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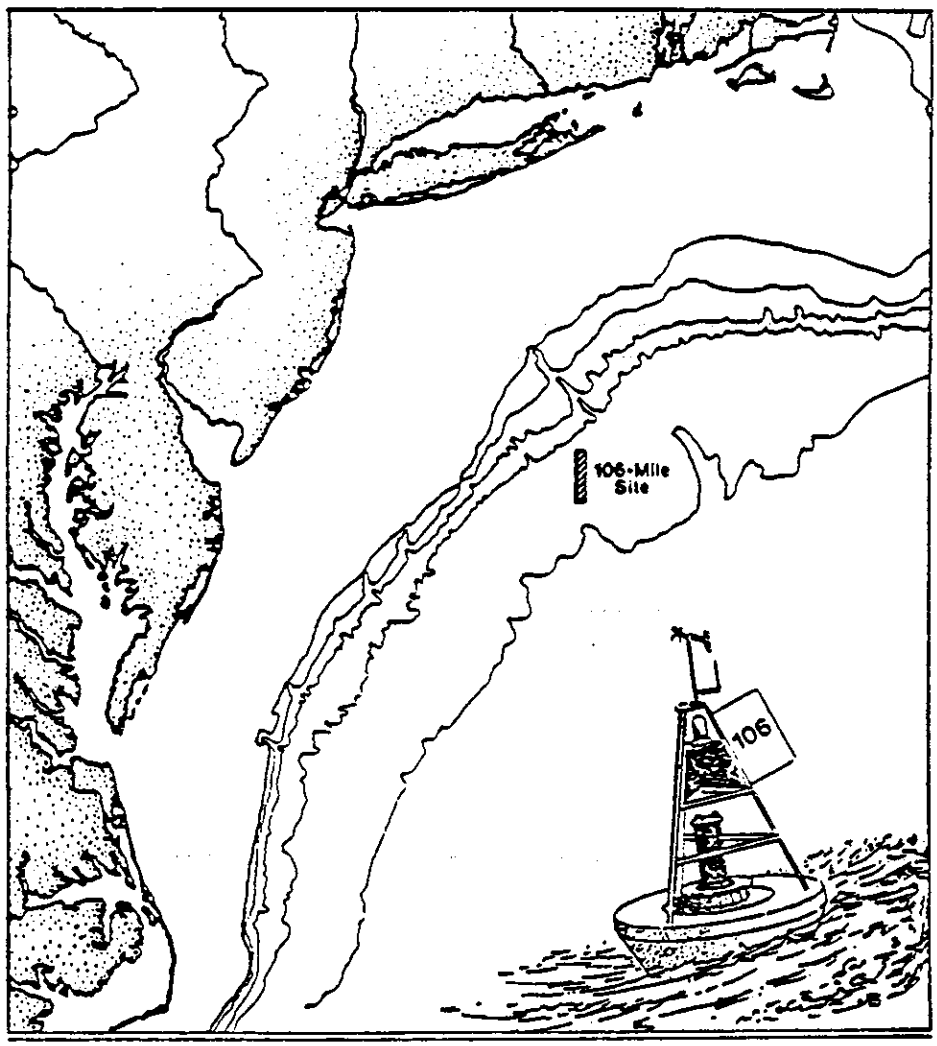
Final Draft Implementation Plan for the 106-Mile Deepwater Municipal Sludge Site Monitoring Program



FINAL DRAFT

IMPLEMENTATION PLAN
FOR THE
106-MILE DEEPWATER MUNICIPAL SLUDGE SITE
MONITORING PROGRAM

March 11, 1988

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

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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 wastes, including sewage sludges, in ocean waters. Under this authority, EPA has published ocean dumping regulations (40 CFR Parts 220-229) which specify procedures for monitoring ocean dumpsites. EPA's responsibility for developing and maintaining monitoring programs for designated ocean disposal sites is described in these regulations.

In carrying out the responsibility for developing monitoring programs, EPA has prepared a monitoring plan for the 106-Mile Deepwater Municipal Sludge Site (106-Mile Site), located off the coast from New York and New Jersey (Figure 1-1) (EPA , 1992). Data generated by the program will be used by site managers to make decisions about site redesignation or dedesignation; continuation, termination, or modification of permits; and continuation, termination, or modification of the monitoring program itself.

CONTENTS OF THE 106-MILE SITE MONITORING PLAN

The 106-Mile Site monitoring plan (EPA , 1992) describes the regulatory basis for the monitoring program and the objective of monitoring that is founded in the regulations. The objective is to ensure that the regulations are met through assessing both compliance with permit conditions and potential impacts of disposal of municipal sludges on resources or other aspects of the marine environment.

The monitoring plan describes the current understanding of the characteristics of the site and of the sludges to be disposed there. The site occupies approximately 100 mi^2 in water depths of 2250 to 2750 m. When designating the site, the significant dispersive forces, deep permanent stratification, and great distance from shore were considered to ensure that potential impacts of sludge disposal would be minimal (49 FR 19005).

Sewage sludges to be disposed at the site have not been fully characterized. However, they are known to be somewhat buoyant, including less than 2 to 4 percent solid material. The chemical composition of the

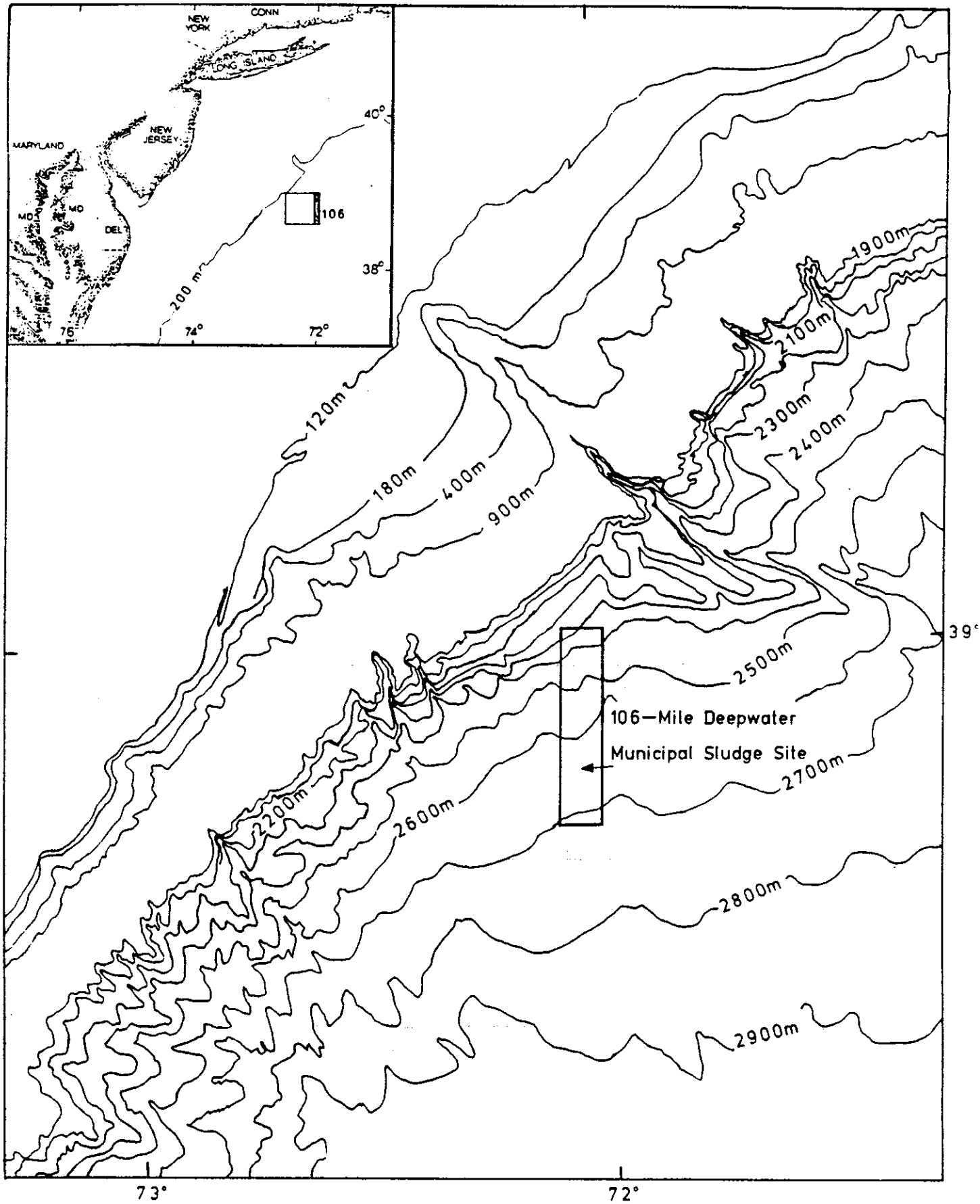

FIGURE 1-1. THE 106-MILE SITE IS SITUATED OFF THE COAST OF NEW JERSEY, BEYOND THE CONTINENTAL SHELF.

sludges includes organic compounds, such as aldrin, dieldrin, chlordane, heptachlor epoxide, DDT and its degradation products, and polychlorinated biphenyls. Metals, including cadmium, copper, chromium, and mercury, are also present.

The monitoring plan further describes the regulatory basis for the program and how the site and waste characteristics have been used to predict possible impacts of sludge disposal and to formulate the null hypotheses that these predictions suggest. The following impact categories itemized in the ocean dumping regulations have been used to develop predictions of possible impacts:

- Impingement of sludge onto shorelines.
- Movement of sludge into marine sanctuaries or 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 to 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.
- Progressive changes in pelagic, demersal, or benthic biological communities as a result of sludge disposal.

The predictions developed for each of these impact categories are summarized in Figure 1-2. These predictions serve as the conceptual foundation for formulating testable null hypotheses. The hypotheses address assessment of permit compliance as well as assessment of potential impacts.

The monitoring plan also presents an overview of the implementation of the monitoring program, including a description of how questions about the impacts of monitoring have been organized into an implementation framework of tiers and a brief discussion of the activities that may be included in the

Impingement of sludge onto shorelines.

P-1: Sewage sludges dumped at the 106-Mile Site will probably not impact any shoreline in detectable quantities.

Movement of sludge into marine sanctuaries or shellfishery or fishery areas.

P-2: Marine sanctuaries and shellfishery areas will probably not be impacted by shoreward movements of sludge.

P-3: Sewage sludge may be transported to the continental slope and shelf where fisheries activities exist.

Effects of sludge on commercial fisheries.

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.

Accumulation of sludge constituents in biota.

P-5: 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, but may be difficult to distinguish from other potential sources.

P-6: Bioaccumulation of low levels of contaminants by resident continental shelf/slope fishes or invertebrates 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.

Progressive changes in water quality.

P-7: Sewage sludge movement and transport beyond the site boundaries may result in significant impact on the water quality beyond the site.

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.

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.

Progressive changes in sediment composition.

P-10: 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 habitat, and/or the accumulation of sludge constituents in surficial sediments will probably be nil to minimal.

Impacts on pollution-sensitive species.

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 the sediments of the 106-Mile Site region. Effects may be detectable, but local and short-lived.

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 sludges.

Impacts on endangered species.

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

Progressive changes in biological communities.

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.

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.

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.

FIGURE 1-2. PREDICTIONS FOR POTENTIAL IMPACTS OF SLUDGE DUMPING AT THE 106-MILE SITE

program. The tiered approach organizes the null hypotheses into a hierarchy, whereby data collected in each tier are required as the foundation for the design and extent of monitoring activities in the next tier. Such an approach ensures that only information needed for making decisions will be collected (Zeller and Wastler, 1986). The four tiers included in the 106-Mile Site monitoring program are 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

CONTENTS OF THE IMPLEMENTATION PLAN

This implementation plan elaborates on the information included in the monitoring plan. Chapter 2 of the implementation plan describes the baseline information available or being generated for the monitoring program. It also presents the background and objectives, null hypotheses and activities, sampling and analytical design, and endpoints and data uses for each tier of the monitoring program. Chapter 3 presents the integrated schedule and sampling plan for the program. Chapter 4 describes how the information generated through implementation of the monitoring program may be used to make decisions about site management.

2. IMPLEMENTATION OF THE MONITORING PROGRAM

2.1 BASELINE INFORMATION

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 was used to develop the framework of the 106-Mile Site monitoring plan (EPA , 1992). It will also be used as the baseline information against which monitoring results will be compared.

Information available on the physiography, physical oceanography, and baseline chemical and biological characteristics of the 106-Mile Site and surrounding regions has been summarized in the monitoring plan (EPA , 1992). The baseline chemical and biological conditions are briefly reviewed in this section. Much of this information is the result of studies funded by EPA in support of the site designation process for the 106-Mile Site or in support of the monitoring program. EPA has also conducted baseline sampling for a proposed ocean incineration site located to the south of the site. Additional studies have been conducted by other federal agencies, either because of interest in potential impacts from the disposal of municipal sludges or other materials in the vicinity of the site or because of other interest in the region. A complete description of many of these programs can be found in EPA (1986) and EPA (1992).

Baseline information includes water column and sediment chemistry 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 will also 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 attributable to dumping operations occur in these variables over time. Water column stations that have been sampled in the vicinity of the 106-Mile Site are presented in Figure 2-1. Surveys that have occupied these stations include a series of

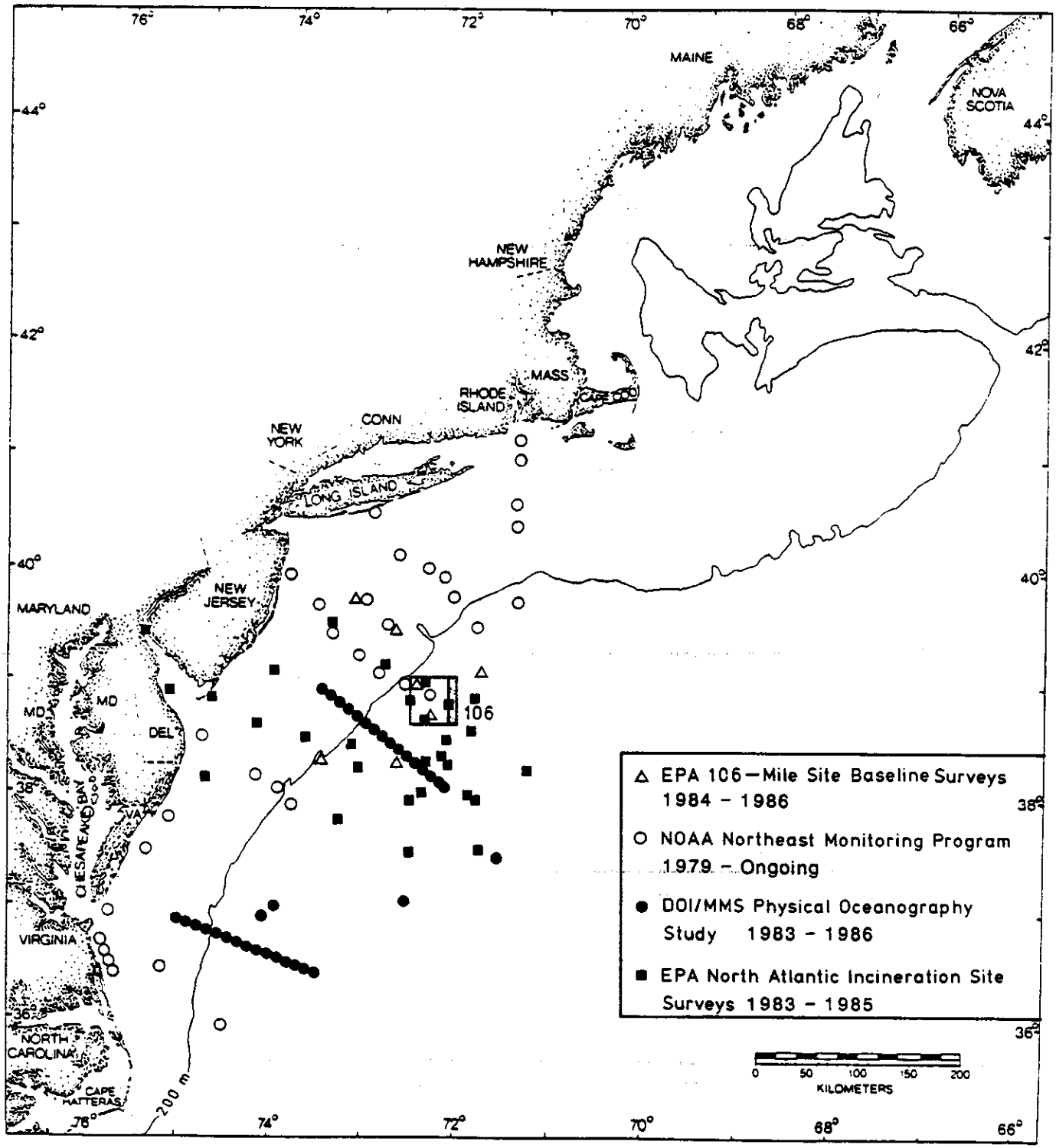

FIGURE 2-1. STUDIES HAVE SAMPLED THE WATER COLUMN IN THE VICINITY OF THE 106-MILE SITE.

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 Mid-Atlantic Slope and Rise (MASAR) study funded by the Minerals Management Service of the Department of the Interior, and water quality stations sampled during the Northeast Monitoring Program funded by National Oceanic and Atmospheric Administration (NOAA).

Average monthly dissolved oxygen levels at the surface within the 106-Mile Site range from 4.9 ml/l in August to 7.5 ml/l in April (Warsh, 1975). The oxygen minimum zone is located between 200 and 300 m, with oxygen values ranging from 3.0 ml/l in February to 3.5 ml/l in September. An oxygen maximum zone develops during several months, ranging from 7.0 ml/l at 30 m during August to 8.2 ml/l at 10 m during February. The winter results were confirmed during a February 1986 survey to the site (EPA , 1987b). 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. Background concentrations of cadmium, copper, and lead in the water column at the site were considered comparable to other oceanic regions (Hausknecht, 1977; EPA, 1980; EPA , 1987b).

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 2-2 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 considered useful to the 106-Mile Site program (EPA, 1980; Maciolek, 1987).

Concentrations of trace metals in the sediments in the vicinity of the site vary considerably depending on local topography, depth, and sediment grain size. 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 concentrations may be higher than values found in other studies due to the proximity of sampling stations to the Hudson Canyon. NOAA (1977) analyzed 5 trace elements at the site, EPA analyzed 8 trace elements at the site (EPA , 1987b), and Bothner et al.

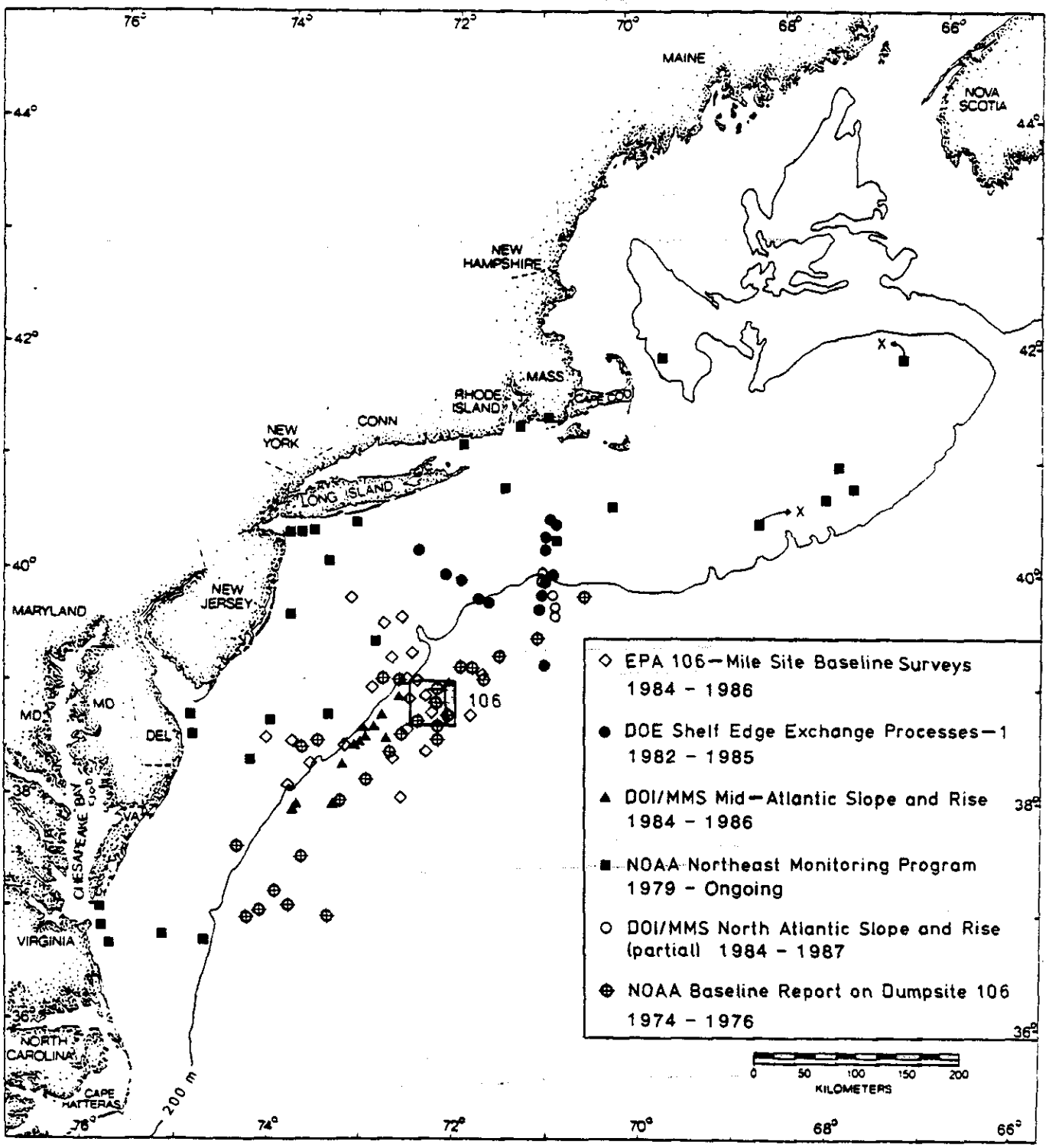

FIGURE 2-2. STUDIES CONDUCTED AT THE 106-MILE SITE HAVE SAMPLED SEDIMENT FOR BASELINE CHEMISTRY INFORMATION.

(1987) analyzed 12 trace elements southwest of the site. The levels of trace metals in surface sediments from these studies were the same as or lower than average levels found in other locations around the world. Concentrations of polynuclear aromatic hydrocarbon and pesticide/polychlorinated biphenyls 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 are occurring in benthic community structure because of dumping operations. Historical stations sampled for benthic infauna on the continental shelf and slope in the vicinity of the site are plotted in Figure 2-3. These stations include those sampled for EPA during a MMS survey at 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. Benthic invertebrate samples collected and analyzed by Pearce et al. (1975, 1977) showed 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. More recently, Battelle found infaunal densities and species compositions at the site similar to slope areas of similar depths north and south of the site (Maciolek, 1987). The latter studies recorded densities of 3567 to 5361 individuals/m^2 at depths of 2000 to 2500 m.

Changes in the community structure of plankton and pelagic species are difficult to assess. Although there is considerable information about the organisms that inhabit the continental slope and shelf waters directly inshore from the site, little information is available on the flora and fauna that inhabit the immediate vicinity of the 106-Mile Site. Most of the information available indicates a patchy and highly variable community of plankton and higher organisms.

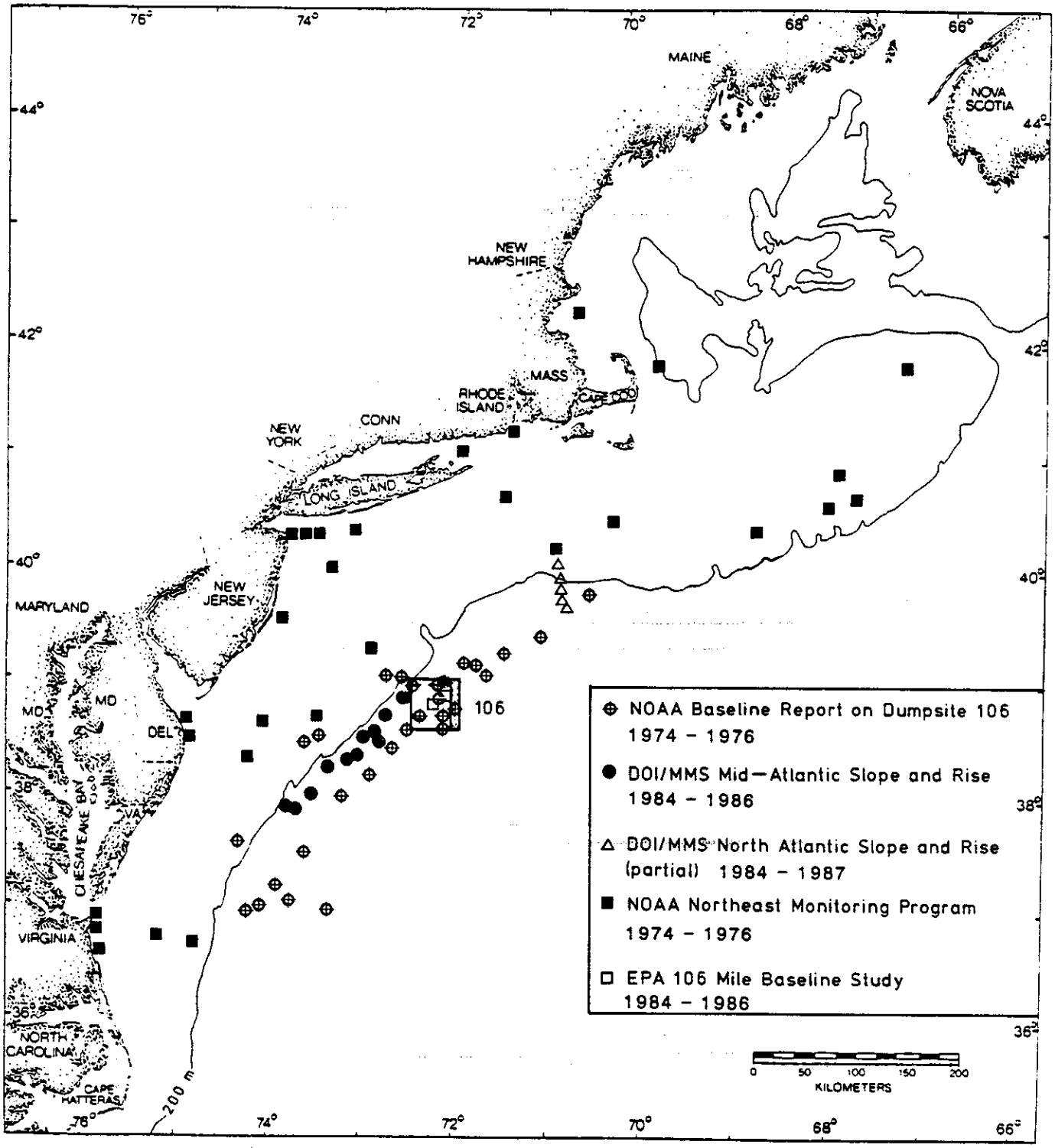

FIGURE 2-3. STUDIES HAVE ANALYZED BENTHIC INFAUNA IN THE VICINITY OF THE 106-MILE SITE.

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 μm) at depths of 60 to 2000 m. The fall bloom tends to be dominated equally by netplankton and nanoplankton (size less than 20 μm). During cooler months of the year, standing stocks of zooplankton in the site region are as high as at inshore areas (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 Stream 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 m 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 for bioaccumulation of low levels of sludge constituents by resident fishes or invertebrates of the continental shelf or slope is addressed in the implementation of the monitoring program. The tilefish, Lopholatilus chamaeleonticeps, and the sea scallop, Placopecten magellanicus, have been identified as relatively non-mobile and commercial species that may be suitable for bioaccumulation studies (EPA , 1987c). Although the two species are not resident within the 106-Mile Site or in deep water south

of the site, they will be suitable for study if sludge is found to move inshore regularly. Baseline contaminant information is not available for these species, but the acquisition of this information is planned for 1988 as part of the monitoring program. Because of the distance from the site, collection of baseline information will be valid, even though dumping has already been initiated.

The potential effect of dumping operations on the distributions of endangered species at the 106-Mile Site is of public concern. Figure 2-4 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.

2.2 TIER 1--WASTE CHARACTERISTICS AND DISPOSAL OPERATIONS

2.2.1 Background and Objectives

Ongoing monitoring of sludge characteristics and disposal operations is important, because the nature and composition of sludges transported to and disposed of at the 106-Mile Site will vary with time among the several source treatment plants. The assumptions made both in writing the permits for sludge disposal and in predicting potential impacts must be validated with adequate characterization data and updated with ongoing monitoring in order to provide the environmental protection intended by the permits.

The objectives of Tier 1, therefore, are to assess and monitor sludge characteristics and disposal operations in order to verify that conditions specified by the permits are met and continue to be adequate during the period of site designation and active disposal. Data generated by this tier's activities may be used in determining whether to revoke or change a permit or whether to redesignate or dedesignate the site. These data may also be used in deciding whether to curtail or change activities in other tiers of the monitoring program.

All applicants for dumping permits must include with their applications a detailed characterization of the waste to be discharged at the 106-Mile Site. EPA guidance for the initial sludge characterization is listed in Section

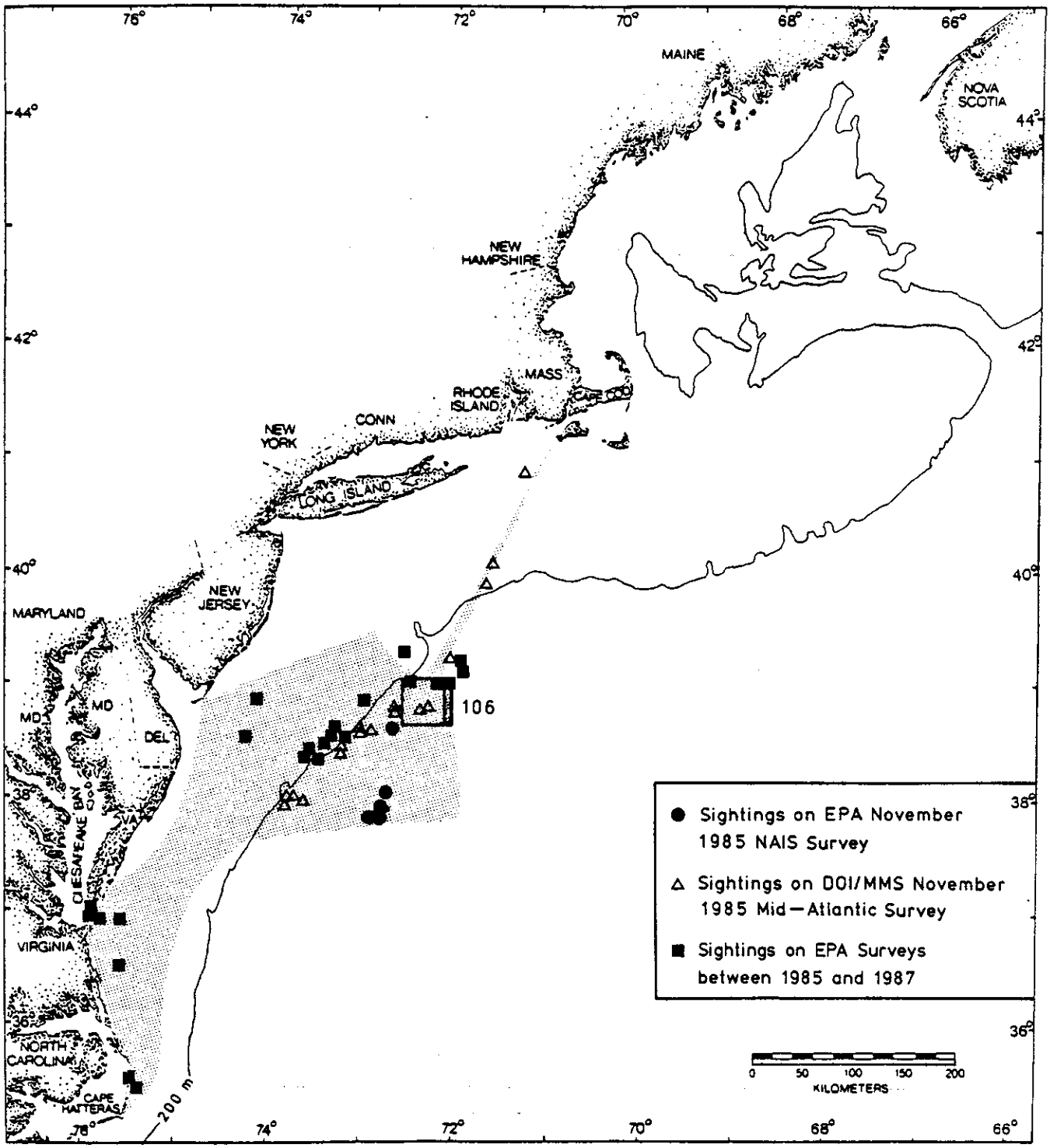

FIGURE 2-4. OBSERVATIONS OF ENDANGERED SPECIES HAVE BEEN MADE IN THE VICINITY OF THE 106-MILE SITE.

2.2.2. At present, sludge dumping at the 106-Mile Site is occurring under court order, and each treatment plant is sending EPA quarterly data based on parameters and methods used historically for sludge dumping at the 12-Mile Site. The completed permit applications must contain the full set of sludge characterization data before EPA can grant actual operating permits to the New York and New Jersey applicants.

The initial waste characterization information used to permit the disposal of specific sludges and stipulate disposal conditions will rely critically on the relevance, reliability, and representativeness of specific data and the methods used to generate those data. Similarly, once permits are issued, compliance monitoring must be appropriate both to detect changes in sludge characteristics and to ensure that permit conditions are being met; the success of compliance monitoring relies on the adequacy of the initial waste characterization efforts.

2.2.2 Null Hypotheses and Activities

2.2.2.1 Sludge Characteristics

Sewage sludges disposed at the 106-Mile Site will have varying physical, chemical, and microbial characteristics, because sewage treatment plants receive wastes from a variety of sources. Table 2-1 summarizes a partial data set of sludge characteristics representative of that currently being provided to EPA by treatment plants participating in 106-Mile Site disposal, indicating the wide ranges that can be expected in sludge composition. Sludges from each plant may also vary significantly over time. Permit conditions depend on determination of the sludge characteristics, and the design of the monitoring program itself is linked to the expected behavior and fate of the sludge after disposal in the ocean. Monitoring of sludge compositions and characteristics must be related directly to specifications in the permit that are based on an initial, thorough sludge characterization supplied by the permittee. The following null hypothesis is central to successful implementation of waste characteristic monitoring.

Table 2-1. Ranges in Sludge Characteristics (Taken From Quarterly Sludge Data Submitted by Five New Jersey Plants and One New York Plant[a])

PARAMETER	UNIT	RANGE
Oil and grease	ppm	2110-134,000
Petroleum hydrocarbons	ppm	77-1280
Mercury	ppm	<0.002-2.37
Arsenic	ppm	0.067-8.7
Chromium	ppm	14.5-185
Copper	ppm	26.5-182
Lead	ppm	2.40-373
Nickel	ppm	6.0-54.5
Cadmium	ppm	0.99-13.0
Vanadium	ppm	<0.25-13.0
Zinc	ppm	22.6-165
Specific gravity[b]	g/ml	0.955-1.08
Chemical oxygen demand	ppm	22,500-82,300
Suspended solids[b]	ppm	15,600-55,300
Total solids[b]	ppm	27,400-50,000
Fecal coliforms[b]	MPN/100ml	2300-2,400,000
Total coliform[s]b	MPN/100ml	160,000-5,600,000
96-h toxicity tests		
Menidia menidia w/o O_2	ppm	1300-20,500
Menidia menidia w O_2	ppm	1070-21,500
Skeletonema costatum	ppm	1800-172,000
Mysidopsis bahia	ppm	100-28,000

[a]Passaic Valley Sewage Commissioner on 12/5/86 and 9/2/86, Middlesex County Utilities Authority on 4/8/86, Bergen County Utilities Authority on 3/5/87, Linden Roselle Sewage Authority on 7/8/86, and Joint Meeting Essex and Union Counties on 12/9/86, New York City Department of Environmental Protection for 7/87.
[b]Three reporting sources only.

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

Permits for sludge disposal must supply the relevant characterization data and methods to allow EPA to set adequate dumping limits that protect the marine environment during the period of site designation.

The activities for testing Tier 1 hypotheses H_o1 in proceeding with 106-Mile Site monitoring include the following:

- **Define the variability in characteristics of sludges to be disposed of at the 106-Mile Site.** This activity involves the following sequence of events:

  Review the waste characterization data and information established during the permit application process. This information is available from quarterly monitoring data being submitted by the participating New York and New Jersey treatment plants.

  Determine the adequacy (i.e., relevance, representativeness, accuracy, precision) of the available data and the methods used to generate them.

  If necessary, revise or add to methods and revise or complete the initial characterization database. Establish as part of the initial waste characterization a measure of the range and variability for key characteristics of each sludge (source).

  Develop a monitoring plan for each permittee, prescribing parameters, methods, and sampling frequencies that will be both practical and reliable for ongoing compliance monitoring, considering the ranges of source sludge characteristics.

- **Conduct regular monitoring of sludge characteristics.** Because this program is likely to be implemented by the permittees, EPA's role will be to evaluate the data as they are generated. An evaluation will involve developing and implementing a data monitoring system that can efficiently evaluate compliance monitoring data as they are generated. Such a system must include range limits of acceptability and tests of data accuracy and precision.

2.2.2.2 Disposal Operations

Final permits will specify the locations at which sludge disposal may occur (i.e., sectors within the 106-Mile Site) and also maximum discharge rates. These rates will be determined in conjunction with the limiting permissible concentrations (LPCs) for sludge, a knowledge of the sludge characteristics, and the expected rates of sludge dilution so that the LPCs are not exceeded after mixing. The applicable hypothesis is as follows:

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

This hypothesis assumes that the ocean dumping permit requirements adequately consider the waste characteristics in conjunction with the receiving environment and the discharge conditions.

As described, the LPC and physical characteristics data in conjunction with "models" of dilution and dispersion are the most relevant input factors for setting disposal conditions.

Activities for testing Tier 1 hypothesis H_o2 include the following:

- **Define range of disposal operations to be used at the 106-Mile Site.** This will include evaluation of the range of disposal methods and conditions among the permittees: (1) onboard combining of different source sludges; (2) conditions during transport; (3) methods of discharge.

- **Prescribe and conduct regular monitoring of disposal operations.** This activity will include two steps:

  Prescribe onboard discharge monitors that can record, compliance with permit conditions (rates, quantities).

  Because the permitees will be primarily responsible for monitoring disposal operations, EPA's role in continued monitoring will be to develop and implement a system for compiling, reducing, and displaying information on discharge condition in a real-time sequence with loading, barging, and dumping.

2.2.3 Approach and Design

2.2.3.1 Sludge Characteristics

Initial Sludge Characterization: EPA Region II has specified to all permit applicants that comprehensive information about waste characteristics must be provided prior to the issuance of sludge dumping permits at the 106-Mile Site. EPA Region II did not provide specific methods in its initial request and guidance to permit applicants. Instead, applicants were requested to either document their recommended methods or otherwise obtain EPA's approval for acceptable methods. Table 2-2 summarizes the compositional and toxicity parameters and the appropriate methods for sludge characterization that should be used in judging the adequacy of applicant submitted data. Once the completed permit applications are available and a comprehensive set of waste characterization data has been compiled for each sludge source, the following activities will be conducted:

- **Each permittee's sludge composition must be acceptable to allow ocean dumping of the material under applicable or relevant and appropriate requirements (ARARs).** In other words, it must be determined from a review of the submitted data that there are no components present above acceptable limits for ocean disposal.

- **A suite of compositional parameters, presumably a subset of the comprehensive characterization data, must be selected for each permit as a specification for regular, ongoing compliance monitoring.** This specification may be slightly different for each permittee, depending on the initial comprehensive characterization, but for all permits it is expected that the basic physical, chemical, and toxicological data now being provided quarterly will be included (see Table 2-1).

Ongoing Sludge Composition Monitoring: Once dumping under permits has begun, permittees will be required to submit regular reports to update information provided during the application process, and to document that no compositional changes are occurring as sludge is generated over time. Previously, at the 12-Mile Site, such reports were submitted quarterly, and there is currently no evidence that this schedule is inappropriate. These data should be compiled into a statistical control limit set for each

Table 2-2. Sludge Characterization Analytes and Methods for the Initial Permit Application

Parameter	Method
Organic priority pollutants	EPA SW 846 Volume I Section B
Inorganic priority pollutants	EPA SW 846 Methods 3050,6010, or 7000
Floatable materials	Standard Methods 206
Specific gravity	Standard Methods 213E
pH	EPA 600/4-79-020 (revised 3/83 Method 150.1
Total, dissolved, and suspended solids	Standard Methods 209
Oil and grease	EPA SW 846 Methods 9071
Petroleum hydrocarbons	EPA 600/4-79-020 (revised 3/83) Method 418.1
Organohalogens	EPA SW 846 Volume I Section B
Carcinogens	EPA SW 846 Volume I Section A and B
Mutagens	EPA SW 846 Volume I Section A and B
Teratogens	EPA SW 846 Volume I Section A and B
Pathogenic organisms	Standard Methods 912
Biological oxygen demand	EPA 600/4-79-020 (revised 3/83) Method 405.1
Chemical oxygen demand	EPA 600/4-79-020 (revised 3/83) Method 410.1-410.4
Total organic carbon	EPA SW 846 Method 9060
Nitrogen species	EPA 600/4-79-020 (revised 3/83) Methods 350.1-354.1
Phosphorus species	EPA 600/4-79-020 (revised 3/83) Method 365.4
Toxicity tests	EPA-600/9-78-010
Enteric viruses	Standard Methods 913
Total and fecal coliforms	Standard Methods 909

permittee and reviewed after six months to determine the variability and occurence of unacceptable compositional changes. Based on this review, the requirements for compliance monitoring could be increased or decreased. Regular monitoring efforts should generate data reports that include the following information, at a minimum:

- Total volume of sludge discharged during each dump and overtime.
- Waste characterization involving the selected subset of compositional parameters provided and reviewed during the application process.
- Toxicity test results to verify dumping rates determined during the application process. Tests should be conducted using the same wastes that have been characterized.

In addition to these regular data on compliance monitoring, EPA should also require each permittee to submit annually a data package on sludge composition identical to that required in the initial permit application. These data will annually confirm that sludge compositions are staying within bounds for all regulated chemical components.

If a substantial change in the composition of a specific sludge is discerned in the regular monitoring reports, the related permit should be reviewed and modified if necessary (for example, by adjusting the discharge rates to reduce environmental impacts if sufficient "worsening" of sludge quality is detected). Waste characterization, therefore, will be a continuing process once the permits are issued and dumping begins.

Sludge samples for waste characterization should be taken from the facility at the point of discharge into the barge and in composite triplicate. This approach will provide the most representative sample for each dumper, because it will account for any compositional changes resulting from holding times at the facilities. Composite triplicates will provide an indication of the sludge load heterogeneity, as well as the quality of the reported data. Because of the expected frequency of barge trips and the difficulties in obtaining completely representative samples, it is not necessary to collect samples directly from barges just prior to discharge at the 106-Mile Site.

The information required to ensure permit compliance and to guide the monitoring efforts in Tiers 2, 3, and 4 will be derived from each permittee's discharge volume and the composition of discharged sludge. And, although variability in sludge compositions are expected to vary (from various treatment facilities), mixing different sludges on board should not result in any significant changes in overall toxicity. Ranges in available sludge characteristics data from various generators (treatment plants) can be found in Section 3.2.3 of the 106-Mile Site monitoring plan (source: Ecological Analysts, Inc. and SEAMOcean, 1983) and in Table 2-1 (source: representative quarterly sludge characteristics data from five New York/New Jersey treatment plants). These data, if representative, indicate that no chemical alterations of environmental consequence should occur from combining different sources of sludge (although higher "strength" sludges will be diluted by sludges with lower contaminant concentrations based on mixing volume proportions and actual compositions). This projection should be checked by a thorough review of the comprehensive data sets provided in each permit application, once complete.

The types of analyses to be conducted on replicate sludge samples are expected to include the following:

- Whole sample determinations of pH, specific gravity, total solids, dissolved solids, suspended solids, biological oxygen demand (BOD), chemical oxygen demand (COD), and total organic carbon (TOC).
- Trace contaminants (from 40 CFR Section 227.6), which include oil and grease, petroleum hydrocarbons, and organohalogens.
- Pesticides and PCBs.
- The following heavy metals: mercury, arsenic, chromium, copper, lead, nickel, cadmium, and zinc.
- Total and fecal coliforms.

As stated previously, upon receiving completed permit applications from the New York and New Jersey treatment plants, EPA will review the comprehensive sludge composition data sets and determine the specific

analytes and methods to be used to regularly monitor and report waste characteristics by the permittees.

In addition to compositional parameters, toxicity tests using established EPA procedures (currently, 96-h toxicity tests using Skeletonema costatum, Menidia menidia, and Mysidopsis bahia) should be conducted quarterly in order to establish or modify LPCs.

Table 2-3 includes the parameters and methods expected to be appropriate for the compliance monitoring of waste characteristics, pending review of the permit application data submitted by each treatment plant. The anticipated list of characterization parameters is a relatively large subset of the initial permit application requirements. In addition, an annual comprehensive waste characterization identical to that required in the initial permit application (Table 2-2) should be required for each sludge source. Eventually, the agreed-upon parameters for ongoing compliance monitoring will be guided by EPA's need to maximize the database for waste contributions from each dumper, as well the Agency's need to monitor, as completely as possible, the amounts of contaminants introduced into the ocean at the 106-Mile Site.

In determining the specifications for compliance characterization monitoring, the use of surrogate measurements will be considered. Although the use of surrogate, or indicator, waste parameters can significantly reduce monitoring cost, to the extent that larger databases may become affordable, hindsight in other monitoring programs has often shown irretrievable lack of important data. The confident use of tracer compounds can sometimes require extensive experimentation in order to obtain causal correlations. However, such an approach may be effective for the 106-Mile Site monitoring objectives, and should be reviewed.

2.2.3.2 Disposal Operations

Initial Information: Appendix B lists the information that EPA Region II requested all sludge dumping applicants to supply about their disposal operations. Once these data have been submitted and compiled, EPA will review them in conjunction with the comprehensive sludge quality data and

Table 2-3. Sludge Characterization Analytes and Methods for Compliance Monitoring Samples

Parameter	Method
Pesticides and PCBs	EPA WE 846 Volume I Section B
pH	EPA 600/4-79-020 (revised 3/83) Method 150.1
Specific gravity	Standard Methods 213E
Total, dissolved, and suspended solids	Standard Methods 209
Biological oxygen demand	EPA 600/4-79-020 (revised 3/83) Method 405.1
Chemical oxygen demand	EPA 600/4-79-020 (revised 3/83) Methods 410.1-410.4
Total organic carbon	EPA SW 846 Method 9060
Oil and grease	EPA SW 846 Method 9071
Petroleum hydrocarbons	EPA 600/4-79-020 (revised 3/83) Method 418.1
Organohalogens	EPA SW 846 Volume I Section B
Mercury	EPA SW 846 Method 3050 and 7471
Arsenic	EPA SW 846 Method 3050 and 7060,7061
Chromium	EPA SW 846 Method 3050 and 7190,7191
Copper	EPA SW 846 Method 3050 and 7210
Lead	EPA SW 846 Method 3050 and 7420,7421
Nickel	EPA SW 846 Method 3050 and 7520
Cadmium	EPA SW 846 Method 3050 and 7130,7131
Zinc	EPA SW 846 Method 3050 and 7950
Total and fecal coliforms	Standard Methods 909
Bioassays	EPA 600/9-78-010

make final determinations of LPCs and dumping rates for each sludge type and disposal condition.

Ongoing Compliance Monitoring: The Coast Guard's Office of Marine Environment and Systems is responsible under the MPRSA for the surveillance and enforcement of regulations concerning the ocean disposal of wastes. The Coast Guard has developed an Ocean Dumping Surveillance System (ODSS) that will remotely monitor the identification, location, and dumping status of all vessels and barges disposing sludge at the 106-Mile Site. The ODSS has been designed to make continuous data regarding dumping operations immediately available to personnel stationed onshore.

The ODSS hardware consists of a base station that monitors remote units located on the disposal vessels. The on-board units consist of a transducer mounted in the hold of each barge and a recording device with a transmitter to send exact information on location and dumping status (e.g., in transit, dumping) based on changes in the vessel's draft. The system relies on VHF-FM signal transmission. The base stations will be located and operated by the Coast Guard and all remote units will communicate with the bases according to a standard format. The remote units will collect data every two minutes and be automatically polled at specific intervals by the base according to the vessel's status. The FULL/DUMPING/EMPTY status of each vessel is determined by transducer (pressure) sensors that are integrated with the ODSS to provide continuous information on the draft of the vessel.

Currently there are prototype ODSS units installed on three barges operating from New York and New Jersey. As of November 1987, the Coast Guard considers the device to be fully tested and ready for use, and has agreed, on behalf of EPA, to manufacture and install sufficient units to have 12 of the potential 21 barges identified as operating at the 106-Mile Site outfitted by May 15, 1988. EPA Region II has stipulated that ODSS installation will be completed by that time for the following barges:

New York City	Spring Creek
	Tibbets Brook
	Udall's Cove

106-Mile Transport Association (Contractor to Westchester County and New Jersey)	Eileen Weeks 702 Morris T. Berman Princess B Kimberly Ann Lisa Maria Weeks 701
National Sea Trade (Contractor to Nassau County)	Sea Trader I

The remaining 9 barges will be outfitted as soon as sufficient units are available.

2.2.4 Data Uses and Relationships to Other Tiers

Tier 1 data will be used in determining whether permit conditions for ocean dumping at the 106-Mile Site are being met and whether permits should be continued, modified, or revoked.

Also, virtually all of the Tier 2 (Nearfield Fate and Short-Term Effects) and Tier 4 (Long-Term Effects) monitoring hypotheses rely on a combination of Tier 1 data and appropriate "models" to determine compliance with permits or to assess the potential environmental impacts of dumping. For example, Tier 1 data from permit applications plus disposal operations data and dispersion models are necessary to set LPCs and to predict nearfield environmental compliance. Tier 1 waste characteristics data are necessary to specify approaches and verify conclusions of nearfield fate (Tier 2), short-term (Tier 2), and long-term impacts (Tier 4).

Tier 1 waste characterization data are necessary to verify that permit specifications are being adhered to and that no unacceptable changes in sludge composition are occurring.

2.3 TIER 2--NEARFIELD FATE AND SHORT-TERM EFFECTS

2.3.1 Background and Objectives

Nearfield fate and short-term effects monitoring addresses both permit compliance and impact assessment. It addresses permit compliance because the permits for disposal of sludges at the 106-Mile Site will stipulate that water quality criteria (WQC), where they exist, may not be exceeded within the site 4 hours after dumping or outside the site at any time. When WQC do not exist, the permits will require that the waste concentration not exceed a factor of 0.01 of a concentration known to be acutely toxic after initial mixing, i.e., the limiting permissible concentration (LPC). The combined conformance to LPCs and WQC is thought to protect the marine environment.

Nearfield fate and short-term effects monitoring also addresses the potential for impacts within the immediate vicinity of the site and in the short-term, defined for convenience as 24 hours. Nearfield fate determinations address the horizontal and vertical behavior and movement of sludge within and immediately adjacent to the site. Monitoring the behavior and movement of sludge immediately after disposal is necessary to confirm assumptions made about dispersion and dilution when issuing permits. Short-term effects studies address the validity of the assumption that permit compliance sufficiently protect the marine environment.

2.3.2 Null Hypotheses and Activities

Not only do sludges have varying physical, chemical, and microbial characteristics that will affect the nature and extent of impacts of sludge disposal at the site, but the characteristics of the site will also affect the behavior of sludges and the possible impacts. The 106-Mile Site monitoring plan (EPA , 1992) presents the following hypotheses about nearfield fate and short-term effects.

Permit Compliance: Nearfield Fate

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 within the site 4 hours after disposal.

H_o5: Pathogen levels do not exceed ambient levels 4 hours after disposal.

Impact Assessment: Nearfield Fate

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

H_o7: The concentration of sludge constituents within the site does not exceed the LPC or WQC 4 hours after disposal and is not detectable in the site 1 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 1 day after disposal.

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

Impact Assessment: Short-Term Effects

H_o10: No significant biological effects in the water column are measurable within the site within 1 day after disposal.

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

H_o12: Sludge constituents do not accumulate in the surface microlayer in the vicinity of the site.

H_o13: No evidence of short-term bioaccumulation of sludge constituents by commercially important species or important prey species found at or adjacent to the site will be found within 1 day after disposal.

Tier 2 activities will test these hypotheses by studying the short-term, nearfield fate of sludges disposed at the site and the associated biological effects. These activities will include direct studies of sludge plumes and

measurement of biological effects under varied oceanographic and meteorological conditions. Specifically, Tier 2 activities will include the following:

- **Measure sludge constituents in the water column to determine fate of sludge constituents, with respect to permit conditions and ambient conditions.** Water quality, chemical, and microbiological parameters will be measured to determine whether concentrations of sludge constituents meet permit conditions and are at background levels within 1 day after disposal. These measurements will address null hypotheses 3 through 5 and 7 through 9.

- **Conduct sludge plume observations to define the seasonal patterns of sludge dispersion at the 106-Mile Site.** Nearfield fate studies will use a variety of methods to track sludge plumes under summer and winter conditions. These studies will be used to determine when and where samples should be taken for measurement of permit compliance parameters, i.e., when and where the sludge plume crosses the site boundary, and where to sample to determine whether sludge constituents are detectable 1 day after disposal. They also will provide information on whether sludge particles settle beneath the pycnocline. The studies will provide information to guide sampling for sludge constituents in the water column and will also address H_o6. Specific activities will include the following:

  Deploying drifters directly into sludge plumes.

  Marking the surface expression of the plume with dyes.

  Using in-situ or shipboard transmissometry, acoustics, and/or UV/fluorescence.

  Measuring physical, chemical, and biological tracers.

  Monitoring the plume with visual observations from the survey vessel and an aircraft.

- **Measure surface currents and water column structure to estimate daily sludge dispersion.** Surface currents and water structure will be measured to estimate daily nearfield fate of sludge dumped at the site. These measurements will provide information on the daily conditions at the site. The information will be used in evaluating null hypotheses 1 through 6.

- **Conduct studies of short-term biological effects of sludge disposal.** These studies will include measurements in the water column (null hypotheses 10 and 11), the microlayer (H_o12), and

in biota ($H_0$12). Specific activities may include measurement of concentrations of chlorophyll a and phaeophytin as determinants of primary productivity, measurement of sludge constituents in zooplankton, measurement of physiological parameters, or other studies of short-term impact of sludge disposal.

2.3.3 Approach and Design

2.3.3.1 Water Column Measurements

Measuring the various sludge constituents in the water column will provide the only direct measurement of regulatory parameters in Tier 2 and the only direct evidence of whether constituents of sludges are detectable 1 day after dumping. Because the physical characteristics of the 106-Mile Site are different in the summer and in the winter, these measurements will be made at both times. During the summer, a seasonal pycnocline is formed in the surface waters in which the 106-Mile Site is located. This pycnocline may provide a barrier to sludge settling and may limit dispersion of the sludge plumes. In the winter, the surface mixed layer extends down to the more diffuse main pycnocline at about 300 m. At that time, the mixing layer for sludge plumes is expected to be much greater than in the summer.

Parameters to be measured in the water column will depend to some degree on the sludge constituents detected under Tier 1 of the monitoring program. Currently, measurements include parameters that are expected to occur in municipal sludges and for which there are water quality criteria (Table 2-4) and enumeration of the microbe Clostridium perfringens. Samples will be taken in conjunction with the plume-tracking measurements discussed in the section that follows, prior to dumping, at 4 hours, and at 24 hours after dumping.

Making direct measurements during each of two consecutive years will provide the minimum acceptable information about variability of conditions at the site. Each exercise will be conducted over a 1-week period. The number of sludge plumes that can be tracked will depend on weather, oceanographic conditions, and cooperation of the permittees. Minimally, three plumes will be tracked for up to 24 hours during each exercise.

Table 2-4. Parameters Analyzed in Baseline Samples for the 106-Mile Site Monitoring Program

Water Samples
1. Trace metals: Ag, Cd, Cr, Cu, Fe, Hg, Pb, Zn
2. Priority pollutant PAH: acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo-(g,h,i)perylene, benzo(k)fluoranthene,chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorene, ideno(1,2,3-cd)pyrene, naphthalene, phen-anthrene, pyrene
3. Priority pollutant organochlorine compounds: aldrin, α-BHC, β-BHC, δ-BHC, γ-BHC, chlordane, 4,4'-DDT, 4,4'-DDE, 4,4'-DDD, dieldrin, endosulfan I, endosulfan II, endosulfan sulfate, endrin, endrin aldehyde, heptachlor, heptachlor epoxide, toxphene, PCB (total)
4. Other organics: phthalate, coprostanol
5. *Clostridium perfringens*
6. Water quality parameters: Total suspended solids, adenosine triphospate, dissolved oxygen, pH, salinity, and temperature

2.3.3.2 Sludge Plume Observations

Plume-tracking measurements will provide direct measurements of the fate of sludge plumes, thereby guiding sampling efforts described in the preceding section and also demonstrating whether sludge constituents settle beneath the pycnocline in the short term.

Plume-tracking exercises will include deployment of drifters directly into sludge plumes; marking of the surface expression of the plume with dyes; use of in-situ or shipboard transmissometry, acoustics, and/or UV/fluorescence; measurement of physical, chemical, and biological tracers; and monitoring of the plume with visual observations from the survey vessel and an aircraft. These methods are described in Battelle (1987d).

2.3.3.3 Current and Water Mass Measurements

Because sludge plumes cannot be directly monitored for all ocean disposal activities at the 106-Mile Site, the information gathered during the seasonal exercises will be used in conjunction with continuous measurements of surface currents and the water mass at the site to estimate behavior and fate of sludge plumes. A surface current mooring capable of acquiring and transmitting data by the GOES satellite data collection system, via the National Environmental Satellite, Data, and Information Service (NESDIS) will be deployed at the site. Information from this meter will describe the speed and direction of currents within the site. Information on the structure of the water column will be obtained by deploying expendable probes (XBTs) from sludge barges to determine the depth of the thermocline and pycnocline. Together, these measurements will provide sufficient information to estimate sludge plume behavior throughout the year. This mooring will be deployed for 2 years, and may be used in Tier 3 as well as Tier 2 studies (see Section 2.4).

2.3.3.4 Short-Term Effects Measurements

Water Column Effects: Final selection of appropriate tests of short-term effects on the water column has not yet been made. Specific measurements

will include use of physiological indicators, such as copepod respiration rates, or conduct of acute or other short-term toxicity tests using surface water or microlayer samples taken during plume-tracking exercises. Tests will be conducted at sea during one summer and one winter plume-tracking exercise, using samples collected before dumping and 24 hours after dumping during the winter and summer surveys. EPA's final decision on appropriate tests will be made prior to the Summer 1988 survey.

Effects on Primary Productivity: Samples will be collected during all plume-tracking exercises before dumping and at 4 and 24 hours for analysis of chlorophyll *a* and phaeophytin. These measurements will be used as an indication of production in the water column during times of dumping.

Bioaccumulation in the Microlayer: During one summer survey, samples of the sea-surface microlayer will be taken before dumping, 24 hours after dumping, and at an intermediate time for a minimum of three plume-tracking events. These samples will be analyzed for the same parameters measured in the water column. If no indication of elevated levels of contaminants is detected in the samples, studies of the microlayer will not be continued. If, however, elevated levels of contaminants are detected, sampling will be repeated during another summer survey. Oceanographic conditions are expected to prevent microlayer sampling during the winter.

Bioaccumulation in Marine Organisms: Bioaccumulation by zooplankton may be studied in conjunction with the other studies being conducted as part of the plume-tracking exercises, or it may be studied at a random set of stations within the site. Both approaches have limitations (EPA , 1987c). Samples collected within the plume would be subject to severe contamination of the biota by the sludge. Samples collected at random stations would not be subject to such contamination. However, because water mass movements are expected to transport sludge constituents from the site, and because zooplankton populations are patchy and transient, results from studies of random stations would be difficult to interpret.

Consequently, bioaccumulation studies will not be included in Tier 2 of the monitoring program, unless no appropriate histological, physiological, or toxicological test is selected.

2.3.4 Endpoints and Data Uses

Information developed in Tier 2 studies will be directly used in determining whether permit requirements are being met and if so, whether they are sufficient to ensure that water quality is maintained and that effects of sludge disposal are minimal. This information will be used in determining whether permit requirements for dumping rates and frequency and location of dumping should be maintained or altered. Studies of surface currents will provide real-time information that may be used not only in determining whether permits should be modified or maintained, but also to direct daily sludge dumping activities at the site. Further, information developed in Tier 2 studies will provide a basis for designing studies of the farfield fate of sludge constituents under Tier 3 and of possible long-term effects under Tier 4.

2.4 TIER 3--FARFIELD FATE

2.4.1 Background and Objectives

Before the long-term effects of sludge dumping at the 106-Mile Site can be estimated, it is necessary to estimate where the sludge goes, the area of the seafloor that may be influenced by sludge particles, and the cumulative concentrations that may be expected in the water column and sediments after many years of dumping. Therefore, Tier 3 of the monitoring program is designed to determine the statistical frequency of transport of the sludge dumped at the 106-Mile Site in the long term and the farfield.

Farfield fate of sludge dumped at the 106-Mile Site depends upon dispersion of sludge plumes in several space and time scales. The principal components of estimating fate of sludges are (1) advection, (2) mixing, and (3) sinking and coagulation. Advection is the transport process of sludge particles by the movement of water, that is, in a current field. Because

sludge particles are expected to spend weeks to months in the water column, they are likely to encounter many current fields and travel long distances, up to 100-1000 km, before deposition on the bottom. Mixing is the dilution of sludge particles in a parcel of water by small-scale turbulent processes that depend on the density and velocity of the water. Turbulent energy due to wind and surface waves, internal waves, vertical current shear, and density profiles of the water mass affect mixing. Sinking is dependent on article size and density. Coagulation, the sticking together of sludge particles, may alter the distribution of particle sizes in a sludge plume and affect sinking. However, coagulation processes are complex and not well understood. They have not been directly considered in this plan.

Estimation of dispersion in the region of the 106-Mile Site involves evaluation of the complex transport and mixing processes on the sludge. These processes are variable, or stochastic. Therefore, estimates can only be made in terms of statistical likelihoods or probabilities, and interpretation of results must be aided by use of models. Currently available models are simple but are likely to become increasingly sophisticated throughout the duration of the monitoring program.

Also, a wide range of time and space scales are involved in estimation of farfield fate of the sludge, from just over a day after dumping to many weeks and months, and from the immediate vicinity of the 106-Mile Site to many miles from it. Consequently, several measurement techniques are required to evaluate the various processes involved in dispersion of sludge.

2.4.2 Null Hypotheses and Activities

Null hypotheses concerning farfield fate address impact issues that pertain to potential movement toward and subsequent impact to shorelines (P-1), to marine sanctuaries and fisheries (P-2), and to the continental shelf/slope (P-3). They will also provide information necessary to decide whether studies should be conducted under Tier 4 to determine whether there is a potential for long-term impacts of sludge dumping, and if so, where those studies should be carried out. The hypotheses related to this category are concerned with where the sludge goes over the long term, as follows:

H_o13: Sludge constituents do not settle beneath the pycnocline outside the disposal site.

H_o14: Ocean currents do not transport sludge to any adjacent shoreline, beach, marine sanctuary, fishery, or shellfishery.

H_o15: Sludge recirculation through the site is not significant.

H_o16: 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 hypotheses require direct estimates of probabilities of specific fates of sludge particles. Assessing the fate of the particles will require monitoring of currents, temperature, salinity, and deposition rates for particles. Unfortunately, there is no direct technique for following the fate of a typical sludge particle as it sinks through the water column and is acted upon by currents and turbulence. Thus, several types of measurements are required to estimate the possible results of all the physical processes acting on the particles:

- **Study water mass movement from the 106-Mile Site.** Study of movements of water masses (i.e., Lagrangian measurements) will involve deploying drifters from barges that use the site.

- **Study surface currents and water structure in the areas expected to be impacted by dumping.** These Eulerian measurements will include temperature and current measurements in surface and mid waters.

- **Use remote sensing information to evaluate large-scale water movements and structure.** These measurements will include use of Advanced Very High Resolution Radiometer (AVHRR) on polar-orbiting satellites.

- **Study settling of sludge particles in the field.** These studies will include deployment of sediment traps in conjunction with current measurements.

2.4.3 Approach and Design

2.4.3.1 Water Mass (Lagrangian) Studies

Information on specific water mass movements will provide the only hard evidence of, for example, whether sludge moves toward shorelines. Even if only 1 drifter in 100 or more reached the shore, it would be evidence that shoreward movement was possible and that calculation of dilution of sludge at that point would be warranted.

Based on findings from Tier 2 on the depth to which sludge sinks in the short term, drifters will be designed with the drogue element at 10 to 20 m. Launching one drifter per week for a period of approximately 18 to 24 months should be adequate to characterize water mass movements. The drifters will be tracked three to four times daily for 6 months by ARGOS satellite. Analysis of drifters tracks will be supported by an AVHRR imaging program.

Launching approximately 12 more drifters of particular interest will provide additional information. Because sludge particles sink, it may be appropriate to use drifters that travel in deeper water, at or below the thermocline, for some measurements. Such subsurface drifters are not commercially available. However, subsurface drifters are being used in the North Atlantic RAFOS float programs. Other subsurface floats that, unlike the RAFOS floats, do not record their position several times a day but surface at a defined time and report their position to the ARGOS satellite, are also available. Either type of drifter will provide information on sludge movements that would not otherwise be available.

2.4.3.2 Fixed Point (Eulerian) Studies

Although Lagrangian measurements, such as those obtained from drifters, will provide hard evidence of where sludge may move in the farfield, such programs can feasibly only collect a limited amount of information. For a statistical estimation of movement of sludge over the long term, that is, the estimation of the percent of time that sludge may move in a particular direction, Lagrangian measurements must be supplemented by Eulerian measurements. Measurements from the surface current mooring deployed for

Tier 2 studies will provide these data. Ideally, data from the mooring will be obtained over the same time period that drogues are being released at the site, although a deployment for a short time period may also yield useful information.

2.4.3.3 Remote Sensing

Data from an AVHRR satellite imagery program can be used to depict the temperature structure of the entire region that could be impacted by the 106-Mile Site. Although these images are not suitable in themselves to characterize the region, they can provide broad regional coverage to aid in interpretation of data from direct measurements.

2.4.3.4 Settling Studies

Settling may be studied through direct measurement, i.e., by settling traps deployed in the field, if studies conducted in Tiers 1 and 2 indicate that sludge is likely to settle in concentrations that may harm the environment. Settling traps may be deployed in conjunction with the fixed current and temperature mooring discussed in Section 2.4.3.2 if it is determined that the locations of that mooring, i.e., in the immediate vicinity of the site, are appropriate for measurements of settling. Otherwise, traps would probably be deployed southwest of the site, along the 2500-m isobath. A decision to deploy traps at all, but particularly at a location other than where the surface current meter mooring is currently planned, will be made only if there is compelling evidence that settling of sludge particles is likely to be detected by the sediment trap studies.

Traps designed by the U.S. Geological Survey for use in deep water would be used. Traps would be set at 50, 100, 250, and 1000 m. The exact design of these deployment will be determined after evaluation of Tier 2 data.

2.4.4 Endpoints and Data Uses

Information developed in Tier 3 studies will be directly useful in approximating whether sludge constituents move towards shorelines, or whether

they move into fisheries regions or areas of special concern for the marine environment. If any of these events are found to be likely, the information will be directly useful in determining whether the designation or use of the 106-Mile Site should be modified.

Conduct of Tier 4 studies, studies of potential long-term impacts of sludge disposal, will greatly depend on the results of studies conducted in Tiers 1, 2, and 3. If, for example, sludge is found to regularly move toward shore, studies of bioaccumulation by resource species on the continental shelf and slope may be important. If, however, it is found that sludge constituents remain in the water column and do not disperse as rapidly as has been predicted, studies of long-term effects in the water column or the benthos (depending on the results of settling studies) would be more appropriate than studies far from the site.

2.5 TIER 4--LONG-TERM EFFECTS

2.5.1 Background and Objectives

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 higher tiers, Tier 4 may include studies of impacts on fisheries species, biological communities that are prey for fisheries species, or other marine resources.

Long-term effects may occur within or outside of the site. Long-term effects in the site can occur if, for example, there is a progressive decline in water quality, although such an effect is not predicted. Effects outside the site, such as bioaccumulation of sludge constituents, may occur if sludge is regularly transported in the direction of marine resource areas.

Because the 106-Mile Site was specifically located in an area that would minimize likelihood of impacts to the marine environment, many long-term impacts are not predicted. For example, because sludges settle slowly and the site is dispersive, long-term impacts on the benthos are not predicted. Sludge may, however, be deposited in minute quantities at great distances from the site. Long-term effects on endangered species or other marine animals that migrate through the region are also not predicted.

2.5.2 Null Hypotheses and Activities

The 106-Mile Site monitoring plan lists the following null hypotheses for assessing long-term effects of sludge disposal at the site:

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 the shelf and 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 biota.

Testing these hypotheses adequately will require a diverse set of measurement activities:

- **Conduct endangered species studies.** Determination of effects on endangered species comprises observations of presence, number, and behavior of all species of marine mammals, reptiles, and birds by a trained observer. This activity addresses H_o18.

- **Conduct bioaccumulation studies.** Bioaccumulation studies involve sampling and tissue analysis of selected biota from areas thought to be within and outside the influence of sludge disposal. This activity addresses H_o19.

- **Conduct benthic community studies.** Benthic community studies involve enumeration of organisms by species and calculation of a variety of community parameters and statistics. This activity addresses H_o20.

- **Conduct studies of sensitive life stages.** Studies of sensitive life stages may include evaluation of specific organisms, populations, or communities. Evaluation of (1) histopathology of organisms, (2) relative abundances of successive life stages of a species, and (3) community parameters each may be used to assess potential impact on marine resources. This activity addresses H_o21.

- **Conduct plankton community studies.** Plankton studies will involve calculation of community parameters and statistics. This activity addresses H_O22.

- **Conduct studies of pathogens.** Studies of long-term persistence of pathogens may involve water column, sediment, or bioaccumulation studies. This activity addresses H_O23.

2.5.3 Approach and Design

2.5.3.1 Endangered Species Studies

EPA includes trained observers of marine mammals, reptiles, and birds on all surveys at the 106-Mile Site, effectively removing this activity from the tiered structure of the monitoring program. The observer records the presence, number, and behavior of all species of mammals, reptiles, and birds in 15-minute intervals along the survey track (Payne et al., 1984). Each observation period represents a transect, and several transects are performed each day during the survey. Data from each survey conducted while dumping is taking place can be compared to data from predumping surveys.

An indication that sludge dumping impacts endangered species in the vicinity of the site would be used in deciding to dedesignate the site. If no indication is found, endangered species observations could be discontinued. However, because of the public concern for endangered mammals and reptiles, such observations are expected to continue throughout the use of the site.

2.5.3.2 Bioaccumulation Studies

If it is determined through Tier 3 studies that sludge disposed of at the 106-Mile Site regularly moves inshore, bioaccumulation studies of tilefish, Lopholatis chaemaeleonticeps, and sea scallops, Placopecten magellanicus, will be conducted. These species have been identified as the organisms most likely to provide useful information on long-term impact of sludge dumping (EPA , 1987c). Tilefish and sea scallops are the least migratory, large species that could be used in bioaccumulation studies. However, neither

species is found within the boundaries of the 106-Mile Site. Both are found inshore from the site, tilefish primarily on the continental slope and sea scallops primarily on the continental shelf.

If sludge is found in Tier 3 studies to move inshore and bioaccumulation studies are deemed to be appropriate, fish and scallops will be taken in areas thought to be impacted by sludge disposal and in areas considered outside the region of potential impact, as defined in Tier 3. Contaminants to be measured will be based on results of Tier 1 measurements of sludge constituents, Tier 2 measurements of sludge constituents in the water, and results of baseline measurements (which have not yet been made; see Section 2.1). Results from organisms thought to be impacted by sludge will be compared to results from reference and baseline stations.

Initially, bioaccumulation studies, if they are conducted at all, will be planned as a one-time survey. If results indicate that sludge constituents have bioaccumulated, another survey may be conducted to confirm those results, or a decision could be made, based on the data, to dedesignate the site. If results indicate that no bioaccumulation is occurring, a decision could either be made to discontinue monitoring, or to conduct another study after some period of time.

As described in EPA (1987c) the organisms will be taken by commercial fishing vessel with a scientist on board to ensure proper sample handling. Tilefish will be taken by long line, and scallops by dredge. Exact number of organisms collected will reflect feasibility of sampling and analysis. Tentatively, 30 organisms would be collected at each site and pooled into three replicate samples. Compositing samples will allow a better estimate of average concentrations than would analysis of individuals.

For tilefish, liver and muscle tissue will be analyzed separately. Concentrations of contaminants in muscle are of greatest value to an assessment of potential impacts on a fishery and will be most responsive to public concern. However, chances of detecting evidence of bioaccumulation of sludge constituents will be greater through analysis of liver tissues, which accumulate greater concentrations of contaminants. Data on size, age, and sex will be recorded for both species, and data will be normalized to lipid content. Sludge tracers in the sediments would also be measured.

It is not likely that bioaccumulation studies will be undertaken within the time frame necessary for information to be used in determining whether redesignation of the 106-Mile Site should occur.

2.5.3.3 Benthic Community Studies

Although effects on the benthos are not expected, studies conducted as parts of Tiers 2 and 3 may indicate that sludge constituents can reach the bottom in significant quantities. In that event, benthic studies will afford an appropriate measurement of impact to the marine environment. Studies will be conducted using the same methods that the U.S. Department of the Interior Minerals Management Service has used for studies of the mid-Atlantic slope and rise (Maciolek et al., 1987). Station locations will be based on information developed in Tier 3 studies. Three replicate samples per station will be collected, using methods that will ensure comparability with methods used to collect baseline data. Analysis of benthic community parameters will include calculation of parameters such as diversity, density, and species richness; display of abundances of dominant species; statistical analysis of total organism density, densities of individual groups, species number, and community parameters; and numerical classification and ordination of species abundance data. Sludge tracers in the sediments will also be measured. Data will be compared to baseline and/or reference stations.

2.5.3.4 Sensitive Life Stage Studies

If it is determined in Tier 2 and 3 studies that sludge constituents persist in the water column in the vicinity of the site, fish eggs and larvae will be studied. Station locations would be based on information generated during earlier tiers. Methods used in such a study would follow those used in NOAA's MARMAP program. Such a sampling program could be used to evaluate impacts on organisms, such as impaired development or disease; impacts on populations, such as effects on growth or mortality (including recruitment to the fishery); or impacts on the community, such as species abundance and diversity.

Such a study, if it takes place, will initially be planned for only one sampling event, to occur during the summer, when abundances of early life stages is expected to be highest for the year. Sludge tracers in the water will be measured in conjunction with the study. Results will be used to determine whether further monitoring is necessary or appropriate.

Briefly, the methods included in studies of eggs and larvae are as follows. Double-oblique tows using a frame fitted with a 0.0505-mm mesh net will be performed at each station. The net will be lowered to a maximum depth of 200 m at 50 m/min, and retrieved at 20 m/min. Ship speed will be maintained at 1 to 2 kn. Information on distribution of fish eggs and larvae will be compared to similar information from reference stations.

2.5.3.5 Plankton Studies

If it is determined in Tier 2 studies that concentrations of sludge constituents remain elevated in the water column for longer than 1 day, and Tier 3 studies further indicate that the 106-Mile Site is less dispersive than had been thought when the site was designated, then longer term studies of plankton may be conducted. For these studies, samples will be collected in the area defined by Tier 3 studies to be impacted. Information on community parameters, such as species composition, and production, e.g., biomass, from these samples will be compared to similar information from baseline and reference stations. Sludge tracers in the water column will also be measured.

2.5.3.6 Pathogen Studies

If studies conducted under Tiers 1, 2, and 3 indicate that the sludges dumped at the 106-Mile Site contain substantial concentrations of pathogenic or potentially pathogenic microorganisms, and that these organisms are present in the water column for as long as 1 day after dumping, longer term studies of pathogens will be implemented. Depending on results from Tier 3, these studies may include more extensive water column monitoring, monitoring of sediments, or inclusion of measurements of pathogens in the bioaccumulation studies described in Section 2.5.3.2.

2.5.4 Endpoints and Data Uses

Indication that no long-term impacts are occurring would be strong argument for redesignating the 106-Mile Site. Conversely, evidence of any long-term impacts from sludge disposal at the 106-Mile Site will be used in determining whether the site should be redesignated or whether in redesignation, additional constraints should be put on its use.

In making decisions about continued designation or dedesignation of the 106-Mile Site, results from monitoring for long-term impacts will be important. It should be stressed, however, that decisions resulting from the process and the management options that are ultimately exercised must be determined in the face of all available information, and therefore may vary, depending on the nature or extent of impacts that are detected.

3. MASTER PLAN FOR THE 106-MILE SITE MONITORING PROGRAM

The overall schedule for the 106-Mile Site monitoring program is presented in Figure 3-1, and lists of recommended EPA contractor work assignments for the years prior to site redesignation or dedesignation are included as Tables 3-1 through 3-3. Monitoring at the 106-Mile Site began in 1984 with surveys for collection of baseline information in support of the site designation process. Additional baseline data were collected during 1985 and 1986. Data collected during 1986 represent a time when dumping at the site had already begun. However, stations were carefully selected to avoid contamination from sludge plumes.

Further baseline studies will be conducted in 1988 to measure presence of sludge constituents in tilefish and shellfish found on the continental shelf and slope. These organisms are too far from the site to be impacted by sludge disposal during the dumping period.

To date, monitoring of sludge characteristics and disposal operations has consisted solely of consideration of background information. Because dumping is occurring under a court order rather than under permits, the initial evaluation of variability and continued monitoring scheduled under Tier 1 has not taken place. With the issue of permits, the initial evaluation of conditions will occur in 1988. Following completion of that evaluation, regular monitoring, presumably including quarterly analysis of sludge samples and regular surveillance of disposal operations will occur.

Tier 2 monitoring was initiated with preliminary observations of sludge plumes in the summer of 1986 (EPA , 1988) and with collection of water samples in the plume in conjunction with plume-tracking exercises in the summer of 1987. Winter and summer measurements will be made in 1988, and winter measurements will be repeated in 1989. Also during 1988 and 1989, a surface current mooring will be deployed and XBTs will be deployed from sludge barges. Biological assessments will be made during the summer 1988 survey, and if warranted, they will be repeated in 1989. Tier 2 studies are expected to be complete in mid-1989.

The surface current mooring deployed for Tier 2 may also be used for Tier 3 studies. If warranted, this deployment will include use of sediment traps. Use of drifters and remote sensing to estimate farfield fate of

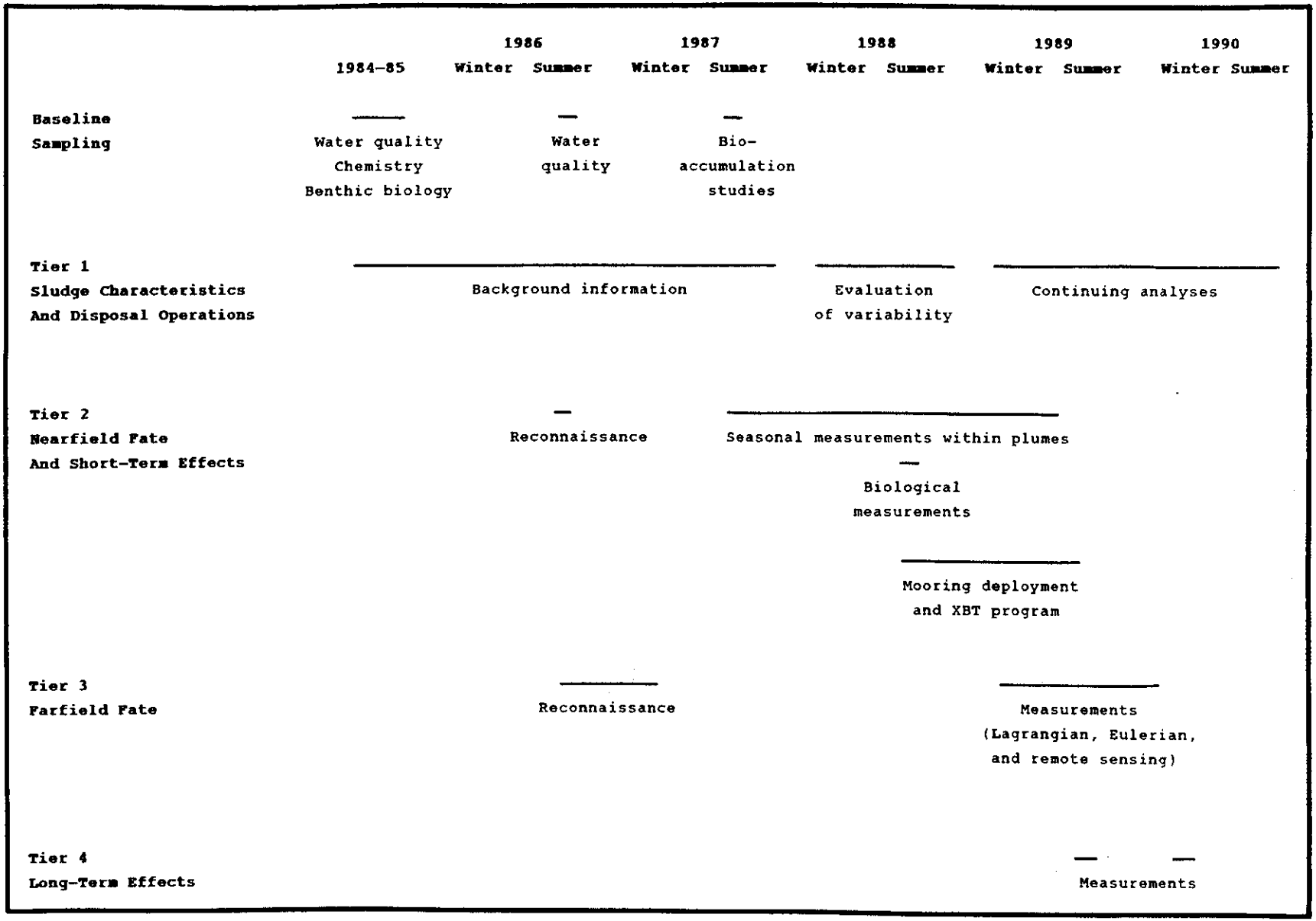

FIGURE 3-1. IMPLEMENTATION SCHEDULE FOR THE 106-MILE SITE MONITORING PROGRAM.

TABLE 3-1. 106-MILE SITE MONITORING PROGRAM
FY 88 WORK ASSIGNMENTS

WA NO.	WA TITLE	APPROX. LOE
New WA	106-Mile Site Monitoring Program Symposium	$100,000
New WA	Bioaccumulation Studies for the 106-Mile Site Monitoring Program (Baseline Studies)	
	Task 1: Field Studies	20,000
	Task 2: Analyses	30,000
New WA	Determination of Waste Characteristics (Tier 1)	50,000
WA 1-63 A1	Plume-Tracking at the 106-Mile Site: Winter Survey and Analyses (Tier 2)	325,000
WA 1-63 A2	Plume-Tracking at the 106-Mile Site: Summer Survey (Tier 2)	200,000
New WA	Surface Current Mooring capable of Real-Time Data Telemetry from the 106-Mile Site	150,000
New WA	106-Mile Site Operating Program	
	Task 1: Determination of Discharge Rates	50,000
	Task 2: Development of System for Monitoring Barge Records	50,000

TABLE 3-2. 106-MILE SITE MONITORING PROGRAM
FY 89 WORK ASSIGNMENTS

TIER	WORK ASSIGNMENT TITLE	APPROX. LOE
Tier 2	Plume-Tracking at the 106-Mile Site: Analysis of Samples from the Summer 1988 Survey	$150,000
Tier 2	Winter 1989 Survey to the 106-Mile Site: Nearfield Fate and Short-Term Effects	300,000
Tier 2	Abbreviated Short-Term Monitoring--XBT Program	50,000
Tier 3	Farfield Fate Monitoring at the 106-Mile Site	
	Task 1: Drifter Program	250,000
	Task 2: Surface Current Program	200,000
	Task 3: Satellite Program	200,000
Operating Program	106-Mile Site Operating Program: Data Management, Use of Models for Interpretation of Existing Near- and Farfield Fate Data	150,000

TABLE 3-3. 106-MILE SITE MONITORING PROGRAM
FY 90 WORK ASSIGNMENTS

TIER	WORK ASSIGNMENT TITLE	APPROX. LOE
Tier 3	Continuation of Drifter, Satellite and Sediment Trap Program	$350,000
Tier 4	Long-Term Effects Survey--Bioaccumulation (Or Other, As Applicable)	300,000
Operating Program	Public Support to the 106-Mile Site Program--Documents, Other Media, Meetings, as Applicable	200,000
Operating Program	106-Mile Site Operating Program: Redesignation of the 106-Mile Site	
	Task 1: Data Analysis and Interpretation, Documentation	150,000
	Task 2: Public Symposium	100,000

sludge disposed at the site will be initiated in late 1988 and continue into 1989 or longer if further studies are justified.

Long-term effects studies are not expected to take place until 1990. The exact nature of the studies will depend on results obtained in the upper tiers.

4. USE OF MONITORING RESULTS FOR SITE MANAGEMENT

Results of monitoring at the 106-Mile Site will be used to make decisions about the monitoring program itself (following the tiered structure of the plan, to make decisions about permit requirements, and ultimately to determine whether the site should be redesignated in 1991. Figure 1-4 presents an idealized picture of the decisions that can be made from monitoring program results.

Decisions about the monitoring program will follow the tier structure outlined in Section 2. A decision to continue or reduce the program may be made if all information gathered indicates that impacts do not occur. Conversely, if results indicate that impacts are occurring, activities within the tier or within lower tiers may be expanded.

Determination in Tier 1 that permit conditions are not being met could lead to enforcement actions, such as revocation of the permit. Results from Tier 1 studies will also be used to determine what measurements will be made in lower tiers.

The regulatory questions to be answered in Tier 2, e.g., whether LPCs are met within 4 hours and at the site boundary, could lead to a decision to maintain, modify, or revoke permits. Information on short-term effects of sludge disposal could lead to decisions about permit conditions, or could ultimately be used as evidence of whether the site should be redesignated in 1991. Information on nearfield fate of sludge constituents will also be used to guide the design of studies conducted in lower tiers.

Tier 3 studies, which estimate the direction of sludge transport over the long term, will be used to guide the design of studies of long-term effects of sludge disposal. Information gathered in this tier will also be used to support decisions about site redesignation or dedesignation.

Tier 4 studies will also be used to support site redesignation studies. Because the 106-Mile Site has only been designated for a 5-year period, studies of long-term impact of sludge dumping will not be definitive at the time of site redesignation. However, an indication of long-term impact at that time would be significant, precisely because it is not expected.

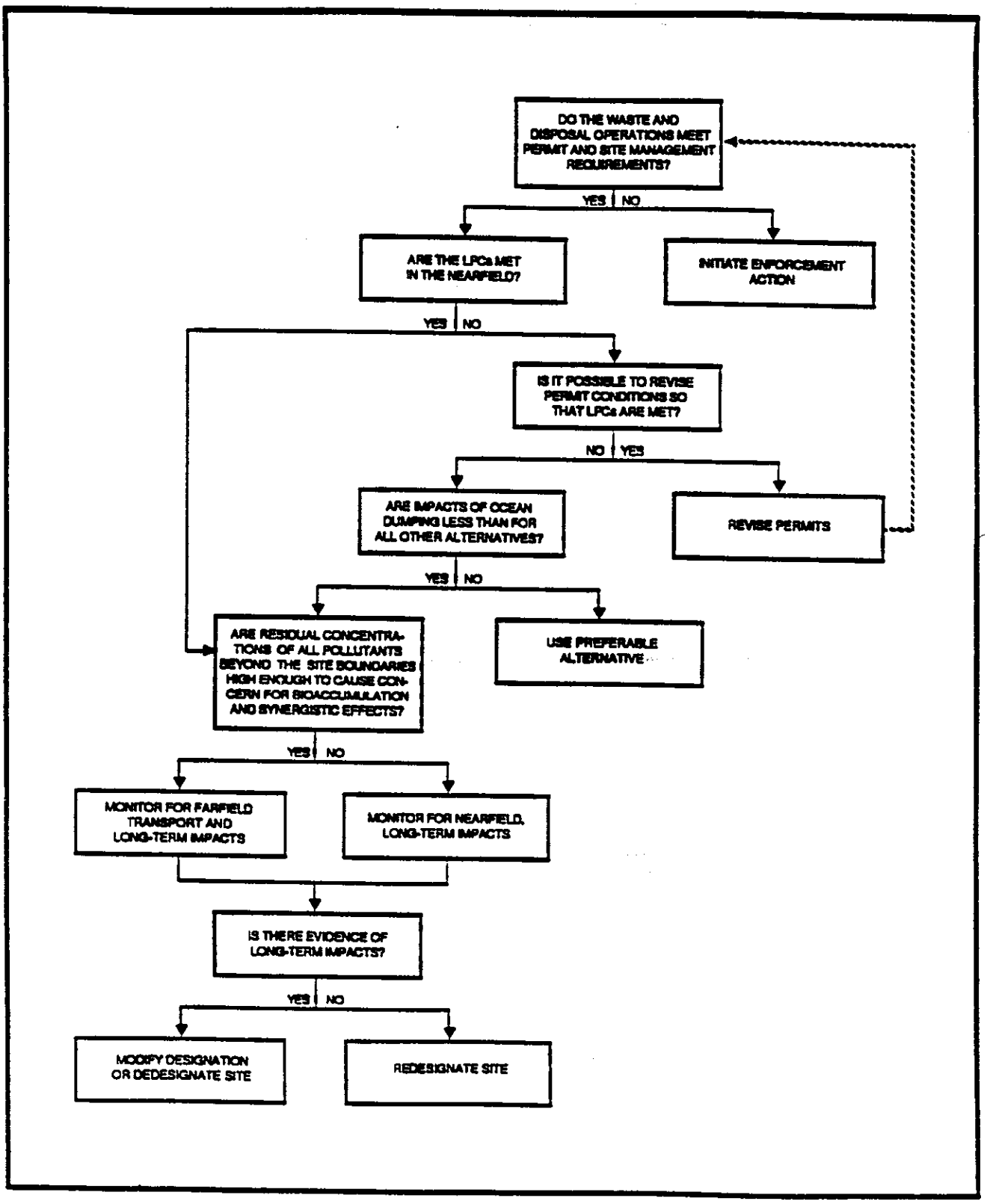

FIGURE 4-1. MONITORING RESULTS CAN BE USED TO MAKE MONITORING PROGRAM, PERMITTING, AND SITE DESIGNATION DECISIONS.

The decision-making process is a complicated one, in which the site manager must evaluate all available information, not just that available from the monitoring program. The implications of allowing multiple dumpers at the site, of possible use of the 106-Mile Deepwater Industrial Waste Site to the east of the 106-Mile Site, and of possible use of the North Atlantic Incineration Site to the south of the site must be weighed and interpreted in the context of monitoring results.

EPA is currently developing an operating program that will facilitate use of monitoring data in the decision-making process. This program will provide the data management capabilities and procedures for analyzing data in support of the program and for presenting records of permit compliance and impact assessment so that they can be used by site managers. Appropriate data management and analysis schemes will be developed and will include use of models to interpret data. (Note that the 106-Mile Site program will not develop new data management systems or models.)

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