontally advected great distances from their point of discharge. Therefore, a large-scale view of the regional oceanographic processes is required in order to assess the mixing characteristics and ultimate fate of sewage sludge dumped at the site.

To date, the most useful data for characterization of currents and hydrographic conditions at the site were obtained from the Mid-Atlantic Slope and Rise Physical Oceanographic Study (MASAR/POS) funded by the Minerals Management Service (MMS); this study of Gulf Stream dynamics was conducted in conjunction with the MASAR/POS program and the Shelf Edge Exchange Processes (SEEP) program funded by the Department of Energy (DOE). Figure 3-3

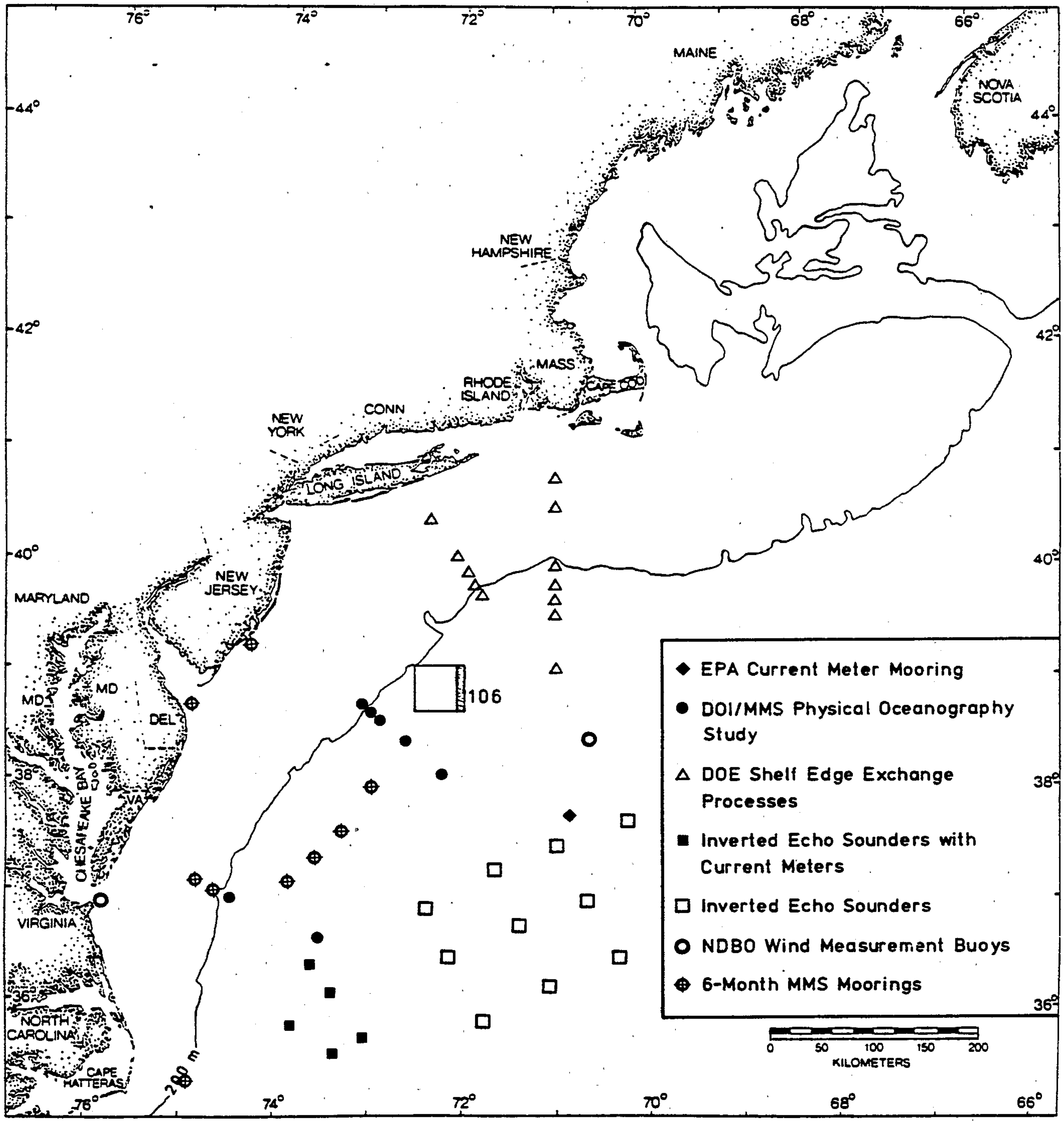


FIGURE 3-3. SEVERAL RECENT PHYSICAL OCEANOGRAPHY STUDIES HAVE BEEN CONDUCTED IN THE VICINITY OF THE 106-MILE SITE.

shows where instrumented moorings were maintained during these measurement programs (1982 through 1986). Historic data are also available from numerous site-specific studies along the continental slope and rise of the mid-Atlantic region. Synthesis of the results from these individual programs yields a practical, conceptual description of the circulatory and mixing processes in the vicinity of the 106-Mile Site, as described below.

3.1.2.1 Circulation within the Slope Sea

The 106-Mile Site is situated within a complex oceanographic region called the slope sea, which is bounded by the Gulf Stream on the south and the continental shelf waters to the north. Although the Gulf Stream and slope sea have been studied since the 1930s, the dynamics of this region have only recently been reasonably well resolved, primarily as a result of the MASAR/POS and SEEP programs.

Csanady and Hamilton (1987) have used recent and historic data to construct a conceptual model of the circulation within the slope sea. The major feature in their circulation model is a large cyclonic (anticlockwise) gyre that lies between the Gulf Stream and the edge of the continental shelf (Figure 3-4). The majority of the transport is confined within a recirculating gyre that extends from the Carolinas to a region southeast of New England. The size and intensity of the gyre are expected to vary in response to changes in the position of the Gulf Stream, the strength of the inflow from the Labrador Sea, and the intensity of the large-scale wind stress. Large perturbations such as Gulf Stream meanders and warm-core eddies are essentially superimposed on this basic circulation.

The 106-Mile Site is situated in the strongest part of the southwestward flowing, inshore side of the anticlockwise slope sea gyre. This is consistent with the moderate (~10 cm/s)

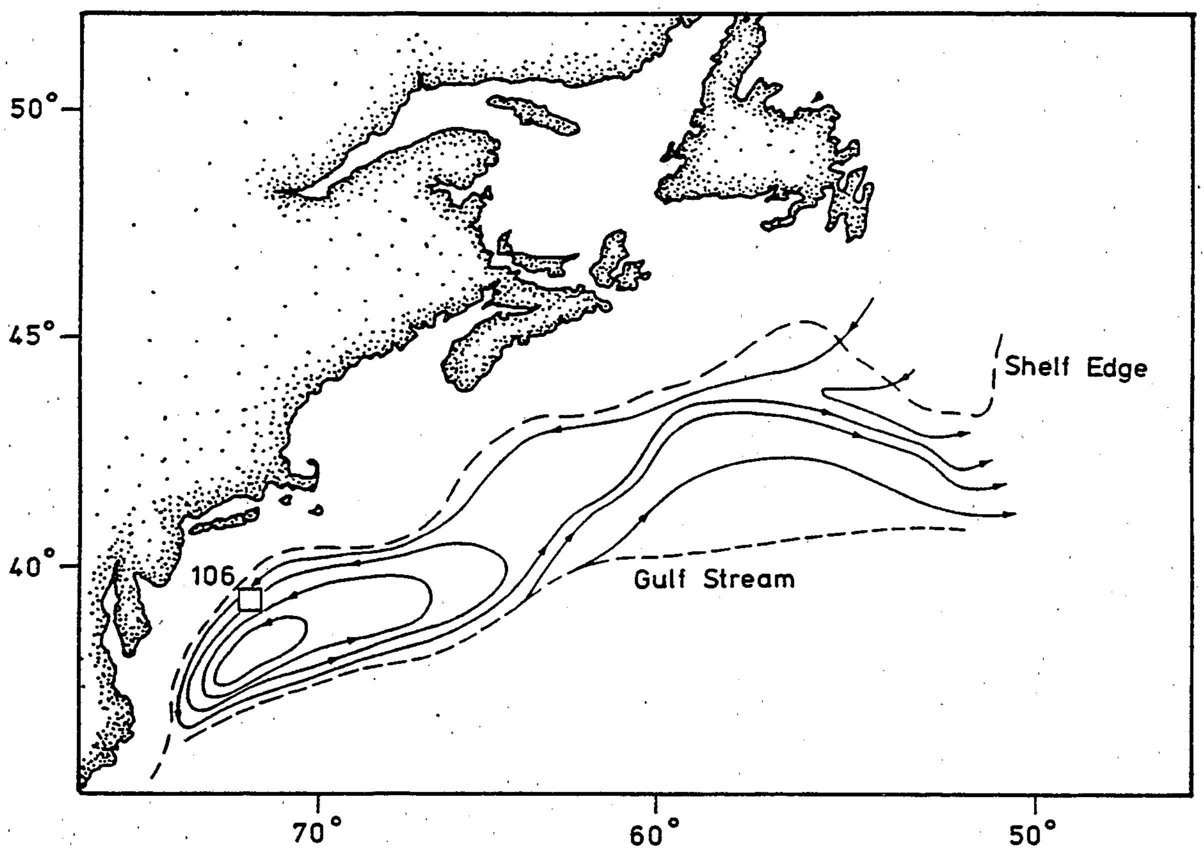


FIGURE 3-4. CONCEPTUAL MODEL OF THE CIRCULATION IN THE UPPER LAYERS OF THE SLOPE WATER FROM CSANADY AND HAMILTON (1987). THE 106-MILE SITE IS SHOWN IN THE INSHORE ARM OF THE SLOPE SEA GYRE. THE DASHED LINES INDICATE THE EDGE OF THE CONTINENTAL SHELF AND THE HISTORIC MEAN POSITION OF THE NORTHERN EDGE OF THE GULF STREAM.

southwestward mean currents that have been observed during numerous current measurement programs in the region. Evidence for a distinct northeastward return flow along the northern edge of the Gulf Stream has been observed in sea surface temperature maps derived from the Advanced Very High Resolution Radiometer (AVHRR) on polar-orbiting satellites. Cool, relatively fresh water is often observed extending in a narrow band from the outer shelf off Chesapeake Bay to the north side of the Gulf Stream, a total distance of several hundred kilometers.

The position of the Gulf Stream has a significant effect upon the characteristics of the southwestward flow within the inshore arm of the slope sea gyre. Moored current data from the two-year MASAR/POS monitoring program illustrate that southwestward flow in the vicinity of the 106-Mile Site is most intense when the Gulf Stream is displaced 100 km north of its historical mean position (a condition that can persist for months). In this configuration, the width of the slope sea gyre is reduced considerably and the northeastward return flow of the gyre may lie close to the southern boundary of the 106-Mile Site. Although the dynamics of this Gulf Stream/slope-sea-gyre interaction are not well understood, it remains an important topic because of its potential effect upon the long-term, farfield transport of sludge dumped at the 106-Mile Site.

The preceding discussion has concentrated on the circulation processes within the upper (0 to roughly 500-m) layer of the slope sea. Because sludge particles settle through the water column, the deep circulation over the slope and rise also must be considered. Strong (20 to 60-cm/s) fluctuating currents have been observed near the bottom on the continental rise of the Mid-Atlantic Bight. These fluctuations are due to long-period (10 to 100-day) planetary waves generated by meanders of the Gulf Stream. The near-bottom, wave-induced currents may be strong enough to resuspend and transport fine sludge particles that had been deposited during periods of less intense current activity.

The near-bottom mean flow on the continental rise and lower portions of the slope is associated with the southwestward flow of the Western Boundary Undercurrent (WBUC), which originates at high northern latitudes. Mean currents of 2 to 3 cm/s have been observed parallel to isobaths along the slope. Sludge particles that settle to the depth of this semipermanent current system would be advected to the southwest. This flow eventually passes beneath the Gulf Stream in the vicinity of Cape Hatteras.

3.1.2.2 Hydrographic Conditions within the Slope Sea

The temperature, salinity, and vertical density structure within the upper water column are important characteristics that affect mixing and dispersion of sludge dumped at the 106-Mile Site. Walker et al. (1987) have shown that mixed-layer depth is a governing parameter in models of farfield dispersion of sludge plumes.

The upper layers of the slope sea in spring and summer generally consist of a well-mixed layer situated above the main thermocline between about 50 and 150 m, This layer, named the slopewater pycnostad (meaning constant density), is formed by convective overturning in late winter due to the cumulative effect of winter storms and intense atmospheric cooling. The temperature and salinity characteristics of this pycnostad are roughly 12°C and 35.5 ppt, respectively. Above the pycnostad, an intense seasonal pycnocline is formed in summer by surface warming of the upper water column. Sharp vertical gradients of temperature and salinity also exist in this feature during summer and early fall. When wind and wave (mixing) conditions have been mild for many days, this seasonal pycnocline may approach the sea surface, but storms and autumn cooling can form a mixed layer at the surface, thus eroding the seasonal pycnocline from above. Continued surface mixing through autumn and early winter completely erodes the seasonal pycnocline until surface waters can mix vertically with the slopewater pycnostad. By late winter, the surface mixed layer extends down to the main pycnocline, often reaching depths in excess of 300 m.

The temperature and salinity characteristics at the 106-Mile Site are generally representative of the slope water mass. They differ significantly from the warm, relatively saline waters of the Gulf Stream to the south, and the highly variable characteristics of the shelf water to the north. Gulf Stream water can displace the surface waters of the slope sea by means of filaments, warm outbreaks, and extrusions. Filaments are shallow (20 to 50-m deep) elongated fingers of Gulf Stream water that trail from the crests of Gulf Stream meanders. Warm outbreaks are similar to, but larger, than filaments and persist for several weeks, as observed by satellite thermal imagery. Extrusions are usually due to the interaction of the Gulf Stream with warm-core eddies.

Water mass exchange events can also occur with the shelf water mass due to warm-core eddies, offshore wind stress, and upper slope eddies. Hydrographic sections that transect the slope sea often show large, subsurface, elliptical parcels of cool, relatively fresh water that have been displaced from the shelf. Some of these isolated water parcels may actually remain attached to the shelf-slope water mass front through complicated three-dimensional structures. The complexity and heterogeneity of the upper 50 to 75 m of the water column at the 106-Mile Site suggest that isolated hydrocasts (especially during summer and early fall) may be insufficient for resolution of the water mass structures within the region.

In summary, the hydrographic information from past studies in the vicinity of the 106-Mile Site indicates that sludge dumped in the slope water during late winter could be readily mixed over the upper 200 m of the water column. In late summer and through autumn, an intense seasonal pycnocline will limit vertical mixing to roughly the upper 20 m of the water column. Observations of complex patterns of distinctly different water masses in the upper 50 to 75 m of the slope sea suggest that moderate-sized parcels of sludge water may be confined to a distinct water mass, thus implying that local mixing (dispersion) may be less effective than horizontal advection for the transport of sludge particles away from their point of discharge within the 106-Mile Site.

3.1.2.3 The Gulf Stream and Warm-Core Eddies

The MASAR/POS program demonstrated that the Gulf Stream profoundly influences the circulation over the slope and may, on occasion, lie over the 106-Mile Site. The position of the Gulf Stream axis is highly variable as it leaves the continental margin at Cape Hatteras and behaves like a free, meandering jet carrying relatively warm, saline waters into the northwest Atlantic. Maximum current speeds reaching 200 cm/s are found at the surface within the Gulf Stream. Strong currents generally persist from the surface to depths of 1000 m.

Statistical analyses of satellite-derived Gulf Stream positions indicate that it is quite rare for the Gulf Stream to lie over the 106-Mile Site, but when it does, current speeds at the site are up to 20 times greater than during normal slope sea conditions. These events normally persist for several days. Because of the strong (200 cm/s) northeastward currents and the intense vertical and horizontal current shears that are known to exist within the Gulf Stream, a sludge release into one of these Gulf Stream events is the most favorable situation for rapid dispersion. The only adverse effect of dumping sludge within the Gulf Stream is that the material will be rapidly advected out of the eastern boundary of the site, possibly before the plumes can be diluted sufficiently to meet lowest permissible concentrations of water quality criteria. Note that if sludge were discharged at the western boundary of the 7.2-km-wide (5′ of longitude) dumpsite and into a Gulf Stream current flowing eastward at 200 cm/s, it would take only 1 hour for the material to reach the eastern boundary of the site. This oceanographic condition could have major implications for meeting permit requirements at the 106-Mile Site.

Intense (>150 cm/s) currents at the 106-Mile Site can also be caused by the large northward meanders that propagate eastward along the northern edge of the Gulf Stream. These meanders vary in size and phase propagation, but they normally travel at a rate of 20 to 40 km/day with periods ranging from 4 to 100 days. Current speeds within these features are often equivalent to those observed within the Gulf Stream, but current direction can vary greatly on time scales of a few days. Because these features have clockwise circulation while they propagate eastward along the northern boundary of the Gulf Stream, an Eulerian (moored) current measurement would normally show southward, eastward, then northward flow during the passage of a meander. Westward current flow is highly unlikely during meander events.

Large meanders can pinch off from the northern edge of the Gulf Stream to produce clockwise-rotating, warm-core eddies that are absorbed by the relatively cool, fresh, slope water mass. Warm-core eddies are essentially bowl-shaped parcels of Gulf Stream and Sargasso Sea water with a diameter of about 100 to 150 km, a depth of 1 km at their centers, and a maximum orbital speed of about 150 cm/s. After formation, these eddies generally move southwestward within the slope sea at rates from 2 to 6 km/day. These eddies have complex life histories before they coalesce with the Gulf Stream, often near Cape Hatteras. Warm-core eddies can interact with the Gulf Stream and shelf waters, extruding warm and cold streamers, respectively, from these water masses, which can wrap around the outer edges of the eddy. The passage of an eddy along the slope can apparently trigger waves and instabilities on the shelf-slope water mass front, creating smaller, warm- and cold-core eddies. These newly discovered small (20 to 50-km diameter) eddies may play an important role in the exchange of shelf and slope waters.

Statistics on warm-core eddies indicate that from five to eight eddies are spawned from the Gulf Stream in a typical year, and average lifetimes range from 2 to 12 months. Because they contain Gulf Stream water, these eddies represent an enclosed environment having physical, chemical, and biological characteristics that differ greatly from the slope water mass in which they reside. As first-order approximation, any sludge that is dumped within an eddy may remain trapped within the closed system for the life of the eddy. Vertical and horizontal current shear within these eddies is large, which would cause significant (localized) dispersion of sludge, but waters from the center portion of an eddy generally undergo minimal exchange with the surrounding waters of the slope sea. On occasion, eddies have been observed with spiral-shaped filaments of shelf or slope water within their centers, suggesting that lateral exchange processes may occur, at least at the sea surface.

3.1.2.4 Shelf-Slope Exchange Processes

The most important, yet difficult, issue in determining the fate of sludge dumped at the 106-Mile Site is related to the exchange of material through the shelf-slope front and consequently, into the highly productive waters of the outer continental shelf. Mechanisms proposed for this exchange include 1) the generation of lateral intrusions due to the passage of warm core Gulf Stream eddies, 2) frontal instabilities, 3) the effects of small clockwise and anticlockwise eddies on the upper slope, 4) wind-forced and density-driven intrusions, and 5) small-scale mixing processes such as double diffusion and caballing. The small-scale processes produce episodic events of limited duration (minutes to hours) and spatial extent (centimeters to tens of meters), whereas the lateral intrusion mechanisms have larger scales and longer durations.

These onshore-offshore flux mechanisms have yet to be studied extensively; consequently they are not well understood. Most of the evidence is from satellite imagery and hydrographic sections across the shelf and slope. With the available information and dynamical theories, there is, however, little doubt that sludge discharged within the slope water could eventually penetrate onto the shelf via one of these transport mechanisms. The probability of this occurrence can be determined only after additional observational and theoretical studies of the dynamics within the shelf-slope region.

3.1.3 Baseline Chemical and Biological Conditions

Baseline data concerning chemical and biological conditions at the site are an integral part of the monitoring program because this information, along with data on waste characteristics and physical conditions at the site, will be used to formulate predictions of potential impacts. A large body of information is already available for this purpose through studies funded by EPA and other federal agencies. A complete description of many of these programs can be found in EPA (1986).

Baseline information includes water column and sediment chemistry and data on pelagic, demersal and benthic biology as well as specific information on endangered species in the area. These data have been used to refine and verify predictions of potential impact and also will be used to determine changes over time that are associated with sludge disposal operations.

Baseline information on water column chemistry and water quality at the 106-Mile Site will be used to determine if any changes in these variables attributable to dumping operations occur over time. Water column stations that have been sampled in the vicinity of the 106-Mile Site are presented in Figure 3-5. Surveys that have occupied these stations include a series of EPA baseline surveys at the site from 1984 to 1986, EPA surveys at the North Atlantic Incineration Site from 1983 to 1985, hydrographic stations occupied during the MASAR/POS study, and water quality stations sampled during the Northeast Monitoring Program funded by NOAA.

Average monthly dissolved oxygen levels at the surface within the 106-Mile Site range from 4.9 ml/liter in August to 7.5 ml/liter in April (Warsh, 1975). The oxygen minimum zone is located between 200 and 300 meters, with oxygen values ranging from 3.0 ml/liter in February to 3.5 ml/liter in September. An oxygen maximum zone develops during several months, ranging from 7.0 ml/liter at 30 meters during August to 8.2 ml/liter at 10 meters during February. Results of a study on heavy metals in the water column at the 106-Mile Site indicated that levels of mercury and zinc were comparable to those found in the open ocean and on the continental shelf (Hausknecht, 1977). Background concentrations of cadmium, copper, and lead in the water column at the site were considered comparable to other oceanic regions (EPA, 1980).

Information on sediment chemistry at the 106-Mile Site will be needed for much the same reason as the water column data; to document potential changes in sediment composition resulting from dumping operations. Figure 3-6 shows the locations of sediment chemistry stations that have been sampled during several programs. These stations include those sampled during two EPA baseline surveys at the site, stations occupied during Studies of Biological Processes of the North and Mid-Atlantic Slope and Rise

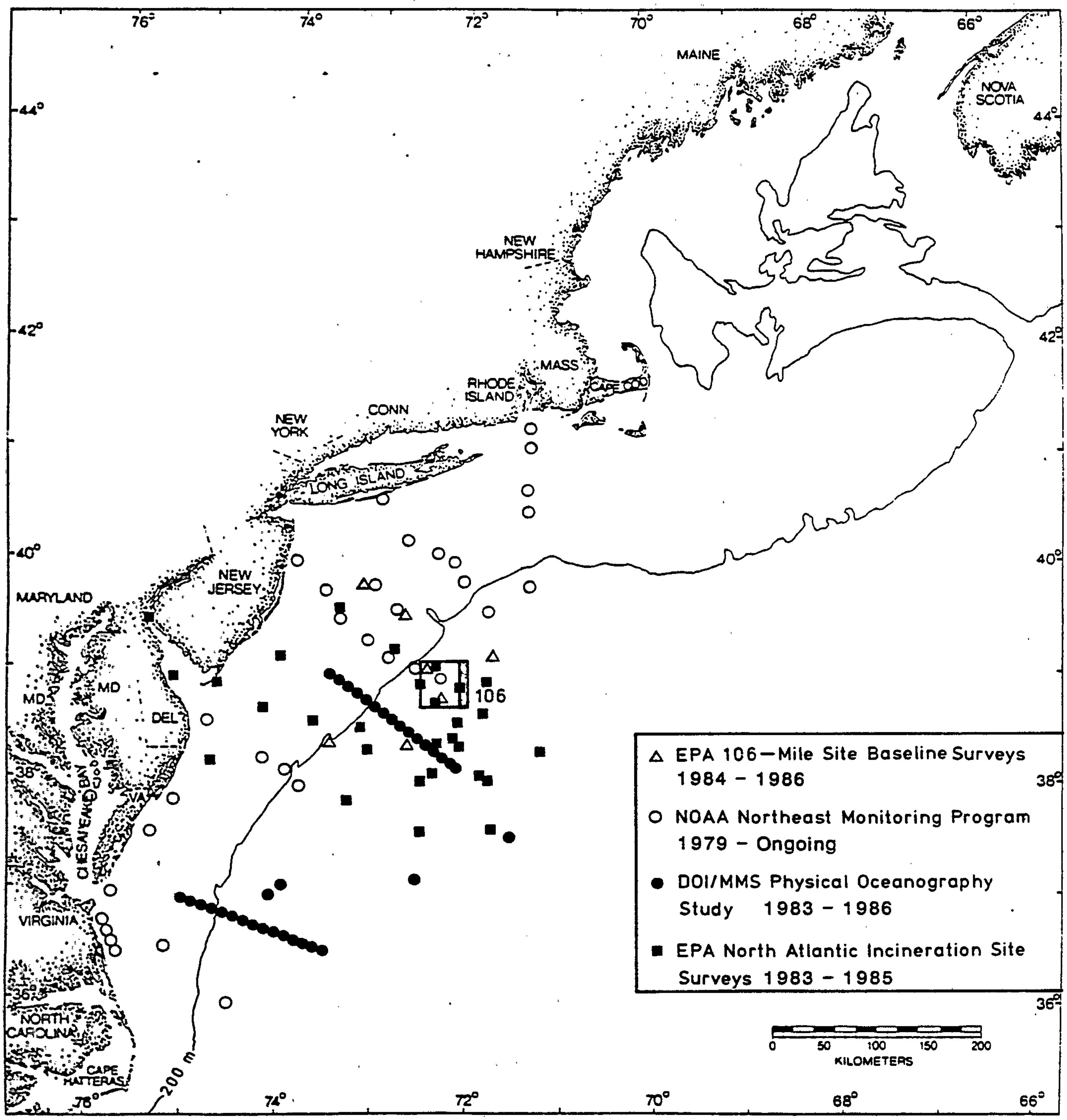


FIGURE 3-5. MANY STUDIES HAVE SAMPLED THE WATER COLUMN IN THE VICINITY OF THE 106-MILE SITE.

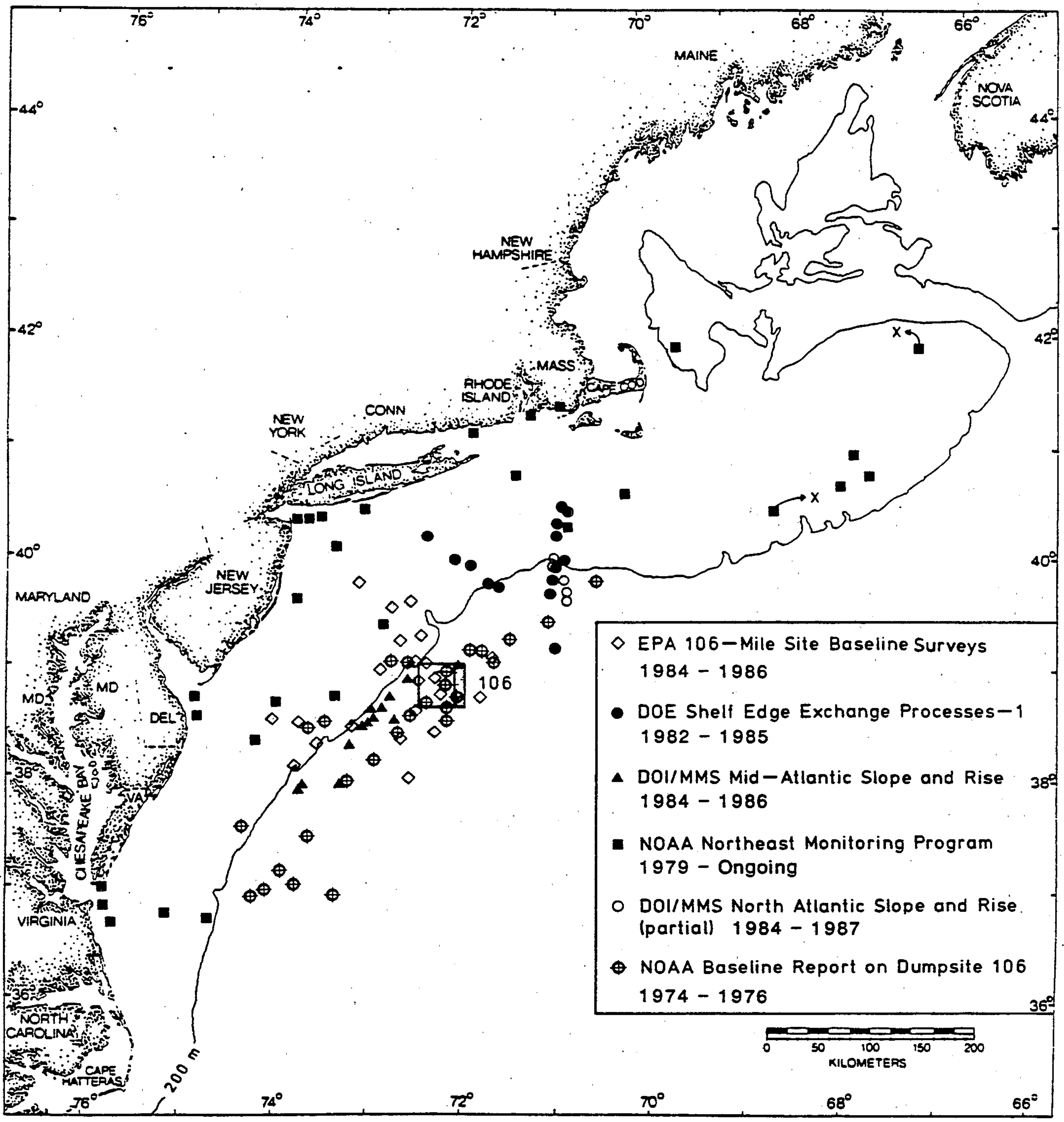


FIGURE 3-6. MANY STUDIES CONDUCTED AT THE 106-MILE SITE HAVE INCLUDED SAMPLING SEDIMENTS FOR BASELINE CHEMISTRY INFORMATION.

sponsored by MMS, DOE's SEEP stations, Northeast Monitoring Program stations, and stations sampled during three NOAA baseline surveys at the site from 1974 to 1976. Additional sediment samples have been collected at the site during other MMS surveys in the area.

Sediment samples collected by NOAA in the vicinity of the site contained higher levels of heavy metals than sediments on the adjacent continental shelf (Pearce et al., 1975). These elevated levels may have been due to proximity of sampling stations to the Hudson Canyon where concentrations of contaminants are expected to be high. Bothner et al. (1987) analyzed 12 trace metals in sediment samples from several stations at 2100 meter depths southwest of the 106-Mile Site. The levels of trace metals in surface sediments were the same as or lower than average levels found in other locations around the world. Hydrocarbon concentrations in sediments collected in the vicinity of the site appear comparable to those found in sediments from uncontaminated continental shelf areas. In addition, hydrocarbon levels in sediments at the site are lower than those found at other dumpsites in shallower waters (Greig and Wenzloff, 1977).

If the monitoring program determines that significant quantities of sludge are settling out of the water column to the seafloor, it may become necessary to determine if changes in benthic community structure associated with dumping operations are occurring. Historical stations sampled for benthic infauna on the continental shelf and slope in the vicinity of the site are plotted in Figure 3-7. These stations include those sampled for EPA during an MMS cruise to the Mid-Atlantic Slope and Rise, those sampled as part of the MMS Studies of Biological Processes of the North and Mid-Atlantic Slope and Rise, stations that were part of the Northeast Monitoring Program, and stations sampled during NOAA baseline surveys at the site from 1974 to 1976.

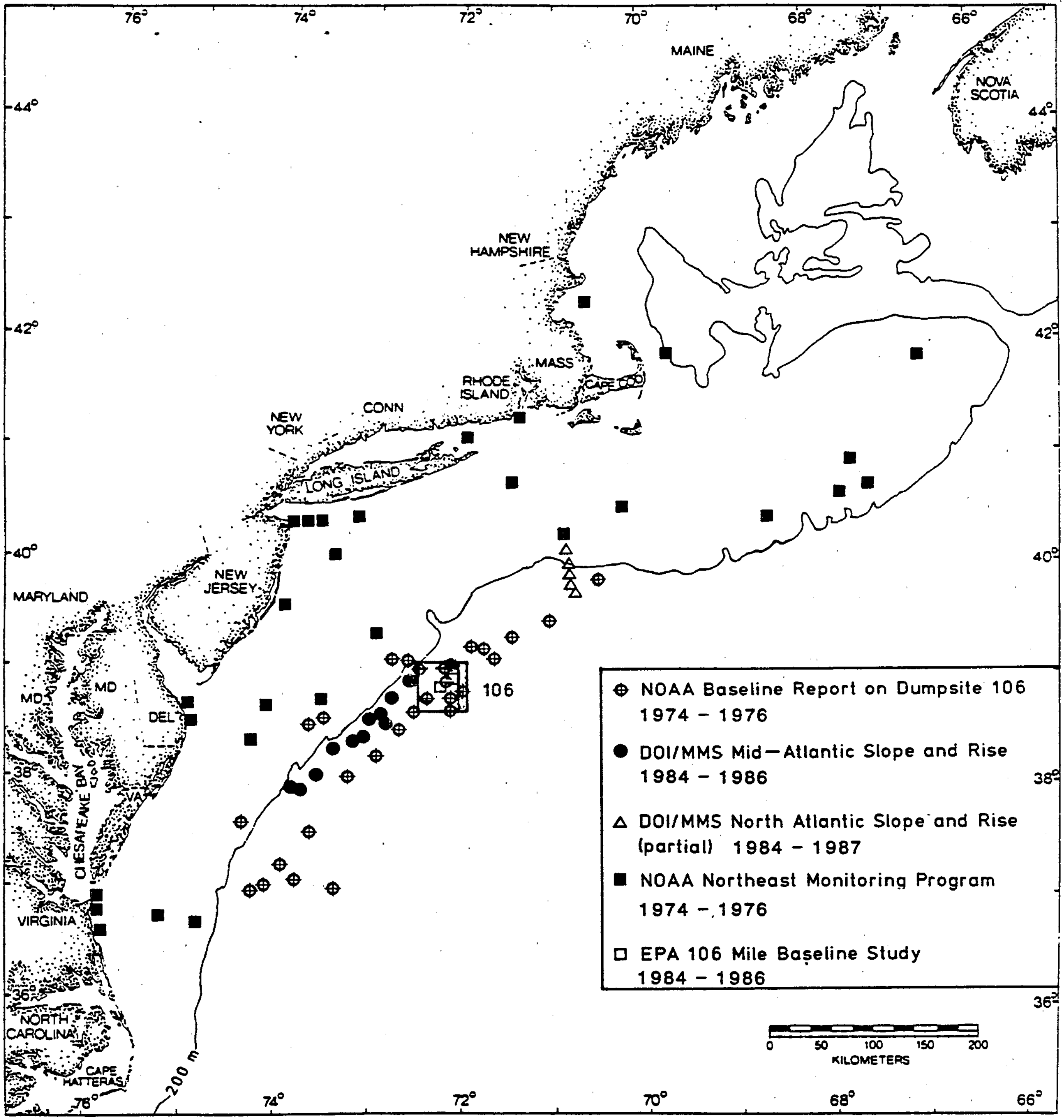


FIGURE 3-7. SEVERAL STUDIES HAVE INCLUDED AN ANALYSIS OF BENTHIC INFAUNA IN THE VICINITY OF THE 106-MILE SITE.

Benthic invertebrate samples collected and analyzed by Pearce et al. (1975, 1977) indicated no significant differences in numbers of individuals, numbers and types of species present, or diversity between stations at similar depths inside and outside the site. Results of a study sponsored by MMS in the area of, but not within, the 106-Mile Site recorded densities of 3567 to 5361 individuals per square meter at depths of 2000 to 2500 m (Maciolek et al., 1985).

The annual cycle of phytoplankton biomass in the area of the 106-Mile Site tends to be bimodal, with peaks occurring in March and November/December (NOAA, 1983). The spring bloom is dominated by netplankton (size greater than 20 micrometers) at depths of 60 to 2000 meters. The fall bloom tends to be dominated equally by netplankton and nannoplankton (size less than 20 micrometers). Standing stocks of zooplankton in the site region are as high as at inshore areas during cooler months of the year (NOAA, 1983). However, peaks are reached earlier in the year at offshore regions than at inshore regions. Larval fishes collected at and surrounding the 106-Mile Site by the Marine Resources Monitoring, Assessment, and Prediction program (MARMAP) include 209 taxa representing 73 families (NOAA, 1983). Most of these are slope water and oceanic species, along with some shelf species that are transported offshore via the Gulf Steam from the Mid-Atlantic Bight and south of Cape Hatteras.

Midwater finfishes found within the 106-Mile Site are mainly slope-water species and species transported to the area by Gulf Stream eddies. Many of these fishes, such as myctophids (lanternfish), migrate vertically in the area, from depths of several hundred meters in the daytime to 0 to 200 meters at night (NOAA, 1977). Two species of squid, long-finned (Loligo pealei) and short-finned (Illex illecebrosus), are found in the vicinity of the site. Thirty-one species of open-ocean predators have been identified moving through the site, including sharks, swordfish, and tuna; however, these predators do not appear to be long-term residents in the site. Cohen and Pawson (1977) observed 55 species of bottom fishes near the site. Most of these were rarely encountered and included the eel Synaphobranchus kaupi, the morid Antimora rostrata, the rattails Nematonurus armatus and Lionurus carapinus, the halosaur Halosauropsis macrochir, and the lizard fish Bathysaurus ferox. Tilefish (Lopholatilus chamaeleonticeps) are fished commercially in continental shelf areas inshore of the site.

The potential effect of dumping operations on the distributions of endangered species at the 106-Mile Site is of public concern. Figure 3-8 presents sightings of endangered species that were made during EPA baseline surveys to the 106-Mile Site and the North Atlantic Incineration Site, and during an MMS survey conducted during the Study of Biological Processes of the Mid-Atlantic Slope and Rise. These data have been collected using standardized techniques, ensuring comparability within the database (Payne et al., 1984).

Sediment and water-column samples collected during five surveys at or in the vicinity of the 106-Mile Site are of particular interest to EPA for their relevance as baseline information. Four surveys were conducted by EPA in July/August 1984, August 1985, February 1986, and August/September 1986. Two surveys were conducted in August 1985 and November 1985 during the MMS-sponsored study of biological processes on the U.S. Mid-Atlantic slope and rise. Thirty-five samples from these surveys have been identified by EPA for analysis. These samples were chosen based on proximity of the station to the site, quality of the sample, methods of collection, and comparability to other samples collected at the 106-Mile Site. Results of these analyses, will be entered into an EPA-compatible database for use as baseline information.

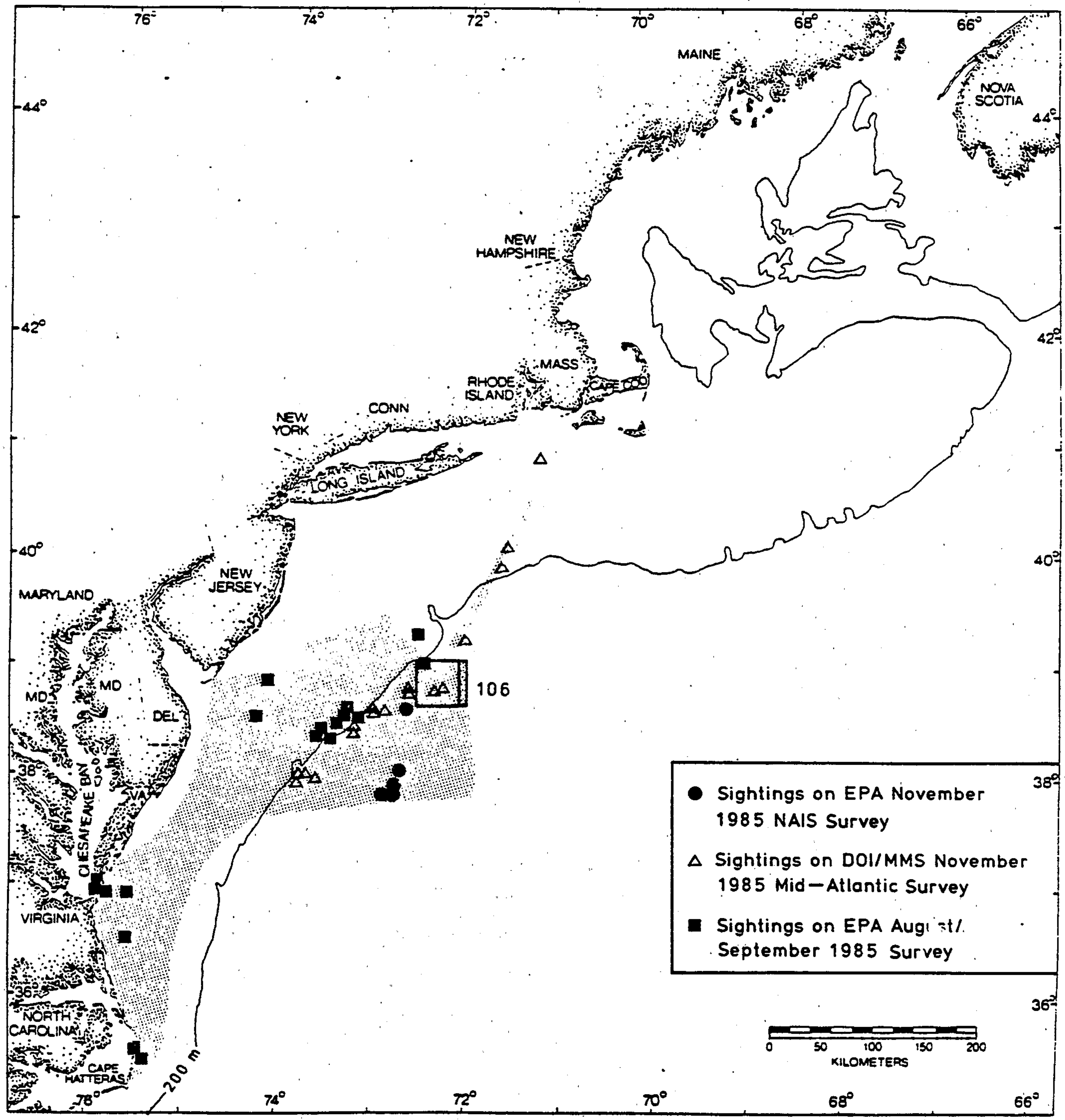


FIGURE 3-8. OBSERVATIONS OF ENDANGERED SPECIES HAVE BEEN MADE IN THE VICINITY OF THE 106-MILE SITE.

3.2 WASTE CHARACTERISTICS AND DISPOSAL OPERATIONS

The following sections discuss the history of the 106-Mile Site, the planned use of the site under the ocean dumping program, and the characteristics of the sludges to be disposed.

3.2.1 History of Waste Disposal at the 106-Mile Site

The area known as the 106-Mile Site was first proposed as a site for ocean dumping in 1965 by the U.S. Fish and Wildlife Service as an alternate to inland disposal of industrial wastes (Figure 3-9). In 1973, EPA issued an interim designation of the 106-Mile Site for use primarily for the disposal of industrial wastes (38 FR 12875). At that time, the site was approximately 500 square nautical miles and was bounded by 38°40'00" to 39°00'00" north latitude and 72°00'00" to 72°30'00" west longitude (Figure 3-9). On December 20, 1982, EPA published its intention to designate the site as an approved ocean dumpsite for the disposal of aqueous industrial wastes and municipal sewage sludges (47 FR 56663).

Concern that mixed dumping of industrial wastes and sewage sludges within the large, interim-designated 106-Mile Site would complicate monitoring efforts led to a decision by EPA to designate two smaller sites for these separate purposes. On May 4, 1984, EPA designated a site within the interim-designated 106-Mile Site as the Deepwater Municipal Sludge Site (49 FR 19005). The processes leading to final designation of this site within the interim 106-Mile Site have been affected by actions taken to end dumping at the 12-Mile Site within the New York Bight Apex. The 12-Mile Site, located approximately 12 miles southeast of New York Harbor, has been used for disposal of municipal sewage sludge since 1924. This site had been given an interim designation by EPA in 1973 (38 FR 12875) and was approved

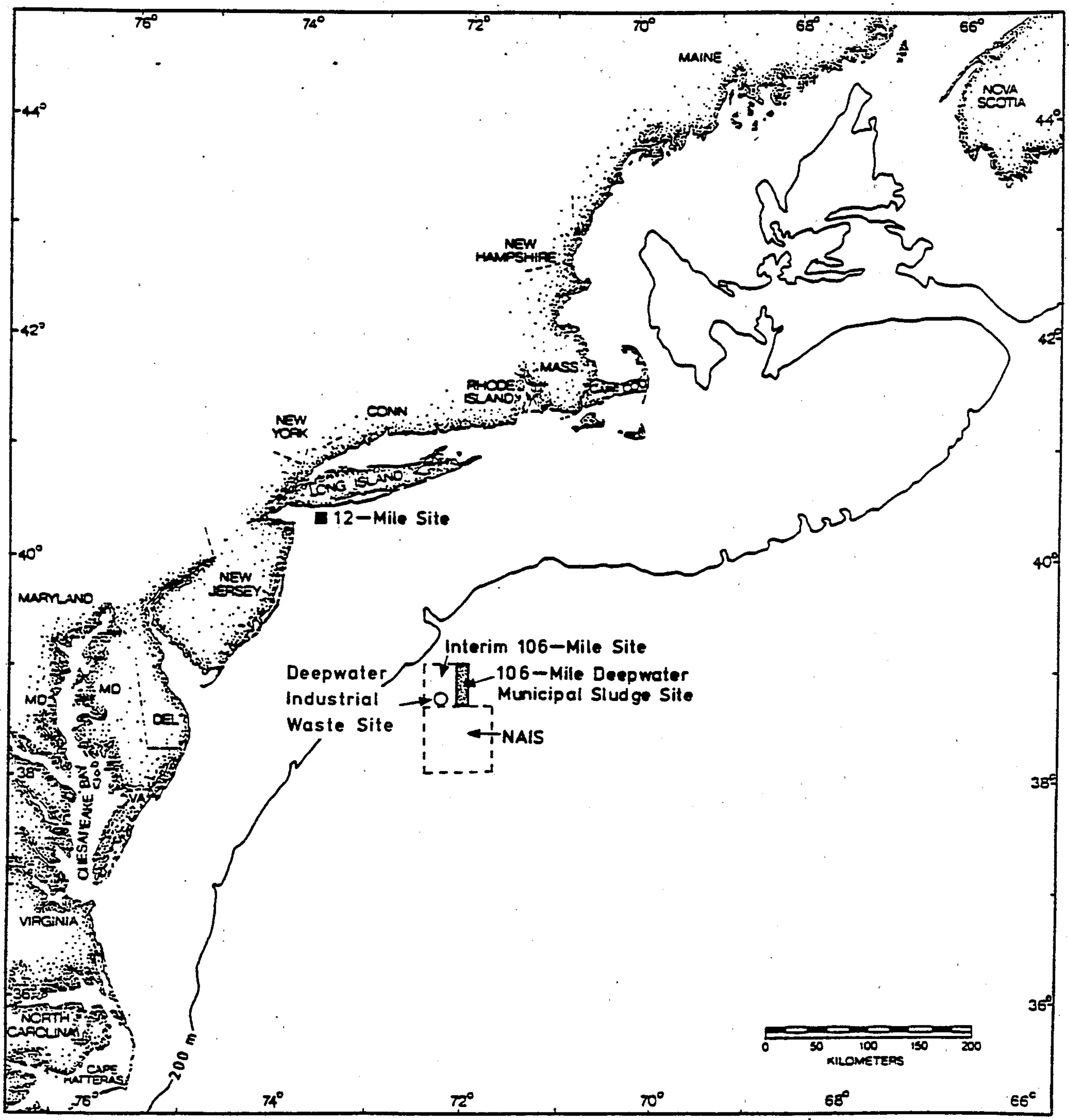


FIGURE 3-9. THE 106-MILE SITE WAS DESIGNATED WITHIN A LARGER, HISTORICAL SITE.

as a site for disposal of sewage sludge on May 18, 1979 (45 FR 29052). This interim designation expired on December 31, 1981. Since 1981, court actions taken on behalf of nine municipal sewage authorities, including the City of New York, barred EPA from prohibiting disposal of municipal sewage sludges at the 12-Mile Site (City of New York v. EPA 543 F. Supp. 1084).

EPA announced its intention to deny petitions to redesignate the 12-Mile Site concurrent with designation of the 106-Mile Deepwater Municipal Sludge Site (49 FR 19005). The final decision to deny these petitions was published on April 11, 1985 (50 FR 14336). By denying petitions to redesignate the 12-Mile Site and establishing the Deepwater Municipal Sludge Site, EPA effectively halted all sludge disposal at the 12-Mile Site allowed by the earlier court order. Municipalities using the 12-Mile Site at the time of EPA's final decision are allowed to shift dumping operations to the 106-Mile Site until EPA rules on the municipalities' permit applications. Amendments to Section 508 of the Clean Water Act in 1987 have limited use of the 106-Mile Site to these municipalities.

3.2.2 Use of the 106-Mile Site

As has been discussed, site designation does not constitute approval by EPA for dumping to begin. Permits must be issued on a case-by-case basis to municipalities that wish to use the site. However, given the circumstances that have accompanied final designation of the 106-Mile Site, EPA Region II and the nine permit applicants that propose to use the site have negotiated a schedule for phase-out of operations at the 12-Mile Site and phase-in at the 106-Mile Site (Figure 3-10). The phase-cut/ phase-in schedule began on March 17, 1986, and is to be completed by December 15, 1987. The following nine municipal authorities currently use the site under this negotiated schedule:

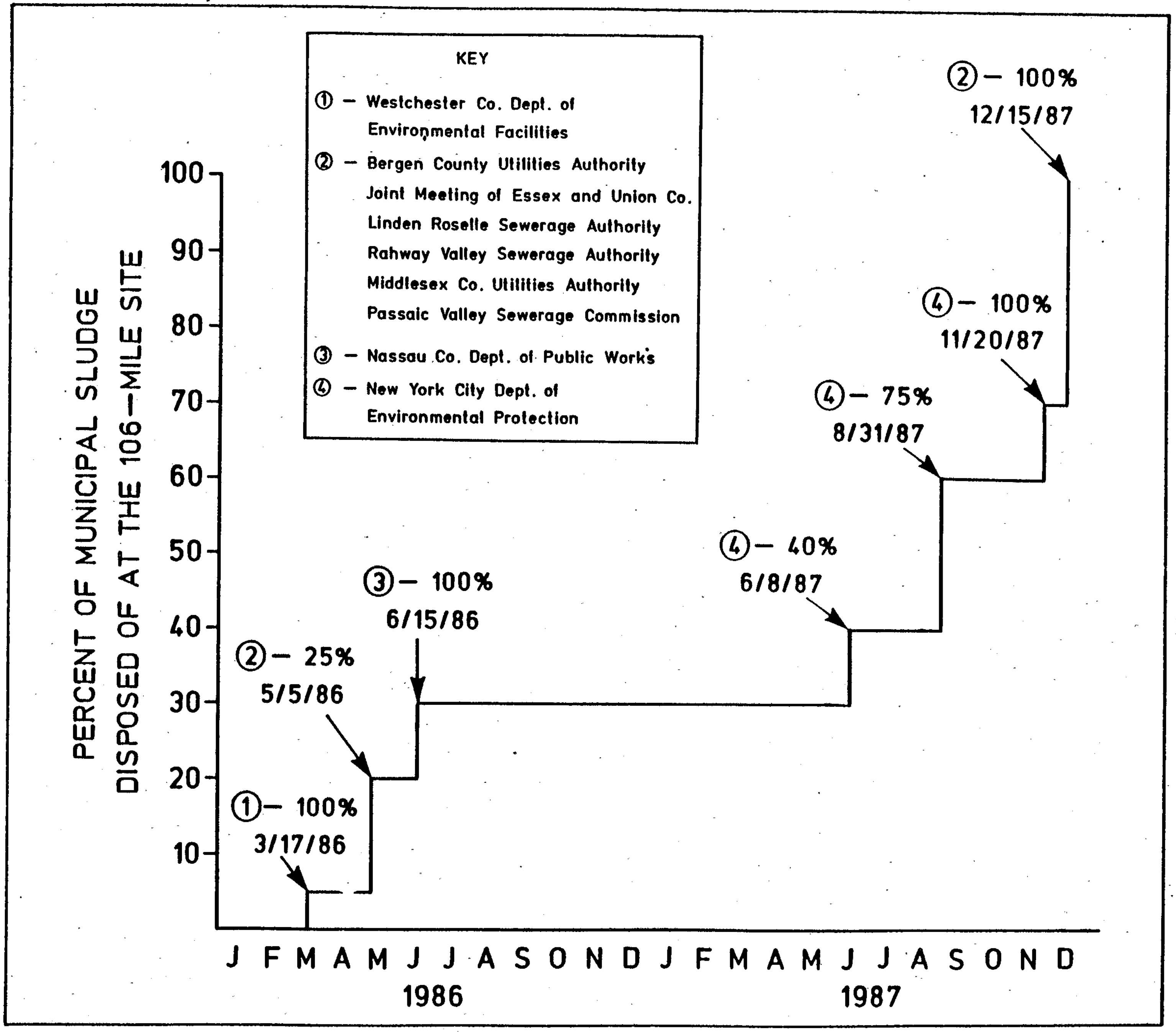


FIGURE 3-10.DISPOSAL OF SLUDGES AT THE 106-MILE SITE IS BEING PHASED IN.

- Westchester County Department of Environmental Facilities
- Bergen County Utilities Authority
- Joint Meeting of Essex and Union County
- Linden Roselle Sewerage Authority
- Rahway Valley Sewerage Authority
- Middlesex County Utilities Authority
- Passaic Valley Sewerage Authority
- Nassau County Department of Public Works
- New York City Department of Environmental Protection

The schedule for shifting dumping operations from the 12-Mile Site to the 106-Mile Site is proceeding concurrent with the permit process established under the ocean dumping regulations. EPA Region II is receiving permit applications from the nine municipal authorities that propose to use the site. Schedules negotiated with the proposed permittees take into consideration time required by the permittees to introduce the increased costs of using the 106-Mile Site into their budgets, the availability of transportation methods, and the time to renegotiate or competitively bid waste hauling contracts (Santoro and Suszkowski, 1986).

3.2.3 Characteristics of the Sludges

The MPRSA defines sewage sludge as "any solid, semisolid, or liquid waste generated by a municipal wastewater treatment plant the ocean dumping of which may unreasonably degrade or endanger human health, welfare, or amenities, or the marine environment, ecological systems, and economic potentialities" (33 USC §1412[a]). Characteristics of the sewage sludges to be dumped at the 106-Mile Site are likely to be somewhat variable, because the sludges will come from several treatment facilities. Specific information on individual sludges will be available through information supplied to EPA in the permit applications. Waste characterization data supplied in a special permit application for the disposal of sewage sludge from 12 New York City water pollution control plants at the 12-Mile Site (Ecological Analysts, Inc. and SEAMOcean, 1983) provide a basic understanding of the general sludge characteristics that can be expected at the 106-Mile Site.

Municipal sludges have four components of environmental concern: a surface film generally transported by prevailing winds; an aqueous phase (sludge is approximately 95 percent water); a suspended-particulate phase that entrains above the thermocline; and a solid phase that can eventually be deposited on the ocean floor (49 FR 19005). Solid-phase definition tests performed on the sewage sludges from the 12 New York City facilities indicated that there were no significant quantities of settleable solids associated with these sludges. All New York City sewage sludges had specific gravities less than that of seawater.

Fecal indicators (total coliforms, fecal coliforms, and fecal streptococci) were found in all sludges, ranging in mean density from 6.9×10^4 to 2.1×10^7, $<3.0 \times 10^4$ to 3.2×10^6, and 4.5×10^4 to 4.1×10^6/100 ml, respectively. Mean densities of _Clostridium perfringens_ ranged from 3.4×10^6 to 2.8×10^7/100 ml. Levels of members of the genus _Salmonella_ were low (<0.6 to 10/100 ml). Mean densities of enteric viruses were <1.3 to <5.0 plaque forming units/100 ml.

Chemical composition of the New York City sewage sludges was determined for both total sludge and a laboratory-prepared liquid phase. Aldrin, dieldrin, chlordane, heptachlor epoxide, and DDT and its degradation products were the only pesticides detected. PCBs were found in all sludges analyzed, ranging in total concentration from 11 μg/liter to 250 μg/liter. Of the volatile organic priority pollutants, chlorobenzene, ethyl benzene, methylene chloride, toluene, and trans-1,2-dichloroethylene were detected. Xylenes were found in sludges from six of the water pollution control facilities. Base-neutral organic compounds were found in all sludges analyzed, with the two most frequently encountered groups being the phthalate esters and the polynuclear aromatic hydrocarbons. PH values for the sludges varied from 6.5 to 7.7. Biological oxygen demand calculated for the total sludges ranged from 650 to 15,150 mg/l.

4. FRAMEWORK OF THE MONITORING PROGRAM

The ocean dumping regulations indicate that monitoring plans should be designed to address the two basic objectives of the monitoring plan as previously presented in Section 2.3. These objectives are to assess permit compliance and assess whether there are adverse impacts on the marine environment (i.e., impact assessment). In addition, the regulations outline several basic types of impacts of concern.

The design of the compliance assessment segment of the monitoring program is based on evaluation of whether permit conditions are met. The permits specify the allowable characteristics of the sewage sludges and the conditions of the disposal operations. Thus, this segment of the monitoring program must be designed to obtain information on these two broad issues.

The design of the impact assessment segment of the monitoring program considers the characteristics of the sludges in the context of the characteristics of the 106-Mile Site. An evaluation of sludge and site characteristics leads to predictions of the behavior, movement, fate and, ultimately, of the potential impacts of the sewage sludge. The impact assessment segment of the monitoring program can be formulated based on the considerable existing knowledge of the waste and site characteristics, discussed in Chapter 2, and considering the types of impacts that are of concern (40 CFR 228.10).

The first step in the design of the 106-Mile Site monitoring program is to translate the requirements of compliance and impact assessment segments into a series of predicted potential impacts. These predictions are restated as a series of questions or hypotheses. The null hypotheses must be stated so that they can be answered or tested by evaluating existing information in concert with information to be acquired as part of the monitoring program. Implementation of the monitoring program consists of specific activities (e.g., evaluation of data supplied by permittees on sludge characteristics, acquisition of field and laboratory data) from which data will be generated to test the hypotheses. The results of the testing of these null hypotheses (i.e., determining whether null hypotheses are falsified) are then used to make specific site management decisions. These include decisions regarding site designation, permitting, and the conduct of the monitoring program itself.

4.1 POTENTIAL IMPACTS OF OCEAN DUMPING OF SEWAGE SLUDGE AT THE 106-MILE SITE

The design of the 106-Mile Site monitoring program relies on two regulatory elements--the ocean dumping permit stipulations and the predicted potential impacts of sewage sludge dumped at the site. The design of the compliance assessment segment of the monitoring program is relatively straightforward and depends directly on the permit stipulations regarding the allowable waste characteristics and on the specifics of the disposal operations. The design of the impact assessment segment of the monitoring plan is more complex, but begins with the basic questions:

- How do the municipal sludges behave after disposal, and where do sludges go after disposal?
- What potential impacts can be predicted based on the behavior and the fate of the sludges?

The characteristics of the various sewage sludges and the characteristics of the 106-Mile Site are the bases for making predictions on potential impacts. To the extent that these characteristics are known from existing baseline data, such predictions can be postulated. As additional data are acquired on sludge and site characteristics during the conduct of the monitoring program, these predictions can be revised to better focus the implementation of the monitoring plan.

The ocean dumping regulations itemize several categories of potential environmental impacts on which the impact assessment segment of the monitoring program should focus. Restated specifically to address sludge disposal at the 106-Mile Site, the impact categories are as follows:

- Impingement of sludge onto shorelines.
- Movement of sludge into marine sanctuaries, shellfishery or fishery areas.
- Effects of sludge on commercial fisheries.
- Accumulation of sludge constituents in biota.
- Progressive changes in water quality related to sludge disposal.
- Progressive changes in sediment composition related sludge disposal.
- Impacts on pollution-sensitive species or life-cycle stages as a result of sludge disposal.
- Impacts on endangered species as a result of sludge disposal.
- Progre.sive changes in pelagic, demersal, or benthic biological communities as a result of sludge disposal.

The sludge and site characteristics, summarized in Chapter 3 of this document, serve as the bases for formulating specific predictions in the above categories. These predictions then serve as the conceptual foundation for formulating testable null hypotheses.

4.1.1 Impingement of Sludge Onto Shorelines

Sewage sludges form plumes during disposal operations. These plumes are largely aqueous. The buoyant plumes are then transported for a considerable distance, becoming diluted as they mix with seawater. Although circulation at the 106-Mile Site is dispersive in nature and the mean net surface flow is to the southwest, surface and subsurface currents are highly variable owing to intrusions of the Gulf Stream that may move through the site. These intrusions take the form of eddies, or warm-core rings. The shoreward component of the surface and subsurface flow is poorly known; the real possibility does exist that under the circumstances of westward flow of surface waters, sludge constituents will be transported to the continental shelf. However, movement of detectable quantities of sewage sludge to a shoreline to the west or north of the site is highly unlikely.

Predicted Potential Impact (P-1): Sewage sludge dumped at the 106-Mile Site will probably not impact any shoreline in detectable quantities.

4.1.2 Movement of Sludge Into Marine Sanctuaries, Shellfishery, or Fishery Areas

Because, the anticipated movement and behavior of the sewage sludge plumes is such that the sludge will be advected from the site and will be diluted by mixing with seawater and given the dispersive nature of the site, it is not scientifically reasonable to predict any shoreline impact nor any impact of any marine sanctuary. This prediction also holds true for shellfisheries located along the shoreline. Although there are no concentrated fishery activities at the 106-Mile Site, sludge may move westward to the shelf edge where fishing for tilefish and other species does occur.

Predicted Potential Impact (P-2): Marine sanctuaries and shellfisheries will probably not be impacted by shoreward movements of sewage sludge.

Predicted Potential Impact (P-3): Sewage sludge may be transported to the continental slope and shelf where fishery activities exist.

4.1.3 Effects of Sludge Disposal on Commercial Fisheries

Effects on commercial fisheries that must be considered include effects resulting in decreased use of the region in the vicinity of the site for commercial fishing, effects that would result in direct or indirect bioaccumulation of sludge contaminants, and effects that would otherwise decrease available fish stocks through damage to fish eggs or larvae.

Potential effects in any of the above categories would be mitigated by the dispersive characteristics of the site, the transience of fish that inhabit the area, and the patchiness of floating fish eggs or planktonic larvae. Industrial waste disposal just to the west of the sludge dumpsite has not been shown to have any important effects on the offshore fisheries. Although eggs and larvae that come in contact with the sludge plumes in the sewage disposal site may be damaged or killed, the distribution of these planktonic life stages is quite patchy. The quantitative importance of this potential effect is predicted to be minimal because the plume is small in relation to the ocean available to eggs and larvae; thus the predicted impact is nil on any populations of species. Although adult fish or important invertebrates (e.g., squid) are found seasonally at the site, they too are transients, making any impact on a scale that would disrupt a fishery highly unlikely.

Furthermore, although sewage sludge does contain pathogenic bacteria and viruses, the survival of many of these organisms is very brief in seawater. Even for microbes that persist, it is unlikely that the low intermittent levels, coupled with the transience of fish at the site, would result in significant incidence of disease in the fish.

- Predicted Potential Impact (P-4): The impact of sludge dumping on commercial fisheries, expressed as direct decrease in fish stocks or decrease in eggs or larvae, will probably not be detected, and the use of any area for fishing will not be reduced.

The issue of bioaccumulation of sludge constituents and its potential effects on fisheries and the human health is discussed in the next section.

4.1.4 Accumulation of Sludge Constituents in Biota

Accumulation of sludge constituents in marine biota can occur in several ways. Sludge-associated chemicals, pathogens, or viruses can be taken up or adsorbed to the bodies of plankton. Animals eating plankton can accumulate these contaminants. If sludge within or transported from the site is ingested or if prey contaminated with sludge is ingested, some bioaccumulation of sewage sludge constituents can occur. In addition, direct bioaccumulation of contaminants or pathogens from seawater can occur.

The FDA has developed "action limits" for several sludge constituents. An "action limit" is a recommended limit for restricting consumption of a foodstuff because of the potential for bioaccumulation. The acquired level for any contaminant is unlikely to be harmful, hence no danger to public health will occur. Any direct effect on the biota will probably also be nil due to the very low levels, if any, acquired. Furthermore, because many of the chemicals of concern in sewage sludge are widespread contaminants in urban coastal waters, and because the migratory patterns of fishes may take them to coastal locations as well as the 106-Mile Site, it probably will be very difficult to separate bioaccumulation from sludge at the site from all other possible sources in the region. Also, it will be difficult to interpret data on the bioaccumulation of certain contaminants such as metals, which are present in the area as a result of the disposal of industrial wastes.

> <u>Predicted Potential Impact (P-5)</u>: Bioaccumulation of low levels of contaminants associated with sewage sludge from the 106-Mile Site will occur, from time to time, at the site or directly adjacent to the site by migrating fishes or invertebrates visiting the site, but may be difficult to distinguish from bioaccumulation from other potential sources.

> <u>Predicted Potential Impact (P-6)</u>: Bioaccumulation of very low levels of sludge contaminants by resident continental shelf/slope fishes may occur depending on direction and extent of transport of sludge to these areas, but may be difficult to distinguish from bioaccumulation from other potential sources.

4.1.5 Progressive Changes in Water Quality

The disposal of sewage sludge will have a profound negative effect on water quality within the site during disposal operations. Impact in this category is defined as concentrations that exceed either the laboratory-determined limiting permissible concentration (LPCs) or any water quality criteria (WQC) at the site boundaries during disposal. The ocean dumping permits will be written taking into account the interactions of sludge toxicity and mixing or dilution rates so that LPCs are not exceeded outside the site during disposal or within the site or elsewhere four hours after disposal. Nonetheless, it is possible that, due to violation or insufficient knowledge of any of these factors, the water quality at the site or outside the site can be affected. Based on observations (e.g., the August 1986 and September 1987 EPA surveys at the site) of recent sludge disposal operations, it is possible that LPCs and WQC could be exceeded outside the immediate disposal site boundaries.

Water quality impacts would also be noted by any progressive (i.e., cumulative) change in the concentration of sludge constituents within the site or in the region adjacent to the site. In the farfield, water quality effects are much less likely. However, the possibility of recirculating flow of water through the site has been postulated. It is possible that sewage sludge transported initially to the southwest could, via counterclockwise flow, return to the proximity of the site, increment the concentration of sludge constituents in the water column, and hence have a long-term cumulative effect within the site or in the region near the site. This potential phenomenon can not be dismissed, though its magnitude will probably be small. Such water quality effects may be noticed when data are compared to levels of these constituents at baseline or reference stations. Low, but detectable, bioaccumulation effects could result from exposure of fish or invertebrates to seawater with elevated levels of sludge constituents.

> Predicted Potential Impact (P-7): Sewage sludge movement and transport of sludge to and beyond the site boundaries may result in significant impact on the water quality beyond the disposal site.

> Predicted Potential Impact (P-8): Sludge constituents may be found in significant quantities within the site at all times and may persist beyond four hours after disposal. Chronic effects on marine biota are possible.

> Predicted Potential Impact (P-9): Though certain sludge constituents may be detectable well outside the site, these levels are not expected to have significant effect on marine biota.

4.1.6 Progressive Changes in Sediment Composition

The buoyancy of the plume will probably prevent rapid settling of sludge within the site, although the sludge particles will settle through the water column over time. The settling behavior is likely to be quite variable owing to the heterogeneous composition of sludges, the variable flocculation of the sludge particles, and the seasonal variability in water column characteristics. Where and to what extent the sludge will reach the sea floor is highly uncertain at this time. A knowledge of the settling rate of the sludge particles, the seasonally dependent water column hydrography and structure, and the surface and subsurface current speed and direction is necessary to compute a settling trajectory and predict a settling location.

In all probability, sludge particles will eventually settle through the water column and deposit in very low quantities on the sea floor. The effect on sediment composition is likely to be nil to minimal given the anticipated low settling rate, expected sludge particle dilution, and the great settling depth. Even if the sludge particles were transported in shore to the continental shelf, such sediment impacts would probably still be minimal.

> <u>Predicted Potential Impact (P-10)</u>: Sludge particles may settle outside the disposal site boundaries. However, this settling will occur over a very large, and as yet undefined area. The resultant changes in sediment composition, the destruction of sediment habitat, and/or the accumulation of sludge constituents in surficial sediment will probably be nil to minimal.

4.1.7 Impacts on Pollution-Sensitive Species or Life-Cycle Stages

As previously stated, the 106-Mile Site is a highly dispersive environment. Pollution-sensitive species or sensitive life-cycle stages (i.e., eggs and larvae) will undoubtedly be found from time to time at the site during migratory events or as a result of oceanic currents. Where sludge may come in contact with individuals, damage may occur. However, the disposal of sludge and its presence in the region is not expected to cause long-term impacts on any population or community.

One area of concern is the sea-surface microlayer. This unique biological and chemical environment is also the site where eggs of some species of marine biota reside. Sewage sludge contains nonpolar hydrophobic organic compounds and surface-active constituents that will tend to migrate to and accumulate in the microlayer. The microlayer is known for its elevated concentrations of pollutants. Should the microlayer of the region of the 106-Mile Site become contaminated with organic and metal pollutants, the sensitive life-cycle stages of organisms residing there may be affected.

Predicted Potential Impact (P-11): The disposal of sewage sludge probably will not cause long-term impacts on pollution-sensitive species or life-cycle stages in the water column or in the sediments of the 106-Mile Site region. Effects may be detectable, but local and short-lived.

Predicted Potential Impact (P-12): The sea-surface microlayer in the disposal site and in an undefined area adjacent to the site and the sensitive life stages of marine biota within may be affected by the surface-active components and nonpolar pollutant compounds present in sludge.

4.1.8 Impacts on Endangered Species

Certain species of marine mammals and reptiles may occasionally be present in the area of the 106-Mile Site, although the area is not known to have significant numbers of any endangered species. In all probability, no mammal, reptile, or any endangered species will be affected by disposal operations or by the sludge itself.

Predicted Potential Impact (P-13): Endangered species of mammals or reptiles will probably not be impacted by sewage sludge disposal at the 106-Mile Site.

4.1.9 Progressive Changes in Biological Communities

For plankton, a relatively long period of potential contact between biota and sludge could conceivably affect the community. However, because the water quality impacts are predicted to be limited in area, any potential effect on the patchy oceanic plankton population is expected to be equally limited. Although some mortality of plankton in the site area is possible, it is also possible that a localized nutrient enrichment could have a stimulatory effect on plankton biomass and community structure. Nutrients from sludge will be diluted rapidly and will never result in eutrophication at the high degree of dispersion expected. However, some short-lived and very limited change in species composition and biomass is conceivable.

As for demersal and benthic communities, the predicted insignificant transport of sludge particles to the benthos precludes any significant effect and any change in benthic or demersal community structure.

> Predicted Potential Impact (P-14): Due to nutrient enrichment in the upper water column, there may be a localized increase in primary productivity related to individual sewage plumes.

> Predicted Potential Impact (P-15): There will probably be no long-term or large-scale impact on the plankton community as a result of sludge disposal at the 106-Mile Site.

> Predicted Potential Impact (P-16): Due to the expected absence of sewage sludge particles in the demersal or benthic environment, no effects on the benthic or demersal community structures are likely.

The analysis of potential impacts of sludge disposal at the 106-Mile Site, patterned after those impact categories of concern in the ocean dumping regulations, has resulted in the above predictions of potential impacts or lack of impact. These predictions form the basis of the impact assessment segment of the monitoring plan. The next step is to formulate questions or hypotheses that are testable. When arranged into tiers, these hypotheses form the basis of the implementation of the monitoring plan.

4.2 MONITORING HYPOTHESES

Once the permit compliance conditions and dumpsite management strategy for multiple dumpers are known, the predicted potential impacts of the sewage sludge disposal can be postulated, and the bases for the compliance assessment and impact assessment segment of the monitoring plan can be established. The next step is to begin to restate these issues and predictions as testable null hypotheses. Monitoring plans can be designed and implemented effectively if they borrow the concept of hypothesis testing from scientific experimentation. For this reason, the 106-Mile Site Monitoring Plan focuses on specific questions or null hypotheses that in turn focus the design of data acquisition efforts and the ultimate use of these data to examine the verification or falsification of these null hypotheses. The null hypotheses are linked together in a progression of transport, fate, and effects, so that each hypothesis concerning effects is supported by information on transport and fate. Ideally, the null hypotheses would correspond to the permit conditions to be monitored and to the impact categories of the ocean dumping regulations.

However, in many cases, scientists may not agree on the exact means to test these hypotheses or the testing may yield equivocal results due to imperfect methods. The means to test these hypotheses may still be under development and prohibitively expensive, or the expected availability of definitive results may not correspond to the time frame available for site managers to make decisions regarding the use of the site. In these cases, the null hypotheses must be given lower priority for testing.

The null hypotheses can be presented in categories as a first step in organizing the null hypotheses into a logical testing or implementation framework. The null hypotheses that address the assessment of impacts (Section 4.2.2) are linked to the predicted potential impacts, previously discussed.

4.2.1 Assessment of Permit Compliance

The hypotheses related to the assessment of permit compliance address the allowable characteristics of the waste, the allowable methods of disposal, and the nearfield fate of the sewage sludge. The hypotheses are stated so that the results of the hypothesis testing yields information on whether permit conditions are met.

4.2.1.1 Waste Characteristics

Sewage sludges to be disposed at the 106-Mile Site will have varying physical, chemical, and microbial characteristics, sludge because various sewage treatment plants generate the sludges. Sludge characteristics may also very dramatically over time. Permit conditions are dependent on determination of the sludge characteristics, and the design of the monitoring program itself is linked to the anticipated behavior and fate of the sludge. Monitoring of sludge compositions and characteristics is generally directed towards specifications in the permits that are based on sludge characterization information supplied by the permittees. The following null hypothesis is central to the waste characteristic monitoring effort:

H_o1: The physical and chemical characteristics of sludge are consistent with waste characterization information supplied with the permit applications.

This overall null hypothesis can be split into individual hypotheses corresponding to each permitted characteristic of the sewage sludges.

4.2.1.2 Disposal Operations

Permit conditions specify the location at which sludge disposal may occur (i.e., in the site) and also specify the maximum discharge rates. These rates have been determined in conjunction with the LPCs for sludge, a knowledge of the sludge characteristics, and the expected rate of dilution of the sludge so that the LPCs are not exceeded after mixing. The applicable hypothesis is

H_o2: Disposal rates and operations are consistent with the requirements of the ocean dumping permits.

4.2.1.3 Nearfield Compliance

Several null hypotheses concerning nearfield fate of the sewage sludge are also related to monitoring permit compliance because they are tied to the assumption that water quality criteria (WQC), when they exist, will not be exceeded within the disposal site four hours after disposal or outside the site at any time. When WQC do not exist, the permits will require that the concentration of the waste not exceed a factor of 0.01 times a concentration known to be acutely toxic after initial mixing. Water quality criteria have been determined for individual chemicals, not for complex mixtures of these chemicals in a matrix such as sludge. The combined conformance to LPCs and WQC is deemed to be sufficient to protect marine life and public health. The hypotheses applicable to nearfield compliance can be stated as follows:

H_o3: Concentrations of sludge and sludge constituents are below the permitted LPC and WQC outside the site at all times.

H_o4: Concentrations of sludge and sludge constituents are below the permitted LPC and WQC values within the site four hours after disposal.

H_o5: Pathogen levels do not exceed ambient levels four hours after at the disposal.

The above null hypotheses form the basis of determining permit compliance. The activities that must be conducted to test these null hypotheses include review of data supplied by permittees and data obtained in the field and laboratory (see Chapter 5).

4.2.2 Assessment of Potential Impacts

The ocean dumping regulations present several impact categories that are of concern and on which the impact assessment segment of the monitoring program must focus. The predicted potential impacts P-1 through P-16 were discussed in Section 4.1. Null Hypotheses can be tested through data acquisition activities and comparisons with baseline data. These impact assessment null hypotheses address aspects of nearfield fate, short-term effects, farfield fate, and long-term effects of sludge.

4.2.2.1 Nearfield Fate

Nearfield fate determinations with respect to impact assessment address the behavior and movement, both horizontal and vertical, of sludge within the disposal site and in the area immediately adjacent to the site. Because sewage sludge has been observed to leave the site in coherent, visually apparent plumes, consideration of the area adjacent to the site (within approximately 5 km) is appropriate (EPA 1988). Hypotheses concerning nearfield fate are formulated to address questions regarding the vertical movement of the sludge and the horizontal mixing and dilution. The data are also used to determine whether certain farfield studies are needed, if so, how to design them, and to provide data to verify or refine predictive models on which permit conditions and farfield transport predictions are based.

The relevant null hypotheses relate to impact predictions P-7, P-8, and P-10 presented in Section 4.1.

H_o6: Sludge particles do not settle in significant quantities to the seasonal pycnocline (50 m) in the summer or to the 50 m depth at any time, within the site boundaries or in the area adjacent to the site.

H_o7: The concentration of sludge constituents within the site does not exceed the LPC or WQC four hours after disposal and is not detectable in the site one day after disposal.

H_o8: The concentration of sludge constituents at the site boundary or in the area adjacent to the site does not exceed the LPC or WQC at any time and is not detectable one day after disposal.

H_o9: The disposal of sludge does not cause a significant depletion in the dissolved oxygen content of the water column nor a significant change in the pH of the seawater in the area.

Hypotheses H_o7 and H_o8 overlap with those in the compliance segment on nearfield fate. However, H_o7 and H_o8 go beyond compliance issues and address important aspects of water quality impacts in relation to ambient, baseline levels. These hypotheses also address the longer term residual concentration of sludge constituents in and adjacent to the site and possible progressive changes in offshore water quality.

4.2.2.2 Short-Term Effects

Null hypotheses formulated in this category of the impact assessment segment begin to address the validity of the assumption that permit compliance protects marine life and public health. The null hypotheses are linked to impact predictions P-4, P-5, P-11, P-12, and P-14 in Section 4.1 as discussed above, and any short-term effects (four hours to one day after disposal) are likely to be confined to the upper water column. Short-term effects can also occur as a result of water quality impacts previously covered under Nearfield Fate. Short-term effects are conceivable in the surface microlayer due to the possible accumulation of pollutants in and the residence of fish eggs at the air-sea interface (P-12). For purposes of this discussion, the "short-term" period is assumed to represent the time from four hours to one day after disposal.

H_o10: No significant biological effects in the water column are measurable within the site within one day after disposal.

This null hypothesis addresses the possible effects of sludge constituents or altered water quality on phyto- and zooplankton and on sensitive life stages such as eggs and larvae. In practice, separate hypotheses will be formulated.

H_o11: No increase in primary productivity or any changes in planktonic biomass or species composition will occur.

H_o12: No evidence of short-term bioaccumulation of sludge constituents by commercially important species found at or adjacent to the site or in important prey species found at or adjacent to the site will be found within one day after disposal.

H_o13: Sludge constituents do not accumulate in the surface microlayer in the vicinity of the site.

In practice, to determine whether the testing of null hypothesis H_o12 is a scientifically valid undertaking, it must be determined whether species of concern are present at the site. The feasibility of testing this null hypothesis deserves additional attention.

4.2.2.3 Farfield Fate

Null hypotheses concerning farfield fate address impact issues that pertain to the farfield transport of sludge; to potential impact to shorelines (P-1) and marine sanctuaries and shellfisheries (P-2), and the continental shelf/slope (P-3); to possible sites of continental slope/shelf bioaccumulation (P-6); and to possible transport to the sediments well outside the site (P-10). Additionally, impacts related to the progressive farfield increase in the levels of sludge constituents due to possible water mass entrainment (P-9) will be addressed. The hypotheses in this category are, however, more concerned with the question "Where does the sludge go?" than with the question "What are its potential effects?"

H_o14: Sludge constituents do not settle beneath the pycnocline outside the disposal site.

H_o15: Ocean currents do not transport sludge to any adjacent shoreline, beach, marine sanctuary, fishery, or shellfishery.

H_o16: Sludge recirculation through the site is not significant.

H_o17: Sludge particles do not settle to the sea floor in the vicinity of the site or in the region predicted as a possible settling region based on laboratory settling measurements and current trajectory analysis.

These null hypotheses are designed to answer questions about the farfield transport of sludge and to help determine if long-term effects measurements should be initiated, and if so, where they should specifically be directed.

4.2.2.4 Long-Term Effects

Long-term effects of the disposal of sludge can occur within the site (i.e., nearfield) or outside the site (i.e., farfield). Long-term effects in the site can occur if there is a progressive decrease in water quality or formation of a disease center. Long-term effects on the benthos in or outside the site are not predicted to occur (P-10), (P-16). Potential effects also concern bioaccumulation of sludge constituents by commercially important shelf/slope animals (P-6). Other categories of long-term effects not predicted to be potentially important are effects on endangered species that are transient in the region (P-13) and effects on commercial fisheries (P-4). The relevant hypotheses are

H_o18: Sludge constituents have no significant long-term effect on the distribution of endangered species in the vicinity of the site.

H_o19: Sludge constituents do not accumulate in the tissues of commercially important species resident in shelf/slope areas adjacent to the site.

H_o20: Benthic community structure does not change significantly due to sludge disposal.

H_o21: Sludge disposal has no effect on the sensitive eggs and larval stages of indigenous animals.

H_o22: Sludge disposal has no measurable long-term impact on offshore plankton communities.

H_o23: Pathogen levels will not increase in the water column or in the biota.

The above null hypotheses encompass a wide range and an expensive array of investigations. The efficient and scientifically defensible rationale for implementing activities that address these null hypotheses must be well thought out. Not only must the rationale for the implementation of these activities be defensible, but the methods to generate timely, defensible data be available. The strategy for implementing parts of the monitoring program and testing these null hypotheses is presented in the next chapter.

5. IMPLEMENTATION OF THE MONITORING PROGRAM

Implementation of the 106-Mile Site monitoring program will follow a "tiered" approach, whereby the null hypotheses or questions are organized into a series of monitoring tiers. This approach is the most effective approach to monitoring (Zeller and Wastler, 1986). The conceptual basis of the approach is that data collected in each of a hierarchy of tiers are required as the foundation for the design and extent of monitoring activities to be implemented in the next tier. Such an approach also ensures that only information needed for making decisions will be collected. Within the hierarchy of tiers, explicit objectives and endpoints guide conduct of work.

Although the hierarchy of tiers provides the organization for the monitoring program, it is important to note that the explicit objectives, null hypotheses, and regulatory endpoints are the real substance of the program (Zeller and Wastler, 1986). Therefore, it is important that each tier be thought of as part of the overall monitoring effort. Data generated in the tiers will be used not only in making decisions about the next steps to take in monitoring, but also in deciding whether to redesignate or dedesignate the site and whether to continue, alter, or revoke permits.

This chapter describes the monitoring tiers that will be used to guide the implementation of the 106-Mile Site monitoring program. It also describes activities that may be included in each of these tiers. These activities have been selected to provide information to test the hypotheses discussed in Chapter 4. The chapter also presents information about the quality assurance and data management activities that are part of the 106-Mile Site monitoring program. These activities are included to ensure that data collected under the program will be scientifically defensible and readily available for use.

5.1 MONITORING TIERS

For the 106-Mile Site monitoring program, the six categories of hypotheses discussed in Chapter 4 have been grouped into a hierarchy of four tiers as follows:

Tier 1--Sludge Characteristics and Disposal Operations

Tier 2--Nearfield Fate and Short-Term Effects

Tier 3--Farfield Fate

Tier 4--Long-Term Effects

These tiers include hypotheses associated with both permit compliance and assessment of potential impacts (Figure 5-1). Permit compliance issues are addressed both in Tier 1, "Sludge Characteristics and Disposal Operations," and in Tier 2, "Nearfield Fate and Short-Term Effects." The hypotheses related to impact assessment are organized around two categories of questions: 1) Where does the sludge go after disposal" and 2) Does the sludge disposal at the 106-Mile Site adversely and unacceptably impact resources or the environment? These questions are assessed in Tiers 2 through 4, which are concerned with assessing impacts by determining fate and effects of sludge disposal at the site.

5.1.1 Tier 1: Monitoring Sludge Characteristics and Disposal Operations

Ongoing monitoring of sludge characteristics and disposal operations is important, because characteristics of the sludges disposed of at the site may vary over time. The assumptions made both in writing the permit for sludge disposal and in predicting potential impacts of sludge disposal may not be valid throughout

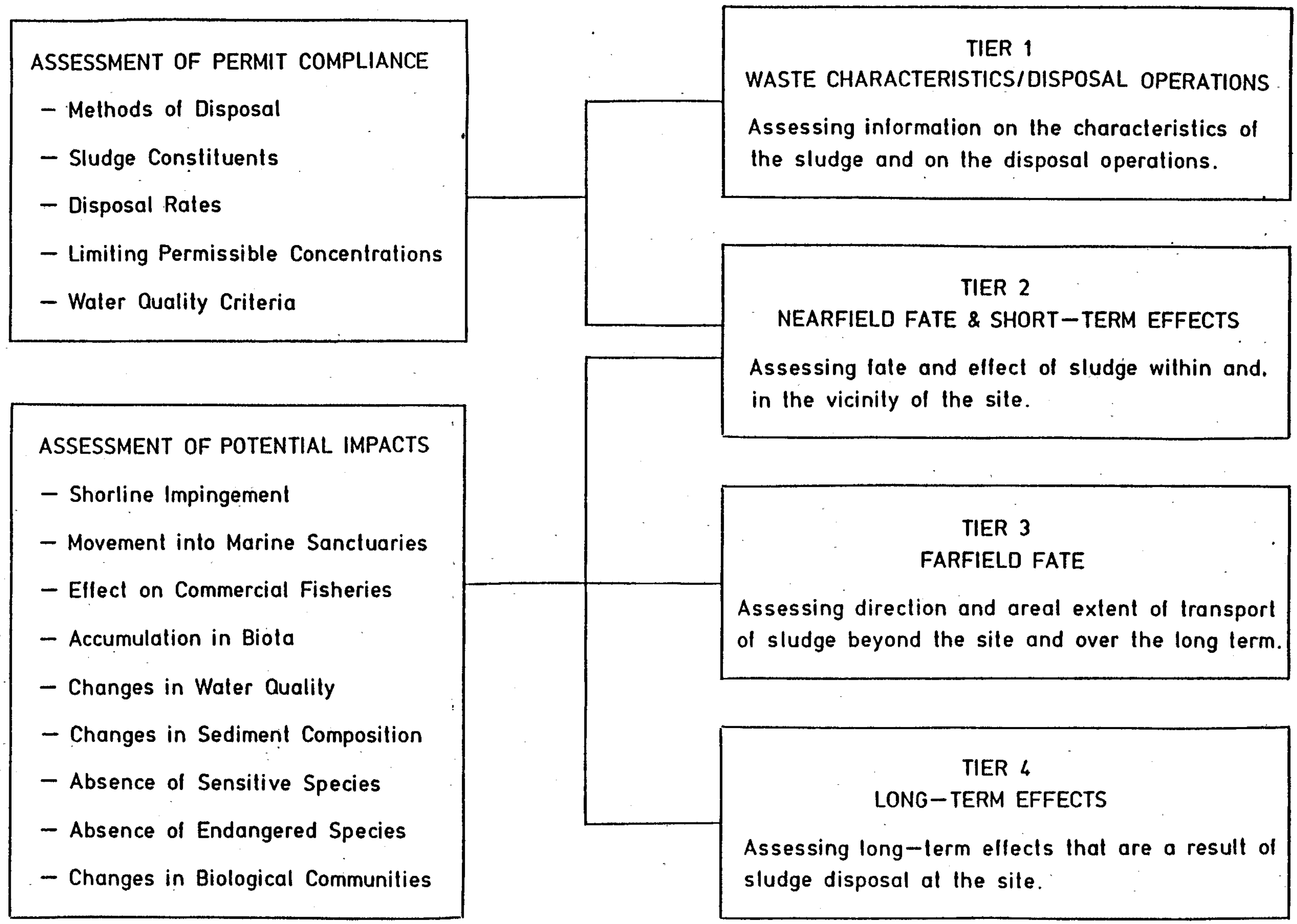


FIGURE 5-1. MONITORING TIERS ADDRESS PERMIT COMPLIANCE AND IMPACT ASSESSMENT.

the period for which the 106-Mile Site has been designated. Therefore, the objective of Tier 1 is to assess sludge characteristics and disposal operations in order to verify that the conditions specified by the permits continue to be true. Data generated by the activities conducted under this tier may be used in determining whether to revoke or change a permit or whether to redesignate or designate the site. These data may also be used in deciding of whether to curtail or change the monitoring program.

5.1.2 Tier 2: Monitoring Nearfield Fate and Short-Term Effects

Some of the hypotheses concerning nearfield fate of the sludge being disposed of at the 106-Mile Site are related to monitoring permit compliance--for example, they examine the assumption that the LPCs or WQC are not exceeded within the site four hours after sludge dumping or outside the site at any time. Other hypotheses included in this tier of the monitoring program are designed to determine whether the sludge disposal affects resources or the environment.

Thus, the overall objectives of Tier 2 of the monitoring program are to assess the short-term behavior, transport, and impact of the sludge within and in the immediate vicinity of the site. Data generated in this tier may, as in Tier 1, be used in site designation, permitting, and monitoring program decisions. For example, if concentrations of sludge or sludge constituents are found to be well below LPCs, a decision could be made to allow increased dumping in future permits. Such a finding might also be used in a determination to limit monitoring outside the site; i.e., to limit or curtail conduct of farfield monitoring under Tiers 3 and 4. Finding that LPCs are greatly exceeded at the site boundary could cause permits to be altered and could ultimately be a major factor in a decision to dedesignate the site. Detection of waste constituents at concentrations near or greater than the LPCs could trigger a more extensive evaluation of transport under Tier 3.

5.1.3 Tier 3: Monitoring Farfield Fate

For many monitoring plans, hypotheses related to farfield fate and long-term effects of wastes disposed of at sea can be grouped into a single tier. Because ocean current and water mass movements (and hence the behavior and transport of the sludge) in the vicinity of the 106-Mile Site are not well understood and because the activities associated with determination of fate differ greatly from those used to determine effects, these hypotheses have been partitioned into separate tiers for the 106-Mile Site program.

The overall objective of this tier is to assess the direction and areal extent of sludge constituents at the 106-Mile Site and in the long term, their ultimate fate. Information generated under Tier 3 will in most instances be useful in addressing questions concerning impact assessment. For example, whether sludge constituents are likely to move towards shore or into productive fisheries areas will be assessed by conduct of Tier 3 activities. In other instances, information generated under this tier will be used in determining whether a thorough examination of long-term effects is warranted, and if so, where that investigation should take place.

5.1.4 Tier 4: Monitoring Long-Term Effects

The objective of Tier 4 studies is to assess whether there are long-term impacts of sludge disposal at the 106-Mile Site. Depending on the results of data generated in earlier work, they may include studies of impacts on fisheries species, biological communities that support fisheries species, or any other marine resources.

Information developed in the conduct of Tier 4 activities will, as for the other tiers, be used in making decisions about site designation, permitting, and monitoring. Findings that no long-term impacts result from disposal of sludge at the 106-Mile Site, for example, would provide grounds for redesignating the site; continuing permits or modifying them to allow increased use of the site; and, depending on the permitting decision, decreasing the monitoring effort or maintaining it to examine effects of the changed permits. Results indicating that undesirable long-term effects did occur could lead to dedesignation of the site, revocation of or changes to permits, and a continued or intensified monitoring effort.

5.2 MONITORING ACTIVITIES

Monitoring activities will be selected to test the hypotheses discussed in Chapter 4 and will be implemented according to the tiered structure described above (Figure 5-2). Specific activities and measurements will be selected by evaluating whether they can be used to test the null hypotheses, whether they will provide timely information that can be readily interpreted, and whether they can be implemented cost-effectively.

5.2.1 Tier 1: Sludge Characteristics and Disposal Operations

Permits are issued based on assumptions about specific physical, chemical, and biological characteristics of the wastes and on the discharge location and rate of discharge. The purpose of monitoring activities associated with waste characterization

	Tier 1 Source Characterization				Tier 2 Nearfield Fate and Short-Term Effects				Tier 3 Farfield Fate	Tier 4 Long-Term Effects **					
	Quarterly Analyses	Barge Samples	Loading Information	Settling Characteristics	Plume Tracking	Nearfield Water Column Chemistry and Microbiology	Short-Term Biology Bioaccumulation	Oceanography	Oceanography (Water Column and Settling)	Water Column Chemistry	Water Column Biology	Sediment Chemistry and Microbiology	Sediment Biology	Bioaccumulation Studies	Observations of Endangered Species
PERMIT COMPLIANCE															
LPC/Water Quality Criteria	●	●			●	●									
Permit Conditions	●	●	●	●	●	●		●							
IMPACT ASSESSMENT *															
"Movement of materials into estuaries or marine sanctuaries, or onto oceanfront beaches or shorelines"									●	●					
"Movement of materials toward procuctive fishery or shellfishery areas"									●	●	●				
"Absence from the disposal site of pollution-sensitive biota characteristic of the general area"							●				●		●		●
"Progressive, non-seasonal changes in water quality or sediment composition at the disposal site, when these changes are attributable to materials disposed at the site"									●	●		●			
"Progressive, non-seasonal changes in composition or numbers of pelagic, demersal, or benthic biota at or near the site, when these changes can be attributed to the effects of materials disposed at the site"											●		●		●
"Accumulation of materials constituents (including without limitation human pathogens) in marine biota at or near the site"							●							●	

* 40 CFR Part 228.10b

** Long-Term Effects Can Occur Within Or Outside The Site

FIGURE 5-2. MONITORING ACTIVITIES ADDRESS PERMIT COMPLIANCE AND IMPACT ASSESSMENT.

and disposal operations is to ensure that the wastes comply with permit limits and regulations and that the discharge of material into the marine environment complies with permit conditions. Both sets of conditions are imposed on the permittee to ensure that the sludge or its constituents will not, for example, exceed LPCs or WQC after initial dilution, and hence possibly result in toxicity to marine organisms.

Activities that may be included under Tier 1 monitoring could include the following:

- Recording of the total volume of sludge dumped at the 106-Mile Site during the quarter.
- Measurement of chemical and microbiological constituents of the sludge dumped. Measurements will probably include all EPA priority pollutants. A list of parameters most likely to differ from ambient conditions is presented in Table 5-1.
- Conduct of toxicity tests to establish the concentration at which the sludge is toxic to marine organisms. (These tests will be used to establish or modify LPCs.)
- Static settling experiments in the laboratory to determine the rates at and conditions under which the wastes settle.

Additionally, position and rate of discharge may be recorded and the waste in the barge may be sampled frequently. Surveillance of dumping operations may also be conducted to see if disposal rates and operations agree with permit conditions.

5.2.2 Tier 2: Nearfield Fate and Short-Term Effects

The objective of the monitoring activities associated with Tier 2 is to assess the behavior, transport, and impact of the sludge within the boundaries and in the immediate vicinity of the 106-Mile Site. Permit requirements are the basic management tool for ensuring that LPCs are not exceeded at the 106-Mile Site.

TABLE 5-1. PARAMETERS THAT COULD BE MEASURED IN MUNICIPAL SLUDGES OR IN THE RECEIVING WATER AT THE 106-MILE SITE

Total organic carbon
Suspended and settleable solids
Turbidity*
Bacteria
Polychlorinated Biphenyls
Chromium
Cadmium
Copper
Lead
Mercury
Zinc
Coprostanol
Toxicity
Aldrin
Benzidine
Benzo(a)pyrene
Bis(2-ethylhexyl)phthalate
Chlordine
DDT/DDD/DDE
Dieldrin
Heptachlor
Toxaphine

* Would be measured only in receiving waters.

Compliance with these requirements is intended to ensure that sludge will not be transported outside the site at concentrations that will result in predictions of farfield impact.

Judging from available information of baseline conditions and sludge characteristics, sludge could be transported beyond the site boundaries at concentrations that greatly exceed ambient levels and that may exceed LPCs and WQC. There is also a potential for short-term biological impacts in the water column and for sludge constituents to settle below the pycnocline within site boundaries. Monitoring activities discussed below are necessary to ascertain where wastes disposed at the 106-Mile Site are transported, in what conditions they persist within site boundaries, and if there are significant short-term biological effects associated with sludge disposal in the vicinity of the site. Additionally, information gained from nearfield monitoring activities may be used to support validation of models for determining the physical short-term behavior of sludge disposed at sea.

Specific monitoring activities directed at nearfield fate may include

- Nearfield tracking and sampling of dissolved and particulate phases of sludge to determine if sludge or sludge components are transported beyond the 106-Mile Site or are transported beneath the pycnocline within the site.
- Analysis of nearfield water quality parameters, contaminant constituents, or pathogens to determine if LPCs, WQC, or other regulatory parameters are exceeded within the boundaries of the 106-Mile Site after the period of initial mixing or outside the site at any time.
- Acquisition of oceanographic information to describe site conditions in terms of parameters that affect the behavior of sludges at the site. Monitoring may

include measurements of wind, sea state, and currents during dumping events. Salinity, temperature, and dissolved oxygen may be used to define water masses occupying the site.

Appropriate direct measurements of short-term impacts on marine organisms have not yet been selected and require further consideration. However, examples of such activities may include the following:

- Studies of short-term bioaccumulation of waste constituents if appropriate indigenous species are available.
- Use of indicators of environmental stress such as copepod respiration rates to assess immediate and short-term impacts of sludge on marine animals present in the water column.
- Conduct of other acute or short-term toxicity tests using surface water or microlayer samples taken from the site during disposal operations.

5.2.3 Tier 3: Farfield Fate

Tier 3 monitoring activities will provide data on the farfield transport of sludges disposed of at the site. Although these data will not be used directly to measure impacts in the farfield, they may be used to assess the potential for impacts outside the site and in the long term. These results will guide the implementation of Tier 4 activities to test long-term effects hypotheses.

Monitoring activities in the farfield are based upon knowledge of the large-scale transport mechanisms affecting the 106-Mile Site. The activities associated with determining farfield fate include activities similar to those used for nearfield fate, but with increased emphasis on physical oceanography. Specific elements of farfield monitoring activities have not been selected. However, examples of such activities may include the following:

- Release of satellite-tracked drifters within the 106-Mile Site to track the movement of the water masses into which the sludge is discharged and to document the frequency and extent of any on-shelf excursions from the 106-Mile Site.

- Continued deployment of current meters in the vicinity of the site to monitor surface and midwater currents in the area.

- Use of satellite imagery to document the frequency and extent on-shelf excursions of water occupying the site.

- Determination of amount and location of sludge particulate deposition on the ocean floor with sediment traps located above the seafloor both inside and outside the 106-Mile Site.

5.2.4 Tier 4: Long-Term Effects

Potential long-term effects include adverse effects on commercial fisheries; accumulation of sludge constituents in marine biota; changes in marine water quality, sediment composition, or biological communities; and absence of sensitive marine organisms from the site. Decisions on specific monitoring activities to determine long-term effects will be based in part upon the results of earlier monitoring results. Specific activities associated with this monitoring effort have not yet been determined, although EPA is currently evaluating the usefulness and practicality of including bioaccumulation studies in this tier. Examples of such activities might include the following:

- Water-column chemistry and microbiology for waste tracers that may be detected above background levels even after extensive dilution. These tracers include organic compounds, such as PCBs and coprostanol; metals, such as zinc, iron, and lead; and microbiological constituents such as Clostridium perfringens (O'Connor et al., 1985).

- Sediment chemistry and microbiology for the same constituents analyzed in the water column.

- Tissue analyses of species living in or near the seafloor, e.g., tilefish, or in the water column, e.g., squid, to determine whether toxic materials are accumulating in their tissues.

- Studies of the distribution and abundance of sensitive stages of fish and invertebrate populations, such as eggs and larvae, in the site. Data could be compared to data already collected by NOAA as part of the Marine Resources Monitoring, Assessment, and Prediction program (MARMAP).

- Endangered species observations to assess any changes in distributions of whales or turtles in the vicinity of the 106-Mile Site.

- Analyses of benthic infaunal communities to determine whether there are any detectable biological effects in the deep sea. Results would be compared with other benthic studies conducted in the same general area before the commencement of sludge dumping.

5.3 QUALITY ASSURANCE

The EPA policy on quality assurance (QA; Administrator's memoranda, 30 May 1979, 14 June 1979; EPA Order 5360.1, "Policy and Program Requirements to Implement the Quality Assurance Program," 3 April 1984) stipulates that every monitoring and measurement project must have a written and approved quality assurance plan. The goal of EPA's QA Program is to ensure that all measurements supported by EPA are of known and acceptable quality. For the 106-Mile Site monitoring program, this goal is achieved by a program that sets standards for personnel qualifications; facilities, equipment, and services; data generation and recordkeeping; and data quality assessments.

5.3.1 Personnel Qualifications

For a quality monitoring program, it is important that all personnel performing tasks and functions related to data quality be appropriately qualified and adequately trained. For the 106-Mile Site monitoring program, the person in charge of each specific unit of work identified as a project is responsible for ensuring that personnel working on that project are qualified and trained. Records of qualifications and training of personnel must be kept current so that training can be verified.

Persons with quality assurance responsibilities for the monitoring program must be technically qualified. Because it is their responsibility to make unbiased assessments of work being performed, they themselves should not be personally involved in generation of data.

5.3.2 Facilities, Equipment, and Services

All facilities, equipment and services used for the 106-Mile Site monitoring program must be appropriate for their intended use and properly maintained. Vessels to be used in field activities must be appropriate to accommodate equipment used for sample collection and on-board analyses. Analytical facilities must be equipped with instrumentation suitable for conducting the analyses required by the monitoring program.

5.3.3 Data Generation and Recordkeeping

Data collected for the 106-Mile Site monitoring program must be recorded directly, promptly, legibly, and indelibly, so that data will be easily traceable. Data entries must be dated on the date of entry and signed or initialed by the person making the measurement and the person entering the data. Changes to entries must not obscure the original entry and must indicate the reason for the change, the person making the change, and the date of change. In computer-driven data collection systems, the person responsible for direct data input will be identified at the time of input.

Quality Assurance Project Plans, developed in accordance with OWRS QA-1, "Guidance for the Preparation of Combined Work/Quality Assurance Project Plans for Environmental Monitoring," May 1984, must be prepared for all specific units of work associated with the 106-Mile Site monitoring program. Topics covered in these documents include provisions for 1) name of the project, 2) what agency requested it, 3) date of the request, 4) date of project initiation, 5) project officer, 6) quality assurance officer, 7) project description, 8) project fiscal information, 9) schedule of tasks and products, 10) project organization and responsibilities, 11) data quality requirements and assessments, 12) sampling and analytical procedures, 13) sample custody procedures, 14) equipment calibration and maintenance procedures, 15) data reduction and reporting, 16) data validation, 17) performance and systems audits, 18) corrective action, and 19) reports. Each monitoring activity identified as a separate project must have a Work/QA Project Plan written and approved by EPA before any monitoring activities are performed.

Like Work/QA Project Plans, Standard Operating Procedures (SOPs) ensure that all persons conducting work are following the same procedures and that the procedures do not change over time. SOPs have been prepared for use of equipment and facilities, measurements, and other aspects of work that impact data quality for the 106-Mile Site monitoring program. SOPs for activities and measurements that are already being made for the program are maintained with general QA Plans for conduct of field and laboratory activities for the monitoring program. Additional SOPs will be prepared as specific activities are selected for use in the program.

5.3.4 Data Quality Assessment

Data validation for the 106-Mile Site Monitoring Program involves all procedures used to accept or reject data after collection and prior to use, including editing, screening, checking, auditing, verifying, and reviewing. Data validation procedures ensure that the standards for data accuracy and precision were met, that data were generated in accordance with the Work/QA Project Plan and SOPs, and that data are traceable and defensible. It is important for all reported data to be properly validated following standardized procedures to ensure that data are of consistent and documented quality.

EPA representatives participate in field surveys to the 106-Mile Site, and the EPA management authority for the program may require that certain samples be routinely submitted to EPA laboratories for analysis. These activities provide an independent quality assurance check on activities being performed and on data being generated.

5.4 DATA MANAGEMENT

All data generated under the 106-Mile Site monitoring program must be readily identifiable and traceable, so that they will be available to the variety of persons who will wish to use them. Ideally, a single data management system will be able to track samples in the field and the laboratory, accommodate data reduction and analysis, and provide for storage and retrieval of data throughout the monitoring program.

6. REFERENCES

Bisagni, J.J. Lagrangian Measures of Near-Surface Waters at the 106-Mile Site. NOAA Tech. Memo. OMPA-11, Office of Marine Pollution Assessment, U.S. Dept. of Commerce Pub. 23 pp.

Bothner, M.H., E.Y. Campbell, G.P. DeLisio, C.M. Parmenter, R.R. Rendigs, M.W. Doughten, R.G. Johnson, J.R. Gillison, and N. Rait. 1986. Analysis of Trace Metals in Bottom Sediments in Support of Deepwater Biological Processes Studies on the U.S. Mid-Atlantic Continental Slope and Rise. Second Interim Report to the U.S. Minerals Management Service. 55pp.

Camp, Dresser, and McKee. 1984. Environmental Impacts of Municipal Sludge Disposal at Deep Ocean Sites. Prepared for EPA. 90 pp.

Csanady, G.T. and P. Hamilton. 1987. Circulation of slopewater. Submitted to Continental Shelf Research.

Ecological Analysts, Inc. and SEAMOcean, Inc. 1983. A Special Permit Application for the Disposal of Sewage Sludge from Twelve New York City Water Pollution Control Plants at the 12-Mile Site. Volumes I-II. Prepared for City of New York, Department of Environmental Protection.

EG&G Consultants. 1983. Assessment for Future Environmental Problems - Ocean Dumping. Prepared for EPA.

EPA. 1977. Proposed revisions to ocean dumping criteria. Final Environmental Impact Statement. Volumes I-II. Oil and Special Materials Control Division, Office of Water Program Operations, U.S. Environmental Protection Agency, Washington, DC.

EPA. 1980 Environmental Impact Statement (EIS) for the 106-Mile Ocean Waste Disposal Site Designation. Final. Oil and Special Materials Control Division, Marine Protection Branch, U.S. Environmental Protection Agency, Washington, DC.

EPA. 1986. Studies Conducted in the Vicinity of the 106-Mile Deepwater Municipal Sludge Site. Environmental Protection Agency Oceans and Coastal Protection Division (formerly OMEP), Washington, DC.

EPA. 1988. Final Report of Analytical Results of the 106-Mile Deepwater Sludge Dumpsite Survey-Summer 1986. Environmental Protection Agency Oceans and Coastal Protection Division (formerly OMEP), Washington, DC.

EPA. 1992. Final Draft Implementation Plan for the 106-Mile Deepwater Municipal Sludge Site Monitoring Program. Environmental Protection Agency. EPA 842-S-92-010.

Flagg, C.N., D.E. Frye, and P.R. Daifuku. 1985. Analysis of Circulation Characteristics in the Vicinity of Deepwater Dumpsite 106. NOAA Tech. Memo. NOS OMA 13. 60 pp.

Greig, R. and D. Wenzloff. 1977. Final report on heavy metals in small pelagic finfish, euphasiid crustaceans, and apex predators, including sharks, as well as on heavy metals and hydrocarbons (C15+) in sediments collected at stations in and near Deepwater Dumpsite 106. In: Baseline Report of Environmental Conditions in Deepwater Dumpsite 106. Volume III: Contaminant Inputs and Chemical Characteristics. NOAA Dumpsite Evaluation Report 77-1. 798 pp.

Hausknecht, K.A. 1977. Results of studies on the distribution of some transition and heavy metals at Deepwater Dumpsite 106. In: Baseline Report of Environmental Conditions in Deepwater Dumpsite 106. Volume III: Contaminant Inputs and Chemical Characteristics. NOAA Dumpsite Evaluation Report 77-1. 798 pp.

Ingham, M.C., J.J. Bisagni, and D. Mizenko. 1977. The general physical oceanography of Deepwater Dumpsite 106. In: Baseline Report of Environmental Conditions in Deepwater Dumpsite 106. Volume I: Physical Characteristics. NOAA Dumpsite Report 77-1. 798 pp.

Maciolek, N., J.F. Grassle, B. Hecker, P.D. Boehm, B. Brown, B. Dade, W. Steinhauer, E. Baptiste, R.E. Ruff and R. Petracca. 1987. Study of the Biological Processes on the U.S. Mid-Atlantic Slope and Rise. Final Report to the U.S. Department of the Interior, Minerals Management Service. Volume I and II.

NOAA. 1977. Baseline Report on Environmental Conditions in Deepwater Dumpsite 106. Volumes I-III. NOAA Dumpsite Evaluation Report 77-1. 798 pp.

NOAA. 1983. 106-Mile Characterization Update. NOAA Tech. Memo. NMFS-F/NEC-26.

O'Conner, T.P., H.A. Walker, J.F. Paul, and V.J. Bierman. 1985. A Strategy for Monitoring of Contaminant Distributions Resulting from Proposed Sewage Sludge Disposal at the 106-Mile Ocean Disposal Site. 24 pp.

Payne, M.P., L.A. Selzer, and A.R. Knowton. 1984. Distribution and Density of Cetaceans, Marine Turtles, and Seabirds in Shelf Waters of the Northeastern United States, June 1980 - December 1983, Based on Shipboard Observations. NOAA/NMFS Contract No. NA-81-FA-C-00023.

Pearce, J.B., J. Thomas, and R. Grieg. 1975. Preliminary investigation of benthic resources at Deepwater Dumpsite 106. In: May 1974

Baseline Investigation of Deepwater Dumpsite 106. NOAA Dumpsite Evaluation Report 75-1. 388 pp.

Pearce, J.B., J.V. Caracciolo, and F. Steimle. 1977. Final Report on benthic infauna of Deepwater Dumpsite 106 and adjacent areas. In: Baseline Report on Environmental Conditions in Deepwater Dumpsite 106. NOAA Dumpsite Evaluation Report 77-1. 798 pp.

SAIC. 1985. Mid-Atlantic Slope and Rise Physical Oceanography Study (MASAR/POS). Semi-Annual Report No. 2 to the U.S. Minerals Management Service. 61 pp. and Appendix A.

Santoro, E.D. and D.J. Suszkowski. 1986. Current status: Phase-out of ocean dumping of sewage sludge in the New York Bight Apex, Sixth International Ocean Disposal Symposium, Asilomar Conference Center, Pacific Grove, California, April 21-25, 1986.

Segar, D.A. and E. Stammen. 1985. A Strategy for Design of Marine Pollution Monitoring Studies for the IAWPRC/NERC Specialized Conference, Plymouth, England.

Segar, D.A., E. Stammen, and P.G. Davis. 1984. Criteria for Development of a Monitoring Program for the North Atlantic Deepwater Dumpsite. 10 pp.

Walker, H.A., J.F. Paul, and V.J. Bierman, Jr. 1987. Methods for waste load allocation of municipal sewage sludge at the 106-Mile Ocean Disposal Site. Environ. Tox. Chem. 6:475-489.

Warsh, C.E. 1975. Physical oceanographic observations at Deepwater Dumpsite 106 - May 1974. In: May 1974 Baseline Investigation of Deepwater Dumpsite 106. NOAA Dumpsite Evaluation Report 75-1. 388 pp.

Zeller, R. W. and T.A. Wastler. 1986. Tiered Ocean Disposal Monitoring Will Minimize Data Requirements. Oceans 86 Volume 3, Monitoring Strategies Symposium. 6 pp.