APPENDIX B
Physical Processes and Geologic Features

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APPENDIX B - Physical Processes and Geologic Features

EXECUTIVE SUMMARY

Geographic Location: Northwest Pacific Coast of continental United States, deep draft ocean entrance to Newport at Yaquina Bay along Central Oregon.

Organizational Oversight: U.S. Army Corps of Engineers - Portland District and U.S. Environmental Protection Agency - Region X.

Project Features Addressed: Ocean Dredged Material Disposal Sites 2 miles Offshore of Yaquina Bay.

Appendix B describes the physical evaluation of dredged sediment placed at Yaquina Bay Ocean Dredged Material Disposal Sites (ODMDS). This appendix presents assessments highlighting the shortcomings of the historic ODMDS (the Interim and Section 103 Sites) and develops analyses that support the optimal selection of new ODMDS locations.

Two ODMDSs (North Site and South Site) are proposed. Each site was conservatively designed to be capable of providing at least 20-years of capacity for dredged material disposal. The proposal for two sites is based on the need to provide for up to 50 years of disposal capacity and to accommodate operational flexibility. Additional consideration was given to providing enough ODMDS area for distributing dredged material to a relatively thin (vertical) accumulation on an annual basis, if needed. This approach was considered for minimizing the vertical accumulation resulting from repeated disposal at one location. The proposed North and South ODMDSs are located offshore of the historic sites, at an average water depth of 135 ft with a minimum depth of 120 feet and a maximum depth of 160 feet, and within the 4.5-mile zone of siting feasibility.

Siting criteria used to assess new ODMDSs are discussed. Physical assessments of open water dredged material disposal are performed with regard to the *in situ* conditions at proposed ODMDS sites. Potential physical impacts resulting from the long-term use of the proposed North and South ODMDSs are identified.

Appendix B is composed of nine sections. Section 1 describes the relevant navigation project features at Newport, Oregon (Yaquina Bay). Section 2 reviews the life cycle of Yaquina Bay ODMDSs and identifies deficiencies of the historic ODMDSs. Section 3 assesses bathymetric change at the historic ODMDSs and related affects on the local wave climate. Section 4 identifies the need for new larger ODMDSs and formulates site selection criteria necessary for successful long-term ODMDS management. Section 5 describes the FATE modeling approach used to select the new ODMDS. Section 6 proposes ODMDS locations based on FATE modeling results. Sections 7 and 8 describe the oceanographic process affecting Yaquina Bay ODMDSs. Section 9 describes relevant geologic resources.

Ocean Dredged Material Disposal Sites at Yaquina Bay

Utilization of Historic ODMDS and Proposed New ODMDS

Section 1 INTRODUCTION

Entrance to Yaquina Bay - Physical Setting

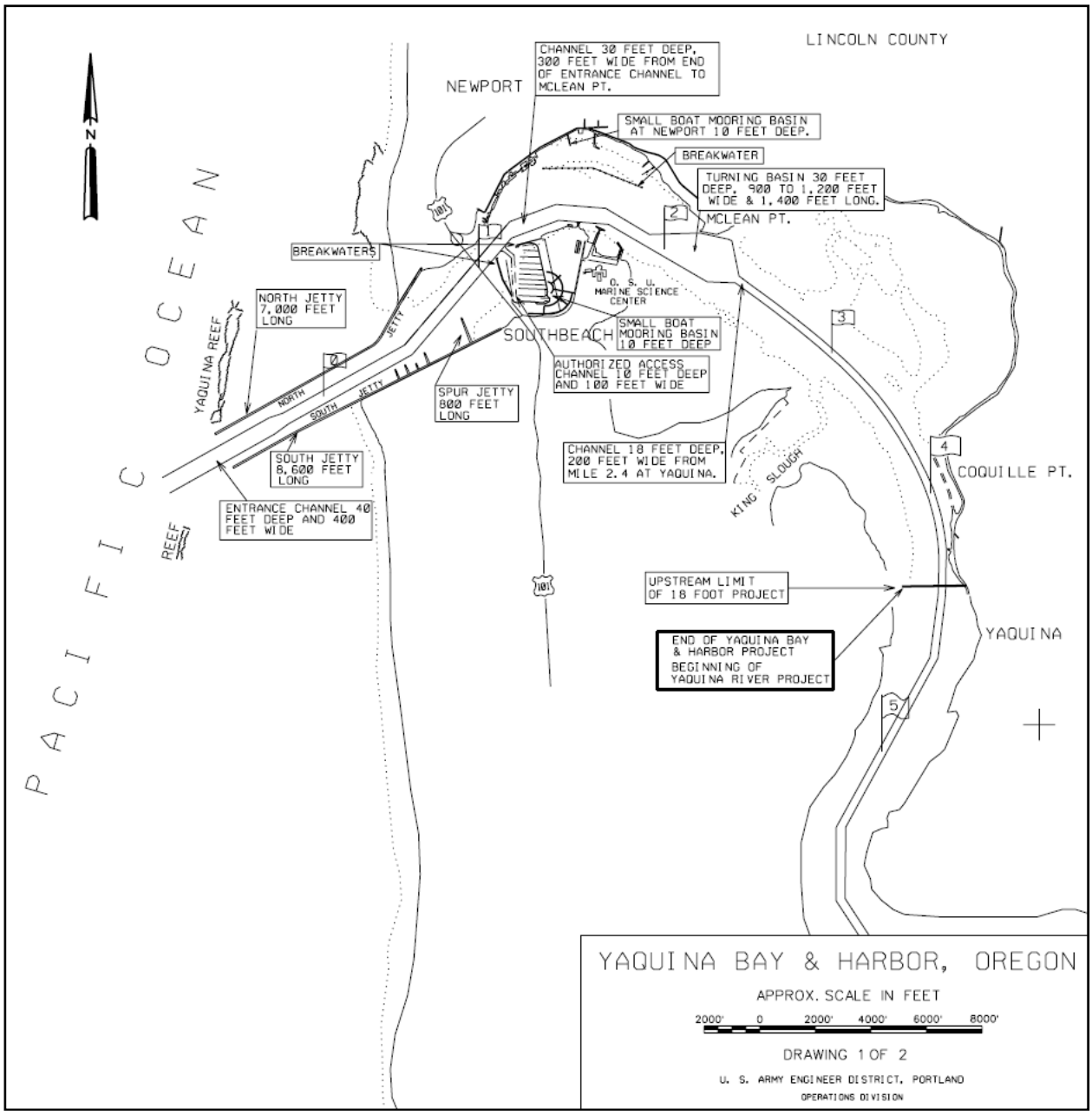
The Yaquina River enters the Pacific Ocean near the city of Newport, Oregon, approximately 115 miles south of the Columbia River (Figure B-1). Yaquina Bay is the fourth largest estuary in Oregon in terms of area. The estuary is fed mainly by the Yaquina River, which drains 253 square miles and is 59 miles long from its mouth to headwaters. The river's annual discharge is marked by a high seasonal variability, typically ranging from 100 cubic feet per second (cfs) to 2,500 cfs. Highest discharges occur during November through February due to rain runoff. Lowest flows occur during July through September [USGS 1990]. The tidal prism of the Yaquina estuary is about 40 square miles/foot [Jarrett 1976].

The shoreline and nearshore vary from wide sand beaches to rocky headlands. Offshore rocks and neritic reefs attest to the retreat of the coastline from erosive ocean forces. Part of this shoreline retreat has been due to a sea level rise of over 30 feet in the past 6,000 years. This is only the latest in a long series of fluctuations in sea level that have affected the area.

The sea cliffs and headlands as well as the rock underlying all the beach and nearshore sands are many millions of years old. The beach nearshore sands are less than one million years old. Coastal rivers deposited some of these sands when sea level was lower (>6,000 years ago). Other sources include erosion from rock outcrops and bluffs as sea level rose and fell. Little, if any, sand is presently escaping from coastal estuaries. In fact, the Yaquina Bay estuary is being filled by marine sand entering from the ocean and deposition of fluvial sediment entering the estuary from upland sources [Komar 1997]. In the nearshore area, wave energy has removed any fine silts and clays from sediments leaving only medium-fine sand covering an area 3 to 10 miles offshore along much of the Oregon coast.

The continental shelf off Oregon is widest from Siuslaw River to Siletz Bay, extending over 30 miles offshore. This is due to a large rocky outcrop complex (Stonewall Bank) beginning about 15 miles offshore of Yaquina Bay and trending southwest (refer to Figure B-22). Little silt and clay is found inshore of this bank and sediments are predominantly fine sand out to depths of 300 feet. This sand zone narrows rapidly south of Siuslaw River and less rapidly north of Yaquina Bay. In three dimensions, this inner shelf sand zone is a wedge or lens of sediment overlying much older rock. See Section 9, *Geologic Resources* for additional discussion of seabed and related geological characteristics.

Figure B-1. Yaquina Bay and Harbor, Oregon.



Yaquina Bay Navigation Project Background

The deep draft navigation project located at the ***Yaquina Bay*** consists of a dredged entrance channel that is 40-feet deep, 400-feet wide, and 4,280-feet long, which extends through a jettied entrance between the Yaquina River and the Pacific Ocean (Figure B-1). A smaller channel (30-feet deep and 300-feet wide) continues from the landward end of the entrance channel [river mile (RM) 0] and proceeds 2 miles northeast into Yaquina Bay, where the channel leads to a turning basin that is 1,200-feet wide at McLean Point.

The process of maintaining a jettied navigation channel at an estuary entrance such as Yaquina Bay involves the periodic relocation of sediment that shoals within the entrance channel. The activity of removing shoaled sediment is called *dredging*. At the ocean entrance to Yaquina Bay, the shoaled sediment is marine sand and originates from littoral areas on the ocean-side of the entrance. Shoaling of the navigation channel occur throughout the year and is driven by waves and currents. The dredged sediment is placed into designated ocean dredged material disposal sites (ODMDS) that are located in open water within 1-3 miles of the entrance channel. Dredging is typically performed during the summer, when ocean waves are small and dredging can be safely performed at the jettied entrance channel.

Federal navigation improvements at Yaquina Bay began in 1879 when Congress authorized the Portland District USACE to begin construction of the south jetty. In 1896, the north jetty was constructed, with the intention of maintaining a 12-foot project depth over the entrance bar. The natural channel had averaged about 7 feet deep and shifted frequently both during and between seasons. Appreciable quantities of sediments have been dredged from Yaquina Bay and the entrance channel since 1928, when consistent dredging was initiated to establish and maintain an 18-foot deep channel across the entrance bar.

In 1949, the entrance channel was deepened to 26 feet. Additional entrance channel deepening to 40 feet was authorized in 1958 and completed in 1969. Presently, the north jetty is 1.3 miles long and the south jetty is 1.6 miles long.

Typically, the Yaquina Bay deep draft project has two main shoaling areas. The sediment dredged from the 40-foot deep entrance channel and associated bar crossing is composed of fine-medium sand [median grain size is 0.18 millimeters (mm) with fines content less than 2%] and accounts for 95% of the annual dredging volume. The interior 30-foot channel (and turning basin) accounts for 5% of the total annual dredging and dredged material properties are more variable, than the entrance channel and bar [see Section 8 of this appendix]. In its present configuration, the entrance channel up to the turning basin require annual dredging of up to 370,000 cubic yards (cy) of shoaled sediment (fine-medium sand with some silt) to maintain the authorized depth. Up to an additional 25,000 cy of material may be removed from the South Beach Marina access channel and up to 100,000 cy of material may be removed from Depot Slough every 5-8 years. The amount and frequency of maintenance dredging depends on the volume of sediments transported into the project area by storm conditions. The sandy dredged material is placed in ocean dredged material disposal sites (ODMDS). Dredging and disposal is typically performed by hopper dredges.

Ocean Dredged Material Disposal Sites

The consistent use of an ocean site for disposal of sediment dredged from Yaquina Bay began in the 1920s and has continued to the present. Prior to EPA *Interim* site designation in 1977, the location of the ocean disposal site was not precisely specified and the placement of dredged material within the disposal site was not strictly controlled, in terms of vessel positioning. The volume of dredged material placed at Yaquina Bay ODMDSs since 1928 is summarized in Table B-1.

In January 1977, the Yaquina Bay ocean disposal site received *interim* designation when EPA issued the final Ocean Dumping Regulations (40 CFR 228). At this time, the *Interim* site was classified as an ocean dredged material disposal site (ODMDS). At the time of interim site designation, the boundaries for the rectangular ODMDS were fixed geographically in terms of corner coordinates. Figure B-2 denotes the boundaries for the EPA *interim*-designated disposal site (solid line). The *Interim* ODMDS was "sized" based on the policy of minimizing the areal extent over which dredged sediments would affect the receiving water column and seabed during disposal. Smaller sites were considered more environmentally acceptable than larger sites.

A Corps-sponsored site evaluation report [USACE 1985] prepared in April 1985, recommended final EPA-approval of the *Interim* ODMDS. In late 1985, it became apparent that significant mounding of dredged sediments placed at the *Interim* ODMDS was occurring. The mounding was affecting incoming waves, resulting in unstable (breaking) wave conditions at the jetty entrance to Yaquina Bay. The mounding of dredged placed material was completely unexpected and was contrary to the assumptions advanced in the USACE 1985 site evaluation report.

To avert additional dredged material mounding and wave-related impacts at the *Interim* site, the Portland District selected a nearshore ODMDS (Figure B-2) under the authority of Section 103 of the Marine Protection, Research and Sanctuaries Act (MPRSA). The nearshore *Section 103* ODMDS, situated north of the *Interim* ODMDS, was used for dredged material disposal after 1985 (no dredged material was placed in the *Interim* ODMDS again until 1999). By 1995, it became apparent that dredged material was accumulating within the nearshore *103* ODMDS; as of 1998, a significant mound feature was forming within the site. To avert additional mounding within the nearshore *Section 103* site, the nearshore *Section 103* site was expanded in 1999 - southward into the previously used *Interim site* in 1999 (material previously placed within the *Interim* site had been completely dispersed by 1999). Between 1999 and 2000, use of the nearshore Section 103 site (the only disposal site available) was reduced to the minimum necessary, due to concerns of mounding. This limited the volume of dredging that can be performed at Yaquina Bay entrance.

In June 2001, the USACE Portland District, under its Section 103 authority, selected the two proposed ODMDSs (North and South) for the disposal of dredged material. EPA concurred in a July 2001 letter for a 5-year period. The North Site was first used during the 2001 dredging season. EPA issued a second Section 103 site use concurrence letter in April 2007. This allowed continued use of the North Site through the 2011 dredging season. The South Site has not been used so is still available for use.

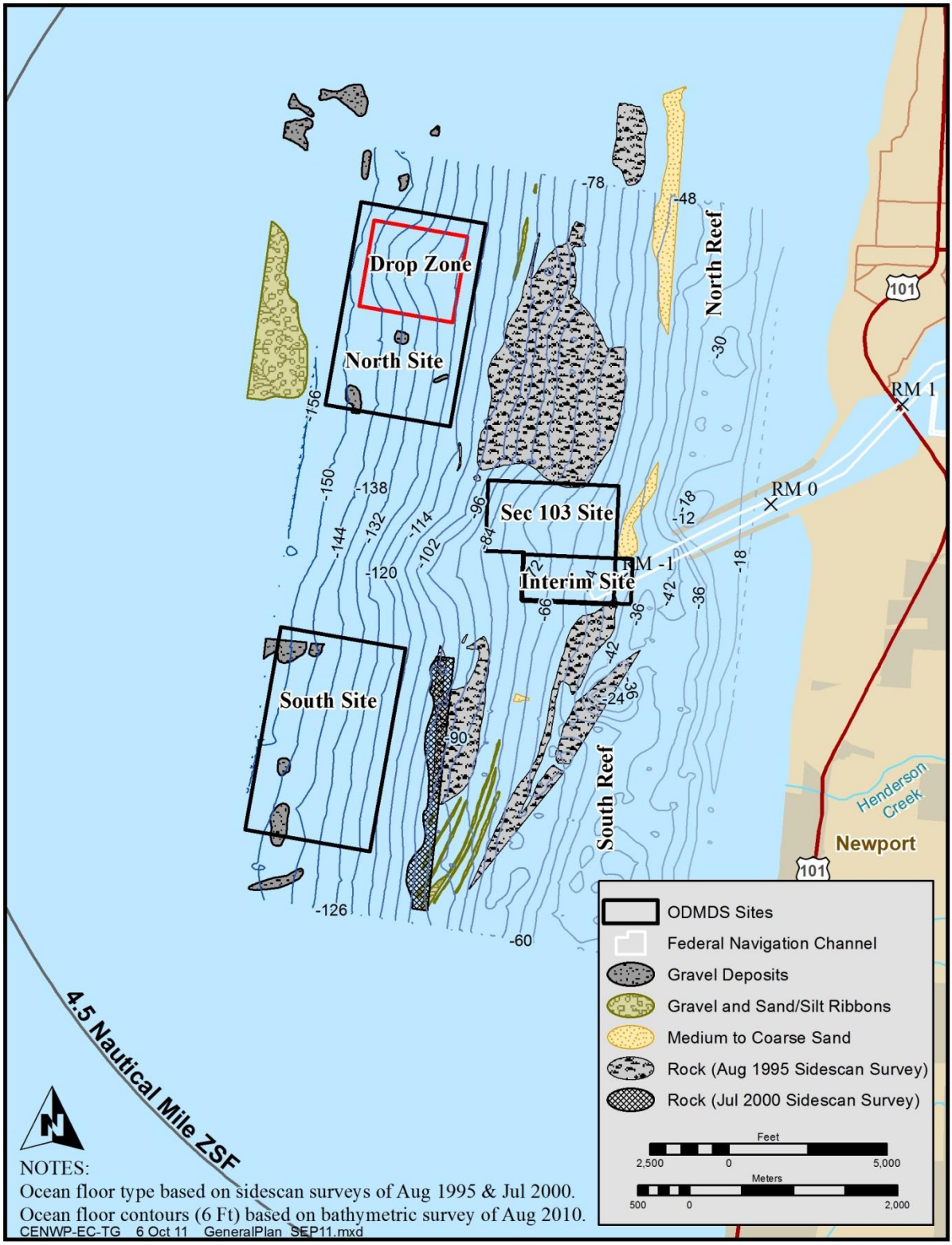
Between 2001-2009 all dredged material was placed in the northern half of the North Site. Maximum mound height in 2007 reached 5 feet and 6 feet in 2008. In 2009-2010, material from Depot Slough was dredged by clam-shell and barged to the North Site. A portion of the material from the Yaquina Bay federal project was placed in the southern half of the North Site. Portions of the North Site mounded 10-12 feet above the 2001 baseline bathymetry. In 2011, all material was placed in the southern half of the North Site.

Table B-1. Volume of dredged material placed at Yaquina Bay ODMDS.

ODMDS Location	Year	Year Total (cy)	Average at Site (cy)	Total Placed at Site (cy)
Interim Site	1928-1940*	1,040,000	252,379	14,638,036
	1941-1967*	5,400,000		
	1968-1981*	6,440,000		
	1982	331,180		
	1983	453,319		
	1984	670,773		
	1985	302,764		
Nearshore Section 103 Site	1986	242,468	310,240	4,653,596
	1987	537,843		
	1988	324,519		
	1989	333,807		
	1990	216,696		
	1991	316,956		
	1992	321,652		
	1993	358,407		
	1994	206,971		
	1995	393,641		
	1996	314,636		
	1997	370,000		
	1998	351,000		
	1999	260,000		
	2000	105,000		
North ODMDS	2001	198,284	217,379	2,173,790
	2002	179,427		
	2003	320,455		
	2004	241,293		
	2005	282,596		
	2006	223,150		
	2007	192,352		
	2008	175,031		
	2009	161,678		
	2010	199,524		
Total		**21,465,422**		

*Volumes are approximate

Figure B-2. ODMDS Feature Map and Approach Bathymetry.



Section 2
MANAGEMENT OF YAQUINA BAY ODMDS

Between 1977 and 2000, two nearshore ODMDSs were utilized by the Portland District for disposal of sediments dredged from the Yaquina Bay navigation project (Table B-1). Prior to 1986, only the *Interim* ODMDS had been used. In 1986, the nearshore *103* ODMDS was selected and used in place of the *Interim* site to increase disposal site capacity and reduce hazards associated with the mounding of placed dredged material at the *Interim* site. In 1998, mounding of placed dredged material within the nearshore *103* ODMDS became an issue of concern motivating the need for a new and much larger ODMDS. Note that from 1928-1981, 12 million cubic yards (mcy) of dredged material had been placed at (or within the vicinity of) the *Interim* ODMDS resulting in little mounding of placed dredged material. During 1982-1985, there was 1.7 mcy placed at the *Interim* ODMDS and from 1986 to 2000 approximately 4.6 mcy was placed at the nearshore *103* ODMDS, resulting in pronounced mounding of dredged material within both sites.

Dredged material mounding at the Yaquina Bay ODMDSs was attributed to changes in disposal site utilization. The rationale for ODMDS management has changed significantly since the initial use of an ocean disposal area in 1928. The transition in ODMDS management at Yaquina Bay is characterized by three important shifts in USACE and EPA policy which are outlined below.

Yaquina Bay Ocean Dredging Disposal Before 1977

Prior to formal designation of the *Interim* ODMDS in 1977, the offshore dredged material disposal area was located only in terms of approximate location and areal configuration. Placement of dredged material within the disposal area was governed by the need to minimize dumped dredged material being transported back into the navigation channel and minimize haul distance. Mounding did not appear to be a 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 than at present. Prior to 1977, dredged material was placed over a wider areal expanse than the configuration of the ODMDS indicates.

Yaquina Bay Ocean Dredging Disposal 1977 to 1985

Between 1977 and 1985, management of the offshore dredged material disposal site at Yaquina Bay was characterized by the transition from unregulated dredged material disposal to a regulated program. In January 1977, the active ocean disposal site at Yaquina Bay received interim designation as an ODMDS when EPA issued the final Ocean Dumping Regulations (40 CFR 228). The *Interim* ODMDS configuration was governed by the requirement to <u>minimize the benthic area of impact due to open-water disposal of dredged sediments</u>. The areal size of the *Interim* ODMDS at Yaquina Bay was based on:

ODMDS length = average dumping run for one dump
= (disposal vessel speed while dumping) **x** (time to empty disposal vessel)

ODMDS width = average turn during one dump = disposal vessel turning radius while dumping

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

The lineal dimensions, boundary coordinates, and water depth variation for the *Interim* ODMDS are described below. Disposal boundary coordinates are in state plane, Oregon north zone, NAD 27 (feet). Geographic coordinates are in NAD 27. These boundaries apply to the *Interim* ODMDS configuration, as shown in Figure B-2.

"Interim" ODMDS: dimensions = 3,600 feet x 1,400 feet, azimuth = 270°, average depth = 60 feet
1996 elevation variation = -72 MLLW to -42 MLLW

Northwest corner -	Easting=1,062,478 ft, Northing=364,249 ft	Lat=44 36 31 N, Lng= -124 06 04 W
Northeast corner: -	Easting=1,065,939 ft, Northing=364,146 ft	Lat=44 36 31 N, Lng= -124 05 16 W
Southwest corner: -	Easting=1,062,411 ft, Northing=362,885 ft	Lat=44 36 17 N, Lng= -124 06 04 W
Southeast corner: -	Easting=1,065,879 ft, Northing=362,730 ft	Lat=44 36 31 N, Lng= -124 05 16 W

The *Interim* ocean disposal site was intended to receive final EPA designation as an ODMDS in August 1986, but did not due to the rapid accumulation of placed dredged material between 1982 to 1985. The unintended consequence of using the aerially restricted *Interim* ODMDS has been creation of potentially adverse impacts to navigation at the Yaquina Bay entrance, by mounding of placed dredged material. The reason for dredged material mounding in the *Interim* site was not associated with increased dredging/disposal volumes. The average annual volume of dredged material placed in the *Interim* ODMDS between 1982 and 1985 was 251,150 cy/yr, which is lower than the 14-year year average of 460,000 cy/yr between 1968 and 1982. The reason for rapid accumulation (mounding) of dredged material within the *Interim* ODMDS has been attributed to two factors:

(1) The restriction of dredged material disposal within relatively small EPA-designated ODMDSs, rather than in larger unconfined areas and in a dispersive manner of placement.

(2) Increased use of contractor operated split-hull hopper dredges in 1982, which enhanced the vertical extent of dredged material placed on the seabed within the ODMDSs.

Prior to the 1982, sediment dredged at the Yaquina Bay and placed in the ODMDS was accomplished using government hopper dredges. ***Government*** hopper dredges utilize a series of "doors" located on the hull bottom to release each load of dredged material. The bottom doors are sequentially opened during disposal until the entire load of dredged material is released from the vessel, resulting in a gradual release of dredged material from the vessel.

Between 1982 and 1985, more than 80% of the material dredged at Yaquina Bay was accomplished using contractor split-hull hopper dredges. ***Contractor*** split-hull hopper dredges release their load of dredged material by opening (splitting) the entire hull of the vessel. The split-hull method of disposal is more rapid 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.

In addition to the type of hopper dredge used, the capacity (volume per dump) of the hopper dredge also affects the amount of vertical accumulation. Since 1982, the bottom-door hopper dredge *Yaquina* (capacity 850-1,000 cy) has been used as the government dredge at Yaquina Bay. Between 1982-1984, the split-hull dredge *Westport* (capacity 1,000 cy) was used as the contractor dredge at Yaquina Bay. Beginning in 1985, larger split-hull dredges such as the *Padre Island* and *Newport* (capacity 2,600 cy) were used as contractor dredges.

To comply with Ocean Dumping Regulations (40 CFR 228), Portland District contract specifications required dredges to place dredged material entirely in ODMDS boundaries. The ODMDS corner coordinates and a single disposal location (coordinate or buoy) were given as a reference for disposal position within the ODMDSs. Conceptually, placement of dredged material was done randomly at some "radius" about the assigned disposal point. Dredged material was usually placed on the side of the disposal area (or specified disposal point) closest to the location of dredging to shorten the haul distance. This effectively minimized aerial extent over which dredged material was dispersed in the ODMDS. This method of dredged material disposal is referred to as "point dumping." Point dumping enhanced the vertical accumulation of dredged material in a small area of the ODMDS.

In 1985, mounding of dredged material at the *Interim* ODMDS began causing incoming waves to shoal and break at the approaches to the jettied entrance channel of Yaquina Bay. Numerous reports by commercial and private mariners and the Coast Guard had implicated the dredged material mounding to the hazardous wave conditions at the jettied entrance.

Yaquina Bay Ocean Dredging Disposal 1986 to 2000

The *Interim* ODMDS which was designated by EPA in 1977 was not given "final" approval by EPA in 1986, as recommended by a Portland District report compiled early in 1985 [USACE 1985]. Rather, another ODMDS was selected by the Portland District under the Section 103 authority of MPRSA. This nearshore *103* ODMDS was located directly north of the *Interim* site in an average water depth of 70 feet (10 feet deeper than the *Interim* site). The nearshore *103* ODMDS was sized with 80% greater area than the *Interim* site. The lineal dimensions, boundary coordinates, and water depth variation for the nearshore *103* ODMDS are described below. Disposal boundary coordinates are in state plane, Oregon north zone, NAD 27 (feet). Geographic coordinates are in NAD 27. These boundaries apply to present nearshore *103* ODMDS configuration as shown in Figure B-2.

"103" ODMDS: dimensions = 4,070 feet x 2,220 feet, azimuth = 270°, average depth = 70 feet
1996 elevation variation = -90 MLLW to -50 MLLW

Northwest corner -	Easting=1,061,352 ft,	Northing=366,679 ft	Lat=44 36 32 N, Lng= -124 06 21 W
Northeast corner: -	Easting=1,065,463 ft,	Northing=366,501 ft	Lat=44 36 54 N, Lng= -124 06 21 W
Southwest corner: -	Easting=1,061,249 ft,	Northing=364,459 ft	Lat=44 36 32 N, Lng= -124 05 24 W
Southeast corner: -	Easting=1,065,372 ft,	Northing=364,276 ft	Lat=44 36 54 N, Lng= -124 05 24 W

Beginning in 1986, all sediment dredged from the Yaquina Bay deep draft navigation channel was placed within the nearshore *103* ODMDS. Additionally, disposal site management became increasingly proactive in the year-to-year operation of the Yaquina Bay ODMDS. Proactive disposal site management was required to maximize site capacity utilization of the Corps-designated nearshore *103* ODMDS and minimize mounding within the site. Refer to Section 4 of this appendix for definition of ODMDS capacity. Important facets of ODMDS management now include consistent site monitoring and uniform distribution of dredged material within the entire site during placement.

Management Actions for Yaquina Bay ODMDSs

Bathymetric surveys serve as the method of choice to monitor the physical environment at ODMDSs. Consistent annual bathymetric surveys have been conducted at Yaquina ODMDSs and vicinity since 1983; the x,y,z data have been digitally stored. The annual monitoring is necessary to track bathymetric change at the ODMDS, ensure that the Corps of Engineers does not un-intentionally worsen a mounding problem, or place dredged material outside of the active ODMDS boundaries.

Since 1997, bathymetric monitoring of the nearshore *103* ODMDS has been used to direct the location of dredged material disposal within the site and avoid "hitting" high spots created by the previous years' disposal operation. Despite the effort to evenly distribute dredged material within the nearshore *103* ODMDS, dredged material has slowly accumulated within this site since 1986 when the nearshore *103* ODMDS was first used. While exclusively utilizing the nearshore *103* site for dredged material disposal between 1986 and 1996, the mound at the *Interim* ODMDS was completely dispersed by waves and currents to an elevation consistent with the ambient seabed.

In 1995, shoaling (breaking) waves associated with mounding at the nearshore *103* ODMDS were reported by anglers and the US Coast Guard. Bathymetric surveys of the nearshore *103* ODMDS indicated the formation of a mound within the site. In 1998, the size of the dredged material mound in the nearshore *103* ODMDS was sufficient to warrant adjustments to site management. See Section 3 of this appendix for an analysis of mound-induced wave amplification at Yaquina Bay ODMDSs. Starting in 1998, use of the nearshore 103 ODMDS was restricted to isolated areas that had not exhibited mounding. By 2001, it was estimated that the nearshore 103 ODMDS would have no capacity for receiving additional dredged material.

Between 2001 and 2010, all dredged material was placed in the northern half of the North Site. Maximum mound height in 2007 reached 5 feet and 6 feet in 2008. In 2009-2010, material from Depot Slough was dredged by clam-shell and barged to the North Site. Some of the material from the Yaquina Bay federal project in 2010 was placed in the southern half of the North Site for the first time. Portions of the north half of the North Site has mounded 10-12 feet above the 2001 baseline bathymetry. In 2011, all material was scheduled to be placed in the southern half of the North Site.

Section 3
PAST BATHYMETRIC CHANGE AND RELATED IMPACTS AT YAQUINA BAY ODMDS

This section discusses site-specific bathymetric ***change*** at Yaquina Bay ODMDSs, in terms of the accumulation (or mounding) of dredged material placed within the sites. The change in wave conditions at the entrance due to the dredged material mounding also is discussed.

Interim ODMDS

Prior to formal designation of the *Interim* ODMDS in 1977, approximately 10.6 mcy of dredged sediment had been placed within or in vicinity of the *Interim* ODMDS. Between 1977 and 1981, approximately 2.3 mcy of dredged material was placed within the boundaries of the *Interim* ODMDS. During this time, no mounding of dredged material was reported or observed within the *Interim* site boundary. Prior to 1982, dredged material was placed using government-operated multiple bottom-door hopper dredges.

Between 1982 and 1985, approximately 1.8 mcy of dredged material was placed within the western half of the *Interim* ODMDS boundaries; 88% of which was placed by Contractor-operated split-hull hopper dredges. The baseline condition (1983) bathymetry for Yaquina Bay ODMDSs and vicinity is shown in the top of Figure B-3. In 1985, significant mounding of dredged material was observed within the western half of the *Interim* ODMDS as shown in the bottom of Figure B-3 and top of Figure B-4.

The top graphic of Figure B-4 shows the "difference" between the 1983 survey and the 1985 survey. The mound feature associated with 3 years (1983-1985) accumulation of dredged material disposal was 20-feet high and 1,800-feet wide at the base with respect to the 1983 site bathymetry. Note that 1,430,000 cy was placed within the *Interim* ODMDS between 1983-1985 (annualized average of 285,000 cy/yr). Approximately 780,000 cy was estimated to have been contained within the 20-foot high mound, or 55% of the total placed between 1983 and 1985. The other 45% of dredged material unaccounted was likely dispersed by waves and currents to a thickness below the survey detection threshold (±1.5 feet). This dispersion rate translates into 214,000 cy/yr, which defines the estimated "dynamic" capacity of the *Interim* ODMDS (the volume that can be placed per year without accumulating; refer to Section 4 for capacity definitions). Note that the above estimated dispersion rate is based in part on the presence of the dredged material mound. Waves and currents interact with the mound to enhance dispersion: The higher the mound for a given water depth, the greater the potential sediment dispersion rate. Dispersion of dredged material placed on a "flat" bottom at the *Interim* ODMDS would likely be significantly less than on a "mounded" bathymetry. Despite the dispersiveness of the *Interim* ODMDS, rapid accumulation of dredged material occurred during 1983-1985. This is because the volume of dredged material placed at the *Interim* ODMDS during 1983-1985 exceeded the site's dispersive capacity (i.e., 285,000 cy/yr was "placed" vs. 214,000 cy/yr "dispersed") resulting in the formation of a pronounced mound, approximately 20 feet high.

Figure B-3. Approach and ODMDS bathymetry for 1983 (A) and 1985 (B).

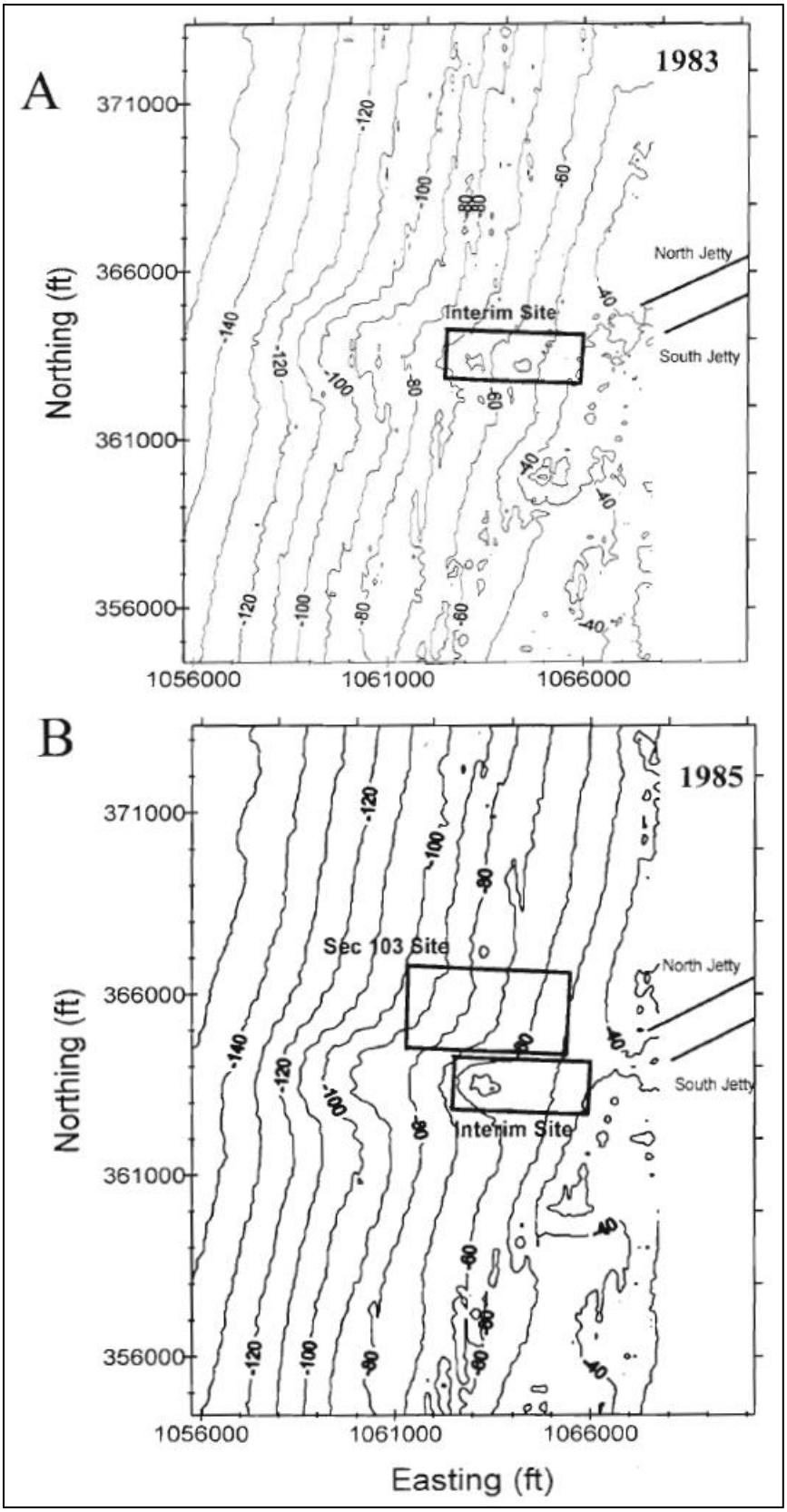


Figure B-4. Bathymetric change at Yaquina ODMDS during 1983 and 2000. Top graphic (A) is bathymetry change for 1983-1985, bottom (B) is bathymetry change from 1985 to 2000.

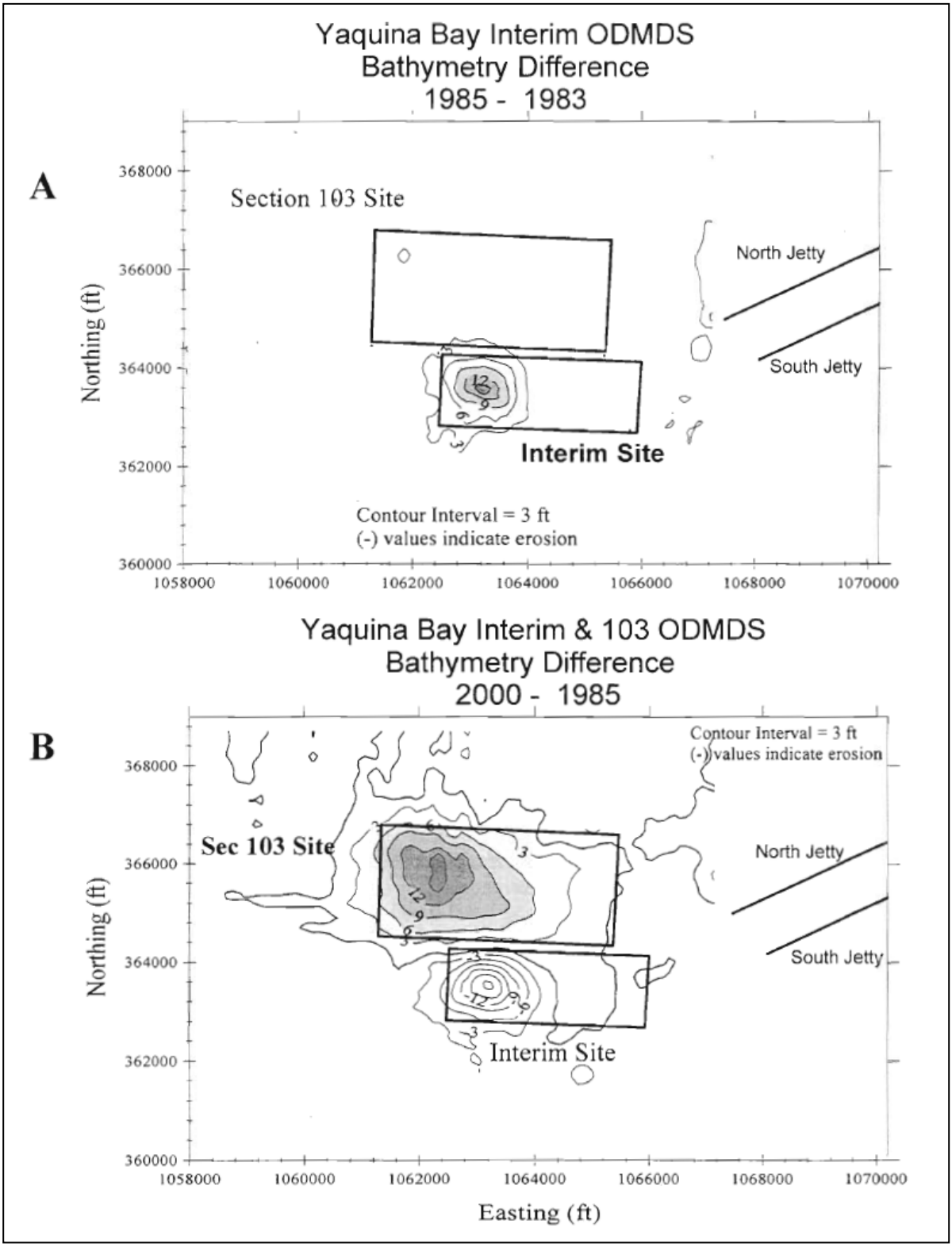
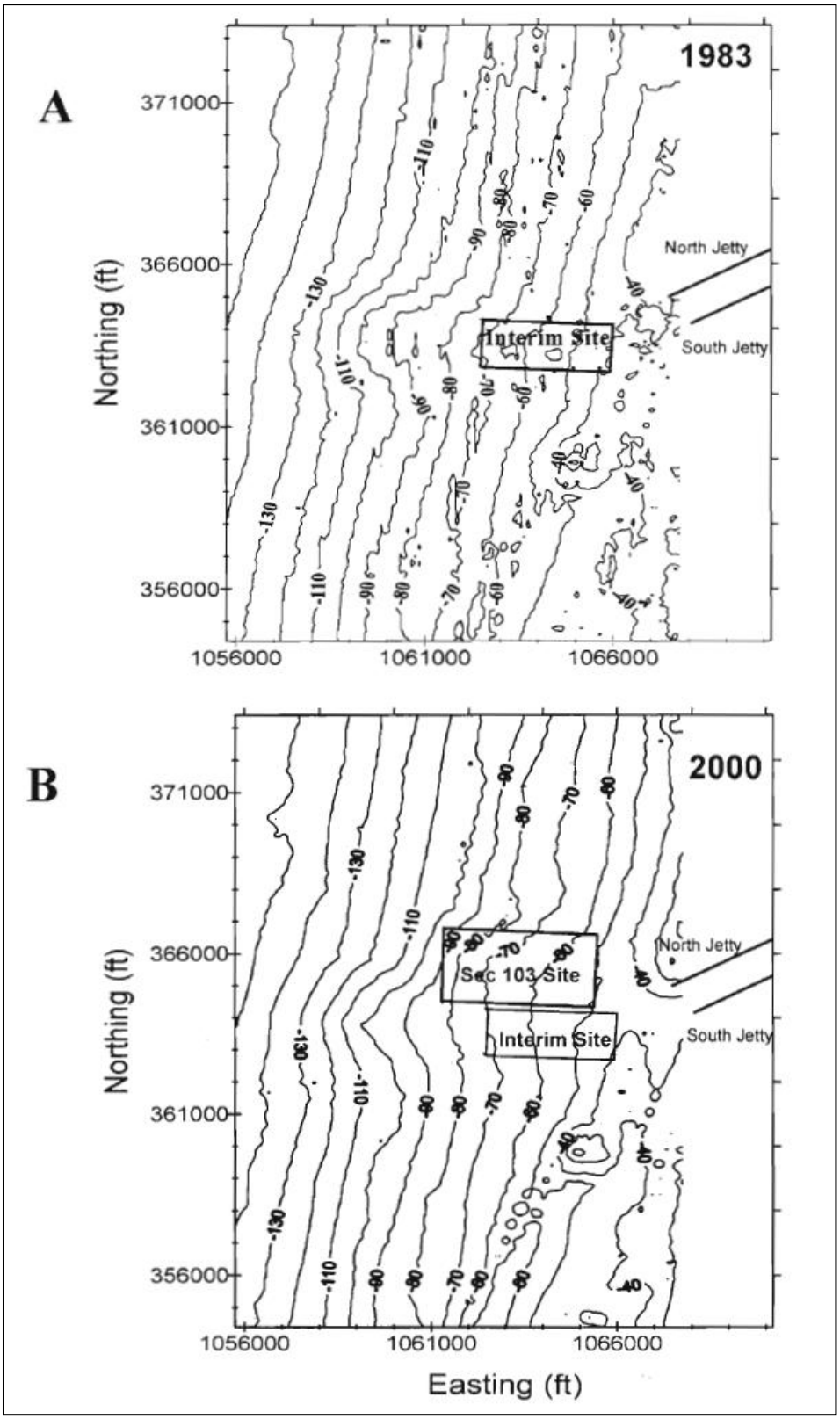


Figure B-5. Approach bathymetry offshore of Yaquina Bay in 1983 (A - top) and 1999 (B - bottom)



The rapid accumulation of dredged material at the *Interim* site indicates that changes in ODMDS management likely contributed to the mounding of placed material from 1982-1985. Initially, the "stage was set" in 1977 when the disposal of dredged material was formally restricted to the boundaries of ODMDSs. During 1982-85, the extensive use of Contractor-operated split-hull hopper dredges and point dumping within the confines of the *Interim* ODMDS resulted in rapid accumulation of dredged material within the site (i.e. mounding). In 1985, the placement of dredged material disposal within the *Interim* ODMDS was halted due to concern of potential wave shoaling associated with the dredged material mound.

By 1999, the mound within the *Interim* ODMDS was completely obliterated (negative contour values shown in the bottom graphic of Figure B-4). In fact, complete dispersal of the *Interim* ODMDS mound was achieved by 1990. Note that the *Interim* site is aligned with the Yaquina Bay jetty entrance. The high dispersion rate of the *Interim* ODMDS appears to be due to localized currents generated by the Yaquina Bay jetties. The jetties act to funnel the Yaquina Bay estuarine (ebb tide) flow over the *Interim* site. Additionally, the jetties act on the littoral current redirecting the littoral current oceanward over the *Interim* site. The direction of sediment transport at the *Interim* site could not be inferred from observed bathymetry change. Based on the curvature of the -90 to -130 feet contours (bottom Figure B-5), it is likely that some of the dredged material placed within the *Interim* ODMDS was transported offshore to an undetectable thickness (±1.5 feet). The jetty intensification of the estuarine and littoral current is assumed to be the main cause for the high rate of dredged material dispersion within the *Interim* ODMDS. This assessment infers that other sites (such as the nearshore *103* ODMDS) would be expected to have a lower dispersion rate than the *Interim* ODMDS.

Nearshore Section 103 ODMDS

After 1985, the nearshore *Section 103* ODMDS was used for disposal of sediments dredged from Yaquina Bay project. Between 1986 and 2000, approximately 4.7 mcy of dredged sediment was placed within the nearshore *103* ODMDS, 30% of which was placed using Contractor-operated split-hull hopper dredges. Despite the enhanced use of a more dispersive (*government*, bottom-door) type of hopper dredge and avoidance of point dumping, progressive accumulation of placed dredged material occurred at the nearshore *103* ODMDS. Within the nearshore *103* ODMDS, bathymetric change between the baseline condition (1983) and 1999 is shown by comparing the contours in the top and bottom of Figure B-5.

The mounding of dredged material that has occurred within the western half of the nearshore *103* ODMDS during 1986-2000 is shown in the bottom of Figure B-4 (positive values). During 1986-2000, the average annual volume of dredged material placed within the nearshore *103* ODMDS was 310,000 cy/yr. The mound feature associated with 15 years (1986-2000) accumulation of dredged material disposal was 18-feet high and 2,000-feet wide x 3,500-feet long at the base with respect to the 1985 site bathymetry. As of 2000, approximately 2.5 mcy was estimated to have been contained within the 18-foot high mound, or 53% of the total placed between 1986 and 2000. The other 47% of dredged material unaccounted was likely dispersed by waves and currents to a thickness below the survey detection threshold (±1.5 feet). This dispersion rate translates into 157,000 cy/yr, which defines the estimated dynamic capacity of the nearshore *103* ODMDS (the volume that can be

placed per year without accumulating). Recall that this apparent dispersion rate is in part due to the presence of the dredged material mound within the nearshore *103* ODMDS: Without the high relief of the dredged material mound, the dispersion rate (due to waves and currents) would likely be much lower.

Despite the moderate dispersiveness of the nearshore *103* ODMDS, accumulation of dredged material occurred during 1986-2000. This is because the volume of dredged material placed at the nearshore *103* ODMDS during 1986-2000 exceeded the site's dispersive capacity (i.e. 310,000 cy/yr "placed" vs. 157,000 cy/yr "dispersed") resulting in the formation of a pronounced mound.

Based on the zero contour interval (bottom of Figure B-4), it appears that dredged material dispersal at the nearshore *103* ODMDS is dependent upon location within site. Dredged material placed in the western half of the site appears to be transported to the north and west. Dredged material placed in the eastern half of the site appears to be transported to the south and east. The jetty intensification of the estuarine current (during ebb flow) is assumed to have some contribution for the moderate rate of dredged material dispersion within the nearshore *103* ODMDS. It is likely that the estuarine current is stronger in the southeastern part of the site.

Observed Sediment Dispersion at Yaquina ODMDS

Table B-2 summarizes the estimated annual dispersion rate and associated bathymetric change at the *Interim* and nearshore *103* ODMDS, based on surveys during 1983 to 2000. Note that the values shown in Table B-2 arise from: (1) the presence of the dredged material mounds within the ODMDSs, (2) an energetic current and wave environment associated with a jettied estuary entrance, and (3) relatively shallow water depth. Without the high relief of a dredged material mound in shallow water near an estuary entrance, the dispersion rates at the *Interim* and nearshore *103* ODMDSs (due to waves and currents) would have been much lower.

Table B-2. Observed dispersion potential at Yaquina ODMDS based on survey differencing.

Disposal Site	Observed Vertical Erosion Rate (ft/yr)	Estimated Net Erosion Volume (cy/yr)	Average Water Depth at Erosion Area (ft)
Interim ODMDS	5	214,000	60
Nearshore Section 103 ODMDS	3	157,000	70

At its greatest extent, the volume of dredge material mound contained within the nearshore *103* ODMDS (2.5 mcy) was 3.2 times larger than the mound that had formed within the *Interim* ODMDS (780,000 cy). The 20-foot high dredged material mound that had formed within the *Interim* ODMDS during 1983-1985 was dispersed within 5 years after dredged material placement was discontinued at the site (1985). This was in accordance with the 214,000 cy/yr dispersion rate observed during 1983-1985. With use of the nearshore *103* ODMDS discontinued in 2001, it was estimated that the 18-foot high *103* mound would be dispersed within 16 years, based on the observed dispersion rate of 157,000 cy/yr.

By comparing the erosion rates of dredged material placed at the *Interim* and nearshore *103* ODMDSs during the active periods of site use, it was estimated that the *Interim* site was 36% more dispersive than the nearshore *103* site. The higher dispersion rate for the *Interim* ODMDS is likely due to the site's shallower water depth and the more direct exposure to tidal and littoral currents associated with the Yaquina jetties.

If the *Interim* and nearshore *Section 103* sites could be relied upon for their combined full dispersive capacity (214,000 cy/yr + 157,000 cy/yr), those ODMDSs could hypothetically accept up to 370,000 cy/yr of dredged material. This would require that the sites maintain pronounced mounding to provide full dispersion potential: Likely, an unacceptable proposition to the navigation community.

It must be stressed that without the presence of the high relief mounds, the rate of dredged material dispersion within Yaquina Bay ODMDS would be significantly lower (less than half the rates shown in Table B-2). While a highly dispersive ODMDS may be desirable from the standpoint of continual renewing site capacity, the presence of large dredged material mounds capable of adversely affecting navigation is not. Without the presence of pronounced mounding, the historic Yaquina ODMDSs are not large enough to accommodate the placement of annual O&M dredged material (up to 370,000 cy/yr).

Capacity Limitations for Interim and Nearshore Section 103 ODMDS

Since the 1980s, the volume (per year) of dredged material placed within Yaquina Bay ODMDS has been at least twice the rate at which the dredged material was eroded out of the sites. The result has been rapid accumulation of dredged material within the ODMDSs and associated undesirable effects.

Yaquina Bay ODMDSs were intended to be moderately dispersive, but have reached capacity within 10 years of initial designation. 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 [Poindexter-Rollings 1990]. Exceedence of ODMDS capacity at Yaquina Bay creates a serious operational problem for the users of the deep-draft navigation project. Dredged material within the ODMDSs has accumulated to an areal and vertical extent which creates adverse sea conditions. In some cases, mounds rise 20 feet above ambient bathymetry producing depth-limited wave conditions. Mariners report that the ODMDS "mounds" cause waves to steepen or break in vicinity of the ODMDSs. These wave conditions are hazardous to navigation at the entrance to Yaquina Bay and may contribute to the degradation of the north jetty.

Figures B-6 and B-7 illustrate the creation of potentially undesirable wave conditions at the Yaquina Bay entrance due to unanticipated mounding of dredged material placed within ODMDSs.

Figure B-6. Mounded bathymetry in 1985 (final year of Interim site use) dredging season (A - top) and resultant wave amplification for 12 second wave period (B - bottom).

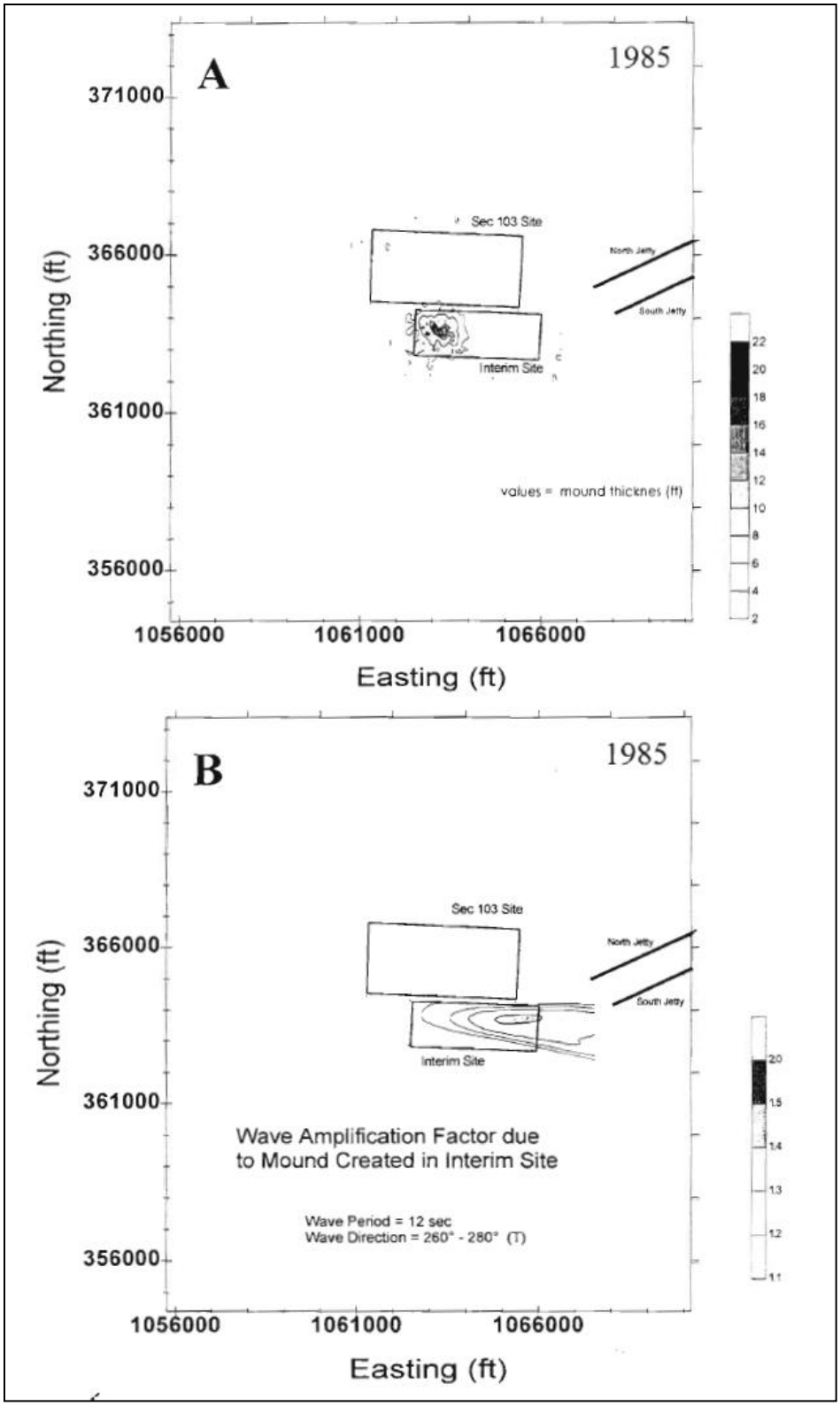


Figure B-7. Mounded bathymetry in Section 103 ODMDS in 2000 (A - top) and potential amplification for 12 second waves (B - bottom).

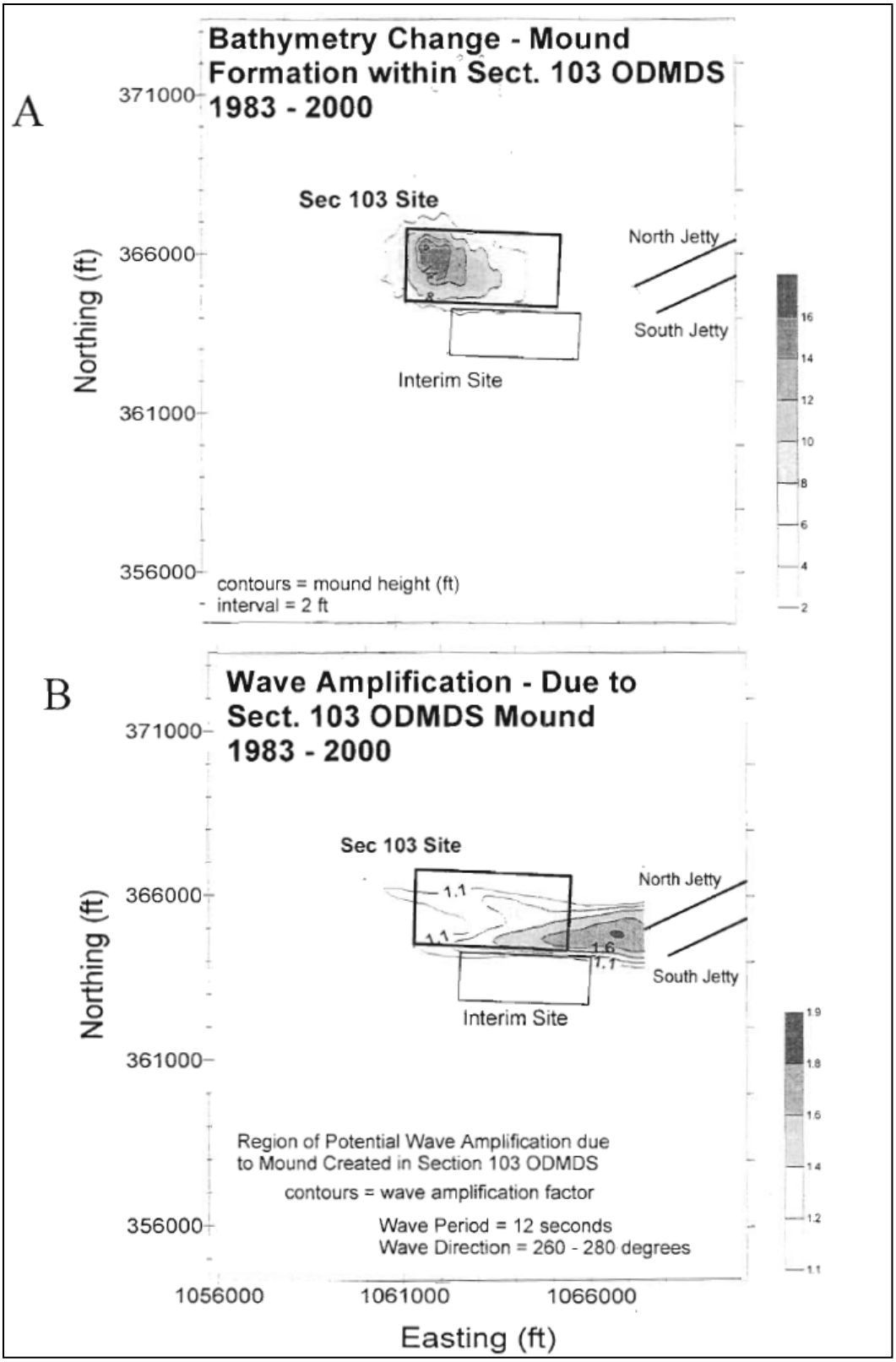


Figure B-6 documents the potential change (amplification) in wave height due to the change in bathymetry at the *Interim* ODMDS between 1983 and 1985. The top graphic of Figure B-6 shows the change in bathymetry within the *Interim* ODMDS. The bottom graphic shows the corresponding estimated change in wave height, in terms of an amplification factor, due to the bathymetric change (mounding of dredged material) within the *Interim* ODMDS from 1983 to 1985. Based results shown in Figure B-6, the dredged material mound at the *Interim* ODMDS may have increased the height of incident waves by 40% for 12-second waves as compared to the (baseline) 1983 bathymetry.

Figure B-7 documents the potential change (amplification) in wave height due to the change in bathymetry at the nearshore *103* ODMDS between 1983 and 1999. The top graphic of Figure B-7 shows the change in bathymetry within the *103* ODMDS. The bottom graphic shows the corresponding estimated change in wave height, in terms of an amplification factor, due to the bathymetric change within the nearshore *103* ODMDS from 1983 to 2000. Based on results shown in Figure B-7, the dredged material mound at the nearshore *103* ODMDS may have increased the height of incident waves by 50% for 12 second waves as compared to the (baseline) 1983 bathymetry. Note that the effect of wave amplification at the *Interim* and nearshore *Section 103* ODMDS was estimated to extend into the Yaquina Bay entrance channel. The method used to estimate the above wave amplification is discussed in Section 5, *Simulating the Fate of Dredged Material Placed at ODMDSs.*

The issue of dredged material accumulating at the *Interim* ODMDS (and associated affects on wave conditions) was ***temporarily*** resolved by USACE selecting an additional ODMDS (the nearshore *Section 103* site). This was only a short-term solution to the ODMDS site capacity problem at Yaquina. As of 2000, an 18 ft high dredged material mound had formed within the nearshore *103* ODMDS and is believed to be negatively affecting the wave climate at the entrance to Yaquina Bay. By 2001, the nearshore *103* ODMDS was expected to have no remaining capacity for accepting additional dredged material. Due to mounding-related problems at the *Interim* and nearshore *Section 103* ODMDSs, the local navigation community had voiced strong opposition to continued use of either site (for the purpose of dredged material disposal), whether mounds are present or not.

The North and South ODMDS are needed to avert additional mounding and related navigation consequences at the historic ODMDSs. Based on past experience with the *Interim* and nearshore *103* sites, that new ODMDSs must be much larger than their predecessors to reliably handle years of dredging disposal without creating additional mounding issues. The new ODMDSs must be large enough to allow distribution of dredged material over a large enough area so that excessive vertical accumulation of placed dredged material is averted.

Section 4
SITING AND MANAGEMENT REQUIREMENTS FOR PROPOSED ODMDS AT YAQUINA BAY

The operational performance of the historic ODMDSs at Yaquina Bay indicates that past site selection objectives and management practices are unreliable. If ODMDS selection methods are unreliable, an expensive re-designation process could still result in unacceptable future conditions. The key to successful ODMDS designation and long-term management is knowing in advance or reliably predicting the fate of dredged material placed at the ODMDS. This is especially true if a new ODMDS is required to have the minimum dimensions necessary to provide adequate site capacity.

ODMDS Requirements

The operational requirements for future site use were assessed to ensure that expanded or new ODMDSs fulfill a minimum life cycle of 20 years. The total volume of dredged material expected to be placed within Yaquina ODMDSs for the next 20 years for this assessment was estimated to be 6.2 mcy (or 310,000 cy/yr based on Table B-1). ODMDS site capacity should be sufficient to handle the expected volume of placed dredged material without negatively affecting the environment outside the ODMDS boundaries. Objectives for successful ODMDS designation and management at Yaquina Bay will:

- Provide ODMDS(s) with a combined 40-year capacity for disposal of dredged material originating from the Yaquina Bay navigation project.
- Avoid disposal of dredged material on rocky reefs, outcrops, or on substrate that is dissimilar (gravel or silt/clay) to the dredged material.
- When placing dredged material within the ODMDS, the deposition of dredge material (on the seabed) should be confined within the formal ODMDS boundaries.
- Locate ODMDS so that average haul distance is within the zone of siting feasibility (ZSF).[1] The ZSF for hopper dredges is a 4.5 nautical mile radius from RM 0.
- Avoid navigation impacts at the new ODMDS due to excessive accumulation of placed dredged material over the life cycle of the proposed ODMDSs. Designate new ODMDSs with large areal configuration and reserve capacity. If needed, manage sub-units of the new ODMDS on an annual rotational basis to minimize cumulative environmental impacts within the ODMDS.
- If large displacement split-hull hopper dredges are used at Yaquina Bay (i.e., the *Newport* @ 3,000 cy/load vs. the *Westport* @ 1,000 cy/load), attention should be focused on ensuring dispersal of dredged material during the disposal process. Large displacement dredges can produce rapid mounding of placed dredged material.

[1] Zone of feasibility is defined by the capacity of the available dredging plant, average annual dredging quantity, and limited dredging time period.

- Enhance the distribution of dredged material placed at new ODMDSs by evenly distributing dredged material on the seabed. Dredged material mound height must be managed to prevent excessive amplification of waves due to shoaling. The new ODMDS could be divided into several sub-areas and each sub-area would be used until the height of accumulated dredged material reaches the maximum vertical limit.
- Ensure that new ODMDS conform to the four general and eleven specific criteria for the selection of ocean disposal sites (40 CFR 228.5), as specified in the main report.

Where the need exists and it was practical and possible, consideration was given to locating new ODMDSs in nearshore waters 60 feet deep or less, to facilitate introduction of dredged material into the littoral zone. Consideration for locating new ODMDSs nearshore was warranted, since the majority of sediment dredged from the Yaquina entrance channel is marine sand and originates from the adjacent littoral environment. However, due to the presence of rock outcrops (reefs) parallel to shore in water depth of 45-50 feet, this initiative was precluded from additional consideration.

ODMDS Capacity – General Considerations

The total site capacity for a given ODMDS consists of two components – static site capacity and dynamic site capacity.

Total ODMDS site capacity = dynamic site capacity + static site capacity

Dynamic ODMDS ***capacity*** is defined as the volume of placed dredged material which is transported out of an ODMDS, by waves and currents. The shallower an ODMDS location, the greater the potential for dispersing placed dredged sediments and the higher its dynamic capacity. Generally, the deeper an ODMDS location, the lower its dynamic capacity. For a given water depth, dynamic capacity may be higher for areas closer to an estuary inlet (such as the *Interim* ODMDS near the Yaquina entrance), than in areas further offshore.

Dynamic capacity is specified in terms of a volume rate (cy/year) at which sediment leaves a given site. Dynamic capacity at a given site can change with time based on changes in site bathymetry (mounding increases dynamic capacity) or changes in waves/currents (winter storms disperse more sediment than summer calm).

Static ODMDS ***capacity*** is defined as the limiting volume of dredged material which can be placed within a given area before the resultant mound feature begins to have a negative impact on either navigation or the ambient environment. Navigation impacts associated with static capacity include reducing vessel keel clearance to an unsafe margin or degrading the sea state by causing waves to steepen, amplify in height, or break. Environmental impacts associated with static capacity, include exceeding a pre-determined burial depth over the site's pre-disposal substrate or promoting down-slope distribution of placed material onto areas beyond the designated ODMDS boundaries.

For the case of Yaquina ODMDS, static site capacity is governed by the need to avoid navigation impacts. This focuses on wave shoaling constraints: Wave amplification effects on the approaches to the navigation entrance, jetties, and channel. To meet wave amplification constraints, a given ODMDS mound must not significantly amplify incident waves with respect to a baseline (pre-disposal) bathymetric condition. The wave amplification criteria are generally more restrictive than keel clearance. Generally, the shallower an ODMDS location, the lower its static capacity and vice versa.

ODMDS Selection – Specific Considerations

Dredging and dredged material disposal practices at Yaquina Bay continually balance the competing interests of providing a safe navigation channel, minimizing adverse impacts to the environment, optimizing dredging and disposal efficiency, and using dredged material as a littoral resource (when it is practical and when required). The over-riding considerations governing the selection of a new ODMDS include the avoidance of mound-induced wave shoaling, avoidance of impacts on sensitive benthic areas (rock "reefs"), and locating the new ODMDS within the ZSF. The new ODMDS should be located away from the *Interim* and nearshore *103* sites, due to the mounding issues associated with the historic sites and attendant wave shoaling problems.

Management of new Yaquina ODMDS will avoid the amplification of incoming waves, due to the formation of large dredged material mounds. At a minimum, new Yaquina ODMDSs should be large enough to permit the distribution of 20- to 50-years of dredged material disposal (facilitate the distribution of 6-15 mcy of dredged material on the seabed) without allowing the accumulated material to exceed a height which would cause significant wave amplification. At any given location within a proposed ODMDS, accumulation of dredged material will be controlled so that incident waves are not significantly amplified as compared to the baseline condition, due to dredged material mounding. The ***baseline condition*** for new ODMDSs refers to the bathymetry and associated wave environment BEFORE the ODMDS becomes operational (is used).

The placement strategy has a large influence on the overall impact of dredged material disposal in an ODMDS. Therefore, the size/location of the proposed ODMDS(s) must accommodate various potential site management scenarios and placement strategies for the purpose of minimizing mounding of placed dredged material and minimizing impacts to the benthic environment (infauna/epifauna). Such management scenarios may be mutually exclusive in approach. Two examples are described below:

1. The annual operational footprint (area affected by disposal) would be minimized. This placement method would concentrate dredged material within a small footprint, on an annual basis, while avoiding the formation of excessively high dredged material mounds. An ODMDS would be divided into several sub-areas; each sub-area would be used on an annual rotational basis. One sub-area would be used in any given disposal year, after which the cell would be left "fallow" for a number of years until it would again be used for dredged material disposal. This would allow benthic recovery within each cell following disposal

2. The annual operational footprint (seabed area affected by disposal) would be maximized. This placement method would distribute dredged material over a wide area annually (perhaps an entire ODMDS), minimize vertical accumulation, and promote immediate benthic recovery within the area affected by dredge material disposal. If two new ODMDS were available, each ODMDS could be used alternatively, on an annual basis. This would allow the area of an entire ODMDS to be left "fallow" for a year, similar to management scenario 1 above but much less vertical accumulation of dredged material in any given year.

To ensure that the new Yaquina ODMDS provides adequate capacity, the size of the proposed site(s) was based solely upon static capacity criteria. In other words, the dynamic capacity for proposed new ODMDS(s) was assumed to be zero. Although the proposed site(s) will exhibit some degree of dynamic capacity, the sites were assumed to be non-dispersive as a conservative measure for ensuring sufficient life-cycle capacity. Results of static capacity estimates are presented in Section 6, *FATE Modeling and Impact Assessment for Proposed ODMDS Locations*. Additionally, the proposed ODMDSs should facilitate redundant site capacity. For example, if at sometime in the future ocean disposal of dredged material is restricted within one ODMDSs, say a site located north of the Yaquina Bay entrance, another ODMDS located south of the entrance would have sufficient capacity to handle all dredged material disposal and vice-versa. For this reason, two new ODMDSs were proposed: a North ODMDS and a South ODMDS. Each new site would have capacity for more than 20 years of dredged material disposal. Refer to Figure B-14 for location and layout of the proposed North and South ODMDS.

The management of the proposed ODMDS may change with time, depending on monitoring results, changes in resources agency criteria, or other unforeseen conditions. For example, at sometime in the future, it may be required that dredged material be dispersed to minimize vertical accumulation on the seabed, per disposal season. This would maximize the area over which dredged material would be placed. Therefore, proposed ODMDSs must be "sized" to permit adaptive management practices; hence, the large areal configuration and redundancy in capacity.

The objective of this appendix was to determine the size for each new ODMDS sufficient to handle 6.2 mcy of dredged sediment (placed over a period of 20 years) and to locate the new ODMDSs in terms of the required size vs. other competing criteria. Consideration of proposed ODMDSs in terms of size and location is described in Sections 5 and 6 of this appendix. Development of a management plan for proposed ODMDSs, to ensure that new sites meet operational requirements, is described in Appendix F, *Site Management and Monitoring Plan*.

Littoral Considerations

Although hopper dredge access to the littoral zone may be attained by transiting 4-5 miles north or south of the Yaquina Bay entrance (the height of the north or south reef may diminish at that point), the long transit distance would render hopper dredge disposal in the littoral zone uneconomical. Other potential biological and operational restrictions also preclude designation of a new ODMDS within the littoral zone (nearshore waters less than 60 feet deep).

The proposed ODMDS(s) will be located offshore of the reefs (active littoral zone) and not facilitate re-introduction of dredged material into the littoral zone. Dredged material placed within the proposed North or South ODMDS will in all likelihood be removed from the littoral zone for an extended period of time (10-20 years). Other statutory authorities may be invoked to permit USACE to place dredged material in the nearshore (littoral zone), but will require local-sponsorship to address cost-sharing arrangements and permitting issues.

Section 5
SIMULATING THE FATE OF DREDGED MATERIAL PLACED AT ODMDS

Coupled Strategy for Numerical Modeling and ODMDS Management

The key to successful ODMDS designation and management is knowing in advance or reliably predicting the fate of dredged material placed at the ODMDS. The Ocean Dumping 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

During the USACE Dredging Research Program (DRP), several sediment FATE numerical models were developed or enhanced in order to improve the reliability of ODMDS management. These FATE models incorporate state-of-the-art techniques for simulating the behavior of dredged material placed in open water, and account for a variety of disposal operations and environmental conditions. Results from FATE model application at Yaquina Bay were used to guide site selection for the North and South ODMDS and facilitate life-cycle management of the proposed site in terms of operational requirements. Site physical impact assessments focused on:

Wave conditions - The use of ODMDSs would not significantly increase (worsen) the wave environment at the ODMDS location or adjacent areas, with respect to the site's baseline condition.

Impacts to biologic community - The use of ODMDSs would minimize potential biological impacts (refer to Appendix A, *Living Resources*). Proposed sites are located to avoid placement of dredged material on a limited habitat or seabed substrate (rock reef) that is significantly different from the sediment dredged at the navigation channel. If needed, proposed ODMDSs may be managed to minimize areas of impact or degradation.

Transport of dredged material into the littoral zone - It is desirable for ODMDSs to promote the littoral re-introduction of placed dredged material along the coast. Shallower portions of ODMDSs can be located in water depths of 30-60 feet to facilitate dredge material being transported by waves and currents to the littoral zone. For the Yaquina ODMDS North and South sites, the presence of rocky reefs and substrate and operational constraints preclude designation of a new ODMDS within the littoral zone.

FATE model results that were used to assess the long-term suitability of the proposed Yaquina Bay ODMDS are described in Section 6, *FATE Modeling Results and Impact Assessment for Proposed ODMDS Locations.* The following paragraphs describe FATE model components and the strategy for using the FATE models in this ODMDS assessment.

Fate of Dredged Sediment Placed in Open Water

The physical processes affecting dredged material placed in open water include gravity, surface waves, and currents. At the point of release from the disposal vessel, dredged material falls through the water column, convects/diffuses laterally, and eventually comes to

rest on the seafloor. This scenario characterizes the ***short-term fate*** of dredged material placed in open water. Figure B-11a illustrates dredged material behavior, when placed in open water by a hopper dredge or split-hull barge. During the disposal operation, dredged material can be spread out on the seabed to varying degrees, depending upon the speed of the disposal vessel, water depth, water column current, ambient bathymetry, and other variables. The timeframe for processes affecting the short-term fate of placed dredged material is during and immediately after the disposal operation (minutes to hours).

After dredged material has come to rest on the seabed, it can be eroded by waves and currents. If the dredged material is cohesive, it can experience self-consolidation due to gravity. If many loads of dredged material are placed one on top of another such that a steep aggregate mound develops on ambient bathymetry, the mound will avalanche and material will be transported downslope. The combination of these processes defines the ***long-term fate*** of dredged material placed in open water. The timeframe for processes affecting the long-term fate of placed dredged material is after the disposal operation (days to years).

Predictive Methods: Applicable Numerical Models

STFATE, LTFATE, and MDFATE are numerical models which incorporate state-of-the-art techniques for simulating short- and long-term bathymetric change due to dredging disposal operations and environmental processes. The models were developed at USACE, Waterways Experiment Station (WES) and are briefly described below.

> **Short-Term FATE**: Predicts the distribution of dredged material thru the water column and bathymetric distribution of dredged material on the seabed after it has passed through the water column, on an individual "dump" (disposal vessel load) basis. The timeframe of interest for the STFATE model is on the scale of minutes to hours, during dredged material disposal. The model accounts for various disposal vessel, water column, and material parameters. In this investigation, STFATE was used in a 2-dimension capacity.
>
> **Long-Term FATE**: Simulates bathymetric change due to self-weight consolidation and sediment transport arising from the interaction of waves and currents. The timeframe of interest for the LTFATE model is from days to years, after dredged material disposal. The model accounts for waves, currents, tidal, and material parameters. LTFATE is a 2-dimensional model.
>
> **Multiple-Dump FATE**: 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 STFATE and LTFATE 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. The timeframe of interest for the MDFATE model is from minutes to years, and simulates processes during and after dredged material disposal. MDFATE is a 2-dimensional model and uses the same parameters as used in STFATE and LTFATE.

Predictions of dredged sediment behavior, when it is placed into the open waters of the ocean, can only be as good as the poorest estimate for the forcing environment (i.e., waves, currents, and other processes). To address this need for input data, tide and wave prediction techniques were developed by WES to provide realistic wave and current data to the FATE models.

The computer programs **HPDPRE** and **HPDSIM** were used to simulate a time series representation for wave height, period, and direction [Borgman and Scheffner 1991]. The **ADCIRC** model was used to simulate equilibrium Newtonian tide in terms of ocean surface elevations and current [Hench et al. 1994].

The numerical model **RCPWAVE** [Ebersol et al. 1986] was used in this investigation to assess the effect of bathymetry change (dredged material mounds) upon the wave environment at the historic and proposed Yaquina Bay ODMDSs. RCPWAVE is a 2-dimensional numerical model that simulates the transformation of wind-generated waves, as the waves propagate into shallow water and eventually break. The model accounts for the two dimensional behavior of wind-generated waves (shoaling and refraction) as the waves are affected by an irregular (mild-sloping) seabed. The model does not include the effects of current, wind, or wave-wave interaction upon the wave transformation process. Therefore, the results presented in this wave analysis consider ONLY the effect of waves interacting with bathymetry (the seabed). It has been observed that the RCPWAVE model overestimates the amplification of waves due to shoaling (the model is conservative). Since USACE would rather "err" by overestimating the potential wave amplification (rather than underestimating), a conservative estimator of potential wave amplification is desirable. If we err, it would be such that wave amplification would be predicted to occur, when in fact, waves would not actually be affected by dredged material accumulation (mounding).

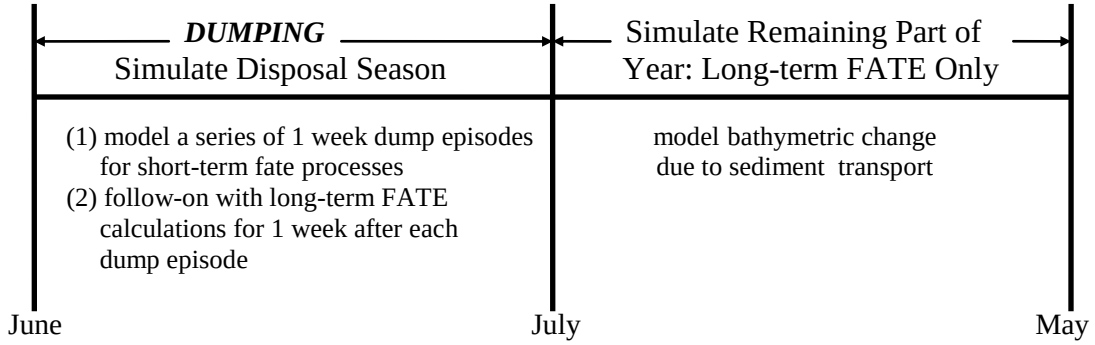
The above models have been calibrated, verified, and successfully applied at several locations within and outside of the Portland District [USACE 1999 and 1995, Clausner et al. 1998 (a and b), Moritz and Randall 1995, Johnson 1978, Johnson and Fong 1995, Thevenot and Johnson 1994, Scheffner 1992, EPA 1978, and Schubel et al. 1978]. Collectively, the above numerical models were used to resolve future ODMDS site management issues related to physical aspects.

ODMDS Modeling Strategy

As a first step toward modeling sediment fate at ODMDSs, existing oceanographic information was consolidated for use in the modeling effort. The year 1996 was chosen as the “base year” for simulating the behavior of dredged material mounds at candidate Yaquina Bay ODMDSs. This was based on the availability of the most recent bathymetric survey for the Yaquina Bay approaches and ODMDSs.

For modeling purposes, the annual dredging and disposal season at Yaquina Bay was broken into two discrete time periods. Dredging disposal at the Yaquina Bay ODMDS normally begins during June and continues through the summer until July or August. After August, the ODMDSs are generally not used and are affected by the energetic wave/current environment until the following May when dredged disposal again commences. The schematic shown below describes how the MDFATE model was applied to simulate dredged material disposal at the proposed Yaquina Bay ODMDS.

Modeling of the Annual Dredged Material Disposal Cycle at Yaquina ODMDS



During a given ODMDS year, short-term fate processes (dredged material disposal) were simulated for a 2-month period (June-July). Long-term fate processes were then simulated for a 10-month period, until the following year when the annual cycle was repeated.

Short-term FATE Model

The STFATE model was used to estimate the geometry of dredged material deposited on the seafloor, on an individual dump basis. These results determined whether flat or peaked "mounds" are produced from dredged material disposal, on an individual dump basis. The above estimates were be performed for the two dredging vessels which have been most used at Yaquina Bay. Results are described in Section 6 of this exhibit. STFATE results were used to optimize ODMDS capacity based on the need to distribute dredged material within the site in terms of thickness, deposition rate, and areal extent per load placed.

Long-term FATE Model

The LTFATE and MDFATE models were used to estimate the capacity of proposed ODMDSs for a 20-year life cycle. The definition of ODMDS site capacity is discussed in Section 4 of this appendix. The MDFATE model was used to simulate the long-term accumulation of dredged material placed at various locations within proposed ODMDSs. MDFATE results were used to determine the ODMDS dimensions required to “acceptably” operate a site over the life cycle. MDFATE model results were also used to ensure that life-cycle management of the proposed ODMDS would meet operational requirements (based on the need to distribute dredged material within a given site, in terms of verifying accumulation thickness and areal extent per year). Results are described in Section 6, *FATE Modeling Results and Impact Assessment for Proposed ODMDS Locations*.

Future management of Yaquina ODMDS will prevent the amplification (shoaling) of incident waves due to the formation of new dredged material mounds by limiting the size (height and plan-form) of new dredged material mounds. Dredged material mound accumulation will be restricted to prevent wave amplification. The RCPWAVE model was used to assess wave-shoaling characteristics of various dredged material mound sizes vs. water depth and wave parameters. The wave amplification criteria were used for purposes of minimizing

undesirable wave conditions due to excessive accumulation of dredged material mounds. Results are described in Section 6, *FATE Modeling Results and Impact Assessment for the Proposed ODMDS* and in Appendix F, *Site Management and Monitoring Plan*.

Calculating Bottom Sediment Transport Potential

The calculation of closure depths [Hallemeier 1981] gives a ***qualitative*** indication of the depth limit for sediment transport rate due to shoaling waves for average and storm wave conditions. Sediment transport closure depths give a general indication for the extent (water depth) of sediment transport, but do not define how much sediment transport will occur.

Hallermeier Sediment Transport Limits

The nearshore region of the seabed can be divided into different transport zones based upon relative rates of littoral sediment transport. Two water depth zonal limits, $\mathbf{d}_\ell$ and $\mathbf{d_S}$ are typically used to describe the transportability of sediment at the seabed due to shoaling waves [Hallemeier 1981]. These depth values are commonly referred to as *closure depths*.

(1) The water depth corresponding to $\mathbf{d}_\ell$ gives a seaward limit for sediment transport associated with highly turbulent surf-zone (or littoral) effects. This depth is a function of the annual mean significant wave height ($H_{1/3}$) and defines the *littoral* zone for which all significant alongshore/cross-shore transport occurs. Algebraically, the littoral closure depth ($\mathbf{d}_\ell$) for typical nearshore sand is defined as:

$$\mathbf{d}_\ell = 2H_{1/3} + 11\sigma \quad \text{where } H_{1/3} = \text{average annual significant wave height applicable at } \mathbf{d}_\ell$$
$$\sigma_h = \text{annual standard deviation of } H_{1/3}$$

The $H_{1/3}$ used for the $\mathbf{d}_\ell$ calculation for Yaquina Bay was determined by transforming the deepwater $H_{1/3}$ (specified by WIS-II station 46, $H_{1/3}$ = 9.0 ft and σ_h = 4.2 feet) to a water depth of 60 feet. The resultant annualized nearshore $H_{1/3}$ = 8.8 feet with σ_h = 3.8 feet. Using the nearshore wave criteria, $\mathbf{d}_\ell$ was calculated to be 59 feet (say 60 feet).

(2) The water depth corresponding to $\mathbf{d_S}$ gives the extreme seaward (outer) limit of wave-induced sediment motion due to extreme waves (storm effects) and is a function of annual mean significant wave height, the annual mean significant wave period, and median sediment grain size. The nearshore zone located seaward of $\mathbf{d}_\ell$ and landward of $\mathbf{d_S}$ (between the two depths) defines the *shoal* zone. The shoal zone between $\mathbf{d}_\ell$ and $\mathbf{d_S}$ is a "gray" area where typical waves have neither a strong nor a negligible effect on the bottom sediment transport during a typical year of wave action [Hallemeier 1981].

$\mathbf{d_s} = (H_{1/3} - 0.3\sigma)T_s(g/5000D_{50})^{1/2}$ where $H_{1/3}$ = 9 feet, estimated average annual significant wave height applicable at $\mathbf{d_s}$

T_s = wave period (associated with $H_{1/3}$) = 11 sec

g = 32.2 ft/sec^2

D_{50} = median sediment grain size = 0.15-0.25 mm = 0.000492 - 0.00082 feet

The median grain size for dredged material to be placed at Yaquina ODMDSs was estimated to be 0.20 mm (Section 8, <u>*Measured Oceanographic Data*</u>). The median grain size for native *in situ* material at candidate areas for new ODMDSs was estimated to be 0.15 mm. The corresponding values for closure depths were calculated to be:

$\mathbf{d_\ell}$ = seaward limit of active littoral zone at (all sediments) = -60 feet MSL
$\mathbf{d_s}$ = extreme seaward limit for wave-induced sediment motion (0.15 mm) = -250 feet MSL
$\mathbf{d_s}$ = extreme seaward limit for wave-induced sediment motion (0.25 mm) = -200 feet MSL

In terms of closure depth, the *Interim* and *103* ODMDSs should experience littoral sediment transport at locations shallower than $\mathbf{d_\ell}$ = -60 feet MSL (about -57 feet MLLW). This in fact has been the case (Section 3 of this appendix). Using closure depths as general criteria for selecting an ODMDS is illustrated as follows. If a new Yaquina ODMDS was needed to prevent any long-term transport of placed dredged material, then the non-dispersive site should be located in water depths deeper than -200 feet MLLW. These criteria would provide for a completely ***non-dispersive*** ODMDS, if placed dredged material had a median grain size of 0.25 mm. Conversely, if a ***dispersive*** ODMDS was required to promote rapid transport of placed dredged material back into the littoral environment, then the proposed site should be located in water depths equal to or shallower than -55 feet MLLW.

If new proposed ODMDSs were to be located in average water depth of 135 feet, dredged sand placed at the sites would be dispersed slowly during infrequent storm events. This would be the case for the proposed North and South ODMDSs.

<u>Modified Ackers-White Sediment Transport Estimates</u>

To obtain a more detailed description of sediment behavior, several relationships have been developed to ***quantitatively*** estimate sediment transport rates [Ackers and White 1973]. The LTFATE model uses the "modified" Ackers and White [1973] equations as the basis for the non-cohesive (total load) sediment transport model. The equations are applicable for uniformly graded non-cohesive sediment in the range of 0.06-0.4 mm. The Ackers-White equations are based on depth-averaged current. Because many ODMDSs are located in relatively shallow water (less than 200 feet), a modification of the Ackers-White equations was made to reflect an increase in the transport rate when ambient currents are accompanied by surface waves [Scheffner et al 1995]. The net direction of sediment transport is governed by current direction only; wave direction has no effect on sediment transport direction.

Several sensitivity tests were conducted to demonstrate the sensitivity of the sediment transport rate with respect to wave height, current speed, water depth, and sediment grain size. Results of the of the Ackers-White sensitivity tests are shown in Figure B-8 (six graphs).

Wave height and current are the governing parameters for sediment transport (upper left and bottom two graphs). If wave height is increased from 7 feet to 20 feet in 48 feet of water depth, sediment transport potential increases by a factor of 10 for a current of 1.5 ft/sec (such would be the case of the eastern part of the *Interim* site during a storm). For water depth less than 125 feet, depth is equally important as wave height in controlling the magnitude of sediment transport (upper right and bottom two graphs), assuming other parameters remain constant. For a water depth of 48 feet (high point of *Interim* ODMDS mound in 1985) with a 20-foot wave and current of 1.5 ft/sec, sediment transport rate is estimated to be about 7 times higher than at 125-foot depth (eastern part of the proposed North or South ODMDSs, see Section 6). Note that regardless of the wave height or water depth, if the depth-averaged current is lower than a threshold value of 0.5 ft/sec, there is no ***net*** sediment transport predicted by Ackers-White formulation.

Sediment grain size has some effect upon sediment mobility (middle left graph Figure B-8), but only at high values of depth-averaged current. The variability in wave period (middle left graph Figure B-8) does not appear to have an appreciable effect upon sediment transport rates.

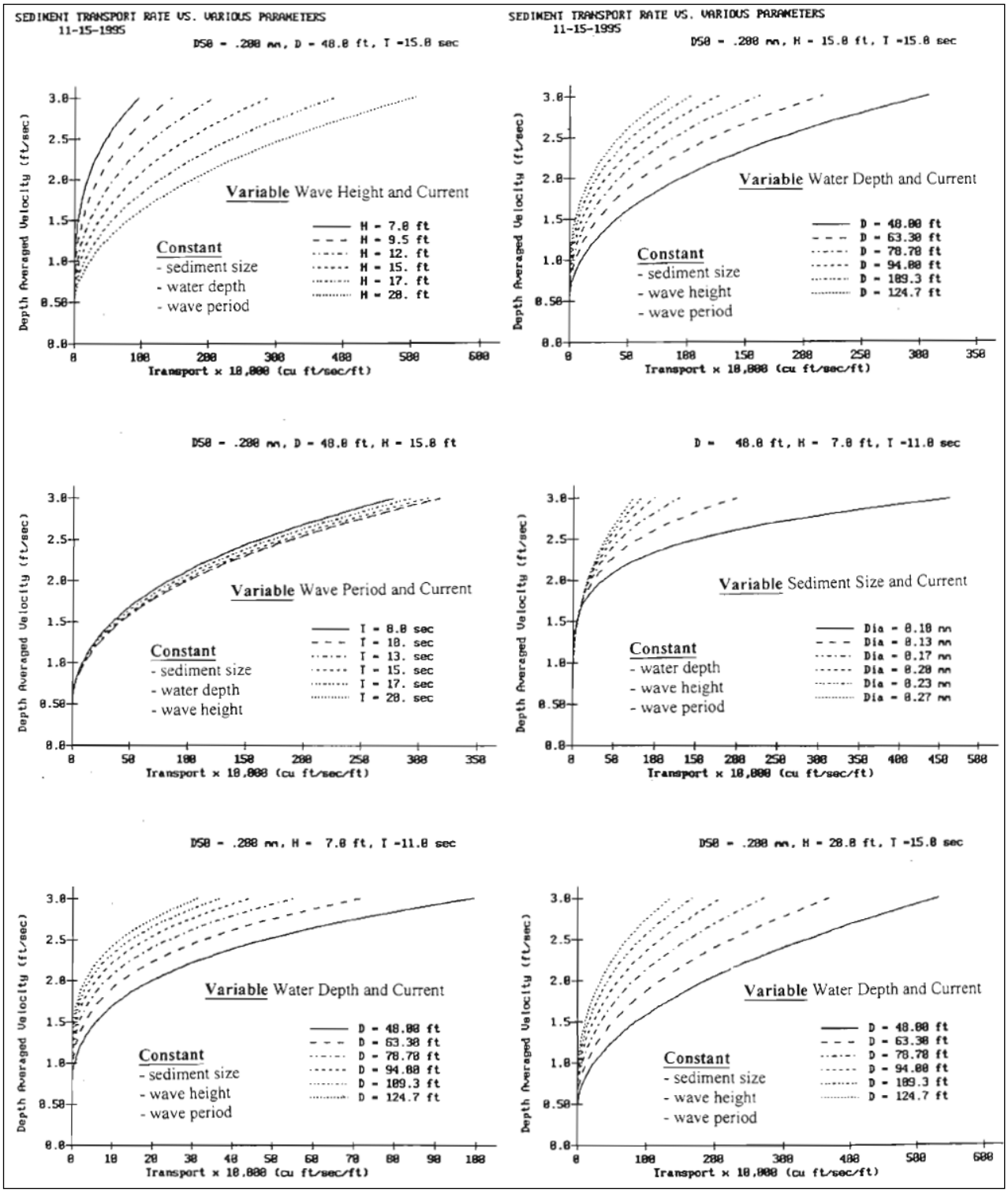
Limitations of Simple Sediment Transport Estimates

Even though the modified Ackers-White equations may provide a realistic estimate of sediment transport potential, the result is only 1-dimensional. The actual (2-dimensional) response of dredged material placed at an ODMDS would remain uncertain, until hindsight from the actual disposal operation is gained through post-disposal condition surveys.

Reliance on 1-dimensional estimates for characterizing sediment transport can be a costly proposition for disposal site selection, if selection does not provide a disposal site with intended dispersive properties or sufficient static capacity. The FATE models use the Ackers-White and other equations to estimate physical processes affecting 2-dimensional sediment transport on the seabed. Application of the FATE models provides the needed predictive means to reliably select a new site or expand the historic ODMDS. The FATE models can also be used to optimize dredged material management at an ODMDS.

It must be noted that the FATE models are only tools that provide estimates of sediment behavior and related processes. The accuracy of FATE model-generated results is highly dependent upon the parameters input to the models. Controlling parameters are physical characteristics of the dredged material, disposal operation sequencing, and forcing environment (waves and currents). As discussed in Sections 7 and 8, much effort was expended to develop reliable input for FATE modeling. Based on previous applications of FATE models and data development outlined above, it is assumed that FATE model results obtained for the Yaquina ODMDSs will meet an accuracy standard of 80% (the difference between predicted and actual conditions is expected to be within ± 20%).

Figure B-8. Results from Ackers-White sensitivity test for sediment transport potential.



FATE Model Data Requirements

Before reliable modeling of dredged material fate could be conducted, environmental processes which govern sediment transport at Yaquina Bay ODMDSs had to be defined. The following prioritization of various environmental parameters is presented in terms of the requirement for FATE model result accuracy:

First Priority = Depth-averaged current magnitude and direction, resolve into seasonal regimes.
Second Priority = Wave height time series, year-long data record with 3-hour record interval.
Third Priority = Characteristic physical properties for dredged sediment and ambient bottom sediments at ODMDSs.
Fourth Priority = Wave period time series, year-long data record with 3-hour record interval.

Section 7, *Oceanographic Processes* provides a general description of regional oceanographic process offshore of Yaquina Bay. Section 8, *Measured Oceanographic Data* quantitatively describes site-specific parameters relevant to FATE modeling.

Section 6
FATE MODELING RESULTS AND IMPACT ASSESSMENT FOR PROPOSED ODMDS LOCATIONS

This section describes procedures that were used to define ODMDS site selection criteria based on physical processes relevant to Yaquina Bay offshore. The physical process criteria were used, in conjunction with other considerations, to evaluate the proposed ODMDS location. Proposed ODMDSs were assessed for life-cycle performance, in terms of physical processes, using the fate models. Long-term management for proposed ODMDSs is discussed in Appendix F, *Site Management and Monitoring Plan*.

Vertical Limit for Dredged Material Mound Height

As stated in Section 4, *Siting and Management Requirements for New ODMDS at Yaquina Bay*, the areal size of new ODMDS was determined based upon the site requirement to provide static capacity for 6.2 mcy of dredged material over a 20-year life cycle ***without significantly affecting baseline wave conditions***. Management of the North and South Yaquina ODMDSs will avoid the amplification of incident waves (sea and swell), due to the formation of large dredged material mounds. The management of the North site for the past 10 years has achieved this goal. At any given location within a proposed ODMDS, accumulation of dredged material will be controlled so that incident waves are not significantly amplified over the baseline (pre-disposal) condition. Biological considerations may impose additional controls to limit annual accumulation rates.

The RCPWAVE model was used to determine the maximum limiting height of a (dredged material) mound feature for various conditions. Figure B-9 summarizes the RCPWAVE results from estimating limiting mound height for several mound geometries in water depths from 40 to 200 feet. The lower bold solid line applies to a large mound feature (2,000-feet wide x 4,000-feet long with 1.2° or 1V:50H side slopes) and was used to determine to maximum mound height applicable for the North and South ODMDS.

Specification of the (baseline condition) water depth of the proposed ODMDS determines the limiting mound height, based on Figure B-9. Once the limiting mound height is determined, the required areal extent of the ODMDS can be calculated from geometric constraints based on the desired volume of static capacity. Refer to Section 4 of this exhibit for the definition of static capacity. All that is needed to begin the ODMDS size calculation is the water depth at the candidate ODMDS location. An example is shown below.

Given:
Water depth at a hypothetical ODMDS = D = 120 ft
Desired static capacity volume = Vs = 6.2 mcy = 167.4 million cubic feet
Side slope for accumulated dredged material = theta = 1.2 ° =1V:50H = 0.020

Required:
Maximum limiting mound height = Hm
Areal Dimensions for ODMDS (assume square site boundaries, length=width) = Ls = Ws.

Solution:

$\boxed{Hm = 14 \text{ ft}}$ (obtained from Figure B-9, lower curve using 120 feet water depth)

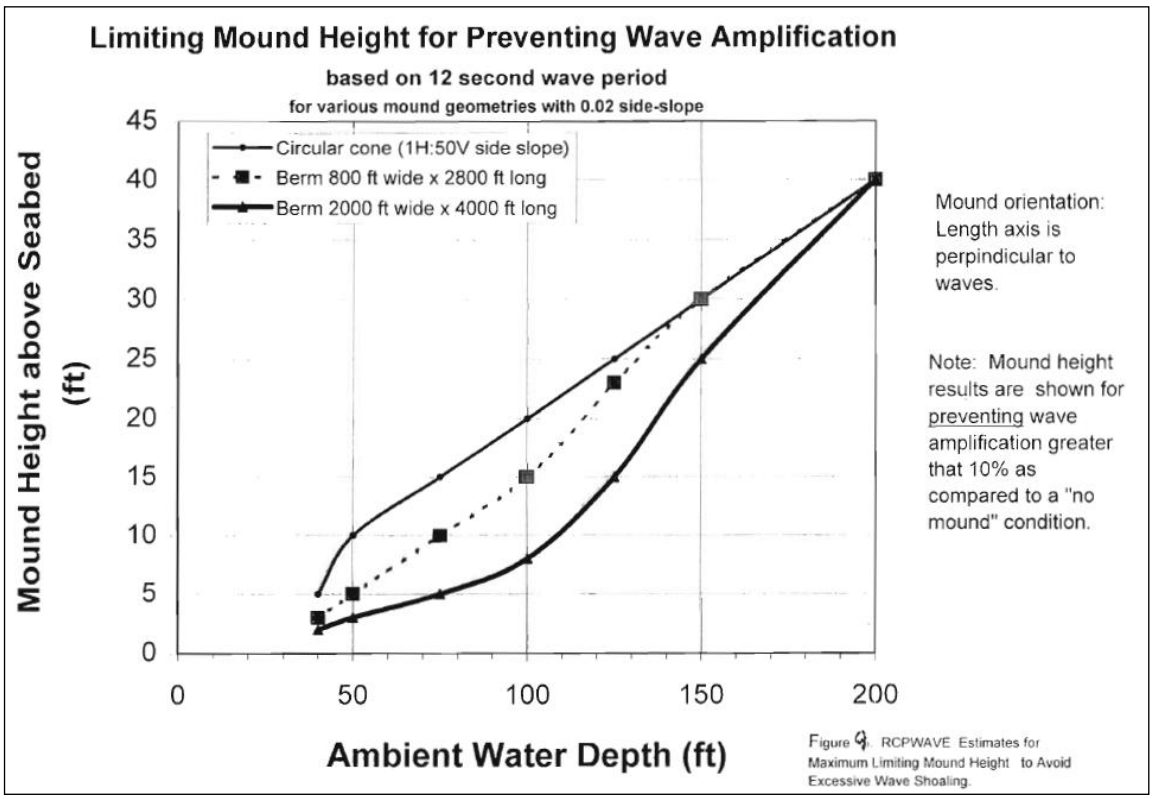
Vs = 1/6*Hm*(A +4B+C), where A = (Ls-2*Hm/theta)*(Ws-2*Hm/theta)
= volume of a prismatoid B = [(Ls-2*Hm/theta) + Ls]*[(Ws-2*Hm/theta) + Ws]/4
C = Ls*Ws

≈ 0.95 * Volume of a solid trapezoid
Volume of a solid trapezoid = ½*Hm[Ws+(Ws-2*Hm/theta)]*Ls

Vs ≈ 0.95* {½*Hm[Ws+(Ws-2*Hm/theta)]*Ls}, since Ws = Ls
Vs ≈ 0.95* {Ls^2 *Hm – Hm^2 *Ls/theta}, at this point Vs can be solved for, or if Vs is known then Ls can be determined by 0 = Ls^2 – Hm*Ls/theta – Vs/(0.95*Hm), by solving for Ls in terms of the quadratic solution for the root.
for this example, Ls = {14/0.02 + $[(14/0.02)^2 + 4*167{,}400{,}000/(0.95*14)]^{1/2}$ }/2 = 3,900 ft

The length of each side of ODMDS (assuming a square ODMDS layout), = $\boxed{Ls = 3{,}900 \text{ ft}}$

Figure B-9. RCPWAVE estimates for maximum limiting mound height.



Note that if Figure B-9 were applied to the designation of an "appropriately sized" *Section 103* ODMDS (located in average water depth 70 feet), the maximum mound height should have been limited to 5 feet. This would have required that the length of each side (for a square site) of the site to be at least 6,100 feet, resulting in an ODMDS 4 times larger than the nearshore *Section 103* ODMDS.

General Location for North and South ODMDS and Required Size

Locating the North and South ODMDS was accomplished by a method of default. As stated in Section 5, the North and South ODMDS could not be located shoreward of the "reefs." Nor should the new site be located over any exposed bottom rock areas offshore of the north and south "reefs." Finally, it was desirable for the new ODMDS not to be located near the historic ODMDSs or near the "mounded" bathymetry located 1 mile due west of the entrance channel. The above restrictions lead to the new ODMDS being located either northwest or southwest of the nearshore *103* site and west of the exposed rock area shown in Figure B-2. Additionally, it was determined that the boundary of a new ODMDS should be located at least 1,000 feet away from any exposed bottom rock area to avoid habitat impacts. This set the location of the landward boundary of the new ODMDS. The width (east-west) and length (north-south) dimensions of the new ODMDS were set such that the middle of the ODMDS would be located as close as possible to the entrance channel. These restrictions confined the general location of the proposed ODMDS to an area either north or south of the bathymetric "bulge" located 0.75 miles due west of the *Interim* ODMDS, having sandy-bottom, and a minimum water depth of about 120 feet.

Based on a water depth of 120 feet and the limiting mound height criteria in Figure B-9, the maximum vertical accumulation of dredged material placed in the new ODMDS was determined to be 14 feet (see above calculation for Hm). The data used in the example static capacity calculation (water depth and required static capacity, shown above) was also applied to determine the minimum area needed for the proposed ODMDS. The length per side (assuming a square site) must be at least 3,900 feet or have an area of 350 acres.

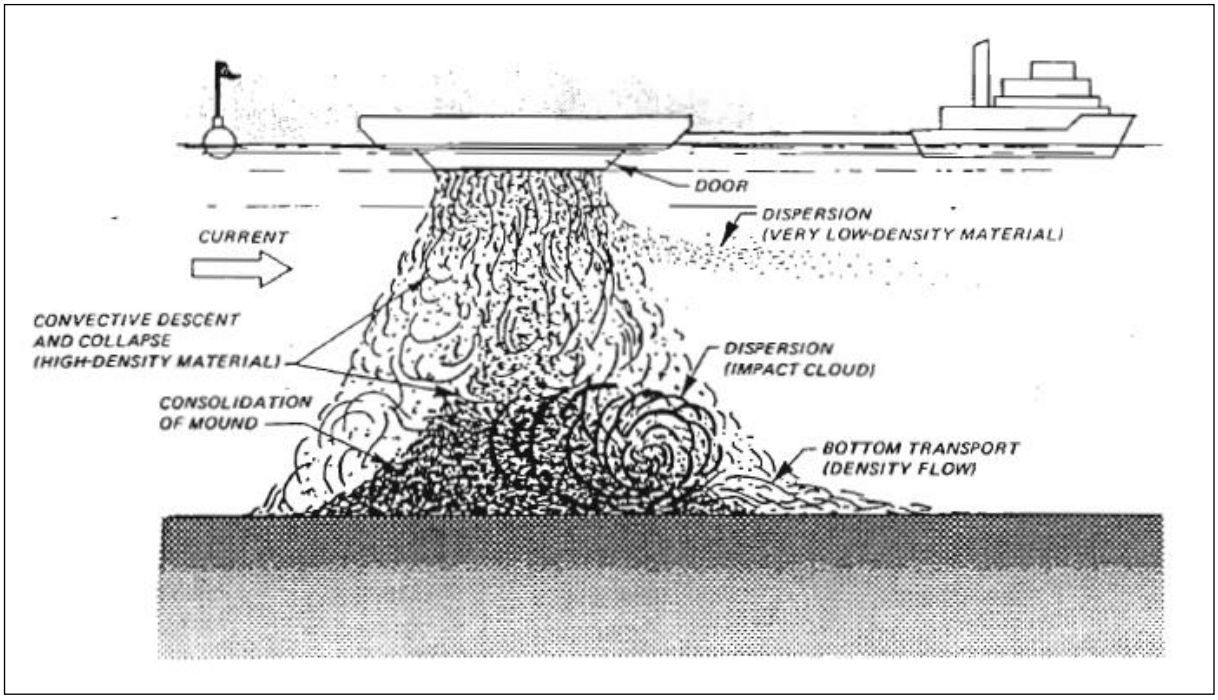
To accommodate for the variable operational aspects of dredged material disposal and other life-cycle uncertainties, the new ODMDS should be "sized" to provide more than the minimum capacity requirement. The following FATE assessments address these considerations.

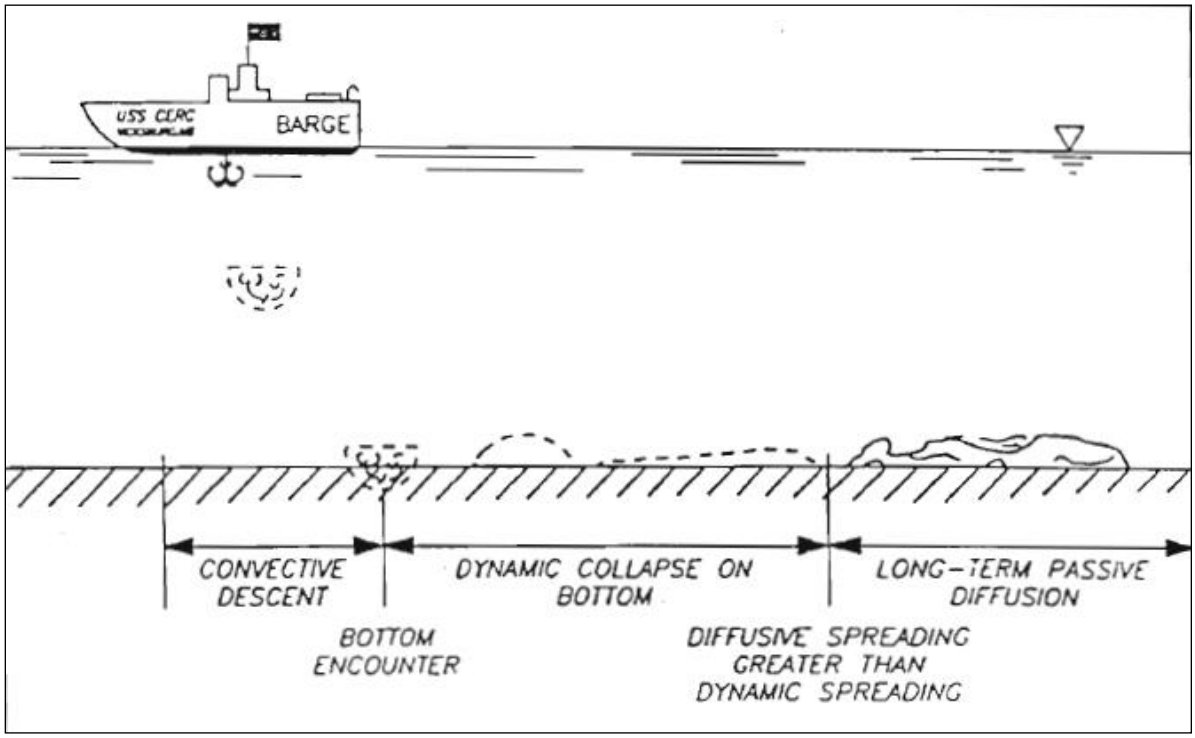
Short-Term Fate Modeling: Bathymetry Impact Assessment

When dredged material is released in open water by a disposal vessel, the material falls through the water column, mixes with ambient water, and forms a plume. This process is called convective descent. When the diluted dredged material plume encounters the seabed, the plume spreads radially along the seabed. This process is called dynamic collapse. After the plume has expended all of its momentum along the seabed, the dredged material slowly settles under the influences of gravity and the ambient current environment. This process is called passive transport and diffusion. Figure B-9a illustrates dredged material behavior, when placed in open water by a hopper dredge.

Bathymetric impacts were defined in terms of the short-term behavior of dredged material on a per dump basis; as dredged material is released from the disposal vessel and accumulates on the seabed. The objectives of the short-term fate assessment were to:

Figure 9a. (Top) Four phases of dredged material behavior during placement in open water. (Bottom) Computational phases of the short-term fate model.





Estimate the disposal footprint geometry (per dump) in terms of thickness and areal extent after the placed material comes to rest on the seabed. This data describes the coverage of dredged material on the seabed data and provides insight to the potential bathymetric impacts in the immediate vicinity of disposal.

Determine the distance that placed dredged material is displaced away from the point of release during disposal. This parameter describes the size of the ODMDS "buffer" zone that is located along the site's perimeter. The buffer zone inscribes the outer area of the ODMDS and is intended to prevent transport of dredged material (by currents or bottom surge motion) beyond the formal site boundary during placement operations.

Short-term fate simulations were conducted for the disposal of dredged material from two types of hopper dredges: (1) split-hull hopper dredge *Westport*, and (2) a multiple bottom door hopper dredge *Yaquina*. Since 1982, about half of all dredging disposal at Yaquina Bay ODMDSs has been performed by the *Yaquina*. The *Westport* has performed about 30% of the Yaquina Bay dredging disposal. Operating parameters for each dredge that has recently been used at Yaquina Bay are shown below.

DREDGE	OVERALL DIMENSIONS			WORKING CAPACITY average (cy)	VESSEL SPEED during disposal (knots)	DISPOSAL vessel type (doors/size of each)	DURATION placement of each load (minutes)
	Length (ft)	Beam (ft)	Draft (ft) loaded/empty				
Westport	270	50	14/8	1,000	2 to 6	split hull/160 x 25 ft	2 to 6
Padre Island	281	52	19/8	2,600	2 to 6	split hull/190 x 30 ft	4 to 6
Atchafalya	197	41	15/6	1,300	2 to 6	split hull/120 x 20 ft	4 to 6
Yaquina	200	58	14/10	1,000	2 to 8	bottom doors (6)/ 4 x 4 ft	2 to 6

For simulation purposes, the vessel speed during disposal was assumed to be 2 knots (3.5 ft/sec) for both dredges. The duration of placement for an individual load of dredged material was assumed to be 3 minutes for the *Westport* and the *Yaquina*. 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 Yaquina ODMDSs ranges from 0.5 ft/sec to 3 ft/sec. The characteristics of sediment dredged from the Yaquina Bay project and placed at ODMDSs are described in Section 8, *Measured Oceanographic Data*.

STFATE Results

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 Yaquina Bay ODMDSs, approximately 98%

of dredged material placed is composed of sand and 2% is composed of fines (silt), on a per load basis. Based on STFATE results for typical conditions, the **time** required for ***sand*** to completely settle out of the water column during dredged material disposal and deposit onto the seabed is approximately 200 seconds (after the completion of the disposal operation). The time required for ***silt*** to completely settle out of the water column and deposit onto the seabed is approximately 2,000 seconds (after the completion of the disposal operation). The above results were obtained for 100-foot water depth with no current. Short-term FATE modeling results are summarized graphically in Figures B-10 to B-13 and are described below for parameters governing mound height, mound width, and displacement distance.

Mound length is directly related to disposal vessel speed during disposal (Figure B-10). For normal operating conditions in water depth of 70 feet, the *Yaquina* and *Westport* produce a dump footprint 600 to 3,200 feet long for vessel speeds ranging from 1-10 ft/sec, respectively. Mound thickness is also affected by vessel speed. For normal operating conditions in water depth of 70 feet, the *Yaquina* (*Westport*) produces a dump footprint 0.2 to 0.05 (0.3 to 0.1) feet thick for vessel speeds ranging from 1-10 ft/sec, respectively.

For similar operating conditions (vessel speed, vessel capacity, water depth, and currents), split-hull hopper dredges produce a thicker (higher) resultant mound footprint than multiple bottom-door hopper dredges (Figure B-11). For average operating conditions in 100 feet of water, without a current, the dredge Yaquina will produce a deposition mound with maximum height of 0.17 feet. The *Westport* will produce a mound with maximum height of 0.3 feet.

The most significant parameter affecting mound geometry (width and height) is water depth**.** Increasing the water depth by a factor of three (60 to 180 feet) will decrease disposal mound height for a single dump by a factor of three for both types of hopper dredges (Figure B-12). Increasing the water depth by a factor of three (60 to 180 feet) will increase disposal mound width for a single dump by a factor of three for both types of hopper dredges (Figure B-13). This applies to dredges disposing in all current conditions tested.

Increasing current speed from 1-4 ft/sec (in 100 feet of water) reduces mound height by a factor of three for both dredges (Figure B-12). The presence of a current act to displace placed dredged material away from the location of release, before the material impacts the seabed (Figure B-13). For disposal in a water depth of 100 feet, a 1 ft/sec current will displace dredged material 400 feet from the site of disposal before most of the material hits the seabed. For the same water depth, a 4 ft/sec current may displace dredged material 1,600 feet from the site of disposal before most of the material hits the seabed.

Figure B-10. Predicted disposal footprint geometry as a function of disposal vessel speed. Top graphic is for mound thickness vs. speed; bottom is for mound length vs. speed.

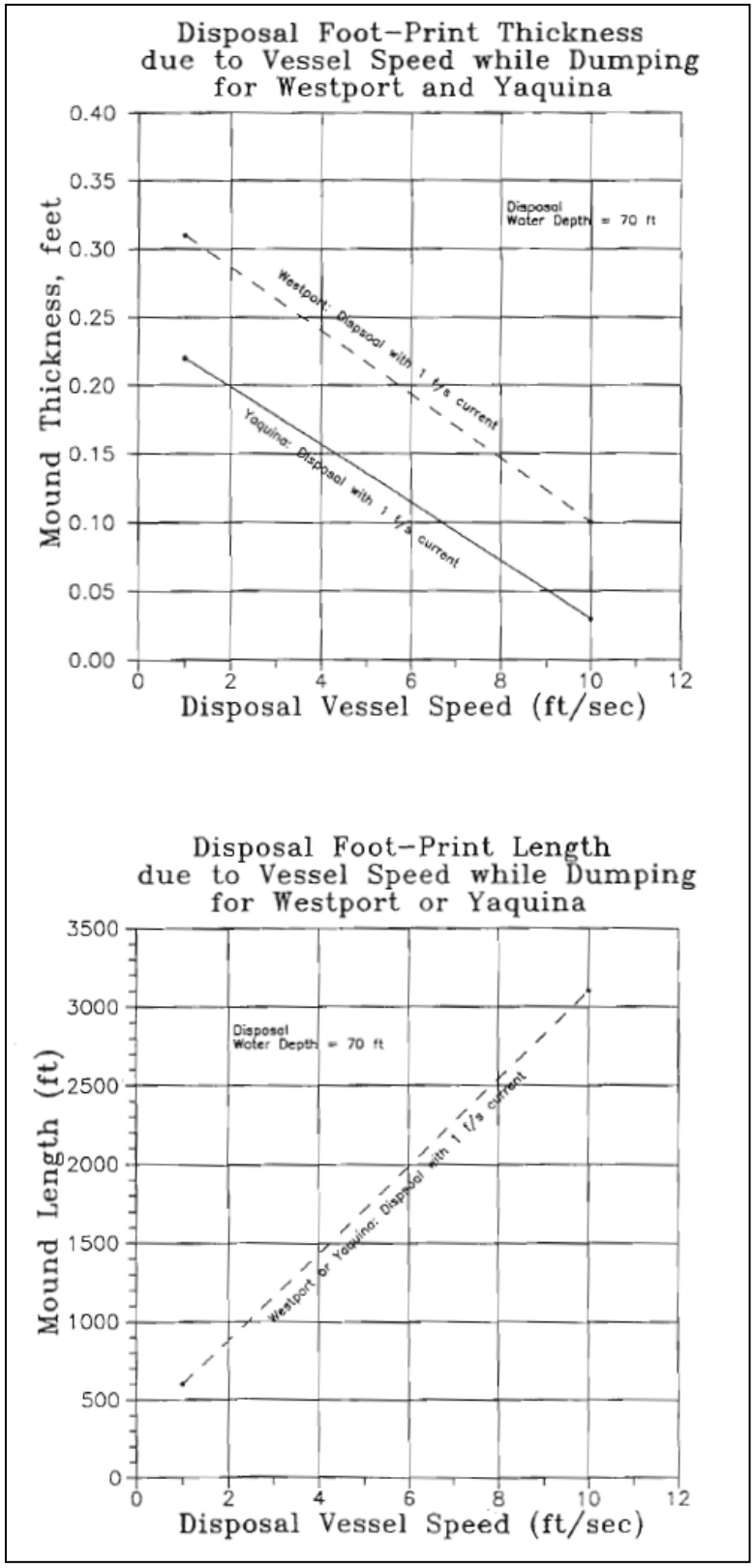


Figure B-11. Predicted disposal footprint thickness for dredges Westport and Yaquina as a function of current speed. Top graphic is for the dredge Yaquina and bottom is for Westport.

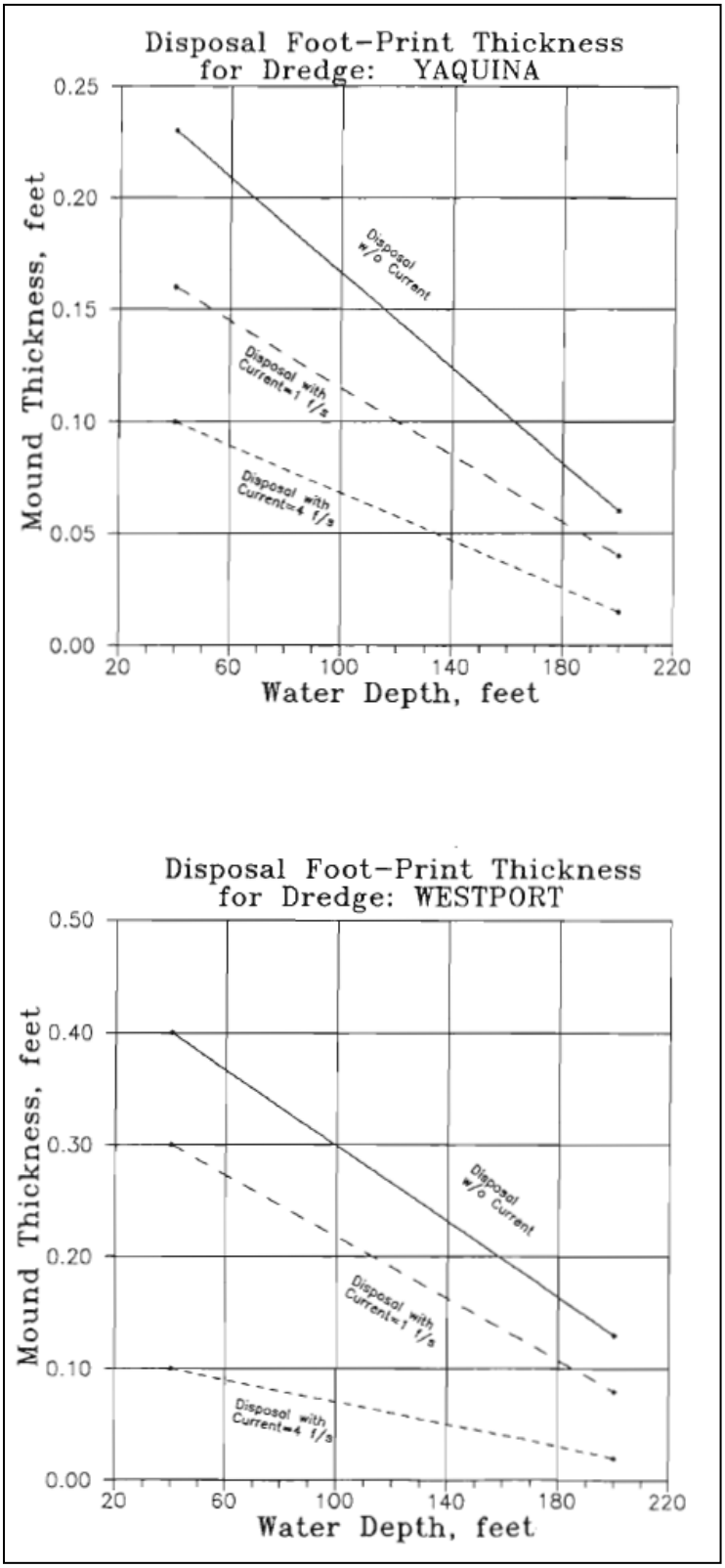


Figure B-12. Predicted disposal footprint geometry as a function of current speed. Top graphic is for footprint width vs. current speed and bottom is for displacement distance of footprint from point of disposal vs. current speed.

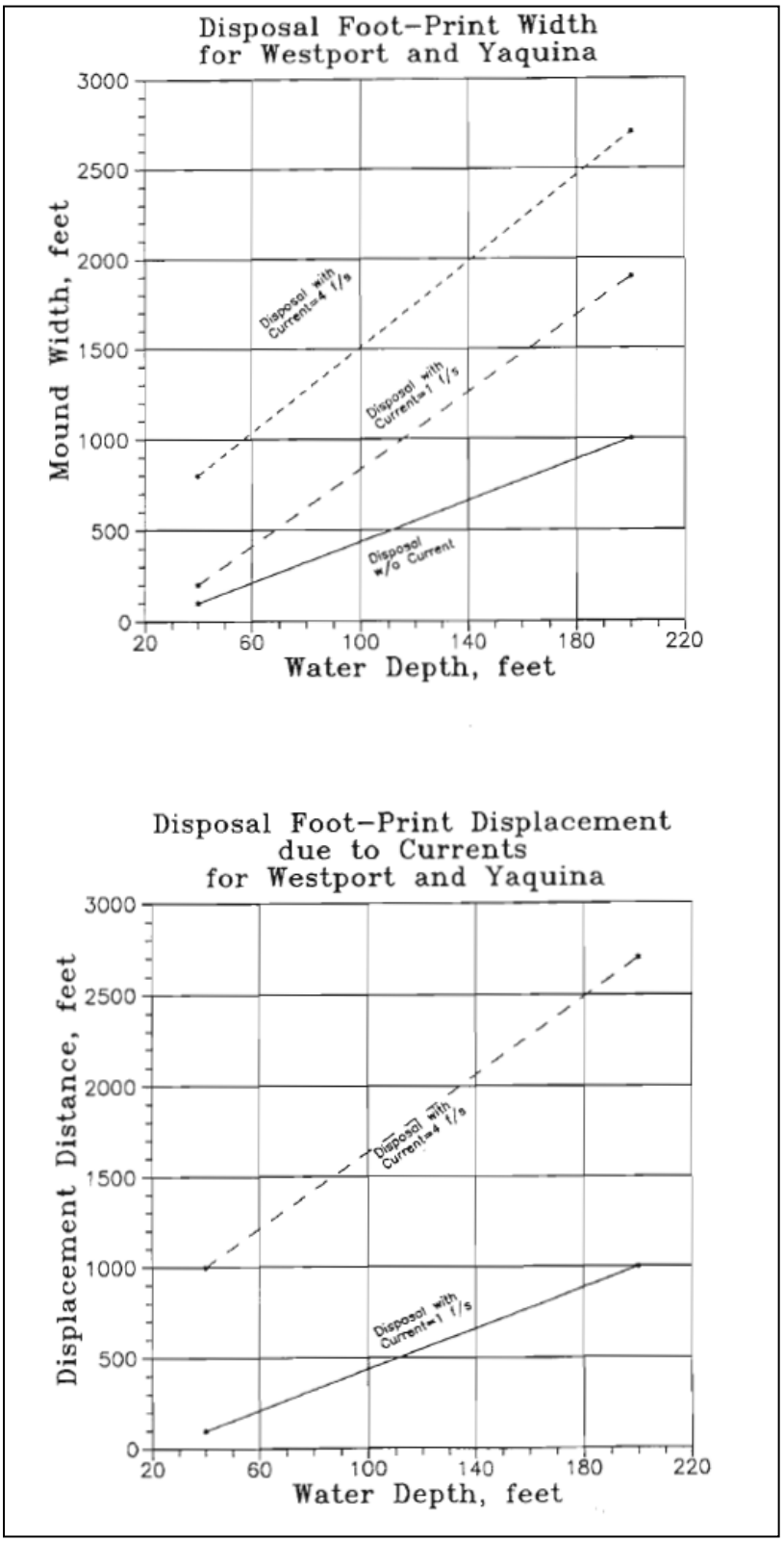
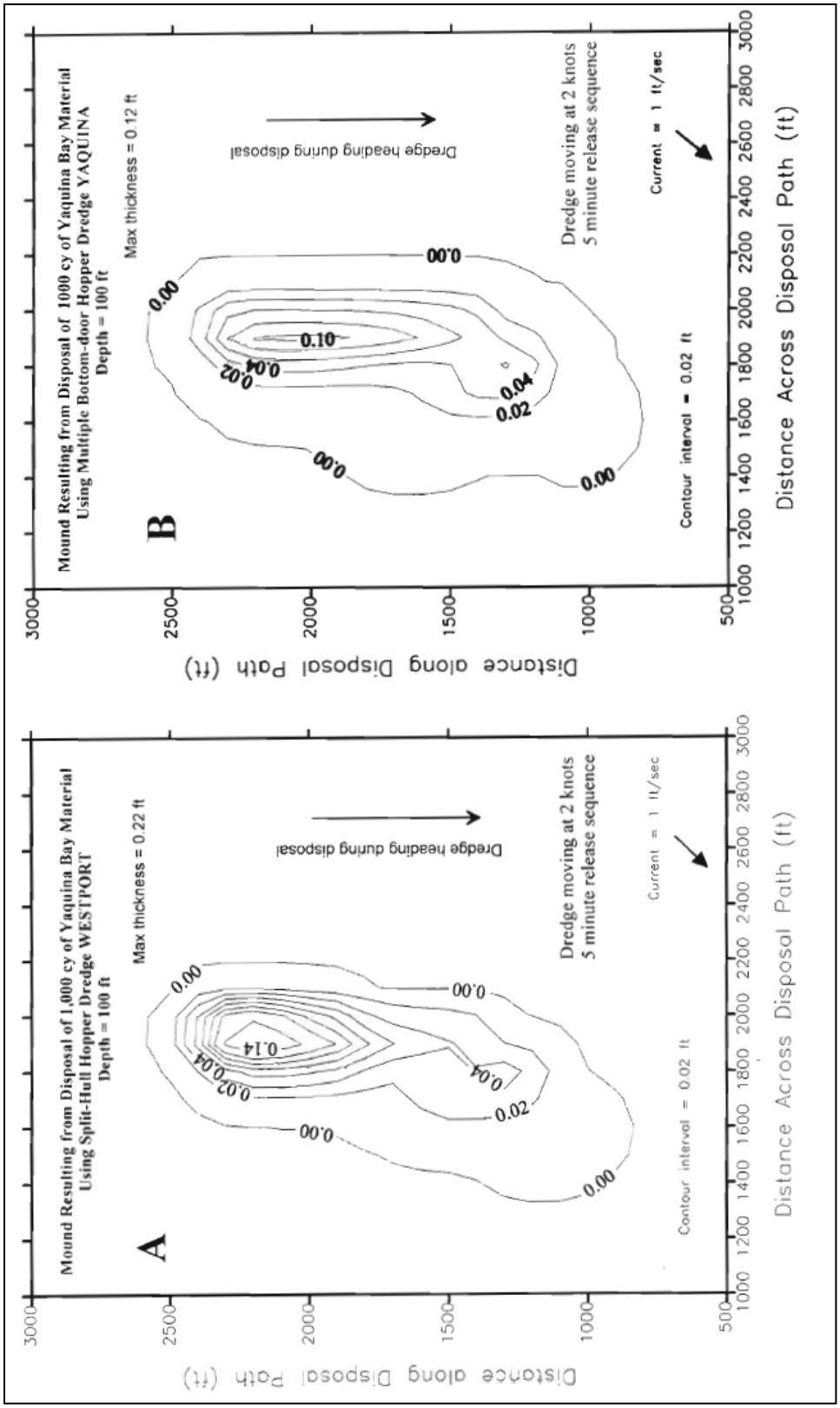


Figure B-13. Predicted bottom distribution resulting from release of one load of sandy dredged material in water depth of 100 feet for two hopper dredges: (A) Westport and (B) Yaquina.



The nominal configuration of a dredged material mound resulting from disposal of one load by the dredge *Westport* and *Yaquina* in 100 feet water depth with a current of 1 ft/sec is shown in Figure B-13. The estimated areal coverage of a mound resulting from a single load placed by the *Westport* in 100 feet water depth is about 17 acres with maximum mound height of 0.22 feet; however, 90% of the mounded area is less than 0.10 feet (1.2 inches). The estimated areal coverage of a mound resulting from a single load placed by the *Yaquina* in 100 feet water depth is about 21 acres with maximum mound height of 0.12 feet; however, 90% of the mounded area is less than 0.07 feet (0.84 inches). The *Westport's* dump footprint is smaller aerially and thicker than the *Yaquina's* dump footprint. The *Yaquina's* footprint is more uniform in terms of deposition (thickness).

For locations offshore of Yaquina Bay where water depths range between 60-150 feet and currents are 1 ft/sec, the mound resulting from an ***individual dump*** could be expected to have the following configuration:

Mound Length: 1,200 - 2,400 feet
Mound Width: 400 - 1,300 feet
Maximum Mound Thickness: 0.1 - 0.3 feet
Displacement of Mound During Disposal: 200 - 700 feet

STFATE Conclusions

The bottom encounter processes associated with dredged material disposal (convective descent and dynamic collapse) are mainly a function of disposal water depth. For shallow water disposal (in 50 feet of depth), the "impact" of the dredged material plume on the seabed is more concentrated (in terms of dredged material plume velocity and density at the seabed) than for disposal in 100 feet of water. However, disposal at deeper water depths increases the areal extent of bottom impact as compared to disposal in shallower water depths. The seabed area affected by the convective descent phase is about 10% of the total dredged material footprint (resulting from completion of the passive transport and diffusion phase).

The thickest area of bottom accumulation for an individual dump represents a small fraction (10% or less) of the overall footprint coverage. For a typical disposal event, most of the disposal footprint area is composed of a thin apron of dredged material (less than 0.1 feet thick, depending on disposal water depth).

Based on the characteristics of dredging vessels typically used at Yaquina Bay, split-hull hopper dredges (*Westport*) are estimated to produce a disposal footprint per dump that has a maximum thickness 50% greater than the multiple bottom-door hopper dredge (*Yaquina*). Dredged material can be dispersed (spread-out on the seabed) by increasing the speed of the disposal vessel while it is placing the dredged material. If the hopper dredge speed is increased while dumping, the mound thickness of individual dumps can be significantly reduced at the expense of increasing mound length. Mound height can be reduced by 45% by increasing the speed of the disposal vessel from 2 ft/sec (1 knot) to 6 ft/sec (3.5 knots). Based on STFATE results assessing displacement of placed dredged material from the point of

release, an ODMDS "buffer zone" of 500 feet (minimum) is recommended to prevent the drift or deposition of dredged material on areas outside of the ODMDS boundary, during disposal.

Specification of Proposed ODMDS Size and Location

The size, location, and layout of the proposed ODMDSs was based on the "site selection and management criteria" described in Section 4 of this appendix and the "general location and required size" discussed above. To summarize:

A. Based on mound height restrictions and simple geometry, the minimum size of each proposed ODMDS (for static capacity) was calculated to be 3,900 feet x 3,900 feet. See Section 6.

B. To reduce the risk of dredged material being placed outside of the ODMDS boundaries, a 500-foot "buffer" zone was inscribed within the formal site boundary. No dredged material disposal is proposed within the site's "buffer zone" although it is formally part of ODMDS. The "buffer" zone functions to keep material within the ODMDS while the placed material is falling through the water column.

C. The orientation of the proposed ODMDSs was such that the primary axis of the sites was aligned with the bathymetry contours.

D. Two ODMDS (identical in size) are proposed to facilitate adaptive management and variable dredged material placement strategies. The proposed sites are referred to as the "North" ODMDS and the "South" ODMDS.

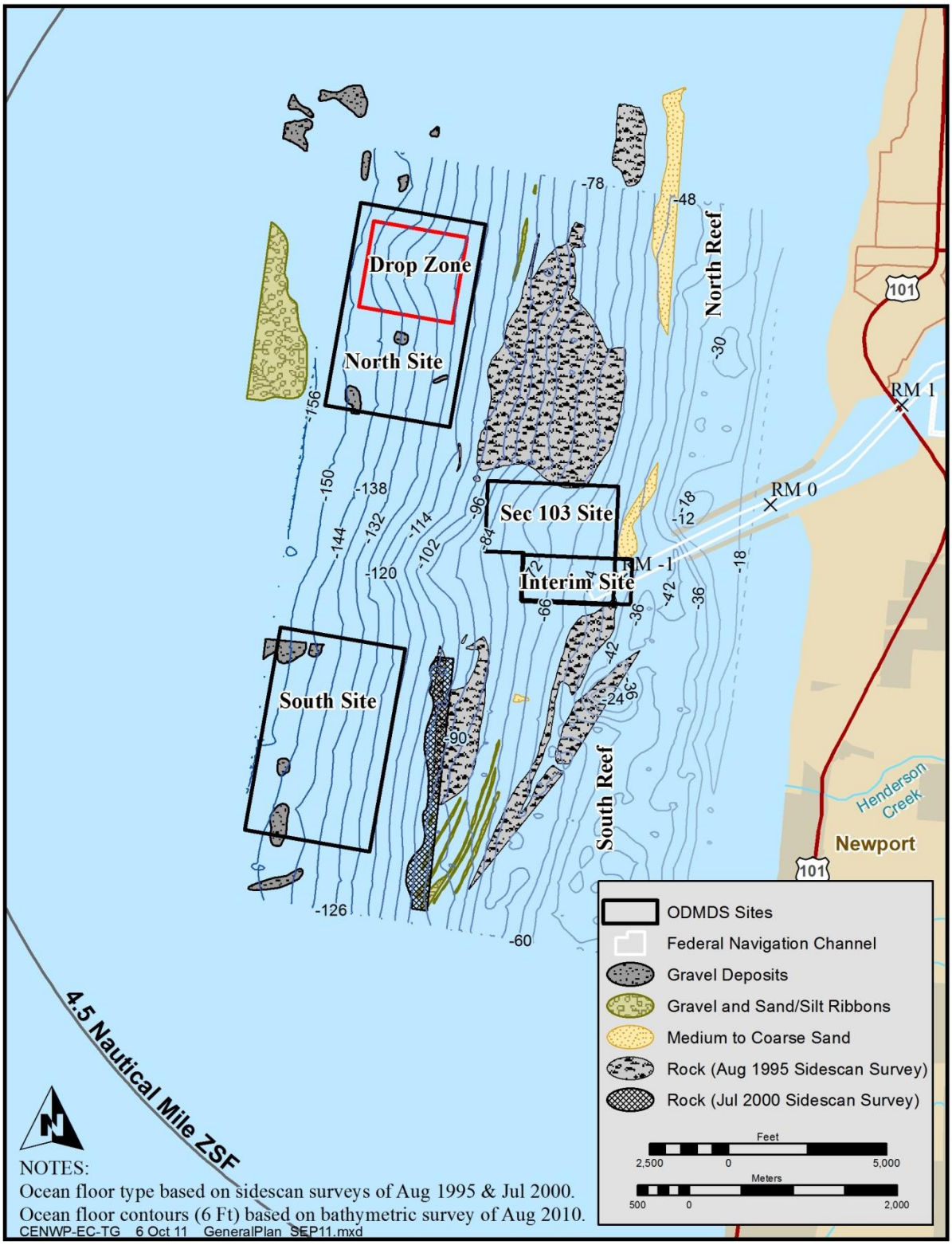
Discounting the buffer zone, the effective usable area for each proposed ODMDS was set at 5,500 feet x 2,800 feet. This is equivalent to the minimum required size of 3,900 feet x 3,900 feet (see the ODMDS "size" calculation in Section 6). The buffer zone along the northern, southern, and western perimeters of the ODMDSs was set at 500 feet. For the purpose of FATE modeling, a larger buffer zone (800 feet) was applied to eastern perimeter of the proposed ODMDSs to account for the presence of potentially sensitive rocky bottom areas east of the proposed ODMDSs. If FATE model results show that 800 feet of buffer is not needed along the eastern perimeter of the ODMDS, the buffer can be reduced to 500 feet. Including the offset buffer zone, the overall dimensions of each proposed ODMDS is 6,500 feet x 4,000 feet.

The lineal dimensions, boundary coordinates, and water depth variation for the proposed North and South ODMDS are described below and shown in Figure B-14. Disposal boundary coordinates in state plane are Oregon north zone, NAD 27 (feet). Disposal boundary coordinates in geographic coordinates are in latitude-longitude, NAD83 (deg min sec).

Proposed "North" ODMDS: dimensions = 6,500 ft x 4,000 ft, area = 597 acres, axis azimuth = 10°, average depth = 135 feet. Baseline bathymetry elevation variation = -115 MLLW to -150 MLLW

Northwest corner - Easting=1,057,355 ft, Northing=375,434 ft	Lat=44 38 17.98 N, Lng= -124 07 25.95 W
Northeast corner: - Easting=1,061,294 ft, Northing=374,740 ft	Lat=44 38 12.86 N, Lng= -124 06 31.10 W
Southwest corner: - Easting=1,056,226 ft, Northing=369,033 ft	Lat=44 37 14.33 N, Lng= -124 07 37.57 W
Southeast corner: - Easting=1,060,166 ft, Northing=368,339 ft	Lat=44 37 09.22 N, Lng= -124 06 42.73 W

Figure B-14. Proposed new locations for Yaquina Bay ODMDSs.



Proposed "South" ODMDS : dimensions = 6,500 ft x 4,000 ft, area = 597 acres, axis azimuth = 10°, average depth = 135 ft. Baseline bathymetry elevation variation = -115 MLLW to -150 MLLW

Northwest corner -	Easting=1,054,819 ft, Northing=362,018 ft	Lat=44 36 04.50 N, Lng= -124 07 52.66 W
Northeast corner: -	Easting=1,058,758 ft, Northing=361,323 ft	Lat=44 35 59.39 N, Lng= -124 06 57.84 W
Southwest corner: -	Easting=1,053,890 ft, Northing=355,617 ft	Lat=44 35 00.85 N, Lng= -124 08 04.27 W
Southeast corner: -	Easting=1,057,629 ft, Northing=354,922 ft	Lat=44 34 55.75 N, Lng= -124 07 09.47 W

Long-Term Fate Modeling: Typical Disposal Year

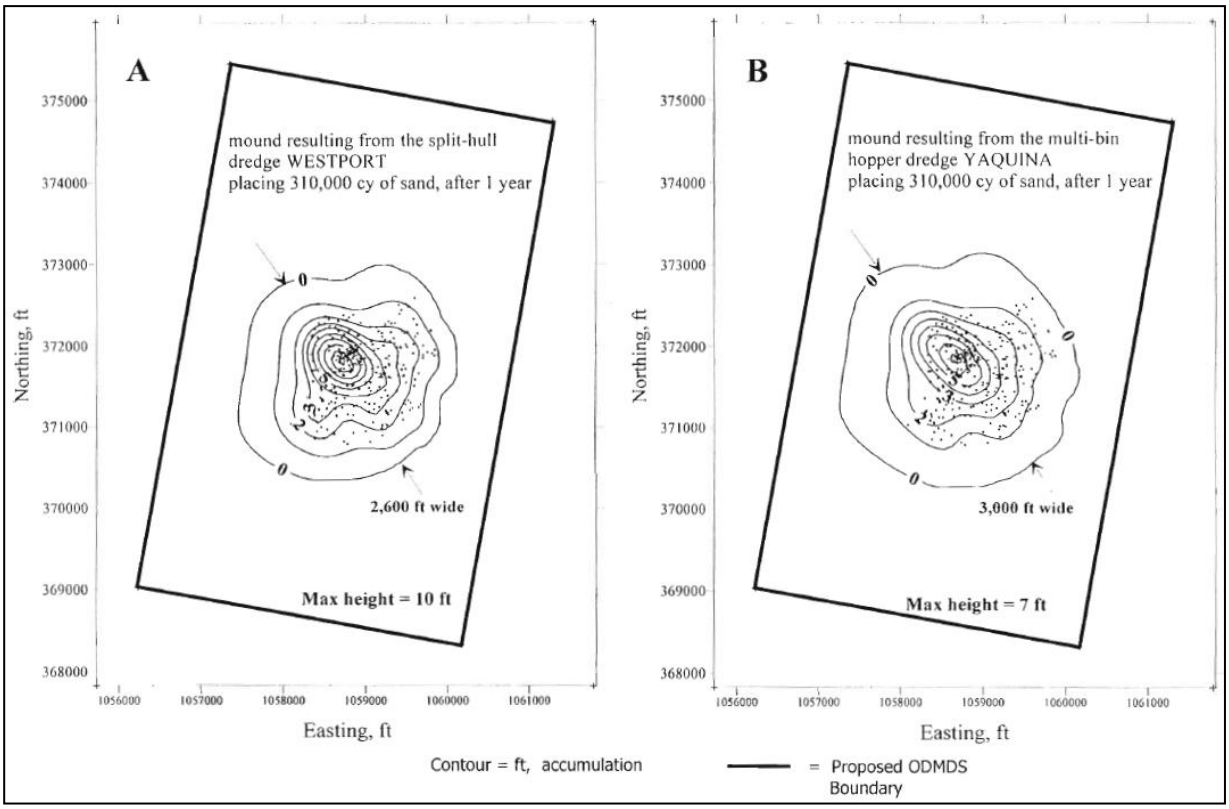
Assessment of life-cycle capacity for the proposed ODMDSs was based on applying the FATE models to the "North" ODMDS. Since the physical environment is basically the same at the North and South sites, similar FATE results are expected for the "South" ODMDS.

The bottom accumulation of dredged material placed within the proposed North ODMDS was estimated based on an annualized sequence of disposal. This was done using two different types of dredging equipment: split-hull and multiple-bottom door hopper dredges. The **MDFATE** model was used to predict the bathymetric distribution of dredged material in response to a year-long disposal cycle. The focus of this endeavor was to assess the "operational dispersiveness" of the multiple-door hopper dredge (*Yaquina*) and the split-hull dredge (*Westport*). Factors under consideration include the areal extent of placed dredged material and the maximum mound height attained after a given year-long disposal cycle. Disposal parameters assumed for both types of dredging vessels are:

- Volume placed = 310,000 cy or 310 loads (annual average 1986-2000).
- Dredged material placed randomly about the center of the proposed ODMDS, using a maximum placement radius of 1,000 feet from the centroid. Water depth at the centroid of the ODMDS was about 135 feet.
- The hopper dredge approaches the disposal release point from the southeast for each dump placed.
- Other operational parameters are as stated above or in Section 8, *Measured Oceanographic Data*.

Results from the year-long simulations are shown in Figure B-15 in terms of accumulated placed dredged material, resulting from a one-year disposal scenario. The left-hand graphic (A) applies to the split-hull dredge *Westport* placing 310,000 cy and the right-hand graphic (B) applies to the multiple bottom-door dredge *Yaquina* placing 310,000 cy. Note that the dredge *Westport* produced a 40% taller and more compact mound (13% smaller), than did the dredge *Yaquina*. This result is consistent with the short-term FATE results described above. Both disposal vessels produced an aggregate mound that was higher than 5 feet.

Figure B-15. Accumulation of dredged sand placed in center of proposed North ODMDS for a split-hull hopper dredge (A) and multi-bin hopper dredge (B), 1,000 cy per load.



Given the above results, it would be hard to prevent accumulation of dredged material to heights less than 14 feet during a 20-year life cycle (assuming dredged material is placed in a similar manner each year). Discrete mounds would likely overlap and accumulate to heights greater than 14 feet. Recall from the ODMDS "size" calculation shown in Section 6 (Figure B-9) that for a large mound 135 feet in depth the maximum mound height that will not affect waves is 14 feet.

It is apparent from both the *Westport* and *Yaquina* disposal scenarios shown in Figure B-15, that "point" disposal methods (random placement about a specified point) are not sufficiently distributive, in an operational sense, for the successful long-term management of site capacity within the configuration of the proposed ODMDSs. To avert future static site capacity problems at the proposed ODMDSs, it is recommended that a pro-active approach be used to enhance the uniform distribution of dredged material during disposal. Basically, this entails the use of a placement grid to evenly distribute the placement of dredged material within the ODMDS by assigning the "starting point" of each dump within specified grid cells. The "placement grid" method of dredged material disposal is discussed below and has been used since 2001 at the North site.

Long-Term Fate Modeling: 20-Year Life Cycle

The "operational" capacity of the proposed North ODMDS was assessed for a 20-year life cycle by conducting 20 back-to-back year-long disposal operations. The goal was to verify that by distributing the placement of dredged material throughout the usable part of the ODMDS was such that dredged material is not deposited outside the formal boundaries of the ODMDS during the placement, and dredged material does not accumulate higher than 14 feet after 20 years of site use. The MDFATE model was used for this series of simulations. For each year of simulation, disposal processes (short-term fate) and bottom transport processes (long-term fate) were included. The left graphic in Figure B-16 shows the baseline bathymetry condition of the proposed North ODMDS.

ODMDS Disposal Placement Grid

For this life-cycle assessment, uniform thin-layer placement of dredged material was accomplished by using a grid of 32 cells that are 700 x 700 feet to establish the *release point* for each load of dredged material. The "placement grid" was contained inside of the ODMDS. The "placement grid" was used to guide the distribution of dredged material disposal for each year.

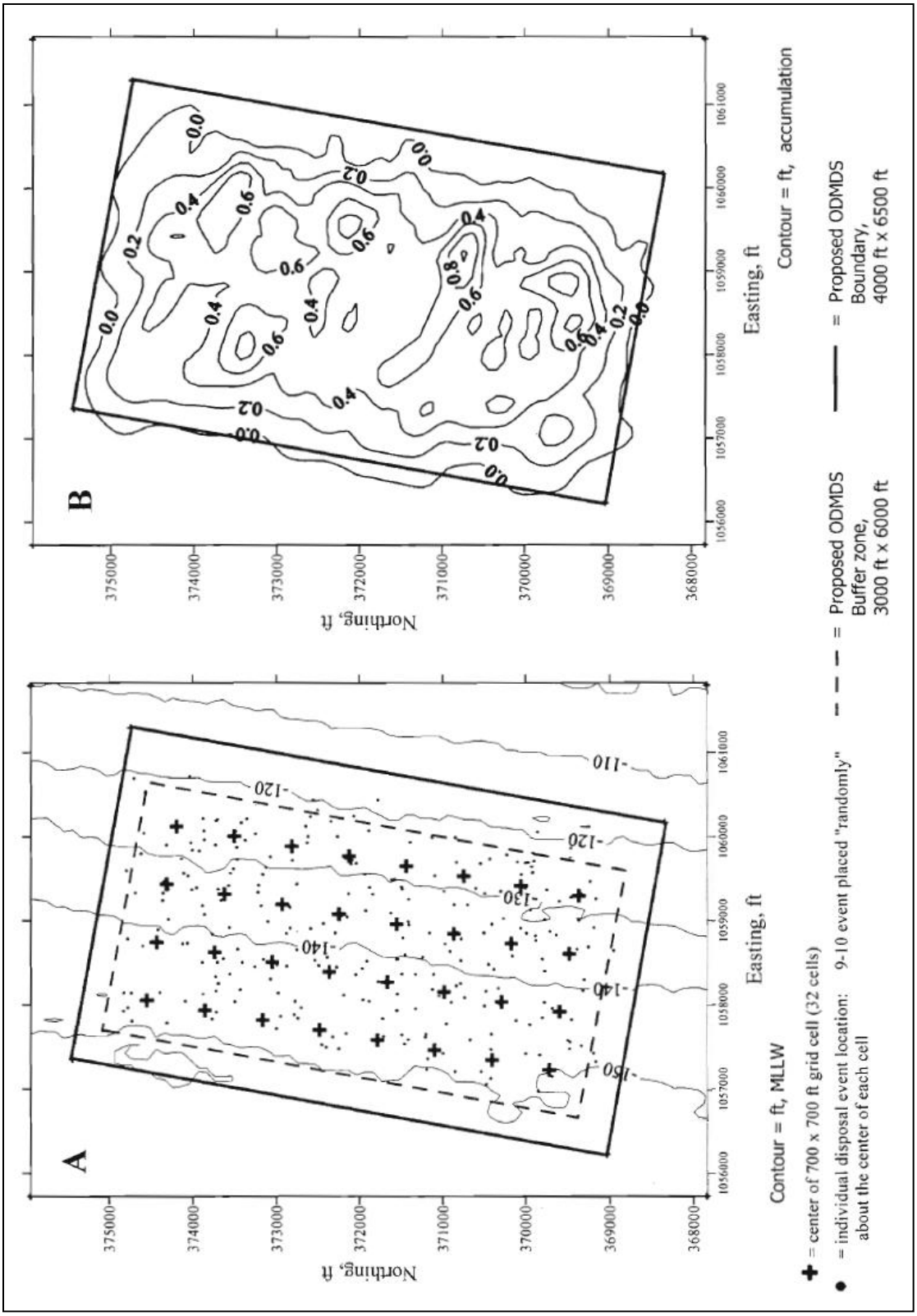
Nine (dredge *Westport*) and 10 (dredge *Yaquina*) dumps per grid cell were needed to place 310,000 cy of dredged material within the site per year. It was assumed that both the *Westport* (30%) and *Yaquina* (70%) would be used for dredging/disposal during the 20-year period. The selection of each simulated dump location was chosen randomly based on a 500-foot radius from the center coordinate for each cell. The center of each grid cell is shown in Figure B-16 (left graphic "+"). Note that "usable" area of the ODMDS is inscribed by the dashed line.

Year One of 20-Year Disposal Sequence

The first year of the 20-year "operational" capacity assessment was simulated based on the dredge *Yaquina* performing dredged material disposal within the proposed North ODMDS. The 32-cell placement grid described above was used to control the disposal of 310 loads of dredged material within the North ODMDS boundaries. The resultant dredged material accumulation, after 1 year of disposal, is show in the right graphic of Figure B-16. The maximum height of dredged material accumulation is estimated to be 1.2 feet and all placed dredged material is contained within the North ODMDS boundaries. Due to the low relief of the dredged material mound, very little material was affected by waves/currents during the first year of simulation.

Comparison of Figure B-16 (right graphic) with Figure B-15 (left graphic) clearly shows that the "placement grid" method of disposal control is superior to "point dump" methods for dispersing material uniformly with an ODMDS.

Figure B-16. Baseline (2000) bathymetry at the proposed North ODMDS (A) and estimated accumulation after 1 year of dredged material placement by hopper dredge Yaquina (B).



Complete 20-year Disposal Sequence

The disposal of 6.2 mcy of dredged material (sand) was simulated based on the dredge *Yaquina* placing 70% of the material and the *Westport* placing 30%. Results of the 20-year disposal sequence are shown in Figure B-17. The left graphic in this figure shows the predicted 20-year bathymetry within the proposed ODMDS. Note that the depth contours are displaced oceanward from the baseline condition. The right graphic of Figure B-17 shows the vertical and areal extent of the dredged material mound resulting from 6.2 mcy of disposal. Note that the maximum height of the resultant dredged material mound is estimated to be 12 feet, which is 2 feet lower than the limiting mound height required to meet the wave amplification constraint (see the ODMDS "size" calculation in Section 6).

Based on the above long-term simulation results, each proposed ODMDS is expected to provide sufficient static capacity for at least a 20-year life cycle without impacting wave conditions at the site. Although the dynamic capacity of the proposed ODMDS (after 20 years of dredged material accumulation) is estimated to be 100,000 cy/year, this was not considered part of the site's operational capacity. Collectively, both the North and South sites are estimated to provide over 40 years of capacity for the placement of Yaquina Bay dredged material. The net direction and distance of sediment movement off of the mound is estimated to be toward the WNW (300°) at 120 feet/year. Based on the estimated deposition pattern shown in Figure B-17B and the direction of dredged material movement (after placement at the North or South sites), a uniform 500-foot setback area is appropriate for the proposed sites. In other words, the 800-foot setback area along the eastern perimeter of the proposed sites is not needed.

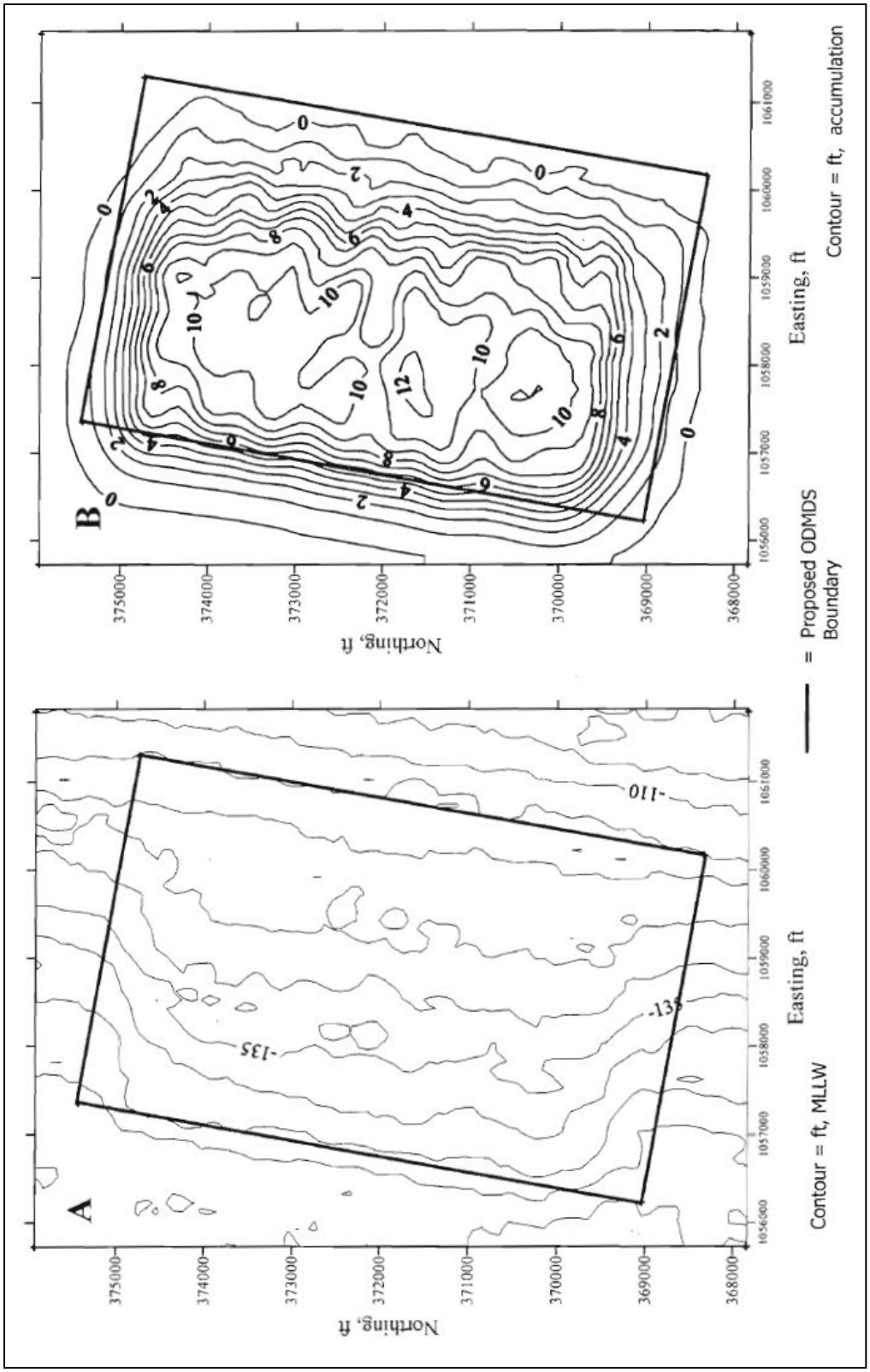
Summary of FATE Modeling Results

The proposed North ODMDS shown in Figure B-10 (and left graphic of Figure B-16) appears to be capable of receiving 310,000 cy/yr of dredged material disposal for a period of 20 years (6.2 mcy total) without impacting the present wave climate. This assessment is based on results obtained using the MDFATE model. The South Site has similar capacity.

The 20-year capacity of each proposed ODMDS can only be met if a "placement grid" or equivalent method of disposal control is used to evenly distribute dredged material within the site during disposal. The "placement grid" would consist of 32 cells that are 700 x 700 feet to "distribute" the *release point* for each load of dredged material.

Net long-term movement of the dredged material placed at the proposed ODMDS would be toward the north-northwest, away from any known rock outcrop features. A 500-foot placement setback should be inscribed within the proposed North and South ODMDS boundaries to keep material within the ODMDS during dredged material placement.

Figure B-17. Predicted bathymetry at proposed North ODMDS after 20 years of dredged material placement (A) and corresponding vertical accumulation (B).



Physical Impacts at ODMDSs due to Dredged Material Disposal

Accumulation of Dredged Material Placed. The seabed at the proposed North and South ODMDSs will be subjected to various degrees of dredged material accumulation (burial) during dredged material disposal operations. On a per dump basis (individual disposal vessel load), the seafloor at the ODMDSs could be subjected to individual burial events ranging from 0.01 - 0.3 feet thick and covering 5-20 acres of seafloor. On a seasonal basis (after an entire dredging-disposal season), the sites may be subjected to dredged material accumulation ranging between 1-10 feet thick covering an area of 100-500 acres, depending upon the disposal scenario. Generally speaking, the more confined the area over which dredged material placement occurs, the higher the accumulation.

Modification of *in situ* Surface Sediment Gradation. There could be a slight change of the surface sediment texture (grain size) at the North and South ODMDSs, in response to dredged material disposal. Specifically, the average grain size of seabed sediment within the sites will likely increase due to the placement of dredged material that is slightly coarser than *in situ* sediments. The overall physical properties of the pre-disposal seabed sediment within the proposed ODMDSs would not be changed. Sand (sediment dredged from the Yaquina Bay project is about 95% sand) will be placed on sand (*in situ* sediment residing on the seabed of proposed ODMDSs). The mean grain-size of *in situ* seabed sediment within the ODMDSs varies between 0.10 - 0.20 mm and has a fine-grain material content of 0-10%. The mean grain size of 95% of the dredged sediment to be placed in ODMDSs varies from 0.15 - 0.25 mm and has a fine-grain material content of 1%-4%.

A small amount of fine-grained dredged sediment may be placed at the proposed ODMDSs. This dredged material originates from periodic dredging of South Beach marina, North Bay marina, Depot Slough, and potentially other permitted projects. The quantities of fine-grained sediment to be placed at the proposed ODMDSs are about 5% of the total volume dredged at Yaquina Bay. It is expected that placement of such small amounts of fine-grain sediment within the proposed ODMDSs will not significantly alter the characteristic grain size of native sediment within or outside the ODMDSs.

Modification of Existing Wave Environment. Use of the proposed North and South ODMDSs will not degrade the existing wave environment either within or outside the ODMDS boundaries.

Modification of Existing Current Environment. Placement of dredged material within the proposed North and South ODMDSs may have a minor affect on circulation within or outside of the site boundaries. Due to the size of the mound resulting from accumulated dredged material placed at the sites (10-14 feet high covering a 0.6 square mile area) over a period of 20 years, it is possible that currents in vicinity of ODMDSs could be affected by disposal operations. A vertical accumulation of 14 feet of dredged material within a water depth of 115 feet will directly affect 10% of the water column. This amount of “protrusion” may modify currents at the disposal site. If realized, the effects upon the site’s current field would not occur until a substantial volume of dredged material has been placed at the site (4-6 mcy, or after 15-20 years of disposal).

Littoral Budget. Most of the sand dredged from the Yaquina Bay entrance channel originates from the marine environment. It is possible that dredged sand placed at the proposed North and South ODMDSs could be removed from the littoral budget for 10-20 years (until infrequent large storms can transport the sand back toward the shore). An important question related to the siting and long-term management of proposed ODMDSs at Yaquina Bay is: Will the use of the proposed North and South ODMDSs affect the littoral sediment budget in vicinity of the Yaquina Bay entrance? If the littoral budget is affected, could there be an associated effect on coastal beaches near the jettied entrance? To address the above questions, the following assumptions must be made:

1. An undetermined but substantial percentage of the sand dredged from the entrance channel originates from active littoral area immediately north and south of the jettied entrance. The active littoral area is the upper shoreface, generally where depths are less than 60 feet. Further, assume that a percentage of dredged material that has been placed at past (Interim and nearshore Section 103 sites) ODMDSs was transported back to the active littoral budget.

2. The littoral budget was in equilibrium with past dredging and disposal practices. That is, use of past ODMDSs did not significantly altered the littoral budget or affected coastal beaches near the entrance.

3. The dredged sand placed at the proposed ODMDSs will be removed from the active littoral budget for a number of years (until infrequent large storms can transport the sand back onto the upper shoreface). Long-term removal of sand from the active littoral budget could produce a recession response of the upper shoreface.

Based on the assumptions, use of the proposed ODMDSs may remove a percentage of sand from the active littoral budget at the Yaquina entrance. If the active littoral budget is reduced, recession of the upper shoreface may occur. Using the proposed North and South ODMDSs for placement of all sediment dredged from the entrance channel could result in erosion of the upper shoreface (and possibly beaches) within close proximity to the jettied entrance. Although this finding is based on conjecture, engineering judgment and experience, it describes the potential for shoreface recession in response to the use of the proposed new ODMDSs for the placement of all sediment dredged from the Yaquina entrance channel.

Changes at the Historic ODMDSs. Since 2000, disposal of dredged material at the Interim or nearshore 103 sites has not occurred. Placement of material into the Interim Site was suspended in 1986 due to mounding. The mound, which reached a maximum of 22 feet, was essentially eroded by 1990. By November 2000, mounding in the nearshore 103 Site had reached a maximum of 20 feet; placement was suspended and subsequent material placed in the North Site beginning in 2001. As of 2006, the last year the nearshore 103 Site was surveyed, the maximum mound height was reduced to 13 feet. When placement in this site was suspended, it was predicted that the mound height would be reduced 1-3 feet per annum. Further, it was predicted that the mound would be completely dispersed by waves and currents within 14 years. Sediment and contours would return to pre-placement conditions. This has occurred in the Interim Site and looks to be on track at the nearshore 103 Site.

Section 7
OCEANOGRAPHIC PROCESSES

Offshore Regional-Scale Circulation

Circulation processes in the coastal waters near the Yaquina Bay result from an interaction of regional oceanic circulation, astronomical tides, wind-generated surface waves and currents, and estuarine flow. One of the direct effects of circulation processes at the entrance to Yaquina Bay is on the transport and seasonal distribution of sediments. These processes act on ebb-tidal shoal and littoral sediments (depths <120 feet) to produce the bathymetric condition observed at any particular time. Time scales for circulation processes range from seconds for wind-generated waves to months for seasonal weather patterns to years for large-scale events such as El Nino.

From a sediment transport point of view, the Oregon continental shelf can be divided into three cross-shore regions [Sternberg 1986]. The first of these regions is the outer shelf (depth >300 feet) where shoaling internal waves and large-scale, wind-driven currents affect the movement of bottom sediments. The second cross-shore region is the mid-shelf (120-300 feet depth), over which wind-driven currents are the most important factor. The third and most active region is the inner shelf (depth <120 feet), on which shoaling waves and tidal (and estuarine) induced currents are at least as important as wind-driven currents for transport of bottom sediments. For the most part, the assessment of the historic and proposed Yaquina ODMDSs is limited to the inner and mid shelf region.

Circulation of the continental shelf waters off Oregon is thought to be nearly geostrophic, i.e., friction plays a minor role in determining the water column circulation when compared to sloping sea surfaces, sloping internal density surfaces, and the rotation of the earth. Consequently, mean circulation on the shelf tends to be along the bathymetric contours.

Circulation of coastal (inner shelf) waters is subject to seasonal reversal, being northward during winter and southward during summer. On time scales of several days, coastal circulation can be highly variable in direction and speed with fluctuations correlating with changes in sea level and the alongshore component of wind [Huyer 1977]. The alongshore component of the coastal current regime is substantially stronger and more responsive to changes in wind conditions than is the onshore-offshore component of current [Collins 1970]. Fluctuations in the mean alongshore circulation appear to be coherent over distances of 125 miles and are independent of depth in both phase and magnitude to approximately 70 feet depth [Huyer 1977]. The magnitude of alongshore current fluctuations decreases rapidly with distance offshore and increasing water depth. Currents averaged over very long periods, e.g., longer than 50 days, correlate better with sea level changes than with winds to depths of 120 feet. By 250 feet in depth, the influence of both sea level and winds appears to be substantially diminished and other processes such as tides, regional circulation, and internal waves control the current regime.

California and Davidson Currents

Net regional circulation along the continental shelf of the Washington and Oregon coasts has been characterized in terms of two seasonal current regimes: summer and winter [Bourke 1971]. Offshore of the continental shelf break (>20 miles from the coast), surface flow down to 500 feet in depth is dominated by the California current. The California current is a broad, shallow, slow moving current which flows southward throughout the year at speeds of 0.1 - 0.7 ft/sec as a diffuse band about 300 miles wide. Inshore (east) of the California is a seasonally varying flow called the Davidson current.

The Davidson current is a northward flowing current attaining speeds of 0.3 to 1.0 ft/sec over extensive distances. On the surface waters of the continental shelf, this current responds to the seasonal wind patterns of the northeast Pacific. The Davidson current develops off of the Oregon-Washington coast in September and becomes well established in January in response to southerly winds. The surface expression of the Davidson current diminishes towards the spring, disappears by May, and becomes incorporated into the permanent California current [Bourke 1971]. The subsurface part of the Davidson current is believed to flow northward throughout the year.

Shelf Circulation

A generalized model for the seasonal changes in the alongshore and offshore circulation along the Pacific Coast of Washington and Oregon has been developed [Huyer 1977]. The *summer circulation* of surface water on the continental shelf is influenced by the southward flowing California current which attains maximum strength during the summer when surface winds are consistently from the north-northwest. *Winter circulation* of shelf waters is dominated by the northward flowing Davidson current which attains maximum strength due to winter storm (wind stress) patterns. The subsurface part of the Davidson current (below 300 feet in depth) is believed to flow northward throughout the year, although the surface waters respond to seasonally varying wind stress patterns (reversals). Thus, the net direction of bottom currents on the mid and outer continental shelf is believed to be northward and along shore.

Inner-Shelf Circulation

Vertical mixing of the inner shelf waters is at a maximum during the winter (December - March) when currents are nearly uniform in speed and direction throughout the water column. During winter, significant wind-generated currents develop in response to strong southerly storm winds. Wind-induced currents may exceed 2 ft/sec flowing northward with event persistence of 5 to 7 days. Wind-driven currents develop within a few hours of the onset of strong winds then decrease slowly over several days following cessation of the winds.

With the onset of southerly winter winds resulting in northward flow, surface coastal waters are directed northward and landward due to Coriolis deflection resulting in downwelling along the coast. Bottom water is directed offshore. The mean alongshore circulation of surface coastal waters during winter is northward at 0.3 - 0.8 ft/sec. The inner shelf current

can be highly variable over periods of several days: Southerly flow (north to south) can sometimes occur during the winter.

Mid-Shelf Circulation

The transition from the winter circulation regime to the spring and summer regime is abrupt along the middle and inner shelf, occurring only in about a week during a strong northerly wind event. The transition is the result of a large cumulative offshore transport of surface water caused by local wind stress and the establishment of strong offshore density gradients in the shelf waters. Upwelling is associated with the spring current transition and continues into July or August. The offshore density gradients are associated with the persistent southward surface current and upwelling due to the summer oceanographic season.

During the summer, southward surface currents can approach 1.3 ft/sec. Reversals in current direction rarely occur during summer. With onset of northerly summer winds (southward coastal current), surface coastal waters are directed offshore due to Coriolis deflection resulting in upwelling along the coast. Bottom water is directed onshore.

During summer, a strong vertical gradient (shear) of the alongshore current can be found over the middle and outer shelf. The subsurface current is northward while the surface current is southward. Maximum surface current speed over the mid-shelf (5-10 miles offshore) occurs during June when the southward flow is reinforced by strong northerly winds. The bottom current along the mid-shelf is reduced, due to the high gradient between surface and bottom waters. The bottom current for inner shelf waters is dominated by surface circulation ands tends to be stronger and more consistently southerly (during the summer) than the bottom circulation further offshore.

The transition between summer and winter nearshore circulation is gradual. The offshore shear zone between the northward flowing bottom waters of the outer-shelf and the southward flow of nearshore coastal waters expands upward and shoreward under the influence of fall and winter southerly winds. Reversal of surface water circulation over the shelf occurs when the winter regime of northward flow (Davidson current) is re-established throughout the water column [Sobey 1977].

Littoral Sediment Transport

Along the inner- and mid-shelf zone of the Oregon coast (water depths less than 300 feet), currents induced by wind, waves, and tides are primarily responsible for sediment transport through the water column and on the seafloor. Wave-induced currents tend to diminish inversely with (water depth)$^{1/2}$ [Komar et al. 1972]. The closer one moves toward shore (the shallower the water depths), the more energetic the effects of wave shoaling will be throughout the water column. Increased wave shoaling accompanied by an ambient current can produce a high sediment transport potential (see Section 5, *Hallermeier Sediment Transport Limits*). The seaward limit of active littoral zone coincides with the Hallermeier closure depth $\mathbf{d}_{\ell}$, which is 60 feet at Yaquina Bay. In water depths less than 60 feet along the project area coast, wind- and wave-induced currents dominate the transport of sediment along

the seabed. This area is called the ***littoral zone***. Within the littoral zone of Oregon, the seabed sediment is primarily composed of sand, gravel, and cobbles. Sediments smaller than sand (silt and clay) generally do not reside within the littoral zone of the Pacific Northwest due to the high mobility of fine-grain sediment. Near the Yaquina Bay entrance, littoral sediments are composed of fine-medium sand. In fact, much of the sediment dredged from the Yaquina Bay entrance is littoral sand or marine origin (the sand was either transported to the coast via rivers long ago or the sand is a product of bluff/rock outcrop erosion).

The transport of bottom sediment within the littoral zone, due to waves and currents, is called ***littoral transport***. In general, littoral transport is a function of wave height and period, bottom sediment size, and strength of ambient current. There are two directional components of littoral transport: cross-shore or perpendicular to shore (onshore-offshore) and alongshore (updrift-downdrift). As waves approach the coast, water depth becomes progressively shallower causing the waves to shoal. Eventually, the shore incident waves break due to bottom friction and conservation of momentum. The dissipation of energy due to wave shoaling and breaking acts to transport bottom sediment, (usually) in the direction of wave propagation. The angle at which waves approach the coast dictates the degree of alongshore and cross-shore littoral transport. For example, waves approaching the shore obliquely tend to produce more alongshore transport than waves which approach the shore straight on. Cross-shore transport is more complex than alongshore transport. Under some wave conditions bottom sediment can be transported offshore while at other times bottom sediment can be transport onshore. In general, the direction of cross-shore transport for sand-sized sediments along coastal areas of the Pacific Northwest is assumed to be onshore during summer and both onshore and offshore during winter.

Although the dominance of southerly waves (and associated northward littoral transport) during the 5-month period of December - March is a documented fact, the remainder of the year is characterized by northerly waves and an attending southward littoral transport. It is possible that the wave and current regime present during the remaining 7 months could generate littoral transport that approaches the transport experienced during the more energetic 5-month period of the year. The onset of long-term climatic perturbations such as El Nino and La Nina can modify the directionality of waves making landfall on the northwest coast, greatly affecting the directionality and strength of the littoral current. Long-term changes in the littoral environment are likely responsible for whether littoral sediment (sand) is transported north or south along the northwest coast.

Estimates for gross alongshore transport (direction independent) along the Oregon-Washington coast exceed 1 mcy per year. In many locations along Oregon, the net long-term average long-shore transport rate is postulated to be close to zero [Komar 1997]. Due to the complexities of the nearshore reef system north and south of Yaquina Bay, a conclusive description for the net direction and magnitude of alongshore transport along coastal areas north and south of Yaquina Bay entrance is not available.

Based on long-term average annual conditions and the orientation of beach alignment north and south of the jettied entrance at Yaquina Bay, it appears that net littoral transport at Newport is slightly toward the north. The issue of “north vs. south” littoral transport at the Yaquina Bay entrance is an important consideration for an ODMDS which is to be located

within the littoral zone. However, the proposed North and South ODMDSs are not located within the littoral zone (60 feet or less); minimum water depth for the proposed ODMDSs will be 115 feet. It is anticipated that "littoral transport" at the proposed ODMDSs will occur only during severe (storm) wave conditions. Dredged material placed within the proposed ODMDSs may be impounded from the littoral zone for 10-20 years.

If the opportunity arose for dredged material to be placed in the nearshore, it is recommended that an equal volume be placed north and south of the Yaquina Bay entrance at alongshore distances no closer than 2,000 feet from the entrance. If the opportunity arose to place dredged material directly on the beach, it is recommended that the dredged material be placed further than 300 feet to the north of the north jetty.

Summary of Seasonal Changes in Circulation

In general, there are three oceanographic seasons for circulation of coastal waters on the inner shelf of Oregon [Borgeld 1978]. These seasons are briefly defined as:

Fall - Winter: Onset of the Davidson current occurs and the coastal current is directed northward by southerly winds. The fall-winter season is generally defined as November - March.

Spring: Onset of the upwelling regime along the continental shelf. Transition between the Davidson and California current regimes occurs in offshore waters. The coastal current begins reversal from northward to southward flow. The spring season is defined as April - June.

Summer: Southerly circulation of shelf waters induced by the California current. The coastal water is directed southward by northerly winds. The summer season is generally defined as July - October.

Cross-shore Circulation

The upwelling and down-welling circulation due to Coriolis deflection induces seasonally varying cross-shore transport of shelf bottom water (Ekman transport) and sediments. Offshore transport of shelf bottom water occurs during winter and onshore transport occurs during summer. Within the immediate vicinity of Yaquina Bay, estuarine circulation also induces cross-shore transport during ebb-tide (offshore flow), flood-tide (onshore flow), and periods of high river discharge (offshore flow).

Significant cross-shore circulation occurs along the Oregon Coast during the upwelling (summer) season [Pillsbury 1972 and Huyer 1976]. This occurs when shelf bottom water moves onshore and converges with less dense (warmer) water of the inner shelf. The cross-shore section shown in Figure B-18 illustrates the mean circulation induced by the upwelling along Oregon continental shelf. The shaded zone is the permanent pycnocline (zone of rapid density change with depth), which is normally located at depths greater than 130 feet in offshore waters deeper than 200 feet deep (6-10 miles offshore).

With the onset of coastal upwelling, the pycnocline rises and is pushed shoreward. When upwelling is fully developed, the pycnocline intersects the water surface within 10 miles from shore. Above and offshore of the pycnocline, mean flow is to the south as expected for the summer season. About 130 feet below the permanent pycnocline, flow is to the north. Under strong upwelling conditions, southward circulation is reinforced in the nearshore waters and the deeper north flowing current weakens and may disappear. Mean currents within 60 feet from the surface are south and offshore at speeds of 0.5 ft/sec due to the influence of the summer wind field combined with upwelling conditions.

Generally speaking, the proposed North and South sites are located within the area of coastal upwelling, but are well inshore of the "mixing" zone (or surface front) associated with the convergence of dense bottom water from the outer shelf and warmer less dense water from the inner shelf. While upwelling increases biological productivity along the coast, the location of the surface front is where intense biologic activity occurs.

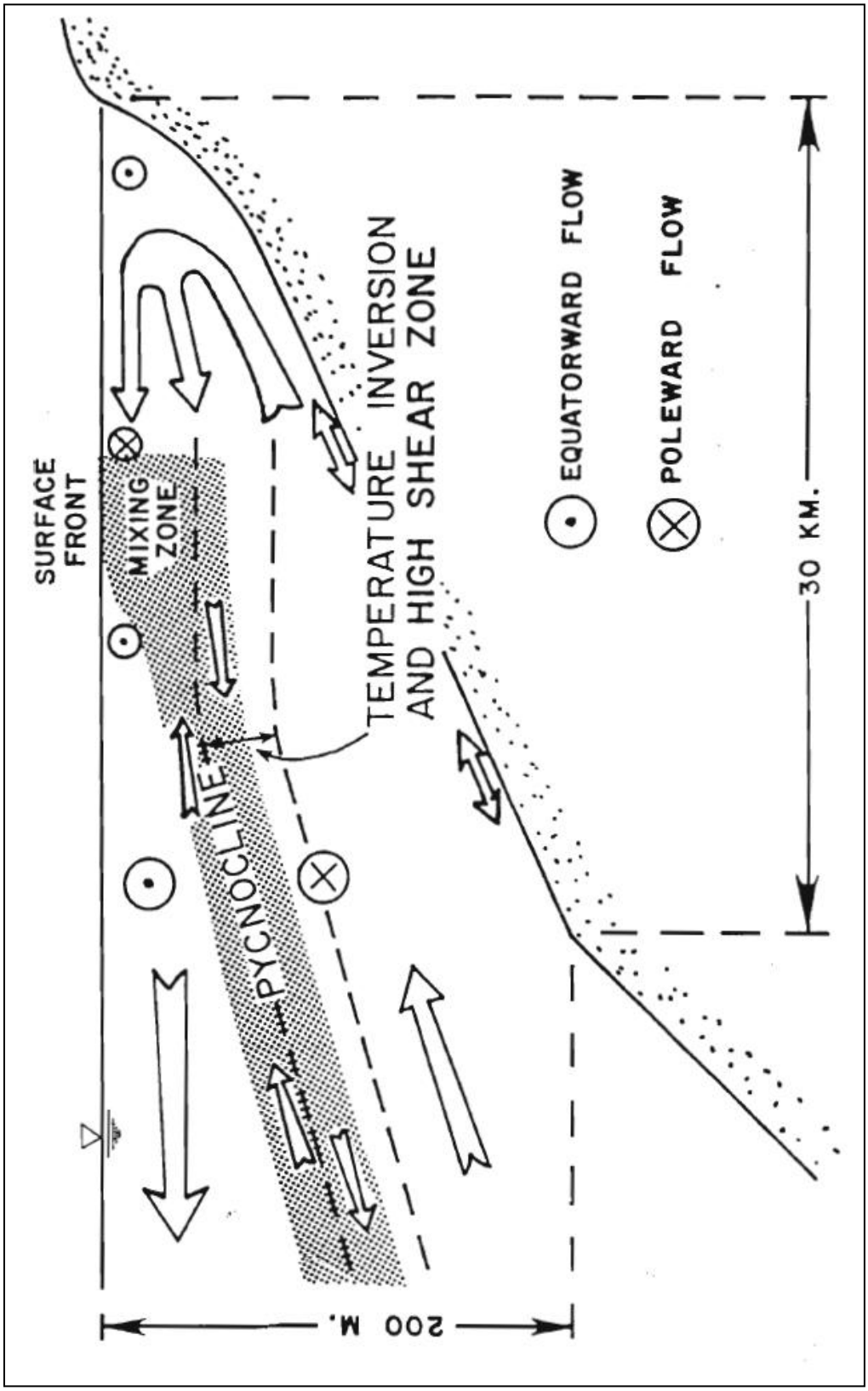
Long-Period Waves

Superimposed upon the slowly varying regional or seasonal circulation are periodic currents due to tides, inertial currents, and internal waves. While variations in wind speed and direction at durations longer than 2 days are reflected in surface currents, shorter duration wind events can give rise to inertial currents that have 17-hour periods and speeds exceeding 0.3 ft/sec [Huyer 1977].

Continental shelf waves are long waves typically generated by atmospheric pressure/system movements. These shelf waves have periods of 4-6 days and propagate toward the north along the western coast of North America. The magnitude of the current associated with shelf waves is on the order of 0.10 ft/sec [Moores 1968]. Shelf-wave flow is uniform throughout the water column and is directed along the shelf. This type of flow may have a significant long-term effect on the transport of fine (silt-clay) sediments, if placed in water depths greater than 120 feet.

Astronomical tides at the Yaquina Bay entrance have diurnal inequality typical of the Pacific Coast with long ebb from higher high to lower low water. Mean tidal elevation is + 4.15 feet mean low lower water (MLLW). The mean tidal range at the Yaquina Bay entrance is 5.9 feet, the range from MLLW to MHHW is 7.9 feet. Extreme tides range from -3 feet MLLW to +11.5 feet MLLW [NOAA 1994]. Offshore Yaquina Bay, tidal currents are believed to account for more than half of the water motion over periods of several days [Stevenson 1974].

Figure B-18. Mean circulation in the coastal upwelling region off central Oregon



The tidal current for a given coastal location can be described in term of two components: (1) the **shelf tidal current** driven by the approach and passage of the tidal wave over the continental shelf and is uniform throughout the water column, and (2) the **estuarine tidal current** generated by flood and ebb flow from a nearby estuary/embayment, which is generally confined to depths shallower than 70 feet. Offshore of Yaquina Bay, the shelf tidal current is rotary. The estuarine (plume) driven tidal current at locations within 0.5 mile of the jettied entrance at Yaquina Bay is appreciable due to the size of Yaquina Bay and the constricting nature of the jettied entrance. The shelf tidal current offshore of the Yaquina Bay entrance may at times be partially or entirely masked by wind-driven, river discharge, or estuarine tidal currents.

Offshore Rotary Currents

Rotary currents are tidal currents that continually change direction, periodically with time, so that in 12.5 hours the current will have set in all directions of the compass. The rotary current offshore of Yaquina Bay generally floods towards 60° (T), and ebb towards 240° (T). Rotary current speeds have been measured at between 0.2 ft/sec and 0.5 ft/sec [Stevenson 1969].

Section 8
MEASURED OCEANOGRAPHIC DATA

Predictions of future ODMDS capacity requirements are highly dependent upon the quality of oceanographic data available. Analyses of the fate of dredged material placed in open water can only be as accurate as the poorest estimate for the forcing environment and dredged sediment composition. Relevant oceanographic data used in this appendix to simulate dredged material disposal at Yaquina Bay include:

- Bathymetric surveys at the historic and proposed ODMDS locations.
- Physical/textural properties for native seabed sediments at and dredged materials to be placed at ODMDSs.
- Wind-generated surface wave characteristics.
- Newtonian tidal signal (for surface elevation and currents).
- Residual currents for each oceanographic season.

Hydrographic Survey Data

Hydrographic surveys at the Yaquina Bay "approaches" and ODMDS have been digitally recorded since 1983. Areal coverage of the ***approach surveys*** is from the seaward jetty ends to 2 miles offshore and 2 miles north and south of the navigation channel. Survey frequency is about once every 2 years. Areal coverage of each ***disposal site*** survey typically extends 500 feet beyond the sites' formal boundary; the survey frequency is twice per year. Elevation (z) values for the hydrosurvey data are recorded in feet, MLLW which is -4.15 NGVD. The horizontal datum (x,y) is Oregon State Plane, north zone, NAD 27.

Survey Error Assessment

Horizontal control (x,y) for the Yaquina surveys is ±3.3 feet (±10 feet before 1987). The vertical accuracy of the wave motion compensator is 5% of the vertical displacement. For a 6-foot swell, this is about ±0.5 feet. The accuracy for vertical data (z), corrected for heave-pitch-roll, at 100-foot water depth is ±1.5 feet. This represents the **random error** inherent in the depth data (z) for hydrosurveys. In summary, the estimated accuracy statistics for the hydrographic surveys are:

Random error for X,Y data = ±3.3 feet (±10 feet before 1987)
Random error for Z data = ±1.5 feet

Digital hydrographic survey data were used in this appendix to assess past and future bathymetric change at Yaquina ODMDSs. All results involving bathymetry change assessment, for both past and future conditions, should be assessed within the data accuracy limits stated above.

Sediments at Yaquina Bay Proposed ODMDSs

The material that is dredged from the channel entrance to RM 1, closely resembles the ambient seafloor sediments in the vicinity of the ODMDSs. Sixteen samples collected within the 4.5-mile ZSF, at depths ranging from 44 to 144 feet, were all classified as fine sand. The average grain size of the seafloor sediment samples was 0.19 mm [USACE 1985]. Recent sediment sampling/testing specifically conducted to establish baseline conditions for the seabed within the proposed North and South ODMDSs produced the following results:

North ODMDS: D_{50} = 0.22 mm, sand content = 98.1%, fines content = 1.9%
South ODMDS: D_{50} = 0.20 mm, gravel content = 0.3%, sand content = 98.1%, fines content = 1.6%

The type of sediment in the federal channel is fine to medium sand with average grain size of 0.22 mm, which is very similar to the ambient seafloor sediments.

Dredged Sediment Characteristics

The type of the sediment dredged from the Yaquina Bay Navigation project material depends on the location. More than 95% of dredged materials historically placed at the Yaquina ODMDSs has been dredged from the entrance channel and classified as poorly graded sand (SP sand, ASTM D 2487) with D_{50} = 0.17-0.23 mm [Appendix C]. A small amount of finer grain material is dredged from the turning basin (RM 2.0 to 2.4), South Beach marina, or Depot Slough and is placed in the ODMDSs.

Analysis of sediments from the channel entrance to the "outer" part of the bay (RM -1 to 2) indicates that these sediments are of uniform grain size and contain very little silts and clays (less than 2%). This sediment is composed of fine to medium sand having a mean grain size (D_{50}) of 0.18 mm. The sediment is also low in organic content as measured by volatile solids (0.60%) [Appendix C].

Two samples taken from the turning basin at McLean Point (RM 2) in 1995 showed more variability. One sample had a large fines content of 72.3 percent and was classified as silt, while the other sample was classified as a medium sand with D_{50} =0.23 (and had a fines content of less than 2%). The amount of material dredged from the turning basin is small. Dredge logs indicate that 4% percent of the sediment placed at the ODMDs is dredged from the turning basin, on an average annual basis.

Physical Properties of Dredged Material Placed at ODMDSs

The specific gravity of the material dredged from the entrance channel at Yaquina was determined to be 2.65 and the resuspended density was 1,920 g/l from sediment analysis completed in 1990 [Appendix C]. The resulting resuspended void ratio (e_{ss}) for fine sand dredged from the channel entrance at Yaquina was calculated to be 0.815 using a standard volumetric method outline below:

$\forall t = \forall s + \forall v$, assume $\forall t = 1.0$ units

where $\forall v$ = volume of voids (entrained water) in sample

$\forall s = 1 - \forall v$ $\forall s$ = volume of solids (sediment constituent) in sample

$\forall t$ = total unit volume of sediment in sample relating volume ($\forall$) to mass (M),

$Mt = Ms + Mv$, Mv is due to entrained water = $\rho v * \forall v$

$\rho t \forall t = \rho s \forall s + \rho v \forall v$ $\rho t = \rho ss = 1920$ g/ℓ (lab data)

$\rho t = \rho s \forall s + \rho v \forall v$ $\rho v = 1024$ g/ℓ, $\rho s = 2650$ g/ℓ (S.G = 2.65)

$\rho t/\rho s = (1 - \forall v) + \rho v \forall v/\rho s$ = S.G. *1,000 g/ℓ

$0.7245 = (1 - \forall v) + 0.3864 * \forall v$

$\forall v = 0.4490$

$\forall s = 1.0 - 0.4831 = 0.5510$

$ess = \forall v/\forall s$

<u>ess = 0.815</u>

Dredged Material Solids Content and Void Ratio

Normally, material which is dredged hydraulically has low solids content. The concentration of solids for hydraulically dredged sediments (Cs, by volume) varies from 0.18 to 0.35. Since hopper (hydraulic) dredges are used to remove channel sediments from Yaquina, it could be concluded that the solids content for each load of dredged material placed at the Yaquina ODMDS would be lower than 0.35. However, the operating practice of overflow dredging is used at Yaquina for sand-based dredged material placed at the ODMDS. This allows for water to be drained out of the hopper bins as dredged sediment is pumped in. The practice of overflow dredging can substantially increase the solids content of each load of dredged material placed at the ODMDS. The concentration of solids for sand in the hopper dredges operating at Yaquina (Cs in dredge) was assumed to be the same as for the resuspended sediment tests (i.e. ρss = 1,920 g/ℓ and ess=0.815) and was calculated by:

$Cs_{\text{in dredge}} = \forall s_{\text{in dredge}} / \forall t_{\text{in dredge}}$ = concentration of solids by volume in the hopper dredge

$ess = \forall v/\forall s = 0.815$, $\forall v_{\text{in dredge}} = \forall s_{\text{in dredge}} * 0.815$

ess = resuspended void ratio

$e_{\text{in situ}}$ = *in situ* void ratio at site of dredging in channel

= 0.68 (assumed value based on typical range) in a volumetric analysis, $\forall t = \forall s + \forall v$, assume $\forall t = 1.0$ units

$\forall t = \forall v_{\text{in dredge}} + \forall s_{\text{in dredge}}$

$= 0.815 \forall s_{\text{in dredge}} + \forall s_{\text{in dredge}}$

$= \forall s_{\text{in dredge}} (1 + 0.815)$

since $\forall t = 1.0$, $\forall s_{\text{in dredge}} = 1.0/(1+0.815) = 0.551$

$Cs_{\text{in dredge}} = \forall s_{\text{in dredge}} / \forall t = 0.551/1.0 = 0.551$ similarly, $Cs_{(\text{in situ})} = 0.595$ ($e_{\text{in situ}} = 0.68$)

Usually, the volume of sediment reported as placed at an ODMDS is different from the volume of sediment removed from the site of dredging. This is due to the cumulative difference between the: (1) the *in situ* void ratio of the sediment before dredging, (2) the resuspended void ratio of the dredged sediment after being placed into the disposal vessel (0.815 this case), and (3) the depositional void ratio of the dredged sediment after placement at an ODMDS. The change in specific volume of dredged material from the site of dredging to the site of disposal is commonly referred to as a "bulking factor." The bulking factor for dredged sediments placed at Yaquina ODMDSs can be calculated by noting the relationship between the volume of sediment removed from the channel ($\forall_{in\ situ}$), the volume of dredged material in the disposal vessel ($\forall_{in\ dredge}$), and volume deposited on the seabed ($\forall d$).

The depositional void ratio for dredged material placed on the seabed (e_d) for sand-based dredged material placed at ODMDSs was assumed to be equivalent to the resuspended case ($e_d = e_{ss}$).

$$\forall t_{ss} = C_{s(in\ situ)} * \forall t_{in\ situ}(1+e_{ss}) = \forall t_{in\ dredge}$$
$$\forall t_{in\ dredge} = C_{s(in\ dredge)} * \forall t_{in\ dredge}(1+e_d)$$
$$= C_{s(in\ situ)} C_{s(in\ dredge)} \forall t_{in\ situ}(1+e_{ss})(1+e_d) = (0.595)(0.551)\forall t_{in\ situ}(1+0.815)(1+0.815)$$
$$= 1.190 \forall t_{in\ situ}$$

where, e_d = depositional void ratio

Bulking factor from dredging site to disposal vessel = 1.190
Bulking factor from disposal vessel to disposal site = 1.000 or $\forall_{seabed} = \forall_{disposal}$

The volume of dredged material hauled to the ODMDS is based on the "dredge logs" for each disposal vessel. The dredge log volume is the volume of dredged material in the disposal vessel before placement at a disposal site ($\forall$disposal). It is <u>not</u> equivalent to the undisturbed volume of *in situ* sediment ($\forall_{in\ situ}$). The "dredge log" volume is equal to the volume of material placed on the seabed at the ODMDSs. Therefore, the dredging volume statistics reported in Table B-1 indicates the "actual" volume of dredged material placed at ODMDSs.

<u>Subaqueous Angle of Repose - Avalanching of Dredged Sediments</u>

As dredged sediments are continually placed (load by load) within a specific open water area, the material builds laterally and vertically. Geometrically, the extent to which the material accumulates is limited by the steepest angle at which the material can attain before gravity (and environmental forces) forces the material to avalanche and redistribute downslope. The avalanched sediment comes to rest when some equilibrium angle is reached. The limiting angle of repose (shearing angle, $\varnothing_s$) for subaqueous dredged sediments is steepest angle the material can attain before avalanching. The post-sheared angle ($\varnothing_{ps}$), defines the slope of the avalanched dredged material after is has come to rest [Larson and Krause 1989, Allen 1970]. The areal and vertical configuration of aggregate dredged material mounds at ODMDSs is controlled by the shearing angle and post-sheared angle of the dredged material.

The range in avalanche angles varies considerably with material type and the forcing environment. The angle of repose for dry loose sand is 26° to 30° from horizontal [Hough 1957]. Reported values for the subaqueous angle of repose (shearing angle) for sand placed on the seabed range from 1.8° to 8° [USACE 1995 and Johnson 1995]. Reported values for the angle of repose for highly disturbed and minimally disturbed cohesive sediments placed on the seabed are 0.3° and 10° respectively.

At the Yaquina ODMDS, the angle at which sandy dredged material begins to avalanche (shearing angle, $\varnothing_s$) varies between 1.7° and 2.5° ($\tan f = \Delta z/\Delta x = \Delta z/\Delta y$). These values are based upon the assessment of recent bathymetric surveys of the dredged material mound at the Section 103 ODMDS. The angle at which avalanching stops (post-sheared angle, $\varnothing_{ps}$) once it has begun was estimated to be 1.5°. These values will define the steepness at which dredged material is permitted to accumulate during the MDFATE simulation.

Summary of Yaquina Dredged Material Parameters

The following dredged material parameters will be used in the DRP fate models when simulation activities are pursued in later phases of this investigation:

Dredged material type = fine to medium sand, SP
D75 material dredged from channel = 0.20 mm.
D25 material dredged from channel = 0.15 mm.
Fines content (D<0.0625 mm) = 2 % (silt).
S.G. of dredged material solids = 2.65.
Cs (disposal) = concentration of solids by volume in the disposal vessel = 0.551.
ed = depositional void ratio = 0.815.
$\varnothing s$ = subaqueous shearing angle = 1.7°, $\varnothing ps$ = subaqueous post-shearing angle = 1.5°.

Surface Waves - Simulated Data

A synthetic time series for the annualized wave environment offshore of Yaquina Bay was generated using HPDSIM, a PC-program developed by USACE [Borgman and Scheffner 1991]. The program uses a finite length wave record to compute a matrix of coefficient multipliers that can be used to generate arbitrarily long time sequences of simulated wave data which preserve the primary statistical properties of the source finite data set. The wave height, period, and direction for the synthetic data set are based upon the 20-year Wave Information Study (WIS) station 41 - Phase II database [Corson et al. 1987]. WIS station 41 is located 30 miles offshore Yaquina Bay. The summary statistics for station 41 are:

<u>Mean WIS Parameters</u>

Water depth at WIS II-41 = 1500 feet.
$H_{1/3}$ = average annual significant wave height = 9.8 feet.
σ_h = annual standard deviation of $H_{1/3}$ = 4.2 feet.
T_s = wave period (associated with $H_{1/3}$) = 11.2 sec.
σ_h = annual standard deviation of T_s = 2.5 sec.

Most frequent wave direction band = 292°(T).
Wave direction for largest wave height = 209 °(T).

An example of the simulated wave environment for wave height ($H_{1/3}$) and wave period (T_s) for a 1-year duration (time = 0 corresponds to January 1) is shown in Figure B-19. Note that the waves are more severe during the late fall, winter, and early spring than other times of the year. The maximum and minimum significant wave heights ($H_{1/3}$) for the synthetic wave year were about 30 feet and 3 feet, respectively.

Based on favorable comparisons of synthetically generated wave data (WIS) and observed wave data for other locations on the Oregon coast [USACE 1995], the WIS data were considered adequate for simulating the wave environment at Yaquina Bay and for use as input for sediment fate modeling.

Simulated Shelf Tidal Elevations and Currents

The shelf tidal environment at the Yaquina Bay ODMDSs was simulated using the five primary tidal constituents generated from the ADCIRC-derived database for the Eastern North Pacific Coast [Hench et al. 1994 and Luettich 1995]. ADCIRC (Advanced CIRCulation) is a two-dimensional finite-element model developed by USACE to simulate hydrodynamic circulation (tides) along shelves and coasts. The time series shown in the top of Figure B-20 represents a simulated equilibrium shelf tide 5 miles offshore Yaquina Bay for 1 month (720 hours). The referenced tidal datum is MLLW. An equilibrium tide is harmonically correct to the actual case, but is not referenced to a specific date or time. The maximum tidal range for the simulated tide shown in Figure B-20 is 11 feet, which agrees with the observed range for the Yaquina bar. The tidal phasing of the simulated and observed tidal data also compared favorably.

Depth-averaged tidal currents (u,v) applicable for the Yaquina bar are shown in the bottom of Figure B-20 and were also produced using the ADCIRC model. The tidal current simulated by the ADCIRC model accounts only for the **shelf tidal current**, based on the approach and passage of the tidal wave. The **estuarine tidal current** generated by flood and ebb flow from the Yaquina Bay estuary is not included in the ADCIRC-predicted tidal current. Based on favorable comparisons of synthetically-generated shelf tidal data (ADCIRC) and observed tidal data for other locations on the Oregon coast [USACE 1995], the ADCIRC data were considered adequate for simulating the wave environment at Yaquina Bay and for use as input for sediment fate modeling.

Observed Currents Applicable for Yaquina Bay ODMDSs

Definition of the residual current regime is of prime importance, since currents significantly affect the short-term fate of dredged material and completely control the long-term fate. For inner-shelf waters (depths <120 feet), the residual current regime is influenced by wind-stress, waves, tidal, and estuarine processes.

Figure B-19. Wave environment offshore of Yaquina Bay simulated from WIS-II data. Top graphic is for wave height and bottom graphic is for wave period. Time 0 corresponds to January 1 and Time 365 corresponds to December 31.

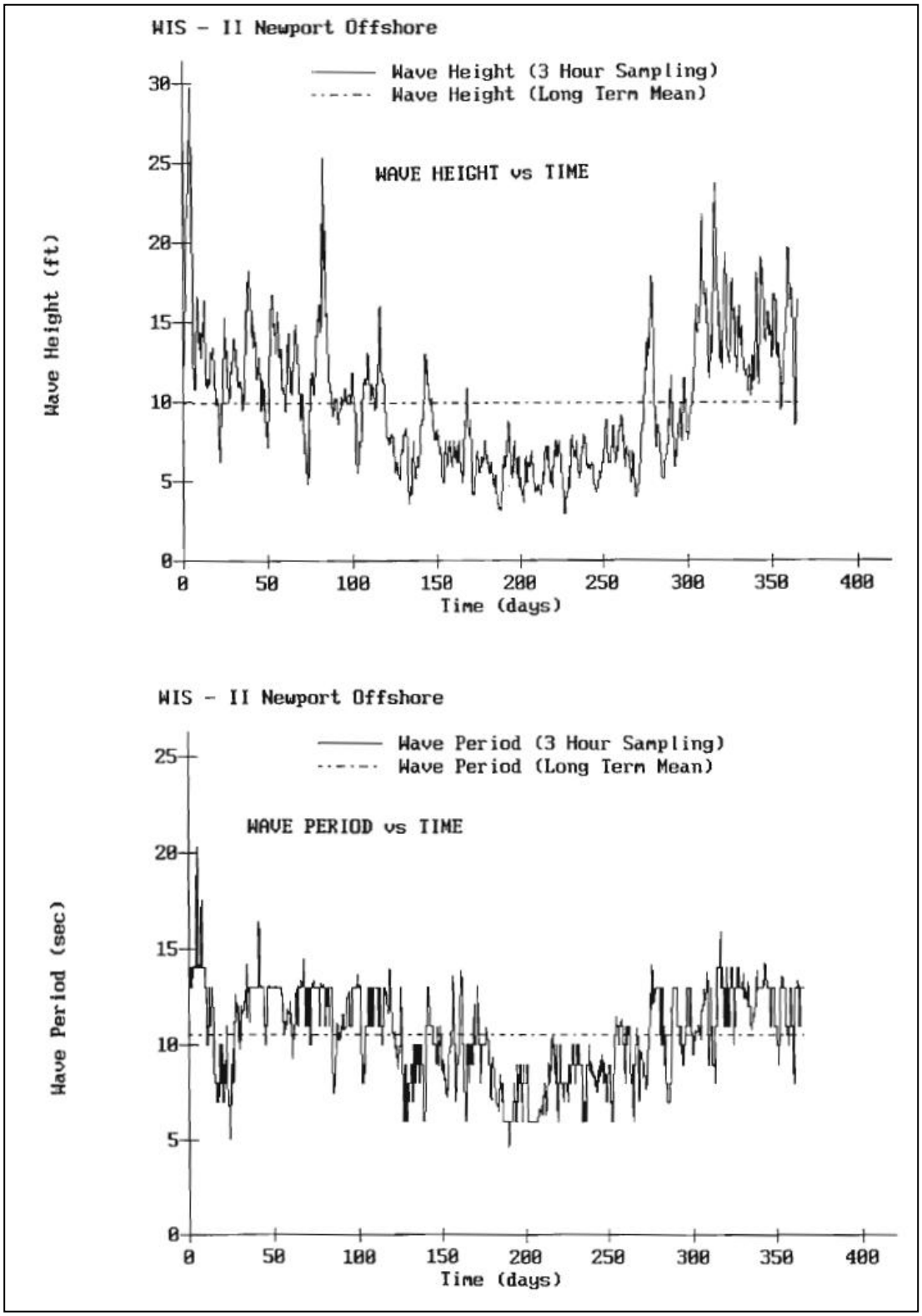
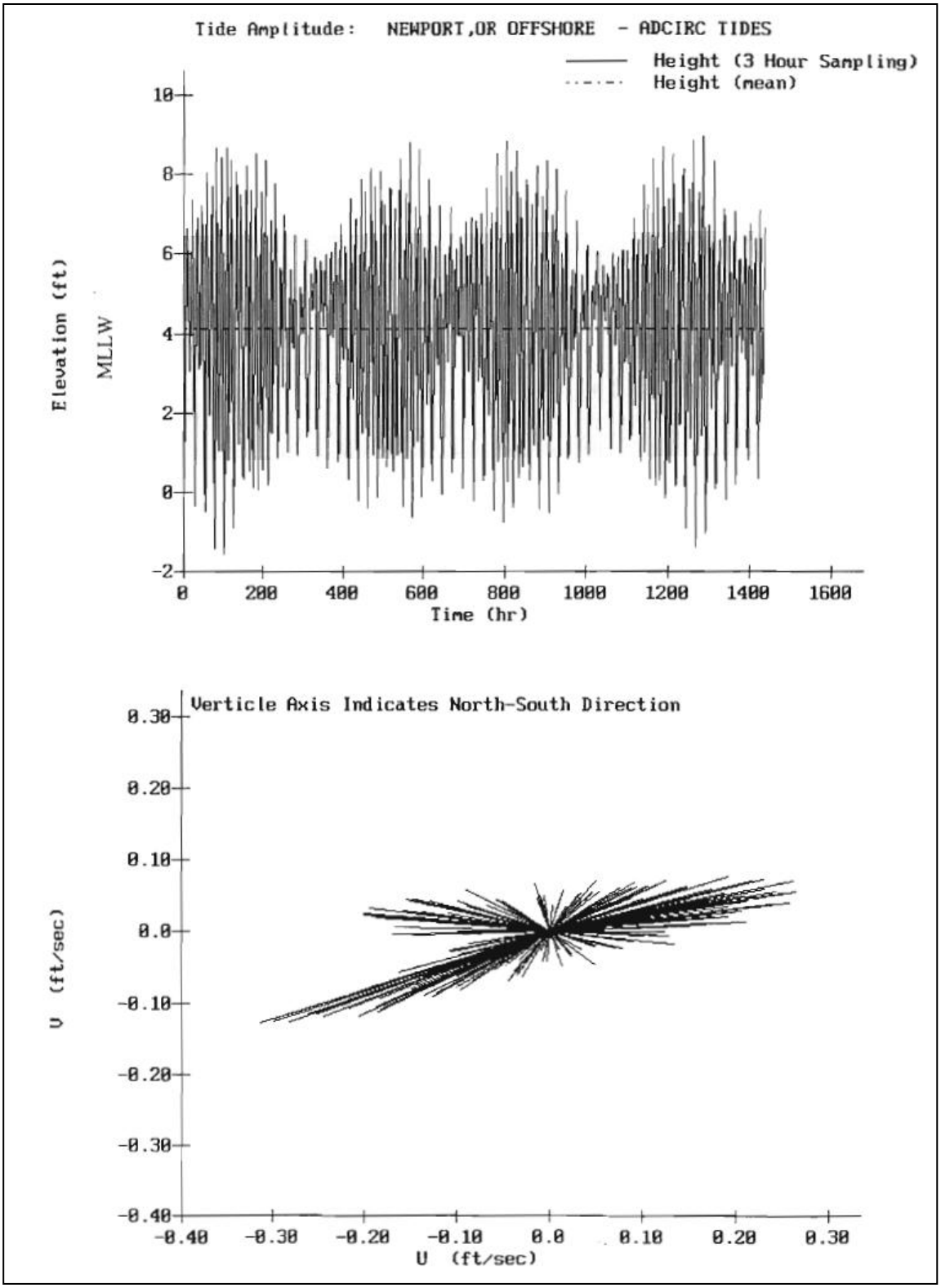


Figure B-20. ADCIRC simulated tidal elevation and current at Yaquina Bay ODMDS for 2-week period. Top graphic is for tidal variation of water surface and bottom is for tidal-induced current.



The term *residual* refers to a time-averaged or long-term net (over days, weeks, or months) result, which does not include short-term (hours to days) variations. A residual currents describes the net flow (direction and speed) for a given location during a given time interval and does not include shelf tidal currents, storm-induced currents, and other episodic events.

In close vicinity to the jetty entrance to Yaquina Bay, discharge from the estuary influences nearshore circulation from the surface to depths of 70 feet for distances of 1-2 miles offshore. Large scale oceanic currents such as the California or Davidson currents generally influence the direction of the shelf current regime, but do not directly affect the magnitude of inner shelf currents. Considerable effort was invested to reliably specify the residual current regime near the Yaquina Bay. Residual current data relevant to Yaquina Bay ODMDS designation and management are summarized below.

Bottom Currents due to Estuarine Discharge and Jetty Effects

On August 21, 1993, an acoustic Doppler current profiler (ADCP) was used to measure bottom velocities in the vicinity of the Yaquina Bay jetty entrance. The ADCP velocity data was measured 2 hours after high tide during an accelerating ebb-tide condition, but before maximum ebb tide. Point measurements of seaward flow at the mouth of the jetties reported near bottom velocities exceeding 3 ft/sec with total volume flow out of the jettied entrance measured by the ADCP at over 81,000 cfs [USACE 1993]. The riverine discharge from the Yaquina River was considered to have a negligible contribution to the observed estuarine discharge. Rainfall within the Yaquina River catchment was minimal during the time of data collection. The ADCP measured bottom current is summarized as:

VADCP = 3 ft/sec at 240° (T) during ebb-flow applicable throughout year

A mild wind out of the northeast was present producing a current velocity field tending toward the south-southwest (alongshore) during most measurements taken north and west of the northern jetty and north reef. Tidal outflow dominated the current filed at locations between the jetties and seaward of and in line with the entrance channel. Current measurements obtained north of the north jetty and inshore of the north reef showed a redirection of the alongshore flow in the offshore direction. Although a slight intensification of current velocity was observed at the north jetty head, potential for greater current velocities can be realized with a stronger alongshore wind (current) being present [USACE 1993].

The flow field observed at the Yaquina Bay jetty entrance on August 21, 1993, was assumed to represent typical estuarine ebb-flow conditions. Given that the alongshore wind field (and associated current) were minimal during the above measurement period, it is assumed that the combined current (estuarine flow + deflection of littoral current along jetties) at the jetty entrance is typically higher than that which was observed on August 21, 1993. Given that the combined current field is typically higher than the above measured data, the observed current is assumed to represent average conditions for the combined current field at the jetty entrance.

Surface Currents at the North Reef

Oregon State University conducted circulation measurements inshore of the north reef between the north jetty and Yaquina Head [Neal 1969]. Wave approach angle and hydraulic (flow redirection) effects of the north jetty had significant affect upon the observed nearshore flow field. Observed currents in the near surface (upper 10 feet) of the water column are summarized below:

November - February: Vreef = 0.4 ft/sec @ 45° (T)
March - October: Vreef = 0.4 ft/sec @ 225° (T)

Bottom Current at the Interim ODMDS

Bottom currents in the Interim ODMDS were observed by SCUBA diver during June 1977 [Montagne-Bierly Associates 1977]. Bottom currents were oriented toward the southwest and were heavily influenced by surge caused by waves passing overhead. The wave conditions during current observation were 4-foot swells from the northwest. Observed bottom currents are summarized below:

June: VODMDS = 0.62 ft/sec @ 225° (T)

Surface Currents 10 miles Offshore of Newport

A description of the seasonal mid-shelf surface current has been developed from transport data obtained by the transit of surface drift bottles released between 1959-1963 [Burt 1964]. The inferred surface currents are summarized below:

November - February: Voffshore = 0.82 ft/sec @ 0° (T)
March - October: Voffshore = 0.82 ft/sec @ 180° (T)

Geostrophic Currents

Estimates of geostrophic currents based on hydrographic observations from the Newport Hydro Line [Huyer 1977] agree well with seasonal observation of flow inferred from direct measurement [Huyer 1975]. In general, geostrophic currents were aligned with bottom contours with northerly mean flows deeper than 160 feet and southerly flows above. The summer geostrophic current at three varying cross-shore locations is summarized below:

June - September: VG70 = 0.6 ft/sec @ 187° (T) water depth = 70 feet
VG150 = 0.2 ft/sec @ 202° (T) water depth = 150 feet
VG200 = 0.2 ft/sec @ 63° (T) water depth = 200 feet

Currents Observed at a Similar Nearshore Location – Coos Bay

Detailed current measurements have been obtained from other similarly situated Oregon nearshore ODMDSs. The most thorough study has been conducted at Coos Bay, Oregon [Sollitt et al. 1984]. Seasonal measurements were made over two-week periods are summarized below (values reported from measurements at 1/3 total depth):

November - March: VCoos = 0.75 ft/sec @ 30° (T)
April - July: VCoos = 0.75 ft/sec @ 210° (T)
August - October: VCoos = 0.50 ft/sec @ 205° (T)

Calculation of Residual Current for Yaquina Bay ODMDSs

To represent the residual current at the proposed North and South ODMDSs, an annualized residual (depth averaged) current was developed based on a two-point value for seasonal representation. The individual current observations described above were vector-averaged according to the proper seasonal sequence of each current observation. This provided a realistic estimate for seasonally varying depth-averaged currents; data which was used to simulate the fate of dredged material to be placed at the proposed North and South ODMDSs. The ***annualized residual current*** applicable for locations within the 4.5-mile ZSF and where water depth is 100-150 feet is described below:

May - October: Vresidual = 0.53 ft/sec @ 202° (T)
November - April: Vresidual = 1.25 ft/sec @ 298° (T)

Note that the current affecting the proposed North and South ODMDSs is primarily a function of open coast flow, being influenced mainly by wind/waves, tide, and offshore processes. Estuarine current affects are, at best, weak within the North and South ODMDSs. This is reflected in the residual current described above.

The **total** depth-averaged current at any given point in time is estimated by adding the seasonal residual bottom current (above) to the simulated depth-averaged tidal (ADCIRC) current. The preceding section defined all oceanographic data required to successfully simulate dredged material behavior using the FATE models.

Section 9
GEOLOGIC FEATURES

Introduction

Geologically speaking, the Oregon coast is young and active. Regional uplift of several hundred feet, intense volcanic activity, and tremendous erosion and sedimentation has occurred over the past several million years to change the shape of the coastline. Changes in sea level caused the ancient coastline to vary from several miles inland to over 10 miles offshore.

This history has resulted in the variety of coastal features we now see from massive volcanic headlands such as Cape Lookout to massive sand dunes such as the Oregon dunes near Florence. The Pacific Ocean has affected this geologic framework to produce spectacular effects within historic times. Coastal landslides and severe beach erosion are common in certain areas and there are numerous submerged nearshore reefs and exposed offshore rock islands or stacks.

General Geology

The geologic sequence at the outer portion of Yaquina Bay consists of over 50 feet of terrace deposits of semi-consolidated sands and silts and occasional gravel formed by marine forces less than one million years ago overlying much older, eroded sandstones, siltstones, and mudstones. These terrace deposits form the steep sea cliffs north of the north jetty but are absent for 1.5 miles to the south where modern sands form the South Beach area. A geologic map and generalized cross-section of the Yaquina Bay area are shown in Figures B-20A and B-21.

A limited number of borings and surface geology identifies the nature of the underlying rock. A succession of Miocene siltstones, mudstones, and sandstones form the bedrock material beneath the bay. The oldest sequence, the Nye Mudstone, comprises the majority of the bedrock portion of western Yaquina Bay. The Nye Mudstone is a predominantly medium to dark gray, massive-bedded sequence of mudstones with some siltstone and sandstone lenses. Within Yaquina Bay, the formation is approximately 4,400 feet thick and extends from near the eastern edge of the bay to a point about 2,400 feet west of the Highway 101 Bridge. West of the bridge these strata have an average strike of north 5 degrees west, and a dip of 18 degrees toward the west. Beds of this formation are exposed at low tide on the north shore of the bay west of the highway bridge.

The Astoria Formation unconformably overlies the Nye Mudstone and is found in the outer navigation channel area from about 2,400 feet west of the highway bridge and westward. Precise location of the contact between the Nye and Astoria Formations is difficult to recognize, as the lower Astoria beds are very similar to the upper Nye beds. A small wedge of this formation is exposed near the base of the sea cliff on the north side of the bay.

Figure B-20A. Geologic map of Yaquina Bay area, Newport, Oregon (from Snavely et al. 1964).

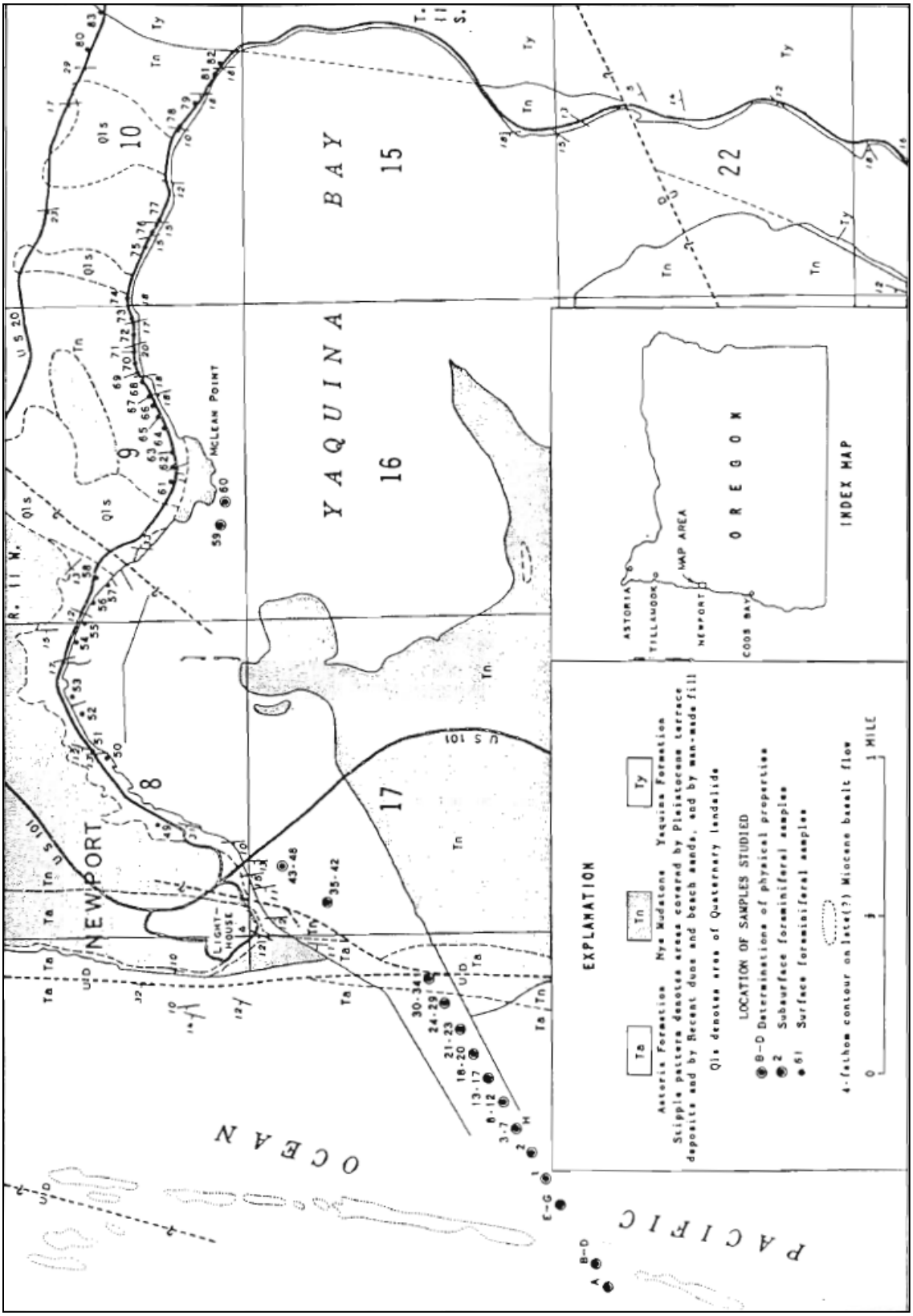
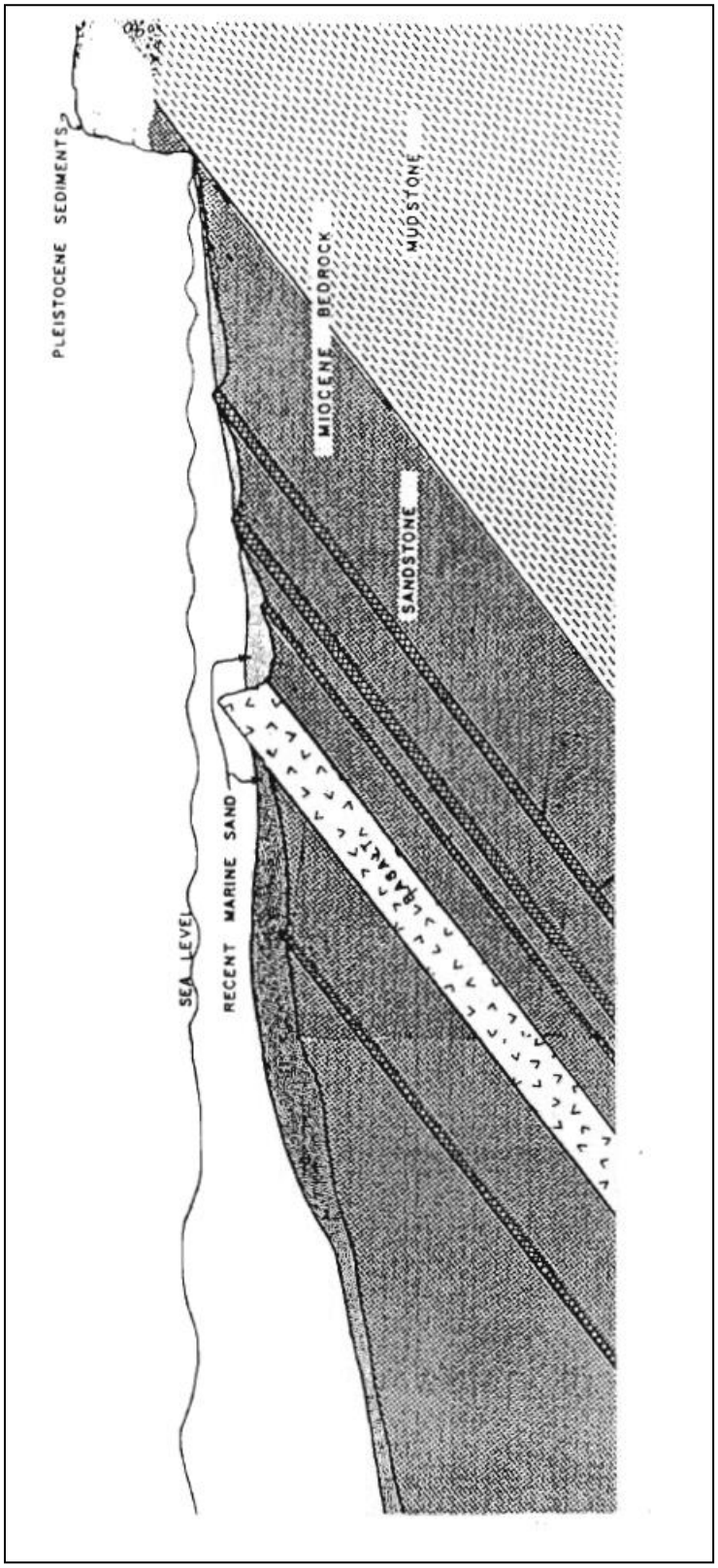


Figure B-21. Generalized geologic cross section at Newport, Oregon.



It has been determined through drill cores taken from navigation channel explorations in 1961 that the strike of the beds is north 8 degrees east, with a dip of 15 degrees toward the west. The most common beds of this formation are olive-gray, fine- to medium-grained arkosic sandstones, carbonaceous siltstones, mudstones and claystones. These beds were deposited in a nearshore environment (Snavely et al. 1964).

Just offshore of the jetties is an unnamed unit that unconformably overlies the Astoria Formation. This unit consists of a basalt flow, water-laid fragmental basaltic debris, tuffs, and fine-grained sandstone. The more resistant basalt flow at the base of this unit forms northerly-trending Yaquina Reef, located about 4,000 feet offshore, which in this area is about 55 feet thick. The Yaquina Reef is located immediately north and south of the Yaquina Bay jetties and appears to be offset by a north-south trending fault that might extend southward along the eastern margin of the project area (Snavely et al. 1964).

Figure B-21, which shows a generalized cross section applicable to Yaquina Bay and offshore vicinity, was obtained using sub-bottom profiling techniques (Earth Sciences Associates et al. 1984). Recent marine sand forms a discontinuous cover over the underlying rock. At the contact between the less resistant mudstone and more resistant sandstone a thick lens of sand has accumulated. This has also happened at the basalt-sandstone contact. Not shown, but present are discontinuous layers of highly resistant tuff within the sandstone. The extent and type of rock are unknown beyond the basaltic layer. The sand layer ranges from 5-35 feet thick over an irregular rock surface throughout the nearshore area adjacent to Yaquina Bay.

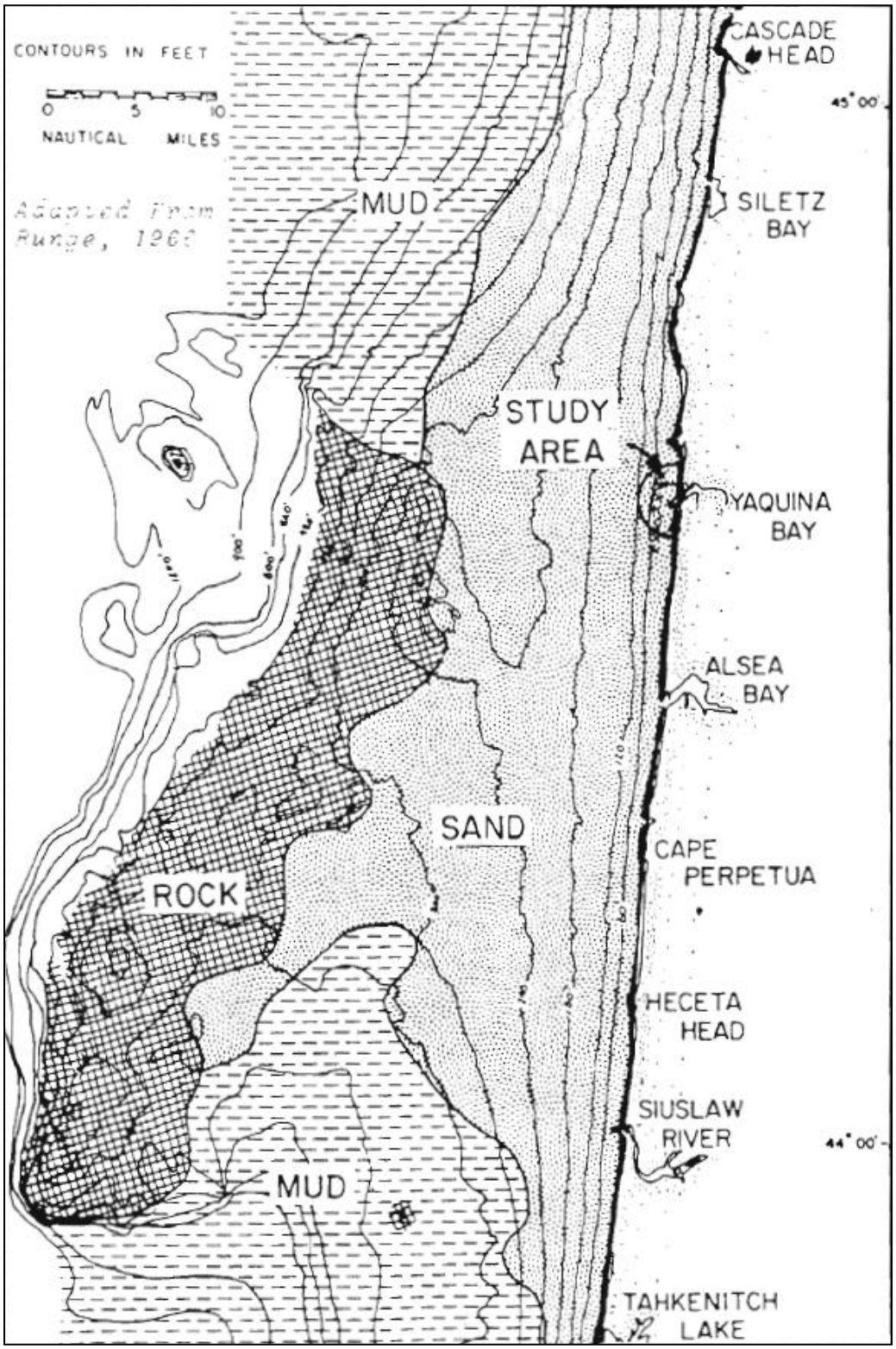
Unconsolidated Marine Deposits

Sediment movement on the Oregon continental shelf consists of two mechanisms depending on the size of the sediment. Anything finer than sand size (0.0625 mm) is carried in suspension in the water column and removed far offshore. The almost total lack of silts and clays within ten miles or more of most of the Oregon coast attests to the efficiency of this mechanism. Sediments sand-size or coarser may be suspended by wave action near the bottom, and are moved by bottom currents as bedload transport. There is almost a complete lack of finer silts and clays offshore of Yaquina Bay. Silt appears offshore from Yaquina Bay at a depth of 300 feet. The lack of silt or clay is likely due to the high wave energy regime. Summer wave conditions produce bottom ripples to depths over 300 feet while winter storm waves can produce ripples to over 600 feet (Komar 1972). The generalized bathymetry and surface sediment coverage of the central Oregon continental shelf is shown in Figure B-22.

Seabed Sediments near Yaquina Bay

Fine sand underlies the major portion of area in the Yaquina Bay 4.5-mile ZSF. Figure B-10 shows the seabed distribution of sand vs. exposed rock outcroppings within the 4.5-mile ZSF. Note the large area of seabed rock exposure occurs in the area directly to the north of the *Section 103* disposal site. These seabed rock outcroppings contribute coarser sediment to the nearshore area as the rock surfaces are eroded by wave action. The classification of bottom sediments shown in Figure B-10 was developed from a high-resolution side-scan sonar survey conducted during July 1995 (Geo Recon International Inc. 1995).

Figure B-22. Surface features and sediment cover of the continental shelf off central Oregon.



The underlying geology, marine forces, and human action influence the nearshore bathymetry at Yaquina Bay. From the tip of the full-authorized end of the north jetty the Yaquina Reef extends northward to Yaquina Head. This reef, with depths less than twelve feet in places, is an eroded layer related to the basalt headland at Yaquina Head. There are numerous submerged rock outcrops between the reef and North Beach. Note the irregularity of this region shown in Figure B-10. These outcrops are probably part of the more resistant sandstone layers. South of the jetties, the offshore reef turns seaward and is less continuous. There are few indications of submerged rock outcrops inshore of the reef and the South Beach area is a wide expanse of recent sand.

Sediment Accretion

A combination of littoral transport and jetty construction has resulted in significant beach advance south of the jetties (i.e. South Beach State Park). This accretionary process began in the 1882 with the first attempt to build the South Jetty and has continued as the jetty has been progressively extended. Beach accretion has not been apparent north from the jetties except for the area immediately adjacent to the North Jetty. The offshore reef apparently limits onshore sand transport in the area between the North Jetty and Yaquina Head (4 miles to the north).

Seaward of the reef complex, the bottom slopes about 60 feet per mile out to below elevation -120 feet (MLLW) where the slope flattens to about 20 feet per mile out to over -250 feet. There is a pronounced seaward bulge of bottom contours between -60 feet and -120 feet extending west from the *Interim* disposal site as shown on Figure B-10. This bulge feature is composed of previously placed dredged material and sediment transported out of the Yaquina Bay estuary during high ebb-tide discharge conditions.

Geophysical Explorations

Geophysical explorations were conducted in 1993 in an area just offshore and adjacent to the North Jetty. These explorations were conducted in an effort to better identify the physical characteristics adjacent to the North Jetty, and to aid in determining the cause for repeated failures of the structure. Explorations consisted of side-scan sonar surveys, seismic reflection and seismic refraction techniques, sub-bottom profiling, and water jet probes. These techniques combined to map out better the location of the Yaquina Reef, show the sub-bottom characteristics of the different geologic units, and identify the presence and depth to bedrock in the vicinity of the North Jetty. Scattered bedrock exposures present within Yaquina Reef and on the north side of the North Jetty are located and shown on Figure B-10.

1995 Side-scan Sonar Survey Results

A side-scan sonar survey was conducted in 1995 of an area approximately 4-miles long by 2-miles wide, of the area immediately offshore of the Yaquina jetties. The purpose of this study was to gain a better understanding of the surficial material types on the ocean floor for the potential of identifying future offshore disposal sites. Figure B-10 shows the location of the different material types within the study area.

This survey identified areas of bedrock outcroppings on the westward side of the Yaquina Reef, extending out a distance of up to a mile. These outcroppings follow the basic trend of the geology in the area, with beds dipping towards the west. The truncated edges of the more resistant layers provide the relief that is visible in side-scan images of the sea floor. A zone of coarse to medium sand is present adjacent to the westward side of the Yaquina Reef north of the North Jetty between the reef and outer rock exposures.

Surrounding the outcrops and the coarser sand is a blanket of fine to medium sand and silt, which is the most prevalent material seen offshore of this area. This material is also present immediately offshore of the jetties and entrance channel and obscures any bedrock exposures present there.

2000 Side-scan Sonar Survey

Additional surveys were conducted in 2000 to further identify material adjacent to the outer margins of the 1995 survey, but concentrating on two areas located both north and south of the jetties. The north area measured approximately 2-miles long by 1.25-miles wide, and the south area was 1.5-miles long by 1.25-miles wide. This survey utilized digital image processing techniques with a mosaic feature to more accurately define where the different material types occurred. Figure B-10 shows the location of the study area and the material types represented.

Results of this survey verified the existence of rock outcroppings in the inner portion of the southern area. The predominant material type present on the bottom in both areas was also verified to be fine to medium sand and silt. This survey also showed the presence of gravel deposits, and gravel interspersed with sand and silt ribbons. Both of these material types occur mostly in the western portion of the study area.

Section 10
REFERENCES

Allen, J.R.L. 1970. The avalanching of granular solids on dune and similar slopes. *Journal of Geology*, 78(3):326-351.

Borgeld, J.C., Creager, J.S., Walter, S.R., Roy, E.H. 1978. An investigation to determine the sedimentary environment at Sites E, G, and H near the Mouth of the Columbia River entrance. Contract number DACW57-77-C0035, Final Report to the U.S. Army Corps of Engineers, Portland District, Portland OR.

Borgman, L.E., and Scheffner, N.W. 1991. Simulation of time sequences of wave height, period and direction. Technical Report DRP-91-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Bourke, R.H. and Glennne, B. 1971. The nearshore physical oceanographic environment of the Pacific northwest coast. Report 71-45, Oregon State University, Department of Oceanography, Corvallis.

Clausner, J. E., Lillycrop, L. S., McDowell, S. E., and May, B. 1998a. Overview of the 1997 Mud Dump Capping Project. Proceedings XVth World Dredging Congress 1998, CEDA, Amsterdam, The Netherlands.

Clausner, J.E., Gailani, J. Z., and Allison, M.C. 1998b. MDFATE Modeling of Contaminated Sediment Placement in the Eastern Section of the North Energy Island Borrow Pit. Draft Report prepared for the U.S. Army Engineer District, Los Angeles, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Earth Sciences Associates and Geo Recon International. 1984. Geologic and Seismic Investigations of Oregon Offshore Dredge Disposal Sites. Prepared for U.S. Army Corps of Engineers, Portland District, Portland OR.

Geo Recon International. 1995. Report on Offshore Side-scan Survey at Yaquina Bay, Newport, Oregon. Prepared for U.S. Army Corps of Engineers, Portland District, Portland OR.

Hallermeier, R. 1981. Seaward limit of significant sand transport by waves: An annual zonation for seasonal profiles. CETA 81-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Hench, J.L., Luettich, R.A., Westerink, J.J., and Scheffner, N.W. 1994. ADCIRC: An advanced three-dimensional circulation model for shelves, coasts, and estuaries. Technical Report DRP-92-6, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Hinds, J.K. 1995. Portland District USACE Memorandum for the Commander: Results from W.O. #95-186, Report of Yaquina Bay and Harbor Sediment Analysis.

Huyer, A. and Smith, R.L. 1977. Physical characteristics of Pacific Northwest coastal waters. The marine and plant biomass of the Pacific northwest coast. R.W. Krauss, ed. Oregon State University Press, Oregon State University, Corvallis.

Johnson, B.H. 1978. Evaluation and Calibration of the Tetra Tech Dredged Material Disposal Models Based on Field Data. Technical Report D-78-47, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Johnson, B.H. 1990. User's guide for models of dredged material disposal in open water. Technical Report DRP-90-5, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Johnson, B.H. and Fong, M.T. 1995. Development and Verification of Numerical Models for Predicting the Initial Fate of Dredged Material Disposed in Open Water, Report 2, Theoretical Developments and Verification Results. Technical Report DRP-93-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Komar, P.D. 1997. The Pacific Northwest Coast – Living with the Shores of Oregon and Washington. Duke University Press.

Komar, P.D., R.H. Neudeck and L.D. Kulm. 1972. Observation and Significance of Deep-water Oscillatory Ripple Marks on the Oregon Continental Shelf. Shelf Sediment Transport, Swift et al. eds. pp. 601-619.

Kulm, L.D. and others. 1975. Oregon continental shelf sedimentation: Interrelationship of facies distribution and sedimentary processes. *Journal of Geology* 83(2).

Larson, M. and Krause, N.C. 1989. SBEACH: Numerical Model for Simulating Storm Induced Beach Change, Report 1: Theory and Model Foundation. Technical Report CERC-89-9, Coastal Engineering Research Center, U.S. Army Waterways Experiment Station, Vicksburg, MS.

Luettich, R.A. 1995. Personal communication. Institute of Marine Sciences, University of North Carolina at Chapel Hill.

Moritz, H.R. and Randall, R.E. 1995. Simulating dredged material placement at open water disposal sites. *Journal of Waterway, Port, Coastal, and Ocean Engineering* 121(1).

Poindexter-Rollings, M.E. 1990. Methodology for analysis of subaqueous mounds. Technical Report D-90-2, Environmental Laboratory, U.S. Army Waterways Experiment Station, Vicksburg, MS.

Scheffner, N.W., Thevenot, M.M., Tallent, J.R., and Mason, J.M. 1995. LTFATE: A model to investigate fate and stability of dredged material disposal sites. Technical Report DRP 94-xx, Coastal Engineering Research Center, U.S. Army Waterways Experiment Station, Vicksburg, MS.

Schubel, J.R., Carter, H.H., Wilson, R.E., Wise, W.M., Heaton, M.G., and Gross, M.G. Field Investigations of the Nature, Degree, and Extent of Turbidity Generated by Open-Water Disposal Operations. TR-D-78-3, U.S. Army Waterways Experiment Station, Vicksburg, MS.

Siipola, M.D. and Braun, E.P. 1995. Management/monitoring Program for the ODMDSs of the U.S. Army Corps of Engineers, Portland District. U.S. Army Corps of Engineers, Portland District, Portland OR.

Snavely, P.D., Jr., Rau, W.W., and Wagner, H.C. 1964. Miocene Stratigraphy of the Yaquina Bay Area, Newport, Oregon. *The ORE BIN* (26)(8).

Sobey, E.J.B. 1977. The response of Oregon shelf waters to wind fluctuations: Differences and the transition between winter and summer. Ph.D. thesis, Oregon State University, Corvallis.

Sternberg, R.W., Creager, J.S., Glassley, W., and Johnson, J. 1977. Aquatic disposal field investigations Columbia River disposal site, Oregon, Exhibit A: Investigation of the hydraulic regime and physical nature of bottom sedimentation. Technical Report D-77-30, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Stevenson, M.R., Garvine, R.W., and Wyatt, B. 1974. Lagrangian measurements in a coastal upwelling zone off Oregon. *Journal of Physical Oceanography* 4(3):321-336.

Squier Associates, Golder Associates, Minister-Glaeser Surveying Inc., and David Evans and Associates, Inc. 1993. Marine Geophysical and Jet Probing Investigation, Yaquina Bay North Jetty Rehabilitation, Newport, Oregon. Prepared for U.S. Army Corps of Engineers, Portland District, Portland OR.

Thevenot, M.M and Johnson, B.H. Verification of Numerical Modeling of the Fate of Disposed Dredged Material. Dredging ’94 - Proceedings of the Second International Conference on Dredging and Dredged Material Placement. Volume 1, American Society of Civil Engineers.

Runge, E.J. 1966. Continental Shelf Sediments, Columbia River to Cape Balnco, Oregon. PhD thesis, Oregon State University, Corvallis.

USACE (U.S. Army Corps of Engineers). 1985. Yaquina Bay Interim Ocean Dredged Material Disposal Site Evaluation Study. Portland District, Portland OR.

USACE. 1995a. Simulation of dredged material disposal at Coos Bay ocean dredged material disposal site F. Portland District, Portland OR.

USACE. 1999. Integrated EIS and Feasibility Study for Columbia River Channel Improvement. Portland District, Portland OR.

Williamson & Associates, Inc. 2000. Offshore Disposal Site Investigation, Newport, Oregon. Prepared for U.S. Army Corps of Engineers, Portland District, Portland OR.