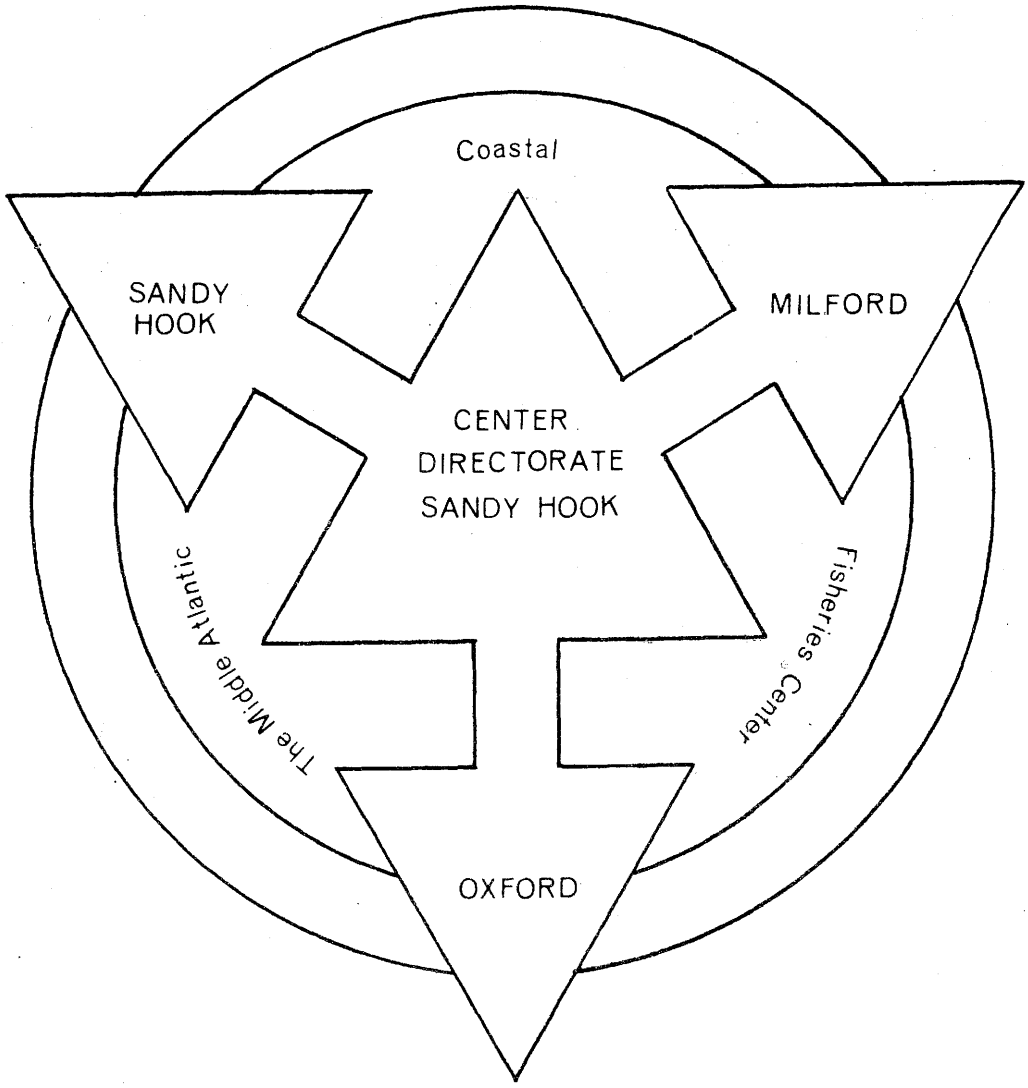
# A PROPOSAL FOR AN ENVIRONMENTAL SURVEY OF EFFECTS OF DREDGING AND SPOIL DISPOSAL IN THE THAMES RIVER AND NEW LONDON DUMPING GROUND

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Region

MIDDLE ATLANTIC COASTAL FISHERIES CENTER

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# A PROPOSAL FOR AN ENVIRONMENTAL SURVEY OF EFFECTS OF DREDGING AND SPOIL DISPOSAL IN THE THAMES RIVER AND NEW LONDON DUMPING GROUND

submitted by the

Middle Atlantic Coastal Fisheries Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
U. S. Department of Commerce
Highlands, New Jersey 07732

to

U. S. Army Corps of Engineers

May 21, 1974

# FOREWORD

This is our definitive proposal to the U. S. Navy for studies in connection with dredging and spoil deposition in the Thames estuary and adjacent waters. Preliminary drafts of the proposal were reviewed by the Interagency Scientific Advisory Subcommittee on Ocean Dredging and Spoiling and the parent Interagency Policy Committee for Dredging and Spoiling. The Interagency Policy Committee consists of Regional Directors of NMFS-NOAA, BSFW-Interior, EPA. The U. S. Army Corps of Engineers has also reviewed the preliminary drafts.

It must be understood that this proposal is submitted with the clear understanding by all parties that a pre-dredging study must be completed before any dredging or spoil disposal begins. At least 30 days must be provided for this pre-dredging study after receipt of contract funds by the subcontractors concerned (University of Connecticut Marine Sciences Institute, New York Ocean Sciences Laboratory).

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# I. INTRODUCTION

The U. S. Navy, to provide navigable water depths for nuclear submarines, plans to dredge approximately 7.1 miles of the Thames River (Connecticut) channel. The dredging is divided into two phases. Phase I will begin in May or June 1974, and continue for 10-11 months until late winter or early spring 1975. During this phase dredging will be confined to a 4.0 mile channel from the river mouth to a point just south of Groton, Conn. (Fig. 1). After an approximate 9-month interim, Phase II dredging of a 3.1 mile section above Groton (Fig. 1) will take place from January 1976 to January 1977. The dredging will create an estimated 2.8 million cubic yards of spoil, to be disposed of in Long Island Sound (LIS), at a site centered 2.7 miles south of the river mouth (41°16.0'N latitude, 72°04.8'W longitude), in a 1-square-mile designated dumping ground bounded by 41°15.7'N to 41°16.7'N latitude and 72°04.0'W to 72°05.3'W longitude (Fig. 2).

An alternate disposal area either in mid-Block Island Sound (BIS) or in the Atlantic Ocean off Block Island is under consideration in the event that Phase I dumping at the principal site is shown to have deleterious effects, as judged by the Interagency Scientific Advisory Subcommittee on Ocean Dredging and Spoiling. This proposal does <u>not</u>

include detailed studies in alternate disposal sites, since their precise locations have not been determined. In the event that such alternate sites are finally designated by appropriate agencies, or if early indications of substantial environmental damage are found, then this proposal will have to be modified to permit more detailed studies in those sites.

The original proposal to examine effects of the Thames project was developed by the Navy (OCEANAV ltr ser. 883/N5, 31 July 1973). This proposal was discussed in an Interagency Scientific Advisory Subcommittee meeting held in Waltham, Mass., on 8 August 1973. The Subcommittee's comments and recommendations were incorporated in a revised Plan A (OCEANAV ltr ser. 1210/N52, 30 October 1973). Because this plan was considered too costly, an abbreviated Plan B was also devised. However, the Subcommittee did not feel that Plan B represented an adequate investigation of spoiling effects. The present proposal by the Middle Atlantic Coastal Fisheries Center attempts to develop a definitive study to determine the environmental impacts of dredging in the Thames estuary and dumping Thames River spoils in the New London disposal area.

It will be necessary to examine the present dredging and spoil disposal areas themselves before, during and after spoiling to determine what, if any, changes are taking place, and whether such impacts merit changing the dumping ground, mode of dredging or tide-related time of dumping. This opportunity to undertake a rather large-scale, interdisciplinary study of environmental effects of spoil disposal in an important estuary should be fully exploited.

A large amount of information is already available about Long Island Sound, and some information is available about the study sites. This information is summarized in Appendix A.

## II. OBJECTIVES

Specific objectives of the proposed research include the following:

(1) Develop information about effects of spoil disposal from the Thames River in the New London disposal site on existing benthic populations in and near the site. Effects will be measured in terms of biomass, species diversity, species abundance.

(2) Develop information about the hydrography of the New London disposal site and adjacent areas, with particular emphasis on understanding current patterns which will enable prediction of direction and extent of movement of spoil material.

(3) Develop information about levels of selected contaminants in sediments and marine organisms from dredge and disposal areas, and examine any changes in levels of such materials in areas peripheral to the disposal site.

(4) Develop information about the historical and present status of shellfish beds and crustacean and finfish populations in the dredge and disposal areas.

(5) Develop information about sediment transport from the disposal site, particularly as it relates to extent of movement of suspended material.

(6) Conduct periodic surveys during and after Phase I dredging to determine whether harmful environmental changes occur.

(7) Report on any findings of environmental changes on a timely basis to the Interagency Scientific Advisory Subcommittee on Ocean Dredging and other appropriate agencies.

## III. LIMITATIONS OF THE PROPOSED STUDY

It should be clearly understood that the contract period is two years from date of award and transfer of funds, regardless of the time of inception of dredging. Thus it may not be possible to study effects of Phase II dredging if it does not occur during the two-year contract period.

It should also be clearly understood that time must be allowed for pre-dredging baseline surveys. A minimum time of three months from actual date of award of contract and transfer of funds to inception of any dredging activity is desirable, with a longer time if possible, so that some indication of normal seasonal changes may be acquired. An ideal pre-dredging baseline study should extend for 13 months. An absolute minimum of 30 days after receipt of funds by all subcontractors must be provided before any dredging begins.

A statistical analysis of benthic sampling patterns and intensities should be an initial effort of the proposed study. Lack of lead time will force us to depend on recent analyses carried out for similar studies in the New York Bight.

It should be reemphasized that no studies are planned in possible alternate disposal sites, since their locations have not been determined. If alternate sites are designated, or if early indications of significant environmental damage are found, this proposal and subsequent studies will have to be modified substantially.

## IV. PROPOSED RESEARCH (SUMMARIES)

Research outlined in this proposal is designed to provide baseline and other data on possible effects of dredging and spoil disposal in the designated areas on the marine environment -- particularly on living resources and the ecosystems which support them. The study will include (1) examination of existing historical data on the area and its resources, (2) a short-term baseline survey in the dredging and spoiling areas, (3) surveys in those areas during Phase I dredging, (4) surveys in those areas after completion of Phase I dredging, and (5) surveys during and after Phase II dredging only if this occurs during the two-year contract period.

The Middle Atlantic Coastal Fisheries Center (MACFC), NMFS, is the prime contractor for the research to be carried out, with the New York Ocean Sciences Laboratory (NYOSL) and the University of Connecticut (UConn) as subcontractors. MACFC will be responsible for benthic surveys, bacteriological studies and contract monitoring. NYOSL will be responsible for physical and chemical oceanographic studies and studies of finfish. UConn will be responsible for studies of sediment transport, shellfish (clams, oysters, and lobsters) studies, and specific aspects of plankton studies. Summaries of each organization's proposals are presented in the following sections, and detailed proposals are included as Appendices B (Middle Atlantic Coastal Fisheries Center), C (New York Ocean Sciences Laboratory), and D (University of Connecticut).

## A. SUMMARY OF RESEARCH PROPOSED BY THE MIDDLE ATLANTIC COASTAL FISHERIES CENTER

### (1) Benthic Ecology

Studies of the distribution, abundance, biomass, and species diversity of benthic animals can provide sensitive indicators of environmental damage. Thus a major part of the studies proposed by MACFC concerns the benthos. Sampling transects through the disposal site and selected stations in the dredging area, will provide baseline data on pre-operational populations. Repeated sampling during and after dredging and spoil disposal will provide data on environmental and population changes.

A total of roughly 1000 samples will be collected, and analyzed as necessary, depending on findings from sediment and hydrographic studies.

### (2) Bacteriology

Bacteriological studies, emphasizing distribution and abundance of fecal coliform, but including vibrios and other genera, will be carried out in conjunction with benthic studies. Determination will be made of the degree of contamination of dredged material, as well as its persistence and spread at the disposal site.

## B. SUMMARY OF RESEARCH PROPOSED BY NEW YORK OCEAN SCIENCES LABORATORY

### (1) Physical Oceanography

Currents at the New London spoil disposal site will be studied to determine transport of spoil material, and to study effects of spoil disposal on turbidity and light transmission. Current patterns will be determined at various depths seasonally and throughout several tidal cycles. Studies will be carried out before, during and after spoil disposal.

### (2) Chemical Oceanography

Concentration of selected heavy metals will be determined in sediments, seston, and benthic animals. Surveys will be carried out, and the residual heavy metal levels determined before, during and after spoil disposal.

### (3) Finfish Distribution and Abundance

Historical and present distribution of finfish in the disposal site and adjacent waters will be determined by review of all available historical data, and by trawling surveys.

## C. SUMMARY OF RESEARCH TO BE CARRIED OUT BY THE UNIVERSITY OF CONNECTICUT

### (1) Suspended Material Transport

This study is designed to provide an estimate of the effect of dredging on the concentration and composition of total suspended particulate matter in the Thames Estuary. Determinations will be made of flushing rates, mass flux, and estuarine circulation before, during and after dredging. Objectives will be to determine the extent to which dredging will modify the composition and amount of suspended material, and to determine routes and rates of sediment transport in the estuary.

### (2) Shellfish Resources

A survey will be made of historical and present distribution and abundance of hard clam and oyster resources in the Thames River Estuary; of historical and present distribution and abundance of lobster populations in the disposal area. Studies of phytoplankton distribution and impact of specific contaminants will also be carried out. At a minimum, field surveys will be conducted before, during and after Phase I dredging.

## V. BUDGET SUMMARY

(Two-year contract period)
Commencing 1 July 1974

Middle Atlantic Coastal Fisheries Center

| | | |
|---|---|---|
| Benthic Studies ..... | $124K | |
| Microbiology ..... | $ 20K | |
| | Total .... | $144K |

New York Ocean Sciences Laboratory

| | | |
|---|---|---|
| Physical Oceanography ..... | $100K | |
| Chemical Oceanography ..... | $130K | |
| Fish Distribution and Abundance ..... | $ 5K | |
| | Total .... | $235K |

University of Connecticut

| | | |
|---|---|---|
| Sediment Transport ..... | $ 60.6K | |
| Shellfish and Plankton ..... | $ 60.4K | |
| | Total .... | $121K |

Total Contract ....$500K

# APPENDIX A

## BACKGROUND INFORMATION FROM PREVIOUS STUDIES

Note: Separate summaries of previous studies have been prepared by MACFC and NYOSL. Both documents are included in this appendix.

(1) DREDGE AND SPOIL DISPOSAL STUDIES
(Prepared by MACFC)

Studies of dredging disposal activities have been conducted at a number of areas along the northeastern Atlantic seaboard. Perhaps most pertinent to the proposed New London study is the work of Saila, Pratt and Polgar (1972) in Rhode Island Sound (RIS). This survey considered the impacts of dumping 8.2 million cubic yards of dredge spoils from the Providence River in a 1-square-mile disposal ground four miles offshore in RIS. Major findings included the following: The spoils formed a 16-18 foot high, mile-wide cone in the disposal area, with patches of spoil as much as a mile outside the site. No traces of the spoil were thought likely to impinge on local beaches, though. Benthic faunal densities were reduced on recently-dumped sediments. However, where spoils had stood for 1-3 years, recolonization by fauna of the surrounding sand-bottom assemblage was well underway. It was expected that the amphipod Ampelisca agassizi would eventually reastablish its pre-spoiling dominance in the disposal area. No effects of the disposal operations on the area's lobstering or commercial finfishing were observed.

Similarities (water temperatures and chemistry, dominant benthos with their high tube densities) between the RIS and LIS dumping grounds invite extrapolation of disposal effects from former to latter. However, there are enough differences that too-direct comparisons should be avoided. The LIS site has shoaler water depths, and maximum bottom

current velocities (Naval Oceanographic Office (NAVOCEANO) 1973) may be three times the maximum 0.35 knots measured at the RIS location. Instantaneous bottom currents of up to 2.9 knots have been measured in the west end of Fishers Island Sound, two miles from the New London disposal site (Dehlinger, et al., 1973). Also, relatively polluted spoil from Providence Harbor was dumped early in the RIS operations, and was in most cases covered by less organic, more erosion-resistant sediment from upper Narragansett Bay. This pattern is recommended to minimize disposal effects (Saila, Pratt and Polgar, 1972) but it is doubtful that it can be followed in dredging the Thames.

Gordon, Rhoads, and Turekian (1972) examined effects of dumping spoils from New Haven Harbor on the New Haven spoil ground. Among their conclusions were: 1) spoils were rapidly repopulated by benthic fauna; 2) no extinctions of unique or endemic species took place; 3) since heavy metals weren't concentrated by the dominant species (the bivalves Pitar and Mulinia), the danger of these contaminants moving up the food web seemed slight; 4) turbidity caused by dumping activities was probably small compared to that of a force 4 storm, which occurred an average of 5 times per month in the disposal area; and 5) since the area had high natural sedimentation rates, spoils would quickly be covered by relatively uncontaminated materials.

Negative findings were that 1) silt-clay fractions were somewhat dispersed from the disposal points; 2) significant resuspension and spreading of spoils could be caused by the type of storm expected every 30-50 years; and 3) there was a chance spoils would impinge on populated shores in the area.

More recently these workers have been studying the forms and mobilities of heavy metals in sediments of central LIS (Turekian, 1973). It is indicated that these elements form relatively immobile sulfides or oxides in the sediments, thus limiting their recycling.

On the other hand, the Environmental Protection Agency has recently observed that waters overlying dredging spoils have higher concentrations of heavy metals than do waters over natural sediments (D. Phelps, EPA Water Quality Laboratory, Narragansett, R.I., pers. comm.).

Leathem et al. (1973) studied the effects of dredging and dumping 250,000 cubic yards of spoils inside a Delaware Bay breakwater. Dissolved oxygen was reduced to 52.5% of saturation shortly after the operation (compared to EPA's minimum requirement of 50% for the State of Delaware). Oxygen had returned to pre-dredging values within two months, however, and potential damage to benthos was considered negligible. Current and settling studies indicated clay particles may have spread over a wide area, though exact distances and effects on biota were unknown. Benthic macrofauna densities were significantly reduced (0.05-0.1 level) soon after dredging, but had recovered two months later.

The Sandy Hook Laboratory has studied the effects of 40 years of dumping contaminated dredge spoils in the New York Bight (Pearce, 1972, National Marine Fisheries Service, 1972a, 1972b, 1972c). The disposal area was found to be impoverished of normal benthic fauna, a fact attributed to low dissolved oxygen levels and toxins associated with the spoils. Benthic communities near the dump site were low in diversity and dominated by resistant forms. Crustaceans exposed to the spoils in field and laboratory studies developed pathological anomalies.

Findings of the above studies are an aid in predicting the environmental effects of dredging and dumping in the LIS operation. However, some of the information (such as to what extent spoiling increases metals in the water column, and how benthic communities are affected) is contradictory. Also, the area in question may be unique in terms of composition of the spoil materials or characteristics of the disposal area.

Determining disposal effects will require a suitable baseline of predisposal information. Present knowledge of the physical, chemical and biological conditions of eastern LIS is not adequate to serve as a baseline. The sole historical study of LIS and BIS in their entireties

is the extensive work of Riley et al. (1949, 1952, 1955, 1956, 1959, 1967). Their data on patterns of currents, transport and mixing, water chemistry and plankton will be drawn upon in planning the present survey. However, the information must be augmented by more up-to-date and extensive measurements of an increased number of benthic and water column parameters.

The most complete data on physical-chemical properties of waters in the primary and alternate dumping areas are held by the New York Ocean Science Laboratory (NYOSL). For the past three years, NYOSL has been charting temperature, salinity, dissolved oxygen, nutrients and pigments at up to 20 stations in BIS and eastern LIS. Plankton samples are also available for analysis, and current investigations using surface and seabed drifters have been conducted. Much of this information can be incorporated into predisposal baselines for the primary and alternate dump sites. In addition, data on current directions, speeds and residual drift will be considered in establishing sampling transects so that the directions and distances of most anticipated spoil effects will be well covered.

The State University of New York at Stony Brook (SUNY) has also been collecting information on the waters of eastern LIS as part of a larger survey of baseline hydrography throughout LIS, begun in 1969. Measurements have included temperature, salinity, dissolved oxygen, nitrates, nitrites, phosphates and chlorophyll A (Hardy, 1970). Investigation of ammonia levels was added in 1970 (Hardy and Weyl, 1970; Hardy, 1972a). The survey was extended into BIS in 1971, and determinations of urea were included (Hardy, 1972b). SUNY has also been conducting research, perhaps relevant to the present operation, on the physical and chemical properties of dredged waste from the New York area (Gross, 1970; Gross et al., 1971). Gross and Bumpus (1972) completed a seabed drifter study of residual near-bottom drift in LIS in 1969. They agreed with Riley (1952, 1956) that a two-layer flow was present at the eastern end, with low-salinity surface waters moving seaward and being replaced by more saline bottom waters. The probability was considered high that spoils deposited in the eastern end would undergo resuspension and movement (Gross and Bumpus, 1972).

The University of Connecticut (UConn) has recently begun a series of investigations aimed at determining budgets for heavy metals in LIS waters (Dehlinger et al., 1973). Studies to date have concentrated on eastern LIS. Some preliminary conclusions bear directly on any proposed study of spoil disposal off New London.

Circulation patterns near the Race were held to be much more complex and variable than originally proposed. Current measurements indicated a large counter-clockwise gyre between the Race and Plum Cut in eastern LIS, suggesting renewal of these waters in 3-7 days. This dynamic regime would hinder the effectiveness of concentrating mechanisms such as biological uptake and incorporation - thus the area would not function as a sink for heavy metals or other contaminants. Suspended matter concentrations were higher in bottom waters, and were strongly affected by storms. UConn's investigation of concentrations and forms of metals in LIS waters is also very pertinent to the present dredging-disposal studies.

Little information is available on sediment characteristics or benthic biology at the actual dredge and dump sites. The University of Connecticut has been examining the benthic macrofauna, particularly molluscs, of nearby Fishers Island Sound. The Middle Atlantic Coastal Fisheries Center, NMFS, has sampled several stations in the disposal area as part of a baseline survey of sediment and benthic macro- and meiofauna throughout LIS.

The only intensive sampling in the disposal area is that conducted by NAVOCEANO to determine the effects of a much smaller disposal operation in 1972-1973 (Naval Oceanographic Office, 1973). This study measured the effects of dumping approximately 92,500 cubic yards of spoil (from a pier construction site at Groton) on the

New London dump site. Surveys were made before, immediately after and six months after the dumping operation. NAVOCEANO recorded bathymetry and currents; salinity, temperature, dissolved oxygen, nutrients, heavy metals and light transmittance of the water column; and sediment grain size, carbonate, organic carbon, Kjeldahl nitrogen, heavy metals, volatile solids, oil and grease, BOD, bacteriology and benthic invertebrates.

It was concluded that the relatively small volume of spoil had little effect on the dump site's bathymetry. Current directions and speeds were such that resuspended sediment would undergo only limited net transport away from the site. Any impact of disposal on water column parameters were obscured by the much larger effects of Hurricane Agnes during the pre-disposal phase. No statistically significant changes were found in sediment grain size, organic carbon, nitrogen, heavy metals, volatile solids, grease and oil, BOD or coliform counts. Faunal densities were reduced immediately following dumping, but showed a marked recovery six months later.

The NAVOCEANO survey generated information of value in establishing baselines for the present operation and in designing an adequate survey to determine dredging-dumping effects. However, an intensive pre-during-post dredging survey is still deemed necessary. The volume of spoil to be dumped is approximately

30 times that of the NAVOCEANO study, so their finding of little environmental perturbation may not strictly apply to the larger project. Also, it is felt that several portions of the NAVOCEANO investigation (effects on water column exotics, plankton, benthic macrofauna) would have to be much expanded to document impacts with any certainty.

## (2) PHYSICAL, CHEMICAL, AND BIOLOGICAL OCEANOGRAPHY OF LONG ISLAND SOUND
(Prepared by NYOSL)

### INTRODUCTION

Recently a proposal has been put forth to dredge substantial portions of the lower section of the Thames River and to dispose of the dredged materials (2.8 x $10^6$ cubic yards) at a dump site located south of New London Harbor in eastern Long Island Sound. In the event that during the course of these operations an impact of significant biological magnitude was found at this dump site an alternative dump site located southeast of Block Island would then be used.

The environmental studies associated with these activities are designed to monitor the physical and chemical characteristics of the water column and sediments and the associated biota. These studies will include the monitoring of such parameters as temperature, salinity, dissolved oxygen, nutrients, suspended solids, turbidity, heavy metals, chlorinated hydrocarbons and PCB's, biological oxygen demand, chemical oxygen demand and sulfides at the dredge site, the disposal site (pre-, during-, and post-) and at the alternate dump site.

### Background Information on Long Island Sound and Block Island Sound.

LeLacheur and Sammons (1932) indicated that the tidal wave characteristics present in Long Island Sound were comparable to a tidal wave that showed some degree of progression. It was also noted that this progression was due primarily to the contraction of the offshore wave in the narrow passages leading into the Sound. Further modification of this wave occurs as a result of obstacles in its path such as islands and shoals, e.g., Stratford Shoals. In this same paper it was also stated that the amplitude of the tidal flow can vary as much

current velocities (Naval Oceanographic Office (NAVOCEANO) 1973) may be three times the maximum 0.35 knots measured at the RIS location. Instantenous bottom currents of up to 2.9 knots have been measured in the west end of Fisheres Island Sound, two miles from the New London disposal site (Dehlinger, et al., 1973). Also, relatively polluted spoil from Providence Harbor was dumped early in the RIS operations, and was in most cases covered by less organic, more erosion-resistant sediment from upper Narragansett Bay. This pattern is recommended to minimize disposal effects (Saila, Pratt and Polgar, 1972) but it is doubtful that it can be followed in dredging the Thames.

Gordon, Rhoads and Turekian (1972) examined effects of dumping spoils from New Haven Harbor on the New Haven spoil ground. Among their conclusions were: 1) spoils were rapidly repopulated by benthic fauna; 2) no extinctions of unique or endemic species took place; 3) since heavy metals weren't concentrated by the dominant species (the bivalves Pitar and Mulinia), the danger of these contaminants moving up the food web seemed slight; 4) turbidity caused by dumping activities was probably small compared to that of a force 4 storm, which occurred an average of 5 times per month in the disposal area; and 5) since the area had high natural sedimentation rates, spoils would quickly be covered by relatively uncontaminated materials.

Negative findings were that 1) silt-clay fractions were somewhat dispersed from the disposal points; 2) significant resuspension

as 40 percent between the neap and spring cycles. Sub-surface measurements indicate that bottom currents, which occur earlier in relation to slack water, are of smaller magnitude than the surface currents. For example at Stratford Shoals the decrease in current velocity with depth ranges from 1-2 knots at the surface to a bottom velocity of 0.9 knots. In this same area the ebb flow velocities are generally greater than those of the flooding tide.

In general the tidal circulation of Long Island Sound is largely determined by the tidal forces acting at the eastern entrance. The contribution from the western end has not as yet been completely determined. Those tidal currents present in the Sound are mainly bi-directional with a semi-diurnal period.

Impressed upon this tidal flow are the effects of fresh water inflows from bordering land masses producing a hydraulic head, and the currents due to wind drift and density variations. Riley (1952, 1956) indicated that the Sound tends toward a two layered system in which a slightly less saline net surface flow is directed toward the east, while a more saline bottom water flows toward the west. He also showed that fresh water drainage, which averages 35 percent of the total volume of the Sound, is less than the volume of transport exchange, the basis for this reasoning being that the freshening effect was observed to be slight.

The non-tidal circulation in the Sound is not well defined. Riley (1952) has postulated a counter-clockwise gyre as being present in the western reaches, whereas two small clockwise gyres are located to the east. A small eastward drift was reported along the shores of Long Island.

In general, the non-tidal flow was considered to be significant, although the volume of the transport involved was small when compared to the ordinary tidal transport. Riley reported variations in this net flow of more than 20 percent between successive tidal cycles under comparable conditions. He also stated that non-tidal flows are extremely difficult to determine from velocity measurements made in high tidal streams, unless the non-tidal flow itself forms a considerable portion of the velocity field.

In 1967 Riley discussed the diffusion or mixing of conservative properties such as temperature and salinity in the Sound. He concluded that the horizontal turbulence was a small but a significant factor in determining the distribution of temperature and salinity. The ratio of turbulent mixing to advection was found to be 0.25. Generally, the degree of the state of turbulence depends upon the stability of the system, and in the Sound the stability was found to be dependent upon the density field.

In Block Island Sound, Riley (1952) observed that surface water moves into the region between Point Judith and Block Island, circulates through Block Island Sound and then exits by joining the southeasterly flow past Montauk Point. He also showed that the deeper water flows toward the west and the velocity of this flow varied throughout the year. Upper waters were characterized by an easterly flow and this he attributed to be part of the Long Island Sound outflow.

At the eastern end of Long Island Sound the most extensive data has been collected by the University of Connecticut and the New York Ocean Science Laboratory.

The Connecticut River has an average discharge of about 560 $m^3$-$sec^{-1}$ (Meade, 1966). During conditions of high runoff (April and May) the discharge rises to characteristic values of 2500 $m^3$-$sec^{-1}$. Riley (1956) found that during this period the outflow to the river was responsible for markedly reduced surface salinities in the eastern end of Long Island Sound. The outflow was clearly discernible as a muddy surface layer with distinct lateral boundaries, and in one case extended from the mouth through the eastern passes of the Sound. On the continental shelf south of Long Island, Ketchum and Corwin (1964) found that the average salinity was closely correlated with the six-month average discharge of the Connecticut River. High discharge values were associated with the low runoff characteristic of summer and fall. The standard error of the correlation was only 0.3°/oo, indicating a rather direct communication of river water with the continental shelf.

Even during river stages near the mean the salinity distribution near the mouth of the Connecticut displays the features of a salt-wedge estuary (Meade, 1966). Ketchum (1951) indicates that the ratio of mean discharge volume to tidal volume is about 2.0, in contrast to the coastal-plain rivers of the Atlantic coast where the ratios are low and mixing normally occurs over an appreciable reach of the rivers themselves. The contribution of the lower Connecticut by a bedrock valley largely accounts for this characteristic. At the mouth the river is 1350m in width and has a cross-sectional area of 2900$m^2$ at mean low water. Under mean conditions salt water does not move more than 13 km above

the mouth (Meade, 1966). In the spring of 1972 and 1973 Garvine (1973) studied the physical nature of the Connecticut River outflow in eastern Long Island Sound during high discharge. Special attention was paid to the factors which control the vertical and horizontal distribution of river effluent. His results indicated that the outflow of the river formed a buoyant plume of a few meters depth whose horizontal location was subject to great variation. Tidal phase and fresh water volume discharge were found to control much of the variations observed and winds very little. The off-shore boundary of the plume was usually formed by a front where surface currents were highly convergent and fluid properties nearly discontinuous. A lack of symmetry between the outflow paths for low and high slack water was found to be consistent with persistent southerly drift.

As indicated above Riley (1952, 1956, 1959, 1967) gave evidence for the existence of a two layered flow at the eastern opening of Long Island Sound during peak discharge of the Connecticut River. Nalwalk et al. (1970) showed that in May 1970 this two-layered flow at the Race consisted of a predominant inflow in the lower two thirds of the water column in the deep portion of the Race. Current measurements in the eastern passages of the Sound indicate that there is a net inflow of water over a tidal cycle in the deep channel of the Race, and a balancing outflow in the remainder of the passage at Plum Gut. Paskausky et al. (1973) suggested that these current measurements coupled with bottom sample data from this same region suggested the existence of a tidally driven counterclockwise circulation gyre which causes renewal of the

water with a period on the order of one week. Additional support for circulation of this gyre was presented by Hollman and Sandberg (1972). Bathymetry and tides seem to be the principal cause of this circulation pattern and Paskausky et al. (1973) suggested that it probably exists year-around since the two layered flow at the Race was observed to exist in July, October and January.

Bohlen (1973) noted that a large portion of the suspended materials observed at his stations one through four (in the Connecticut River) is deposited within the estuarine reach of the river. Evidence for this was provided by the annual 3 mm accretion on the tidal marshes (Bloom, 1967), as well as the rapid filling of North and South Cove and the maintenance of the extensive tidal flats east of the breakwater. Meade (1972) as a result of his examination of historical geomorphological data and quantitative estimates of the amounts of material required to maintain these depositional areas, indicated that most of the suspended riverine sediments are retained in these regions. Only the finest size fraction of the suspended load is transported into the open Sound (Bohlen, 1973). Examination of the distribution of selected heavy metals also indicated that transport of several of these elements is closely associated with the presence of fine particulate matter (Fitzgerald, et al. 1973). The distribution of lead for example, showed a sharp variation across the plume boundary. Adsorption of this element onto fine grained clay particles is a major mode of transport.

The chemical oceanography of Long Island Sound and Block Island Sound is also

not completely understood. Riley (1956) reported the nitrate nitrogen to be detectable in Long Island Sound only during the cooler months of the year. Phosphate phosphorous showed an inverse relationship with nitrate, and peak concentrations of 2.0 µg-at/L were found in the summer. A winter concentration of less than 0.5 µg-at/L was generally present throughout the Sound. Summer stratification of the waters resulted in reduced oxygen concentrations of approximately 50 percent of saturation. The two layered transport system mentioned above was postulated by Riley and Conover (1956) to provide the mechanism whereby plant growth and the accompanying positive gradients in nutrients automatically leads to retention of nutrients within the Sound and regulates the supply at a slightly higher level than that in adjacent waters.

Hardy (1969), as a result of three cruises in Long Island Sound, showed that the concentrations of phosphates in Long Island Sound were approximately twice those found by Riley and it was suggested that the use of detergents was largely responsible for this. He also showed that nitrate nitrogen increased in concentration along a profile extending from Fisher's Island to Throgs Neck.

In Block Island Sound Riley (1952) found the annual range of phosphate phosphorous to be approximately 0.5-2.0 µg-at/L. Maximum concentrations were present in the winter. He postulated that phosphate was not a "strongly limiting factor". Chlorophyll analyses from these same waters showed them to be typical of coastal temperate regions.

Alexander and White (in prep.) showed evidence for the presence of seasonal cycles similar to those of Riley although their concentrations were somewhat higher. They considered these waters to be deficient in nitrogen and that the nutrients are utilized by the phytoplankton rather quickly. Although they found relatively large seasonal changes in the concentration of nutrients and pigments the correlation between these parameters and chlorophyll *a* was not considered to be significant. Particulate phosphorous and chlorophyll *a* showed a strong correlation ($r = 0.815$). Particulate phosphorous generally ranged between 0.5 and 3.5 μg-at/L.

During the late fall and winter months chlorophyll *a* concentrations generally remain low in Block Island Sound with concentrations ranging from 0.5-1.0 $mg/m^3$. A spring flowering of relatively short duration is present in March and chlorophyll *a* concentrations range up to 8.4 $mg/m^3$.

Data on the distribution of heavy metals in these waters are limited. Fitzgerald (1973) noted that mercury and copper are both organically and inorganically associated; lead also appeared to have large fractions of organic components. Oysters along the Connecticut coast have been shown to take up Hg, Cu, Cd, Mn, Ni and Zn (Feng and Ruddy, 1973). Alexander (1973) and Alexander and White (1973) showed evidence for diurnal fluctuation in the copper, nickel and cadmium concentrations present in the waters contiguous to Long Island. Alexander (1974) showed that the mercury content of the waters of Block Island Sound was generally less than 0.2 μg/ℓ. In phytoplankton and zooplankton, the mercury concentration

was 0.05 and 0.15 ppm respectively while in the coastal fishes of New York the mercury content was a function of age, sex, feeding habits and locality with the observed concentrations ranging from an average concentration of 0.1-0.2 ppm in flounder to over 2.0 ppm in mako sharks.

Conover (1956) reported that the annual cycle of phytoplankton in Long Island Sound was characterized by a late winter bloom, followed by lower numbers of organisms in the spring and summer. Late summer and early autumn were characterized by small sporadic blooms. In the colder months few organisms were present, with light and turbulence being the controlling physical factors. Nitrogen appeared to be the most important limiting nutrient.

Diatoms, except for the summer flora, were the most abundant forms throughout the year. The warmer months were characterized by the presence of dinoflagellates and other small flagellates. The succession of species throughout the year was reported by Conover to be clear cut, and he indicated that the relative importance of the various forms from year to year was mainly due to environmental differences.

In Block Island Sound, Riley (1952) noted that the pigmented population was approximately twice that of Long Island Sound. The waters of Block Island Sound also had a higher concentration of phytoplankton than those of the New York Bight and Long Island Sound.

Marked seasonal variations were also noted in the phytoplankton populations

in Block Island Sound. *Skeletonema costatum* was the dominant species throughout the year. *Thalassionema nitzschioides* and *Nitzschia closterium* were also present throughout the year although their numbers were generally less than those of *Skeletonema*. Other organisms such as *Asterionella japonica*, *Guinardia flaccida*, *Ditylum brightwelli*, *Leptocylindrus danicus*, *Nitzschia seriata* were also present for short intervals during the year.

Recent data collected by our Laboratory in Block Island Sound indicates *Skeletonema*, species of *Rhizosolenia* and *Chaetoceros*, *Thalassionema*, *Thalassiothrix* and *Nitzschia seriata* are abundant in mid-summer. *Ceratium tripos* and *C. fusus* were present to a lesser degree. Other organisms found include: *Ditylum brightwelli*, *Bacteriastrum*, *Asterionella japonica*, *Nitzschia closterium* and representatives of the Coscinodiscaceae.

Zooplankton also were cyclic in their appearance and Deevey (1956) showed that the maximum numbers were present in late spring and again in late summer. Copepods were the dominant component of the zooplankton. Larvae of bottom invertebrates were second, while species of *Cladocera* and a few other forms were abundant seasonally. The total number of species present within Long Island Sound was limited chiefly by the lower salinities.

The important species of copepods were *Acartia clausii*, *A. tonsa*, *Temora longicornis*, *Pseudocalanus minutus*, *Paracalanus crassirostris*, and *Oithona* spp. *A. clausii* and *A. tonsa* were the two dominant members of the zooplankton. The former was present in the colder months of the year, while *A. tonsa* was present

from July to early January. In the winter both of these species appeared to depend upon *Thalassiosira* and *Thalassionema nitzschioides* for nutrition. At the height of the spring bloom, the gut of both copepods was packed with *Skeletonema costatum* in addition to the above. In the summer, less recognizable material was present in the gut. Generally the major difference in the gut content during the summer was the frequent occurrence in *A. tonsa* of the naked dinoflagellate *Prorocentrum* (rarely was this found in *A. clausii*).

In Block Island Sound Deevey (1952) found that the seasonal changes in the zooplankton population were directly related to the seasonal changes in salinity. She noted that the important members of the zooplankton were the copepods, cladocerans, pelagic tunicates, larval forms of bottom invertebrates, and coelenterates. Minor concentrations of heteropods, pteropods, ostracods, and fish eggs and larvae were found.

Of such copepods as *Centropages typicus*, *Pseudocalanus minutus*, *Acartia tonsa*, *Temora longicornis*, *Paracalanus parrus*, *P. crassirorostris* and *Oithona similis* the latter was the dominant (numerical) organism present throughout the year. Her data also indicate that the entire population in Block Island Sound appears to change semi-annually; for example, littoral and neritic species were present from January through June, while organisms characteristic of offshore and southerly waters were found for the remainder of the year.

Perlmutter (1939) surveyed the distribution of fish eggs and larvae in the waters contiguous to Long Island. Observations on new taxonomic characters as

as well as on the temperature and salinity characteristics of some spawning species were also included.

In Long Island Sound no definitive ichthyoplankton surveys have been conducted since the Bingham Oceanographic Group published their series in the middle-late 50's (Wheatland, 1956; Richards, 1959). The most intensive ichthyoplankton sampling conducted in Long Island Sound is that by the New York Ocean Science Laboratory under contract to the Long Island Lighting Company. This survey is designed to show fluctuations that are seasonal, diurnal, tidal, or advective in nature in a localized area along the northeast shore of Long Island. The ichythyoplankton of Block Island Sound, as in Long Island Sound, has not been examined since 1952 (Merriman and Sclar, 1952). This report has since been shown to be inaccurate (taxonomically) and suffers from a lack of supportive physical-chemical data. The New York Ocean Science Laboratory is currently analyzing 2-1/2 years of samples from Block Island Sound (some with six discrete depth samples at one station) which should show areas of origin, mechanisms of transportation, and vertical distribution.

Recent synoptic plankton studies tied to remote satellite sensing have shown the degree to which surface populations are advected tidally (Nuzzi, 1973; Austin and Stoops, 1973) in eastern Long Island Sound and Block Island Sound. The study of Austin and Stoops also provided criteria based upon tidal changes in salinity and copepod species composition for differentiating shelf and Sound waters.

In the Thames River where the actual dredging will occur and at the prime dumping site only limited data is available. In June and November, 1972, an "Experimental Investigation of a Dredge Spoil Disposal Site, New London, Connecticut" was conducted by the physical oceanography division of the Naval Oceanographic Office, Washington, D.C.

This report concluded that (1) dredge spoil disposition (some 92.5 x $10^3$ cubic yards) resulted in minor changes in bathymetry at the site; (2) current direction and speed indicated that resuspended sediment would undergo limited net transport and probably would remain in the general vicinity of the site; (3) deposition of the dredged wastes did not significantly affect the distribution of the trace metals in the water column; (4) the mean grain size of the sediments was not significantly different; (5) no significant change in the organic carbon and Kjeldahl nitrogen content of the sediments had occurred; (6) although the $\overline{X}$ of the concentrations of Pb, Zn, Cu and Cd had increased in the sediments it was concluded that "on the basis of heavy metal concentrations in the sediments, one cannot differentiate phase 1 from phase 2. Mercury was not detected"; (7) the $\overline{X}$ (% weight) gain in volatile solids of the sediments was not considered to be significant; (8) no adverse effect of dumping the dredged spoils was found with respect to oil and grease; (9) no adverse bacteriological (coliform) effects were noted nor was the BOD and (10) final faunal re-colonization studies were incomplete.

In this brief survey of the specific area no pertinent information for the Thames River was located.

In addition to the data mentioned above the New York Ocean Science Laboratory has for the past three years been investigating the oceanography of Block Island Sound in detail and to a limited extent the oceanography of eastern Long Island Sound. Data for the former areas has been collected from three transects extending from Watch Hill, Rhode Island to Montauk Point to Block Island to Point Judith, Rhode Island. At each of the stations located on these transects samples for the determination of salinity, dissolved oxygen, particulate, reactive and organic phosphorous, nitrite and nitrate nitrogen, silica and the pigments were routinely collected from three to six depths in the water column. Coincident with the removal of water from the samplers one liter of water was also removed for phytoplankton studies. At least one year of zooplankton and larval fish egg samples have also been collected from these waters. Diurnal variation on selected physical and chemical parameters for this area were published in Alexander et al. (1973). Since most of these data were routinely collected in a quasi-synoptic fashion over a tidal cycle we feel that a reconnaissance survey of Block Island Sound would not be warranted in this investigation, although financial support for the "working up" of the biological samples and for the collection and analysis of the more exotic parameters, e.g. heavy metals, pesticides, etc. is requested. Our data for eastern Long Island Sound and the Race is not as complete as that for Block Island Sound although the same parameters were followed. We are also in the process of reducing a large amount of physical, chemical and biological data collected at Northport, Shoreham and at Jamesport, Long Island. A series of sediment samples collected from Gardiners Bay, western Block Island Sound and eastern Long Island Sound is available for at least heavy metal analysis if necessary.

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# APPENDIX B

## DETAILS OF RESEARCH PROPOSED BY THE MIDDLE ATLANTIC COASTAL FISHERIES CENTER

(1) BENTHIC ECOLOGY

It is becoming increasingly evident (Blacker, 1957; Olson and Burgess, 1967; Reish, 1960) that benthic communities are more sensitive indicators of chronic point-source impingement than either planktonic or pelagic fauna. Natant species, particularly, are capable of selective avoidance of contaminated areas. Benthic organisms, while motile, are effectively sessile with respect to the spatial dimensions of the Thames River project. Unable to avoid introduced contaminants and other environmental perturbations the benthos, primarily through changes in population density and community structure, has great balue as an indicator of environmental change.

Historically, benthic investigations have formed a major part of studies examining the reaction of the faunal milieu to stress. Galtsoff, et. al., (1935) investigated the reaction of oysters to crude oil pollution and Reish (1965) studied the effects of oil refinery wastes on the benthos as a whole. The celebrated Torrey Canyon oil spill in the English Channel generated many papers dealing with deleterious effects on the benthos (e.g., Bellamy, et. al., 1967; Smith, 1968). More recently Blumer, et. al (1970, 1971), Blumer, Souza and Sass (1971), Blumer and Sass (1972) and Sanders et. al (1972) found certain benthic groups to be extremely sensitive indicators of hydrocarbon pollution. In one instance, (Blumer, et. al. (1970) Ampeliscid amphipods responded to levels of contamination near the lower limit of the rather sophisticated chemical analyses employed.

Recent studies (Cunningham and Tripp, 1973; Pentreath, 1973; Schulz-Baldes, 1973) indicate that many benthic organisms are capable of concentrating contaminants by several orders of magnitude, thus making earlier detection of these pollutants possible.

As indicated in the background statement (Appendix A), there is a sound historical precedent for the inclusion of an extensive benthic program in any study of spoil disposal (Gordon, Rhoads and Turekian, 1972; Leathem, et al., 1973; Maurer, et al., 1973; Saila, Pratt and Polgar, 1972). Although a more extensive review of the voluminous literature in the general area of benthic communities as indicators is beyond the scope of this proposal, it is clear from the foregoing that an extensive study of the benthic fauna should form a major part of this assessment program. Accordingly, the limited faunal study outlined in the original Plan A and the EPA guidelines has been expanded to better utilize this important source of information.

METHODS

A. Station Location

At the disposal site, where the major thrust of this study is oriented, a transect approach was considered appropriate for a point-source input of this type. Two major transects will intersect at the designated release point (see Fig. 2).

The longer of these is oriented parallel to the direction of residual bottom drift. The shorter transect, perpendicular to the first, follows the slope of the bottom, which may also be a factor in spoil dispersal.

Stations will be placed along these transects beginning at 0.125 nmi. from the release point and at distances increasing as a geometric series with a factor of two. The most distant stations will be 1 nmi. except in the direction of residual bottom drift where a 2 nmi. station will be added. This scheme places more stations near the release point where the greatest impact is expected.

It is evident that this station pattern relies heavily on an accurate prediction of the probable direction of spoils movement. If the actual direction of movement were displaced a few degrees from the transect line it would be possible to miss any transported spoils entirely. To reduce this possibility and, hence, allow for some degree of error in the predicted movement, additional transects will be sampled as shown in Figure 2. The fan-shaped array will be sure to encompass any relocation of the spoils. With the addition of a station at the release point the number of stations is brought to 40.

The alternate disposal site; where a more general sort of information is desired, will not be sampled with the

same intensity as the primary disposal site scheme proposed above. Five stations will be created in the alternate site, one in the center and the other four near the periphery on each side. If the site is eventually selected for use a high-intensity survey may be initiated at that time. Five stations, however, are felt to be sufficient for the low-level background type data to be developed at this time.

The dredging site will be analyzed in three zones: one above the dredging activities, one below and one defined by the dredging area (fig. 1). One benthic station will be created in each of the first two zones. In the dredging zone two stations will be sampled: one in the channel and one adjacent to the channel.

B. Sampling

The Smith-McIntyre, or Aberdeen, type grab (Smith and McIntyre, 1954) will be used exclusively for macrofaunal work. This instrument has been used successfully by this laboratory for several years, is currently being used by the NOAA-MESA Program and appears to be rapidly gaining wide acceptance as the grab sampler of choice. The only other alternatives of any note are the .04 $m^2$ Shipek, which has been judged too small for macrofaunal work (Holme and McIntyre, 1971) and the 0.1 $m^2$ VanVeen which takes consistently smaller samples than the equivalent

size Smith-McIntyre (Smith and McIntyre, 1954) and also generates a compression wave which biases the sampler against the vagile epifauna (Wigley, 1967).

The buckets of the Smith-McIntyre are closed with 0.5 mm mesh screen which prevents the loss of any organisms while the sampler is being retrieved. The screen, however, does allow some winnowing of the finer sediments but experience indicates this will not be of major significance in the depths being worked. Completely closing the tops of the buckets would prevent this only at the expense of generating a pressure wave similar to that of the Van Veen.

Five Smith-McIntyre grab samples will be analyzed at each station, with one additional grab to secure material for sedimentary analyses. This figure is suggested by the EPA guidelines and is also being used by the MESA Program. Holme and McIntyre (1971) working with actual sampling data show that the 95% confidence interval is not appreciably narrowed by taking even as many as 20 grabs. They suggest that the small degree of extra confidence thus gained does not justify multiplying the sampling and sorting effort by four.

Longhurst (1959) indicates that when gross faunal indices are being considered (i.e. total biomass, total number) the five grab figure will provide an adequate estimate.

He uses experimental data from several sediment types to derive this figure.

All macrofaunal samples will be screened in the field using a sieve of 1.0 mm aperture. Ecological studies have commonly employed mesh sizes ranging from 2.0 mm to 0.5 mm. Clearly the choice of a mesh size is largely arbitrary. However, the choice can be narrowed using a few basic criteria. Reish (1959) indicated that a mesh size of 0.27 mm was required to routinely capture 95% of all individuals. The effort required to screen and then sort many samples of that type, however, would be prohibitive. Also, since such small meshes have never been extensively used in ecological work the results would make comparisons with the literature extremely difficult.

On the other hand, Reish's data also indicate that 90% of the biomass at a given station is retained on a rather large 1.4 mm screen. That is to say, the ecologically more important species would appear to be adequately sampled by the 1.0 mm mesh sieve.

There is no question that, historically, the 1.0 mm mesh is the standard for benthic macrofaunal surveys. Another popular size is 0.71 mm which is selected because it has a diagonal aperture of 1.00 mm and is felt by some workers to be a "true" 1.0 mm sieve. Nonetheless, the wide

acceptance of the 1.0 mm mesh dictates its use in this study as well.

Screened samples will be relaxed for 5 min. in a 0.15% solution of propylene phenoxetol and preserved entire in 10% seawater formalin. After approximately 48 hrs. of fixation samples will be transferred to 70% ethanol for storage prior to sorting.

Stations at the alternate dump site will be occupied only once to obtain baseline data. Stations in the dredging area and primary disposal site will be sampled six times: one each before and after Phase I dredging and quarterly during the 11 months of actual dredging.

All screened and preserved samples will be stored at the Sandy Hook Laboratory while a determination is made as to which samples from the disposal site will be sorted. This determination will be based on data from the sediment and hydrographic analysis program. Stations which show measurable impact from dredging spoil will be analyzed completely. Stations which show no measurable impact will either not be analyzed or will be analyzed as controls. All samples from the dredging site and alternate disposal site will be completely analyzed. Also, all samples from the pre-disposal and post-disposal samplings will be processed. It is expected that this type of program, using data from approximately 1,000 benthic samples will provide a sufficient data base to determine the impact of this operation on benthic communities in the area.

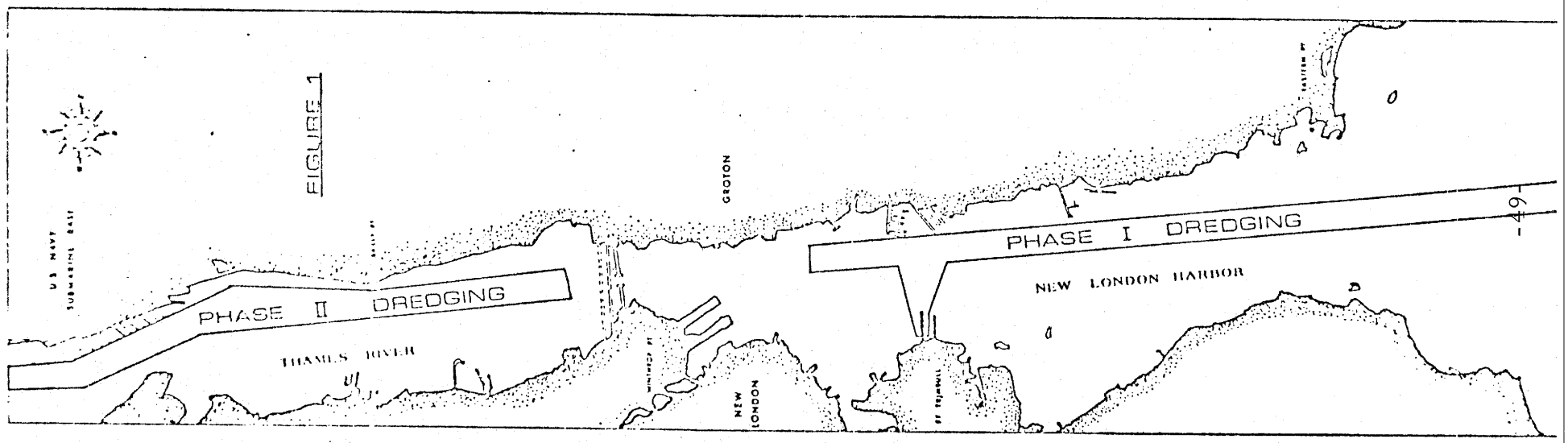
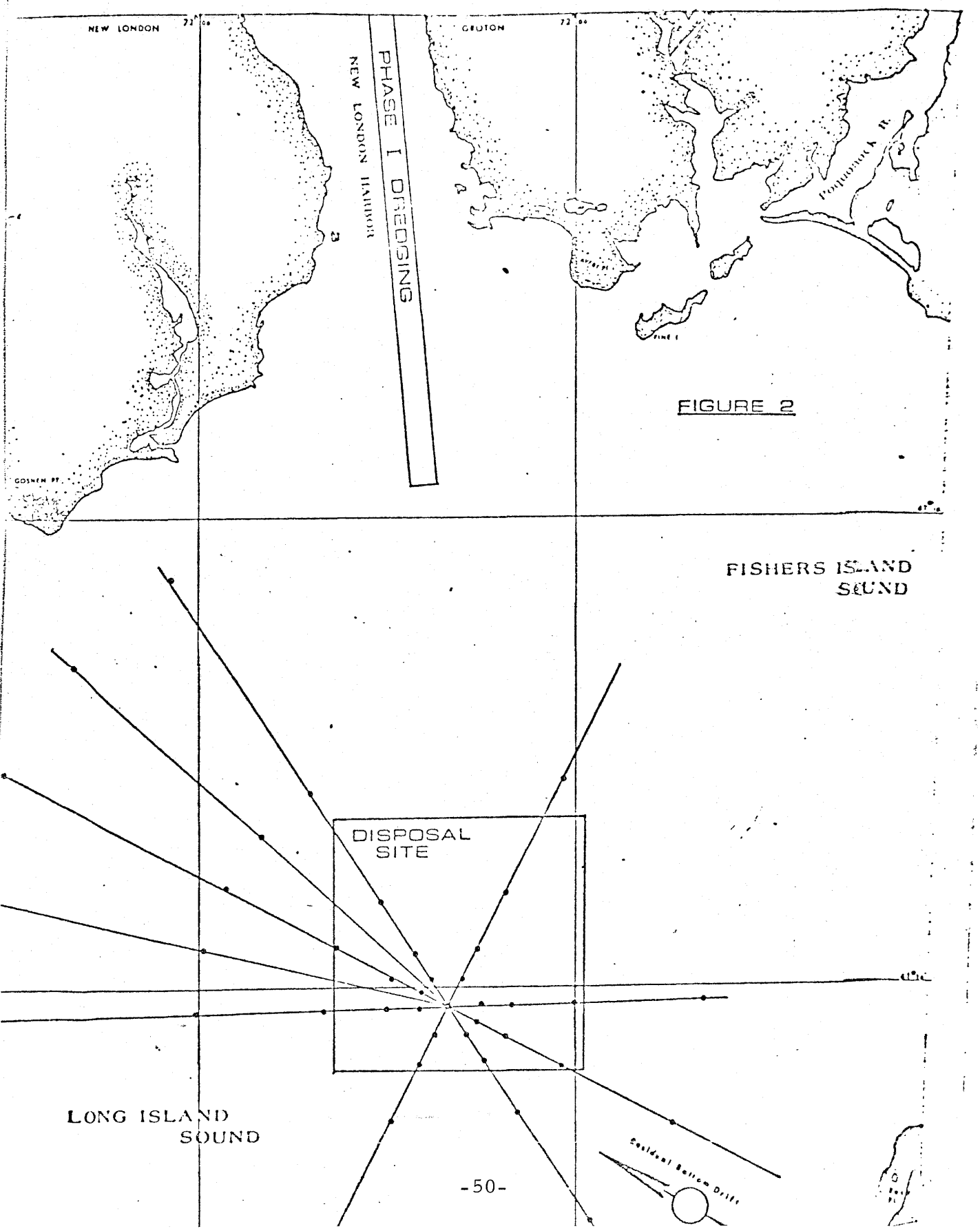

U.S. NAVY
SUBMARINE BASE
PHASE II DREDGING
THAMES RIVER
GROTON
NEW LONDON
PHASE I DREDGING
NEW LONDON HARBOR

FIGURE 1


NEW LONDON
GROTON
PHASE I DREDGING
NEW LONDON HARBOR
Poquonnock R.
FIGURE 2
FISHERS ISLAND SOUND
DISPOSAL SITE
LONG ISLAND SOUND

## (2) BACTERIOLOGY

The Environmental Microbiology Investigation of the Middle Atlantic Coastal Fisheries Center has been determining the presence of coliform bacteria in sediments from the disposal areas of the New York Bight since December, 1971. The objective has been to determine the degree of microbial contamination of the environment. The introduction and persistence of microbial pathogens in marine sediments introduced by spoil disposal has not been adequately investigated. Also of immediate concern is the migration of the disposed material with further contamination of the marine environment.

What is proposed is sampling of stations on predetermined transects from the center of the disposal site to peripheral areas. This should be accomplished during a short period of time and on a seasonal basis.

Preliminary studies show that sediments of river mouths act as depositories for large numbers of bacteria. For example, we have obtained counts of 100,000 fecal coliforms per 100 ml in New Haven harbor sediments indicating fecal pollution. The significance of fecal coliform bacteria is that they are indicators of the possible presence of disease-producing or pathogenic bacteria that could affect man and marine animals.

In reference to the planned dredging operation for the Thames River we propose obtaining baseline data on fecal coliform bacteria employing the MPN technique. The fate of the coliform bacteria during and post dredging operations will be followed in order to determine the degree and spread of fecal contamination of the disposal area. This will be correlated with total viable bacterial counts (aerobic and anaerobic).

Samples to be analyzed will be water, bottom sediments and select marine animals at established stations in the river and at the disposal site. The frequency and number of stations to be monitored will be based on preliminary results obtained in the baseline survey. In general, sediments and animals would be monitored on a quarterly basis, whereas water at more frequent intervals, possibly biweekly, until trends are established by the data. Stations selected will be on transects from the center of the dump sites to peripheral areas at distances such that migration patterns can be established.

Other studies, which are part of our ongoing in-house effort and to be included in order to obtain additional and supportive microbiological data will be direct bacteria counts, detection and quantitation of bacteria belonging to the groups Vibrio and Clostridium (perfringens) and the presence of drug-resistant bacteria.

This proposal for the area of research pertaining to microbiological aspects of dredge disposal follows the same approach to obtain the necessary information on the MESA-related project on the New York Bight. An integrated and comparative approach on this problem is possible to obtain the desired information from the several geographical areas.

# APPENDIX C

## DETAILS OF RESEARCH PROPOSED BY

## NEW YORK OCEAN SCIENCES LABORATORY

## PHYSICAL OCEANOGRAPHY

### Introduction

Two important physical parameters that are inherent to the dumping of dredged materials are currents and alterations to the ambient light transmission characteristic of the water column. The currents in the vicinity of the dump site are fundamental to the determination of the distribution of the disposed material. The natural light transmission characteristics that are fundamentally of biological importance are affected by the increased turbidity of the water column induced by the dumping of dredged material.

### Proposed Program:

A two year field study is proposed wherein the typical current at the dump site will be studied by Eularian and Lagrangian techniques to determine the transport of the dumped material. These studies will take place during winter and summer wind systems (NW in winter and SW in summer).

Light transmission characteristics will be monitored in the water column at the dump site as well as the surrounding area.

### Objectives:

One objective of this proposed study is to provide quantitative estimates of the transport of the dredged material.

Another objective is to study the effects of the dumped material on the inherent light transmission characteristics of the water column.

## Methods and Procedures

### A. Primary Dump Site

#### 1. Foreword

A basic problem in the dump site will be navigation control. This problem will also affect the spacing of stations to a significant degree. Therefore, it is suggested that at a minimum, four permanent buoys be installed at each corner of the dump site, and one buoy be located at recommended dump position (to be determined). Each buoy should be equipped with radar pingers. In addition, it would be most advantageous to the precision as well as the accuracy of the proposed experimental and monitoring programs if a system such as DECCA Hi-Fix be temporarily installed to cover the area.

#### 2. Pre-Dump Program

Another fundamental problem in the dump site is the net or non-tidal drift. The direction that this drift takes should govern the orientation of the sampling transects. Therefore, it is proposed that an array comprising at least 2 current meters (near surface and bottom) be deployed at the center of the dump site for a minimum period of 4 tidal cycles. Concurrently, drogues will be planted in both the surface and bottom layers of the water column and tracked for at least one tidal cycle. These data will be reduced and analyzed as quickly as possible so that recommended dump positions can be determined and the transects oriented with respect to the direction of the net drift as determined from both the current meter data and drogue tracks. The reduction and analysis should not take more than 30 days.

Within the same period of time, it is proposed that a quasi-synoptic sampling program at a minimum of 5 stations (the corners and center of the dump site) over a lunar day (25 hours) be undertaken to determine a base line for variations to be encountered over a tidal cycle

Other parameters and methods will be discussed in the Chemical Oceanography Proposal.

Light transmission and turbidity will be measured at each station.

3. Dump Disposal Experiments

a) An experiment is proposed that will determine the length of time required for the site to return to a pre-dump condition. This will involve the quasi-synoptic sampling of select stations just prior to a dump, and following through after the dump for a minimum period of one complete tidal cycle. It is proposed that two such experiments be carried out, one in spring, the other in fall during Phase I and Phase II. Concurrent current measurements, surface and bottom, will also be made. The frequency of sampling will be as high as is possible and will include the following parameters: light transmission, turbidity, temperature, salinity, dissolved oxygen, suspended and volatile solids (see Chemical Oceanography Proposal). The peak concentration and dumping background concentration of suspended material can be calculated from data acquired in this experiment.

b) The second experiment is designed to study the fate of a particular plume generated by a dump. It is proposed that the water column be sampled at

the center of the dump site at slack water just prior to a dump. Immediately following the dump, two drogues will be planted, one in the surface layer and the other in the bottom. These drogues will be tracked and the water column at each drogue sampled at least on an hourly basis for a minimum period of a complete tidal cycle. The parameters are as above. Concurrent current observations will be made at the dump site. This experiment will also be carried out twice during the year, during winter and summer. The width of the plume would also be monitored to study dispersion effects of tides and winds.

B. Alternate Dump Site

At the alternate dump site approximately 5 stations will be located and sampled once during the summer (Aug./Sept.) for all of the parameters determined at the primary dump site. In the event that this site were to be used for dumping then all of the operations previously proposed for the primary dump site would be continued at the new site. The location of this site is understood to be approximately 10 miles southeast of Block Island and centered at 41°02'30"N and 71°30'48"W. The method to be followed for the establishment of the stations will be similar to that employed at the primary dump site. In the event that the two additional experiments requested for the prime dump site have not been completed we would then do so at the new site.

Temperature, salinity and dissolved oxygen measurements will be made with a MARTEK MARK III Water Quality Monitoring System which has been previously calibrated (and recalibrated during the course of these studies). Discrete

samples of water will be collected during each sampling period as a check.

Light transmission measurements will be made using an underwater transmissometer (HYDRO Products or equivalent).

Current measurements will be made using General Oceanics Film Recording Current Meters where applicable.

## FACILITIES

The following materials are available for the physical and chemical program: Salinometers (Beckman RS5 and RS7-B); Spectrophotometers (Beckman DU-3 and DBG); Gas Chromatograph (Beckman CRS-101) with an interfaced digital integrator (Infotronics CRS101) and atomic absorption spectrophotometer (Beckman Model 440 with Autolam Burner). Other standard laboratory equipment such as balances, furnaces and ovens are also available.

The Laboratory's inventory of current meters includes numerous self-contained units (Hydro Products and General Oceanics) as well as a number of read-out types.

Our sampling program will be conducted by the R/V KYMA which is on indefinite loan to us from NOAA. The ship (a 65-foot T-boat) is equipped with an oceanographic and BT winch, AC and DC generators, Decca "Transar" Mod. 426 radar with variable range marker, Loran A and C, Sperry Gyro Compass, Raytheon Fathometer (770 fathoms max.). The laboratory space is in the converted cargo hold and is equipped with laboratory benches, sink, and 120-volt AC and DC power. Additional equipment such as the Niskin water samplers and all-glass filtration systems are on board. Supporting craft to be used in conjunction with the R/V KYMA for certain phases of the field program are available.

## CHEMICAL OCEANOGRAPHY

### Introduction

The release of barged materials into the open waters of the marine environment poses potentially large problems to the planktonic, nektonic and benthic organisms. These problems relate not only to the smothering effect and oxygen demanding characteristics of these materials but also to the potential uptake of toxic meterials by these organisms. So that the potential impact of these materials upon the organisms not only within the dump zone but also downstream of it can be ascertained it is necessary to monitor the levels of the toxicants in the sediments and the biota.

### Proposed Program and Specific Objectives

In this present investigation we propose to (1) monitor on a quarterly basis the concentration of selected toxicants, e.g. heavy metals in both the organisms and sediments; (2) determine semi-annualy the length of time required for the dump area to return to background; and (3) on a similar time scale to follow the dumped materials after they are released to determine their transport characteristics. For these studies we propose a two-year field study.

### Methods and Procedures

A. Primary Dump Site

1. Foreword

The need for precise navigation in all of these proposed studies is apparent in all of these proposed studies. The presence of the equipment suggested in the physical oceanography section would seem to satisfy a large portion of these requirements.

Pre-Dump Program

So that appropriate baseline data can be made available for comparative purposes we propose to conduct at least quasi-synoptic sampling for selected parameters from a minimum of 5 stations (the four corners and the center of the dump site) over a lunar day. Specifically we propose to determine the spatial and temporal distribution of salinity, oxygen, pH, Eh, TOC, suspended and volatile solids. Samples for these determinations will be collected from approximately 6 depths in the water column at as high a sampling frequency as possible (hourly except for oxygen, which will be collected at two-hour intervals).

The concentration of Hg, Pb, Zn, Cd, Ni, Fe, Cu, total phosphorus and Kjeldahl nitrogen will also be determined for the seston (taken from the same stations but at three depths only). Although the prime analysis will be conducted on a composite sample from each station attempts will be made - sample size permitting - to determine the body burden of these materials present in the organisms (total sample) collected from a given depth.

Subsequent to these studies and in conjunction with the benthic biological group sediments and benthic organisms will be collected from 40 stations - the grid pattern for this has been established by the Middle Atlantic Coastal Fisheries Center. Five grab samples will be analyzed at each station in accordance with the biological program. The concentration of Hg, Pb, Zn, Cd, Ni, Fe, Cu, total phosphorus, Kjeldahl nitrogen and COD will be determined for all

of the samples from at least 20 stations (additional stations will be analyzed where perturbations in the data dictate). Representative benthic organisms (both deposit and suspension feeders) will also be analyzed for the above heavy metals, total phosphorus and Kjeldahl nitrogen. It is anticipated that the choice of the organisms to be analyzed will be dictated by the biological group and that the appropriate organisms will be removed from the samples by this group in conjunction with the chemists.

3. Dump Disposal Experiments

a) In conjunction with the physical oceanographic program an experiment is proposed to determine the length of time required for the dump site to return to "normal" (this level is largely dictated by the frequency of dumping). We anticipate dumping to be conducted at least twice per day and through appropriate scheduling we propose to commence this sampling program several hours before a dump occurs and to follow through after the dump for a minimum of one tidal cycle (this will be largely dictated by the settling rates of the released materials and additional perturbations). It is proposed that two such experiments be conducted, one in spring and the other in the fall during Phase I and Phase II. The data for this experiment will be collected quasi-synoptically from selected stations at as high a frequency as possible. Such parameters as salinity, dissolved oxygen, pH, Eh, TOC and suspended and volatile solids will be determined. As indicated in the physical oceanography proposal the peak concentration and dumping background concentratio of suspended material can be calculated from data acquired in this experiment.

b) The second experiment is designed to study the fate of the materials contained in a particular plume generated by a dump. For this study we propose to sample the water column at the center of the dump site (that is, where the barges are actually releasing their materials) at slack water just prior to a dump. As indicated in the Physical Oceanography Proposal two drogues will be planted, one in the surface layer and the other in the bottom immediately following the dump. These drogues will be tracked and the water column at each drogue sampled at least on an hourly basis from at least three depths in the water column for a minimum of a complete tidal cycle. The parameters will be as above. These studies will also be carried out twice during the year, namely, winter and summer (February and August). The width of the plume would also be monitored.

c) In a manner similar to that described in the pre-dump program quarterly sampling and analysis of the seston and benthic organisms will be conducted.

B. Alternate Dump Site

At the alternate dump site approximately 5 stations will be located and sampled once during the summer (August/ September) for all of the parameters determined at the primary dump site. In the event that this site were to be used for dumping then all of the operations and parameters previously proposed for the primary dump site would be continued at the new site. The location of this site is understood to be approximately 10 miles southeast of Block Island and centered at 41°02'30"N and 71°30'48"W. The method to be followed for the

establishment of the stations will be similar to that employed at the primary dump site. In the event that the two additional experiments requested for the primary dump site have not been completed, we would then do so at the new site.

C. Methodology

1. Collection of Samples

(i) Water

Niskin samplers will be used to collect the water. Once on deck and after the appropriate samples have been withdrawn (salinity, dissolved oxygen, COD, TOC, pH, Eh, etc.) the samplers are connected via Tygon tubing to all glass filtration apparatus in the laboratory on board ship and the necessary filtration completed.

(ii) Seston and Benthic Organisms

Samples for seston analysis will be collected with 3/4 meter opening 363μ mesh, metered, opening closing nets. One net will be towed at the surface and the other two at depth. Their fishing depths will depend upon analysis of the thermal structure of the water column. These samples will be stored in specially cleaned one liter glass bottles fitted with Teflon lined screw caps and stored at low temperature until analysis. Benthic organisms will be stored in acid cleaned polyethylene bags at low temperature until analysis.

(iii) Sediments

Samples of sediments to be analyzed for the various parameters specified will be removed from the Smith-McIntyre grab samples taken for benthic macro-

fauna studies. These samples will be stored in cleaned polyethylene bags at low temperature until analysis.

2. Sample Preparation and Methods of Analysis

| Parameter | Method |
|---|---|
| 1. Salinity | Conductivity |
| 2. Oxygen | (1) |
| 3. pH | (1) |
| 4. Total Organic Carbon | |
| 5. Suspended Solids | (1) |
| 6. Volatile Solids | (1) |
| 7. Metals | |
| a. seston | (3) |
| b. benthic organisms | (3) |
| c. sediments | (3) |
| 8. COD | (1) |
| 9. Nitrogen and phosphorus | (2) and (4) |

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(2) Methods for Chemical Analysis of Water and Wastes, 1971. Environmental Protection Agency, Cincinnati, Ohio.

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(4) A Practical Handbook of Seawater Analysis, 1968. Fisheries Research Board of Canada. Bull. No. 167.

## Report Schedule

Quarterly reports detailing the status of and problems encountered in the course of the investigation will be submitted. Due to the nature of certain of the analyses the final report will be submitted within 90 days of the completion of this investigation.

## Facilities

The following materials are available for the physical and chemical program: Salinometers (Beckman RS5 and RS7-B); Spectrophotometers (Beckman DU-3 and DBG) and atomic absorption spectrophotometer (Beckman Model 440 with Autolam Burner). Other standard laboratory equipment such as balances, furnaces and ovens are also available.

The Laboratory's inventory of current meters includes numerous self-contained units (Hydro Products and General Oceanics) as well as a number of read-out types.

Our sampling program will be conducted by the R/V KYMA which is on indefinite loan to us from NOAA. The ship (a 65-foot T-boat) is equipped with an oceanographic and BT winch, AC and DC generators, Decca "Transar" Mod. 426 radar with variable range marker, Loarn A and C, Sperry Gyro Compass, Raytheon Fathometer (770 fathoms max). The laboratory space is in the converted cargo hold and is equipped with laboratory benches, sink, and 120-volt AC and DC power. Additional equipment such as the Niskin water samplers and all-glass filtration systems are on board. Supporting craft to be used in conjunction with the R/V KYMA for certain phases of the field program are available.

## FISH DISTRIBUTION AND ABUNDANCE

### Introduction

Relatively little information, as a single paper, is available on the distribution and abundance of finfish in eastern Long Island Sound, particularly in the Thames River estuary. As part of the study of dredging and spoiling in the Thames River estuary it is proposed that NYOSL examine the historical data concerned with marine recreational and commercial finfish in the eastern waters of Long Island Sound. It is also proposed that field studies be conducted to determine if dredging and spoiling has any immediate impact upon finfish resources.

### Proposed Program

A historical review of the published literature and unpublished data reports concerned with finfish will be conducted. The library of the New York Ocean Sciences Laboratory, through a grant from the Hayden Foundation, has a reprint collection on Long Island Sound numbering some 1500 papers. These will be reviewed and analyzed to provide the information and data necessary to the preparation of the proposed report. In order to detail the seasonal distribution and abundance of finfish at the spoiling site, replicate 35 foot head-rope otter trawl tows (2" stretch mesh body, 1" stretch mesh cod end liner, 1/4" stretch mesh cod end) will be made at the site. All finfish will be identified and inumerated. As part of an

ongoing NYOSL technical program winter flounder will be tagged and released. A representative sample of each species collected will be retained for laboratory analysis. These fish will be preserved in 10% formalin and in the laboratory the length, weights and ages will be measured. The gonads and stomachs will be excised and examined. Gonad weights will be measured and stomach contents identified and weighed. Fish will be examined externally for the presence of fin rot and other disease.

Trawling operations will be conducted during June 1974 (prior to dumping), late summer 1974 (during dumping), winter 1974-75 and in June 1975. It is agreed that a vessel suitable for trawling will be supplied to NYOSL. Data will be expressed as a quantitative seasonal species list (number of fish per hour of trawling) per trawling station or location. Lengths, weights and ages will be presented in table form and gonad weights expressed as principal gonad weight or total body weight. Stomach contents will be expressed quantitatively. Evidence of disease will be immediately reported to the MACFC.

# APPENDIX D

## DETAILS OF RESEARCH PROPOSED BY

## THE UNIVERSITY OF CONNECTICUT

# SUSPENDED MATERIAL TRANSPORT IN THE THAMES ESTUARY

## INTRODUCTION

An understanding of the concentration and composition of the suspended particulate matter characteristics of the lower Thames River estuary is essential within determinations of the impact of channel dredging on the local ecosystem. Fine-grained sediments suspended in an aqueous solution can serve as adsorption nuclei for a variety of organic and inorganic molecules (Grim, 1968; Gross, 1972). Bulk turbidity can have significant long-term effects on the benthic and pelagic communities (Renn, 1962; Brehmer, 1965; Ritchie, 1972). Both factors can be significantly perturbed by a long-term dredging operation.

## PROPOSED PROGRAM

A two-year field study of the characteristics of suspended material transport in the lower Thames River is proposed. This investigation extends over the proposed period of dredging in the river, which includes Phase I and that part of Phase II completed within the two-year duration of our investigations. The study is designed to provide an estimate of the effect of dredging on the concentration and composition of total suspended particulate matter.

### Previous Work

Relatively little information is available pertaining to the characteristics of suspended material transport in the Thames River.

Previous investigations of the physical, chemical, and biological characteristics are summarized in Cortell (1973) and Gallagher and Bohlen (1972). A review of this work indicates that sufficient hydrographic data are available to permit estimates of the estuarine circulation prior to dredging. These data similarly may be used to compute flushing rates and mass flux. Suspended material data necessary to complete a preliminary material budget are not available. These data are to be obtained in the proposed investigation.

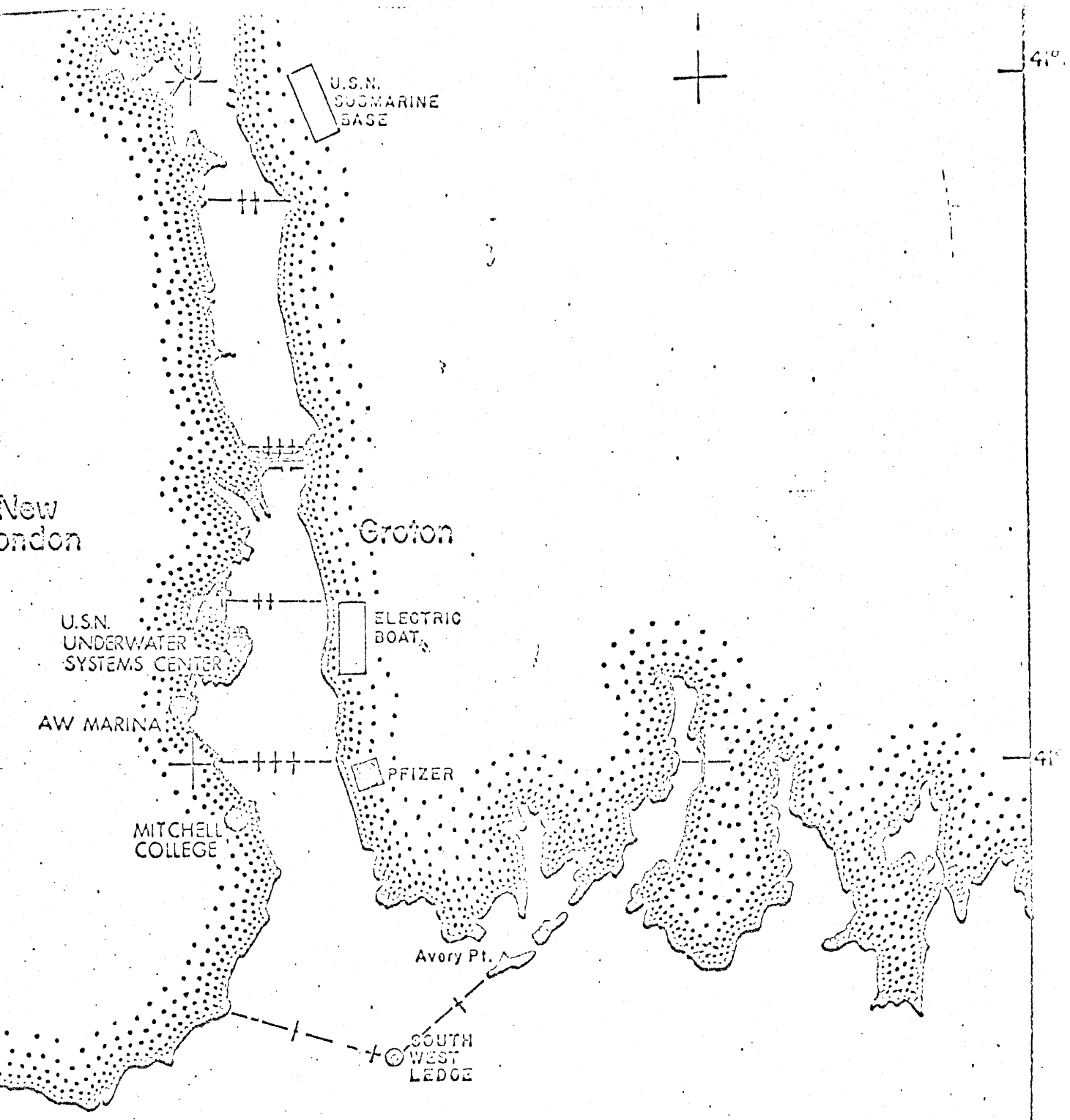
Objectives

1. To determine the extent to which dredging will modify the concentration and composition of total suspended materials in the lower Thames River Estuary.

2. To provide quantitative estimates of the rates and routes of suspended material transport.

Methods and Procedures

Average suspended material characteristics will be monitored monthly at a series of five transects spanning the lower river (Fig. 1). Each transect will contain two or three stations, depending on its width. Station sampling will commence two hours after the beginning of the ebb tidal cycle. Drawn water samples will be obtained at three depths in combination with *in situ* profiling of turbidity (determined from transmissometer measurements) and the temperature-salinity field (obtained with a temperature-


U.S.N.
SUBMARINE
BASE
New
London
Groton
U.S.N.
UNDERWATER
SYSTEMS CENTER
ELECTRIC
BOAT
AW MARINA
PFIZER
MITCHELL
COLLEGE
Avery Pt.
SOUTH
WEST
LEDGE

conductivity probe). The monthly survey will be supplemented by quarterly sampling over a tidal cycle. Designed to determine the degree of tidal influence, these measurements will detail maximum flood and ebb conditions during both spring and neap tides.

To determine the direct influence of the operating dredge, a high resolution survey of the waters adjacent to the dredge and barge will be conducted three times during the dredging of the lower river. The first survey will be initiated immediately after the project begins. The second sampling period will be conducted when the dredge reaches the mid-point of the project. A third sampling period will coincide with the completion of the project. The detailed survey will profile the turbidity characteristics in combination with drawn water sampling of the suspended load. The observed spatial distributions will be referenced to the dredge and located with respect to prominent landmarks. Positions will be determined using horizontal sextant angles.

Laboratory determinations of the by-weight concentration of total suspended material will employ standard vacuum filtration techniques. Dried and preweighed silver membrane filters (47mm-0.45μ) mounted in glass Millipore filtration assemblies will be used to filter a minimum of 1.0 liter from each sample.

The relative percentage of organic and inorganic materials in suspension will be determined using a total organic carbon analyzer in combination with carbon-hydrogen and nitrogen analyses. Particular emphasis will be placed on the seasonal variations in organic

concentrations and perturbations produced by high energy meteorological events. The magnitude and frequency of occurrence of these naturally induced anomalies will be compared to those resulting from the dredging operation.

Particle size distributions will be determined using microscopic sizing techniques (Swift et al., 1972). Particular emphasis is to be placed on the clay-sized fractions, including colloidal size particles.

Geofungi associated with the suspended and bottom sediments will be detailed at each of three stations located in the main channel (Fig. 1). Sterile Niskin bags (Niskin, 1962) will be used to obtain water samples at a depth of one meter below the surface and two meters above bottom. Quarterly sediment samples will be obtained using a stainless steel grab sampler.

Samples will be stored in a chill chest and returned to the laboratory for analysis. Aliquots will be plated out on two types of agar media and maintained at room temperature for daily examination.

The distributions of soil-related fungi will be mapped and examined as an indicator of the sources of material in suspension. Preliminary studies in this area indicate that this technique may prove useful (J. H. Cook, personal communication).

These data concerning the composition and concentration of suspended materials in combination with the tidal characterictics and the temperature-salinity field will be used to provide a

quantitative estimate of the routes and rates of material transport and the degree to which dredging will modify the system.

## MILESTONES

First Quarter - (3 months prior to initiation of dredging).

1. Initiate monthly survey of designated transects.
2. Synthesize existing data concerning the physical characteristics of the study area (e.g., density field, tidal heights and currents, etc.)
3. Establish the average concentration and composition of total suspended solids characteristic of the area before dredging.
4. Obtain an estiamte of the spatial and temporal variability in suspended material concentrations.
5. Progress report.

Second Quarter - (dredging begins)

1. Continue monthly survey.
2. Conduct first high resolution survey in the immediate vicinity of the dredge and barge.
3. Provide first estimates of the impact of dredging on the concentration and composition of suspended particulate matter.
4. Initiate attempts to obtain an indication of the response time of the field of suspended particles to perturbations produced by dredging.
5. Progress report.

Third Quarter

1. Continue monthly survey.

2. Develop initial estimates of the routes and rates of suspended material transport within the study area.

3. Progress report.

Fourth Quarter

1. Continue monthly survey

2. Conduct second high resolution survey in the immediate vicinity of the dredge and barge.

3. Detail the observed seasonal variability in concentration and composition of suspended materials.

4. Delimit the seasonal variations (if any) in the impact of dredging on the field of suspended materials.

5. Progress report.

Fifth Quarter - (complete Phase 1 dredging).

1. Continue monthly survey.

2. Conduct third high resolution survey in the immediate vicinity of the dredge and barge.

3. Delimit the spatial variability (if any) in the impact of dredging on the field of suspended materials.

4. Progress report.

Sixth Quarter

1. Continue monthly survey

2. Develop an estimate of the impact of dredging on the hydraulic characteristics of the study area.

3. Determine the magnitude of long term variations in suspended material composition and concentration produced by dredging.

4. Progress report.

Seventh Quarter

1. Continue monthly survey.

2. Complete estimates of the routes and rates of suspended material transport within the study area.

3. Provide estimates of the impact of Phase I dredging on the suspended particulate matter and turbidity levels characteristic of the study area.

4. Initiate detailed surveys of Phase 2 dredging area (Use results of Phase 1 investigation to determine optimum station location and sampling frequency).

5. Progress report.

Eighth Quarter - (Phase 2 dredging begins).

1. Continue monthly survey.

2. Prepare summary report detailing the impact of phase 1 dredging.

3. Use phase 1 data to estimate impact of phase 2 dredging.

Report Schedule

Final reports will be presented within thirty days of the completion of this investigation. Progress reports will be prepared and submitted quarterly.

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## INTRODUCTION

There are extensive hard clam (Mercenaria mercenaria) beds in the vicinity of the dredge site (Phase I) on the New London side below the Gold Star Memorial bridge. At present, owing to the general poor bacteriological quality of the river water in that region, harvesting of hard clams is prohibited by the Connecticut State Health Department. However, plans for reclaiming this untapped resource by relaying in clean waters are being formulated within several concerned state agencies, e.g., Division of Aquaculture (Department of Agriculture and Natural Resources), Health Department, Department of Environmental Protection and the University of Connecticut. Two nautical miles north of the Phase II dredge site there exists one of the few remaining natural oyster seed beds in eastern Long Island Sound, which could play an important role in the rehabilitation of the oyster industry in this region. Due to the close proximity of both Phase I and II dredge sites to these valuable living resources, the objective of this proposal is primarily concerned with the effect of dredging operations, if any, on the shellfish resources and phytoplankton which constitutes the major source of food for the shellfish.

It is conceivable that increased turbidity and the release of nutrients as well as toxic chemicals from the spoil associated with dredging activities could exert a significant influence on the phytoplankton and shellfish which are known for their propensity

to take up domestic and industrial pollutants. The critical information needed in order to properly evaluate the effect of dredging on the above mentioned biota is the physical and chemical property of the spoil as well as its concentration, spatial, and temporal distribution. While the spoil-associated suspended solids may be readily resettled, the fate of released toxicants may remain in the water column for a relatively longer period of time. Depending upon the volume of the river run-off, such released dissolved materials could conceivably last several tidal cycles in the river and be less readily dissipated than in the open waters of the dump site. Thus, one would expect a greater spatial distribution of the materials than that of the suspended solids in the river. Clearly, studies designed to elucidate the insidious effect of the greatly diluted dissolved chemicals as well as the turbidity on the phytoplankton and particularly the shellfish populations are needed, since it has been well documented that shellfish are notorious for their ability to concentrate trace amounts of pesticides, herbicides, polychlorinated biphenyls, hydrocarbons, heavy metals, radioactive nuclides, toxins, bacteria and viruses present in the environment (Butler et al., 1962; Jensen et al., 1969; Koeman et al., 1969; Kobayashi et al., 1969, 1970a, b; Blumer et al., 1970; Pringle et al., 1968; Chipman et al., 1968; McFarren et al., 1960; Hashimoto and Kamiya, 1970; Hedstrom and Lycke, 1964; Rindge et al., 1964; Metcalf and Stiles, 1965). The toxicity of

heavy metals and other pollutants on the adult and larval marine molluscs has been investigated and is exemplified by the study of Butler (1962), Davis and Hidu (1969), Eisler (1970), Calabrese et al. (1973), and Brown and Newell (1972).

Recently there have been increasing numbers of reports documenting the effects of heavy metals (Ukeles, 1962; Nuzzi, 1972), various pesticides and PCB's (Ukeles, 1962; Whitacre et al., 1972; Keil, 1969; Menzel et al., 1970; Keil et al., 1971; Mosser et al., 1971) on estuarine and marine phytoplankton. Toxicity of these chemicals ranges from direct overt effects on growth rates, reproduction and changes in specific metabolic rates or photosynthesis to more subtle effects such as alteration in species composition in mixed cultures of algae and diminishing concentrations of RNA and chlorophyll.

A brief survey of the above mentioned literature reveals that most of the data were obtained from short term experiments under static laboratory conditions which bear no close relationship to the dynamic situation of a natural environment. The value of such information at best can serve only as a guide for interpreting data derived from field observations. It is further noted that in some of the investigations the concentrations of toxicants used exceeded normal levels for marine or estuarine waters so as to render the results ecologically meaningless.

In order to adequately assess the possible effects of spoil associated toxicants on the phytoplankton and shellfish populations and the potential for transfer of these residues to higher trophic

levels in marine food chains, one must know the degree to which marine organisms accumulate residues of toxicants from the environment.

## PROPOSED RESEARCH PROGRAMS

Although there exist a fair number of references dealing with bioaccumulation of certain toxicants by marine organisms, information on the subtle pathological changes induced by various toxicants is generally limited or not available, though urgently needed. These subtle and insidious effects may inhibit photosynthesis of phytoplankton and interfere with feeding, renal function, growth, resistance to diseases and other stresses without necessarily killing the shellfish. In time such insidious effects may be more disastrous than overt mass mortalities. Thus, determining the concentration of toxicants in the environment and suitable indicator organisms is only a prerequisite to the understanding of ecological consequence of toxicants in the environment. The significance of a given toxicant in the environment must be evaluated against changes induced in biological systems, so that damages, if any, inflicted upon segments of the ecosystem, may be ascertained.

To answer some of the questions raised above we wish to propose a study designed to investigate the possible effects of turbidity and heavy metals on oysters, hard clams and phytoplankton associated with the dredging operation in the Thames River and to study the effect of dumping of dredge spoils on lobsters at the disposal site.

Field observations and laboratory analyses of field samples will be carried out to achieve the objectives of the study.

A. Field Monitoring Programs

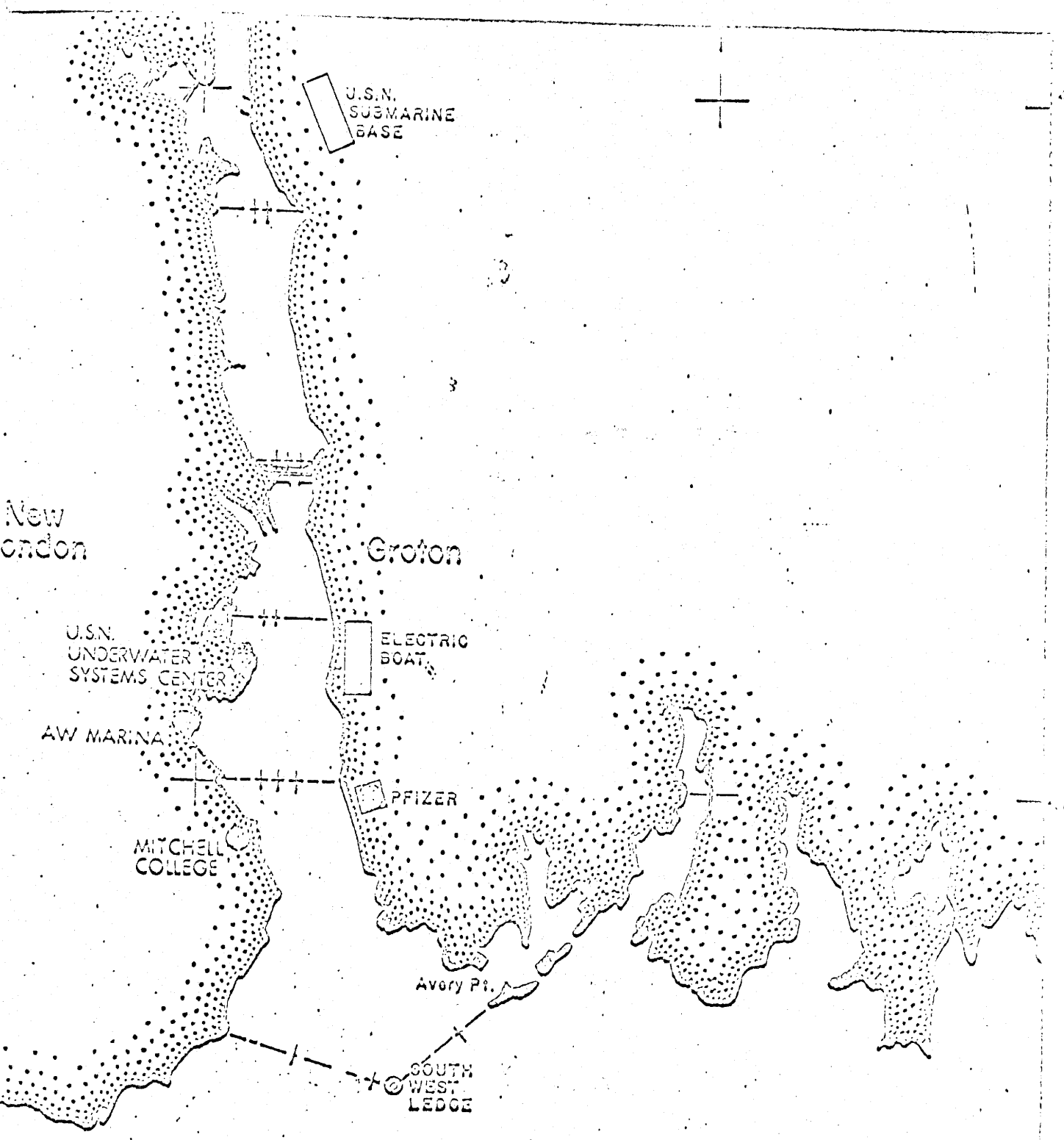
1. Stations. Six transects designated as Zone 1, 2, 3, 4, 5 and 6 from north to south will be established in the river. Zone 1 and 6, each located above and below the dredge sites, being beyond the influence of the dredging operations, serve as the controls. Zones 2, 3, 4 and 5 are to be established within the dredge site. Each zone consists of two or three stations depending on its width. These stations are shown in Figure 1 (Zone 6 stations are located in Montville, which is beyond the area covered by the chart).

2. Frequency of Sampling.

a. Survey of Lobster Populations in the Disposal Site

A survey will be made of historical and present distribution and abundance of lobster populations in the disposal site. Field surveys will be conducted before, during and after Phase I dredging.

Before-dumping survey will be accomplished by direct underwater visual enumeration of lobster burrows. During the dumping operation the movement of sonic tagged lobsters will be monitored by hydrophones, since high turbidity in the water column will render direct underwater observation ineffective. The normal movements of lobsters in Fishers Island Sound has been studied using sonic tags developed in this Laboratory, constantly for over one year. This information will be used as controls to interpret the movement of lobster activities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PFIZER
MITCHELL
COLLEGE
Avery Pt.
SOUTH
WEST
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during dumping. After the completion of dumping (Phase I) direct underwater visual inspection will again be employed to determine the impact on lobsters.

b. Survey of Montville Oyster Seed Bed and New London Hard Clam Bed

Prior to the dredging operation a survey of the beds will be made to determine the distribution and abundance of hard clam and oyster resources in the study area. Similar surveys will be carried out during and after Phase I dredging. In addition, on a quarterly basis, samples will be obtained for determining heavy metal concentrations (Hg, Zn, Cd, Cu and Ni).

c. Survey of Phytoplankton

Samples will be obtained quarterly from each station at two depths: surface and bottom. A composite sample from each zone will be analyzed for heavy metals: Hg, Zn, Cd, Cu and Ni. The standing crop of phytoplankton at any given sampling period will be expressed in terms of mg chlorophyll per $m^3$ of water.

A more or less synoptic sampling scheme will be carried out by using three boats, each being responsible for two zones. After the boats have arrived at their assigned locations (Zone 2, 4 and 6), sampling will commence simultaneously on prearranged radio command at maximum flood and ebb of the reference Zone 6.

d. Sediment Samples

Prior to the dredging operation three sediment samples in the ship channel from each of the six zones will be obtained. The available heavy metal contents of each sediment sample will be

determined.

B. Determining the Possible Effect of Heavy Metals on Hard Clams, Oysters and Phytoplankton

1. Hard Clams and Oysters

Shellfish samples obtained quarterly from the six zones will be dissected to determine whether gross pathological conditions exist. Kidney of the shellfish in particular will be carefully inspected for abnormal deposits which were found in hard clams collected from dump site and polluted harbors, e.g., Providence River. If such abnormality is discovered, histological sections will be made on these organisms. In addition, excretory function of the shellfish will be assayed quantitatively by measuring the nitrogenous excretory products of the intact animal in the water in which the animals have been held for a given period of time. Ammonia and urea will be determined by the method of Solorzano (1969) with and without urease treatment. Total free amino acids are to be determined by the photometric hydrinadation method of Moore and Stein (1954). Renal function study will be conducted only if gross pathological conditions in the kidney are detected in the shellfish.

2. Phytoplankton

A high resolution survey in the immediate vicinity of the dredge and barge will be initiated during the dredging operation. Continuous fluorometric measurement of chlorophyll will be carried out to determine the impact of dredging on the primary production.

Limited studies on the inhibitory or stimulatory effect of the river water from the dredge site on the primary productivity will be conducted by determining the rate of photosynthesis of mixed natural population of algae using either the "light and dark bottle" method or the uptake of radioactive carbon method as outlined by Strickland and Parson (1968).

## MILESTONES

First Quarter - 3 months prior to the initiation of dredging.

1. Commence survey of Montville oyster seed bed and New London hard clam bed and phytoplankton in the study area; determine heavy metal concentrations in the biota.

2. Initiate survey of lobsters in the disposal area.

3. Examine shellfish tissues for gross pathological conditions and carry out renal function studies on the intact shellfish if pathological conditions exist.

4. Conduct limited studies on phytoplankton photosynthesis.

5. Obtain sediment samples from the study area and determine the available heavy metals contained in the samples.

6. Submit quarterly report.

The overall activity of this quarter is designed to obtain baseline information.

Second Quarter - Dredging begins

1. Obtain shellfish samples and phytoplankton samples from the study area and determine heavy metal concentrations in the biota.

2. Monitor the activity of lobsters in the disposal area during dumping operations.

3. Examine shellfish tissues for gross pathological conditions and carry out renal function studies on the intact shellfish if pathological conditions exist.

4. Participate in the first high resolution survey in the immediate vicinity of the dredge and barge. Make continuous fluorometric measurement of chlorophyll to determine the impact of dredging on the primary production.

5. Submit quarterly report.

Third Quarter

1. Continue quarterly sampling programs as well as conduct laboratory analyses of field samples.

2. Submit progress report.

Fourth Quarter

1. Continue quarterly sampling programs as well as conduct laboratory analyses of field samples.

2. Participate in the second high resolution survey in the immediate vicinity of the dredge and barge. Conduct continuous fluorometric measurement of chlorophyll.

3. Submit quarterly report.

Fifth Quarter

1. Continue quarterly sampling programs as well as conduct laboratory analyses of field samples.

2. Participate in the third high resolution survey in the immediate vicinity of the dredge and barge. Make continuous fluorometric measurement of chlorophyll.

3. Submit quarterly report.

Sixth Quarter

1. Continue quarterly sampling programs as well as conduct laboratory analyses of field samples.

2. Submit quarterly report.

Seventh Quarter - End of Phase I dredging

1. Continue quarterly sampling programs as well as conduct laboratory analyses of field samples.

2. Conduct the final survey of lobster population at the disposal area.

3. Submit quarterly report.

Eighth Quarter - Phase II dredging begins

1. Continue quarterly sampling programs as well as conduct laboratory analyses of field samples.

2. Prepare and submit final report detailing the impact of Phase I dredging.

# APPENDIX E

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