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AIMS & SCOPE OF THE JOURNAL

The *Journal of Dredging* is published by the Western Dredging Association (WEDA) to provide dissemination of technical and project information on dredging engineering topics. The peer-reviewed papers in this practice-oriented journal will present engineering solutions to dredging and placement problems, which are not normally available from traditional journals. Topics of interest include, but are not limited to, dredging techniques, hydrographic surveys, dredge automation, dredge safety, instrumentation, design aspects of dredging projects, dredged material placement, environmental and beneficial uses, contaminated sediments, litigation, economic aspects and case studies.

APPLICATION OF THE DREDGED MATERIAL WASTE ASSESSMENT GUIDELINES: A CASE STUDY FROM NEW HAVEN HARBOR, CONNECTICUT, USA

Thomas J. Fredette[1]

ABSTRACT

The international Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention) of 1972 regulates waste disposal into the world's oceans and has developed Waste Assessment Guidance, a systematic framework used to classify the quality of dredged sediment and aid regulators in the identification and implementation of management alternatives. The framework encompasses such factors as dredged material suitability, disposal and use options, impact hypotheses, monitoring, and compliance. The dredging of New Haven Harbor, CT, USA in 1993 is used to illustrate these evaluative steps in action. One million m^3 of sediment was planned for dredging. An alternatives analysis determined that open water disposal was the best method of disposal. Extensive testing involving physical, chemical, and biological testing in three "tiers" deemed outer harbor sediment environmentally suitable, but inner harbor sediment unsuitable for unconfined open-water disposal due to amphipod toxicity. Inner harbor sediment was thus disposed of at a disposal site in Long Island Sound in a ring of previously created sediment mounds and capped with outer harbor sediment. The site has been monitored using a variety of tools. Monitoring has demonstrated benthic recovery on the mound and no acute toxicity. Recolonization has been somewhat slower than expected, however, likely due to highly organic sediment and seasonal hypoxic events that occur throughout Long Island Sound.

INTRODUCTION

Waste disposal into the world's oceans is regulated under the international Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972. More commonly, this agreement is referred to as the London Convention as a result of the location where the international drafting group met. The United States, along with 78 other coastal countries, is a signatory to the Convention. This international agreement, revised with the drafting of what is termed the 1996 Protocol, regulates a number of wastes, including fish wastes, vessels, sewage sludge, platforms, geologic materials, dredged material, and others. Separate waste assessment guidelines for each of these categories have been developed to help participating countries with implementation of the Convention. The objective of this paper is to provide a tangible example of the use of evaluative steps under the Convention guidelines developed for assessment of dredged material (Scientific Group, London Convention, 2001) in the context of the U.S.-developed evaluation approach (EPA/USACE, 1991, 1998). Both the Convention guidelines and the U.S. approach are designed to be tiered processes that not only

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provide a logical, consistent framework for evaluation, but are intended to allow decision-making (project approval or denial) at the end of each tier if the collected information is sufficient and unambiguous. The specific example used is the dredging of New Haven Harbor, Connecticut in 1993.

Project Background

New Haven is located on the shores of Long Island Sound in the northeast United States. The harbor is served by a 10.7 m deep channel about 7.2 km long and varying in width from 120 to 240 m (Fig. 1). Adjacent to the channel is a 10.7 m deep turning basin and a five m deep anchorage. Three smaller channels lead up the tributary rivers.

New Haven Harbor is the second busiest port in the six-state New England region, supporting 24 commercial terminals. Products handled by the terminals include petroleum products, scrap metal, lumber, steel, cement, chemicals, and general cargo. New Haven Harbor is also important for recreational activities and commercial fisheries use, primarily oyster harvesting and lobster fishing. Maintaining the navigation channel is the responsibility of the United States Army Corps of Engineers (USACE), New England District, headquartered in Concord, Massachusetts.

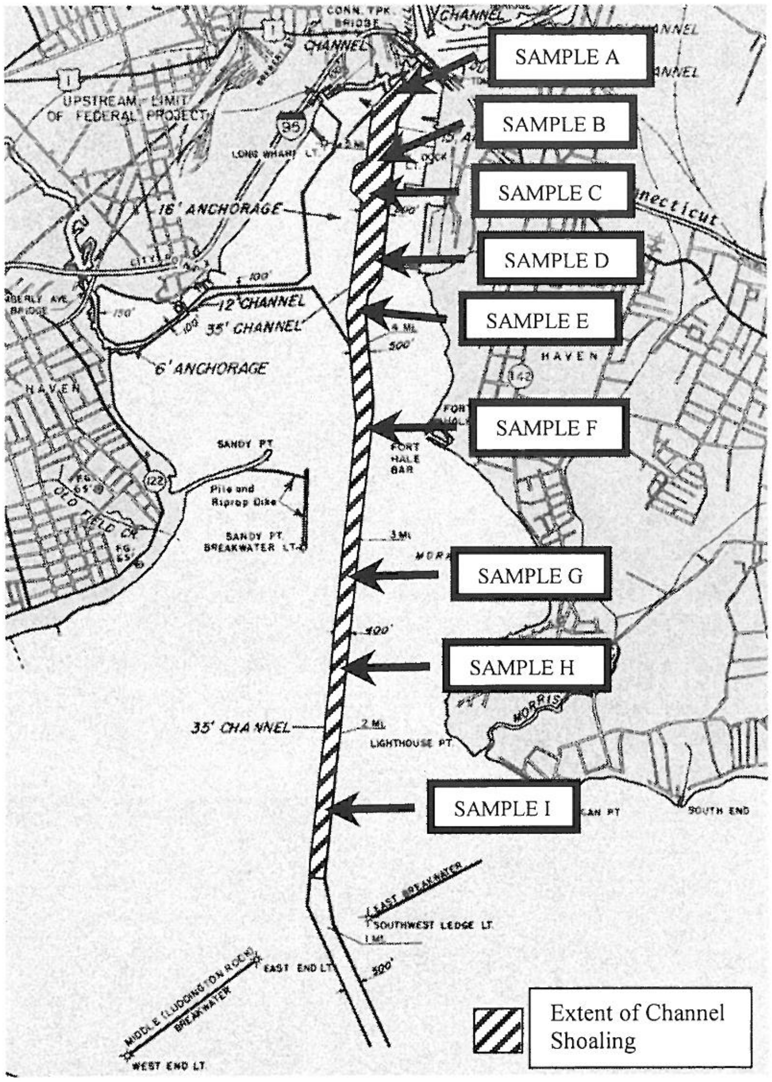

Figure 1. New Haven Harbor channel and sediment sampling stations.

Overview of the Waste Assessment Guidance and U.S. Tiered Testing

A framework for evaluating dredged material has been developed in accordance with the Convention that illustrates the steps for making management decisions on dredging projects (Fig. 2). When dredging is deemed necessary, several key factors must be considered, including the character of the material, its potential disposal and use options, and project compliance. Potential for beneficial use of the sediment and treatment needs are also addressed during the process. The U.S. sediment evaluation process fits into the Dredged Material Characterization step of the Waste Assessment Guidance and consists of inter-connected tiers.

The New Haven Harbor example addresses all of these steps, though as is often the case in project development, the steps do not always adhere to the linear depiction of the framework (Fig. 2). At times steps are sequential, but often they may be occurring in parallel or in a slightly different order depending on the specifics of the individual project. The key for project success is that each of these steps be addressed in the process. These steps are illustrated in the following sections.

Need for Dredging

To maintain access to harbor docking facilities, dredging was needed to remove channel shoals formed since the last dredging in 1983. The controlling depth of the channel had been reduced to 8.2 m. To return the channel and adjacent navigation areas to their authorized dimensions, 1,000,000 m^3 of sediment needed to be dredged. The area needing dredging extended from the head of the channel to a location just inside the breakwaters that protect the harbor entrance (Fig. 1).

Dredged Material Characterization

The U.S. testing approach consists of up to four evaluative tiers. Each successive tier involves more intensive testing and evaluation of the sediment if information gathered for the lower tier is insufficient to make a project decision. Tier 1 involves evaluation based on existing or easily collected information on the project itself or neighboring areas that have been previously tested. Tier 2 involves water quality and bioaccumulation screening. Tier 3 requires bioassay and/or bioaccumulation testing. Tier 4, not illustrated below, could involve any number of project specific studies including pilot tests or assessments of toxicity or bioaccumulation under field conditions.

Tier 1. The first step in characterizing the sediments to be dredged was a review of historical information from the harbor area. The channel had last been sampled prior to maintenance dredging in 1983. Several nearby ship berths had also been tested by their owners for separate permit applications. In addition, spill records and discharge permits from local industries and

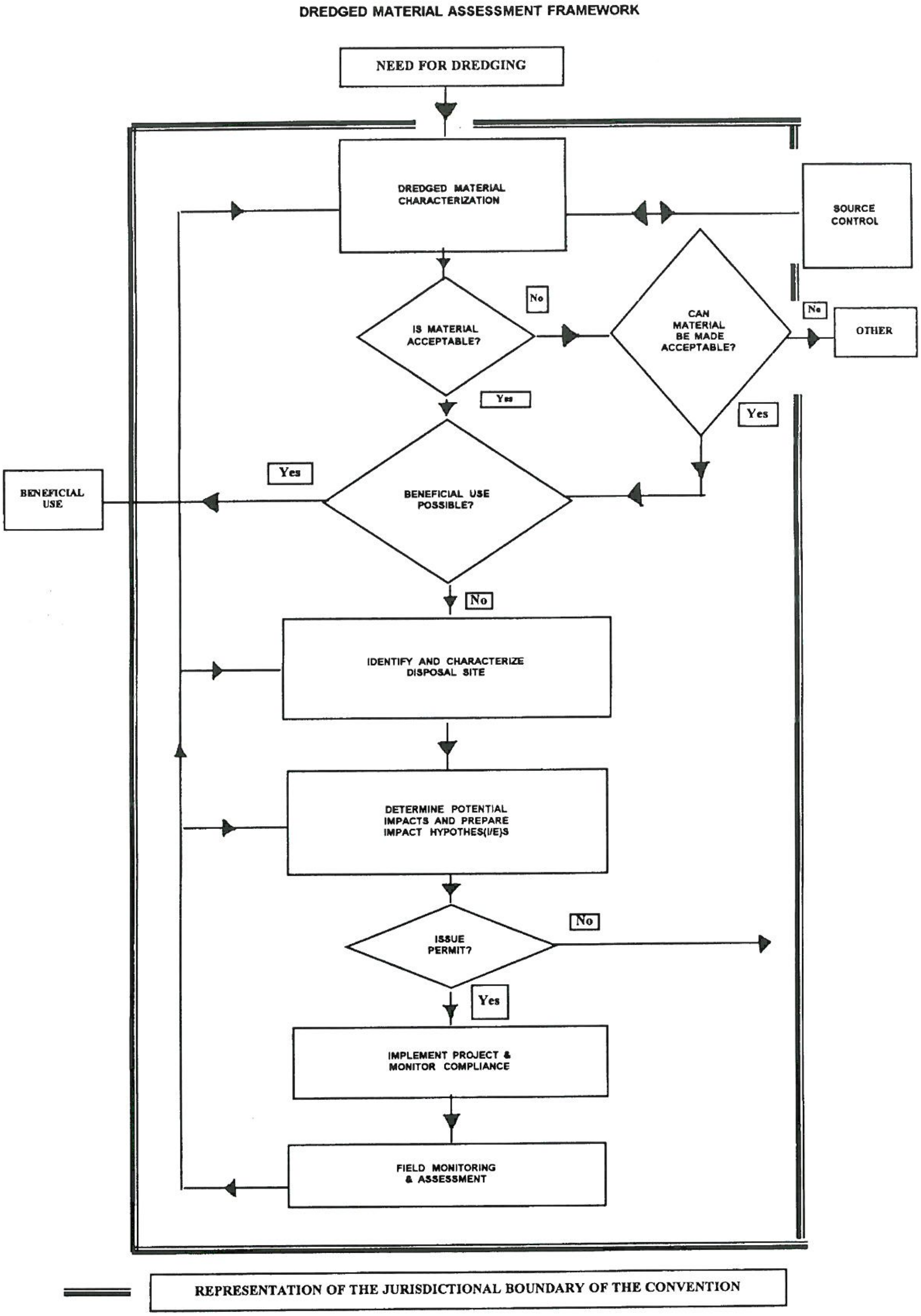

Figure 2. Dredged material assessment framework (reproduced from "Specific Guidelines for Assessment of Dredged Material," International Maritime Office).

municipal wastewater treatment plants provided information on discharges into the harbor. Review of these types of data comprise "Tier 1" in the U.S. evaluation protocols (EPA/USACE, 1991, 1998). Based on the information from these reviews, a list of contaminants of concern (COC) was developed (Table 1) and sampling stations were selected (Fig. 1).

Table 1. Contaminants of Concern

Mercury
Lead
Zinc
Arsenic
Cadmium
Chromium
Copper
Nickel
Polychlorinated Biphenyls (PCB)
Pesticides (18)
Polynuclear Aromatic Hydrocarbons (PAH)

The sediment to be dredged was then sampled for physical and chemical assessment. Core samples were taken to dredging depth at nine stations along the length of the channel (Fig. 1). Samples were more closely spaced in the inner harbor, where the contaminant concentrations were expected to be greater. Physical characteristics measured included grain size, percent solids, and Atterberg limits. The sediment ranged from 93 to 99% silts and clays and 30 to 40% solids.

Chemical testing entailed analysis of a suite of heavy metals and organic compounds (Table 1). Because initial results from the polynuclear aromatic hydrocarbon (PAH) testing were substantially different from the testing done at adjacent projects identified in Tier 1, archived sediment from the first round of sampling was re-analyzed along with a second round of field samples to better assess the actual concentrations. These results indicated that the sediments, including the archival samples, had PAH levels comparable to those from the nearby projects and historically recorded concentrations. For this reason the results from the first round of sampling were determined to be unreliable. Metals and pesticide results from the first round of testing and PAH results from the second round of testing are shown in Table 2. Only the contaminants measured above detection limits are displayed. Metal concentrations were variable along the length of the channel, with the highest concentrations of arsenic, cadmium, and zinc at station A; mercury and lead highest at station I; and copper, nickel, and chromium peaking at station H. PAHs generally decreased along the length of the channel, although some individual PAHs peaked at station H (e.g., phenanthrene, fluorine, and benzo(a)pyrene). The only pesticide detected was heptachlor epoxide. Polychlorinated biphenyls (PCBs) were not detected.

	Sample Stations								
Analyte	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
% Fines (<63μ)	93	97	96	96	95	97	97	99	98
Metals (mg/kg)									
Mercury	0.15	0.21	0.18	0.1	0.19	0.22	0.24	0.24	0.28
Lead	67	98	32	47	90	100	80	98	106
Zinc	595	174	136	81	101	440	117	218	321
Arsenic	13.8	0.56	0.86	0.12	0.03	12.6	3.9	1.4	1.5
Cadmium	7.7	0.94	3.1	2.9	4.2	1.1	3.9	1.1	0.76
Chromium	163	168	168	266	320	220	278	318	162
Copper	109	99	111	279	260	340	258	420	149
Nickel	45	75	82	71	36	76	96	181	60
Organics (mg/kg)									
Heptachlor Epoxide	0.46	1.42	1.79	1.94	1.39	0.62	0.82	<0.01	0.53
Naphthalene	0.2	0.18	0.31	0.19	0.14	0.3	0.14	0.48	0.06
2-Methyl Naphthalene	0.09	0.06	0.12	0.06	0.06	0.1	0.09	0.21	0.05
Acenaphthylene	0.03	0.03	0.04	0.04	0.02	0.02	0.05	0.05	0.06
Acenaphthene	0.11	0.05	0.05	0.03	0.02	0.03	0.05	0.26	0.06
Fluorene	0.17	0.09	0.1	0.04	0.04	0.06	0.08	0.47	0.06
Phenanthrene	0.69	0.34	0.55	0.29	0.33	0.45	0.36	1.07	0.18
Anthracene	0.27	0.11	0.13	0.08	0.08	0.1	0.08	0.22	0.06
Fluoranthene	1.52	0.82	1.31	0.82	0.63	0.76	0.83	0.94	0.43
Pyrene	2.39	1.12	1.38	0.87	0.85	1.14	0.78	0.93	0.43
Benzo(a)anthracene	0.71	0.32	0.47	0.28	0.27	0.39	0.28	0.31	0.19
Chrysene	0.73	0.41	0.6	0.36	0.34	0.48	0.38	0.3	0.19
Benzo(b)fluoranthene	0.63	0.36	0.7	0.39	0.39	0.46	0.34	0.37	0.13
Benzo(k)fluoranthene	0.62	0.36	0.46	0.38	0.38	0.45	0.32	0.35	0.13
Benzo(a)pyrene	0.47	0.32	0.45	0.27	0.26	0.38	0.31	0.35	0.13
Dibenzo(a,h)anthracene	0.03	0.03	0.04	0.04	0.01	0.02	0.05	0.05	0.06
Benzo(g,h,i)perylene	0.03	0.03	0.31	0.19	0.17	0.26	0.3	0.29	0.06
Ideno(123-cd)pyrene	0.03	0.03	0.04	0.04	0.24	0.23	0.05	0.05	0.06

Table 2. Dry-Weight Bulk Chemical Results from Sediment Samples

Tier 2. Characterization under Tier 2 of the U.S. protocols involves comparison of potential contaminant releases to water quality criteria and calculation of Thermodynamic Bioaccumulation Potential (TBP) values. Historical data from other projects on the sediment to water partitioning of contaminants (elutriate data) were considered acceptable to estimate and compare contaminants to water quality criteria, in lieu of these additional, specific tests being done for the New Haven project. This analysis determined that, after allowance for initial mixing, no violations of water quality were expected.

The TBP analyses to estimate bioaccumulation (which is only applicable to non-polar organics) were not conducted, because the COC list contained both metals and non-polar organic contaminants and bioaccumulation tests were planned which would result in laboratory estimated bioaccumulation. Jumping to a higher tier after only partial evaluation with the lower tier, or even skipping a tier, is part of the flexibility that the system is intended to provide for both cost and time efficiency.

Tier 3. Biological assessment using acute toxicity and bioaccumulation assays were completed after the physical and chemical analyses of Tier 1 and the evaluations of Tier 2. The need for biological testing was based on the presence of elevated levels of several of the contaminants of concern. Biological testing was conducted on the same cores used for Tiers 1 and 2. Biological testing is usually conducted both on the sediment, or "solid," phase and on an aqueous/suspended phase. Acute toxicity testing of the aqueous/suspended phase of the sediment was not conducted for this study because water column impacts at the site were modeled previously for similar projects. This modeling predicted rapid mixing to below water quality criteria. The modeling was based on toxicity tests of 96-hr and 48-hr exposure of juvenile fish (*Menidia menidia*) and bivalve larvae (e.g. *Mytilus edulis*), respectively, to a dilution series of sediment elutriate extracts.

For the solid phase testing, two sediment composites were prepared and divided into five replicates each. One composite was made up of sediments from stations A, B, C, and D (composite 1) and the other composite was a combination of stations G and H (composite 2) (Fig. 3). These composites were selected based on proximity and general similarity in contaminant concentrations. Because contaminant concentrations at E, F, and I were lower than at the composited stations, the composites represented "worst case" conditions.

Acute, solid phase toxicity tests were conducted in the laboratory by exposing marine benthic amphipods (*Ampelisca abdita*) to the composite replicates and to Long Island Sound reference sediment for 10 days. Average amphipod survival was significantly lower in composite 1 compared to reference (Table 3; based on

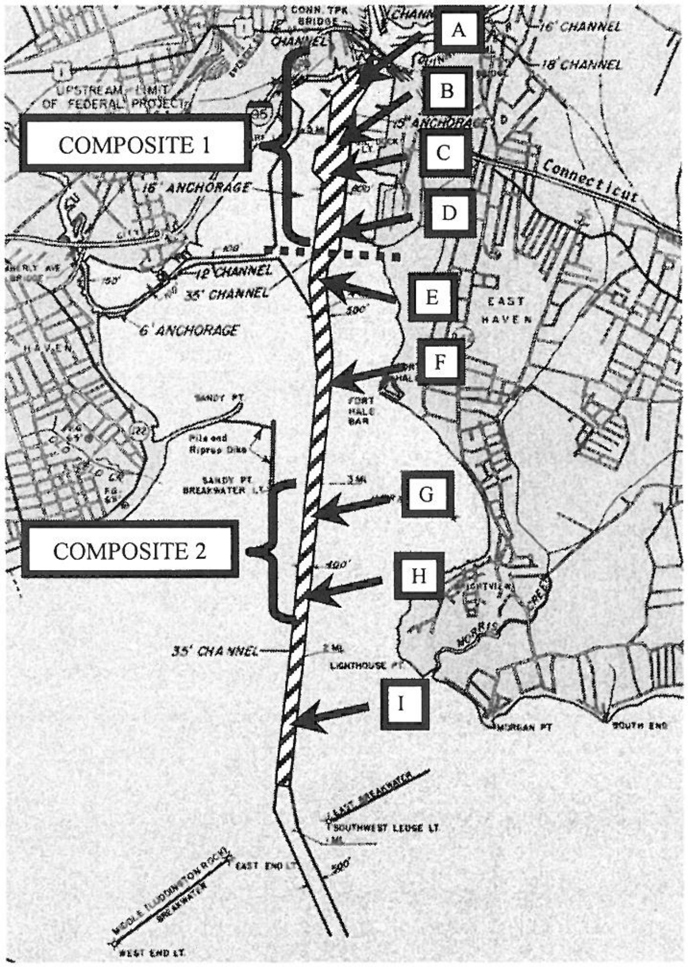

Figure 3. Biological sampling composites.

analysis of variance with α=0.05). Composite 1 survival was more than 20% lower than reference, indicating a negative finding in the assessment (the 20% difference criteria is based on national policy guidance for amphipod tests (EPA/USACE, 1991, 1998)). Composite 2 showed no statistically significant difference from reference. Control samples, used to assure test procedure acceptability, all exceeded 90% survival.

Based on results of previous bioaccumulation tests at nearby sites and a background station in Long Island Sound, PAHs, pesticides, zinc, cadmium, and copper were selected as analytes for the bioaccumulation test. For this laboratory test, marine bivalves (*Macoma nasuta*) and marine polychaetes (*Nereis virens*) were exposed to the composite, reference, and control replicates for 28 days. These species were selected because their body mass is relatively large (50 g wet weight per replicate is needed for chemical analysis) and they are known to accumulate contaminants. In addition, these species provided an assessment of potential toxicity to a wider range of invertebrate species. Contaminant concentrations after the 28-day exposure to composites 1 and 2 were not significantly different from those in reference samples (data not shown; based on analysis of variance with α=0.05). Survival was also not significantly different between composite and reference conditions (Table 3).

Table 3. Mean Survival in the Acute Toxicity and Bioaccumulation Tests

	% Survival		
Sample	10-Day Amphipod	28-Day Polychaete	28-Day Bivalve
Control	92.2	91.5	93.3
Reference	86.6	90.0	94.6
Composite 1	51.0	88.0	90.0
Composite 2	81.3	93.0	90.6

Evaluation – Is Material Acceptable?

Inner harbor sediments, represented by composite 1 (stations A through D), were deemed unsuitable for unconfined open-water disposal due to the observed amphipod toxicity. Sediments represented by composite 2 (stations G and H), however, were not different from reference and thus determined suitable for unconfined open water disposal. Because contaminant concentrations were lower at stations E, F, and I than at stations G and H, sediments represented by stations E, F, and I were also determined suitable for unconfined open water disposal.

Evaluated Beneficial Use/Characterize Disposal Site

Open water disposal was selected as the most practicable alternative for this project. The sediment was more than 90% silts and clays, disqualifying it for beach nourishment. Creation of salt marshes or islands in the harbor or along the nearby coastline was incompatible with existing uses or resources (e.g., fishing areas, shellfish beds) and counter to environmental regulations that discourage the filling of aquatic sites. Upland disposal was determined impractical, due to the complicated logistics of de-watering and trucking the sediment and the absence of acceptable sites with sufficient capacity (estimated need of >26 hectares). The open water site proposed for this project is about 8 km from the mouth of New Haven Harbor and has been used for at least the last 50 years for disposal of sediments from this and other regional projects. Long-term monitoring of the disposal site has revealed minimal environmental impact.

Management Decisions – Can Material be Made Acceptable?

Capping the sediments from the inner harbor at a nearby open-water disposal site in Long Island Sound was selected as the most practical way to minimize potential adverse impacts from these sediments. To maximize cap success, a location surrounded by previously created sediment mounds was selected (Fig. 4). These topographically higher features were used to limit the lateral spread of the inner harbor disposal material and thus facilitate capping. This bowl-like feature on the seafloor had been intentionally created for this purpose through planned management of the disposal site (Fredette, 1994). Sediment from the outer harbor was used as a cap for the unsuitable material. This resulted in 590,000 m^3 of sediment from the inner harbor being capped by 569,000 m^3 from the outer harbor (volumes based on barge estimates).

Impact Hypotheses

The impact hypotheses from this project included both the success of the cap operations and the response of the marine benthic community to the disposed sediments. It was hypothesized that the bowl-like feature of historic disposal mounds would help to limit the spread of the sediments. This would enable the capping to occur using a smaller volume of sediment than would normally be necessary without such lateral confinement. Secondly, it was hypothesized that the cap could be successfully placed over the inner harbor sediment. The third hypothesis was that once disposal was completed the marine benthic animals would recolonize the sediments and develop into a community similar to reference sediments in two to three years. This last expectation was based on the results of the tiered testing, which is designed to predict response of the biological community. Therefore, if no adverse effects are observed in the laboratory tests, then the sediments should be environmentally suitable after disposal. Monitoring at the disposal site during and following the dredging and disposal was designed to test these hypotheses.

Project Compliance

A contractor to the USACE dredged the harbor and disposed of the sediment as planned, with outer harbor sediment capping inner harbor sediment. USACE inspectors and a hydrographic survey crew were on site to observe and review the work of the contractor. Representatives of environmental resource agencies also visited the site to observe the work in progress. In addition, every barge disposal event at the open-water site was observed by an independent certified disposal inspector, who rode the tugboat to and from the dredging site.

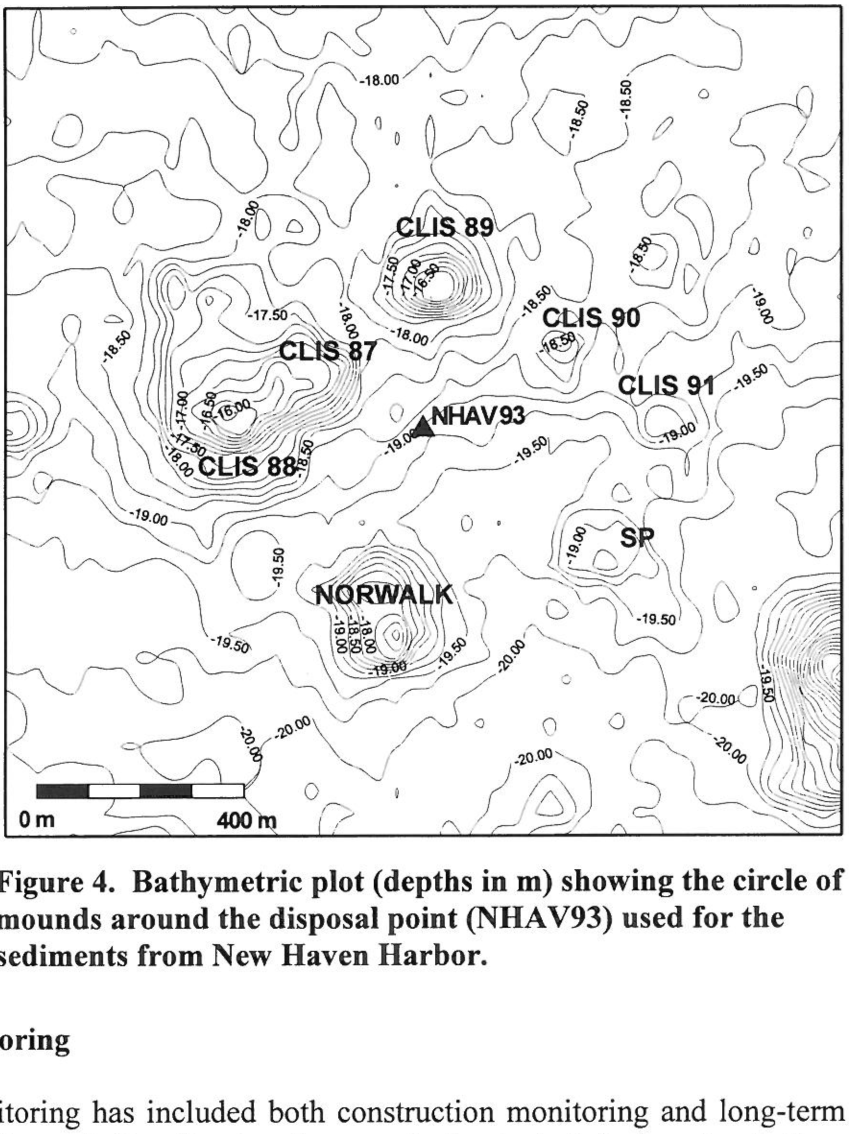

Figure 4. Bathymetric plot (depths in m) showing the circle of mounds around the disposal point (NHAV93) used for the sediments from New Haven Harbor.

Field Monitoring

Project monitoring has included both construction monitoring and long-term monitoring at the open-water disposal site. Construction monitoring included a baseline bathymetric survey of the seafloor where the sediment was to be placed, interim surveys during placement of the sediment needing capping and of the cap, and a post-cap survey (Fredette, 1994). Long-term monitoring has been conducted under an umbrella of a tiered design (Fredette et al., 1986; Germano et al., 1994) and has included additional bathymetric surveys, coring, sediment profile camera photos, and sediment toxicity testing (Morris et al., 1996; Morris, 1997; Morris, 1998). Sampling conducted for a separate study, which included solid phase toxicity tests, has confirmed the benthic community recovery and lack of acute toxicity of the deposit (ENSR, 2000, 2001). Recolonization on this mound has been somewhat slower than expected, likely due to the highly organic sediment and seasonal hypoxic events that occur throughout Long Island Sound. These potential causes of slow recolonization are supported by subsequent toxicity testing on mound sediment. Monitoring of the mound is continuing, however, and sediment from other projects may be added to the mound as a protective measure.

CONCLUSIONS

Application of the Waste Assessment Guidelines provides a systematic framework that can be used to classify the quality of dredged sediment and aid regulators in the identification and implementation of management alternatives. These, along with the U.S. sediment testing approach, provide a process that is intended to be a logical and consistent method for reaching decisions on sediment disposal projects. The compliance and monitoring aspects of the Guidelines serve as important components of the overall framework, assuring that the project is conducted as designed and providing important feedback on the strengths and weaknesses of the project design and sediment evaluation process. This interplay of evaluation, prediction, and feedback allows for a process that can evolve and strengthen with time and experience leading to greater acceptance by project proponents, regulators, and environmental interest groups.

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MANAGEMENT OF OCEAN DREDGED MATERIAL DISPOSAL SITES AT THE MOUTH OF THE COLUMBIA RIVER

Hans R. Moritz[1]

ABSTRACT

This paper describes the evaluation of sediment deposition and transport at ocean dredged material disposal sites located offshore of the Mouth of the Columbia River. The first half of the paper introduces the Mouth the Columbia River (MCR) navigation project and ocean dredged material disposal sites that have been used at the MCR since 1977. Changes in the life-cycle management for MCR ocean dredged material disposal sites (ODMDS) and present capacity limitations are highlighted. The second half of this paper describes the methodology used to justify expansion of existing MCR ODMDSs. Analyses used to predict behavior of dredged material when placed in open water are described. Expanded site boundaries are proposed.

INTRODUCTION

The deep draft navigation project located at the **Mouth of the Columbia River** (MCR) consists of a dredged navigation channel 5 miles long and 2,640-foot-wide which extends through a jettied entrance between the Columbia River and the Pacific Ocean (figure 1). Substantial quantities of sediments have been dredged near the Mouth of the Columbia River (MCR) since 1904, when dredging was initiated to maintain a 30-foot deep channel across the entrance bar formed by Clatsop spit. The natural channel had averaged about 25 feet deep and shifted frequently both during and between seasons. In order to establish a consistent 30-foot channel across the bar, the south side of the river entrance was jettied between 1885-1889. In 1914, the north side of the entrance channel was jettied to prevent shoaling from Peacock spit. The north jetty is approximately 2.5 miles long and the south jetty is 6.6 miles long.

The channel was deepened, via dredging, to its present authorized depth of 55 feet in 1984. The northerly 2,000 feet of the channel was deepened to 55 feet (plus 5-feet for over dredging), and the southerly 640 feet of the channel was deepened to 48 feet (plus 5-feet for over dredging). The MCR project has two main shoaling areas. The outer (ebb tidal) shoal extends from approximately river mile (RM) -2 to RM -0.8. The inner (flood tidal) shoal, Clatsop Shoal, extends from approximately RM 0.3 to RM 2.6, beginning on the south side of the entrance and crossing the channel near RM 1.0. In its present configuration, the entrance channel at MCR requires annual dredging of 3 to 5 million

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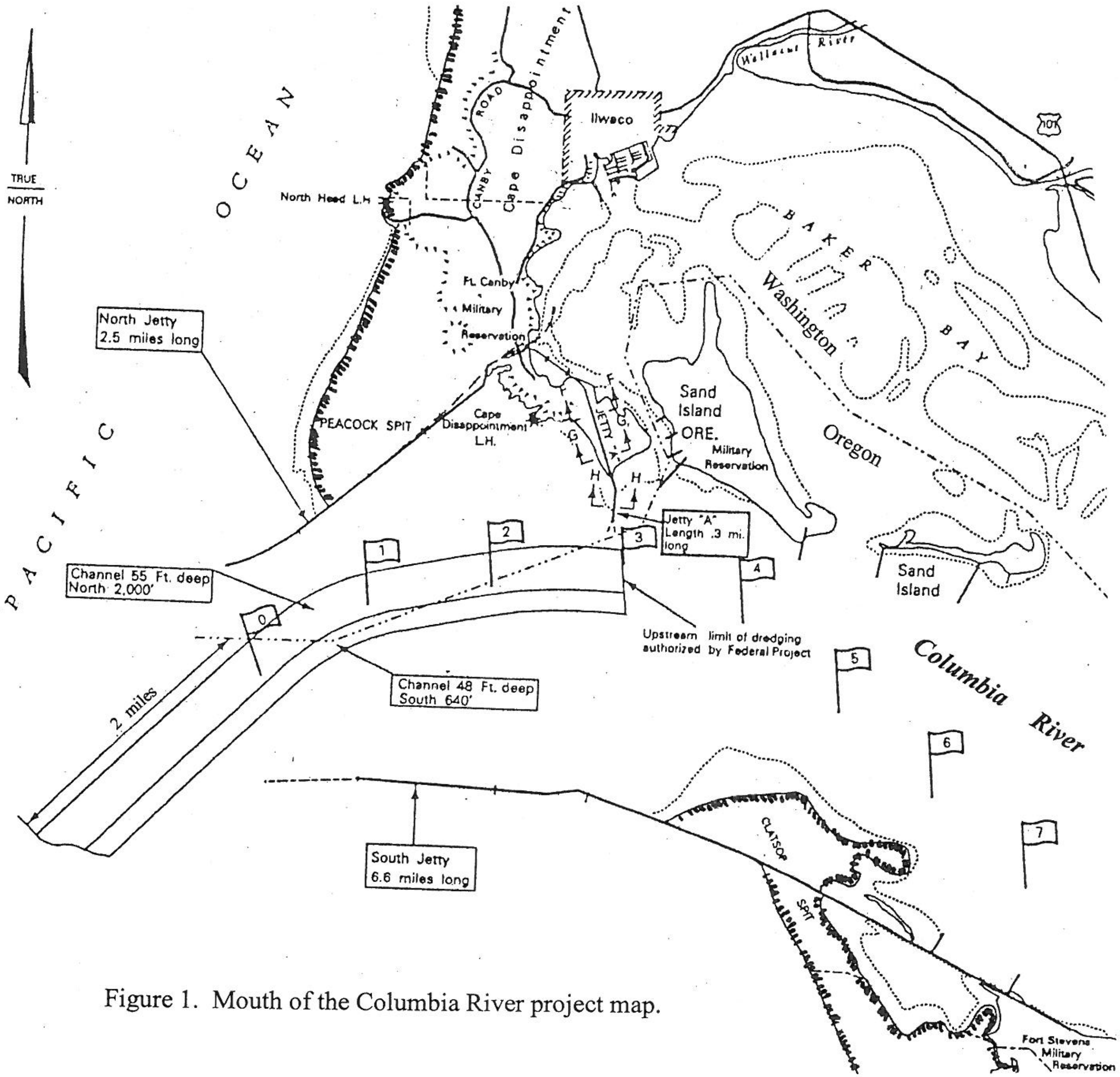

Figure 1. Mouth of the Columbia River project map.

cubic yards of fine-medium sand (97% sand and 3% fine grain sediment) to maintain the navigation channel at the authorized depth. Dredging at the MCR is performed by hopper dredges. The sandy dredged material is placed in EPA designated ocean dredged material disposal sites (ODMDS).

OCEAN DREDGED MATERIAL DISPOSAL SITES

Before 1977 (prior to EPA designation), MCR ocean disposal sites were not precisely specified and the placement of dredged material within the disposal sites was not strictly controlled. In January 1977, ocean disposal sites A, B, E, and F received interim designations when EPA issued the final Ocean Dumping Regulations (40 CFR 228). At the time of interim site designation, the boundaries for the rectangular disposal sites were fixed geographically in terms of corner coordinates.

Ocean dredged material disposal sites (ODMDS) A, B, E, and F received final designation in August 1986. Figure 2 denotes the official boundaries for the EPA interim-designated sites A, B, E, and F (dashed line). Since 1977, material dredged from the MCR project has been placed at sites A, B, E, and F. In 1993, ODMDSs A, B, and F were temporarily expanded to address increased capacity needs (figure 2, solid line). The volume of dredged material annually placed at MCR ODMDSs since 1977 is summarized below in table 1.

Table 1. Volume of dredged material placed at MCR ODMDSs from 1977 to 1996.

MCR Ocean Dredged Material Disposal Site	Volume of Dredged Material Placed 1977 - 1996
ODMDS "A"	24 million cy
ODMDS "B"	34 million cy
ODMDS "E"	37 million cy
ODMDS "F"	8 million cy

Since 1988, ODMDSs A and B have been the primary locations where MCR dredged material has been placed. These two ODMDSs are located on the westward boundary of the ebb-tidal shoal and are economical (in terms of haul distance) for disposal of sediments dredged from both the outer and inner bars at MCR. Since 1992, ODMDS B has received most of the MCR dredged material as concerns arose that sediments deposited in ODMDS A were accumulating, creating an adverse wave climate, and might migrate northward back into the entrance channel.

ODMDSs E and F have been used as secondary disposal sites for sediments dredged from the entrance channel at MCR. During 1988-1996, the volume of dredged material placed at ODMDS E was restricted to a maximum of 1 million cy annually. This was done to prevent overloading the site (prevent excessive mounding and reduce the likelihood of placed dredged material being transported back into the navigation channel) due to the small ODMDS boundaries. The continual, but limited, use of site E is partially in response to a request from the Washington Department of Ecology to enhance sand by-passing and retard erosion of the coastal beaches north of MCR. Use of ODMDS F has been limited due to its alignment with the MCR entrance (potential interference of hopper dredges with inbound/outbound vessels) and the site's longer haul distance from the point of dredging.

MCR OCEAN DREDGED MATERIAL DISPOSAL SITE MANAGEMENT

The transition in ODMDS management at MCR is characterized by several paradigm shifts in USACE and EPA policy. Prior to 1977, ODMDSs at MCR were sited only in terms of approximate location and areal configuration. Placement of dredged material within the ODMDSs was governed by the need to minimize navigational impact from dumped dredged material being transported back into the navigation channel. Mounding did not appear to be a major concern due to the spatial variability of dredged material disposal within a given site: The site boundaries were not fixed and it was not required to place material strictly within the disposal site. The operational "flexibility" of disposal site boundaries and vessel control during material placement resulted in a higher degree of dredged material dispersal during placement than at present. Prior to 1977, dredged material was placed over a wider areal expanse than the configuration of the ODMDSs indicate.

Between 1977 and 1986, the management of the ODMDSs at MCR was characterized by the transition from unregulated dredged material disposal to a regulated program. In January 1977, active ocean disposal sites at MCR received interim designations as such when EPA issued the final Marine Protection Research and Sanctuaries Act and associated regulations (40 CFR 228). The exact position for each of the interim ocean disposal sites was fixed by specification of the corner coordinates, by EPA, in order to abide by the rules of the MPRSA. The interim ocean disposal sites received final designation in August 1986. The final EPA approved configuration for each ODMDS was governed by the requirement to minimize the benthic area of impact due to openwater disposal of dredged sediments. The areal size of formally designated ODMDSs at MCR was based on:

- <u>ODMDS length</u> = average dumping run for one dump
  = (disposal vessel speed while dumping) **x** (time to empty disposal vessel).
- <u>ODMDS width</u> = average turn during one dump = disposal vessel turning radius while dumping.

- ODMDS axis orientation = preferential approach-heading during dredged material disposal. (site orientation is set by disposal vessel operators and is based on dumping efficiency and vessel sea-keeping due to incident wave direction).

Prior to the 1980's, sediment dredged at MCR and placed in ODMDSs was accomplished using only government hopper dredges. Government hopper dredges utilize a series of "doors" located on the hull bottom to gradually release dredged material from the vessel. Contractor hopper dredges normally used at MCR are split-hull vessels. Dredged material released from a split-hull hopper dredge is rapidly placed on the seabed, in a manner much more quickly (efficiently) than bottom-door hopper dredges. While the use of split-hull hopper dredges reduces the time required for material disposal, split-hull dredges reduce the horizontal dispersal of dumped dredged material on the seabed while increasing the vertical extent of accumulation per dump. Beginning in 1980, approximately half of the material dredged at MCR was accomplished using contractor split-hull hopper dredges. The use of split-hull hopper dredges likely accelerated the mounding of dredged material within the MCR ODMDSs.

After final EPA approval of the MCR ODMDSs in 1986, disposal site management has been progressively improved and enhanced in order to maximize site capacity utilization of the EPA designated ODMDSs. The unintended consequence of using the areally restricted ODMDSs has been creation of potentially adverse impacts to navigation at MCR, by mounding of placed dredged material. In 1990, accurate navigation and positioning control became available for hopper dredges operating on the open coast. The ship's position was known to several meters accuracy, on a real-time basis. Hence, the hopper dredges could reliably place dredged material within the assigned ODMDS locations during all times of operation [Soderlind 1995]. Instead of placing material within some marginal "radius" from a pre-determined location, hopper dredges could return to the exact assigned dump coordinate (ODMDS centroid) and place dredged material within a very limited area. The rapid accumulation of dredged material within ODMDSs A and B (formation of high mounds) during the late 1980s and early 1990s is attributed to three factors: (A) The restriction of dredged material disposal within relatively small EPA-designated ODMDSs, rather than in large unconfined areas and in a dispersive manner of placement. (B) Increased use of split-hull hopper dredges, which tend to enhance the vertical extent of dredged material placed on the seabed within the ODMDSs. (C) The improvement of ODMDS navigation in 1990 allowing for precise positioning control during disposal and repeated dumping at the same location.

Since 1986, dredged material placed within ODMDS A and B has accumulated at a rate faster than the Portland District had anticipated when the disposal sites were formally designated by EPA. Ocean dredged material disposal sites that were intended to be

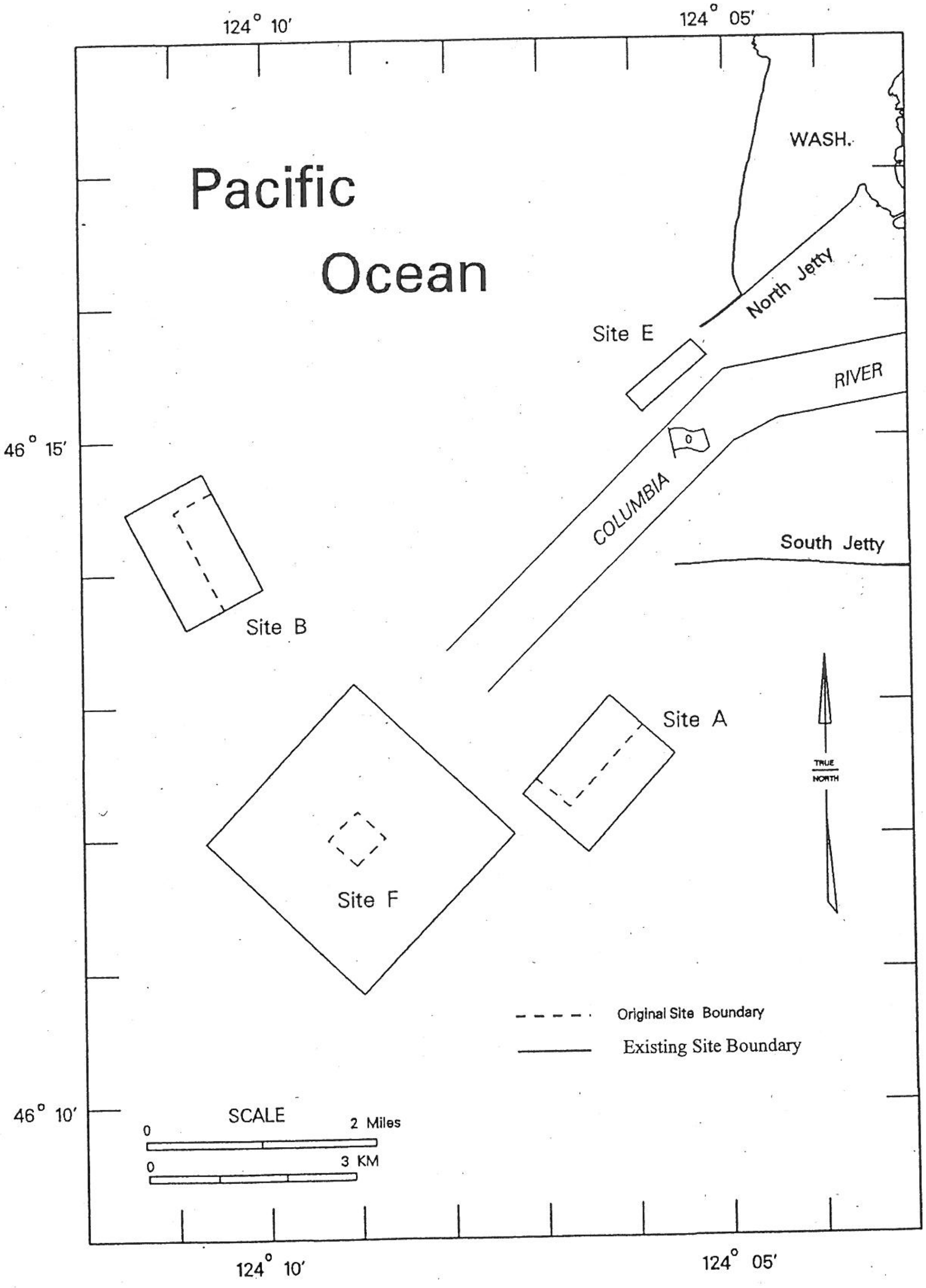

Figure 2. Mouth of the Columbia River - ocean dredged material disposal sites (ODMDS).

moderately dispersive and have a 20 year life-cycle, have reached capacity within 10 years of initial operation. ODMDS capacity is defined as that quantity of material that can be placed within the legally designated disposal site without extending beyond the site boundaries or interfering with navigation. Presently, exceedence of ODMDS capacity at MCR creates two regulatory/operational problems:

- The overall footprint of dredged material contained within existing ODMDSs extends beyond the sites' formally permitted boundaries, by as much as 3,000 feet in some cases.

- Dredged material within the ODMDSs has accumulated to an areal and vertical extent which may create adverse sea conditions. In some cases, mounds rise 40-70 ft above surrounding bathymetry. Mariners report that the ODMDS "mounds" cause waves to steepen or break in vicinity of the ODMDSs and that these wave conditions are hazardous to navigation at MCR.

Present Wave Conditions at MRC ODMDSs

The recent (1994) bathymetry for MCR and vicinity is shown in figure 3. Since 1985, unanticipated bathymetric mounding has occurred at ODMDSs A and B due to rapid accumulation of placed dredged material. The accumulation of dredged material at MCR ODMDSs during 1985 -1994 is illustrated in figure 4 (which is the sub-area "boxed" within figure 3). The top half of figure 4 shows the MCR bathymetry for 1985, the bottom half for 1994 (note the seabed change at ODMDSs A and B). The present dredged material mounding problem at MCR has now limited the annual volume of dredged material that can be placed at ODMDS A and B.

The issue of present dredged material mounds creating potentially hazardous wave conditions for navigation MCR is illustrated in figure 5. Results were obtained using a wave transformation model called RCPWAVE [Ebersole et al 1986]. RCPWAVE is a 2 dimensional numerical model that simulates behavior of waves as they are refracted and shoaled by the bathymetry that the waves pass over. It must be noted that results obtained using RCPWAVE can be higher than the actual case: The RCPWAVE program tends to overestimate how waves interact with variable bathymetry. The use of RCPWAVE reflects a conservative "precautionary" approach to ODMDS management, whereby any degree of potential change in wave amplitude was considered undesirable.

Figure 5 describes the estimated change (amplification) in wave height due to the change in bathymetry at MCR between 1985 and 1994 for 12-second period waves and include all likely directions of incident offshore wave approach. Effects due to currents are not included. The outline border for figure 5 corresponds to the "boxed" area shown in figure 4. Based on the above RCPWAVE model results, existing dredged material mounds at ODMDSs A and B may have increased the height of incident waves by 20% for 6-second waves and 50% for 12-second waves, as compared to 1985. The areas affected by

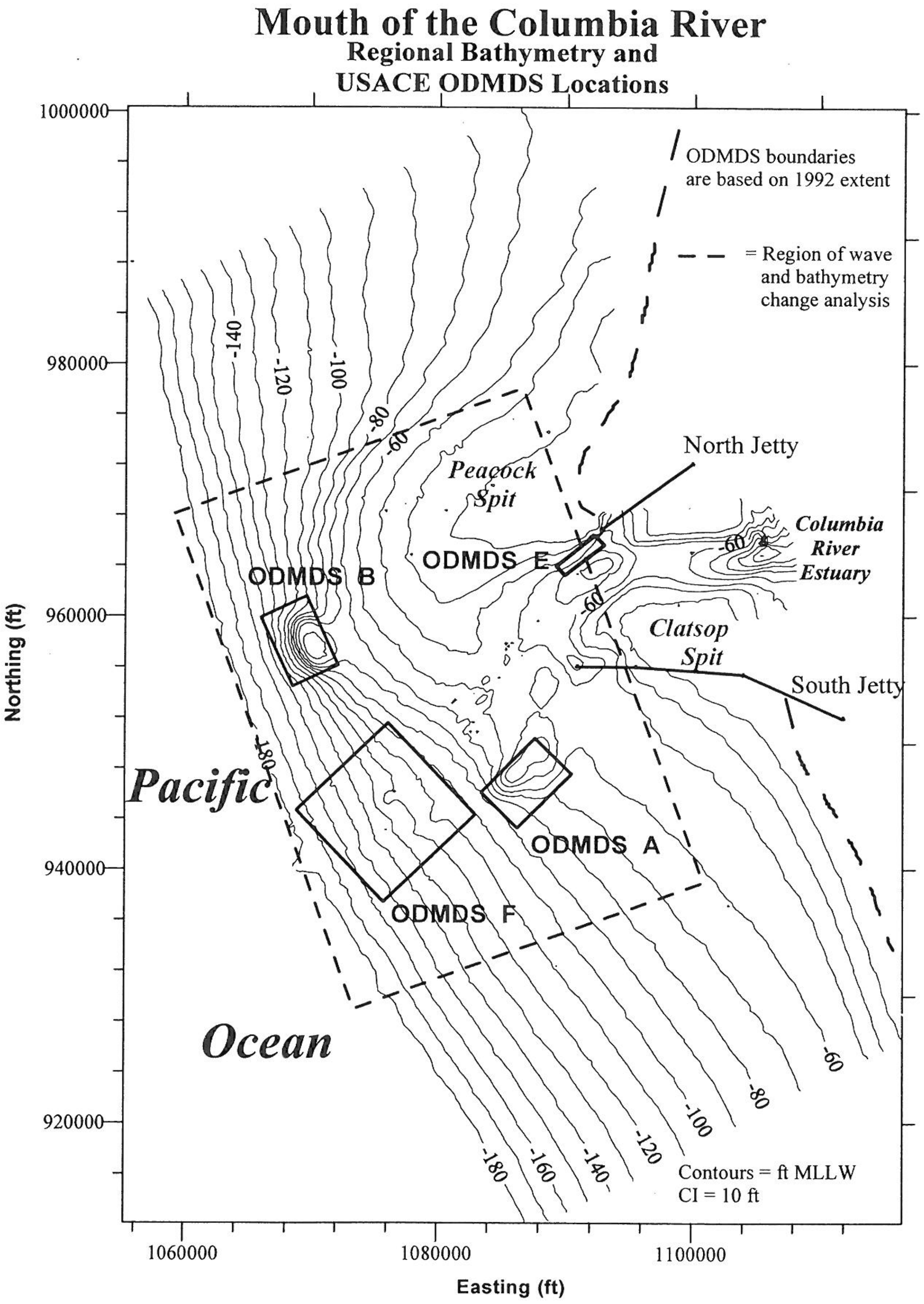

Figure 3. Regional bathymetry for MCR - 1994

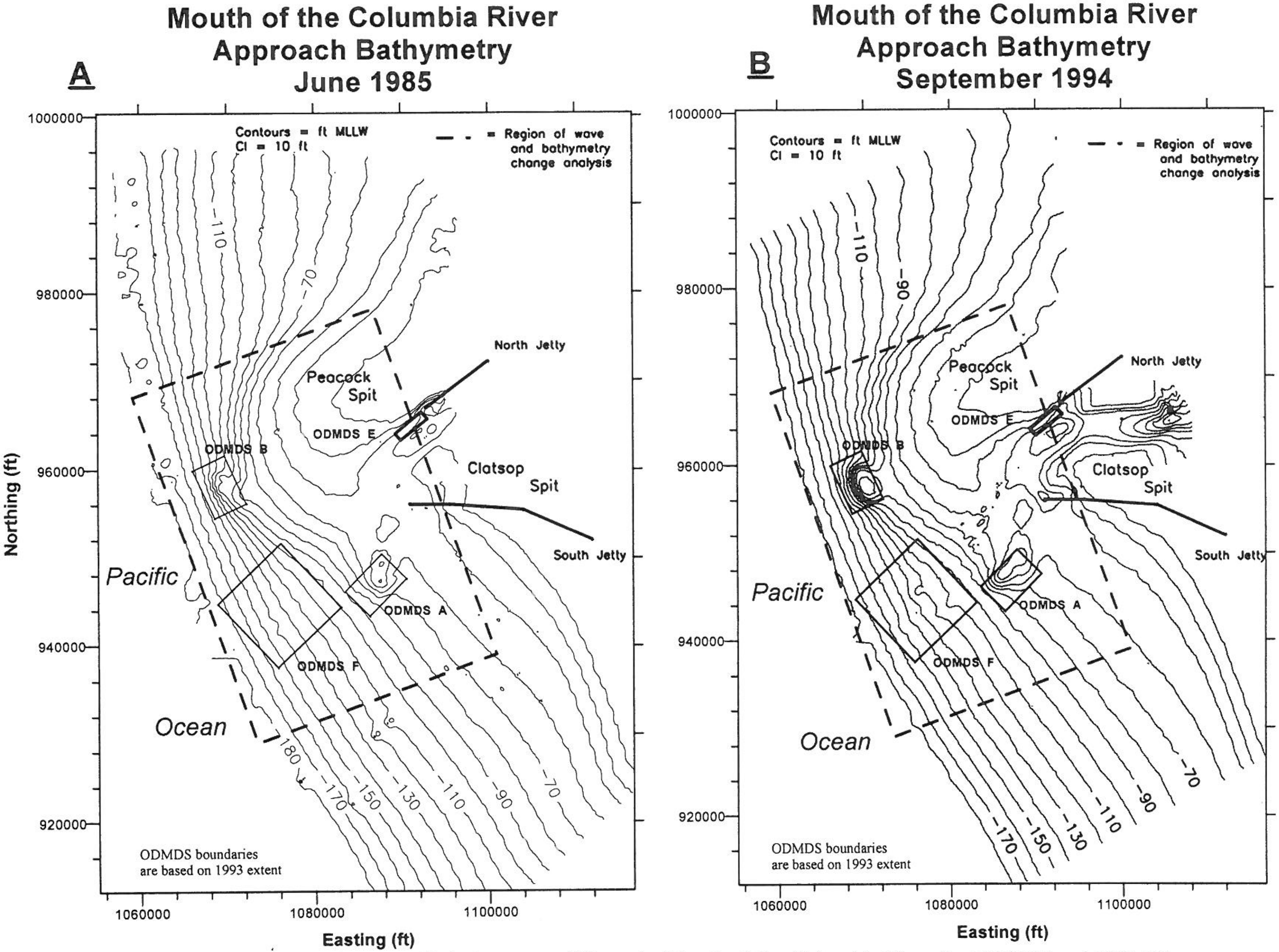

Figure 4. Regional (approach) bathymetry offshore the Mouth of the Columbia River for 1985 (A) and 1994 (B).

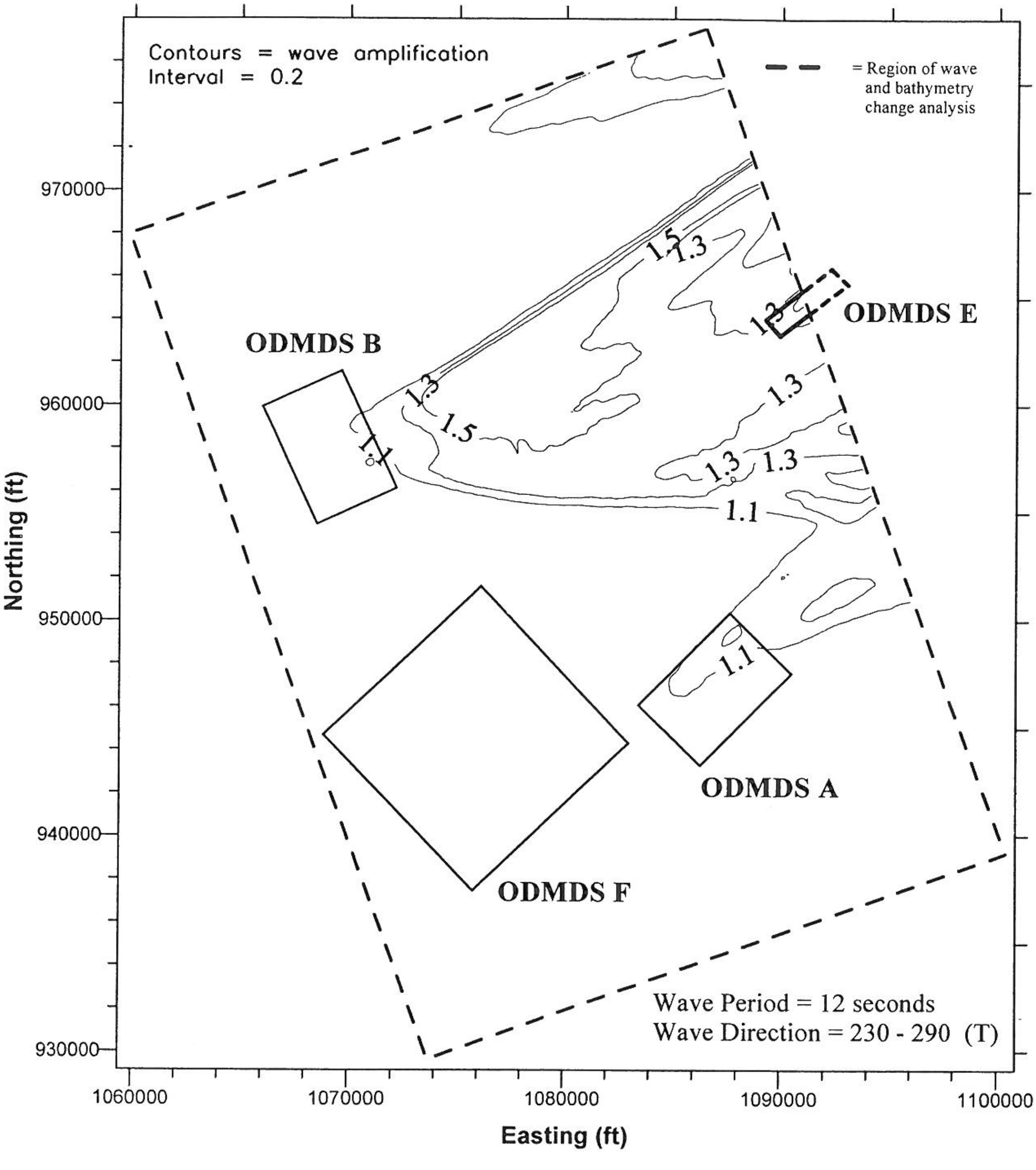

Figure 5. Estimated Wave Amplification at MCR Due to the Change in Bathymetry Between 1985 and 1997. Results based on RCPWAVE.

dredged material mounds at ODMDSs A and B are located immediately north and south of the MCR entrance. The safest ocean approach to the MCR entrance channel is now directly in-line with ODMDS F.

Present Site Capacity at MRC ODMDSs and Management Options

Due to rapid accumulation of dredged material (mounding problems) at ODMDSs A and B, those-two sites and site F were expanded in 1992 (figure 2, solid line). Despite the site expansions, placement of additional material at ODMDS A has been restricted and ODMDS B had been limited to 2 million cy/yr. After 1996, dredged material disposal within the existing site B boundaries will be further limited in terms of the location, timing, and volume of dredged material placed at this site.

By temporarily expanding ODMDS F by a factor of 20-fold, it was assumed that the capacity of site F to handle increased dredging disposal volume could be substantially increased. It was anticipated by USACE and EPA that dredged material disposal at sites A and B would be decreased while disposal at site F would increase due to its increased capacity: ODMDS F would become the primary ODMDS for MCR dredging disposal. The temporary expansion of MCR ODMDSs was intended to "buy time" until additional studies could be completed and final expanded or new ODMDSs could be designated. Based on studies recently completed by the Portland District, it was determined that ODMDS F does not to have the capacity to accept large volumes of placed dredged material. Several observations regarding ODMDS F follow:

- Total cumulative mound height at ODMDS F should be kept under 13 feet (as compared to 1992 bathymetry) in order to avoid adverse navigation impacts due to wave amplification.
- For future dredged material disposal at ODMDS F, only the northwestern half of the site should be used in order to minimize mounding and associated impacts to the local wave environment.
- The estimated capacity remaining within the northwestern half of ODMDS F is approximately 10 million cy, assuming that the dredged material is optimally distributed (using thin layer disposal). If dredged material is not optimally distributed, the remaining capacity in site F is about 7 million cubic yards.
- The remaining capacity in ODMDS F will facilitate 2 - 3 years of MCR dredged material disposal, assuming all MCR material is placed at site F. The entrance channel at MCR requires annual dredging and ocean disposal of 3-5 million cubic yards of fine-medium sand. Placing more than 1 million cy/yr at site F is not desirable, due to excessive interference of disposal operations with inbound /outbound shipping traffic.

Dredged material placed in ambient water depths at ODMDS F (-100 to -180 ft MLLW) does not significantly disperse in the longterm time-frame. This was concluded from long-term fate calculations (greater than 1 year) for dredged material behavior at ODMDS F. The water depths at this location would preclude any dredge from re-working placed dredged material to mitigate for inadvertent mounding problems caused by dredging disposal.

ODMDS F is in the direct line of approach to the MCR entrance channel. Columbia River bar pilots use the area as a staging location for transferring pilots to vessels of commerce. ODMDSs A and B have been used to an extent at which safe navigation may be presently impaired at or near these sites, due to significant mounding and related wave conditions. If similar conditions were created at ODMDS F, overall navigation at MCR may be impaired. Based on the above, either new ODMDSs must be economically sited or existing MCR ODMDSs must be expanded (excluding site F) in order maintain the navigation channel at the MCR.

Designation of new ODMDSs at MCR is currently being initiated through the Columbia River Channel Deepening Feasibility Study and EIS, which will require 3 more years to fully coordinate (1999). Until new MCR ODMDS are formally designated, the only feasible option for providing an additional 3-4 million cy/yr disposal capacity for the MCR navigation project is to temporarily expand existing candidate ODMDSs. The expanded ODMDSs would be used for dredged material placement until which time new ODMDSs are formally designated. As a conservative estimate, the expanded sites were expected to be utilized for 5 years, beginning in 1997.

Rationale for ODMDS B and E Expansion

ODMDSs A and F were not be considered for site expansion (continued operational use) for reasons previously discussed. This rationale left ODMDSs B and E as the only remaining candidate sites available for temporary expansion. Both sites B and E were expanded to allow for greater operational flexibility and minimize the potential impacts associated with using a single ODMDS for all MCR disposal needs.

During a 5-year utilization period, expanded ODMDSs B and E will need to accept up to 25 million cy of dredged material (5 million cy/yr). Although ODMDS F could accept 1 million cy/yr, its was not included in this analysis to ensure project capacity is met, in the event that navigation interests require limited use of site F. Initially, the proposed boundaries for expanded ODMDSs B and E were configured as shown in figure 6. Expanded site B would be approximately 12,000 ft x 12,000 ft. Expanded site E would be approximately 2,500 ft x 10,000 ft.

Initially, expanded site B was expected to receive 4 million cy/yr of dredged material. Expanded site E would receive 1 million cy/yr, due to its proximity to the MCR

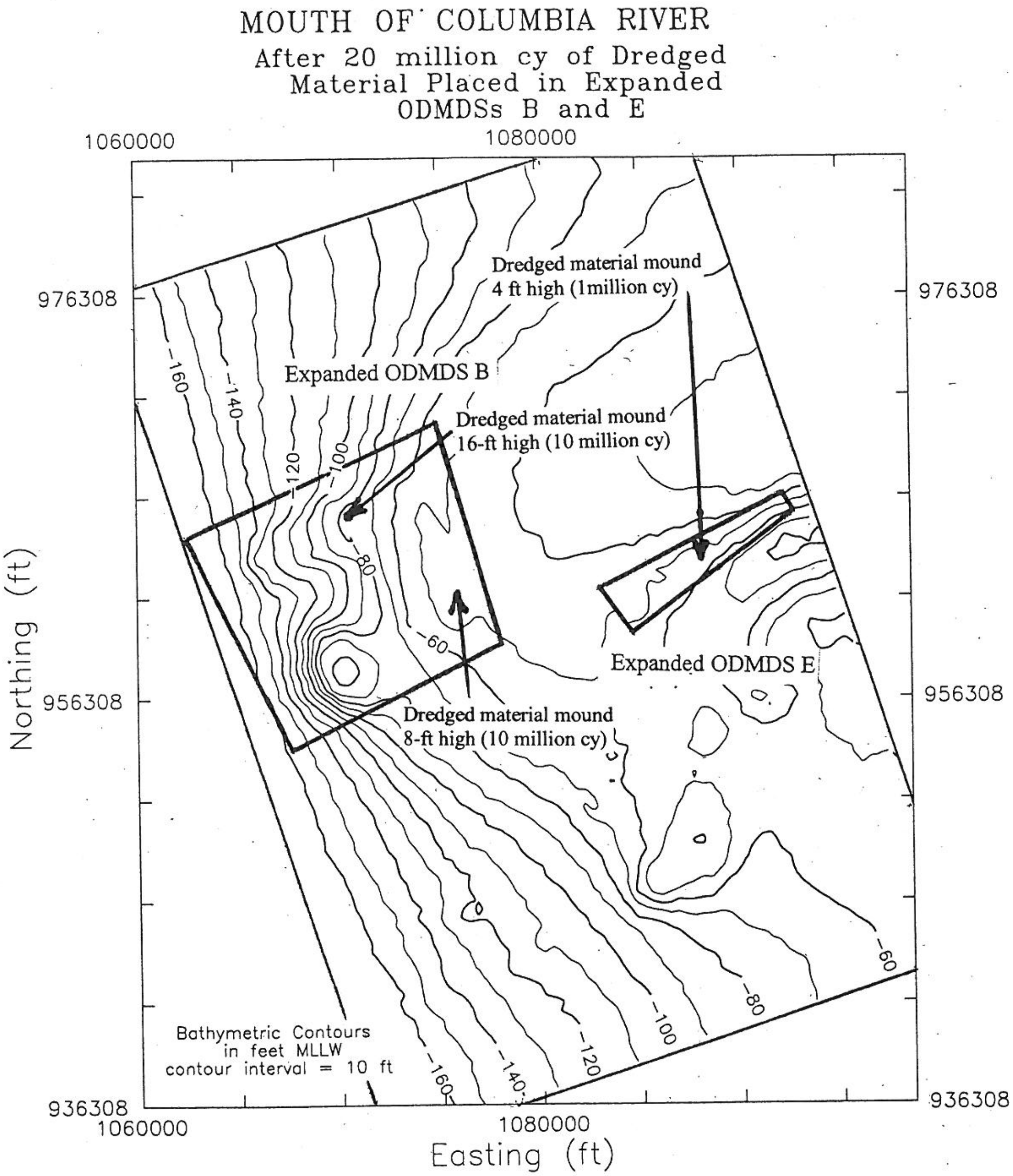

Figure 6. Regional View for Predicted Mound Bathymetry for Expanded ODMDSs B and E.

navigation channel (concern that material may be transported southward into the channel). It is anticipated that increased volumes of dredged material could be placed within expanded site E, as site monitoring results warrant. This measure would reduce the volume of material to be placed in site B.

IMPACT ASSESSMENT FOR EXPANDED ODMDSs

The Ocean Dumping Act and Clean Water Act require that field-verified, state of the art procedures be used for the assessment of possible physical impacts due to the operation of proposed ODMDSs. A key to successful ODMDS designation and management is knowing in advance (or reliably predicting) the fate of dredged material placed at the ODMDS. To meet this need at MCR, the MDFATE numerical model [Moritz and Randall 1995] was used for the analysis of dredged material placed at expanded ODMDS B and E.

MDFATE is a 2-dimensional numerical model which simulates short-term (minutes to hours) and long-term (days to years) behavior of dredged material placed in open water. Short-term considerations govern the behavior of the dredged material as it falls through the water column and accumulates on the seabed, on a per dump or disposal sequence basis. Long-term considerations govern dredged material behavior after the material comes to rest on the seabed and include: transport due to waves and currents, avalanching, and self-consolidation. The MDFATE model predicts the change in bathymetry at an ODMDS resulting from a series of "dumps" and simulates long-term change of the resultant bathymetry. MDFATE uses components of the STFATE model [Johnson 1995] and the LTFATE model [Scheffner 1995] to simulate a disposal operation which could extend over a year and consist of hundreds of "dumps". The model accounts for overall disposal operation and long-term environmental processes. Disposal vessel, water column, dredged material, wave, current, and tidal parameters are included in the MDFATE model. The FATE models were developed under the USACE sponsored Dredging Research Program.

Results from the numerical modeling of dredged material behavior at MCR guided the proposed ODMDS expansion and ensured that management of the sites meets operational requirements. Modeling results were also used to determine the potential impacts of dredged material placement into the expanded boundaries of ODMDSs B and E. Site impact assessments focused on:

- Wave conditions - The use of expanded ODMDSs would not increase (worsen) the wave environment at the MCR approaches more than 10% over the present (baseline) condition. The 10% criteria was based on the capability to measure or predict changes in wave conditions within the ocean. Any wave changes below this threshold were deemed to be within the "noise level" of predicting/measurement; changes above 10% would be an indication that a real change was likely.

- Impacts to benthic in-fauna - The use of expanded ODMDSs would minimize potential impacts to benthic in-fauna. A per disposal event (single hopper load) burial depth of 0.33 ft was determined to have minimal impact on crabs and flatfish; whereas a 0.80 ft burial event could impact 50% of the affected crabs/flatfish [Antrim and Gruendell 1998]. The maximum (per disposal event) burial depth of 0.80 ft should not be exceeded per disposal event.

- Transport of dredged material into the littoral zone - The transport of dredged material placed within the expanded ODMDSs would be maximized, within context to minimizing wave and benthic community impacts.

Utilization of Expanded ODMDS B

The proposed configuration for expanded site B was intended to minimize haul distance from the site of dredging in the MCR navigation channel, while maximizing the return of dredged sediments back to the littoral environment. Minimum existing water depth within the expanded site B boundaries is 50 ft, as compared to 90 ft for the present site B boundary (excluding the mounded area). A 50-foot water depth is considered a minimum safe navigable depth for hopper dredges operating at the western flank of Peacock Spit. During the 5 year period of expanded site operation, the entire ODMDS B was assumed to receive a total of 20 million cy. It was initially assumed that half of the material to be placed in expanded ODMDS B, would be placed in the shallow part of the site (10 million cy during a five year period). The deeper part of the site would receive the other half of the dredged material volume (10 million cy during a five year period).

Dredged material placement within shallower area (50-70 ft) of expanded ODMDS B would be conducted in manner which would avoid formation of any mound feature greater than 8 ft in height. Applying 10 million cy into the formation of a mound 8 ft tall, would require dimensions of: 5,900 ft long, and 3,400 ft wide with 0.012 side slopes. Within the deeper part (80-160 ft) of expanded site B, dredged material placement would avoid formation of any mound feature greater than 16 ft in height. Applying 10 million cy into the formation of a mound 16 ft high, would require dimensions of: 4,500 ft long, and 4,100 ft wide with 0.012 side slopes. Figure 6 shows the configuration of expanded site B with the addition of the two mounds. It was anticipated that by limiting dredged material accumulation as indicated above, the wave environment at MCR would not be worsened due to mound induced refraction-diffraction. Increasing wave height (sea and swell) greater than 10% of the existing (non-mounded) bathymetric condition was considered unacceptable.

Utilization of Expanded ODMDS E

ODMDS E is a highly dispersive site. The proposed configuration for expanded site E was intended to take advantage of the high rate of sediment dispersion which occurs at site E. Material which is placed within the present boundaries of site E (1 million cy/yr) does not accumulate within the site: Some of the material is transported northward onto Peacock spit during Fall and Winter where it is re-introduced into the littoral system north of MCR.. During summer, the littoral transport at Site E is believed to be southward toward the navigation channel. Expanded site E would be in similar water depths as the present configuration. Dredged material placement within expanded site E would be conducted in manner that would avoid formation of a large-scale mound feature greater than 4 ft in height. If a distinct mound feature did form at expanded site E, it is anticipated that would not remain for more than one year before being obliterated by the site's wave and current regime. The formation of a mound 4 ft tall containing 1 million cy of sediment (one year of disposal) would correspond to 5,200 ft long and 1,000 ft wide (0.012 side slope). It is highly unlikely that this type of bathymetric feature would form at an energetic site such as ODMDS E: It was only considered from the stand-point of a conservative site impact assessment. Figure 6 shows the configuration of expanded site E with the addition of the mound as described above.

Initially, expanded ODMDS E would receive 1 million cy/yr of dredged material disposal. As confidence is gained concerning the favorable disposition of placed material (site surveys indicate that material is not accumulating in the expanded site or moving into the navigation channel), the annual volume of dredged material placed into site E will be increased. At this point, the amount of dredged material placed into expanded site B will be reduced. This scenario will enhance the transport of dredged sediment into the littoral environment of Peacock Spit, while minimizing benthic impacts to biota at site B.

Bathymetry Impact Assessment: Short-Term Fate Modeling

Bathymetric impacts are defined in terms of the short-term behavior of dredged material; as dredged material is being released from the disposal vessel and impacts the seabed. The STFATE model was used to predict the bathymetric distribution ("foot-print") of dredged material after it has been placed at a disposal site and has passed through the water column, on an individual dump (disposal vessel load) basis. The STFATE model accounts for various disposal vessel, water column, and dredged material parameters. The objectives of the short-term fate assessment were to: (A) Determine the disposal foot-print geometry in terms of thickness and areal extent. This data provides insight to the potential bathymetric impacts in the immediate vicinity of disposal; and (B) Determine the distance that placed dredged material is displaced away from the point of release: This parameter describes the ODMDS "buffer zone" which is needed to keep material within the disposal site boundary while the placed material is falling through the water column.

Short-term fate simulations were conducted for the disposal of dredged material from two types of hopper dredges: (A) a split-hull hopper dredge - *Newport*; and (B) a multiple bottom door hopper dredge - *Essayons*. Operating parameters for each dredge are shown in table 2. Short-term fate simulations were conducted for disposal water depths ranging from 40 to 200 ft. Three types of current conditions were also tested: No current, a 1 ft/sec current , and a 4 ft/sec current. Currents were modeled as being oriented 45° into the heading of the disposal vessel. The current regime at MCR ODMDSs ranges from 0.5 ft/sec to 5 ft/sec. The characteristics of sediment dredged from the MCR project and placed at ODMDSs are described as: Dredged material type = fine to medium sand, SP (D_{50} = 0.20 mm); Fines content ($D<0.0625$ mm) = 3 % (silt); $C_{s(disposal)}$ = concentration of solids by volume in the disposal vessel = 0.485; and e_d = depositional void ratio = 1.062 (S.G.of dredged material solids = 2.71).

Table 2. MCR hopper dredge operating parameters.

DREDGE	OVERALL DIMENSIONS			CAPACITY	VESSEL SPEED	DISPOSAL	DURATION
	length (ft)	beam (ft)	draft (ft) loaded/empty	average (cy)	during disposal (knots)	vessel type (# of doors/size of each)	placement of each load (minutes)
Newport	300	55	20/10	3,000	2 to 6	split-hull/ 200x30 ft	4 to 8
Essayons	350	68	27/15	4,500	2 to 8	bottom doors(12)/ 8x8 ft	6 to 12

As dredged material is released from a disposal vessel and falls through the water column, the material mixes with ambient environment and forms a plume. The dredged material plume slowly settles to the seabed under the influences of gravity and the ambient current environment. The time required for dredged material to fall to the seabed and completely settle out of suspension is largely dependent upon the water column environment and the material type placed at a given disposal site. At MCR ODMDSs, approximately 96% of dredged material placed is composed of sand and 4% is composed of fines (silt), on a per load basis. Short-term fate (STFATE) modeling results are summarized graphically in figure 7 and are described below for parameters governing mound thickness, mound width, and displacement distance.

Mound length is directly related to disposal vessel speed and dump duration. For normal operating conditions, the *Essayons* produces a mound foot-print 1,800-2,100 ft long for water depths ranging from 40 to 200 ft, respectively. The *Newport* produces a mound foot-print 1,200-1,500 ft long for water depths ranging from 40 to 200 ft, respectively.

For similar operating conditions (vessel speed, water depth, and currents), the larger the disposal vessel capacity, the thicker the resultant mound foot-print. For average operating conditions in 60 feet of water, without a current, the dredge *Essayons* will

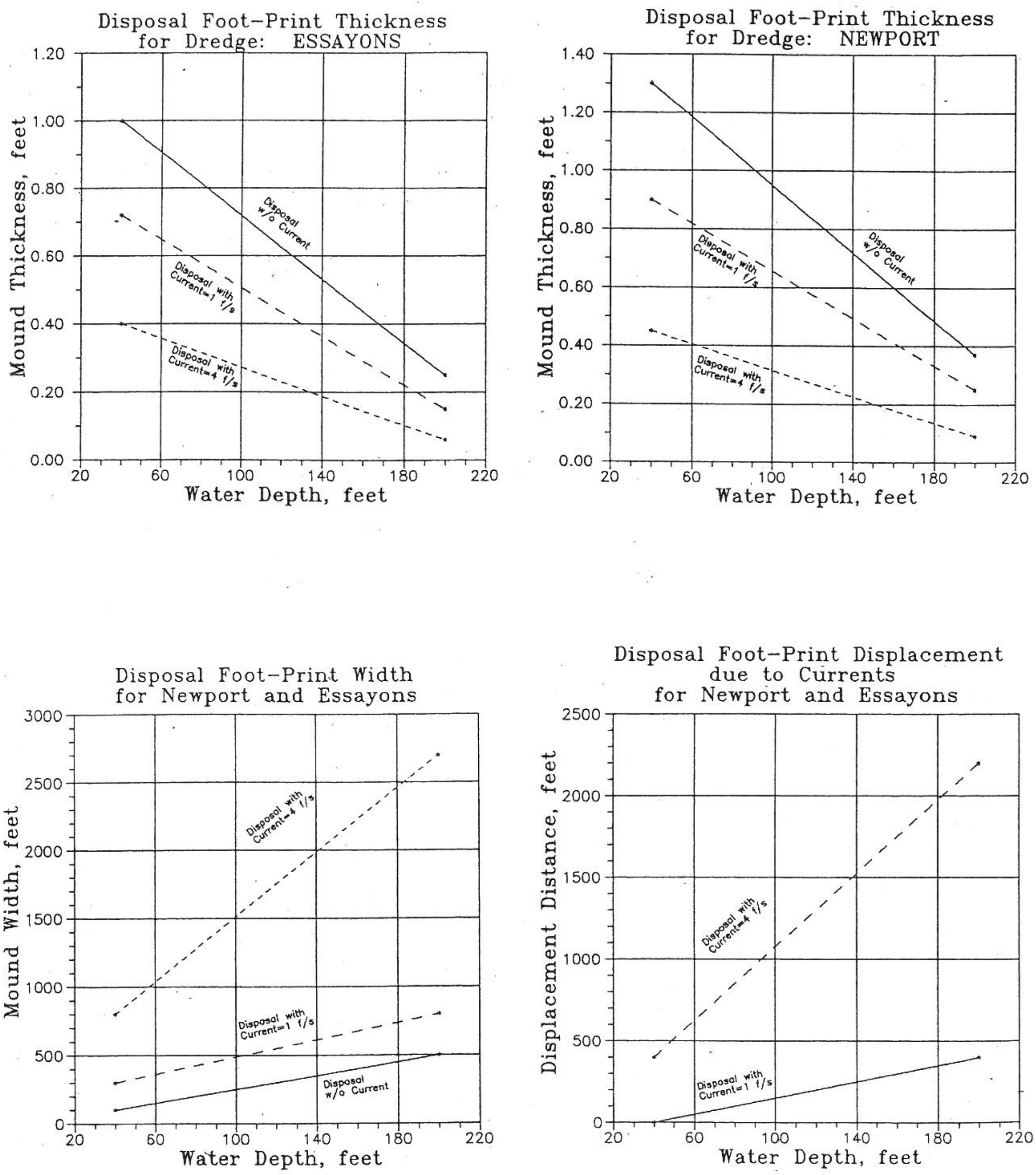

Figure 7. Top graphs are predicted thickness for dredged material disposal foot-print per dump for: *Essayons* (top-left) and *Newport* (top-right). Bottom graphs are predicted disposal footprint geometry: Bottom-left graph is dump footprint width. Bottom-right graph is displacement distance (offset) due to current.

produce a deposition mound 0.9 ft thick (high). The *Newport* will produce a mound 1.2 ft. high. The most significant parameter affecting mound geometry (width and height) is water depth . Increasing the water depth by a factor of 3 (60 ft to 180 ft) will decrease disposal mound height for a single dump by a factor of 2 for both hopper dredges. Increasing the water depth by a factor of 3 (60 ft to 180 ft) will increase disposal mound width for a single dump by a factor of 2.5 for both dredges. This applies to dredges disposing in all current conditions tested. Increasing current speed from 1 to 4 ft/sec (in 60 ft of water) reduces mound height by a factor of 2 for both dredges. The presence of a current acts to displace placed dredged material away from the location of release, before the material impacts the seabed. For disposal in a water depth of 180 ft, a 1 ft/sec current will displace dredged material 400 ft from the site of disposal before most of the material hits the seabed. For the same water depth, a 4 ft/sec current will displace dredged material 2,000 ft from the site of disposal before most of the material hits the seabed.

Sediment Transport Assessment: Long-Term Fate Modeling

The long-term fate of dredged material that is expected to be placed within expanded ODMDSs B and E was assessed using the MDFATE and LTFATE models. Transport of sediment "off" of the dredged material mounds was simulated for a period of one year for the mound configurations within the expanded ODMDSs (figure 6). Results from the long-term fate simulations for ODMDS B are summarized below in terms of applicable current seasons: (A) April - June = no net movement of mounded dredged material; (B) July - October = very little (17,000 cy) movement of sediment to the SW, mound height reduction was less than 0.5-foot; (C) November - March = appreciable sediment movement (1,465,000 cy) to the NW, mound height reduction 2 ft for the 16-foot high deep-water mound and 6 feet for the 8-foot high shallow-water mound.

The above results for expanded ODMDS B indicate that the spring and summer seasons produce little sediment transport or mound movement. The winter season produces appreciable sediment transport of dredged material placed at site B. Based on the simulation results, the shallow water area of expanded site B has favorable potential for dispersing placed dredged material and re-introducing dredged sediments into the littoral zone.

Results from the long-term fate simulations for ODMDS E are summarized below in terms of applicable residual current seasons: (A) July - October = movement of sediment (160,000 cy of the 1 million cy simulated) was to the SW, mound height reduction 2 feet for the 4-foot high mound; (B) November - June = significant sediment movement (660,000 cy of the 1 million cy simulated) to the N, mound height reduction 3.5 feet. Long-term fate results for expanded site E clearly indicate that this site is dispersive in terms of transport of dredged material placed on the seabed. Given the

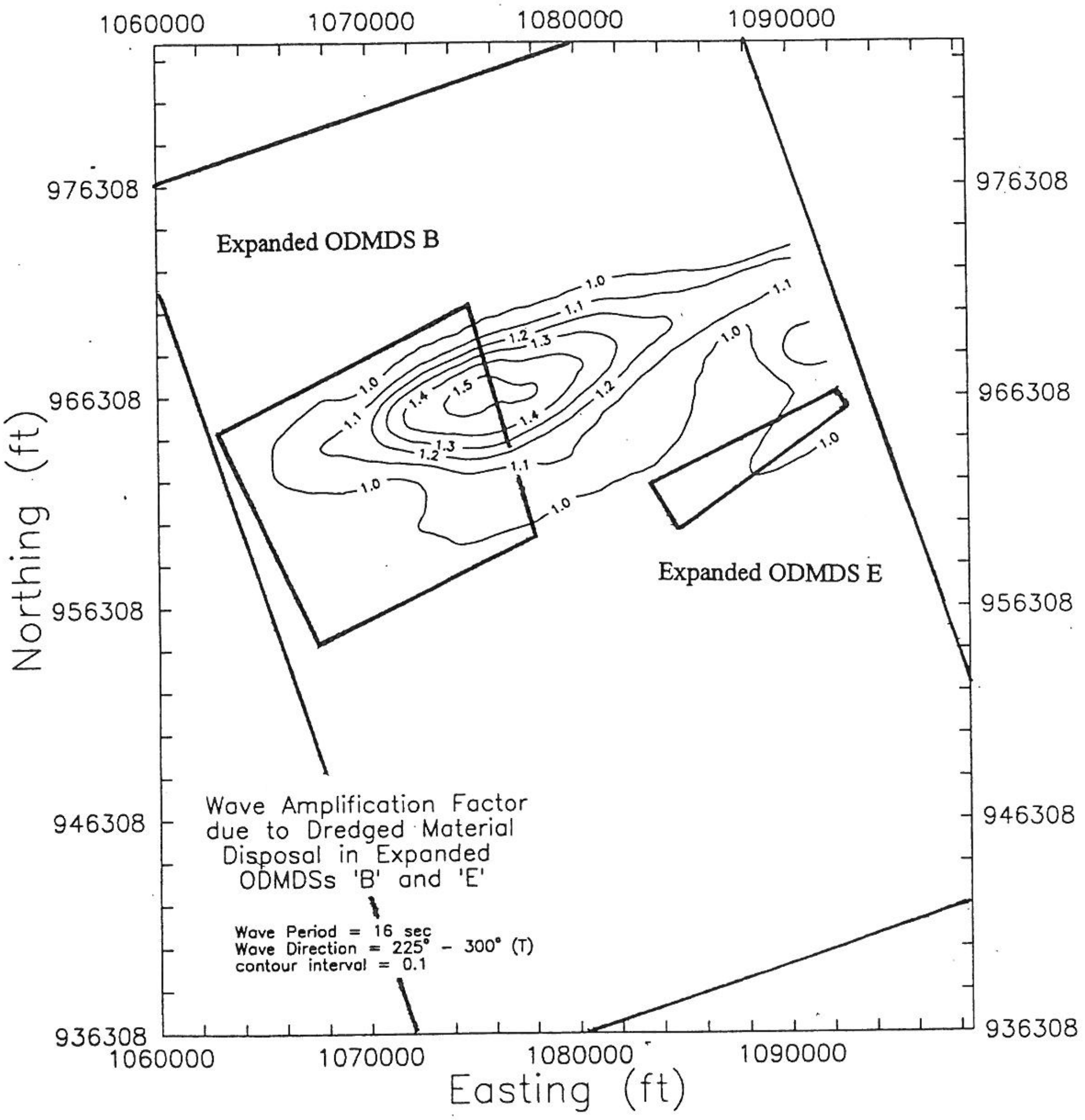

Figure 8. Wave Analysis Results for 16 second Wave Period over Mounded Bathymetry.

amount of sediment transport predicted for 1 year, it appears that 1 million cy of dredged material could be dispersed annually at this site. Based on the above results, the direction of sediment transport during the summer is toward the southwest (SW). A SW transport direction would disperse placed dredged material back into the navigation channel: An unacceptable outcome. This trend concurs with field experience at ODMDS E. Dredged material is not placed at site E during early to later summer, due to migration of the material into the MCR navigation channel. During the Winter and Spring season, a 4-foot high dredged material mound at site E would be completely dispersed toward the north, away from the navigation channel and onto Peacock spit: A highly desirable result assuming that dispersed dredged material does not re-accumulate in a manner which hazards navigation.

Wave Assessment for Dredged Material Placed at Expanded ODMDSs

Changes in wave height at MCR due to bathymetric changes at expanded ODMDSs B and E were estimated using the RCPWAVE model. The "mounded" configuration accounts for 20 million cubic yards of dredged material placed within expanded ODMDSs B and E (figure 6). Waves were transformed from offshore through the area of interest. The RCPWAVE simulation was performed for a wave period of 16 seconds and offshore incident wave direction of 225° to 300°. Results for the mounded bathymetric condition were compared to the "baseline" condition to derive an estimate of wave amplification.

Wave amplification results are shown in figure 8. The 10% criterion is exceeded within the expanded ODMDS B by the "mounded" bathymetry configuration shown in figure 6. Both the deep-water and shallow-water mounds (16-foot and 8-foot high, respectively) within ODMDS B contribute to exceedence of the wave criterion. The 4-foot high mound within ODMDS E does not affect the wave environment at MCR.

CONCLUSIONS

Maintaining a navigation channel at an ocean entrance is two-fold operation: A) Shoaled sediment is dredged from the navigation channel and; B) The dredged sediment is placed at a disposal site. There can be no dredging without some sort of disposal operation (which necessitates a disposal site). Although the navigation channel is considered "the" project feature, ODMDSs are legitimate project features and require a rationale for design, utilization, and designation. Design and management of an ODMDS is predicated on the need to achieve full utilization of the site while minimizing impacts to navigation and the environment. This paper presents the results of managing ODMDSs at the mouth of the Columbia River (MCR), and summarizes the approach used to "design" the temporary expansions of two key sites.

The 5-mile long deep draft entrance channel at MCR requires annual maintenance dredging of 4.5 million cy. The disposition (disposal) of MCR dredged material is a major consideration. Navigation impacts associated with ODMDSs at the MCR are related to wave shoaling/refraction, caused by large mounds formed by dredged material disposal. Potential environmental impacts of MCR ODMDSs deal with the effect of dredged material disposal on the commercial bottom fishery (crab and bottom fish). An additional environmental consideration for MCR ODMDSs is associated with the littoral disposition of sand dredged from MCR; many regional stakeholders view dredged sand as a resource to be placed (kept) within the littoral zone north and south of MCR. In 1997, MCR ODMDSs did not have sufficient capacity to safely accept additional dredged material disposal for an additional 5 years. To provide additional 5-years of disposal site capacity, until a new ODMDS could be formally designated, sites B and E were expanded.

To avoid exceeding the 10% wave amplification criterion at ODMDS B, the accumlation of dredged material within the expanded area of the site, less that 60 ft deep, can not exceed 4 ft high. Within the expanded area of ODMDS B where water depth is 100-130 ft, dredged material accumulation should not exceed 8 ft. With these constraints, the capacity of the expanded area of ODMDS B is limited to about to 7 million cubic yards (1.5 million cy/yr for 5 years). To permit disposal of 20 million cubic yards of dredged material in ODMDS B without negatively affecting the wave environment (due to mounding), the site's boundaries must be expanded well beyond the proposed configuration shown in figure 6. The optimal configuration for such an ODMDS B configuration would be to expand the site seaward in the same manner that the site was originally proposed to be expanded landward. This provision would expand ODMDS B to 12,000 ft x 24,000 ft.

As initially proposed, utilization of expanded ODMDS E avoids exceedence of the 10% wave criterion as long as dredged material mounds are not allowed to exceed 4-5 ft in height with respect to the "baseline" (1997) bathymetry. The boundaries of expanded ODMDS E, as shown in figure 6 and 8, are considered adequate for utilizing site E in a fully dispersive manner: Placement of 1 million cy/yr within the site would be dispersed before the next year's dredging disposal cycle. As experience is gained through the annual use (and monitoring) of expanded ODMDS E it is anticipated that this dispersive site may be able to handle 2-3 million cy yards of dredged material disposal per year.

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