Report to the Congress on Ocean Dumping Monitoring and Research

January through December 1978

May 1980

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration

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Submitted in compliance with Section 201,
Title II of the Marine Protection, Research,
and Sanctuaries Act of 1972
(Public Law 92-532)

May 1980

U.S. DEPARTMENT OF COMMERCE
Philip M. Klutznick, Secretary
National Oceanic and Atmospheric Administration
Richard A. Frank, Administrator

THE SECRETARY OF COMMERCE
Washington, D.C. 20230

25 MAR 1980

Dear Sirs:

It is my honor to transmit to the Congress this sixth annual report on ocean dumping monitoring and research.

Under Title II of the Marine Protection, Research, and Sanctuaries Act of 1972, the Congress assigned to the Department of Commerce a responsibility to initiate a comprehensive program of monitoring and research to improve our understanding of the effects of dumping wastes into the ocean. Section 201 of the Act specifies that the Secretary shall report at least once a year to Congress on the findings of this monitoring and research.

This report describes the ocean dumping investigations carried out by the National Oceanic and Atmospheric Administration during calendar year 1978. It focuses upon three major categories of pollutant materials: sewage sludge, industrial wastes, and dredged materials. Field and laboratory studies of these types of pollutants were completed during the year and apply to several marine areas. The effects of dumping industrial wastes into deep waters were investigated in the Atlantic Ocean off New Jersey and a site north of Puerto Rico. The environmental effects of sewage sludge and dredged material disposal were studied in the New York Bight and on the Louisiana coast.

Substantial progress was made during the year in furthering the general understanding of the basic environmental effects of dumping waste materials into the ocean. Substantial progress was also made in developing remote-sensing techniques for monitoring the dispersal patterns of dumped wastes. These advances were made through a series of waste-tracking experiments performed in the field in unison with laboratory studies of the chemical and physical nature and biological impacts of the same wastes.

The Department of Commerce will continue to fulfill its responsibilities under the law for carrying out monitoring and research on the effects of ocean disposal of wastes. The work provides valuable and immediate support to regulatory agencies and also improves our scientific understanding of the environmental implications of ocean dumping.

Sincerely,

Philip M. Klutznick

Secretary of Commerce

President of the Senate
Speaker of the House of Representatives

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Executive Summary

This report summarizes results of 1978 National Oceanic and Atmospheric Administration (NOAA) monitoring and research under Section 201, Title II of the Marine Protection, Research, and Sanctuaries Act (PL 92-532), and indicates the initiatives to be undertaken in 1979. Emphasis has been on describing the response of the ocean and its living resources to waste dumping. Knowledge of that response is crucial to balancing the consequences of ocean dumping against those of other waste disposal methods on economical, ecological, and social grounds.

Two major efforts concerned industrial waste dumping at two deepwater sites, the 106-mile dumpsite about 160 km east of Delaware Bay, and a site 74 km north of Puerto Rico. Dispersion studies up to 2 days following dumping defined the areas (about 50 km^2) and depth (the mixed layer, 20 to 150 m, depending on season) containing waste with maximum concentrations in the range of 5 to 50 parts per million. The occurrence of storms forces the dispersion area to increase and concentrations to decrease. Ongoing studies involve long-term rates of horizontal dispersion and mixing of wastes and water below the mixed layer. Laboratory studies indicated little or no response to tested wastes at the low concentrations found in the ocean. It was demonstrated, however, that oceanic organisms are more sensitive to wastes than similar organisms isolated from coastal areas receiving waste input. Work includes field measurements of biological response to dumping and continued collection of organisms for pathobiological examination. The possiblity of waste accumulation within the upper waters of dumpsites continues to be studied through chemical sampling and investigations of rates and directions of water movement through the sites. Chemical studies also include examination of alteration and degradation of waste constituents upon mixing with seawater.

Waste dumping in the New York Bight, unlike that in deepwater sites, entails accumulation of material on the seafloor and consideration of many nondumping waste inputs. There were no crises in the New York Bight during 1978, similar to 1976 when large areas experienced low dissolved oxygen concentrations. During June 1978 monitoring cruises, observations were made of lowering of oxygen concentrations and of the presence of a phytoplankton species (<u>Ceratium tripos</u>) associated with the 1976 anoxic event. In July, however, oxygen levels had increased significantly and <u>C. tripos</u> was not found. Two studies were initiated on the mechanism of nutrient transfers within the Bight to discern the cause of periodic anoxic incidents and to quantify their contribution to ocean dumping as opposed to other waste additions.

Studies of bacteria within sediments at dumpsites of the Bight showed the presence of genetically altered organisms with unique resistance to metallic contaminants and to antibiotics. Analysis of mackerel eggs in surface waters of the Bight showed the occurrence of chromosomal damage to be high within waste-receiving areas.

Observations of fin-rot disease showed a marked decrease in its frequency relative to 1973 when the syndrome was first identified. Laboratory studies revealed a phytoplankton response to low levels of polychlorinated biphenyls which would favor the growth of small species at the expense of the larger phytoplankton which serve as the basis of food chains leading to commercially harvestable fisheries.

Extensive chemical and sediment analyses of dredged material waste in the Bight were made in preparation of future studies on the consequences of continued disposal of this material.

Studies in the Gulf of Mexico on the deep ocean dumping of biological sludge waste were completed. This dumping no longer occurs and was not studied extensively, but no biological responses to it were identified. Studies on dredged material dumping at shallow water sites within the Gulf of Mexico were initiated.

In addition to the above-mentioned work, ongoing and future studies by NOAA will include investigations at the Philadelphia sewage sludge dumping site, a dredged material dumping site near the mouth of the Chesapeake Bay, and a study on the social and economic factors associated with ocean dumping of wastes.

Increased awareness of and participation in ocean dumping research and monitoring among the scientific community were facilitated by the First International Ocean Dumping Symposium sponsored by NOAA in October 1978.

CHAPTER I

INTRODUCTION

Background

The Marine Protection, Research, and Sanctuaries Act (MPRSA) was enacted October 23, 1972. This legislation was the result of concern on the part of the Congress, the Executive Branch, and the public over the potential harmful effects of continued unregulated ocean waste disposal. The Council on Environmental Quality (CEQ) reviewed the problems of ocean dumping in its 1970 report to the President on ocean dumping. The CEQ report recommended a comprehensive national policy on ocean dumping of wastes to end unregulated ocean dumping and to prohibit ocean disposal of all materials harmful to the marine environment. Specific recommendations on the three major categories of dumped waste materials were as follows:

- Dredged material: "Ocean dumping of polluted dredged spoils should be phased out as soon as alternatives can be employed. In the interim, dumping should minimize ecological damage. The current policy of the Corps of Engineers on dredging highly polluted areas only when absolutely necessary should be continued, and, even then, navigational benefits should be weighed carefully against damages."

- Sewage sludge: "Ocean dumping of undigested sewage sludge should be stopped as soon as possible and no new sources allowed. Ocean dumping of digested or other stabilized sludge should be phased out and no new sources allowed. In cases in which substantial facilities and/or significant commitments exist, continued ocean dumping may be necessary until alternatives can be developed and implemented. But continued dumping should be considered an interim measure."

- Industrial waste: "Ocean dumping of industrial wastes should be stopped as soon as possible. Ocean dumping of toxic wastes should be terminated immediately, except in those cases in which no alternative offers less harm to man or the environment."

Passage of the Marine Protection, Research, and Sanctuaries Act of 1972 committed the United States on a national basis for the first time 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 marine environment, ecological systems, or economic potentialities."

Agency Roles and Responsibilities

The Marine Protection, Research, and Sanctuaries Act of 1972 is organized into three Titles. Title I deals with regulatory aspects of ocean dumping. The Act assigns regulatory authority and involvement to the Environmental Protection Agency (EPA), the Corps of Engineers (COE), and the Coast Guard (USCG). Title II of the Act deals principally with monitoring and research aspects of ocean dumping effects that are needed to support the intent of the Act to cease ocean dumping of harmful materials. The monitoring and research responsibilities described in Title II are to be coordinated by the Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), in consultation and coordination with other Federal agencies. Title III of the Act provides for the designation of marine sanctuaries. NOAA also administers this Title in consultation with other Federal departments and agencies.

Section 201 of Title II assigns responsibility to the Department of Commerce for a comprehensive and continuing program of monitoring and research regarding the effects of dumping material into ocean waters, coastal waters, and the Great Lakes. The legislation also directs the Secretary of Commerce to provide to the Congress at least once a year the findings from the monitoring and research program.

Scope of the Work

This is the sixth annual report to Congress by the Department of Commerce pursuant to Section 201 of the legislation. In addition to the Section 201 research of NOAA, the first three annual reports by Department of Commerce described research activities of EPA, COE, and USCG carried out in support of their respective regulatory responsibilities under Title I of MPRSA. Amending legislation in 1976 (Public Law 94-326) directed that those agencies submit to the Congress separate annual reports on their administration of Title I. This report, therefore, covers only NOAA monitoring and research on ocean dumping during calendar year 1978.

CHAPTER II

NOAA OCEAN DUMPING MONITORING AND RESEARCH - 1978

Introduction

The NOAA programs have taken a lead role in developing a long-range plan for monitoring ocean areas. These areas include the New York Bight and the Atlantic Bight to a limited extent. Research has been aimed at answering the fundamental questions of marine environmental quality to improve the information base for wiser resource management decisions. Monitoring is being developed to expand on the information base. Monitoring is generally conducted to determine existing conditions and ongoing changes. If any change has occurred, or is taking place, monitoring determines whether or not such a change is detrimental to the marine ecosystem.

A monitoring plan is being developed for the New York Bight to provide a high degree of assurance that monitoring data will be appropriately used to guide "environmental management" decisions, including those related to ocean disposal. An important feature of the plan is periodic corrective review of the monitoring strategy based on data and supportive research results. Substantial efforts are being devoted to assessing the sensitivities of the systems involved and in determining the costs of monitoring measurements.

This report covers those areas of monitoring and research conducted with emphasis on the research to enhance the further development of a monitoring plan. Some routine oceanographic measurements are carried out presently while work is being accomplished on the determination of pollution indices.

106-Mile Ocean Waste Disposal Site

Background

The 106-mile Ocean Waste Disposal site (formerly referred to as Deepwater Dumpsite 106 (DWD-106)) is a 1,650-square-kilometer area between 38°40' -39°00'N and 72°00' -72°30'W (figure 1). It lies in water 1,750 to 2,700 m deep and is 106 nautical miles (195 km) southeast of New York's Ambrose Light Tower and about 160 km east of Cape Henlopen, Delaware. During 1978 it was used for the EPA-regulated disposal of 800 million liters of waste. With the exception of 55 million liters of sewage sludge from Camden, New Jersey, which ceased being dumped in June 1978, the materials dumped at the 106-mile site were industrial wastes.

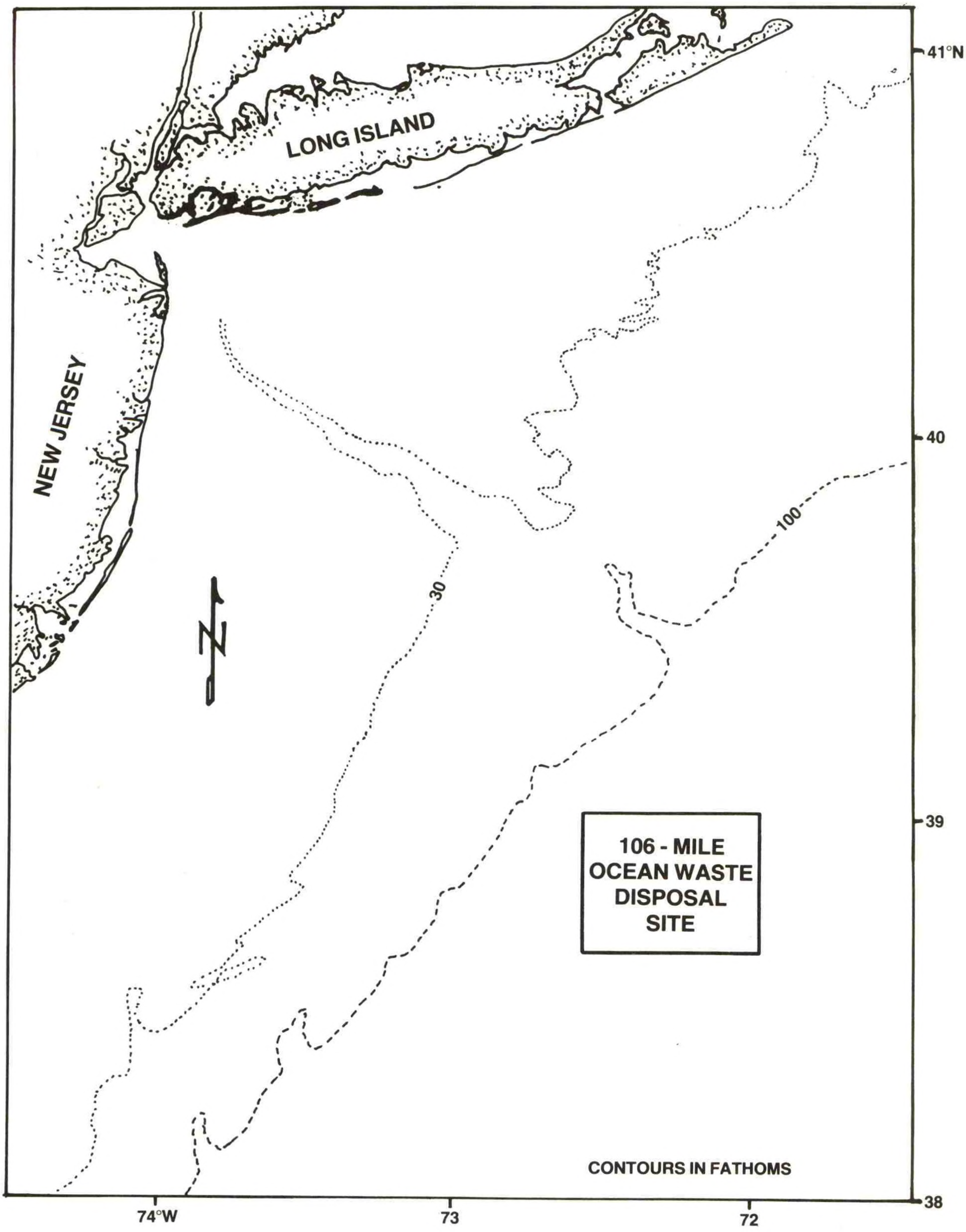

Figure 1.--Location of the 106-mile dumpsite.

The waste sources and volumes dumped during 1978 are listed in table 1. In the past year the volume of highly alkaline waste from the production of anisole and dimethylhydroxylamine at the DuPont-Grasselli plant in Linden, New Jersey, has increased from the 1977 level. The 1977 level was low in comparison to previous years due to low industrial production. The two other major dumpers at the 106-mile site are American Cyanamid Warner's plant, also at Linden, New Jersey, and the DuPont-Edge Moor plant in Edge Moor, Delaware. NOAA's efforts in regard to the 106-mile site have centered almost exclusively on these three waste sources.

The objective of NOAA's 106-mile site investigation is to identify the effect dumping is having upon marine organisms and upon human use of marine resources. This objective is addressed through studies that include:

1. waste chemistry to define waste constituents and determine how they react with each other and with seawater;

2. dispersion studies to measure concentrations of waste in the ocean after dumping events;

3. measurement of advection of water through the dumpsite to determine where, other than at the dumpsite, wastes are likely to be found;

4. effects of wastes on marine organisms under laboratory conditions to estimate possible effects occurring in the ocean;

5. collection of marine organisms in the ocean to observe effects that may be related to dumping.

Chemistry

DuPont-Edge Moor waste derived from titanium dioxide production is a highly acidic solution rich in iron. It also contains chromium and vanadium in the hundreds of parts per million (ppm) range, copper, zinc, nickel, and lead in the 10 to 100 ppm range, and cadmium in the less than 1 ppm range. At the rate it is dumped at the 106-mile site, there is negligible effect on oceanic pH, but the almost immediate neutralization of the waste causes the iron to precipitate as hydrous ferric oxide flocs. These newly created particles serve as adsorptive sites for other waste components and have been demonstrated to accumulate almost all the waste-derived lead. Copper is not absorbed to the extent expected, implying that it may form complexes with the small amount of organic material in the waste. Much of the

Table 1.--Waste inputs to the 106-mile site

Source	1976 Thousand wet tons	1977 Thousand wet tons	1978 Thousand wet tons	1978 Million liters[1]
DuPont-Edge Moor	---[2]	418	409	384
DuPont-Grasselli	180	118	189	178
American Cyanamid	131	143	122	115
Modern Transportation[3]	69	91	79	74
Camden, New Jersey	---[2]	53	59	55
General Marine[3]	5	1	0	0
Total	385	824	858	806

[1]The 1978 input is given in terms of liters as well as wet tons to indicate the size of liquid volumes being dumped. The conversion is not exact since it assumes all wastes to have a specific gravity of 1.0. Actual specific gravities vary from 1.02 to 1.16.

[2]In 1976 and during previous years, the DuPont-Edge Moor and Camden, New Jersey, wastes were dumped over the continental shelf, not at the 106-mile site.

[3]Modern Transportation and General Marine are concerns that dump waste at the 106-mile site for a variety of individual industrial waste producers. The inputs of each individual are small, none exceeding 40,000 wet tons.

cadmium remains free of the iron oxide as would be expected on the basis of its marine chemistry. Work in progress concerns the fate of chromium from this waste, the size distribution of the particles created by the formation of the iron oxide flocs,and methodology for measuring low iron concentrations continuously at sea in the process of determining waste dispersion and biological effects.

DuPont-Grasselli waste is an alkaline solution (pH 13) of sodium sulfate with small amounts of dissolved metals and 0.5 to 1 percent organic carbon derived from the manufacture of N,O dimethylhydroxylamine (DMHA), and anisole (methyl phenyl ether). The organic compounds in the waste include methyl sulfate, methanol, phenol, small amounts of the product manufactured, and unknown compounds. When high concentrations of this material are mixed with seawater, such as at an outlet port on a dumping barge, its high alkalinity causes the precipitation of magnesium from seawater as magnesium hydroxide. This precipitate is theoretically unstable at the normal oceanic pH conditions that prevail almost immediately behind a dumping barge. Nevertheless, the particles persist and have been observed acoustically in the ocean a day after a dumping event.

American Cyanamid Warner waste is a slightly acidic solution, pH 5, containing 1 to 2 percent organic carbon. Of the three major wastes, it is most difficult to characterize because it is derived from a large and diverse array of plant operations. The primary waste sources are by-products of the production of organophosphorous pesticides and water treatment chemicals with additional wastes coming from the production of intermediates, surfactants,and chemicals used in the mining, paper, and rubber industries. Unlike the other major wastes, no significant particulate phase is associated with this material.

Recently inaugurated work with the American Cyanamid Warner and DuPont-Grasselli wastes centers on their complex mixture of organic compounds. These mixtures generate, through gas-chromatographic analysis, spectra or "fingerprints" which allow their detection in the ocean. Similarly, this analytical technique is being used to indicate any changes in waste composition which may occur in the marine environment.

Dispersion

Measurements of dispersion are basically analyses of some waste characteristic in the ocean after a dumping operation. The only useful characteristics are those which distinguish waste from seawater. Given the large initial dilution which does occur, the useful characteristics are those which are very highly concentrated in or totally unique to waste. Dispersion measurements have been based on iron analyses, dye which has been added to waste, acoustic sensing of particulate phases that form upon dumping, and, most recently, gas chromatography.

Wastes are delivered to the 106-mile site in approximately 4-million-liter lots, usually by barge though occasionally by tanker. By regulation, each dump occurs within a given quadrant of the dumpsite with the specified quadrant for each waste changing quarterly. The wastes are discharged by gravity from moving barges or by pumping from moving tankers at a rate not exceeding the regulated maximum, which varies from 70,000 to 120,000 liters per kilometer. The result is that over a year's period about 200 roughly U-shaped 45-km-long ribbons of waste are released within the 106-mile site. Such a U-shaped track is illustrated through LANDSAT satellite imagery (figure 2). LANDSAT information is being scanned to see if information can be obtained on how long these plumes may persist. The critical questions are: what are the concentrations of waste in the ocean, what is its vertical distribution, and what is its ultimate fate. The answers depend on season, weather, advection of water, and our ability to find evidence of waste at long times after dumping events.

Wastes are diluted by at least a factor of 10,000 within 2 hours of a dump. Except for studies made in 1976 when wastes were dumped at faster rates, there have been no findings of less diluted waste except in very fresh plumes. This extensive and fast initial dilution is due primarily to barge-generated turbulence, and it should be noted that dilution achieved by dumping from a moving barge is about 100 times that obtained by well-designed outfall pipes.

Concentrations observed within 2 to 4 hours following a dump are subject to change due to natural mixing processes, and these processes can be very slow. DuPont-Edge Moor and American Cyanamid waste concentrations of about 10 ppm have persisted for more than 24 hours. DuPont-Grasselli waste at 50 ppm has been found to persist for 17 hours. In all these cases the concentrations may have decreased only very slowly over longer times, but observations ceased after the stated intervals. It cannot be claimed that each waste has unique dispersion characteristics. In fact, since densities of waste are not very different from that of seawater, 1.02 to 1.16 g/ml, and all wastes are quickly diluted by about 10,000 times, it would be expected that dilution history is a function of oceanic rather than waste characteristics. Calm seas allow higher "persistent" waste concentrations. During storms it has been difficult to even find evidence of dye added to DuPont-Grasselli waste, implying that it was diluted by more than 500,000 times, and only gas chromatographic analysis of seawater samples confirmed the presence of waste.

Even under calm sea conditions, dilution is more extensive in winter than in summer, because the vertical extent of the surface mixing zone is larger. Chemical and acoustical measurements have indicated that the bulk of waste is constrained to lying between the sea surface and the pycnocline (the depth where water density begins to increase rapidly with depth). This depth is between 15 and 30 meters during

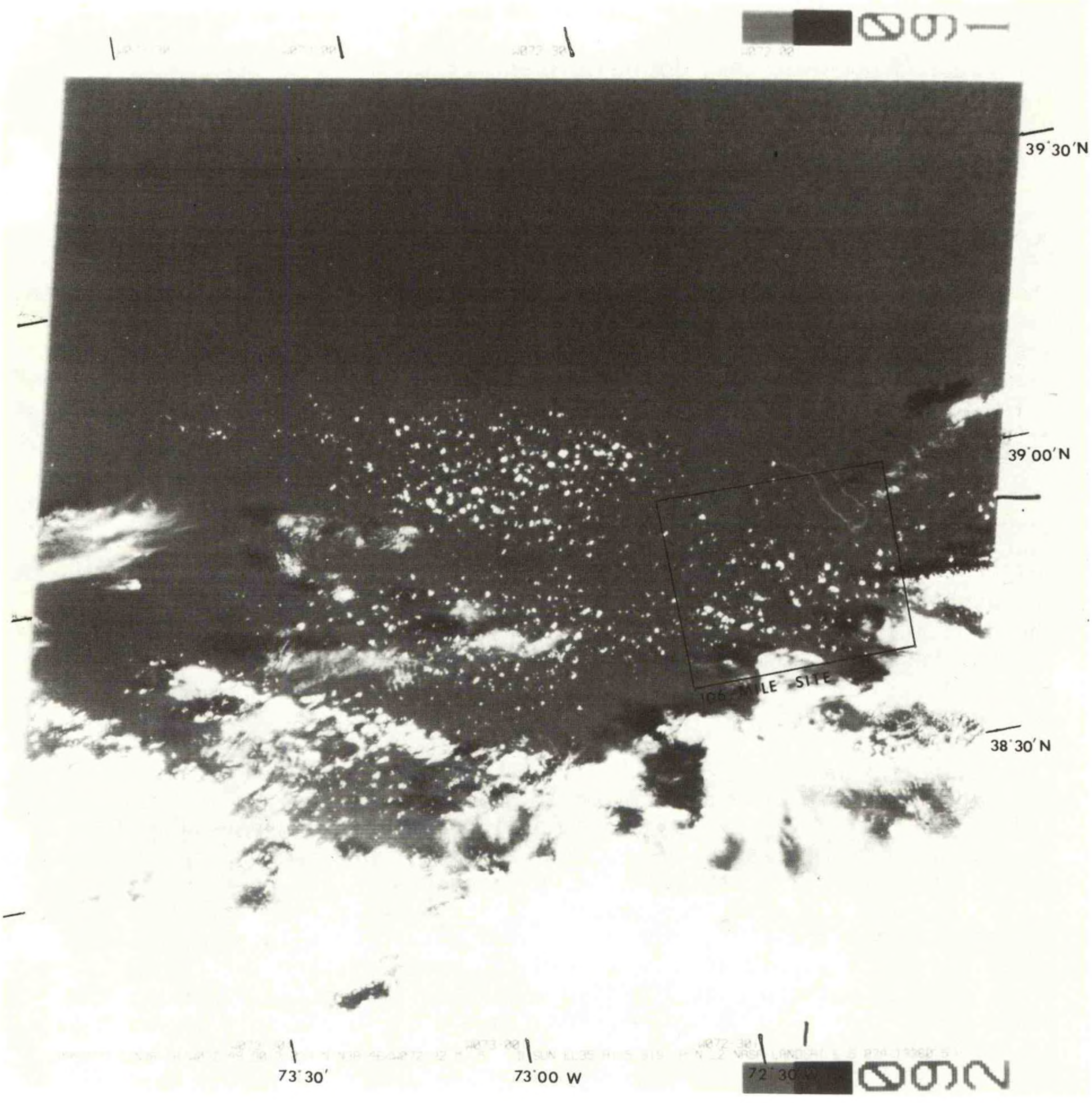

Figure 2.--Acid-waste ocean dumping as seen by LANDSAT satellite imagery. The U-shaped track shown comes from the acid-waste ocean dumping.

summer months due to warming of the surface layers. Between November and March, however, this shallow pycnocline has decayed, and the waste can descend to the permanent pycnocline at 150 to 200 meters. In shallower waters, such as over the continental shelf, there is no permanent thermocline, and waste dumped during the winter can reach the seafloor. At deep ocean sites, however, such as the 106-mile site, there is no evidence to date that wastes are present on the seafloor.

From waste dilution, one is able to infer a volume of ocean which contains waste. A volume 50 by 0.02 by 1 km can hold 4-million liters of uniformly distributed waste at a concentration of 4 ppm. Observations show that the waste is not uniformly distributed in either width or depth. Waste tracking experiments and remote observations of DuPont-Grasselli waste from LANDSAT satellites indicate rather narrow zones of 1,000 m or less containing measurable concentrations. It should be noted that a 50-km by 1-km zone of waste corresponds to about 3 percent of the area within the 106-mile site.

If the 106-mile site was an enclosed basin, no matter how dilute each individual dump became or how much of the 106-mile site it occupied, each event would add to all previous ones and the waste load would accumulate. If water movement through the site was very sluggish so that on the average each waste plume remained onsite for a year, there could be the cumulative effects of 200 dumps. The 106-mile site is not enclosed and the residence time of water is much less than 1 year, but more data are needed and are being collected to define how long the effect of a single dump is likely to remain at the site.

Owing to the varied conditions at the 106-mile site, the best estimates on waste accumulation are twofold. Warm-core Gulf Stream eddies periodically traverse the dumpsite, remaining in the site about 3 weeks. These eddies, about 50 km in radius, move toward the southwest and can theoretically capture 12 dumping events (4 per week) within their 8,000-km^2 area and move them toward the southwest following the edge of the continental shelf. In the absence of an eddy, the mean movement of water and waste should also be toward the southwest and the average residence time of water at the 106-mile site should be about 1 week. This would imply that only four independent dumps could possibly interact or mix with one another.

The picture developed here is that of relatively narrow plumes of contamination being created in the surface layer of the dumpsite and moving to the southwest. The waste concentrations are at most at 100 ppm with extensive dilution having been achieved within hours of dumping. Further dilution is due to oceanic processes and can be very slow except under stormy conditions. Sooner or later, of course, a storm will occur and further dilution with consequent wider distribution of waste will result. Evidence of waste has been found about 30 km east of the site (having been carried clockwise by an eddy), but little effort, to date, has been given to confirming the expected movement of plumes long after dumps. Evidence of dumps having occurred 24 to 48 hours previously has been found within the 106-mile site. Efforts now are directed toward documenting the slow oceanic mixing of wastes by following single dumps for 2 to 5 days to measure oceanic mixing and to understand the basic causes of waste plume dynamics.

Biological Effects

During 1978 the Ocean Dumping Program emphasized biological effect studies based on laboratory measurements of the response of planktonic organisms to low concentrations of waste. This approach was chosen because of the low level of wastes in the ocean and because planktonic organisms inhabit the upper water layer and can be exposed to the waste for extended periods. During the 1977 field program our monitoring and research data showed that genetic damage in fertilized fish eggs was slightly more frequent at the 106-mile site than in uncontaminated areas. This work was not developed during 1978, because of a lack of suitable eggs for laboratory study and because field sampling failed to get enough eggs at either the 106-mile site or control regions. Other biological field samples were collected in 1978 for pathological and chemical analysis.

Growth rates of three phytoplankton species have been studied in the presence of DuPont-Grasselli waste over the concentration range of 10 to 1,000 ppm. Response depended on not only concentration and species, but also for a given species, on particular clones. Among seven clones of the species, *Skeletonema costatum*, for instance, growth rates in the presence of 500 ppm waste varied from 50 to 100 percent of control values. The most sensitive clones were those isolated from open ocean areas while the tolerant isolates were from highly utilized coastal areas. At 100 ppm or less, however, there was no inhibition of growth for any clone of the three species. Work is continuing with other wastes, and various clones will continue to be tested, because, as demonstrated, the response of one isolate of a given species is not necessarily representative of that species' general response.

Over the concentration range of 10 to 100 ppm, the effect of this same waste upon zooplankton has been examined. For one herbivorous species, *Pseudocalanus*, there were no deaths at concentrations below 1,000 ppm. At 100 ppm an omnivore, *Centropages typicus*, however, had about 15 percent mortality relative to controls. Sublethal effects upon these organisms were evident at lower concentrations. Filtration feeding rates for *Pseudocalanus* were about 50 percent less in the presence of 10-ppm waste than in the presence of no or 1-ppm waste. Feeding and fecal pellet production rates for *Centropages* decreased slightly at 50-ppm waste with large decreases at 100 ppm, the concentration which causes significant mortality.

In terms of effects in the ocean, these experiments with zooplankton indicate that death of organisms is unlikely to be of concern. There may be a shift in metabolic activity to cope with low levels of waste with a corresponding decrease in the use of available energy for feeding, growth, and reproduction needed to maintain population levels.

Mixed marine bacteria populations taken from coastal waters have been used as test organisms and found to be more sensitive to wastes than specially isolated single species populations. Concentrations required to achieve a 50-percent decrease in metabolic rate as determined by glucose uptake for the mixed population were 100 ppm for American Cyanamid, 200 ppm for DuPont-Edge-Moor, and 1,000 ppm for DuPont-Grasselli wastes. This may indicate that for other organisms the relative toxicities of the three major industrial wastes are in the same order, though industry-sponsored studies show the decreasing order of toxicity toward phytoplankton and zooplankton is American Cyanamid, DuPont-Grasselli, and DuPont-Edge Moor.

Using bacteria as a bioassay organism, it has been shown that DuPont-Edge Moor waste toxicity is due to its metal content, because toxicity decreases in the presence of organic compounds which form complexes with metals. The toxicity of DuPont-Grasselli waste, on the other hand, is due to its organic compound content. Those compounds responsible for the toxicity seem to be stable ones, because toxicity is not decreased by subjecting the waste to ultraviolet irradiation and only slightly decreased (about 20 percent) by chemical oxidation with potassium persulfate. This implies that while dilution in the sea may mitigate any toxic effects of DuPont-Grasselli waste, it is not likely to be detoxified by exposure to sunlight and seawater.

Field studies on phytoplankton and bacterial activity at the 106-mile site have not, in the past, shown any changes attributable to ocean dumping. A reason for this may be that there are no biological consequences to present dumping practices, a possibility which cannot logically be proven. Alternatively, laboratory experiments have shown that if there are biological effects they are probably subtle ones and dump-related biological aberrations may lie within the range of natural biological variation. Field work is planned to study the distribution of phytoplankton and zooplankton species composition and bacterial activity at and near the dumpsite and in conjunction with specific dumping events. Since there is a species, and clone, variation in response to wastes, the consequence of dumping may not be changes in plankton biomass, per se, but in its species composition. This effect could be detrimental if species which begin to dominate are of little value in the marine food web. Many more samples will have to be taken than in the past in order to differentiate natural from any dump-related changes in species composition.

During cruises to the 106-mile site, planktonic crustacea are collected for pathological examination. This activity seeks to observe characteristics of organisms that indicate disease or injury suffered as a result of waste disposal into the ocean. Conditions such as black gills and ciliate infestations in euphausiids, infection in amphipods, and exoskeleton damage to isopods have been observed. The isopod condition may be related to accumulation of waste precipitates on the surface of the animal. However, no condition has been found which is totally unique to the dumpsite and, without better knowledge of the natural distribution of disease or injury, no dump-related effects can be defined.

Dumped material could be accumulated by planktonic organisms, indicating a biological response to waste disposal. This could serve as a method, other than simple mixing, for the dispersal of wastes. Heavy metal analyses were made on samples collected by surface and subsurface nets during summer 1978. These collections were made in a manner which avoided to some extent the possibility that metal analysis could be contaminated by effects of the nets themselves or the ship. Only 1 out of 10 stations had a metal level higher than that at other stations. Lead was high in a sample taken at the same location where iron in seawater was at 60 parts per billion due to a dump made 8 hours earlier. At nearby stations and at all other stations, lead concentrations from net samples were low. Cadmium, chromium, copper, or nickel levels in net samples did not differ from station to station. The single occurrence of high lead may indicate that the net had been towed through a zone containing hydrous iron oxide flocs. These flocs have been shown to adsorb lead from the waste, and the towing process may have had the effect of forcing the precipitate to adhere to the net sample. This finding does justify, though, a continued effort to determine if there is a biological accumulation of waste and, in this context, specific organic compounds in net samples are worth examination.

Puerto Rico Dumpsite

Background

The Puerto Rico dumpsite is a 500-square-kilometer area located between 19°10' - 19°20'N and 66°35' - 66°50'W (figure 3). It lies in water 6,000 to 8,000 m deep and is 74 km north of Arecibo Harbor, Puerto Rico. The dumpsite was established in 1972 as an interim disposal location pending completion of the Barceloneta Regional Wastewater Treatment System, now scheduled for operation starting July 1981.

During 1978 the Puerto Rico dumpsite received about 360 million liters of liquid waste. Of that total, approximately 15 percent was an alkaline solution of hydrogen sulfide from a hydrocarbon refining company, Puerto Rico Olefins Company, and the remainder was aqueous organic waste from seven pharmaceutical firms. The sulfide disposal occurs separately while the pharmaceutical wastes are mixed prior to barge loading. The wastes, trucked from various plants, accumulate in a holding tank until on 2 or 3 consecutive days they are dumped from a moving barge in 2.5-million-liter lots over a distance of about 35 km. The NOAA program has centered on the studies of dispersion, and biological and chemical effects of pharmaceutical wastes.

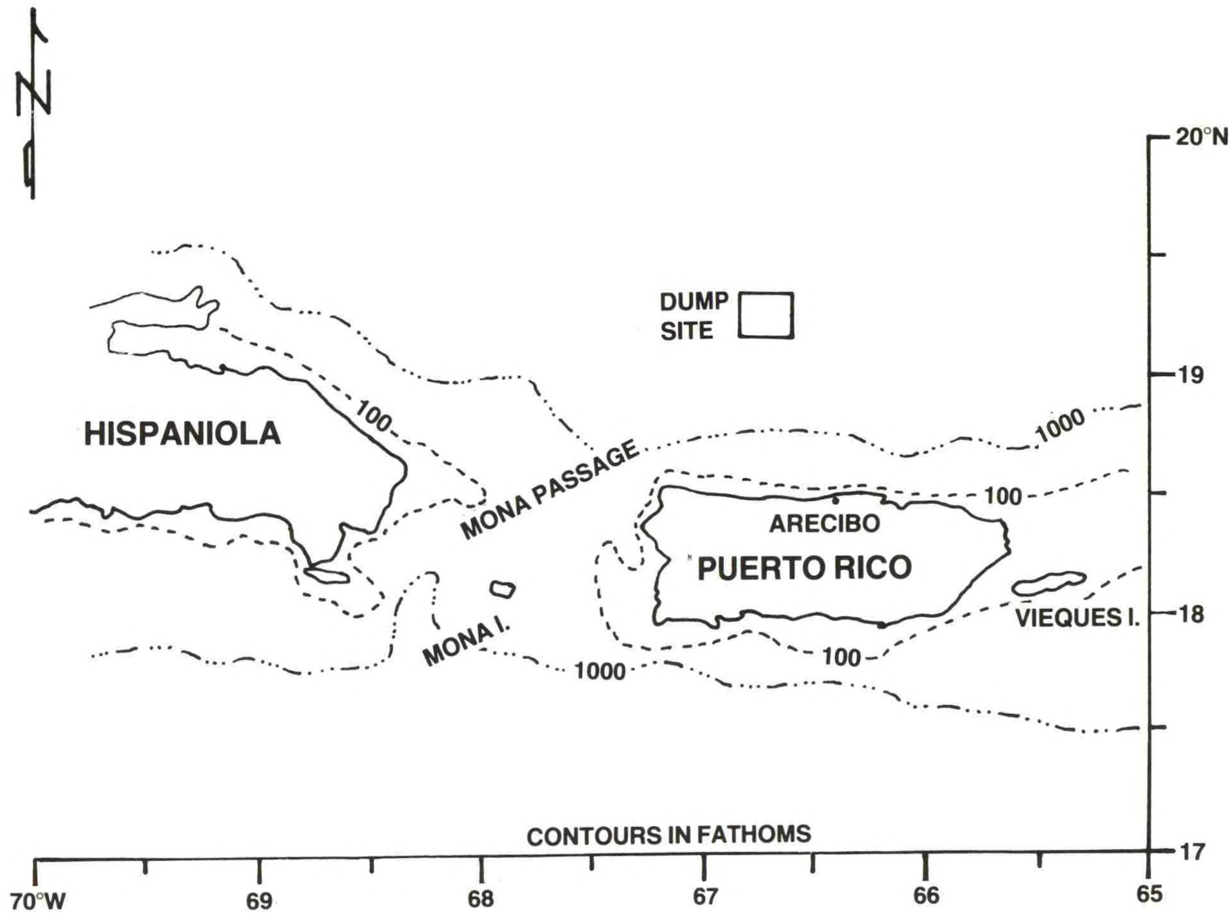

Figure 3.--Puerto Rico dumpsite.

The objective and approach to NOAA's Puerto Rico dumpsite investigations are the same as those for the 106-mile site.

Chemistry

Table 2 lists the seven pharmaceutical firms and their products, most of which are antibiotic substances. The wastes contain pharmaceutical products in trace amounts, spent fermentation broths from Upjohn and Schering and contain a large, diverse array of chemicals used for drug synthesis and purification. The reported metal concentrations of the waste are low, less than 1 ppm, and the organic carbon content high, 1 to 4 percent by weight, relative to wastes dumped at the 106-mile site. Chemical compounds in seawater samples taken after dumping events include alcohols, fatty acids, fatty acid esters, ketones, aromatic solvents, and other compounds, all of which contribute to the generation of gas-chromatographic spectra which identify the presence of waste. Some of these compounds, such as fatty acids, occur naturally, others are alien to the marine environments. One compound which is not natural to the sea, N, N dimethylaniline, was found to be 5.2 percent by weight in a barge sample and served as an excellent quantitative indicator of waste. The waste contains 1 to 2 percent suspended solids derived primarily from spent fermentation liquors, which allows the waste to be acoustically sensed in the ocean.

Chemical studies in progress are directed toward determining the stability of this waste. Some compounds are volatile and are lost to the atmosphere; others may be unstable in the marine environment or degraded biologically. The ultimate fate of this waste in the ocean will depend on all the above interactions.

Dispersion

Because this waste is primarily water, similar to those dumped at the 106-mile site, and because it is dumped in an identical manner, its dilution history is also similar. Using dye or dimethylaniline as an indicator, the initial dilution of waste observed is 10,000 times, corresponding to 100-ppm waste. Pharmaceutical firms funded a study in 1977 which found that dilutions 1 to 10 hours after dumping varied from 10,000 to 50,000 times. This is consistent with observations at the 106-mile site that showed extensive initial dilution followed by slow further dilution. NOAA studies at the Puerto Rico dumpsite during 1978 observed similar behavior.

In one case where maximum concentrations of 10 to 50 ppm for the 2- to 10-hour postdump period were found, acoustic sensing indicated relatively discrete horizontal distribution with plume widths of 1 to

Table 2.--Pharmaceutical firms in Puerto Rico using deep ocean for waste disposal

Firm	Products	Percentage of total pharmaceutical waste*
Upjohn Manufacturing Company	Lincomycin, Clinomycin	46
Merck Sharpe and Dohme Quimica de Puerto Rico, Inc.	1-methyl dopa	20
Schering Corp. (Puerto Rico)	Gentamicin, Sisomicin	15
Cyanamid Agricultural de Puerto Rico	Veterinary drugs	9
Pfizer Pharmaceuticals, Inc.	Diabinese, Sinequon, Bonine	5
Bristol Alpha Corp., Inc.	Ampicillin and other varieties of penicillin	3
Squibb Manufacturing Inc.	Penicillin, Cephadine	2

* Percentages are based on amounts stated in permit applications.

2 km. In other cases, dye could be detected sporadically or not at all and acoustic sensing indicated rather widespread distributions. This would imply dilutions by more than a factor of 500,000; chemical data generally confirm a widespread and consequently very dilute occurrence of waste.

As at the 106-mile site, waste is confined primarily to the upper water layer. The depth of the pycnocline, which essentially acts as a floor to waste distribution, varies at the Puerto Rico site from 30 to 80 m, being shallower during the summer. Unlike the 106-mile site, this area is not subject to annual disappearance and subsequent reformation of a shallow pycnocline. Therefore, the wide range in the vertical distribution of wastes as occur at the 106-mile site is not expected. At both sites, however, the extreme depth of the ocean relative to the pycnocline depth precludes appreciable penetration of waste to the seafloor.

Advection of water through the Puerto Rico site is usually a steady movement to the west-northwest in conformance to the flow of the Antilles Current. Current speeds are estimated at 1 to 2 km/h, yielding a residence time of water within the site of 20 to 40 hours. Chemical measurements after specific dumping events detect waste in samples taken at and west of the site as would be indicated by the current system. However, samples taken east of the dumpsite at arbitrary locations not in conjunction with specific waste-tracking experiments have detected waste 24 hours after dumps. Planned studies using drogues to be followed for long times from shore will yield better estimates of the residence time of water within the dumpsite and will determine if there are periodic reversals of the expected westward flow of water.

Biological Effects

Measurements of the toxicity of samples of mixed pharmaceutical waste on a variety of organisms showed that, in general, it may be less toxic than any tested wastes related to the 106-mile site.

Among phytoplankton, two species of green algae grew as well in the presence of waste at a concentration of 10,000 ppm as in controls. One species of blue-green algae did not grow at 1,000 ppm, but was unaffected at 250 ppm; a second species grew at 80 percent of its control rate in 250 ppm waste and was unaffected at 50 ppm. Two species of diatoms were also tested; neither was affected at 50 ppm, though responses differed at higher concentrations. As with wastes dumped at the 106-mile site, response varies with species, and growth inhibition occurs usually at concentrations greater than those existing in the ocean.

Adult and some larval stages of invertebrates including amphipods, anemones, crabs, gastropods, isopods, jellyfish, polychaete worms, and shrimp, were tested at concentrations ranging from 100 to 100,000 ppm. Except for shrimp larvae (Palaemonetes pugio) and both juvenile and adult amphipods (Marinogrammarus finmarchicus), survival of invertebrates was unaffected at concentrations below 1,000 ppm. Shrimp larvae had only 60 percent of their control survival at 1,000 ppm after 4 days of exposure. Survival was less at higher concentrations up to 40,000 ppm, except that at 10,000 ppm survival was about 90 percent of its control value. Seven-day survival of amphipods was the same in the presence of 100-ppm waste as in controls, but for both juveniles and adults survival decreased by about 15 percent at 500 ppm. Future experiments will center on sublethal effects of waste on pelagic invertebrates likely to be found at the Puerto Rico dumpsite.

A third type of biological effect study is unlike any done in the 106-mile site program, because it deals with fish. Since waste is relatively discrete in its distribution, free-swimming organisms may be attracted to waste if it is a food source, or they may avoid contamination. However, the particular test procedure used here discerns subtle variations in metabolic systems due to waste not detectable in tests with smaller organisms. Red snapper (Lutjanus campechanus) was used to measure respiration rates while at rest and while swimming. Respiration of nonswimming fish was found to be unaffected by wastes up to a concentration of 5,000 ppm, which was lethal. Respiration of swimming fish was found to decrease. At 2,500-ppm waste, fish died when forced to swim. At the lowest concentration tested (625 ppm), the rate of oxygen utilization decreased about 15 percent relative to the control. This is interpreted to indicate that in order to cope with the added stress induced by having to swim in the presence of low levels of waste material, the organisms are sacrificing energy that otherwise would be expended on normal physiological processes.

New York Bight

Introduction

During 1978 the New York Bight had no major pollution-related incidents. As a result, efforts of NOAA in the Bight were directed to accomplishing the planned and projected monitoring and research outlined in the NOAA/MESA (Marine Ecosystem Analyses) New York Bight Project Development Plan and delineated in the Project's Technical Development Plan. Emphasis was placed on studies related to dredged material and sewage sludge.

New York Bight Water Quality Monitoring

During 1978 NOAA continued its assessment of New York Bight water quality through a series of four "expanded water column characterization

(XWCC)" cruises. The station grid for the XWCC cruises is shown in figure 4. These cruises were conducted seasonally, in the spring-summer period. This period is of particular interest, because dissolved oxygen in the bottom waters, which are quite isolated from surface waters during periods of stratification, becomes depleted. These field efforts not only allow us to monitor the dissolved oxygen levels in bottom waters under stratified conditions, but also provide us a means of assessing periodically the impacts of sewage sludge dumping on the water column.

In the summer of 1978 there was some initial concern when the dissolved oxygen levels near the sewage-sludge dumpsite were found to be below 5.0 ml/liter, for organisms begin to get stressed when the dissolved oxygen levels fall below 2.0 ml/liter. This occurred as early as June 6, 1978. At the same time, the phytoplankton Ceratium tripos was found in the area. There was some speculation that Ceratium, which had significantly lowered the dissolved oxygen levels during summer 1976, would cause a similar happening again. This turned out not to be the case. The next set of observations was taken on July 5, 1978, at which time no Ceratium was observed, and dissolved oxygen levels at the site had increased to 5.7 ml/liter.

During the period late spring and early fall 1978, NOAA presented data and information from XWCC cruises on water quality to a New York Bight ad hoc Interagency Advisory Committee. The Committee meetings, held approximately monthly, addressed the seasonal progression of conditions and potential influences (natural and human) on these conditions such as weather and ocean dumping of sewage sludge. The topics which were addressed included oxygen depletion, algal blooms, floatables, water quality based on coliform data, and oil spills. Representatives of some 14 Federal, State, and local government agencies were present to exchange data and information and to coordinate field efforts. The XWCC cruises have provided much useful information and understanding on the relative chemical impacts of dumping. In the Bight Apex (figure 5) dumping-derived organic and inorganic materials affect substantially the water and sediment quality in the immediate vicinity of the dumpsites. Away from the dumpsite, however, the effects are masked by other sources, such as the Hudson-Raritan Estuary, or become less primarily as a result of dilution.

Sewage Sludge Studies

The water quality monitoring studies showed no significant influence on dissolved oxygen levels by sewage-sludge dumping. However, a more obvious effect of pollutants in the New York Bight is potential eutrophication of the area. Although the bulk of nutrients imported into the Bight enters by way of runoff from the Hudson-Raritan estuary, direct outfalls of sewage-treatment plants, and from nutrient-rich, deep-sea water that moves toward shore, a fraction is contributed by the dumping of sewage sludge and dredged material. Through a number of related studies, the

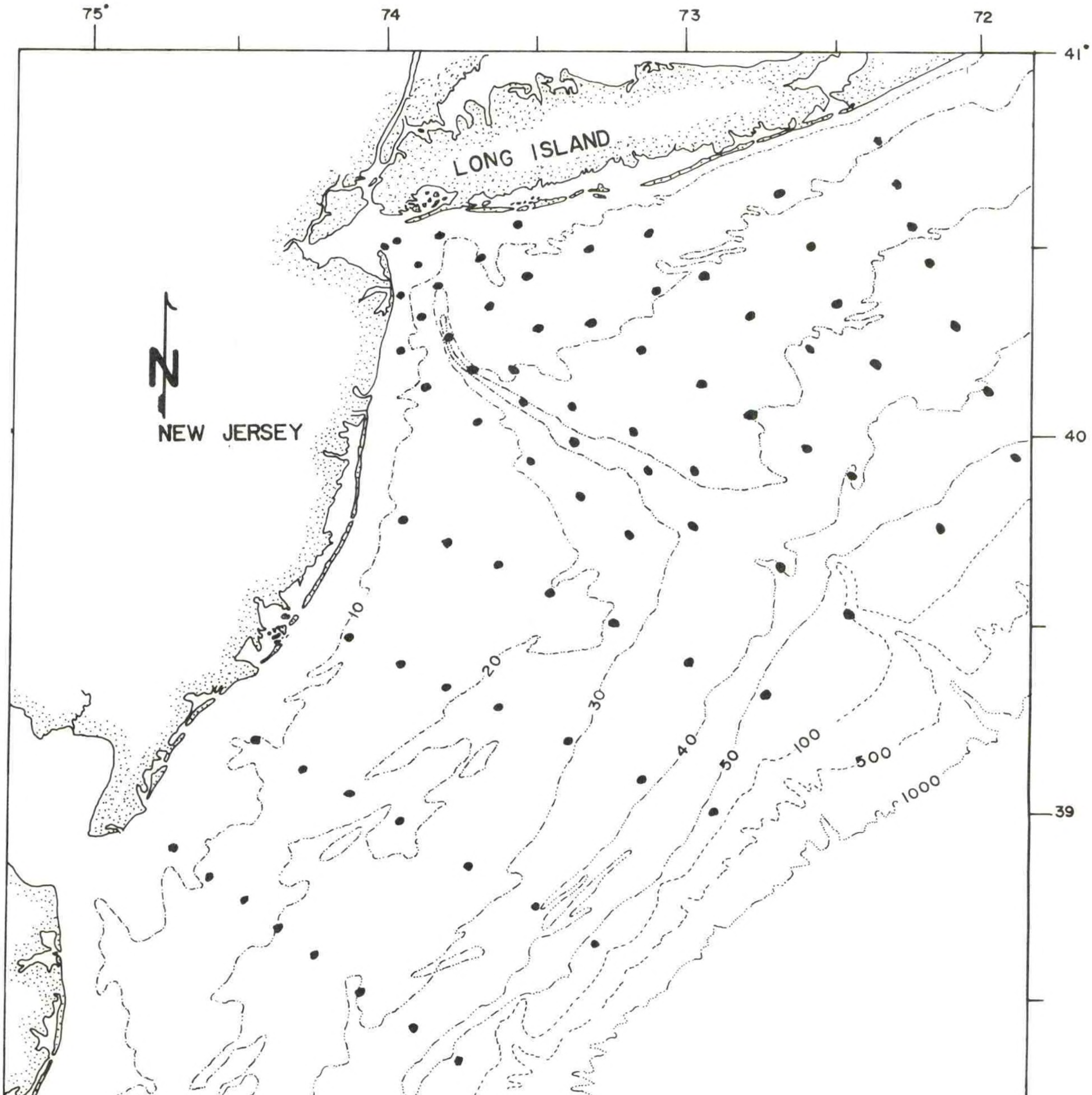

Figure 4.--Expanded Water Column cruise grid stations. Characterization (XWCC) (Dots denote stations.)

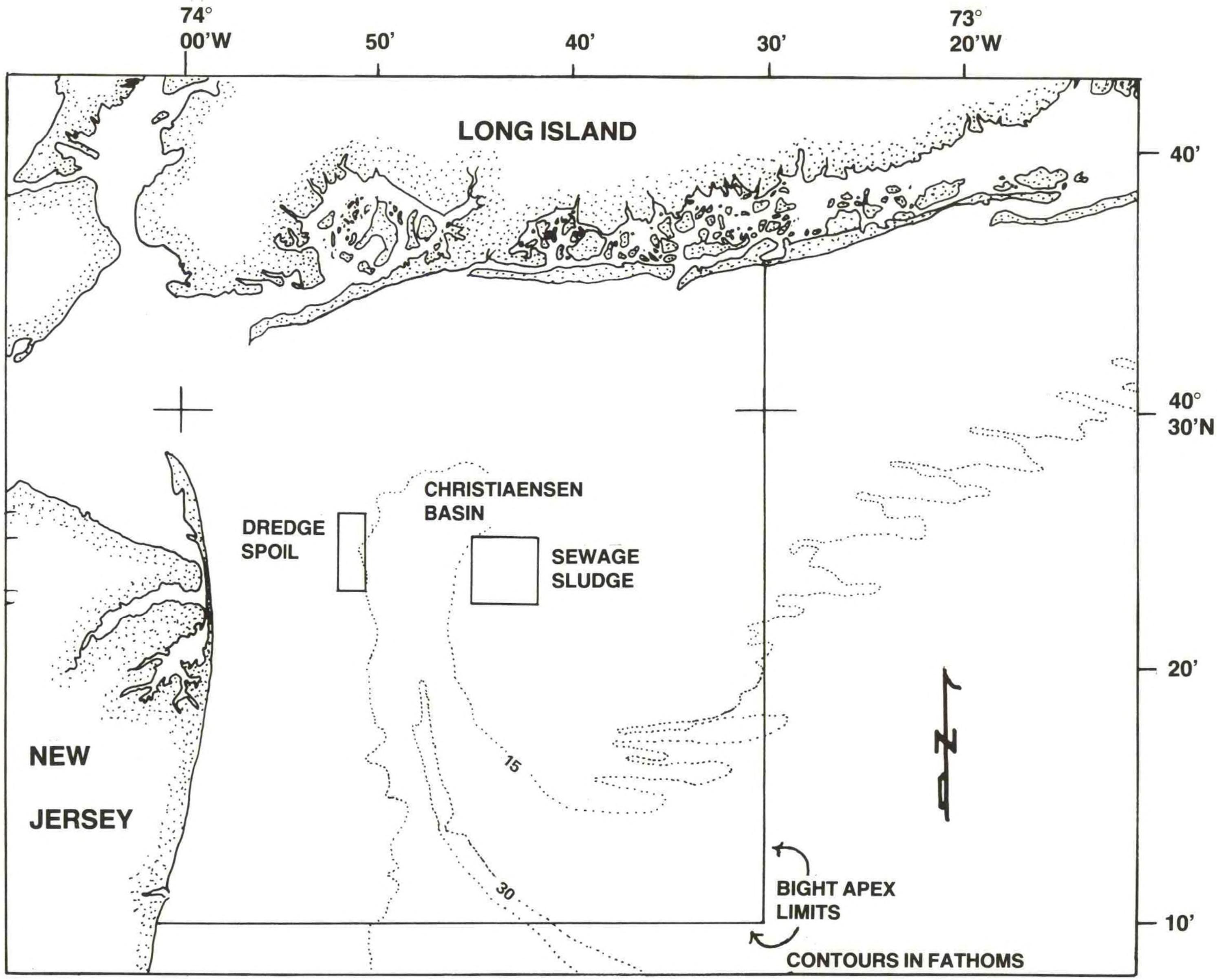

Figure 5.--Dumpsite study areas in the New York Bight.

factors associated with the cycling of carbon, oxygen, and nitrogen (C/O/N) in the Bight were investigated.

During 1977 and 1978, a series of four seasonal monitoring cruises were carried out to assess the cycling of nutrients in parcels of water as they pass through the Bight Apex. This Synoptic Investigation of Nutrient Cycling (SINC) examined items such as (1) the factors regulating primary productivity, (2) the rates of nutrient utilization and regeneration, and (3) the roles of zooplankton and bacteria in carbon and nutrient dynamics.

Two independent but related efforts to model C/O/N cycling in the Bight were initiated in late Fiscal Year 1977 and early Fiscal Year 1978. Both are attempts to provide mathematical frameworks for evaluating the probable causes of the 1976 anoxic episode and for assessing the influence of anthropogenic nutrient loadings. The Fiscal Year 1977 effort adopted an "engineering" approach which minimized the ecosystem complexities and allowed the consideration of some management issues that otherwise would be intractable, given existing data and process understanding. The Fiscal Year 1978 effort attempted to integrate factors such as nutrient dynamics, food chain interactions, and more precisely defined circulation patterns to assess the 1976 low dissolved oxygen episode. This effort will incorporate data generated as the result of the SINC activities and independent investigations off Shinecock Inlet.

Recently a study yielding insight into the bacteria in sediments and their abnormal tolerances for unusually high concentrations of some metals and antibiotic substances was completed. Efforts concentrated upon *Bacillus*, by far the most common genus found in all sediments. Large numbers of *Bacillus* from near the dumpsites of the inner Bight were found to be resistant to mercury and the antibiotic ampicillin in concentrations which would kill normal *Bacillus* strains. Mercury-resistant strains were also commonly resistant to additional heavy metals and antibiotics. Evidence from this and other studies suggests that the genetic material determining resistance to a few metals and antibiotics is often transmitted as a single unit during reproduction. Because the concentrations of several trace metals are high enough in the more contaminated sediments, resistant strains have a selective advantage over strains more susceptible to metal toxicity. While antibiotics are presumed to be essentially absent from the sediments, metal concentrations are high. The observed antibiotic resistance is probably perpetuated, because its genetic basis is often linked with that of metals. This study documented a clear association between levels of sediment contamination and incidence of *Bacillus* resistance to metals and antibiotics. An additional finding was that one-third of the *Bacillus* strains from the dumpsite metabolized mercury and released it as elemental mercury. Because *Bacillus* is such a dominant bacterium of Bight sediments, this could be a significant mechanism for promoting a flux of mercury from sediments to seawater.

Another study was completed which projects future waste loads from all major sources and provides a contrast with existing loads. Projections were made to the year 2000, under the combined assumptions of some regional population increase, elimination of existing raw sewage discharges, upgrading of some sewage treatment plants and elimination of others, and addition of some new sewer districts, under alternative chlorination/no chlorination strategies for domestic treatment-plant effluents. The most striking effect is a projected decline by 85 percent in summer fecal coliform loadings under chlorination. If the projected treatment-plant improvements and uniform chlorinations practices would take place, this measure (coliform) of water quality would improve greatly in the New York/New Jersey harbors and near some ocean outfalls. However, given the assumed changes by the year 2000, total loadings are expected to remain about the same or increase slightly for suspended solids, organic carbon, nutrients, and chemical contaminants. Significant portions of these total loadings are now dumped at sea. Land-base alternatives for all ocean dumping in the Bight by 2000 would reduce the total input by 20 to 60 percent, depending upon the type of waste.

Fish Studies

The causes of fin rot disease in the Bight have been studied since 1973. The causes of this syndrome, primarily found in winter flounder, are still uncertain. However, it seems that several chemical stresses together may cause fin rot in winter flounder. The incidence of fin rot in winter flounder and other species in the Bight is now apparently at an unusually low level (less than 1 percent). This is in marked contrast with an incidence of 16 percent in the Apex during the spring of 1973. The reason for the decline is unknown.

The linking of genetic damage of eggs and larvae of Atlantic mackerel with concentrations of several contaminants in surface waters was examined. Data have been analyzed from two mackerel spawning seasons, 1974 and 1977. This study hypothesized that contaminants in contact with mackerel eggs cause genetic damage serious enough to kill many of the mackerel at very early developmental stages, i.e., as eggs or early larvae. Mackerel eggs were sampled throughout the Bight, together with associated contaminant concentrations in surface waters and in the neuston layer at the water surface. It is known that both metallic and organic contaminants can be concentrated in the neuston layer, a region to which mackerel eggs are exposed. Associated measurements were made of physical/chemical attributes of the surface water. These included several metals, biphenyl, total hydrocarbons, phenanthrene, pyrene, polychlorinated biphenyls (PCB's), and several other synthetic organic compounds. The highest frequencies of mackerel eggs and early larvae with fatal genetic abnormalities were found in the most contaminated regions of the inner Bight. Abnormalities were also frequent near inlets to embayments.

The overall impact of these contaminant effects upon successful reproduction of mackerel stocks is probably not great. Atlantic mackerel spawn over very wide areas, most of which have much lower contaminant concentrations than the inner New York Bight. The possibility is being assessed, however, that some fishes having localized distributions might be affected seriously.

The National Oceanic and Atmospheric Administration cosponsored a study on the implications of increasing PCB contamination in the marine environment upon phytoplankton. The study indicated that relatively low environmental concentrations of PCB's may cause the rupture of phytoplankton cells. Susceptibility varies from species to species and is partially dependent upon factors such as temperature and season. As a rule, however, large phytoplankton (e.g., diatoms) tend to be more severely affected than small phytoplankton. Work by other scientists suggests that most harvestable fish resources are supported by short food chains with relatively large species of phytoplankton as a base. Food chains with small species of phytoplankton as a base tend to be longer and tend to support organisms such as ctenophores and jellyfish which are not harvested by humans. The study thus suggests that increasing PCB pollution in the marine environment may have three effects: (1) reducing primary productivity, (2) being taken up by food organisms, and (3) altering marine food webs and, as a consequence, reducing fish stocks.

Dredged Material Studies

As an extension of the study entitled "A Preview of the Impact of Dredged Material Disposal in the New York Bight Apex, with Emphasis on Chemical Processes" completed last year, new studies were initiated in 1978. These studies included:

- More detailed definition of the composition of dredged material dumped in the New York Bight, particularly with regard to metal and organic components, and characterization of the physicochemical state of these components.

- More detailed studies of the changes of dredged material after deposition at the dumpsite to ascertain the routes and rates of contaminant release from the sediments to the water column and biosphere.

One area of study was scheduled to start in 1979. This study was designed to give a better definition of the physical and chemical processes occurring during and immediately after dredged material dumping to assess the initial fate of contaminants in the dredged material.

A panel of marine science experts was asked to identify and rank those contaminants which are, or are likely to be, the most serious in the Bight. The panel identified chlorinated pesticides, polynuclear aromatic hydrocarbons (PNAH's), and PCB's as major perceived threats among the organic compounds. As a result of these recommendations, broad-scan analyses of major sources, sinks, and potentially affected biota were undertaken for these classes of organic compounds. These "broad-scan" analyses included determinations of concentrations of 17 aromatic hydrocarbons, 22 pesticides, and PCB's. Samples for analyses included sediments from three dredged channels that are known to be contaminated: Newtown Creek, Gowanus Canal, and Pierhead Channel. Values in dry weight for individual aromatic hydrocarbons ranged from 50 to 120,000 ng/g dry weight; for chlorinated pesticides, less than 5 to less than 200 ng/g; and for total PCB's 500 to 1,700 ng/g.

Bottom sediments from Lower Bay, Christiaensen Basin, and the outer Bight were analyzed in the same fashion. Not surprisingly, concentrations in almost all the outer Bight samples were orders of magnitude below those of samples from the Christiaensen Basin and Lower Bay, for all three classes of organic materials.

Also sponsored was a study using radio-chemical and x-ray radiographic techniques to provide additional information on sediment accumulation and stability in the Bight Apex. Diver-collected box cores were obtained from sites 2 to 6 km northwest of the dredged material dumpsite, and the sediments were analyzed for several radionuclides and for macrofauna. Based on exponentially decreasing excess thorium-234 and constant thorium-228 and lead-210 with depth in the sediment strata, as well as fine laminations visible in x-ray radiographs, it is inferred that the area is characterized by periods of rapid sediment accumulation separated by periods of slower sedimentation. Well-developed thorium-234 profiles and the presence of a 1-year age class of <u>Nucula proxima</u> (a bivalve) indicate stability on the order of about 1 year.

The extent of remobilization of metals in the sediment at the dredged material dumpsite and the subsequent release of these metals to the Bight water are the major thrusts of another study in progress. It is extremely important to understand these processes, since many of the metals there can be accumulated by, and can be toxic to, marine organisms. This study, using coring and seismic profiling techniques, was begun in February 1978 and produced some preliminary findings. Bulk metal analyses of six long sediment core samples (3 to 9 meters long) indicated that concentrations of metals present in dumped dredged material are highly variable and greatly elevated, up to 1,000 times, over metal concentrations in sediments beyond the dredged material mound and in natural sediment underlying the mound. First indications from the associated bathymetric survey show substantial recent shoaling at the dumpsite of more than 1 m since a 1973 survey.

A study to ascertain the physicochemical processes occurring during and immediately after dredged material dumping and to assess the initial fate of the dumped materials is being planned for 1979. A dredged material acoustic tracking experiment will use acoustic tracking and chemical sampling methodologies already proven during the sludge-tracking investigations. Information on particulate dispersion, and physical and chemical transformations will become available in 1979.

Gulf of Mexico

Dredged Material Disposal Sites

Background

In Fiscal Year 1977 two potential dredge material disposal sites located near southwest pass of the Mississippi Delta were identified for study. The two sites are off Bayou Fontanelle and Tiger Pass in shallow water (figure 6). Field investigations began in spring 1978. This work was performed in cooperation with the U.S. Army Corps of Engineers (COE) and with the U.S. Coast Guard (USCG). Funding for this project was supported jointly by the COE, New Orleans District, and NOAA. The USCG Eighth District provided personnel and ships.

The objectives of this program are as follows:

1. To perform detailed baseline surveys to assess the quality of the predredge environment.

2. To measure the short- and long-term environmental effects of dumping dredged materials into the ocean.

3. To develop techniques and strategies for monitoring the impacts.

4. To establish environmental monitoring programs for selected dumping sites for dredged material.

The dredging operations to occur in the future are maintenance dredging and possible deepening of the channels to accommodate increased traffic and larger vessels if deepwater ports become a reality. The areas selected for this study yield many oysters and shrimp.

Field Studies

The field study evaluating the two dredge disposal sites in the Gulf of Mexico was made in spring 1978. The program was planned and implemented in cooperation with the U.S. Army Corps of Engineers, New Orleans District.

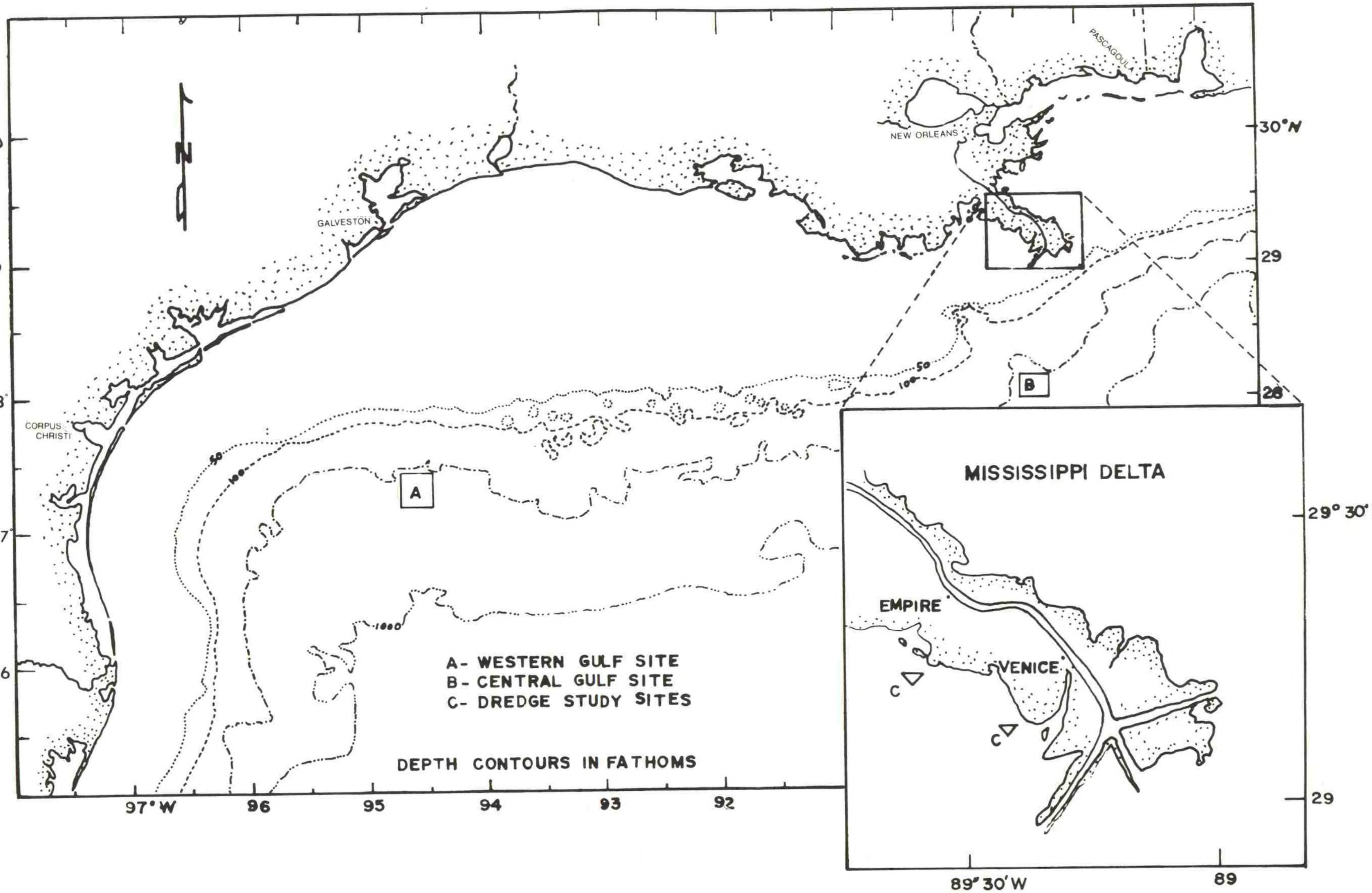

Figure 6.--Waste disposal sites, Gulf of Mexico.

The areas were assessed for use as future disposal sites for dredged material. Site characterizations were performed, and sediment, water, and biota samples were obtained for trace metal analysis and bioassay studies. The bioassays followed the guidelines outlined in the EPA/COE Manual for ecological evaluation of proposed discharge of dredged material into ocean waters. These investigations may be expanded in the future to include further biological and chemical studies which will lead to development of monitoring techniques to assess the ecological impact of marine disposal of dredge material.

Bayou Fontanelle and Tiger Pass are about 22 km apart, both in very shallow water, but are environmentally different, resulting from direct contact with the Mississippi River. The head of Bayou Fontanelle has a lock that lessens the effect of the river; Tiger Pass has direct contact with the river.

Bayou Fontanelle, the more northerly of the two, lies exposed to all kinds of waves. The shoreline is eroding at about 40 cm/year. The current regime is generally anticyclonic, and there is longshore transport of heavy sediments. Temperature and salinity are variable and a function of season. Water temperature closely approximates air temperature. Salinity is dependent on tide and river flow. The sediments at the site are classed as deltaic destructional, predominently sand and shell, which means an area of high erosion.

Tiger Pass is in an area less exposed to all wave types and is in an area of high sedimentation. There is little longshore transport of heavy sediments and no predominant current direction. The water temperature approximates air temperature, and salinity is low due to the direct contact with the river. The sediments are classified as deltaic, which is high in silt and clay with less than 2 percent sand.

The climate of the area is marine under the influence of the Gulf of Mexico. The winds are southerly to easterly in all months except January when the winds become northerly. They range in speed from an average of 23 km/h in the winter to 14 km/h in July. Rainfall ranges from 8.1 cm in October to 18.8 cm in July, with an annual accumulation between 125 and 195 cm.

Bayou Fontanelle is surrounded by extensive salt marshes with oyster grass. The soils are high in organic matter, and the biological productivity of the Bayou is high. The fishery harvest for this area is 134,000 $kg/km^2/year$.

The marsh area surrounding Tiger Pass has low salinity. The marsh grass consists of oyster grass and rousseau. The soils are low in organic matter, high in mineral content. Its biological productivity is low. The fishing harvest for this area is 25,000 $kg/km^2/year$.

Elutriate tests were performed on the sediments to be dredged. Large amounts of phosphate and ammonia were released from the Bayou Fontanelle sediments. These, however, would be rapidly reduced to background levels when dumped in open water. Tiger Pass sediments contain certain forms of iron that adsorb phosphate. Trace metal levels were found to be within the EPA criteria limits.

The trace metals, copper, cadmium, iron, lead, manganese, and zinc, were measured in organisms in and up and downstream from the dumping region at Bayou Fontanelle. Muscle tissue of the commercial shrimp Penaeus *setiferus* and blue crab *Callinectes sapidus* was used. The data are limited and inconclusive.

The bioassay analyses followed the EPA/COE implementation manual of July 1977. Test organisms were more affected by the suspended and solid phase bioassays than the liquid phase. The control groups had large mortalities, thus yielding inconclusive results. It is not yet known if the mortalities were due to toxic elements in the sediments or to physical factors. From the results, however, the sediments from Tiger Pass seemed to affect the test organisms less than the sediments from Bayou Fontanelle.

Disposal of dredged material for this area would not be serious environmentally. The disposal operations would be small compared to amount of sediment transported in the area. However, care should be taken not to disturb or destroy the marsh grasses.

Industrial Waste Studies

Background

The investigation of dumping of industrial wastes into the Gulf of Mexico was started in 1977 and was completed in 1978. The study program focused on the environmental effects of discharging a biological sludge produced by a chemical factory near Galveston, Texas. The dumping site was about 200 km south of Galveston. The objectives of these studies were to: (1) describe the basic environmental characteristics of the dumping area, (2) estimate the magnitude of onsite effects of dumping, and (3) determine where the effects of dumping would occur in the Gulf ecosystem and the biological nature of the effects.

The dumping site is south of Galveston and east of Corpus Christi, Texas, at 27°20'N, and 94°31'W. Surface dimensions of the area are 25 by 29 km; the site lies in waters 900 to 1,400 meters deep (figure 6).

The dumping location was used over the duration of this project exclusively by the Shell Chemical Company of Deer Park, Texas. The material dumped at the site was a sludge consisting of living and dead microorganisms and a variety of organic chemical compounds in suspension and solution. The sludge was produced by a biological waste-water treatment system; hence, the bulk of the material was water.

The chemical plant producing the sludge is on the southern margin of Galveston Bay, and barge loads of the waste were towed from the plant to the dumpsite for disposal at intervals of about 1 week during most of 1977. EPA regulated dumping at the site, and the permit controlling disposal at the study site limited the rate of dumping to 3,450 tons of sludge per week, or 50,000 tons per quarter. Through the cooperative efforts of EPA and the Shell Chemical Company, dumping at the site ended in August 1977. At that time, and in response to EPA directives, the Shell Chemical Company began using a land-based technology to dispose of the sludge from the Deer Park plant.

Field and Laboratory Research

The field portion of the program was completed during July-August 1977. The 1977 Report to the Congress summarizes details of the field study. The study centered on a waste plume tracking experiment. Scientists aboard the NOAA Ship RESEARCHER, the Coast Guard Cutter ACUSHNET, and a NASA aircraft followed the plume produced by discharging a barge load of the chemical waste at the disposal site. The plume was followed, using prototype acoustical and remote sensing technologies and also more conventional oceanographic techniques including water sampling, shipboard current meters, and radar tracking of drogues.

Physical and chemical analyses of the data and water samples accumulated during the summer 1977 field study were completed during late 1977 and early 1978. The 1977 Report to the Congress presented preliminary results of these undertakings. In summary, the results indicate that the wastes did not have significant amounts of harmful materials, that the plume dispersed and diluted rapidly and dramatically, and that the physical and chemical characteristics of the dumpsite were typical of waters of the central Gulf hydrodynamic and ecological systems.

Samples of the Shell wastes for chemical analysis were collected at the chemical plant several times in 1977. Laboratory examinations of the samples began in 1977 and were completed in 1978. The analyses indicated the material to be chemically and physically similar to sewage sludge, consisting primarily of organic materials, small amounts of minerals and metals, and small amounts of nutrients, such as nitrogen and phosphorus. The wastes did not have significant amounts of either natural or synthetic compounds known to be toxic in low concentrations.

All of the Gulf industrial waste program research completed in 1978 dealt with the Shell wastes. Research at the Gulf dumping site consisted of laboratory biological tolerance studies on organisms similar to the natural inhabitants of the dumping area. The organisms studied were selected to represent the major components of the ecosystem in the disposal area. The organisms were also selected to provide species known to lend themselves to controlled experiments in the laboratory.

The organisms dealt with during the tolerance studies are three diatoms, two green algae, two blue-green algae, two invertebrates, and one vertebrate. The biological processes examined are metabolism (growth, productivity, and respiration), survival, and reproduction.

The tolerance experiments were performed at a sublethal level rather than at an acutely toxic level, because of the dramatic dilution of the Shell sludge when dumped at sea. Because of this, the chronic biological and ecological effects, if any, of the disposal practice at sea are likely to be of a subtle, sublethal nature. Our tolerance experiments were designed to estimate the general types of biological effects that could result from dumping the Shell sludge into the Gulf and to demonstrate where the effects might appear in the Gulf ecosystem.

The laboratory tolerance studies demonstrated that all the organisms tested exhibited weak to moderate changes in rates of basic biological processes when exposed to low ambient concentrations of the Shell wastes. Metabolic activities of the red snapper were depressed by the wastes, as were rates of growth and reproduction in the invertebrates and most of the algae tested. In contrast, the metabolic rate in Skeletonema costatum, a planktonic diatom, actually increased at particular low exposures to the sludge.

The degree to which changes similar to these would appear in nature in the vicinity of the dumping site is difficult and perhaps impossible to estimate at this time. Few organisms actually occupy the dumpsite; this is particularly true in the upper levels of the water strata where the wastes were injected and dispersed. Moreover, because the sludge released at the site diluted rapidly below measurable levels--and well below the test concentrations used in the laboratory tolerance studies--it seems unlikely that the Shell wastes have had measurable damaging effect upon environmental quality in the vicinity of the dumping site.

In summary, data collected during the 1977 field study in combination with historical information about the vicinity of the dumpsite indicate this region to be typical of deepwater environments in the open Gulf. The area is sparsely populated, and the water layers exhibit strong thermal stratification, particularly during the warm months when well-defined thermoclines persist within the upper 30 to 40 m.

The magnitude of onsite environmental effects of dumping the Shell wastes appears to be minimal. The wastes dilute rapidly to concentrations below measurable levels, and apparently well below those inducing biological responses in the laboratory tolerance studies. This, together with the generally depauperate nature of the water masses occupying the dumpsite, suggests that both the short- and long-term ecological effects of ocean disposal of the Shell sludge have been minimal and probably trivial. Although the laboratory tolerance studies indicated that most major segments of the Gulf ecosystem could be adversely affected by suitable concentrations of the Shell wastes, the rapid dilution of the wastes in actual dumping situations probably has prevented the effects from developing. This seems to indicate that dumping the Shell sludge into the Gulf in years past may not have generated a trend of environmental abuse and degradation. If environmental quality were deteriorating in the Gulf as a result of disposal of the Shell wastes, the trend was not detected during our study.

CHAPTER III

OCEAN DUMPING SYMPOSIUM

The First International Ocean Dumping Symposium was held October 10-13, 1978, at the W. Alton Jones residential conference center of the University of Rhode Island. This meeting brought together about 60 research scientists who have been involved in ocean-dumping studies during the past several years. The primary focus was to compare and integrate the findings from physical, chemical, and biological studies at three deepwater dumpsites, the 106-mile site, Puerto Rico, and Gulf of Mexico, where industrial wastes are discharged into seawater. A book containing collected papers of this symposium is scheduled for publication in April 1980. A second symposium is being planned for April 15-18, 1980, at Woods Hole Oceanographic Institution with emphasis on the ocean dumping of dredged material and radioactive wastes.

At this stage, there has been no general consensus on the acceptability or unacceptability of ocean dumping as a means of waste disposal. There are three main problem areas requiring consideration. The spatial distribution of waste as a function of time must be established to determine the regional extent and magnitude of environmental exposure to the waste. The chemical reactivity of constituents in the waste must be known to determine their availability to organisms. And, finally, the effects of the waste on the ecosystem must be determined. It appears that each waste and each environment must be considered as a separate case, because each situation will be determined by its own set of characteristics. Nevertheless, investigations of different ocean dumping problems may share similar methodologies and criteria.

There is good evidence that waste disposal on continental shelves produces environmental alterations, especially to the benthic ecosystem. However, it has not been possible thus far to demonstrate a detrimental impact from ocean dumping at deepwater dumpsites. It is clearly more difficult to determine the environmental effects of waste disposal in the pelagic region of the deep ocean than on the continental shelves. More research is needed to determine the dumping impact at the deepwater dumpsites.

CHAPTER IV

NEW INITIATIVES

Philadelphia Sewage Sludge Disposal Site

Introduction

Plans are being formulated for NOAA to take the lead role in investigative studies at the Philadelphia sewage sludge site (figure 7). The transition from EPA to NOAA should be completed by early Fiscal Year 1980. An interagency agreement is being initiated for formal working relations with EPA, Region III, for field and laboratory research in the area of the Philadelphia sewage sludge site.

Field and Laboratory Research

Since 1973, EPA Region III Office, the Annapolis Field Office in Maryland, and the Environmental Research Laboratory in Narragansett, Rhode Island, have led the field monitoring program at the new Philadelphia sewage sludge dumpsite. The chronology of the Philadelphia sludge ocean dumping is illustrated in figure 8. The site study effort included 1 baseline cruise in early 1973 prior to initial dumping and over 20 other cruises since dumping began in April 1973. The field program had two basic objectives:

1. Determination of the fate of dumped sewage sludge in the environment.

2. Determination of the effects of such disposal activities.

The program was initially designed to describe many parameters in the environment and later emphasize only those which proved to be more significant. A large station grid system was established covering 6,500 km^2, placing primary emphasis on fate and effects of dumping relative to the sediments and bottom dwelling community. Of equal importance to ocean dumping in a hydrographic sense are currents and circulation. Both tidal currents and storm induced currents were found to be capable of moving bottom materials, with the net movement to the southwest. Sediment size analyses were performed; they showed mostly medium to fine sands. EPA analyzed the sediments for metals, although to date no general trend with time could be identified. EPA also routinely analyzed sediments for total organic carbon, which later was used to identify areas of apparent sludge accumulation. Chlorinated hydrocarbons are being studied and may also prove valuable in identifying accumulations of human derived sludge.

Two other sensitive methods for identifying areas of sludge contamination have been bacteriological studies by the U.S. Public Health Service and measurements of the steroid coprostanol by NOAA. The results of

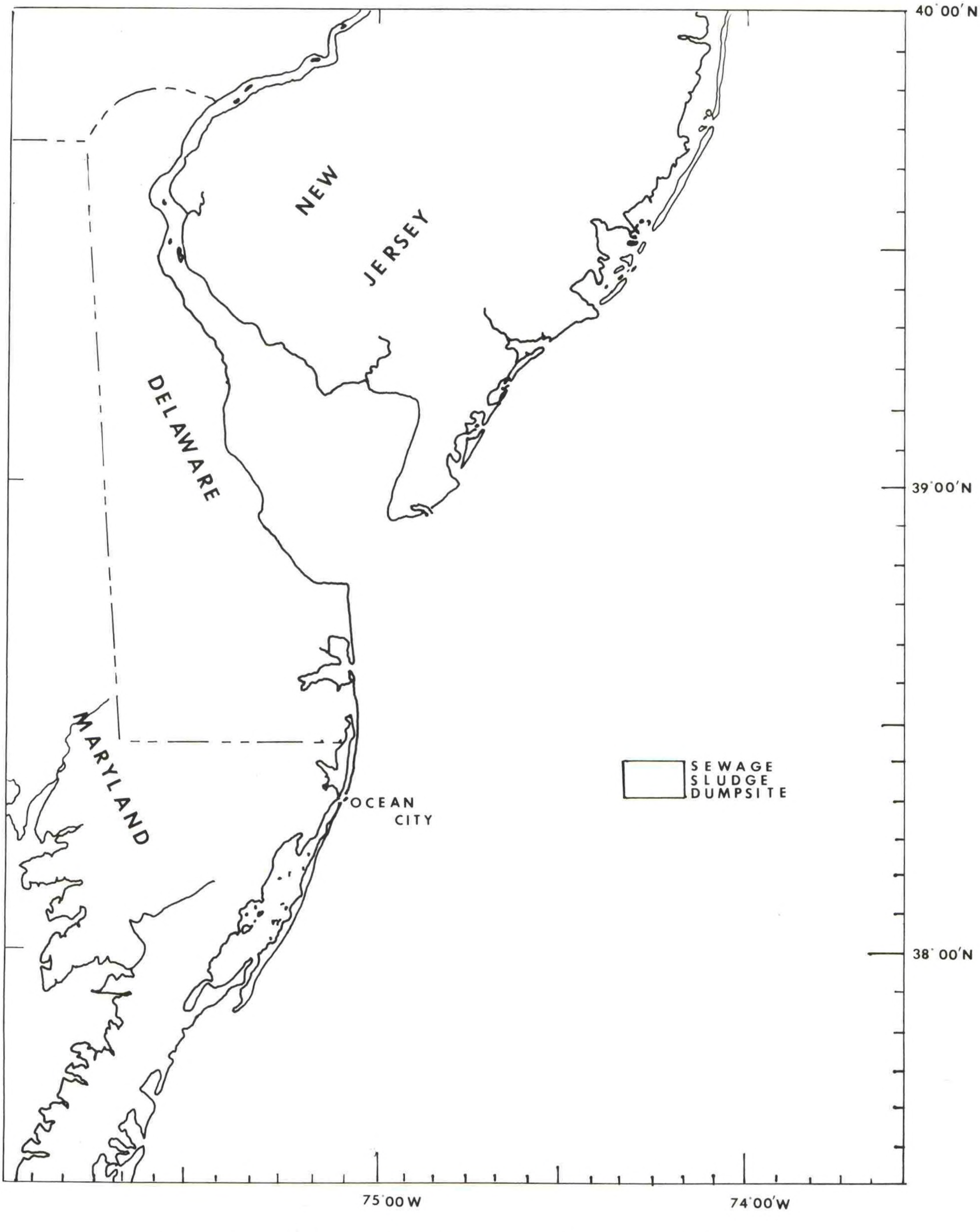

Figure 7.--Philadelphia sewage sludge dumpsite.

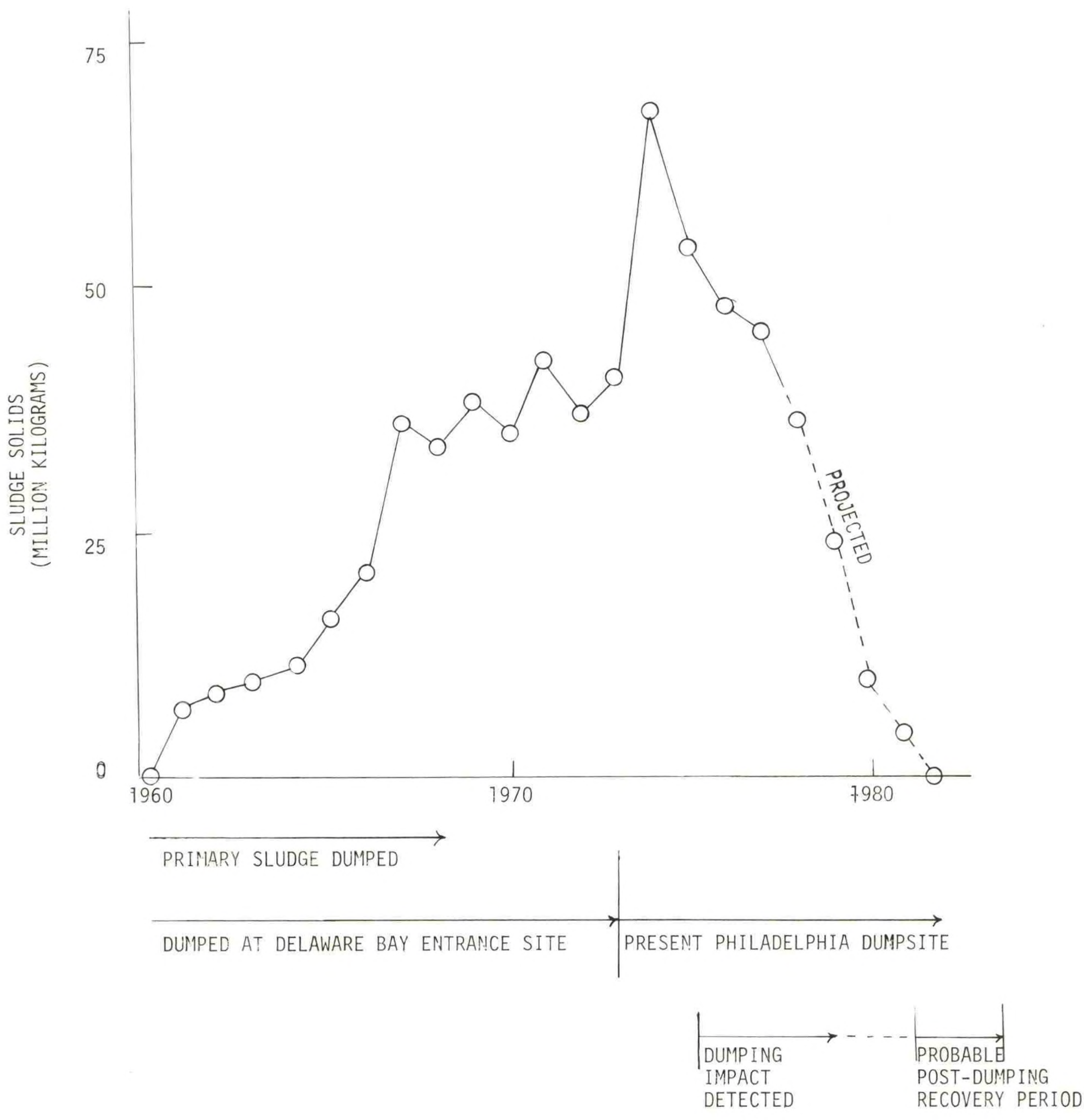

Figure 8.--Sewage sludge ocean dumping by Philadelphia. The City produces over 100 million kilograms of sludge solids a year.

bacteriological studies involving coliform and fecal coliform bacteria have been instrumental in the closure of the dumpsite and nearby vicinity to the offshore clam industry. The use of the steroid coprostanol is a new technique still involving some experimental methodology. Coprostanol, however, may become one of the most important sludge indicators due to its specificity; it is now believed to be characteristic of only mammalian fecal materials.

The bottom-dwelling animal communities have shown some of the greatest changes to the dumping of sewage sludge. Entire biological compositions have changed because of dumping. During early 1975, less than 2 years after dumping began at the offshore site, benthic community similarity indices indicated an area immediately south of the sewage sludge site already impacted. This area was shown to have accumulations of sludge in the depressions. The presence of sludge was based on the total organic carbon content of the sediments and bacteriological data. This finding is especially significant because, based on bottom-drifter studies, this area is considered in the path of the major transport out of the dumpsite. Metals that are characteristic components of the sludge have been shown to be taken up by shellfish (e.g., clams and sea scallops).

In summary, the important aspects of the study at the Philadelphia sewage sludge site are as follows:

1. Initial baseline study work was completed before dumping began in 1973.

2. The absence of any other source of sludge contamination (e.g., outfalls).

3. Documented impact at the site occurring within less than 2 years from the time dumping began.

4. Possibility of carrying out a comprehensive study to know how the site returns to predumping condition after the sludge dumping ends in 1981.

Additional Data Needs

Interstate Electronics Corporation (IEC), under contract with EPA, has prepared a summary of data for the Philadelphia sewage sludge site. The report identifies additional data needs that are not now met within the EPA program. It is from these additional data needs that future joint EPA-NOAA work is being planned.

Data gaps discussed in the IEC report included biological, chemical, and physical and bioassay measurements. The need was expressed for more studies demonstrating waste-plume trajectories and dispersion, and waste-plume behavior within the continental shelf environment. Correlation between chemical constituents measured from the sediments, including total organic carbon, organohalogen compounds, metals, and coprostanol could be used to collectively identify the benthic region influenced by sludge. Comparisons among station grids north and south of the site have also been suggested. Further correlations among percent of fine-grained sediments, chemical compounds measured within the sediments, and bathymetry might yield information on the transport of sludge or its constituents. This information could provide answers regarding the role of bottom currents in relation to the location of impacted and nonimpacted stations in and around the dumpsite.

Additional analyses for bacteria in seawater, sediments, and benthos are needed to further delineate sewage sludge contamination. Comparison of benthic invertebrate data with sedimentological data would help better describe the benthic distributional patterns. Analyses of benthic organisms with respect to their body concentrations of metals, organohalogens, and bacteria might show more clearly their relation to specific sediment types and bathymetry.

Some of the study needs discussed by the IEC report have already been completed by EPA. Others will be incorporated into NOAA monitoring and research objectives.

Chesapeake Bay Mouth Dredge Dumpsite

Work will be performed in partial support of the Corps of Engineers' (COE) site designation studies for a new site off the mouth of the Chesapeake Bay. Planning is in progress to formulate studies for a dredge material dumpsite. Both the COE Baltimore and Norfolk Districts are interested in using this site for disposal of material to be dredged from the lower Chesapeake Bay. The site designated for study is near 36°59'N and 75°39'W with a radius of about 8 km (figure 9).

The present open ocean disposal site at Dam Neck is an interim site, the permit for which expires on January 11, 1980. This makes it essential that a site be designated to dispose of material from anticipated channel-deepening projects and periodic maintenance dredging.

The COE Baltimore District is interested in the site for disposal of dredged material from the Cape Henry Channel in the lower Chesapeake Bay and the lower York Spit Channel. It is their intention to deepen the channels in the bay to 15 m, thus allowing larger vessels to travel up the bay to Baltimore Harbor. Approximately 15 x 10^6 m^3 will be dredged in these channels by the COE Baltimore District. Concurrently, COE Norfolk District is interested in using the site to deposit sediments from Thimble Shoal Channel and assessing the Chesapeake Bay site or locating an alternative ocean disposal site for possible disposal of sediments arising from dredging

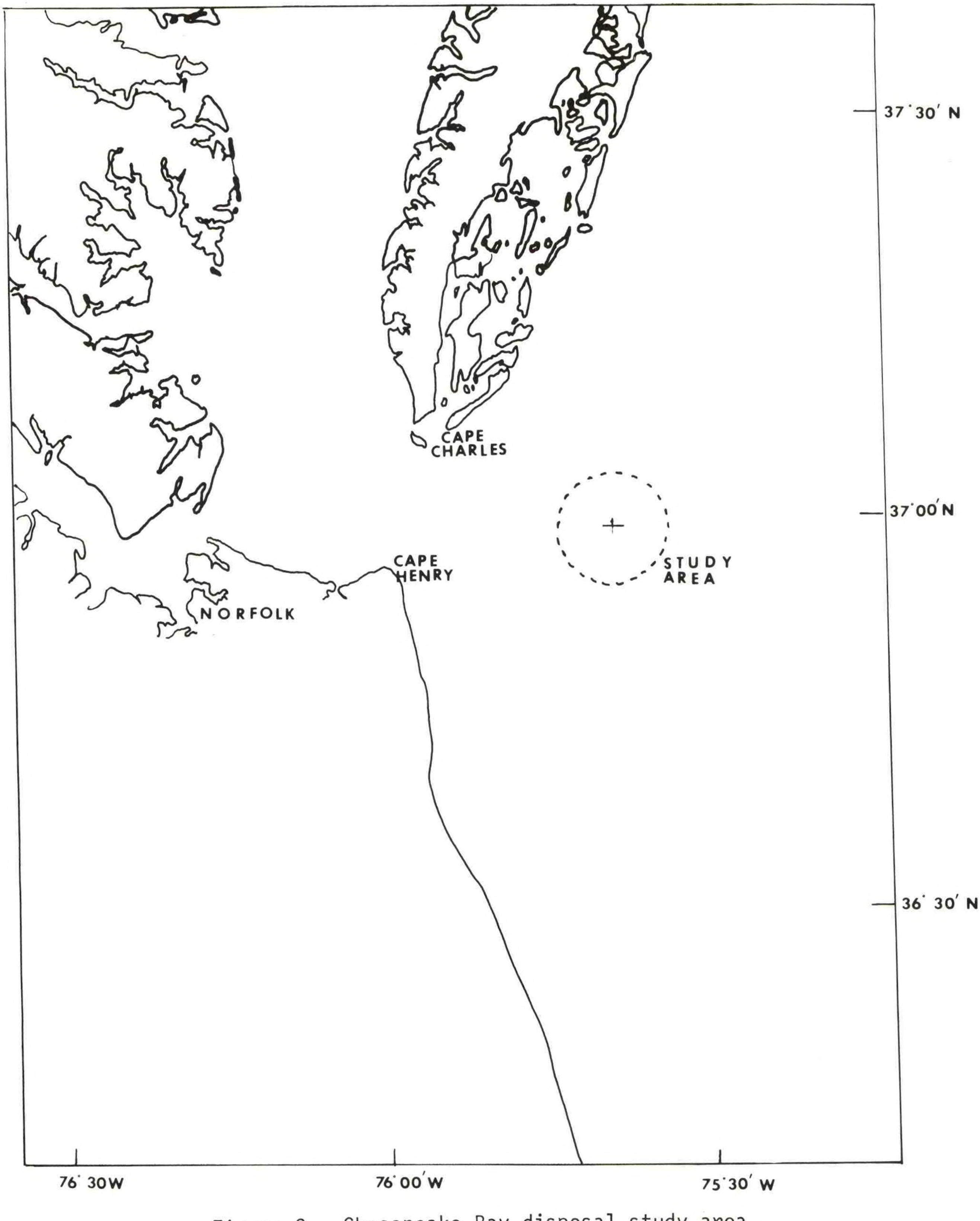

Figure 9.--Chesapeake Bay disposal study area.

operations in the Hampton Roads Channels and the Elizabeth River. Dredging for the Baltimore District is to begin in Fiscal Year 1980 and should continue for about 8 years. NOAA plans to initiate studies in coordination with COE in Fiscal Year 1979 to assess the biological, chemical, and physical conditions of the dumpsite before dumping commences. Bioassay analyses will be made and monitoring techniques developed for biological, chemical, and geological changes. The physical oceanographic work includes the determination of circulation and sediment transport.

The NOAA program objectives of this study are as follows:

1. To describe the physical properties of the dumpsite and dredged material, emphasizing seasonal water-mass changes, circulation, and sediment characteristics.

2. To determine the bathymetry of the disposal site before and after dredged material disposal to detect changes.

3. To perform a biological and chemical survey of the dumpsite and dredged material and identify sensitive or ecologically important species and potential toxins at the dumpsite.

4. To conduct bioassays using the EPA/COE evaluation criteria manual to predict environmental effects from disposal of dredged material.

5. To conduct bioassays of contaminated sediments.

6. To develop methods for monitoring and tracking movement of dredged material at the disposal site.

Field work is scheduled to begin in this area in 1979.

Social and Economic Considerations

By studying the current ocean dumping practices and their accompanying risks, we have been elucidating and quantifying the effects of ocean dumping on public health, oceanic ecology, aesthetics, societal conflicts, and economics. Conceptually, the basic principle of the existing ocean dumping practices is to minimize the total sum of legal, institutional, societal, environmental, and economic costs. Usable inputs to quantify the total sum and the multidependence of these costs should emerge as we analyze the current dumping practices and their mitigations. A better understanding of the environmental costs should emerge from the short-term ecological effect studies we have been carrying out. This understanding will aid in implementing effective waste management system into our society.

An initiation of a study on the social and economic factors involved in ocean dumping practices will be carried out in accordance with the Section 201 mandate.

Development of Interagency Agreements

Under the Marine Protection, Research, and Sanctuaries Act, EPA, COE, USCG, and NOAA have responsibilities regarding permit approval, surveillance, monitoring, and research of ocean dumpsites. EPA and NOAA entered into an interagency agreement in 1975.

In December 1978, NOAA and USCG entered into an interagency agreement. Under the terms of the agreement, NOAA will identify the assistance necessary from USCG to carry out NOAA's responsibility for monitoring and research mandated by Title II of the Marine Protection, Research, and Sanctuaries Act. USCG will then provide, to the maximum extent practicable, vessel time for the scientific observations. Although those activities have been informally arranged in the past, the formal agreement will provide for more efficient coordination of operations.

An agreement will be worked out between NOAA and COE that concerns cooperative evaluations of ocean disposal of dredged materials. NOAA has been working on an informal basis with COE Districts, and the agreement will formalize arrangements for additional cooperation.

APPENDIX A

Agency funding levels for ocean dumping monitoring and research

	Section 201 funds Estimated NOAA expenditures for ocean dumping monitoring--related research: fiscal year 1978
106-Mile dumpsite	$ 920,000
Gulf dumpsites	320,000
Puerto Rico	630,000
Total	$1,870,000

	Estimated NOAA expenditures on ocean dumping monitoring--related research: fiscal year 1978
New York Bight/Marine Ecosystem Analysis (MESA)	$860,000