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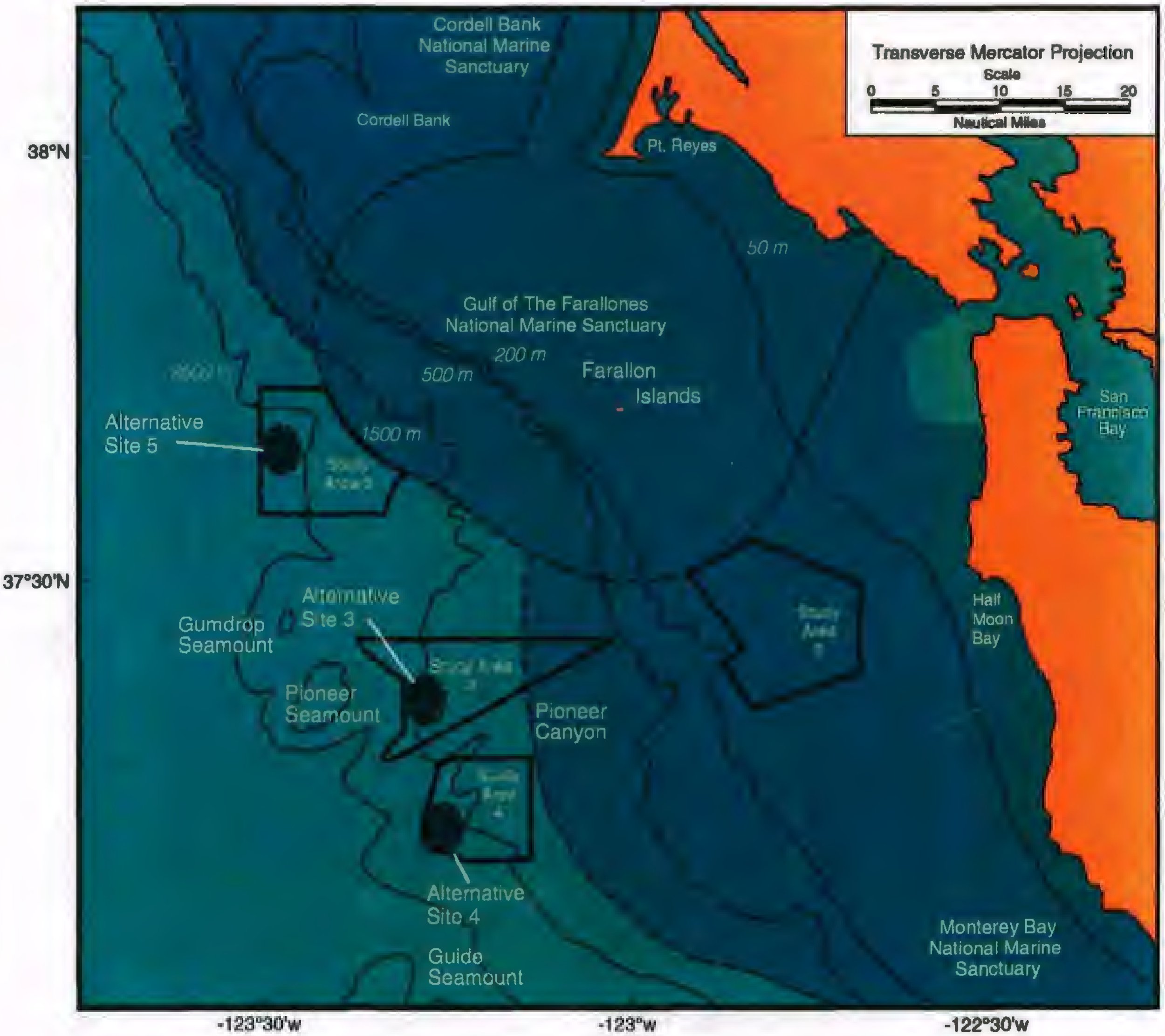
Environmental Impact Statement (EIS) for San Francisco Bay Deep Water Dredged Material Disposal Site Designation

December 1992



EPA

U.S. Environmental Protection Agency
Region IX, 75 Hawthorne Street, San Francisco, CA 94105

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Environmental Impact Statement (EIS) for San Francisco Bay Deep Water Dredged Material Disposal Site Designation

December 1992

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DRAFT
ENVIRONMENTAL IMPACT STATEMENT
FOR
SAN FRANCISCO BAY DEEP WATER DREDGED MATERIAL DISPOSAL SITE DESIGNATION

U.S. Environmental Protection Agency
Region IX
San Francisco, California

Comments on this administrative action should be addressed to:

Mr. Harry Seraydarian, Director
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U.S. Environmental Protection Agency
75 Hawthorne Street
San Francisco, California 94105

Comments must be received no later than:

January 25, 1993, 45 days after publication of the notice of availability in the Federal Register for the DEIS.

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ABSTRACT

This environmental impact statement (EIS) evaluates the proposed designation of a deep-water ocean dredged material disposal site as part of the Long-Term Management Strategy (LTMS) for San Francisco Bay, California. The LTMS is a Federal and State partnership responsible for addressing options for dredged material disposal, including ocean sites, sites within the Bay, nonaquatic sites, and beneficial uses of dredged material. Once designated, the proposed ocean site will provide a disposal option for an estimated 6 million yd^3 per year of dredged material over a 50-year period. Before ocean disposal may take place, proposed projects must demonstrate a need for ocean disposal and material must be acceptable according to U.S. Environmental Protection Agency and U.S. Army Corps of Engineers criteria and regulations.

The preferred alternative site (Alternative Site 5) is located on the continental rise off San Francisco approximately 50 nmi from shore and in 2,500 to 3,000 m of water. Selection of the preferred alternative site, as compared to two alternative ocean sites (Alternative Sites 3 and 4) and the No-Action alternative, is based on evaluation of the 5 general and 11 specific criteria of the Ocean Dumping Regulations listed at 40 CFR sections 228.5 and 228.6, respectively. Alternative Site 5 was chosen as the preferred alternative site primarily because, in contrast to the other alternative sites, it is located in deeper waters away from productive fishery areas and in an area that has been used historically for disposal of low-level radioactive waste and chemical and conventional munitions.

Use of the site is not expected to cause any significant long-term adverse environmental effects outside of site boundaries. Within the site, sediment composition will be altered and benthic infaunal and epifaunal communities will be affected due to burial and smothering by dredged material. However, because this site is located in deep water, where organism abundances are low, impacts are expected to be minimal. Potential impacts on water quality, plankton communities, pelagic and demersal invertebrates and fishes, marine birds, marine mammals, threatened and endangered species, and marine sanctuaries are expected to be insignificant. Similarly, potential impacts to socioeconomic resources (such as commercial and recreational fishing, military and commercial shipping, oil and gas or other mineral development, or cultural and historical resources) are expected to be insignificant due to the distance offshore of the preferred alternative site and minimal resource use in this area.

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DRAFT
ENVIRONMENTAL IMPACT STATEMENT
FOR
SAN FRANCISCO BAY DEEP WATER
DREDGED MATERIAL DISPOSAL
SITE DESIGNATION

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GLOSSARY OF ACRONYMS

ACSAR	Atlantic Continental Slope and Rise Program (U.S.)
ADCP	acoustic doppler current profiler
AEC	Atomic Energy Commission
ASBS	Area of Special Biological Significance
BART	Bay Area Rapid Transit
BCDC	Bay Conservation and Development Commission
BFBA	Bay Farm Borrow Area
CalCOFI	California Cooperative Oceanic Fisheries Investigations
CBNMS	Cordell Bank National Marine Sanctuary
CCC	California Coastal Commission
CDFG	California Department of Fish and Game
CEQ	Council on Environmental Quality
CEQA	California Environmental Quality Act
CFR	Code of Federal Regulations
CHASE	Cut Holes and Sink 'Em
CMDA	chemical munitions dumping area
CO	carbon monoxide
CODE	Coastal Ocean Dynamics Experiment
COE	Corps of Engineers (U.S. Army)
CSWRCB	California State Water Resources Control Board
CWA	Clean Water Act
CZMA	Coastal Zone Management Act
CZMPs	California Coastal Zone Management Plans
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane

DEIS	draft EIS
Eh	redox potential
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
ENSO	El Niño/Southern Oscillation
EPA	Environmental Protection Agency (U.S.)
ESA	Endangered Species Act (Federal)
FEIS	final EIS
FR	Federal Register
FWS	Fish and Wildlife Service (U.S.)
GOFNMS	Gulf of the Farallones National Marine Sanctuary
INPFC	International North Pacific Fisheries Commission
km	kilometers
LDC	London Dumping Convention
LSMs	least-squares means
LTMS	Long-Term Management Strategy
MB	Monterey Bay
MBNMS	Monterey Bay National Marine Sanctuary
MD	mid-depth
MMPA	Marine Mammal Protection Act
MMS	Minerals Management Service
MPRSA	Marine Protection, Research and Sanctuaries Act
NDBC	National Data Buoy Center
NEPA	National Environmental Policy Act
NESS	Normalized Expected Species Shared
NMFS	National Marine Fisheries Service
nmi	nautical mile
NMS	National Marine Sanctuaries
NO_2	nitrogen dioxide
NOAA	National Oceanic and Atmospheric Administration

NODS	Navy Ocean Disposal Site
NO_x	oxides of nitrogen
NS&T	National Status & Trends
OAQPS TTN	Office of Air Quality, Planning and Standards Technology Transfer Network Bulletin Board System
OCS	Outer Continental Shelf
ODMDS	ocean dredged material disposal site
ODSS	Ocean Dumping Surveillance System
OMZ	oxygen minimum zone
OSC	Oakland Scavenger Company
PAH	polynuclear aromatic hydrocarbon
PC	Pioneer Canyon
PCBs	polychlorinated biphenyls
PDEIS	preliminary draft EIS
PM	particulate matter
ppb	parts-per-billion
ppm	parts-per-million
ppt	parts-per-thousand
PRBO	Point Reyes Bird Observatory
ROV	remotely operated vehicle
RPD	redox potential discontinuity
RWQCB	Regional Water Quality Control Board
SFBRWQCB	San Francisco Bay Regional Water Quality Control Board
SHPO	State Historic Preservation Officer
SO_2	sulfur dioxide
SWOOP	Southwest Ocean Outfall Project
T-S	temperature-salinity
TSS	total suspended solids
USCG	United States Coast Guard
USFWS	United States Fish and Wildlife Service

USGS	United States Geological Survey
USN	United States Navy
USSC	United States Steel Corporation
VOC	volatile organic compounds
VTS	Vessel Traffic Service (San Fransisco)
yd^3	cubic yards
ZSF	zone of siting feasibility
μ	micro

Unit Conversion Table (Metric System with U.S. Equivalents)

Metric Unit	U.S. Equivalent(s)
Length/Depth	
millimeter (mm)	0.039 inches (in)
centimeter (cm)	0.39 inches (in)
meter (m)	39.37 inches (in)
	3.28 feet (ft)
	0.55 fathoms (fm)
kilometer (km)	0.62 statute miles (mi)
	0.53 nautical miles (nmi)
Area	
square centimeter (cm^2)	0.155 square inches (in^2)
square meter (m^2)	1.196 square yards (yd^2)
square kilometer (km^2)	0.3861 square statute miles (mi^2)
	0.292 square nautical miles (nmi^2)
hectare (ha) = 10,000 m^2	2.471 acres
Volume	
cubic centimeter (cm^3)	0.061 cubic inches (in^3)
milliliter (ml)	
cubic meter (m^3)	1.31 cubic yards (yd^3)
liter (l)	61.02 cubic inches (in^3)

Metric Unit	U.S. Equivalent(s)
Mass	
gram (g)	0.035 ounces (oz)
1,000 milligram (mg)	
kilogram (kg)	2.2046 pounds (lb)
metric ton (MT)	1.1 tons
	2,205 pounds (lb)
Speed	
centimeter per second (cm/sec)	0.02 knots (kn)*
meter per second (m/sec)	1.94 knots (kn)
	2.24 statute miles per hour (mi/hr)
kilometer per hour (km/h)	0.55 knots (kn)
Temperature	
degree Celsius (°C)	degree Fahrenheit (°F)
	= (1.8 x °C) + 32
0°C	32°F (freezing point of water)
100°C	212°F (boiling point of water)

*1 knot (1 nautical mile per hour) equals 1.15 statute (land) miles per hour.

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EXECUTIVE SUMMARY

S.1 Introduction

This Draft Environmental Impact Statement (DEIS) evaluates the proposed designation of a deep water ocean dredged material disposal site (ODMDS) off San Francisco, California (Figure S-1). The U.S. Environmental Protection Agency (EPA), Region IX, is issuing this EIS in accordance with Title I of the Marine Protection, Research, and Sanctuaries Act (MPRSA) and as required by EPA's national policy on the designation of ocean disposal sites (39 FR 37119, October 21, 1974).

The EIS has been prepared in coordination with other components of the Long-Term Management Strategy (LTMS) for San Francisco Bay, an effort led by a Federal and State partnership consisting of EPA, U.S. Army Corps of Engineers (COE), the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB), and the San Francisco Bay Conservation and Development Commission (BCDC). An LTMS goal is to provide "timely, technically feasible, cost-effective, and environmentally acceptable disposal alternatives for dredged material." Disposal options, including sites within the Bay, nonaquatic sites, and ocean disposal sites, as well as beneficial uses of dredged material are being developed by the LTMS.

An ODMDS is required to fulfill the LTMS objective of a range of disposal options for sediments dredged from San Francisco Bay. Presently, no ocean disposal site is available to accept this dredged material. Maintenance dredging of channels and expansion of dock capacities are essential to sustain economic growth and strategic use of the ports. An estimated six million yd^3 per year of dredged material could be disposed at the designated site over the next 50 years.

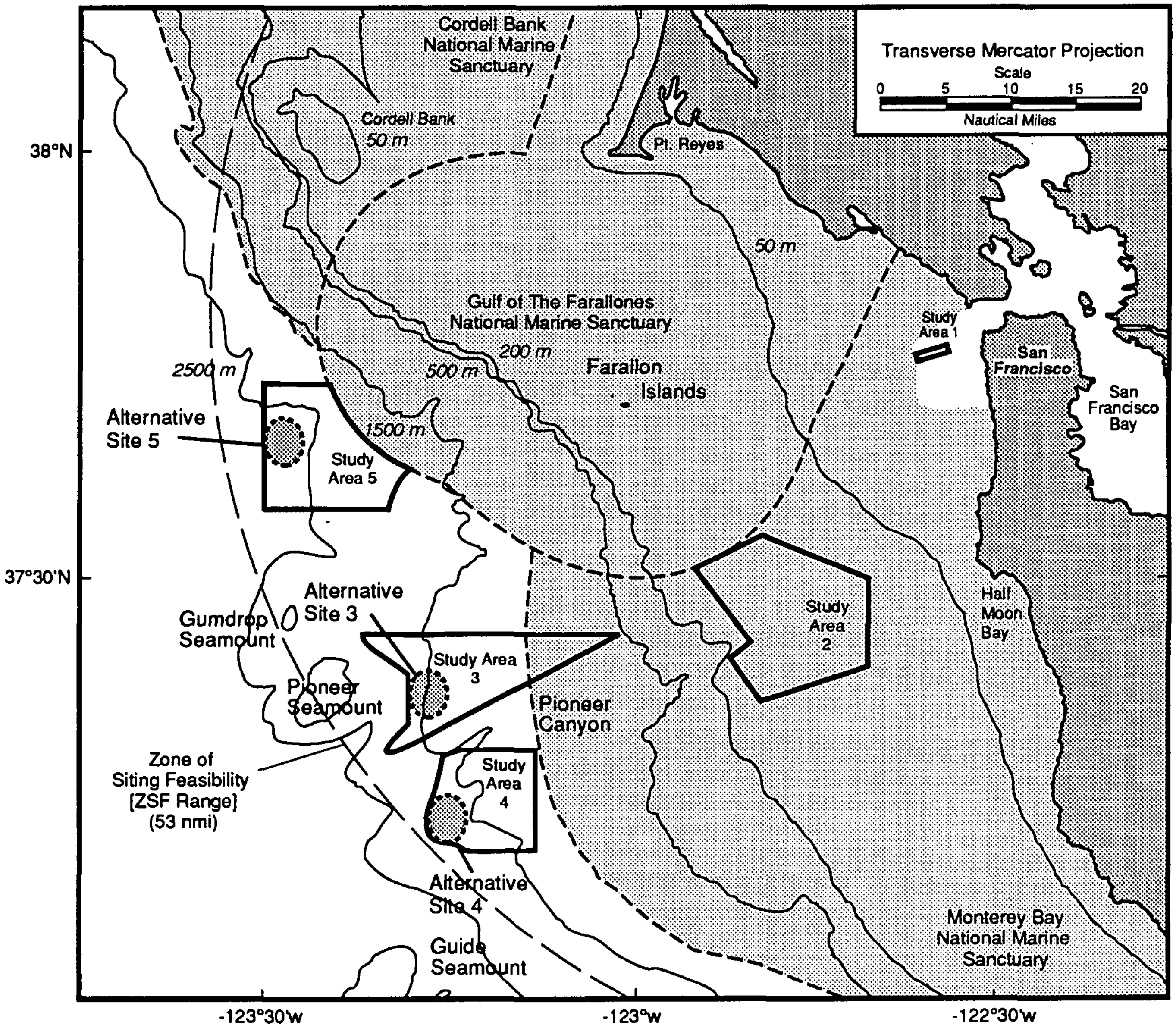

Figure S-1. Locations of Study Areas and Alternative Sites in the LTMS Study Region.

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The specific goal of this EIS is to provide an acceptable ocean disposal site which will not cause unreasonable degradation of the ocean with respect to human health and the marine environment. Other non-ocean alternatives are being addressed by the LTMS In-Bay Work Group and the Nonaquatic/Reuse Work Group.

The proposed action is to designate Alternative Site 5 (Figure S-1) as the ODMDS to receive dredged material from San Francisco Bay, in accordance with LTMS objectives. The designated site can only be used for the disposal of dredged material from Federal projects and permit applications that meet EPA and COE criteria and regulations. The site will not be used for disposal of industrial or municipal wastes.

Five general and eleven specific site selection criteria (40 CFR 228) were used in the determination process to evaluate three alternative ocean disposal sites:

- Alternative Site 5 (Preferred Alternative),
- Alternative Site 3, and
- Alternative Site 4.

Information contained in this EIS is used to characterize the physical, biological, and socioeconomic environments (Section S.2) and evaluate the potential environmental consequences of dredged material disposal at the preferred and alternative sites (Section S.3). The environmental characteristics and potential disposal-related impacts are compared and evaluated according to the five general and eleven specific site selection criteria (Section S.4).

S.2 Affected Environment

The following sections summarize the physical, biological, and socioeconomic environments of the preferred and alternative sites.

S.2.1 Physical Environment

The preferred and alternative ocean disposal sites are located on the continental slope and rise off San Francisco (Figure S-1). The size and configuration of the sites are uniform with an oval shape of dimensions of approximately 3.7 nmi (6.9 km) long and 2.2 nmi (4.1 km) wide. Alternative Site 3 is located in the western part of Study Area 3 (depths ranging between 1,400 and 1,900 m), south of the Gulf of the Farallones National Marine Sanctuary (GOFNMS), north of Pioneer Canyon, and approximately 47 nmi from the Golden Gate. Alternative Site 4 is located in the southwestern part of Study Area 4 (depths ranging between 1,900 and 2,100 m), approximately 55 nmi from the Golden Gate and 15 nmi SE of Pioneer Seamount. Alternative Site 5, the preferred alternative, is located on the continental rise (depths between 2,500 and 3,000 m), approximately 49 nmi from coast and 50 nmi from the Golden Gate.

The coastal environment off San Francisco has a maritime climate, characterized by a general lack of weather extremes, with cool summers and mild, wet winters. Fog occurs off the coast throughout the year, but is most persistent during summer. Winds are an important influence on water column characteristics and currents over the continental shelf and upper continental slope. Strong north and northwest winds in spring and early summer promote offshore-directed flow of surface waters and upwelling.

Current flow in the vicinity of Alternative Site 3 is primarily to the northwest in the upper 800 to 900 m of the water column, although periodic reversals in flow occur. Currents below 1,000 m are generally weaker than near-surface currents, while near-bottom flows are enhanced by tidal influences and topography. Similar trends in current flows occur in Alternative Sites 4 and 5. Considerable seasonal variability in surface water temperature and salinity reflect large-scale current patterns, outflow from the Bay, and small-scale flow features. Although the site-specific data are limited, the existing water quality conditions at all alternative sites likely are similar, with comparable dissolved oxygen, suspended particle, and trace chemical constituent concentrations and turbidity levels.

Sediments at Alternative Site 3 are mostly silt-sized particles, while sediments at Alternative Site 4 comprise mostly sand and silt-sized particles, and sediments at the preferred alternative comprise mainly fine-grained silts and clays. All of the sites are characterized by background or low concentrations of chemical constituents. No known hard-bottom areas occur within any of the sites.

S.2.2 Biological Environment

The preferred alternative site is characterized by somewhat lower infaunal diversity and abundance than Alternative Sites 3 or 4. The number of species and abundances of megafaunal invertebrates at Alternative Site 5 is moderate, with sea cucumbers, brittlestars, and sea pens predominating. Some species of midwater fishes, such as juvenile rockfishes, have higher seasonal abundances at the preferred alternative than at Alternative Sites 3 or 4. Based on limited data on plankton communities and other midwater species, there do not appear to be any significant differences among the sites. The preferred alternative site has relatively high use by marine birds and mammals as compared to the alternative sites.

Alternative Site 3 is characterized by a diverse and abundant infaunal community comprising of polychaetes, amphipods, tanaids, and isopods. Abundances and species diversity for megafaunal invertebrates is moderate at this site, with sea cucumbers, seastars, and brittle stars predominating. Juvenile rockfishes are seasonally abundant, while marine birds and mammals make moderate use of this site.

Alternative Site 4 is characterized as having a very similar infaunal species composition as Alternative Site 3, but with fewer amphipods. This site also has moderate numbers of species and abundances of megafaunal invertebrates. Juvenile rockfishes use this site seasonally, while marine birds and mammals utilize this site less than Alternative Site 3.

S.2.3 Socioeconomic Environment

The region off San Francisco supports important commercial and recreational fisheries, consisting of a variety of pelagic and demersal fishes and megafaunal invertebrates. However, use of the preferred or alternative sites for commercial and recreational fisheries is minimal due to the great depths and limited resource value. Pelagic fishes collected in the vicinity of the sites consist mainly of tunas, mackerels, and some salmon, while demersal fishes consist primarily of flatfishes, such as Dover sole, and rockfishes such as thornyheads.

The area offshore of San Francisco is one of the nation's largest naval operating zones. However, none of the alternative sites are located within submarine operating areas or navigational lanes. The potential for conflicts with oil and gas development at alternative sites is extremely low. Although large repositories of oil and gas reserves are located in several areas along and offshore of the California coast, there are no existing or planned oil and gas development activities or structures within the general study region. Current technological limitations preclude such activities at depths greater than approximately 400 m, while bottom depths at the preferred and alternative sites are all greater than 1,400 m. Further, there are no known features of cultural or historical significance within the sites.

S.3 Environmental Consequences

Potential environmental consequences associated with dredged material disposal at the preferred and alternative sites are summarized in Table 4.1-1 (Chapter 4). The impact category and spatial and temporal extents of potential impacts to specific environmental conditions are identified in the table.

Evaluations of potential effects from dredged material disposal on air quality, on water quality parameters (suspended particle concentrations), and on seafloor conditions (bottom deposit thicknesses) were performed using computer models to simulate disposal at the preferred and alternative sites. Additional information concerning environmental impacts obtained from research and monitoring of other dredged material disposal sites also was used to evaluate potential impacts at these sites.

S.3.1 Physical Environment

Impacts from dredged material disposal operations on air quality, water quality, and geology are considered insignificant. Exhaust emissions from dredged material transport operations would not result in concentrations of air pollutants that exceed State and Federal standards. The water quality model predicted a low probability that fine-grained sediments would reach the boundary of any of the National Marine Sanctuaries following disposal at any of the alternative sites. Therefore, potential effects on water quality are considered insignificant. A sediment deposition model predicted that, within the boundaries of the preferred and alternative sites, areas covered by deposits with thicknesses greater than or equal to 10 cm (100 mm), would be less than 10 km^2. Depending on the characteristics of the dredged material, significant localized changes in the grain size of the bottom sediments could be expected in areas with the highest deposition. However, according to the deposition model calculations, no measurable deposition and alteration of bottom sediments would occur within the sanctuaries. Significant impacts on sediment quality in any area are not expected given that the dredged material must be tested and determined suitable, according to EPA and COE testing criteria, for disposal in the ocean.

S.3.2 Biological Environment

Impacts on infauna, epifauna, and fishes at deep-water sites are expected to occur over a wider area than at shallow shelf sites because of greater sediment dispersal in the water column before it reaches the bottom. The benthic community would be similarly affected by dredged material disposal at the preferred or alternative sites as a result of smothering of some organisms and alteration of sediment characteristics. However, these impacts are expected to occur only in areas with depositional thicknesses equal to or greater than 10 cm. Areas with depositional thicknesses less than 10 cm would not be expected to incur significant changes in abundance or diversity of infauna, epifauna, or demersal fishes. Impacts on water column organisms such as plankton, pelagic fishes, pinnipeds and cetaceans are expected to be minimal and temporary at the preferred and alternative sites. Further, exposure of marine organisms to dredged material is not expected to result in significant effects because all dredged material must be approved by EPA and COE before disposal.

S.3.3 Socioeconomic Environment

At the preferred and alternative sites, it is unlikely that dredged material disposal will interfere with other ocean uses, including shipping, fishing, and recreation. The effects of disposal activities on commercial and recreational fishing are expected to be temporary and insignificant. Most disposal impacts will occur near the sea bottom, and no significant demersal fisheries exist within any of the alternative sites.

Potential hazards to commercial and recreational navigation resulting from dredged material transport and disposal are expected to be minimal at the preferred and alternative sites. Dredged material barge transits to the preferred alternative site could cause some interference with commercial, recreational, and scientific boat traffic, particularly near the Farallon Islands. However, this could be mitigated by specifying barge transit routes that avoid the vicinity of the Islands. No existing or planned oil and gas development activities occur within the region. Therefore, dredged material disposal will not affect oil and gas development. Disposal activities at the preferred or alternative sites should not pose a significant danger or cause interference with military vessels because the number of dredged material barge trips is small compared to the overall volume of vessel traffic in the region.

No known cultural or historical resources exist within the preferred or alternative sites. Therefore, dredged material disposal would not affect cultural resources. Potential impacts on human safety should be very low because the number of barge trips is small compared to the overall volume of traffic, and measures such as specifying barge transit routes would avoid interference in the vicinity of the Farallon Islands. As stated in MPRSA, no materials considered to be hazardous may be disposed at an ODMDS. Therefore, the potential for human health hazards is minimal at all the sites.

S.4 Comparison of the Alternative Ocean Disposal Sites With the 5 General and 11 Specific Site Selection Criteria

The preferred alternative (Alternative Site 5) and the two alternative disposal sites (Alternative Sites 3 and 4) are compared to the 5 general criteria listed at 40 CFR 228.5 and the 11 specific site selection criteria listed at 40 CFR 228.6(a). A detailed summary of the 11 site selection criteria is contained in Table 2.2-1 (Chapter 2).

S.4.1 General Selection Criteria

1. **The dumping of materials into the ocean will be permitted only at sites or in areas selected to minimize the interference of disposal activities with other activities in the marine environment, particularly avoiding areas of existing fisheries or shellfisheries, and regions of commercial or recreational navigation.**

The preferred and alternative sites are located in water depths greater than 1,400 m, characterized by sparsely distributed fisheries species of potential commercial value. Use of the sites for dredged material disposal would have minimal effects on existing or potential fisheries or shellfisheries. None of the sites is located within established precautionary zones, navigation lanes, or submarine operating areas. The additional vessel traffic represented by dredged material barge transits to the alternative sites is considered small compared to overall traffic volumes, therefore representing a negligible potential impact on commercial or recreational navigation.

2. **Locations and boundaries of the disposal sites will be so chosen that temporary perturbations in water quality or other environmental conditions during initial mixing caused by disposal operations anywhere within the site can be expected to be reduced to normal ambient seawater levels or to undetectable concentrations or effects before reaching any beach, shoreline, marine sanctuary, or known geographically limited fishery or shellfishery.**

The preferred and alternative sites are outside of any sanctuary boundaries. Modeling results indicated low probabilities of material disposed of at the alternative sites being transported into the National Marine Sanctuaries. Further, predicted dilution rates would reduce the suspended particle concentrations to normal ambient levels at the sanctuary boundaries. Similarly, use of the alternative sites is unlikely to affect water quality or other environmental conditions at any beach, shoreline, or resource or amenity area due to the large distances offshore and the ability to specify dredged material barge transit routes, to avoid resources associated with the Farallon Islands.

3. **If at any time during or after disposal site evaluation studies, it is determined that existing disposal sites presently approved on an interim basis for ocean dumping do not meet the criteria for site selection set forth in Sections 228.5 through 228.6, the use of such sites will be terminated as soon as suitable alternate disposal sites can be designated.**

Continued use of a designated disposal site will be evaluated as part of the site management and monitoring program.

4. **The sizes of ocean disposal sites will be limited in order to localize for identification and control any immediate adverse impacts and permit the implementation of effective monitoring and surveillance programs to prevent adverse long-range impacts. The size, configuration, and location of any disposal site will be determined as a part of the disposal site evaluation or designation study.**

The sizes and configurations of the preferred and alternative sites are based on the result of water quality and deposition modeling studies. Site size will be limited, yet will encompass modeled regions of significant sediment deposition (i.e., 10 mm). The site locations are chosen to coincide with depositional zones where resuspension and dispersion of dredged material will be minimized and monitoring of long-term effects will be facilitated.

5. **EPA will, wherever feasible, designate ocean dumping sites beyond the edge of the continental shelf and other such sites that have been historically used.**

All of the alternative sites are located beyond the edge of the continental shelf. Historical disposal operations of low-level radioactive wastes and chemical and conventional munitions have occurred in the general vicinity of the preferred alternative. Additionally, the U.S. Navy is seeking a project-specific permit for disposal of approximately 1.6 million yd^3 in a location that corresponds to the preferred alternative. In contrast, no historical waste disposal has occurred at Alternative Sites 3 and 4.

S.4.2 Specific Site Selection Criteria

1. **Geographical position, depth of water, bottom topography, and distance from coast.**

The preferred alternative (Alternative Site 5) is located on the continental rise at depths ranging between 2,500 and 3,000 m, with a moderately sloping bottom that is relatively unbounded, Alternative Sites 3 and 4 are located in shallower depths on the lower continental slope. All sites are located at least 45 miles from the Golden Gate.

2. Location in relation to breeding, spawning, nursery, feeding, or passage areas of living resources in adult or juvenile stages.

The preferred and alternative sites contain low numbers of fish species and abundances (as compared to inshore areas) and moderate numbers of megafaunal invertebrate species and abundances. The preferred alternative has higher use by some organisms, such as marine birds and mammals and some midwater fishes, but relatively lower diversity and abundances of infauna as compared to Alternative Sites 3 and 4.

3. Location in relation to beaches and other amenity areas.

All sites are located at least 45 nmi from any coastal resources and at least 10 nmi from any National Marine Sanctuaries. Based on water quality modeling results, concentrations of sediment particles transported across Sanctuary boundaries will be within the range of normal background levels.

4. Types and quantities of wastes proposed to be disposed of, and proposed methods of release, including methods of packing the waste, if any.

Up to 6 million yd^3 per year of predominantly silt and clay material dredged from San Francisco Bay could be disposed at the ODMDS. Disposal most likely will be from split hull barges. The total amount of dredged material disposed over a 50-year period could total 400 million yd^3. No dumping of toxic materials or industrial or municipal wastes would be allowed at the site.

5. Feasibility of surveillance and monitoring.

The USCG has surveillance responsibility at the designated site. Physical, chemical, and biological sampling is possible at all alternative sites. However, the preferred alternative is the deepest site and, therefore, may be more difficult to monitor as compared to Alternative Sites 3 and 4. Additionally, monitoring activities at the preferred alternative site may require special precautions due to previously disposed waste materials.

6. Dispersal, horizontal transport, and vertical mixing characteristics of the area, including prevailing current direction and velocity, if any.

At all the sites, ocean currents flow primarily to the northwest in the upper 800 to 900 m of the water column, although periodic reversals in flow occur. Currents below 1,000 m are generally weaker than near-surface currents. Near-bottom currents may be enhanced by tidal influences and topography. Sediment resuspension and transport is expected to be minimal within all the alternative sites.

7. Existence and effects of current and previous discharges and dumping in the area (including cumulative effects).

No current disposal activities occur within the preferred or alternative sites. However, the Navy has requested an MPRSA Section 103 permit for disposal of up to 1.6 million yd^3 of dredged material at the preferred alternative site. In addition, disposal of radioactive waste containers was conducted between 1951 and 1954 in the vicinity of Study Area 5. Chemical and conventional munitions were disposed from approximately 1958 to the late 1960s at the Chemical Munitions Dumping Area, within which the preferred alternative is located. No residual contamination from either source was detected during recent surveys and disposal of dredged material is unlikely to have any synergistic or additive effects. Dredged material disposal may, in fact, serve to isolate any residual contamination.

8. Interference with shipping, fishing, recreation, mineral extraction, desalination, fish and shellfish culture, areas of special scientific importance and other legitimate uses of the ocean.

Dredged material barge transit to the preferred alternative site could cause minor interference with recreation and scientific boat traffic in the vicinity of the Farallon Islands. However, under normal conditions, no interference is expected. A requirement that barges avoid the Farallones vicinity could minimize potential impacts. Further, no significant interferences with fishing or shipping would be expected at the preferred alternative site. The potential for interference of dredged material disposal with shipping, fishing, recreation, and areas of special scientific importance also would be minimal at Alternative Sites 3 and 4.

9. Existing water quality and ecology of the site as determined by available data, by trend assessment, or by baseline surveys.

The water quality conditions at the preferred and alternative sites likely are similar. Sediments at all the sites contain low to background concentrations of trace metal and organic contaminants. Ecological characteristics are discussed under site-specific criterion 2. Potential impacts at any of the sites are expected to be transitory and insignificant.

10. Potentiality for the development of nuisance species at the disposal site.

It is unlikely that nuisance species would recruit to any of the sites due to dredged material disposal. This is based on the significant differences in depth and environment at the preferred and alternative sites compared to the dredging site(s).

11. Existence at or in close proximity to the site or any significant natural or cultural features of historical importance.

There are no known significant natural or cultural features within or in the vicinity of any of the alternative sites.

S.5 Conclusions

Impacts from disposal of dredged material at the preferred alternative are expected to be minimal for the following reasons:

- Bathymetric and sediment surveys indicate Alternative Site 5 is located in a depositional area which, because of topographic containment features, is likely to retain dredged material which reaches the sea floor;
- No significant impacts to other resources or amenity areas (e.g., marine sanctuaries) are expected to occur from designation of Alternative Site 5;
- Existing and potential fisheries resources within Alternative Site 5 are minimal and this site is removed from important fishing grounds located nearer to Alternative Sites 3 and 4;
- Densities and biomass of demersal fishes and megafaunal invertebrates are estimated to be relatively low compared to those at Alternative Sites 3 and 4;
- Potential impacts to other organisms (e.g., marine birds and mammals and midwater organisms) are expected to be insignificant, even though Alternative Site 5 tends to have slightly higher abundances of these organisms; and
- Waste disposal has occurred historically in the vicinity of the site (and disposal of dredged material may occur as part of the Navy MPRSA Section 103 project).

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CHAPTER 1
INTRODUCTION

1.1 General Introduction

This Draft Environmental Impact Statement (DEIS) evaluates the proposed designation of a deep-water ocean dredged material disposal site (ODMDS) off San Francisco, California. A variety of maintenance dredging and new channel and harbor deepening projects proposed for San Francisco Bay will generate material that will be evaluated for disposal at the ODMDS (COE 1992a). The proposed ODMDS could receive up to 6 million cubic yards (yd^3) of sediments per year over the next 50 years (COE 1991).

Sediment dredging and disposal are regulated under two federal laws: Title I of the Marine Protection, Research and Sanctuaries Act (MPRSA), and Section 404 of the Clean Water Act (CWA). Both Acts require that a number of alternative methods, including ocean disposal, be evaluated for environmental acceptability prior to disposal. The U.S. Environmental Protection Agency (EPA) and the U.S. Army Corps of Engineers (COE) share responsibility for the management of ocean disposal of dredged material. Under Section 102 of MPRSA, EPA has the responsibility for designating an acceptable location for the ODMDS. With concurrence from EPA, the COE issues permits under MPRSA Section 103 for ocean disposal of dredged material deemed suitable according to EPA criteria in MPRSA Section 102 and EPA regulations in 40 CFR Part 227.

It is EPA's policy to publish an Environmental Impact Statement (EIS) for all ODMDS designations (39 FR 37119, October 21, 1974). A site designation EIS is a formal evaluation of alternative sites in which the potential environmental impacts associated with disposal of dredged material at various locations are examined. The EIS must first demonstrate the need for the proposed ODMDS designation action (40 CFR §6.203(a) and 40 CFR §1502.13) by describing available or potential aquatic and nonaquatic (i.e., land-based) alternatives, and the consequences of not designating a site—the No-Action Alternative. Once the need for an ocean disposal site is established, potential sites are screened for feasibility through the Zone of Siting Feasibility (ZSF) process. Remaining alternative sites are evaluated using EPA's ocean dumping criteria at 40 CFR Part 228 (Table 1.1-1) and compared in the EIS. Of the sites which satisfy these criteria, the site which best complies with these criteria is selected as the preferred alternative for formal designation through rulemaking published in the *Federal Register*.

Formal designation of an ODMDS in the *Federal Register* does not constitute approval for ocean disposal. Designation of an ODMDS provides an ocean disposal alternative for consideration in the review of each proposed dredging project. Ocean disposal is allowed only when EPA and COE determine that the proposed activity is environmentally acceptable according to the criteria at 40 CFR Part 227. Decisions to allow ocean disposal are made on a case-by-case basis through the MPRSA Section 103 permitting process.

Upon application for a permit, an evaluation process, shown diagrammatically in Figure 1.1-1, ensures that the proposed disposal operation conforms to the provisions of EPA's Ocean Dumping Regulations (40 CFR Parts 220, 225, 227-228) and COE's dredged material disposal permit requirements under MPRSA Section 103 (33 CFR Parts 320-330 and 335-338). Material proposed for disposal at the designated ODMDS must conform to EPA's permitting criteria for acceptable quality (40 CFR Parts 225 and 227), as determined from physical, chemical, and bioassay/bioaccumulation testing (EPA and COE 1991). Permits to use a designated ODMDS also can specify the times, rates, and methods of disposal, as well as the quantities, types, and sources of the dredged material.

1.2 Purpose of and Need for Action

The purpose of the proposed action is to provide an ocean disposal site for sediments dredged from San Francisco Bay. Dredging is required to remove millions of cubic yards of accumulated

Table 1.1-1. Five General and Eleven Specific Site Selection Criteria.

General Site Selection Criteria—40 CFR 228.5

(a) The dumping of materials into the ocean will be permitted only at sites or in areas selected to minimize the interference of disposal activities with other activities in the marine environment, particularly avoiding areas of existing fisheries or shellfisheries, and regions of heavy commercial or recreational navigation.

(b) Locations and boundaries of disposal sites will be so chosen that temporary perturbances in water quality or other environmental conditions during initial mixing caused by disposal operations anywhere within the site can be expected to be reduced to normal ambient seawater levels or to undetectable contaminant concentrations or effects before reaching any beach, shoreline, marine sanctuary, or known geographically limited fishery or shellfishery.

(c) If at any time during or after disposal site evaluation studies, it is determined that existing disposal sites presently approved on an interim basis for ocean dumping do not meet the criteria for site selection set forth in Sections 228.5 through 228.6, the use of such sites will be terminated as soon as suitable alternate disposal sites can be designated.

(d) The sizes of the ocean disposal sites will be limited in order to localize for identification and control any immediate adverse impacts and permit the implementation of effective monitoring and surveillance programs to prevent adverse long-range impacts. The size, configuration, and location of any disposal site will be determined as a part of the disposal site evaluation or designation study.

(e) EPA will, wherever feasible, designate ocean dumping sites beyond the edge of the continental shelf and other such sites that have been historically used.

Table 1.1-1. Continued.

Specific Site Selection Criteria—40 CFR 228.6(a)

(1) Geographical position, depth of water, bottom topography, and distance from the coast;

(2) Location in relation to breeding, spawning, nursery, feeding, or passage areas of living resources in adult or juvenile phases;

(3) Location in relation to beaches and other amenity areas;

(4) Types and quantities of wastes proposed to be disposed of, and proposed methods of release, including methods of packaging the waste, if any;

(5) Feasibility of surveillance and monitoring;

(6) Dispersal, horizontal transport and vertical mixing characteristics of the area, including prevailing current direction and velocity, if any;

(7) Existence and effects of current and previous discharges and dumping in the area (including cumulative effects);

(8) Interference with shipping, fishing, recreation, mineral extraction, desalination, fish and shellfish culture, areas of special scientific importance and other legitimate uses of the ocean;

(9) Existing water quality and ecology of the site as determined by available data or by trend assessment or baseline surveys;

(10) Potentiality for the development or recruitment of nuisance species in the disposal site; and

(11) Existence at, or in close proximity to, the site of any significant natural or cultural features of historical importance.

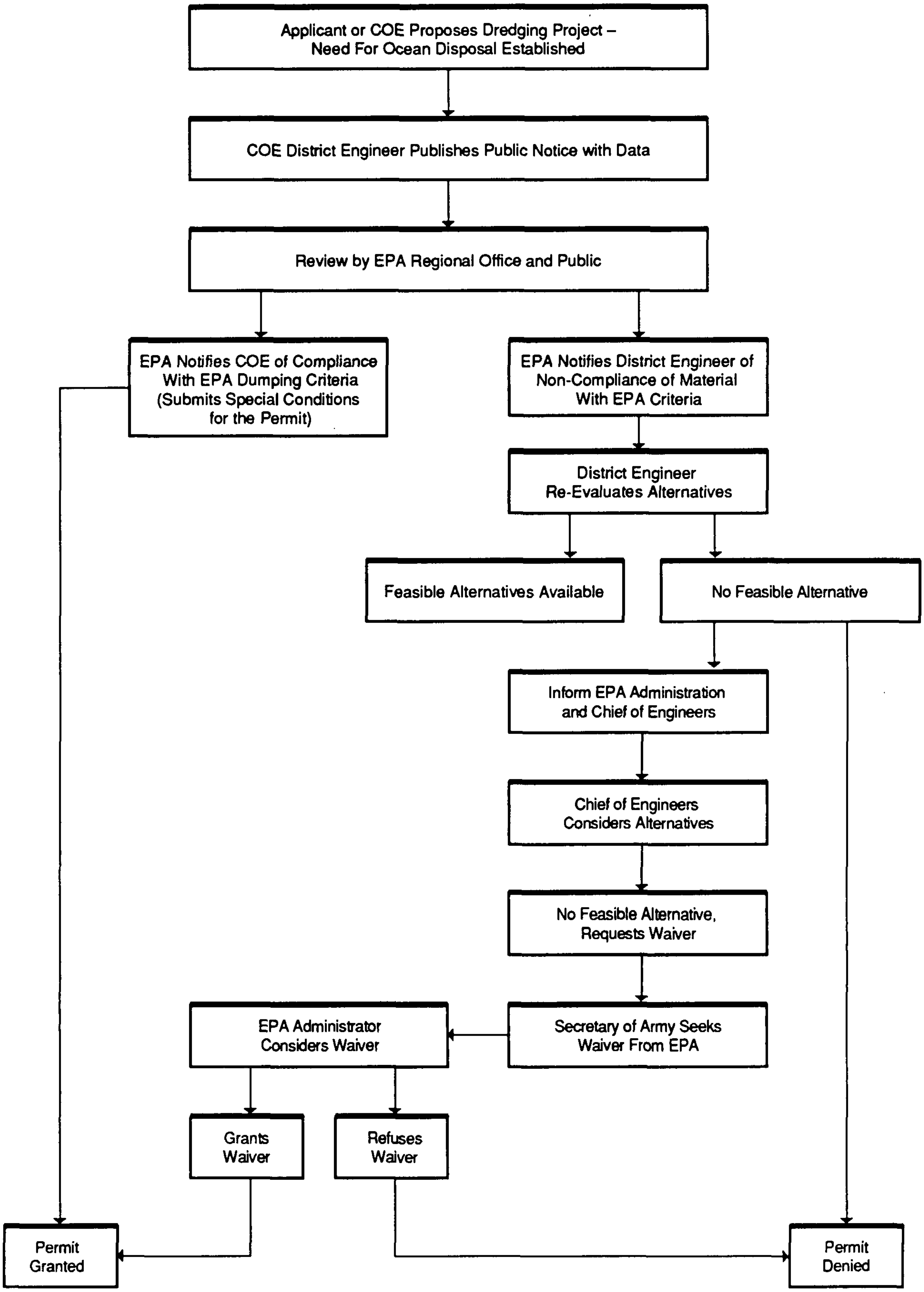

Figure 1.1-1. Evaluation Process for Dredged Material Permits.

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sediments transported by natural processes into San Francisco Bay (COE 1992b). In depositional areas with weak currents, these sediments settle to the bottom, accumulate, and gradually cause portions of the Bay to become shallower. Sediment deposition and accumulation, particularly in the navigation channels and port facilities, may seriously interfere with vessel traffic, vessel loading and unloading, and vessel mooring or storage.

Dredging is needed to maintain over 85 miles of authorized deep and shallow navigation channels in San Francisco Bay that provide vessel access to commercial, recreational, and fishing facilities. The COE (1990a) stated that:

> "Navigation channel maintenance and improvements are essential to the nation's ability to compete effectively in international import/export markets. The San Francisco Bay and estuary act as a critical thoroughfare for the nation's increasing role in Pacific Rim Trade with its numerous ports and intermodal links. As of 1983, the San Francisco Bay Area was the fifth largest export manufacturing center in the United States with export-related employment of over 68,000 and a dollar value of close to 7 billion dollars (Skinkle, 1989). In 1980, trade with the Pacific Rim nations (Japan, Korea, Taiwan, Australia and other countries in the Far East) accounted for one-quarter of the nation's imports/exports—today the share is over one-third and rising (Skinkle, 1989)."

Furthermore, the COE (1992a) concluded that:

> "Dredging needs to continue in order to provide adequate depths for deep and shallow draft vessels serving the commercial and recreational needs of the Bay. Over 4,000 deep draft vessels annually call at container ports, oil and auto facilities, bulk terminals and other facilities throughout the Bay and the inland ports of Sacramento and Stockton. The U.S. Navy and Coast Guard maintain a major presence in the Bay Area and many of their facilities require dredging. Dredging is also required to maintain the depths necessary for shallow draft vessels serving recreational boaters, tourists and ferry riders, commercial fishing and miscellaneous other activities."

Under the Rivers and Harbors Act of 1889, as amended (33 USC Sections 401 *et seq.*), the COE is responsible for maintaining the navigability of major waterways. The COE's maintenance dredging operations throughout the Bay comprise 13 civil works projects that historically have generated approximately 5 million yd^3 per year of dredged material. Other channel-deepening and new work projects have been proposed that would generate additional volumes of dredged material. The annual and projected 50-year volumes for dredging projects within San Francisco Bay are 7.6 million yd^3 and approximately 400 million yd^3, respectively (Table 1.2-1; COE 1992a). Approximately 6 million yd^3 of the 7.6 million yd^3 annual volume is under consideration for disposal at the ODMDS.

Disposal options, including the use of sites within the Bay, nonaquatic sites, and ocean disposal sites, as well as beneficial uses of dredged material are being evaluated as components of the Long-Term Management Strategy (LTMS) for San Francisco Bay (COE 1992a). The goal of the LTMS is "to secure timely, technically feasible, cost-effective, and environmentally acceptable disposal alternatives for dredged material." Evaluations of these alternatives are scheduled for completion in 1994. The LTMS envisions that several options will be available for disposal, depending on the volumes and characteristics of the dredged material and the location of the dredging project. Disposal options are necessary because it is unlikely that a single site can satisfactorily accommodate the planned volumes and characteristics of the dredged material (COE 1990a).

Historically, most sediments dredged from the Bay have been disposed at sites within the Bay. The primary disposal site within the Bay, the Alcatraz Site, is mounding due to previous disposal practices (COE 1992a). Due to present mounding problems and concerns about potential effects of dredged material disposal on fisheries resources, water quality, and habitat alteration, restrictions have been placed on the use of sites within the Bay (COE 1990a). The present capacities of existing sites within the Bay for dredged material disposal are unknown (COE 1990a). The feasibility of dredged material disposal at sites within the Bay is being evaluated by the LTMS In-Bay Work Group.

Nonaquatic sites also have been used historically for the disposal of dredged material from the Bay. Dredged material has been used primarily as fill at these sites, although disposal at nonaquatic sites also can have beneficial effects, such as marsh restoration, creation of wetlands, and levee maintenance. However, nonaquatic sites generally have limited capacities, and

Table 1.2-1. Projected Annual and 50-Year Dredging Volumes for Projects in San Francisco Bay. Dredging Volumes in Cubic Yards.

Project	Annual Volume	50-Year LTMS Volume
COE Maintenance	4,276,000	213,800,000 *
John F. Baldwin New Work		9,000,000
Oakland New Work		7,000,000
Richmond New Work		1,500,000
Navy Maintenance	1,780,000	89,000,000
Navy New Work		1,700,000
Oakland Permit**	140,000	7,000,000
San Francisco Permit**	200,000	10,000,000
Chevron Permit**	196,000	9,800,000
Other Permit**	1,040,000	52,000,000
TOTAL	**7,632,000**	**400,800,000 ***

Source: COE 1992a

*Includes maintenance dredging volumes from new work projects (T. Wakeman, COE, pers. comm. 1992).
**Permit projects are non-Congressionally authorized projects that may include maintenance or new work dredging (T. Wakeman, COE, pers. comm. 1992).

presently no sites are available to accommodate the large volume of material projected to be dredged from San Francisco Bay (COE 1992a). Also, the high costs associated with land acquisition and transport, constraints against filling wetlands, and a variable and vaguely defined permitting process complicate the selection of nonaquatic areas as disposal sites (COE 1990a). The feasibility of dredged material disposal at nonaquatic sites is being evaluated by the LTMS Nonaquatic/Reuse Work Group. Given the lack of capacity at sites within the Bay and nonaquatic sites, the COE (1990a) concluded that "clearly, there exists a shortfall in disposal capacity for the improvement projects scheduled by the USACE [COE], the Navy and the ports for this region."

Presently no ocean disposal site is available to accept dredged material from San Francisco Bay. The Channel Bar Site is a designated ODMDS [40 CFR 228.12(b)(14)]; however, only coarse-grained sediments dredged from the entrance channel to San Francisco Bay are permitted for disposal. Most sediments from San Francisco Bay are fine-grained and, therefore, are not suitable for disposal at the Channel Bar ODMDS (EPA 1982). Thus, although the goal of the LTMS is to provide a range of options that include ocean disposal, presently no ODMDS is available. Designation of an ODMDS for large quantities of dredged material from San Francisco Bay is considered an integral component of the LTMS (COE 1992a). The California State Water Resources Control Board's (SWRCB) resolution 90-37 "places all dredging parties and agencies on notice that failure to reach specific commitments for designation of [such] an ocean disposal site in a timely manner will result in the State Board exercising its full authority regarding water quality certification [for disposal within the Bay]..." The feasibility of dredged material disposal at an ODMDS is being evaluated by the LTMS Ocean Studies Work Group.

1.3 Proposed Action

The proposed action is the designation of a deep-water ODMDS that could be used for disposal of sediments dredged from San Francisco Bay. This DEIS evaluates three alternative disposal sites according to the five general and eleven specific criteria promulgated at 40 CFR §228 (Table 1.1-1) and recommends the preferred alternative. The locations of the alternative disposal sites are shown in Figure 1.3-1. Alternative Sites 3, 4, and 5 are located within LTMS Study Areas 3, 4, and 5, respectively. Alternative Site 5 is the preferred alternative.

Study Areas 3, 4, and 5 are located off the continental shelf. Study Area 3 is south of the Gulf of the Farallones National Marine Sanctuary (GOFNMS), north of Pioneer Canyon, and approximately 47 nautical miles (nmi) from the Golden Gate. Study Area 4 is south of Pioneer Canyon, 55 nmi from the Golden Gate, and between two former explosives disposal areas. Study Area 5 is south of the Cordell Bank National Marine Sanctuary (CBNMS), adjacent to the western side of the GOFNMS, and approximately 50 nmi from the Golden Gate. This study area contains low-level radioactive waste and chemical munitions. Study areas were selected through a screening process which considered proximity to marine sanctuaries and designated areas of special biological significance, vessel traffic lanes, submarine operating areas, Pioneer Canyon, areas with significant hard-bottom features, and sites used historically for disposal of chemical munitions, explosive munitions, and low-level radioactive wastes (EPA 1991; see Chapter 2).

Alternative sites within each of Study Areas 3, 4, and 5 were delineated from the results of EPA surveys at Study Areas 3 and 4 (SAIC 1992b,c) and EPA and Navy surveys at Study Area 5 (SAIC 1992a). These results are summarized in Chapter 3. Specific portions of these study areas that are characterized as low-energy, depositional zones containing sediments which are similar in grain size to those within the Bay were selected as alternative sites. These conditions are considered important for minimizing dispersion of dredged material and minimizing the area of potential impacts. The site sizes and positions of the site boundaries were determined by modeling the fate of dredged material based on simulated discharges over a one-year period (see Chapter 4).

No alternative sites are considered for Study Areas 1 or 2. Study Area 1 corresponds to the Channel Bar ODMDS; however, as noted above and discussed in Chapter 2 of this DEIS, Study Area 1 was dropped from further consideration as an alternative for disposal of dredged material from San Francisco Bay. Study Area 2 is located on the continental shelf, in depths shallower than 180 meters (m), and adjoins the boundary of the GOFNMS. This study area also was

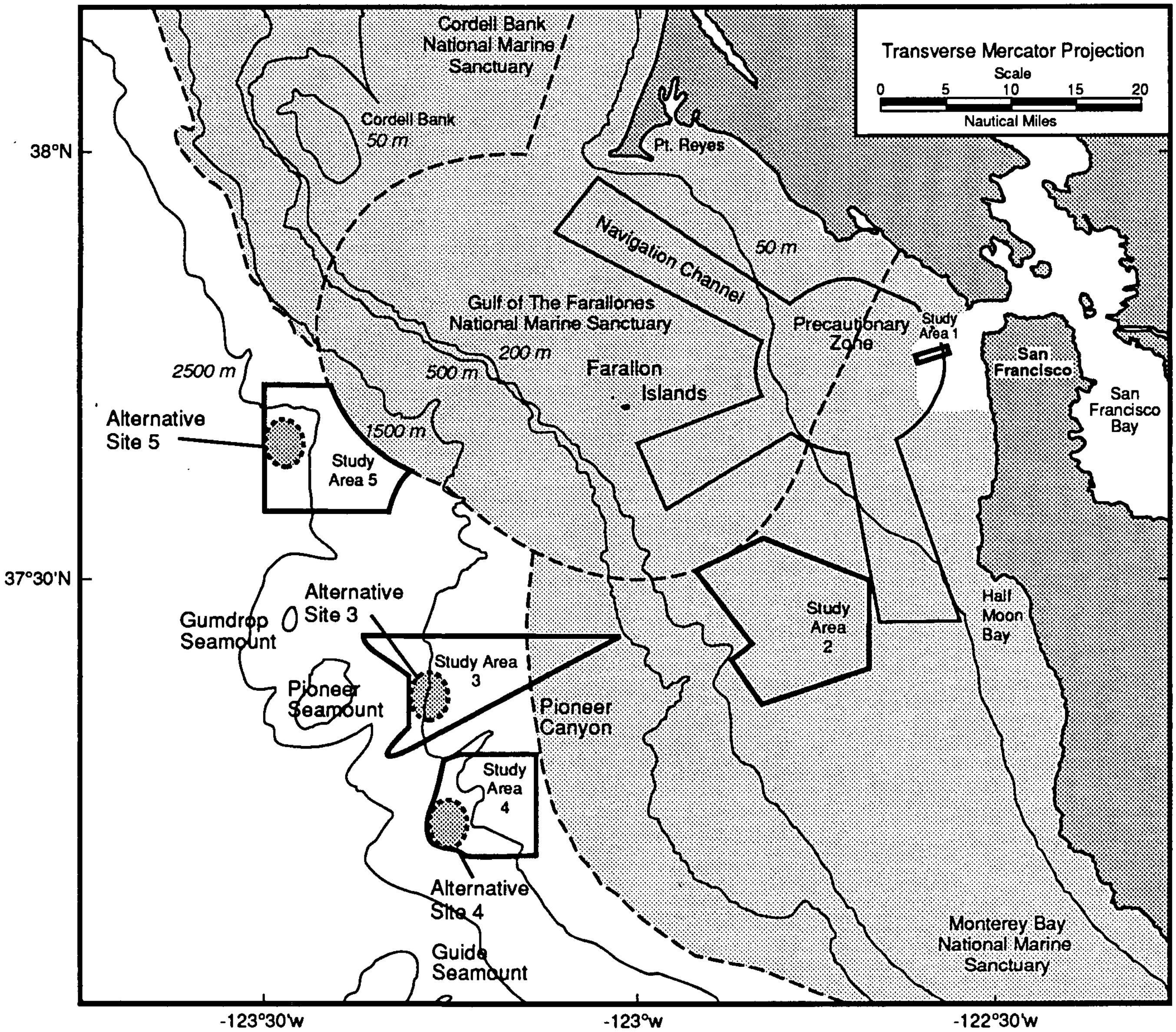

Figure 1.3-1. Locations of Study Areas 1 Through 5 and Alternative Sites 3, 4, and 5 in the LTMS Study Region.

The 50m, 200m, 500m, 1,500m, and 2,500m contours correspond to the 28, 110, 275, 825, and 1,375 fathom contours, respectively.

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dropped from further consideration because it lies within the boundaries of the Monterey Bay National Marine Sanctuary (MBNMS). The Final Rule for MBNMS designation prohibits dredged material disposal at any new ODMDS within the Sanctuary boundaries. Therefore, EPA will not pursue designation of an ODMDS within the MBNMS.

1.4 Areas of Controversy

This section summarizes issues raised during the Public Scoping Meeting, the scoping period, and the LTMS public involvement process (Chapter 5). The general areas of controversy include:

- Proximity of the ODMDS to national marine sanctuaries (NMSs), areas of hard bottom, and Pioneer Canyon;
- Potential interferences with existing and/or future fisheries resources, and to feeding, breeding, and migratory activities of marine birds and mammals;
- Potential impacts to other water column organisms should particles remain suspended;
- Potential problems predicting the area affected by disposal operations; and
- Potential problems monitoring short- and long-term effects from disposal operations at a deep-water disposal site.

An additional area of controversy involves the relationship of the ODMDS to the MBNMS. The continental shelf area from the Gulf of the Farallones to Cambria is encompassed by the MBNMS. This Sanctuary includes all of Study Area 2 and the eastern (shallow) portion of Study Area 3, and precludes the use of these areas as an ODMDS. Furthermore, the 12-mile wide zone contiguous with the seaward boundary of the Sanctuary, as described in EPA site monitoring regulations [40 CFR §228.10(c)(1)(i)], includes Alternative Sites 3, 4, and 5. Although the National Oceanic and Atmospheric Administration (NOAA) will not regulate dredged material within this zone (NOAA 1992), any site selected as an ODMDS may require a more intensive monitoring effort because of its proximity to the Sanctuary resources.

1.5 Issues To Be Resolved

Major issues discussed in the DEIS that will be resolved prior to publication of the Final EIS include location, boundaries, and size of the site to be designated, monitoring objectives, and the areas of controversy identified in Section 1.4.

1.6 Regulatory Framework

An international treaty and several laws, regulations, and orders apply to ocean disposal of dredged material and to the designation of an ODMDS. The relevance of these statutes to the proposed action and to related compliance requirements is described below.

1.6.1 International Treaty

The principal international agreement governing ocean disposal is the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (26 UST 2403: TIAS 8165), also known as the London Dumping Convention (LDC). This agreement became effective on August 30, 1975, after ratification by the participating countries, including the United States. Ocean dumping criteria incorporated into MPRSA have been adapted from the provisions of the LDC. Thus, material considered acceptable for ocean disposal under MPRSA also is acceptable for ocean disposal under the LDC.

1.6.2 Federal Laws and Regulations

1.6.2.1 Marine Protection, Research and Sanctuaries Act of 1972, as amended (33 USC Section 1401 *et seq.*)

The MPRSA regulates the transportation and ultimate disposal of material in the ocean, prohibits ocean disposal of certain wastes without a permit, and prohibits the disposal of certain materials entirely. Prohibited materials include those which contain radiological, chemical, or biological warfare agents, high-level radiological wastes, and industrial waste. MPRSA has jurisdiction over all United States ocean waters in and beyond the territorial sea, vessels flying the U.S. flag, and vessels leaving U.S. ports. The territorial sea is defined as waters three miles seaward of the nearest shoreline. For bays or estuaries, the three-mile territorial sea begins at a baseline drawn across the opening of the water body.

Section 102 of the Act authorizes EPA to promulgate environmental criteria for evaluation of all dumping permit actions, to retain review authority over COE MPRSA 103 permits, and to designate ocean disposal sites for dredged material disposal. EPA's regulations for ocean disposal are published at 40 CFR Parts 220-229. Under the authority of Section 103 of the MPRSA, COE may issue ocean dumping permits for dredged material if EPA concurs with the decision. If EPA does not agree with a COE permit decision, a waiver process under Section 103 allows further action to be taken (Figure 1.1-1). The permitting regulations promulgated by COE, under the MPRSA, appear at 33 CFR Parts 320 to 330 and 335 to 338. Based on an evaluation of compliance with the regulatory criteria of 40 CFR Part 227, both EPA and COE may prohibit or restrict disposal of material that does not meet the criteria. The EPA and COE also may determine that ocean disposal is inappropriate because of ODMDS management restrictions or because options for beneficial use(s) exist. Site management guidance is provided in 40 CFR §228.7-228.11.

1.6.2.2 National Environmental Policy Act of 1969 (42 USC Section 4341 *et seq.*)

The National Environmental Policy Act (NEPA) was established to ensure that the environmental consequences of federal actions were incorporated into Agency decision-making processes. It establishes a process whereby the parties most affected by the impact of a proposed action are identified and their opinions are solicited. The proposed action and several alternatives are evaluated in relation to their environmental impacts, and a tentative selection of the most appropriate alternative is made. A DEIS is developed which presents sufficient information to evaluate the suitability of the proposed and alternative actions. A Notice of Availability, announcing that the DEIS can be obtained for comment, is published in the *Federal Register*. After the DEIS comment period, the comments are addressed, revisions are made to the DEIS, and the document is published as a Final EIS. A proposed rule is published with the FEIS. For ODMDS designations, publication of a Final Rule in the *Federal Register* is equivalent to a NEPA Record of Decision.

The Council on Environmental Quality (CEQ) has published regulations at 40 CFR Parts 1500 to 1508 for implementing NEPA. EPA NEPA regulations are published at 40 CFR Part 6. The COE regulations for implementing NEPA are published at 33 CFR Part 220.

1.6.2.3 Clean Water Act of 1972 (33 USC Section 1251 *et seq.*)

The Clean Water Act (CWA) was passed to restore and maintain the chemical, physical, and biological integrity of the Nation's waters. Specific sections of the Act control the discharge of pollutants and wastes into aquatic and marine environments.

The major section of the CWA that applies to dredging activities is Section 401 which requires certification that the permitted project complies with State Water Quality Standards for actions within State waters. Under Section 301, states must establish Water Quality Standards for waters in the territorial sea. Dredging or disposal of dredged material may not cause the concentrations of chemicals in the water column to exceed State standards. To receive State certification, a permit applicant must demonstrate that these standards will not be exceeded.

1.6.2.4 Clean Air Act as Amended (42 USC Section 1451 *et seq.*)

The Clean Air Act is intended to protect the Nation's air quality by regulating emissions of air pollutants. The Act is applicable to permits and planning procedures related to dredged material disposal within the territorial sea. It is not applicable to the proposed designation of an ODMDS.

1.6.2.5 Fish and Wildlife Coordination Act of 1958 (16 USC Section 661 *et seq.*)

The Fish and Wildlife Coordination Act requires that water resource development programs consider wildlife conservation. Whenever any body of water is proposed or authorized to be impounded, diverted, or otherwise controlled or modified, the U.S. Fish and Wildlife Service (FWS) and the State agency responsible for fish and wildlife must be consulted. Section 662(b) of the Act requires federal agencies to consider recommendations based on the FWS investigations. The recommendations may address wildlife conservation and development, any damage to wildlife attributable to the project, and measures proposed for mitigating or compensating for these damages. The Act is applicable to the evaluation of MPRSA Section 103 permits and other water resource development projects.

1.6.2.6 Coastal Zone Management Act of 1972 (16 USC Section 1456 *et seq.*)

Under the Coastal Zone Management Act (CZMA), any federal agency conducting or supporting activities directly affecting the coastal zone must proceed in a manner consistent with approved State coastal zone management programs, to the maximum extent practicable. If a proposed activity affects water use in the coastal zone (i.e., the territorial sea and inland), the applicant may need to demonstrate compliance with a state's approved CZMA program.

The Coastal Zone Reauthorization Amendments of 1990 (Section 6208) state that any federal activity, regardless of its location, is subject to the CZMA requirement for consistency if it will affect any natural resources, land uses, or water uses in the coastal zone. No federal agency activities are categorically exempt from this requirement. As part of the designation process, EPA will prepare a coastal consistency determination and will seek approval from the California Coastal Commission (CCC). The CCC will continue to review permit applications for dredging projects and federal determinations of consistency for federal dredging projects, including the transport of dredged material through the coastal zone, for consistency with the California Coastal Zone Management Plan (CZMP).

1.6.2.7 Endangered Species Act of 1973 (16 USC Section 1531 *et seq.*)

The Endangered Species Act protects threatened and endangered species by prohibiting federal actions which would jeopardize the continued existence of such species or which would result in the destruction or adverse modification of any critical habitat of such species. Section 7 of the Act requires that consultation regarding protection of such species be conducted with the FWS and/or the National Marine Fisheries Service (NMFS) prior to project implementation. During the site designation process, the FWS and the NMFS evaluate potential impacts of ocean disposal on threatened or endangered species. Their findings are contained in letters which provide a certification that endangered and threatened species will not be affected. Copies of letters initiating the consultation process with these agencies are included in Chapter 5.

1.6.2.8 National Historic Preservation Act of 1966 (16 USC Parts 470 *et seq.*)

The purpose of the National Historic Preservation Act is to preserve and protect historic and pre-historic resources that may be damaged, destroyed, or made less available by a project. Under this Act, federal agencies are required to identify cultural or historical resources that may be affected by a project and to coordinate project activities with the State Historic Preservation Officer (SHPO). EPA is coordinating the proposed activity with the SHPO (see Chapter 5).

1.6.3 Executive Orders

1.6.3.1 Executive Order 11593, Protection and Enhancement of the Cultural Environment (36 FR 8921, May 15, 1971)

This executive order requires federal agencies to direct their policies, plans, and programs so that federally-owned sites, structures, and objects of historical, architectural, or archaeological significance are preserved, restored, and maintained for the inspiration and benefit of the public. Compliance with this order is coordinated with the SHPO.

1.6.3.2 Executive Order 12372, Intergovernmental Review of Major Federal Programs (47 FR 3059, July 16, 1982)

This order requires federal agencies to consult with elected officials of state and local governments that may be affected directly by a proposed federal development. In providing for this consultation, existing state procedures must be accommodated to the maximum extent practicable. For this EIS, the EPA, through the LTMS program, has consulted with the Resources Agency of California, the California Environmental Protection Agency, and the appropriate state agencies, boards, and departments of the proposed action (see Chapter 5).

1.6.4 State of California

1.6.4.1 California Coastal Act of 1976, Public Resources Code Section 3000 *et seq.*

This Act establishes the CZMP, which has been approved by the U.S. Department of Commerce. All federal actions which affect the coastal zone must be determined to be as consistent as practicable with this plan (see CZMA above).

1.6.4.2 California Environmental Quality Act, June 1986 Public Resources Code Parts 21000-21177

The California Environmental Quality Act (CEQA) establishes requirements similar to those of NEPA for consideration of environmental impacts and alternatives, and for preparation of an Environmental Impact Report (EIR) prior to implementation of applicable projects. However, this proposed action is a federal action involving site designation outside state boundaries and, therefore, does not fall under the purview of CEQA.

1.7 Relationship to Previous NEPA Actions or Other Facilities That May Be Affected by Designation of the Disposal Site

Several NEPA actions in the project area potentially may be affected by disposal of dredged material at an ODMDS. Because disposal activities would occur over open-ocean water, no facilities or structures would be affected directly. However, resuspension of dredged material or disposal plumes from an ODMDS must be considered in terms of cumulative impacts to the water quality, sediment quality, and the biological environment. These projects are shown in Figure 1.7-1 and described briefly below.

- Channel Bar ODMDS: This site is designated for disposal of material from maintenance dredging of the San Francisco main ship channel [40 CFR section 228.12(b)(22)]. The site is 5.6 kilometers (km) from shore, adjacent to the ship channel.

- San Francisco Southwest Ocean Outfall Project (SWOOP): The outfall is located 10.2 km from shore off San Francisco at a depth of 23 m (37°42.267'N, 122°34.65'W). It is operated by the City and County of San Francisco, and discharges 24 million gallons per day of primary treated sewage effluent and stormwater runoff.

- City of Pacifica Outfall: The outfall is located 0.8 km from shore off Pacifica (37°37.917'N, 122°30.500'W) at a depth of 10 m. It discharges 3.2 million gallons per day of secondary treated sewage effluent.

- Northern San Mateo County Outfall: The outfall is located 0.8 km from shore off northern San Mateo County (37°42.800'N, 122°30.833'W) at a depth of 10 m. It discharges 8 million gallons per day of secondary treated sewage effluent.

The Channel Bar ODMDS and three ocean outfalls are at least 45-55 nmi from the alternative sites. Because of this large distance, these activities will not be affected directly by the designation of an ODMDS at any of the alternative sites (see Section 4.4.1.3, Water Quality Modeling). The Channel Bar Site, designated to receive dredged material from the entrance channel to San Francisco Bay, does not receive any dredged material from other parts of the Bay.

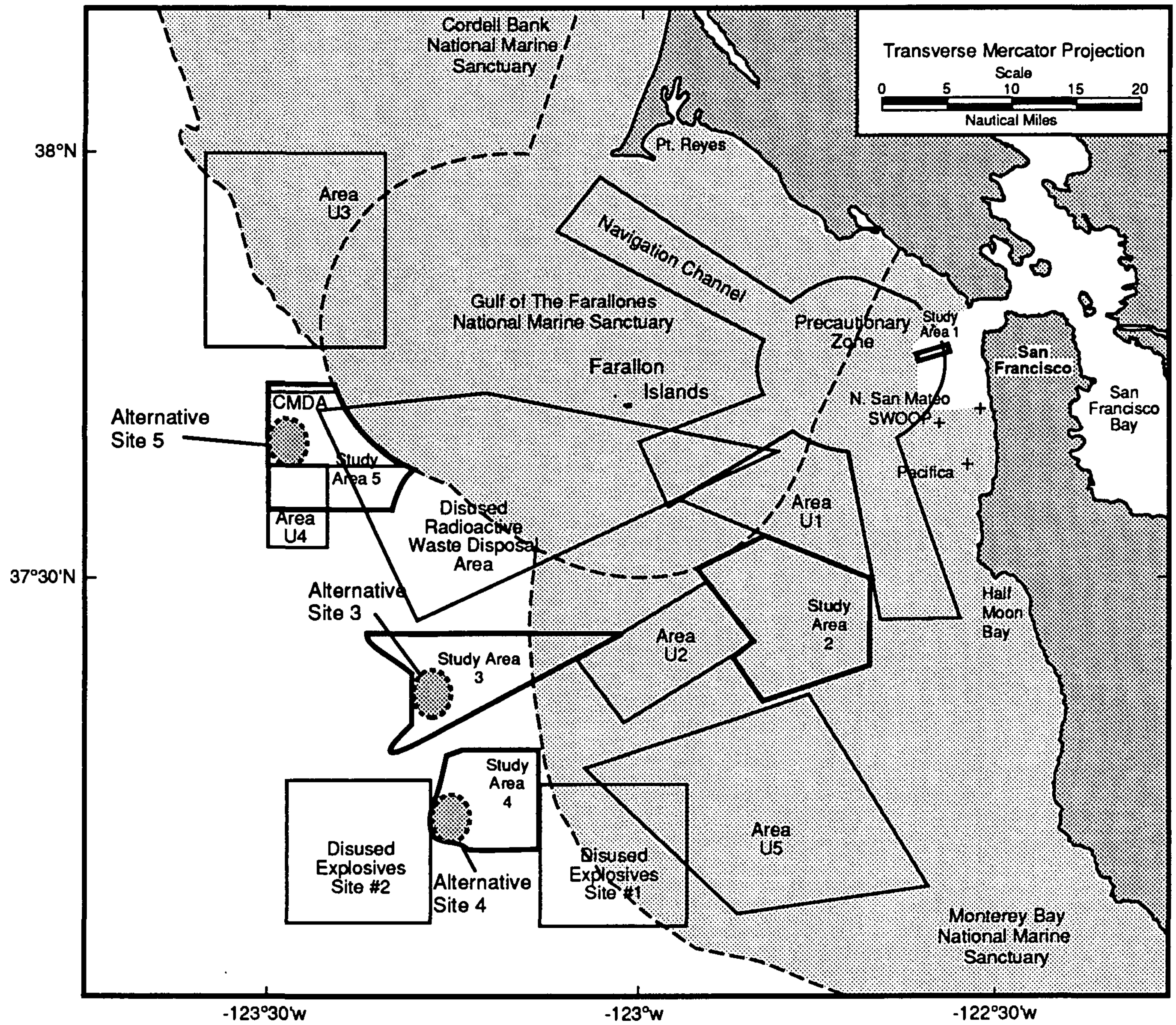

Figure 1.7-1. **Locations of Existing ODMDSs, Ocean Outfalls, National Marine Sanctuaries, Submarine Operating Areas, Vessel Traffic Lanes, and Historical Waste Disposal Sites in the LTMS Study Region.**

Thus, disposal volumes and activities at the Channel Bar ODMDS are independent of the amount of material that might be discharged at an offshore ODMDS.

Three national marine sanctuaries (GOFNMS, CBNMS, and MBNMS) have been designated in the region. The GOFNMS was designated in 1981 (46 FR 7936; January 26, 1981). The boundaries of the GOFNMS extend from Bodega Rock to Rocky Point (near Bolinas) and 19 km beyond the Farallon Islands. GOFNMS regulations prohibit dredged material disposal within the Sanctuary boundaries. The CBNMS was designated in 1990 (55 FR 4994; December 4, 1990) and is located adjacent to and north of the GOFNMS boundary. CBNMS regulations also prohibit dredged material disposal within the Sanctuary boundaries, as well as discharges outside the boundary which could enter the Sanctuary and injure a Sanctuary resource (NOAA 1989). The MBNMS includes areas of the continental shelf from the Gulf of the Farallones to Cambria. The Final EIS for sanctuary designation states that dredged material disposal at a new ODMDS within the MBNMS boundaries is prohibited (NOAA 1992). The Final Rule for designation of the MBNMS was published on September 18, 1992.

Project-specific, dredged material disposal operations are proposed by the Navy under Section 103 of MPRSA within a portion of the historical chemical munitions dumping area (CMDA) that also corresponds to Alternative Site 5 in this DEIS. A Final EIS (Navy 1990) and Supplemental EIS (Navy 1992) have been prepared for this proposed action. The Final Supplemental EIS presently is being prepared by the Navy.

A number of other areas delineated in the study region correspond to submarine operating areas, vessel traffic lanes, and historical waste disposal sites (Figure 1.7-1). These areas are not previous NEPA actions or facilities. However, they are legitimate uses of the ocean that may be affected by ODMDS designation (see Chapter 2). Continued use of these areas or, in the case of historical waste disposal sites, cumulative environmental impacts associated with these areas could be affected by the designation of an ODMDS. Potential impacts from ODMDS designation, including cumulative impacts with other disposal operations, are discussed in detail in Chapter 4 (Environmental Consequences).

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CHAPTER 2
ALTERNATIVES INCLUDING THE PROPOSED ACTION

This chapter discusses five general alternatives for the disposal of dredged material from San Francisco Bay and compares three alternative ocean dredged material disposal sites (ODMDS). Each of the alternative ocean disposal sites is evaluated on the basis of the five general and eleven specific site-selection criteria listed at 40 CFR sections 228.5 and 228.6(a), respectively (Table 1.1-1). Disposal alternatives are described in Section 2.1 and evaluated in Section 2.2.

2.1 Description of Alternatives

Five general alternatives for the disposal of dredged material from San Francisco Bay are available: (1) No-Action; (2) ocean disposal; (3) disposal within the Bay; (4) nonaquatic (i.e., land-based) disposal; and (5) reuse or treatment options, such as landfill cover, beach nourishment, or marsh restoration.

These alternatives are being evaluated as part of the Long-Term Management Strategy (LTMS), an interagency effort led by a State/Federal partnership consisting of the Environmental Protection Agency (EPA), the U.S. Army Corps of Engineers (COE), the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB), and the San Francisco Bay Conservation and Development Commission (BCDC). It is the intent of the LTMS to provide an array of disposal options—including ocean, within the Bay, and nonaquatic sites—to accommodate the volumes and composition of material proposed for dredging over the 50-year planning period (COE 1992a). The LTMS also will develop general guidelines for evaluating the use of individual disposal options for specific projects, as well as promote utilization of dredged material for beneficial uses such as wetlands creation and levee maintenance (COE 1992a). These options are being developed by the LTMS Ocean Studies Work Group, In-Bay Work

Group, Nonaquatic/Reuse Work Group, and the Implementation Work Group. Overall management and policy guidance of these groups is provided by an Executive Committee with LTMS coordination and technical direction delegated to a Management Committee (Section 5.2).

Because other options will be evaluated by ongoing LTMS efforts concerning disposal within the Bay, nonaquatic/reuse sites, and implementation, this Environmental Impact Statement (EIS) evaluates only the ocean disposal and No-Action alternatives. Evaluations of non-ocean disposal options are scheduled for completion in 1994.

The process of designating an ODMDS begins by establishing the need for an ocean disposal site. Designation of an ODMDS would not preclude the use of other disposal options or beneficial uses of dredged material. Land-based disposal evaluations are required under 40 CFR sections 227.14 to 227.16 in EPA's Ocean Dumping Criteria for all Marine Protection, Research and Sanctuaries Act (MPRSA) Section 103 permits. These evaluations are considered by the COE and EPA as part of the review of individual applications for use of an ODMDS. If disposal within the Bay or at a nonaquatic/reuse site is feasible, a decision whether an ODMDS is the best disposal option will be made during the National Environmental Policy Act (NEPA) and permit review process according to the existing regulations and other guidelines developed by the LTMS.

2.1.1 No-Action Alternative

The LTMS mission is to develop long-term options that include an array of potential ocean, within the Bay, and nonaquatic disposal sites to accommodate the dredged material volumes and composition projected for the 50-year planning period (COE 1992a). The No-Action Alternative would preclude ocean disposal except under an MPRSA Section 103 permit. Use of an MPRSA Section 103 interim ODMDS is project-dependent and does not provide a long-term management option. Therefore, the No-Action Alternative would not fulfill the LTMS goal of providing a long-term, multi-user ODMDS. In addition, in the absence of a designated ODMDS, or Section

103 interim ODMDS, other disposal options would be required for dredged material, or planned dredging programs would have to be delayed until a suitable disposal option is identified.

2.1.2 Ocean Disposal Alternatives

The process of identifying potential alternative ocean disposal sites involves several steps (EPA 1986). Once the need for an ocean site has been established, the next step typically is to define a zone of siting feasibility (ZSF) which establishes a broad potential area for locating an ODMDS. The geographic boundary of the ZSF is determined by evaluating operational and economic considerations and jurisdictional limitations. Within the ZSF, historically used disposal sites and sensitive and incompatible use areas then are identified from existing information sources (EPA/COE 1984). Sensitive areas may include marine sanctuaries, breeding, spawning, nursery, feeding, or passage areas of living resources, and significant natural or cultural features of historical importance. Incompatible use areas may include shipping lanes, mineral extraction sites, or geographically limited fisheries or shellfisheries (EPA 1986a). After sensitive or incompatible use areas have been delineated, the remaining portions of the ZSF then may be considered as candidate areas for siting an ODMDS. Candidate sites are evaluated further based on site-specific information, plus other considerations such as disposal management requirements (EPA/COE 1984). Additionally, the Ocean Dumping Regulations (40 CFR 228.5) require that "EPA will, wherever feasible, designate ocean dumping sites beyond the edge of the continental shelf and other such sites that have been historically used."

Potential alternative ocean disposal sites within the LTMS study region were identified from an initial screening process that considered the following: (1) marine sanctuary boundaries; (2) navigation lanes; (3) submarine operating areas; (4) areas of hard bottom; and (5) Pioneer Canyon. Study Areas 1, 2, 3, 4, and 5 were delineated by EPA and members of the LTMS Management Committee as potential alternative ocean disposal sites that represented a range of depths and distance from shore and that avoided previously identified incompatible use areas (EPA 1991).

EPA prepared an Ocean Studies Plan (OSP; EPA 1991) that summarized existing information on the environmental conditions of the LTMS study region. The OSP also described methodologies for obtaining additional information and for conducting studies at Study Areas 2, 3, 4, and 5, and Pioneer Canyon, that were needed to support the site designation process. Although the background information available prior to these surveys suggested that areas such as Pioneer Canyon and shelf locations in the vicinity of Study Area 2 might contain potentially unique or sensitive features or resources which should be avoided for ODMDS designation, the OSP included sampling at these locations to fill specific data gaps and document the areas' characteristics for the EIS. EPA-sponsored surveys of Study Areas 2, 3, and 4 and Pioneer Canyon subsequently were conducted from 1990 to 1992. Study Area 5 was surveyed by EPA from 1990 to 1992 and by the Navy in 1990 and 1991. Results from these surveys (summarized in Chapter 3) were used to evaluate further the individual LTMS study areas, and eventually to select the three alternative sites addressed in this EIS.

Coincidental with the development of the OSP, the COE (1991) prepared a draft final ZSF report that "...delineate[s] the outer geographical boundaries of operational and economic acceptability within which further environmental, regulatory and socio-economic analysis is performed to achieve a site designation." Based on analyses of the benefit-to-cost ratios of ten representative dredging projects in San Francisco Bay, the COE recommended that the ZSF encompass an area within 53 nmi (100 km) from the Golden Gate Bridge. The ZSF (Figure 2.1-1) includes areas beyond the edge of the continental shelf, all of which would be accessible using existing technology and equipment (COE 1991). All of the LTMS study areas are within the region defined by the ZSF.

The following sections discuss historically used ODMDSs and the sensitive and incompatible use areas within which dredged material disposal operations would interfere with other activities, uses, or resources within the LTMS study region. These uses and their geographical locations are described below and summarized in Figures 2.1-1 through 2.1-4.

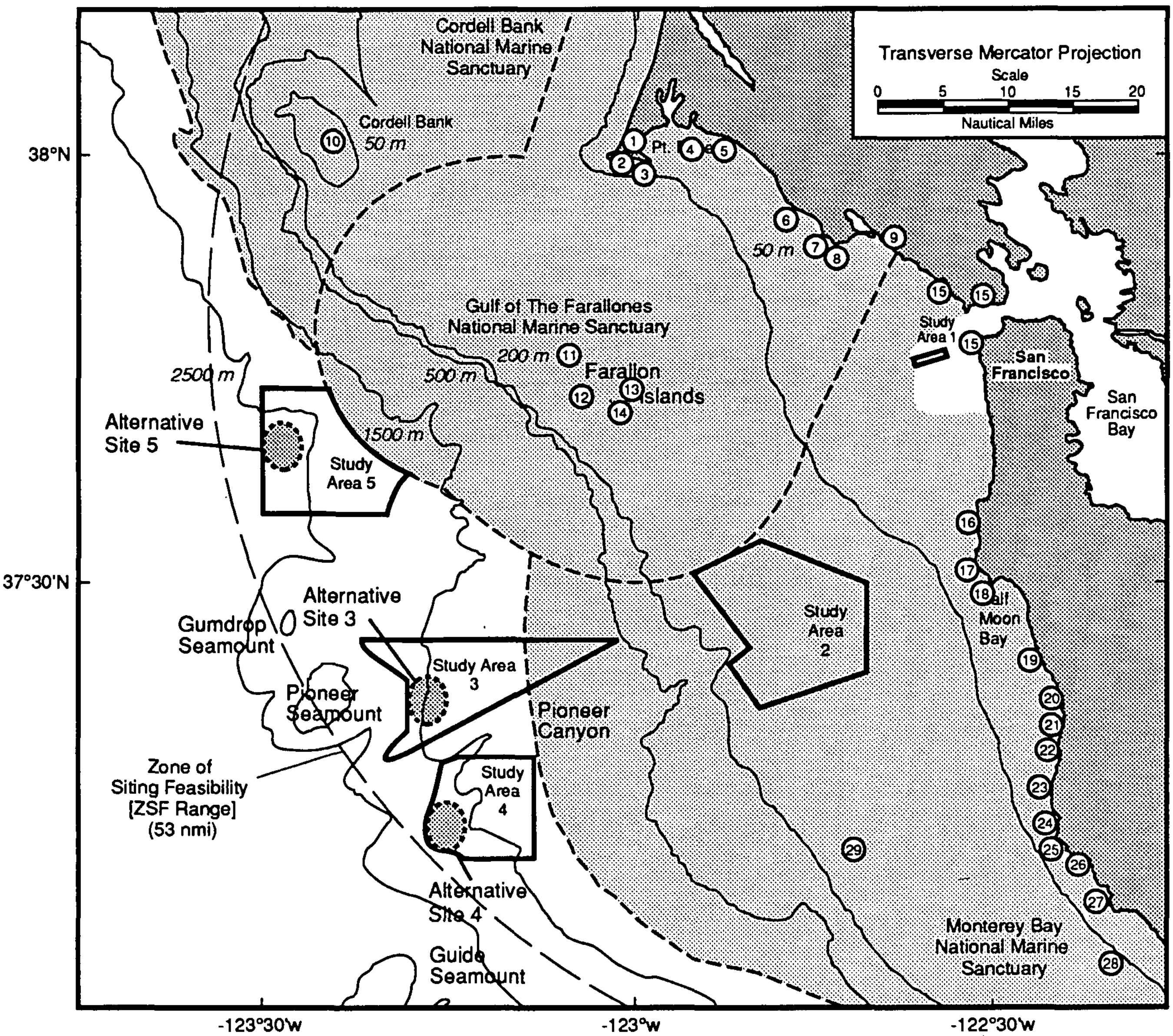

Figure 2.1-1. **Locations of National Marine Sanctuaries, Areas of Special Biological Significance, Reserves, and Features of Potential Scientific Importance in the LTMS Study Region.**

See Table 2.1-1 for a legend to the numbered circles.

The 50m, 200m, 500m, 1,500m, and 2,500m contours correspond to the 28, 110, 275, 825, and 1,375 fathom contours, respectively.

Table 2.1-1. Areas of Special Biological Significance (ASBSs), Reserves, National Marine Sanctuaries (NMS), and Features of Potential Scientific Significance Shown in Figure 2.1-1.

1.	Point Reyes National Seashore	15.	Golden Gate National Recreation Area
2.	Point Reyes Headlands Reserve	16.	Montara State Beach
3.	Point Reyes Headlands Reserve and ASBS	17.	James Fitzgerald Marine Reserve and ASBS
4.	Drakes Estero	18.	Pillar Point, Half Moon Bay
5.	Estero de Limantour Reserve	19.	Purisima Creek
6.	Double Point ASBS	20.	Lobitos Creek, Tunitas Creek
7.	Duxbury Reef Reserve	21.	San Gregorio State Beach
8.	Duxbury Reef Reserve and Extension ASBS	22.	Pomponio State Beach
9.	Bolinas Lagoon	23.	Pescadero Marsh
10.	Cordell Bank NMS	24.	Pescadero Point
11.	Gulf of the Farallones NMS	25.	Bean Hollow State Beach
12.	Farallon Islands Game Refuge	26.	Pigeon Point
13.	Farallon National Wildlife Refuge	27.	Franklin Point
14.	Farallon Islands ASBS	28.	Año Nuevo State Reserve
		29.	Monterey Bay NMS

Source: KLI 1991.

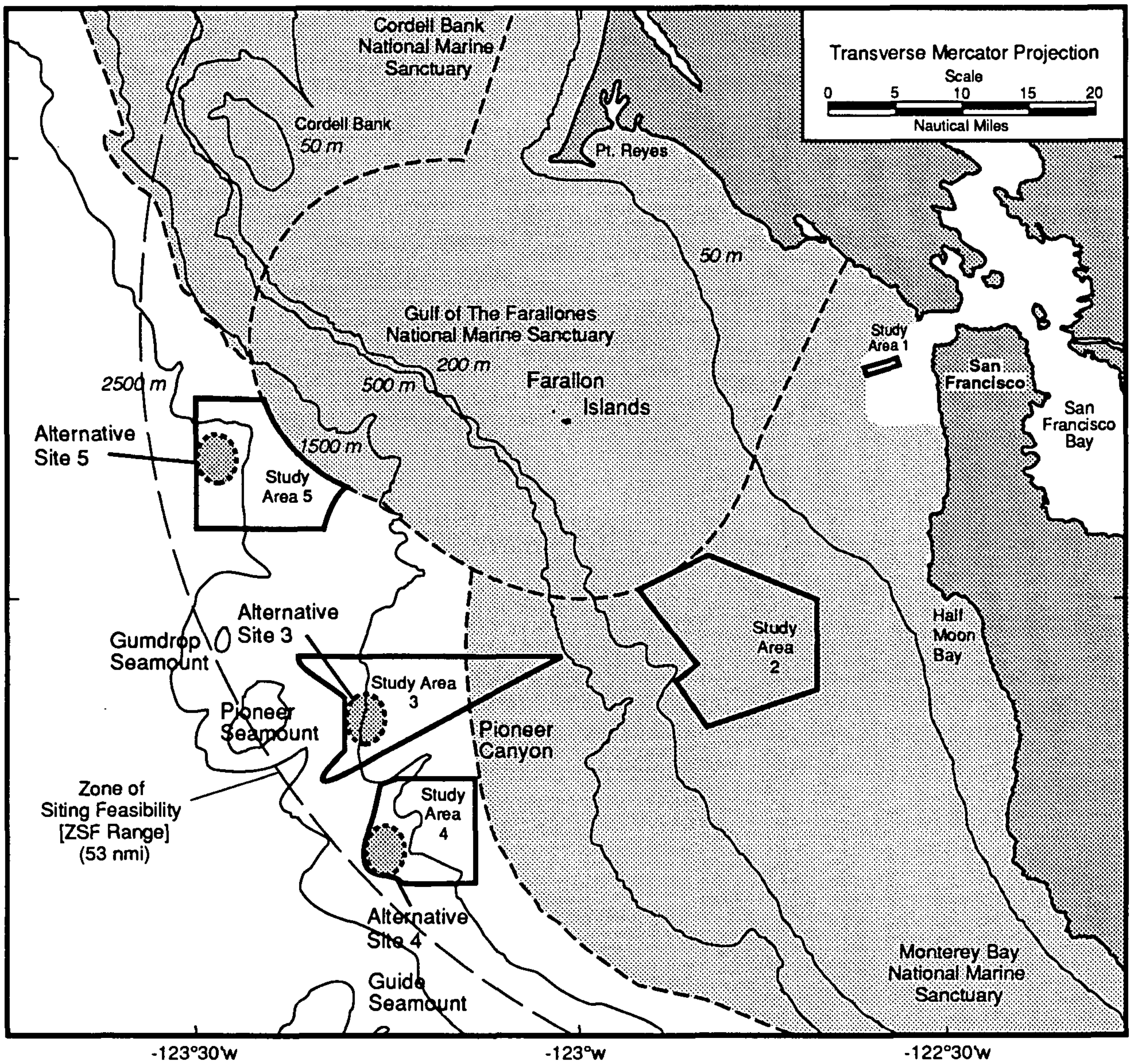

Figure 2.1-2. Location of Physiographic Features in the LTMS Study Region.

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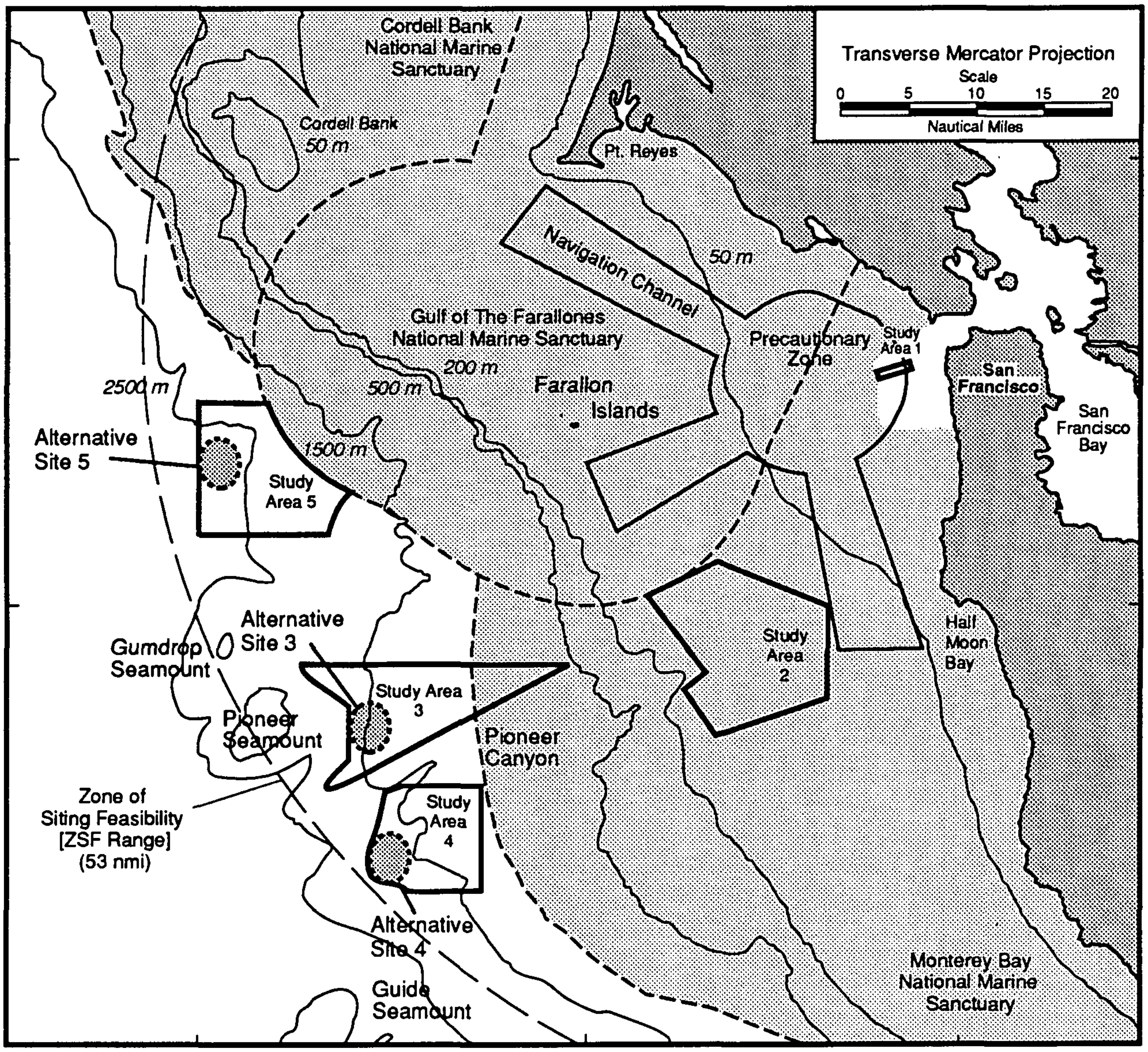

Figure 2.1-3. **Location of Navigation Channels and Precautionary Zones in the LTMS Study Region.**

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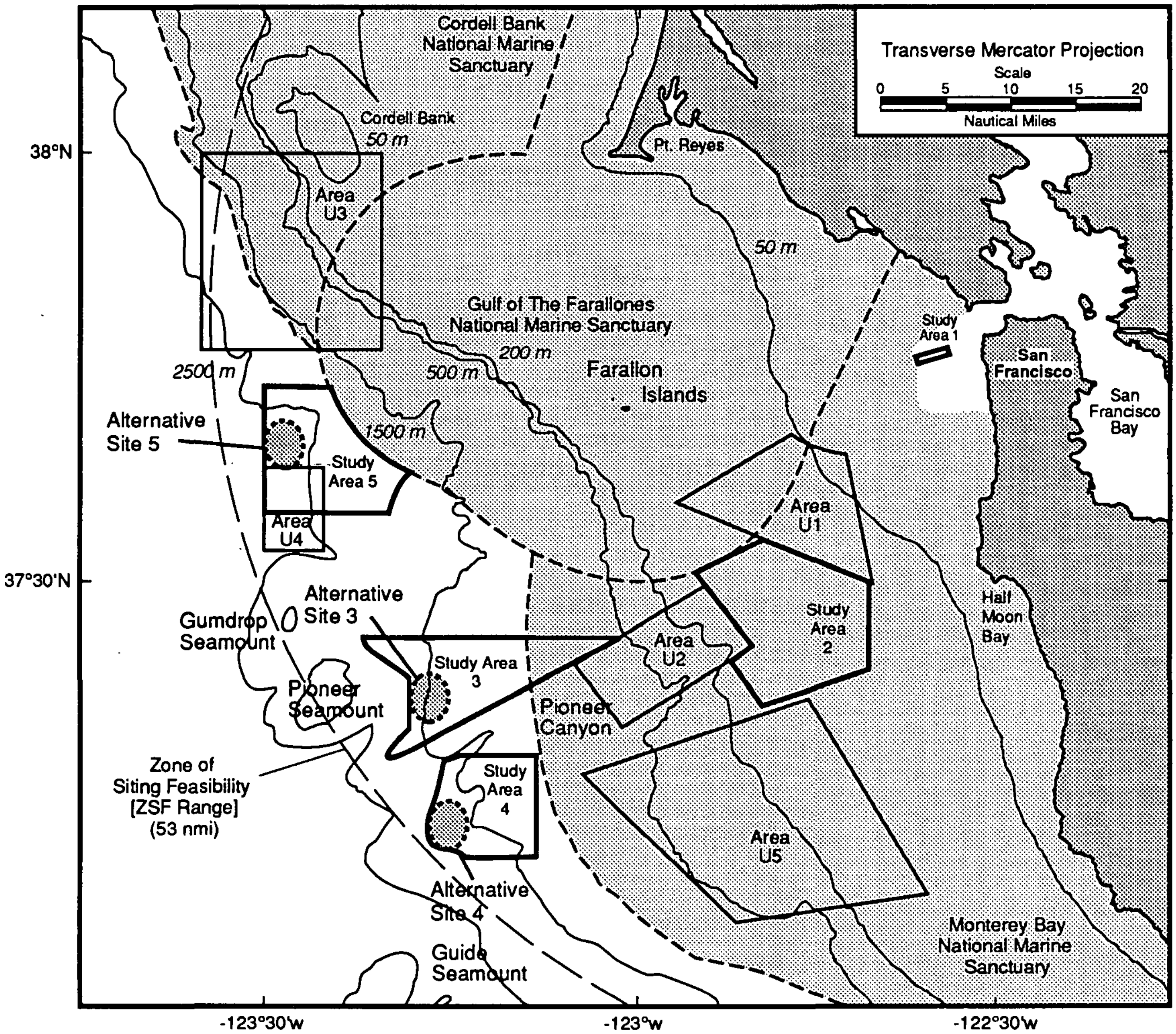

Figure 2.1-4. Location of Submarine Operating Areas in the LTMS Study Region.

2.1.2.1 Historically Used ODMDSs

The Channel Bar Site (corresponding to LTMS Study Area 1) is the only historically used ODMDS presently designated for disposal of dredged material (see Section 3.1.1, Historical Use of the Study Region). This site received final designation (50 CFR 38524; September 23, 1985), but can be used only for disposal of sandy sediments dredged from the entrance channel to San Francisco Bay. The Farallon Island or 100-Fathom site was given interim designation by EPA in 1977. However, this site is now within the Gulf of the Farallones National Marine Sanctuary (GOFNMS), which was established in 1981 (46 CFR 7936; January 26,1981), and disposal of dredged material inside the Sanctuary boundary is prohibited except where necessitated by national defense or in response to an emergency (15 CFR 936.6). Consequently, the interim designation of the 100-Fathom site was canceled in 1983 (48 CFR 5557; February 7, 1983). This site has not been used for dredged material disposal since 1978.

Disposal of dredged material from San Francisco Bay has not occurred routinely at any other ocean site, except for the limited or experimental use of three sites that have not been designated for further use (Section 3.1.1): the COE experimental 100-fathom site, the Bay Area Rapid Transit (BART) site, and Site B1B (Chapter 3, Figure 3.1-1). These sites could be considered historical sites because they have been used previously for dredged material disposal. However, the COE experimental 100-fathom site is eliminated from further consideration because it is within the GOFNMS. The BART site is located in close proximity to the Golden Gate, nearshore resources, and the Monterey Bay National Marine Sanctuary (MBNMS), and was eliminated from further consideration for these reasons. Site B1B is located within the boundaries of the MBNMS, and has also been eliminated from consideration as an ODMDS.

The Navy presently is seeking a project-specific (MPRSA Section 103) permit for disposal of 1.6 million yd^3 of dredged material at the proposed Navy Ocean Disposal Site (NODS) located within the former chemical munitions dumping area (CMDA). This site coincides with LTMS Alternative Site 5. The COE, with EPA concurrence, will decide whether to designate the site after outstanding issues regarding site management and monitoring and dredged material suitability have been resolved. Therefore, depending on the timing and outcome of this process, the site may or may not be a historically used ocean disposal site at the time of the MPRSA Section 102 site designation.

2.1.2.2 Sensitive Areas

EPA's ocean site selection criteria [40 CFR section 228.5(b)] require that impacts to sensitive areas such as sanctuaries, restricted habitats, and areas with high resource values be avoided. Sensitive areas in the LTMS study region are discussed below.

The ocean adjacent to San Francisco Bay contains several marine sanctuaries, areas of special biological significance (ASBSs), ecological preserves, and other areas of special scientific importance (Figure 2.1-1 and Table 2.1-1). The GOFNMS boundaries extend from Bodega Rock to Rocky Point (Bolinas) and approximately 19 km seaward of the Farallon Islands. Cordell Bank, located north of the GOFNMS and 30 km west of Point Reyes peninsula, became a designated national marine sanctuary in 1990 (55 CFR 4994; December 4, 1990). Routine disposal of dredged material within the boundaries of either sanctuary is prohibited. Therefore, the areas within these sanctuary boundaries are eliminated from further consideration as an ODMDS.

A large area of the California coast from Marin County to Cambria (4,024 nmi^2) has been designated as the MBNMS. The Final EIS for sanctuary designation (NOAA 1992) states that sanctuary regulations will prohibit disposal of dredged material within the boundary, except at ODMDS(s) existing on the effective date of designation. Following the EIS public comment period, the National Oceanic and Atmospheric Administration (NOAA) published a Notice of National Marine Sanctuary Designation and Final Rule in the *Federal Register* on September 18, 1992 (57 FR 43310). On November 3, 1992, President Bush signed a bill sponsored by Congressman Leon Panetta authorizing a bypass of Congressional review of the MBNMS designation and regulations. Therefore, the MBNMS regulations will become effective 30 days after NOAA publishes a *Federal Register* notice of the bypass action. NOAA anticipates this will occur prior to January 1, 1993. Because the Final Rule will prohibit dredged material disposal within the MBNMS boundaries, EPA will not designate an ODMDS within the sanctuary. EPA regulations [40 CFR section 228.10(c)(1)(i)] also describe a 12-mile zone around sanctuaries in reference to monitoring of disposal sites. However, EPA and NOAA agree that designation of an ODMDS within this zone is not precluded by EPA or sanctuary regulations, or by MPRSA (W. Reilly, EPA, letter to Gov. Pete Wilson dated June 22, 1992).

Several ASBSs occur along the coast between the Point Reyes National Seashore and Año Nuevo Point, within the GOFNMS and the MBNMS (Figure 2.1-1). These locations represent breeding, nursery, haul-out, and feeding areas for marine mammals; over-wintering, breeding, roosting, and migratory passage areas for birds; or geographically limited habitat for large numbers of plant and animal species, including several threatened and endangered species. The need to protect these ASBSs is, in part, justification for including these regions in the GOFNMS, the CBNMS, and the MBNMS. Further, the nearshore zone adjacent to this portion of the coast would not be appropriate for further considerations of ODMDS siting because of potential shoreward transport of dredged material and degradation of water quality at the shoreline.

The presence of several hard-bottom features, submarine canyons, or seamounts has been identified in locations off the continental shelf (e.g., Nybakken *et al.* 1984; Towill, Inc. 1986; Parr *et al.* 1988; SAIC 1992b). Significant hard-bottom features are located at depths of approximately 900 m near the GOFNMS boundary, on and adjacent to Pioneer Seamount, and scattered within Pioneer Canyon south of the GOFNMS (Karl 1992). Sparse hard-bottom habitats also were noted within portions of LTMS Study Areas 3 and 4 (SAIC 1992b) and Study Area 5 (SAIC 1992a). Other areas with potential hard-bottom features are associated with Gumdrop and Guide Seamounts located to the north and far south of Pioneer Seamount, respectively (Figure 2.1-2). Previous studies conducted in submarine canyons off southern California and within Monterey Canyon revealed the presence of rich or unique biological communities (e.g., Hartman 1963; Embley *et al.* 1990). Therefore, significant hard-bottom features, submarine canyons, and seamounts off San Francisco may represent unique biological habitats or areas of scientific importance. In addition, the difficulty of predicting dredged material dispersion in the vicinity of seamounts and canyons also makes these areas unlikely to be suitable for an ODMDS. Nevertheless, because the information previously available for characterizing and evaluating the potential sensitivities of these features or habitats was sparse, EPA conducted surveys within Pioneer Canyon (SAIC 1992b,c) to complete the regional characterization.

Information on potentially sensitive areas within the study region was obtained during studies sponsored by the COE (Nybakken *et al.* 1984; Towill, Inc. 1986; Stevenson and Parr 1987; Parr *et al.* 1988) to evaluate potential ocean disposal sites, the majority of which were located on the continental shelf (Figure 2.1-5 and Table 2.1-2). These studies were intended to characterize the physical features (e.g., bathymetry and sediment grain size) and biological habitat (benthic infauna and demersal fishes). Based on the study results, Stations 1 and 2 and Site B4 were considered inappropriate locations for an ODMDS due to the presence of hard-bottom features or rich biological assemblages and fisheries resources (Table 2.1-2). The remaining sites were ranked by Parr *et al.* (1988) for potential disposal site suitability based on the density and diversity of the infaunal and demersal fish assemblages and abundances of Dungeness crabs. Sites B2, B5, and D1 appeared to be used by sensitive life stages of Dungeness crabs, and Site 1M was located in an area of intensive crab fishing. Site B3 was located close to shore and to nearshore kelp beds, as well as being within heavily used vessel traffic areas; this site also contained some hard-bottom habitat. Site B1 was near the GOFNMS boundary, and Site B1A was located near productive rockfishing reefs. Survey data indicated that Site B1B is removed from Dungeness crab and rockfish habitat, and that the site supports low infaunal abundances and diversity. Additionally, historical fish block data for this area suggested that the commercial fish catch was relatively low. Based on this assessment, Site B1B was considered the most suitable of the sites evaluated. This site was selected as the preferred alternative site for disposal of 400,000 yd^3 of dredged material from the Oakland Inner Harbor Deepening Project. However, only 18,000 yd^3 of dredged material was disposed at Site B1B before the project was halted by the State court system.

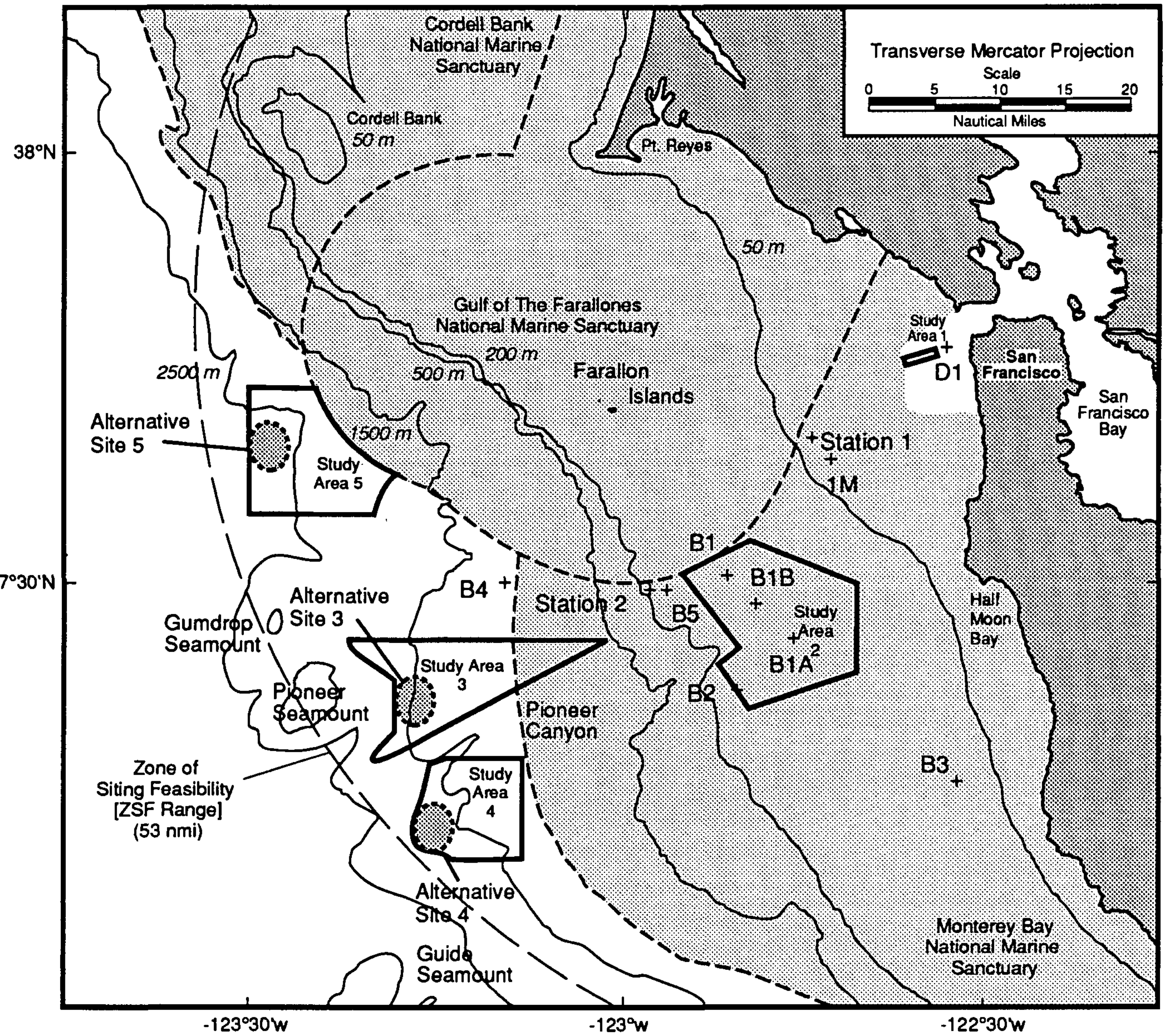

Figure 2.1-5. **Location of the Ocean Disposal Sites Evaluated by the COE in the Vicinity of the Gulf of the Farallones.**
Refer to Table 2.1-2 for site details.

Table 2.1-2. Potential Ocean Disposal Sites Evaluated by the COE, as Shown in Figure 2.1-5.

	Center Coordinates					
Site	Latitude	Longitude	Depth (m)	Sampling Date	Study Conclusions	Reference
Station 1	37°40.00'N	122°44.00'W	50	March/June, 1983	Productive fishery area for lingcod, flatfish, and Dungeness crab; designation considered inappropriate until other alternatives explored.	Nybakken *et al.* 1984
Station 2	37°29.00'N	122°57.00'W	180	March/April, 1983; September, 1983	Highly productive hard-bottom area that supports rockfish and sablefish fishery; designation considered inappropriate until other alternatives explored.	Nybakken *et al.* 1984
B1	37°31.27'N	122°50.18'W	80-90	January-May, 1986; October, 1986; April, 1987	Fish abundances low to high; site may be important nursery habitat for two fish species.	Towill Inc. 1986; Stevenson and Parr 1987; Parr *et al.* 1988
B2	37°22.77'N	122°50.18'W	110-140	January-May, 1986; October, 1986; April, 1987	Supports high numbers of commercially important fish species and Dungeness crab; may be particularly important habitat for brooding crabs.	Towill Inc. 1986; Stevenson and Parr 1987; Parr *et al.* 1988
B3	37°16.10'N	122°31.00'W	60-80	January-May, 1986; October, 1986	Includes some hard-bottom habitat and supports rich fish and benthic assemblages; also, possible interferences with coastal shipping routes.	Towill Inc. 1986; Stevenson and Parr 1987; Parr *et al.* 1988
B4	37°30.00'N	123°08.50'W	900	January-May, 1986	Located in a large submarine canyon; eliminated from further consideration due to high-relief rock outcroppings.	Towill Inc. 1986

Table 2.1-2. Continued.

	Center Coordinates					
Site	Latitude	Longitude	Depth (m)	Sampling Date	Study Conclusions	Reference
B5	37°29.65'N	122°55.20'W	110-140	January-May, October, 1987, April, 1987	Productive rockfish area, possibly due to presence of mixed hard-bottom habitat, and supports sensitive life stages of Dungeness crabs; considered inappropriate for site designation.	Towill Inc. 1986; Stevenson and Parr 1987; Parr *et al.* 1988
B1A	37°27.00'N	122°44.50'W	80-85	April, 1987	Possible hard substrate downcoast from site; moderate to high fish abundances; site used as nursery area by two commercial fish species.	Parr *et al.* 1988
B1B	37°29.00'N	122°48.00'W	84-88	April/May 1988	Low to high fish abundances; minor to moderate use of site as nursery area. Low crab densities and historically low commercial fish catch.	Parr *et al.* 1988
1M	37°38.70'N	122°42.27'W	42-46	April/May, 1988	Medium to high densities of Dungeness crabs; located in area of intensive commercial crab fishery activity.	Parr *et al.* 1988
D1	37°46.83'N	122°32.66'W	18-24	April/May, 1988	Historical BART site - 1 nmi from shore and 0.5 nmi south of Entrance Channel; site contains medium sand-sized sediments considered incompatible with dredged materials. Contains high densities of juvenile crabs.	Parr *et al.* 1988

Sources: Nybakken *et al.* 1984; Stevenson and Parr 1987; Parr *et al.* 1988.

Although results from these studies indicated significant resource values at many of these stations, there remained substantial controversy regarding the scope and methodology of the studies. Therefore, EPA retained some stations from the previous studies in the surveys of LTMS Study Area 2 to better characterize and document the resources in this area.

2.1.2.3 Incompatible Use Areas

As part of ODMDS designation, incompatible use areas such as regions of heavy commercial or recreational navigation should be avoided [40 CFR 228.5(a)]. Within the LTMS study region, incompatible use areas include vessel traffic lanes and submarine operating areas. The effect of incompatible use areas on selection of the LTMS study areas is discussed below.

The U.S. Coast Guard (USCG) established vessel traffic lanes and a precautionary area within the Gulf of the Farallones (Figure 2.1-3) to promote safe navigation of marine traffic to and from ports within San Francisco Bay. The "General Approach to Site Designation Studies for Ocean Dredged Material Disposal Sites" (EPA/COE 1984) lists navigational lanes as incompatible use areas. Therefore, areas corresponding to the traffic lanes and the precautionary zone were eliminated from consideration (Table 1.1-1).

Submarine operating areas U1, U2, U3, U4, and U5 are used by the U.S. Navy for classified submarine operations and post-overhaul seatrials (Figure 2.1-4). Portions of area U3 are within the Cordell Bank National Marine Sanctuary (CBNMS) and the GOFNMS, and the northern boundary of area U4 is contiguous with the southern boundary of the CMDA and Study Area 5. The Navy confirmed that it was acceptable for EPA to conduct studies within some of the submarine operating areas [E. Lukjanowicz (Navy) pers. comm. to S. Clarke (EPA) June 16, 1992], but the Navy also expressed concern that dredged material disposal within areas U1, U2, and U5 could jeopardize submarine operations or result in collisions between disposal barges and submarines or support vessels. Therefore, areas corresponding to submarine operating areas U1, U2, and U5 were eliminated from consideration.

Based on the location of sensitive and incompatible use areas, and comments received at a Scoping Meeting held on April 11, 1989, EPA and members of the LTMS Management Committee selected LTMS Study Areas 1 through 5 (Figure 2.1-1) as potential locations for siting an ODMDS. The LTMS study areas represent appropriate ranges of depths and distances from shore within the ZSF and avoid most of the sensitive and incompatible use areas. Figure 2.1-6 provides a summary overlay of the primary sensitive and incompatible use areas in the LTMS study region. LTMS Study Area 1 corresponds to the Channel Bar ODMDS, which is designated for disposal of sandy material from the entrance channel to San Francisco Bay. The previously used Site B1B is located within LTMS Study Area 2 and the historical CMDA is within LTMS Study Area 5. Ocean disposal alternatives are described further in Section 2.2.

2.1.3 San Francisco Bay and Nonaquatic Disposal and Reuse Alternatives

The feasibility and environmental consequences of using sites within the Bay, nonaquatic sites, and reuse options for disposal of dredged material are being investigated under the LTMS program by the COE, the SFBRWQCB, and the BCDC, with significant input from other LTMS participants (see Chapter 5). Detailed evaluations of these dredged material disposal options are beyond the scope of this EIS. However, the following summarizes the present status of these options.

2.1.3.1 San Francisco Bay Alternatives

Eleven open water (unconfined) disposal sites in the San Francisco Bay region have been used historically for disposal of sediments dredged from within the Bay. Four of these sites—Carquinez Straits (SF-9), San Pablo Bay (SF-10), Suisun Bay, and Alcatraz (SF-11)—presently are used for dredged material disposal (Table 2.1-3). The Carquinez Straits, San Pablo Bay, and Alcatraz disposal sites are used for most Federal and private maintenance dredging projects; the Alcatraz site also has been used for new work projects in the Bay. The Suisun Bay site is used exclusively for material composed of at least 95% sand dredged from the adjacent Suisun Bay Channel. The sites are located in high current energy areas to promote

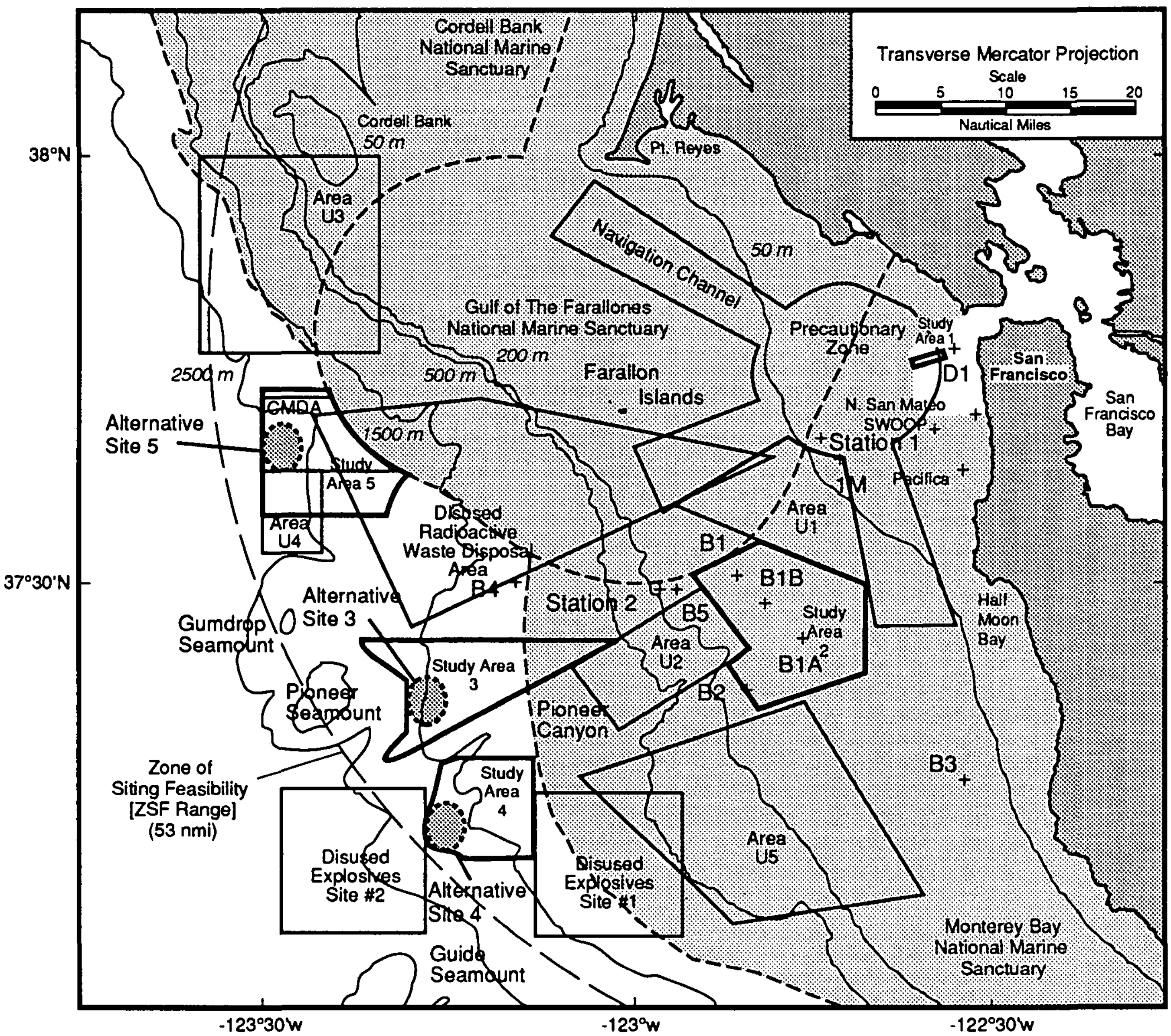

Figure 2.1-6. **Locations of Study Areas 2 Through 5 Within the LTMS Study Region as Related to Sensitive and Incompatible Use Areas.**

Table 2.1-3. Designated Open Water Dredged Material Disposal Sites in the San Francisco Bay Region.

Site	Location	Target Disposal Volumes (yd^3)	Site Use Restrictions
Alcatraz	San Francisco Bay; Central Bay	4 million (annual) 0.3 million (monthly; May-September) 1.0 million (monthly; October-April)	Slurried Bay sediments
San Pablo	San Francisco Bay; North Bay	0.5 million (monthly or annual)	Slurried Bay sediments
Carquinez Straits	San Francisco Bay; North Bay	2.0 million (annual) 3.0 million (annual-wet year) 1.0 million (monthly)	Slurried Bay sediments
Suisun Bay	Suisun Bay; North Bay	0.2 million (annual-planning estimate)	Disposal of sandy sediment from adjacent shipping channel

Source: COE 1992a; COE 1990a.

dispersion and eventual transport of dredged material to the ocean (COE 1990a). The seven other historical disposal sites in the Bay, typically located within one mile of the respective dredging sites, have not been used since 1972 (COE 1990a).

The San Pablo and Carquinez Straits sites receive average annual dredged material volumes of 0.2 million yd^3 and 1.4 million yd^3, respectively (COE 1992a). In accordance with present COE policy, dredged material discharged at these sites is slurried prior to discharge. The annual dredged material disposal volume planned for the Suisun Bay disposal site also is 0.2 million yd^3 (COE 1990a). The capacities of these sites are not known. The Alcatraz disposal site has received an average volume of over three million yd^3 of dredged material per year since 1972. Studies conducted at the site in the early 1980s (e.g., SAIC 1987) indicated dispersion of the discharged sediments was lower than predicted, and accumulation and mounding of dredged material within the site was significantly limiting the capacity for long-term use. Consequently, since 1986, the COE has imposed a slurry requirement for material disposed at the site to promote dispersion and to minimize accumulation (COE 1990a). The present capacity of the Alcatraz site to accept slurried material is not known because the factors controlling dispersion are poorly understood (COE 1990a). Periodic removal of a portion of the accumulated materials from the Alcatraz site may be required in the future.

Other sites within the Bay which are potentially suitable for dredged material disposal were investigated by Nolte and Associates (1987) and PTI (1989). The capacities and dispersive characteristics of most of these sites also are not known (COE 1992a). Designation of new sites within the Bay must comply with the requirements of Section 404(b)(1) of the Clean Water Act (CWA). The COE, in cooperation with the EPA, is responsible for regulating the use of sites within the Bay, and the State and Regional Water Quality Control Boards are responsible for issuing water quality certifications (COE 1992a).

Several resource and regulatory agencies—including the California Department of Fish and Game (CDFG), National Marine Fisheries Service (NMFS), and the SFBRWQCB—have expressed concern about: the effects of open water disposal operations on fisheries resources in the Bay;

alteration of benthic and shoreline habitats; increased water column turbidity; and remobilization of chemical contaminants associated with resuspended sediments. In 1990, SFBRWQCB Resolution No. 89-130 was adopted conditionally by the California State Water Resources Control Board (Resolution No. 90-37). Resolution 89-130 included: (1) target monthly and annual disposal volume limits for each of the sites within the Bay; and (2) a requirement for the COE to demonstrate "...that there are no significant or irreversible impacts occurring from the disposal of maintenance dredged material in San Francisco Bay." The target limits for the annual disposal volumes at the San Pablo and Carquinez Straits sites are 0.5 million yd^3 and 2.0 million yd^3, respectively (except that the limit for the Carquinez Strait site during wet weather years is 3.0 million yd^3). The target annual volume for the Alcatraz site is 4.0 million yd^3 (Table 2.1-3). The resolution also states that the RWQCB will encourage land and ocean disposal alternatives whenever possible. The measures contained in this resolution are implemented by the RWQCB through the issuance or denial of waste discharge requirements, water quality certifications under Section 401 of the CWA, or other orders for individual dredging projects that propose disposal volumes which exceed the annual or monthly targets.

The Bay Farm Borrow Area (BFBA) is being investigated by the COE as a potential confined aquatic disposal site. This site is located in the central Bay, immediately west of the northern portion of Bay Farm Island, and it consists of a "borrow pit" that was excavated in the 1950s for material used as fill for the Island and for dike construction and maintenance. The site dimensions are 2,800 m by 1,500 m, with an average potential fill depth of 3 m (i.e., the depth below the adjacent bottom) and an estimated capacity of 16 million yd^3. The environmental characteristics, including the physical and chemical characteristics of the bottom sediments, benthic infaunal abundances, fish abundances, and current patterns, and the potential suitability of the BFBA as a confined open-water disposal site presently are being evaluated.

2.1.3.2 Nonaquatic Disposal and Reuse Alternatives

Existing and potential nonaquatic and reuse sites presently are being evaluated by the LTMS Nonaquatic/Reuse Work Group as candidate dredged material disposal sites. Of the 65 potential sites originally identified, nine sites have been characterized as "highly feasible sites." These sites and their potential uses are listed in Table 2.1-4. The LTMS selected three of these sites—Cullinan Ranch, Cargill Salt Div-1 (East), and Cargill Salt Div-1 (West)—for preliminary engineering feasibility assessments. The assessments are scheduled for completion in June 1994. The primary factors affecting the feasibility of dredged material disposal at nonaquatic sites include groundwater quality, distance from the dredging area, site capacity, local resource concerns, and monitoring requirements (COE 1992a). The use of existing nonaquatic disposal sites has declined in recent years due to extensive development, exhausted capacity, and restrictions against filling wetlands (COE 1990a).

Dredged material may have beneficial uses for projects such as marsh restoration, levee maintenance, beach nourishment, and landfill cover. These alternative disposal options are being evaluated independently as part of the LTMS process. However, the suitability of dredged material for use in any project will depend on a variety of engineering, economic, environmental, and regulatory considerations. For example, key factors affecting the feasibility typically include site access and capacity, compatibility of the dredged material with construction or engineering requirements, contaminant levels in dredged material, presence of critical habitat or endangered species, habitat replacement value, and regulatory requirements of local, state, and federal governments (COE 1992a). Specific beneficial or reuse options are summarized briefly below.

Several habitat development and marsh restoration projects have been proposed at sites within the San Francisco Bay area. The six sites/projects ranked as highly feasible by the LTMS Upland/Reuse Work Group are: (1) Cargill Salt Div-1 (West); (2) Hamilton Antenna Field; (3) Cullinan Ranch; (4) Sonoma Baylands; (5) Montezuma Wetlands; and (6) Skaggs Island (Table 2.1-4). The capacities of these proposed projects for dredged material range from approximately 2.5 to 40 million yd^3.

The proposed levee rehabilitation/maintenance projects evaluated as dredged material disposal options are located in the Sacramento and San Joaquin River delta area. The primary sites and estimated capacities are: Sherman Island (1.8 million yd^3); Twitchell Island (0.4 million yd^3);

Table 2.1-4. Upland Reuse/Disposal Options Classified as "Highly Feasible" by the LTMS Nonaquatic/Reuse Work Group.

Candidate Site	Site Status and Feasibility	Projected Site Capacity (yd^3)*	Additional Remarks
Port Sonoma-Marin	Presently used and "highly feasible" for continued use as rehandling facility.	0.05 million/yr throughput (for use at Redwood Sanitary Landfill).[1,2]	0.2 miles from existing barge access channel.
Leonard Ranch	Identified as "highly feasible" for dredged material rehandling project. LTMS preparing feasibility study to construct on-site rehandling facility. COE directed by Congress to study.	Up to 0.95 million/yr throughput (for possible use at Redwood Sanitary Landfill), if entire site used.[1,2]	1 mile from existing barge access channel. Need funding to undertake. Site owned by Sonoma Land Trust.
Praxis/ Pacheco	Identified as "highly feasible" for dredged material confined disposal and/or rehandling project. LTMS preparing more detailed feasibility study.	0.64 million/yr throughput for rehandling, or 2.5 million for confined disposal.[1,3]	Project constraints due to sewer easement. No project sponsor. Privately-owned; site acquisition and funding required. 3 miles from existing barge access channel.
Sonoma Baylands (330-acre project)	Identified as "highly feasible" for dredged material habitat creation project. Congressional direction to COE to undertake has yet to be approved.	2.5 million for habitat creation.	Need funding to undertake. 0.6 miles from existing barge access channel.
Montezuma Wetlands	Identified as "highly feasible" for dredged material habitat creation, contained disposal, and/or reprocessing project; proposals pending for first two uses.	20 million for habitat creation.	0.1 mile from existing barge access channel.
Skaggs Island (Navy-owned)	Identified as "highly feasible" for dredged material confined disposal and/or habitat creation project; will be the subject of additional LTMS research.	14 million for habitat creation, or 72 million for confined disposal.[3]	3-mile pumping distance across salt ponds. Would require Navy base closure and funding to undertake.
Cargill Salt Div. 1 (East and West)	Identified as "highly feasible" for dredged material confined disposal, rehandling, and/or habitat creation project; LTMS will prepare conceptual plan.	Up to 3 million/yr throughput for rehandling, or 14.2 million for confined disposal (at east site).[1,3] 40 million for habitat creation (at west site).	Site acquisition and funding necessary; site available only if Cargill cannot find buyer for salt. No project sponsor. Adjacent to existing barge access channel.
Cullinan Ranch	Identified as "highly feasible" for dredged material habitat creation project. Possible subject of further LTMS research; FWS conducting preliminary planning.[4]	7.2 million for habitat creation.	Need funding to undertake. 0.5 miles from existing barge access channel.
Hamilton AFB: Antenna Field	Identified as "highly feasible" for dredged material habitat creation project.	2.7 million for habitat creation.	Public site ownership; COE and CDFG potential project sponsors. Need funding to undertake. 3 miles from existing barge access channel.

*Capacities are preliminary planning estimates.
[1]Rehandling projection based on assumption that total amount of rehandled material removed annually; subject to change depending upon disposal site size and specific needs of end-user.
[2]Redwood will need up to 14 million yd^3 of wet material, if landfill expansion permitted; if not permitted, only 1.6 million yd^3 of wet material will be needed by Redwood.
[3]Confined disposal projection based on assumption that multiple disposal events and an average 40% compaction rate for in-place, dry material will occur; subject to change depending upon disposal site size.
[4]Shell Oil Trust will fund initial studies.

Source: LTMS Non-Aquatic/Reuse Work Group, 1992.

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Jersey Island (1.6 million yd^3); Lower Jones Tract/Mitchell Island (1.8 million yd^3); Chipps Island (2.0 million yd^3); and Tubbs Island (capacity presently unknown) (COE 1992a). The primary constraints in using sediments dredged from San Francisco Bay for delta area levees are the potential effects of adding saline waters (associated with the dredged material) to a freshwater environment (COE 1992a).

Some of the sediments dredged from San Francisco Bay may be suitable for landfill cover and construction fill. Nolte and Associates (1987) estimated that 115,000 yd^3 per year of dried (processed) dredged material could be used for construction fill near a given processing site, and 15,300 yd^3 per year could be used at sanitary landfill sites. The Redwood Sanitary Landfill near San Pablo Bay was identified by the LTMS Upland/Reuse Work Group as a landfill which could use from 140,000 to 440,000 yd^3 of dredged material per year. Both Port Sonoma-Marin and Leonard Ranch sites have been identified as highly feasible sites for re-handling dredged material intended for Redwood Sanitary Landfill (Table 2.1-4).

Ocean Beach, south of the Golden Gate, has been severely eroded, and California Coastal Commission staff has suggested that this area may be a candidate site for beach nourishment (L. Madalon, COE, pers. comm. 1992). However, it is unlikely that the majority of sediments from any of the planned dredging projects would be appropriate for nourishment of this or other local beaches because the sediments are expected to consist primarily of fine-grained materials. These sediments would not be consistent in quality or size with the sands that occur on the beaches. The use of dredged material for beach nourishment will be evaluated by COE on a project-specific basis.

As discussed in Chapter 1 of this EIS, designation of an ODMDS does not preclude further consideration of within the Bay or Nonaquatic/Reuse alternatives for specific projects. The COE and EPA will evaluate other feasible alternatives on a project-specific basis during the MPRSA Section 103 permitting process. In addition, the LTMS Implementation Work Group will address disposal and beneficial reuse options for the San Francisco Bay area.

2.2 Discussion of Alternatives

This section presents a discussion of the alternatives that are not being considered for further analysis (Section 2.2.1), a discussion of how the three proposed ocean disposal site alternatives comply with EPA's general and specific site selection criteria (Sections 2.2.2 and 2.2.3, respectively), and a discussion of the preferred alternative (Section 2.2.4). Detailed information and an evaluation of each candidate disposal site with EPA's general and specific criteria are presented in Chapter 3, Affected Environment, and Chapter 4, Environmental Consequences.

The LTMS initially included Study Areas 1, 2, 3, 4, and 5 as potential areas within which an ODMDS might be designated for disposal of San Francisco Bay sediments. However, because Study Area 1, corresponding to the Channel Bar ODMDS, is only designated for disposal of sandy material from the San Francisco Bay entrance channel, Study Area 1 was eliminated from further consideration because the characteristics of fine-grained, dredged material would be incompatible with restrictions on disposal site sediments. Study Area 2 originally was included as a candidate location on the continental shelf, and was subjected to considerable study effort by the COE (KLI 1991) and EPA (SAIC 1992b,c). Nevertheless, based on its location within the MBNMS, and because dredged material disposal at a new ODMDS within the Sanctuary is prohibited (NOAA 1992), Study Area 2 also has been eliminated from further consideration as an ODMDS. Because extensive and valuable studies have already been conducted as part of EPA's ocean site designation efforts, the environmental characteristics of Study Area 2 are presented in this EIS to provide a basis for comparison with Study Areas 3, 4, and 5 and corresponding Alternative Sites 3, 4, and 5 within these areas.

The locations of the three alternative sites correspond to low-energy depositional zones within each of Study Areas 3, 4, and 5 and contain sediments which are similar in grain size to those within the Bay (Section 3.2). Disposal in such zones should minimize the dispersion of dredged material and minimize the area of impact. Alternative Sites 3 and 4 are located along the central western and southwestern boundaries of Study Areas 3 and 4, respectively. Alternative Site 5 is located along the central portion of the western boundary of Study Area 5, and corresponds to the approximate location of the proposed NODS Site (Navy 1992) (Figure 2.1-1).

The size of the alternative sites was determined from the results of dredged material deposition (footprint) modeling (Section 4.2.1.4), and corresponds to the area represented by the model-predicted 10-mm thick deposit of "mostly silt-clay" material (74% clay and 16% silt) after a one-year dredged material disposal period at Alternative Site 5. The areas of the model-predicted 10-mm thick deposits at Alternative Sites 3 and 4 are relatively smaller than that at Alternative Site 5. (However, to be conservative, the size and configuration of all the alternative sites were kept uniform, corresponding to Alternative Site 5, with an oval shape of dimensions of approximately 3.7 nmi (6.9 km) long and 2.2 nmi (4.1 km) wide.) The site boundaries completely incorporate the model-predicted 100 mm (10 cm) thick deposit, which is the threshold above which impacts are expected to be significant (such as smothering of bottom-dwelling organisms). Deposition over a one-year period, instead of the 50-year project period, was used as the basis for delineating the site boundaries because natural physical and biological recolonization processes are expected to offset potential effects due to deposition of dredged material at rates less than 10 cm per year. Thus, the present site boundaries are intentionally conservative. Also, because the site boundaries are based on the sediment deposition footprint, the authorized discharge area at the surface will be smaller than the area of the actual disposal site to account for dispersion during settling and to allow material to reach the bottom within the site boundaries.

2.2.1 Alternatives Not Considered for Further Analysis

Study Area 1, Study Area 2, and the No-Action Alternative will not be considered further as alternatives in this EIS. As noted above, the physical characteristics of the dredged material are expected to be incompatible with those of the existing sediments within Study Area 1. Further, Study Area 2 is located entirely within the MBNMS, and designation of a new ODMDS within Sanctuary boundaries is prohibited (NOAA 1992). Therefore, Study Areas 1 and 2 were considered by the LTMS to be inappropriate for further analysis as potential ODMDSs. However, limited discussison of Study Area 2 is included in this document to provide a basis for comparison with Alternative Sites 3, 4, and 5. The LTMS mission is to provide long-term options, including ocean disposal, to accommodate the dredged material volumes and compositions anticipated for the 50-year planning period. The No-Action Alternative would impede the use of ocean disposal as a long-term management option and therefore is an undesirable alternative.

2.2.2 Compliance of the Alternative Sites and Study Area 2 with General Criteria for the Selection of Sites

2.2.2.1 General Criterion 40 CFR 228.5(a)

The dumping of materials into the ocean will be permitted only at sites or in areas selected to minimize the interference of disposal activities with other activities in the marine environment, particularly avoiding areas of existing fisheries or shellfisheries, and regions of commercial or recreational navigation.

Alternative Sites 3, 4, and 5 are in water depths greater than 1,600 m, on the lower continental slope or rise, and are characterized by sparsely distributed fisheries species of potential commercial value, including marginally targeted commercial fisheries species such as rattails (Section 3.4). The use of any of the alternative sites would have minimal effects on existing fisheries or shellfisheries regions, although vessels towing dredged material barges would pass through sanctuary and fisheries areas. A direct route to Alternative Site 5 (Figure 2.1-1) is of concern because accidents or problems with barges in the vicinity of the Farallon Islands could result in inadvertent releases of dredged material with potential impacts to biological communities. However, a requirement for barges to stay within the recommended navigation lanes and away from the Islands would minimize potential impacts of transit to all alternative sites.

None of the alternative sites is located within established precautionary zones, navigation lanes, or submarine operating areas (Section 2.1.2.3). Therefore, commercial shipping traffic heading south towards or north from San Francisco should not be affected by use of any of the alternative sites. Dredged material barges transiting directly to Alternative Site 5 would pass along routes potentially used by boats engaged in such activities as bird watching, whale watching, or sailing near the Farallon Islands. However, requirements for dredged material barges to stay within the navigation lanes and away from the Islands would minimize any potential effects.

Because of its location closer to shore and the Golden Gate, the nearshore region including Study Area 2 represents greater potential access for smaller vessels, as well as larger commercial traffic, passing south from or north to San Francisco. Therefore, Study Area 2 likely would be associated with more commercial and recreational boat traffic than Alternative Sites 3, 4, or 5.

2.2.2.2 General Criterion 40 CFR 228.5(b)

Locations and boundaries of the disposal sites will be so chosen that temporary perturbations in water quality or other environmental conditions during initial mixing caused by disposal operations anywhere within the site can be expected to be reduced to normal ambient seawater levels or to undetectable concentrations or effects before reaching any beach, shoreline, marine sanctuary, or known geographically limited fishery or shellfishery.

Alternative Sites 3, 4, and 5 are located outside of any sanctuary boundaries. Results of modeling dispersion of dredged material from the alternative sites (see Sections 4.2 and 4.4) indicate very low probabilities of suspended particles from the disposal being transported into the GOFNMS, CBNMS, or MBNMS. Further, predicted dilution rates would reduce the suspended particle concentrations to within the range of normal, ambient levels near the sanctuary boundaries. Thus, all sites would result in undetectable effects on water quality parameters such as turbidity, dissolved oxygen, or trace contaminant concentrations at sanctuary boundaries. Based on sediment footprint modeling studies for each alternative site (see Sections 4.2 and 4.4), dredged material would not be deposited in detectable thicknesses within any of the sanctuary boundaries.

Alternative Sites 3, 4, and 5 are located at least 25 nmi from the Farallon Islands and approximately 60 nmi from any mainland beach or shoreline (Figure 2.1-1). Therefore, dredged material disposal activities are not likely to cause effects to these resource or amenity areas. Alternative Sites 3, 4, and 5 are not located within or adjacent to a geographically limited fishery or shellfishery.

Study Area 2 is located entirely within the MBNMS (Figure 2.1-1) and therefore cannot meet this criterion of avoiding any significant water quality changes within a sanctuary. Also, an important fisheries area exists on the continental shelf off San Francisco and encompasses Study Area 2 and the shoreward portion of Study Area 3.

2.2.2.3 General Criterion 40 CFR 228.5(c)

If at any time during or after disposal site evaluation studies, it is determined that existing disposal sites presently approved on an interim basis for ocean dumping do not meet the criteria for site selection set forth in Sections 228.5 through 228.6, the use of such sites will be terminated as soon as suitable alternate disposal sites can be designated.

The MPRSA site selection process is designed to identify a preferred alternative that minimizes or avoids unacceptable impacts to the physical, biological, and socioeconomic environment. Evaluation of the continued use of a designated disposal site will be conducted as part of the site management and monitoring program administered jointly by EPA Region IX and the COE, San Francisco District (see Section 4.6).

2.2.2.4 General Criterion 40 CFR 228.5(d)

The sizes of ocean disposal sites will be limited in order to localize for identification and control any immediate adverse impacts and permit the implementation of effective monitoring and surveillance programs to prevent adverse long-range impacts. The size, configuration, and location of any disposal site will be determined as a part of the disposal site evaluation or designation study.

The sizes and configurations of the three alternative sites are based on the results of footprint and water quality modeling studies to identify potential areas of significant sediment accumulation and plume dispersion from dredged material disposal (Sections 4.2 and 4.4). In general, site size will be limited, yet will encompass modeled regions of detectable sediment deposition, based on one year of disposal activity. The site locations are chosen to coincide with low-energy depositional zones, identified by survey results (Section 3.2), where resuspension and dispersion of the deposited dredged material will be minimized and monitoring of long-term effects will be facilitated. Water quality modeling results indicate that disposal within any of the alternative sites would result in only low probabilities of suspended particles being transported into a sanctuary boundary (Sections 4.2 and 4.4). Evaluation of the continued acceptability of a designated site will be conducted in accordance with the site management and monitoring plan.

2.2.2.5 General Criterion 40 CFR 228.5(e)

EPA will, wherever feasible, designate ocean dumping sites beyond the edge of the continental shelf and other such sites that have been historically used.

Alternative Sites 3 and 4 are located on the continental slope, and Alternative Site 5 is located on the continental rise.

The only study area that has been used extensively for historical disposal operations is Study Area 5 (which contains Alternative Site 5). From 1951–54, the general Study Area 5 region, particularly the southeast area, received sealed containers which included mixtures of low-level radioactive waste from defense-related, commercial, and laboratory activities (Section 3.1). Additionally, from approximately 1958 to the late 1960s, the northern portion of the Area received chemical and conventional munitions disposed of by the U.S. Army (Section 3.1). It is not known how much of this waste material is present within the boundaries of Alternative Site 5.

Historically, no dredged material disposal has occurred at Alternative Site 5. However, the U.S. Navy presently is seeking a project-specific permit under MPRSA Section 103 for disposal of approximately 1.6 million cubic yards within the proposed NODS Site, corresponding to the approximate location of Alternative Site 5 (Navy 1992). Thus, if this project receives approval, dredged material disposal may have occurred at the site prior to designation of an MPRSA Section 102 ODMDS.

Study Area 2 is the only study area located on the continental shelf, representing water depths less than approximately 200 m (Figure 2.1-1). The B1B site, located within Study Area 2, was used in 1988 for limited dredged material disposal (approximately 18,000 yd^3) (Section 3.1). Although this site could be considered a historically used site, it now lies within the MBNMS.

2.2.3 Comparison of the Alternatives to EPA's 11 Specific Criteria for Site Selection 40 CFR 228.6(a)

Comparisons to the specific criteria are summarized in Table 2.2-1, and support the selection of the preferred alternative as discussed in Section 2.2.4. Detailed information on the physical, biological, and socioeconomic environment is presented in Chapters 3 and 4.

2.2.4 Selection of the Preferred Alternative

Alternative Site 5 has been selected by EPA and the LTMS Ocean Studies Work Group as the preferred alternative. This site was selected for the following reasons:

- Bathymetric and sediment surveys indicate Alternative Site 5 is located in a depositional area which, because of existing topographic containment features, is likely to retain dredged material which reaches the sea floor. This is similar to the containment potential at Alternative Site 3 but should provide greater containment than at Alternative Site 4;
- No significant impacts to other resources or amenity areas (e.g., marine sanctuaries) are expected to occur from designation of Alternative Site 5;

Table 2.2-1. Comparison of the Three Alternative Ocean Disposal Sites and Study Area 2 Based on the 11 Specific Criteria at 40 CFR 228.6(a).

Criteria	Alternative Site 3 (Study Area 3)	Alternative Site 4 (Study Area 4)	Alternative Site 5 (Study Area 5)	Study Area 2
1. Geographical position, depth of water, bottom topography and distance from coast.	• Lower Continental Slope site, approx. 50 nmi from coast and 47.12 nmi from Golden Gate*; 5 nmi N of Pioneer Canyon, and 5 nmi E of Pioneer Seamount (Figure 2.1-2).	• Lower Continental Slope site, approx. 50 nmi from coast and 54.95 nmi from Golden Gate*; 10 nmi S of Pioneer Canyon, and 15 nmi SE of Pioneer Seamount (Figure 2.1-2).	• Continental Rise site, approx. 60 nmi from coast and 49.23 nmi from Golden Gate* (Figure 2.1-2).	• Continental Shelf site, approx. 10-25 nmi from coast and 26 nmi from Golden Gate (Figure 2.1-2).
	• Depths range from approx. 1400 to 1900 m.	• Depths range from approx. 1900 to 2100 m.	• Depths range from approx. 2500 to 3000 m.	• Depths range from approx. 70 to 90 m.
	• Located in a topographic low that is bounded to the west by Pioneer Seamount and to the east by a moderately steep slope.	• Moderately sloping bottom that is unbounded (as compared to Alternative Site 3).	• Same as Alternative Site 4.	• Gently sloping bottom.
	• Sediments comprised mostly of silt-sized sediments; no known hard-bottom areas occur within the site.	• Sediments comprised mostly of sand and silt-sized sediments; no known hard-bottom areas occur within the site.	• Sediments comprised mostly of fine grained silts and clays; no known hard-bottom areas occur within the site.	• Sediments comprised mostly of sands with some silts; no known hard-bottom areas occur within the site.

*Assumes barges would be required to stay within westbound traffic lanes (Ogden Beeman 1992).

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Table 2.2-1. Continued.

Criteria	Alternative Site 3 (Study Area 3)	Alternative Site 4 (Study Area 4)	Alternative Site 5 (Study Area 5)	Study Area 2
2. Location in relation to breeding, spawning, nursery, feeding or passage areas of living resources in adult or juvenile stages.	• Low numbers of fish species and abundances (as compared to Study Area 2).	• Same as Alternative Site 3.	• Same as Alternative Site 3.	• Important fisheries area of general shelf region.
	• Moderate numbers of megafaunal invertebrate species and abundances.	• Same as Alternative Site 3.	• Same as Alternative Site 3.	• Low abundances of megafaunal invertebrates, although high abundances of juvenile Dungeness crabs have been reported historically in the vicinity.
	• Moderate use by marine birds and mammals.	• Low use by marine birds and mammals (as compared to Alternative Sites 3 and 5).	• High use by marine birds and mammals (as compared to Alternative Sites 3 and 4).	• Same as Alternative Site 5.
	• Moderate abundances of midwater fish species including juvenile rockfishes.	• Same as Alternative Site 3.	• High seasonal abundances of some midwater species including juvenile rockfishes (as compared to Alternative Sites 3 and 4).	• Same as Alternative Site 5.
	• Infauna community very diverse and abundant.	• Same as Alternative Site 3.	• Infauna community with relatively lower diversity and abundance (as compared to Alternative Sites 3 and 4).	• Typical shelf community but very high abundances and moderate diversity.
	• Located approx. 5 nmi from Pioneer Canyon and Pioneer Seamount; both reportedly characterized by hard-bottom communities; currents move away from Canyon.	• Located approx. 10 nmi South of Pioneer Canyon but transport of dredged material would be towards Canyon based on generally northward-flowing currents.	• Located approximately 30 nmi from Pioneer Canyon; currents move away from Canyon.	

Table 2.2-1. Continued.

Criteria	Alternative Site 3 (Study Area 3)	Alternative Site 4 (Study Area 4)	Alternative Site 5 (Study Area 5)	Study Area 2
3. Location in relation to beaches and other amenity areas.	• Located at least 50 nmi from coastal resources and amenity areas (Figure 2.1-1); therefore unlikely to be of concern. • Located approx. 10 and 15 nmi from MBNMS and GOFNMS, respectively, and 30 nmi from the Farallon Islands. Therefore, limited concern based on water quality modeling results (Section 4.4).	• Same as Alternative Site 3. • Located approx. 10 and 30 nmi from MBNMS and GOFNMS, respectively, and 45 nmi from the Farallon Islands. Therefore, limited concern based on water quality modeling results (Section 4.4).	• Located at least 60 nmi from coastal resources and amenity areas (Figure 2.1-1); therefore unlikely to be of concern. • Located approx. 10 and 30 nmi from GOFNMS and the Farallon Islands, respectively. Therefore, limited concern based on water quality modeling results (Section 4.2).	• Located at least 15 nmi from coastal resources and amenity areas (Figure 2.1-1); therefore unlikely to be of concern. • Located within MBNMS, adjacent to the GOFNMS, and approx. 15-30 nmi from the Farallon Islands. Primary concern related to within-sanctuary location.
4. Types and quantities of wastes proposed to be disposed of, and proposed methods of release, including methods of packing the waste, if any.	Composition of dredged material is expected to range between two types: predominantly "silt-clay" (74% clay, 5% silt, 21% sand) versus "mostly sand" (76% sand, 21% clay, 3% silt). Site use over a 50-year period could total 400 million cubic yards, with approx. 6 million cubic yards per year and between 1,000-6,000 cubic yards per barge trip. Split-hull barges towed by ocean-going tugboats are most likely disposal method.	Same as Alternative Site 3.	Same as Alternative Site 3.	Not applicable.

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Table 2.2-1. Continued.

Criteria	Alternative Site 3 (Study Area 3)	Alternative Site 4 (Study Area 4)	Alternative Site 5 (Study Area 5)	Study Area 2
5. Feasibility of surveillance and monitoring.	• USCG has surveillance responsibility; radar not feasible; ODSS-like system feasible.	• Same as Alternative Site 3.	• Same as Alternative Site 3.	• USCG has surveillance responsibility; radar or ODSS-like system feasible.
	• Monitoring feasible but more difficult because of deep water depths and subsequent greater dispersion of dredged material, and limited knowledge of potential impacts to deep-water communities.	• Same as Alternative Site 3; however, Alternative Site 4's location near Disused Explosives Sites #1 and #2 may represent some additional potential for hazards during monitoring of bottom conditions.	• Monitoring feasible but possibly the most difficult because of greater water depths, generally larger footprint, limited knowledge of deep-water communities, and potential hazards from historical disposal of radioactive waste containers and chemical and conventional munitions.	• Monitoring would be simplified due to shallow depths, but material would be resuspended and dispersed farther, making impact assessment more difficult.
6. Dispersal, horizontal, transport and vertical mixing characteristics of the area, including prevailing current direction and velocity, if any.	• Flows primarily to northwest in upper 800-900 m, although periodic reversals in flow occur. Currents below 1,000 m generally weaker than near-surface currents. Near-bottom flows may be enhanced by tidal influences and topography. Sediment resuspension within Site expected to be minimal.	• Similar to Alternative Site 3.	• Similar to Alternative Site 3.	• High energy area; frequent bottom scouring and rapid dispersal of sediments.

Table 2.2-1. Continued.

Criteria	Alternative Site 3 (Study Area 3)	Alternative Site 4 (Study Area 4)	Alternative Site 5 (Study Area 5)	Study Area 2
7. Existence and effects of current and previous discharges and dumping in the area (including cumulative effects).	• No current or previous disposal activities.	• No current or previous disposal activities.	• No current disposal activities; however, the Navy has requested an MPRSA Section 103 permit for disposal of up to 1.6 million cubic yds of dredged material.	• No current disposal activities.
	• The site is within approx. 5 nmi of Disused Explosives Site #2 (Figure 2.1-6); however, there are no known effects.	• The site adjoins Disused Explosives Site #2 and is within approx. 5 nmi of Disused Explosives Site #1 (Figure 2.1-6); however, there are no known effects.	• No documented disposal within the site; however disposal of radioactive waste containers was conducted in the general Study Area region from 1951-54. Chemical and conventional munitions were disposed from approx. 1958 to late 1960s at the Chemical Munitions Disposal Area. Potential environmental effects are unknown, but there was no evidence during recent surveys of residual contamination. Potentials for cumulative impacts are considered unlikely.	• Limited historical dredged material disposal (18,000 cubic yards) in 1988; this small volume is unlikely to have caused any significant effects.

Table 2.2-1. Continued.

Criteria	Alternative Site 3 (Study Area 3)	Alternative Site 4 (Study Area 4)	Alternative Site 5 (Study Area 5)	Study Area 2
8. Interference with shipping, fishing, recreation, mineral extraction, desalination, fish and shellfish culture, areas of special scientific importance and other legitimate uses of the ocean.	• Only slight potential interference with other uses of the ocean, including shipping, fishing, recreation, and areas of special scientific importance (such as the Farallon Islands), is likely. • NMFS has a sablefish study area within Study Area 3 but it is shallower than the alternative site.	• Same as Alternative Site 3.	• Dredge barge transit could cause some interference with recreational and scientific boat traffic, particularly near the Farallon Islands. Under normal conditions, no interference with areas of special importance is expected; however, accidents resulting in releases of material near the Farallones may be a concern. A requirement for barges to avoid the Farallones vicinity could minimize potential impacts.	• Relatively greater interference (as compared to other alternative sites) with shipping, fisheries, and recreation due to location on Continental Shelf. No significant interference with other uses of the ocean is expected.

Table 2.2-1. Continued.

Criteria	Alternative Site 3 (Study Area 3)	Alternative Site 4 (Study Area 4)	Alternative Site 5 (Study Area 5)	Study Area 2
9. Existing water quality and ecology of the site as determined by available data or by trend assessment or baseline surveys.	• Good water quality.	• Same as Alternative Site 3.	• Same as Alternative Site 3.	• Good water quality, although turbidity may be high (as compared to the alternative sites) due to proximity to San Francisco Bay outflow.
	• Sediments contain background levels or low concentrations of trace metal and organic contaminants.	• Same as Alternative Site 3.	• Same as Alternative Site 3.	• Same as Alternative Site 3.
	• Fish community has low (as compared to Study Area 2) numbers of species and abundances (rattails, thornyhead rockfish, eelpouts).	• Same as Alternative Site 3.	• Fish community has low (as compared to Study Area 2) numbers of species and abundances (rattails, eelpouts, finescale codling).	• Fish community diverse and abundant (e.g., flatfishes and rockfishes).

Table 2.2-1. Continued.

Criteria	Alternative Site 3 (Study Area 3)	Alternative Site 4 (Study Area 4)	Alternative Site 5 (Study Area 5)	Study Area 2
9. Existing water quality and ecology of the site as determined by available data or by trend assessment or baseline surveys (continued).	• Moderate number of megafaunal invertebrate species and abundances (sea cucumbers, seastars, brittlestars). • Infaunal invertebrates very diverse and abundant (polychaetes, amphipods, tanaids, isopods). • Moderate use area by marine birds and mammals (as compared to Alternative Site 5 and Study Area 2). • Juvenile rockfishes less abundant seasonally (as compared to Alternative Site 5 and Study Area 2.	• Same as Alternative Site 3. • Infaunal invertebrates same as Alternative Site 3, but fewer amphipods. • Low use area by marine birds and mammals (as compared to Alternative Site 3). • Same as Alternative Site 3.	• Moderate number of megafaunal invertebrate species and abundances (sea cucumbers, brittlestars, sea pens). • Infaunal invertebrates lower diversity and abundance (polychaetes, amphipods, isopods, tanaids) (as compared to Alternative Sites 3 and 4). • High use area by marine birds and mammals (as compared to Alternative Sites 3 and 4). • Mid-water organisms, including juvenile rockfish, abundant seasonally (as compared to Alternative Sites 3 and 4).	• Megafaunal invertebrates sparse. • Infaunal invertebrates very high abundances and moderate diversity (polychaetes, amphipods, gastropods). • High use area by marine birds and mammals (as compared to Alternative Sites 3 and 4). • Juvenile rockfishes abundant seasonally (as compared to Alternative Sites 3 and 4).
10. Potentiality for the development of nuisance species at the disposal site.	Unlikely to recruit nuisance species from dredged material due to significant differences in water depth and environment at the disposal site as compared to dredging site; no other disposal site impacts are expected that would result in nuisance species.	Same as Alternative Site 3.	Same as Alternative Site 3.	Same as Alternative Site 3.

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Table 2.2-1. Continued.

Criteria	Alternative Site 3 (Study Area 3)	Alternative Site 4 (Study Area 4)	Alternative Site 5 (Study Area 5)	Study Area 2
11. Existence at or in close proximity to the site of any significant natural or cultural features of historical importance.	There are no known significant natural or cultural features.	Same as Alternative Site 3.	Same as Alternative Site 3.	Same as Alternative Site 3.

- Existing and potential fisheries resources within Alternative Site 5 are minimal and the site is removed from important fishing grounds located near Alternative Sites 3 and 4;

- Densities and biomass of demersal fish and megafaunal invertebrates are estimated to be relatively low compared to those at Alternative Sites 3 and 4;

- Potential impacts to other organisms (e.g., seabirds, mammals, and midwater organisms) are expected to be insignificant even though Alternative Site 5 tends to have slightly higher abundances of these organisms;

- Waste disposal has occurred historically in the vicinity of the site (and disposal of dredged material may occur as part of the Navy MPRSA Section 103 project).

CHAPTER 3
AFFECTED ENVIRONMENT

This chapter describes ocean disposal site characteristics, and the physical, biological, and socioeconomic characteristics of the LTMS study areas and alternative sites (Sections 3.1 through 3.4, respectively). This information provides the basis for evaluating the environmental consequences of the proposed action (Chapter 4) and for evaluating the specific alternatives (Chapter 2). The information regarding disposal site characteristics also addresses elements from several of the general and specific ocean disposal selection criteria (Table 1.1-1).

3.1 Ocean Disposal Site Characteristics

This section addresses: historical uses of the LTMS study areas (Section 3.1.1); types and quantities of materials to be disposed of (Section 3.1.2); existence and effects of current and previous disposal operations in the study region (Section 3.1.3); and the feasibility of surveillance and monitoring of alternative sites (Section 3.1.4).

3.1.1 Historical Use of the Study Region (40 CFR 228.5[e])

3.1.1.1 Dredged Material Disposal

Routine dredged material disposal operations have not occurred within any of the study areas. However, limited dredged material disposal activities have occurred at Site B1B located within Study Area 2 (Figure 3.1-1). Historically, three ocean sites outside of the study areas have received dredged material from San Francisco Bay. These sites include: (1) the nearshore Bay Area Rapid Transit (BART) site; (2) the 100-Fathom site; and (3) the COE experimental site (Figure 3.1-1). The Channel Bar Site is used routinely for disposal of dredged material from the

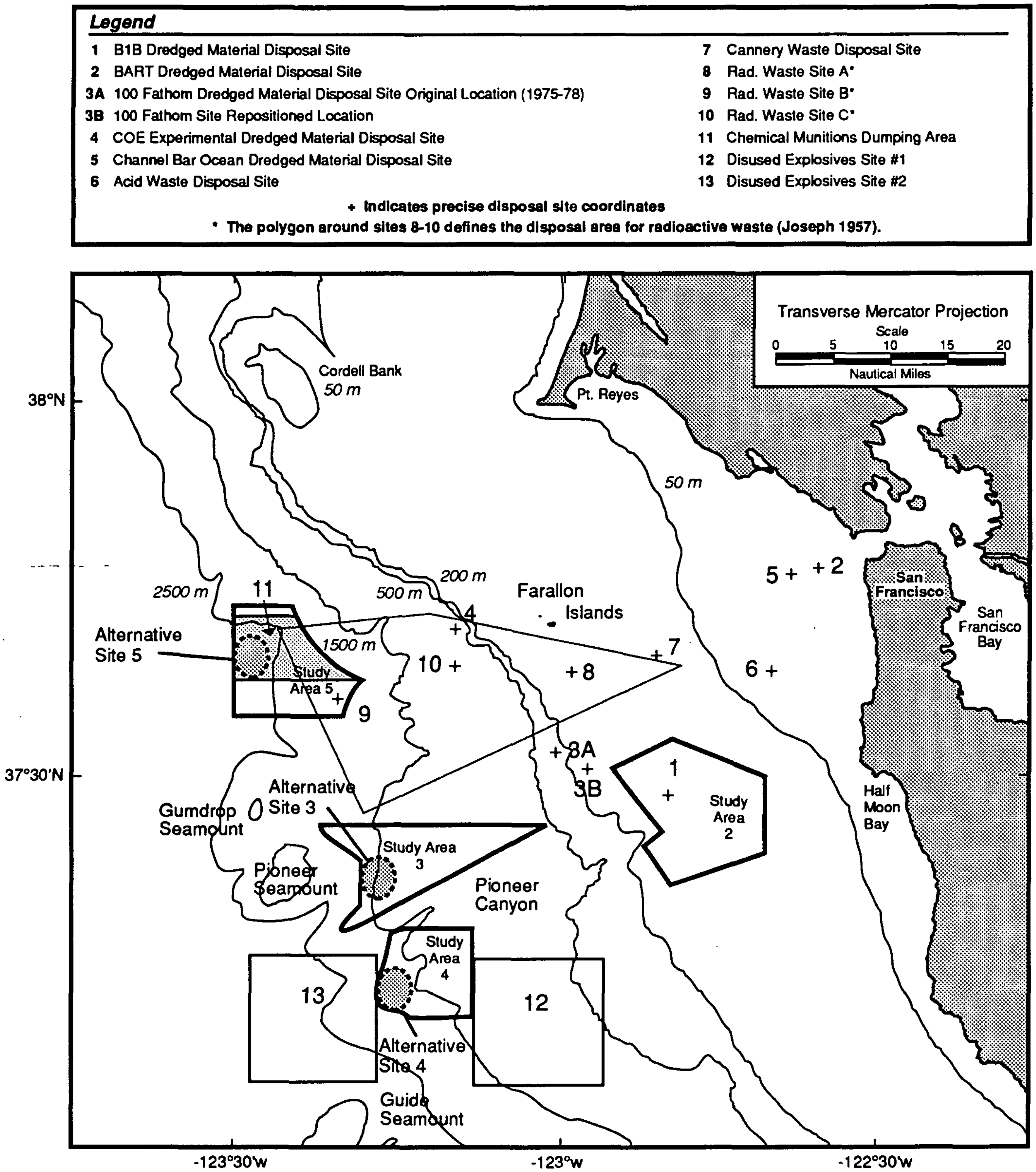

Figure 3.1-1. Locations of Previously Used Ocean Waste Disposal Sites Within the LTMS Study Region.

The 50m, 200m, 500m, 1,500m, and 2,500m contours correspond to the 28, 110, 275, 825, and 1,375 fathom contours, respectively.

Sources: IEC 1973; EPA 1975; Dyer 1976; NOAA 1980; MMS 1986; Delgado and Haller 1989; Colombo and Kendig 1990.

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entrance to San Francisco Bay, but because of differences in grain size is not designated for disposal of sediments from within the Bay. The historical uses of these sites for dredged material disposal are summarized in Table 3.1-1.

The B1B site, located within Study Area 2, was used between May 12 through 16, 1988 for disposal of 18,000 yd^3 (six hopper barge loads) of sediments from the Port of Oakland Harbor Deepening Project. Disposal operations at this site were enjoined due to a lawsuit and a State Court injunction (COE 1989). Additionally, the B1B site is located within the boundaries of the Monterey Bay National Marine Sanctuary (MBNMS).

The BART site received dredged material, primarily mud-sized sediments, generated during 1966 and 1967 from construction of the Trans-Bay Tube. The site was located inshore from the Channel Bar Site and 0.9–5.6 km from shore. The quantities of sediments generated from this project were estimated to be 2.3 million yd^3 (Ebert and Cordier 1966). However, the site also is located near the boundaries of the MBNMS.

The 100-Fathom site was used in 1975 for disposal of an unspecified volume of material from Oakland Harbor that was considered too contaminated for disposal within the Bay (COE 1989). An additional 20,000 yd^3 and 60,000 yd^3 of muds from Oakland Inner and Outer Harbors were reportedly discharged at this site in 1977 and 1978, respectively (EPA 1982). The site was then moved five kilometers closer to shore to allow radar surveillance of the disposal operations. However, there is no record that the new site was ever used for dredged material disposal. The site was canceled in 1983 upon establishment of the GOFNMS (48 FR 5558, February 7, 1983).

The COE experimental site was located approximately 20 km northwest of the 100-Fathom site. The experimental site was used in 1974 for a test disposal of 4,000 yd^3 of muddy sediment from San Francisco Bay (COE 1975). The purpose of the test was to provide a qualitative description of the general dispersion of dredged material disposed at the continental shelf break. Post-disposal monitoring determined the amount of dredged material successfully placed at the site. This new location was selected to avoid interactions with previous disposal operations at the

Table 3.1-1. Summary of Dredged Material Disposal Site Locations and Disposal Activities Within the LTMS Study Region.

SITE NAME	DEPTH (m)	DATE & DURATION OF USE	ESTIMATED VOLUME DISPOSED	LATITUDE, LONGITUDE
Channel Bar Site[1,2]	18.3	Maintenance Work (1959-present) New Projects (1972-1976) Total Maintenance (1976-present)	600,000 yd^3/yr 8,800,000 yd^3 9,079,533 yd^3	37°45'N, 122°36'W
BART Site[3]	20.1-25.6	1966-1967	2,300,000 yd^3	37°46.5'N, 122°32.5'W
100 Fathom Original Location[1,4]	183	1975 1977 1978	unknown 20,000 yd^3 60,000 yd^3	37°32'N, 122°59'W
100 Fathom Repositioned Location[4]	183	unknown	unknown	37°31'N, 122°57'W
COE Test Site[5]	183	1974	4,000 yd^3	37°41'N, 123°7.5'W
B1B[4]	69.5-87.8	1988	18,000 yd^3	37°29'N, 122°48'W

Sources:
[1] EPA 1982
[2] T. Bruch (COE), pers. comm. 1992
[3] Ebert and Cordier 1966
[4] COE 1989
[5] COE 1975

100-Fathom site that could compromise test results. Results from the post-disposal survey are described in COE (1975).

The Channel Bar Site has been used since 1959 for maintenance dredged material from the main San Francisco shipping channel. The original site was located 0.5 nmi south of the main ship channel (EPA 1982). In 1972, the site was moved from its original location to a site 1.0 nmi south of the main ship channel to reduce the possibility that discharged sediments could be transported back into the channel. Present channel maintenance programs generate approximately 900,000 cubic yards (yd^3) of dredged material per year which are disposed of at this site (T. Wakeman, COE, pers. comm. 1992). Estimated maintenance volumes (272,300 yd^3) from fiscal year 1991 were lower than anticipated due to drought conditions (T. Bruch, COE, pers. comm. 1992). In addition to maintenance dredging volumes, an estimated 8.8 million yd^3 from Phase I of the J.F. Baldwin Ship Channel project (D. Myers, COE, pers. comm. 1992) also were placed at the site between 1972 and 1976 (EPA 1982).

The general site selection criterion at 40 CFR 228.5(c) specifies that "EPA will, wherever feasible, designate ocean dumping sites ... that have been used historically." With the exception of the Channel Bar Site, historical use of the other dredged material sites was episodic, and none of them received final designation for continued disposal use for dredged material from San Francisco Bay. The Channel Bar Site is suitable for sandy material only, the BART site and the B1B site are within the boundaries of the MBNMS, and both of the COE experimental sites and the 100-Fathom site are within the GOFNMS. Therefore, none of the five historically used dredged material disposal sites in the LTMS study region remain under consideration as a potential alternative for designation as a permanent site for disposal of dredged material from San Francisco Bay. In recent years, due in part to the absence of an acceptable ocean disposal site, most dredged material disposal has occurred at sites within San Francisco Bay.

3.1.1.2 Other Waste Disposal

Other waste disposal operations have occurred since 1946 at several sites within the Gulf of the Farallones. However, it is difficult to identify and characterize all of the waste materials and the extent of the disposal operations because of:

- Lack of regulations at the time of some disposal events;
- Involvement of numerous agencies and organizations in some disposal operations;
- Generally poor record-keeping for many of these activities;
- Security classification of military operations; and
- Problems in monitoring the exact location of some disposal activities.

The types of waste materials disposed of in the vicinity of the Gulf of the Farallones include the following (IEC 1973):

- Acid waste
- Cannery waste
- Low-level radioactive waste
- Conventional and chemical munitions
- Refinery waste
- Vessels and dry dock materials.

These historical waste disposal operations are summarized in Table 3.1-2 and are described below. Estimated locations of disposal site areas are shown in Figure 3.1-1. Anecdotal information (Anon. 1980) suggests that some waste disposal occurred outside of intended sites due to operational problems (e.g., bad weather) or indiscriminate disposal practices. These historical waste disposal operations, including the presence of residual low-level radioactive wastes, chemical munitions, and vessel/dry dock sections within the vicinity of the LTMS study

Table 3.1-2. Summary of Waste Disposal in the LTMS Study Region.

Waste Category	Responsible Agency/Company	Period of Activity	Estimated Annual Quantity	Estimated Total	Latitude, Longitude
Acid waste[1]	USSC	1948 - 1971	10M gal	240M gal	37°38'N, 122°40'W
Cannery waste[1]	OSC	1961 - 1972	22,000 tons	246,000 tons	37°39'N, 122° 50'W
Radioactive waste[1,2]	AEC	1946 - 1965	varied	47,500 containers	See Table 3.1-3
Munitions[1]	USN	1958 - 1969	varied	746 tons	See Table 3.1-4
Dredged material[3]	COE	1976 - Present	900,000 yd^3	9,079,533 yd^3	See Table 3.1-1
Refinery waste[1]	Standard Oil, Shell Oil	1966 - 1972	$\geq$ 45M gal	315M gal	Three generalized locations: approximately 5 miles offshore; 1-3 miles west of the Gulf of the Farallones; and 50-100 miles from shore.
Vessels and drydock materials[4]	See Table 3.1-5	1951-1987	varied	unknown	See Table 3.1-5

USSC = United States Steel Company
OSC = Oakland Scavenger Company
AEC = Atomic Energy Commission
USN = United States Navy
COE = United States Army Corps of Engineers

Sources:
[1]IEC 1973
[2]EPA 1975, Dyer 1976
[3]T. Wakeman, T. Bruch, COE, pers. comm. 1992
[4]P. Cotter, EPA, pers. comm. 1991

areas, represent a possibility for cumulative environmental effects in combination with proposed dredged material disposal operations.

3.1.1.3 Acid Waste

Between 1948 and 1971, the United States Steel Corporation (USSC) annually discharged approximately 10 million gallons of steel pickling waste acids (hydrochloric and sulfuric acids) in an area located approximately 22.5 km southwest of the Golden Gate Bridge, 14.5 km offshore, at a water depth of approximately 40 m (IEC 1973). Exact coordinates for the disposal area are unknown due to erroneous documentation of these disposal activities. However, the site coordinates have been estimated based on reported distances from the Golden Gate Bridge and from shore (IEC 1973) (Table 3.1-2).

3.1.1.4 Cannery Wastes

Cannery wastes generated by six East Bay fruit and vegetable canneries were disposed of 32.2 km offshore of San Francisco at depths of approximately 80 m. These wastes consisted of solid residuals (i.e., fruit and vegetable pulp) from canning processes. Estimated weights of 22,000 tons per year were discharged from 1961 to 1972, at which time concerns over increased costs, monitoring requirements, and environmental issues led to termination of further disposal activities (IEC 1973).

3.1.1.5 Radioactive Waste

Disposal of low-level radioactive waste materials off the coast of San Francisco occurred between 1946 and 1965. Waste materials originated from several agencies and organizations including: Nuclear Engineering Company; Ocean Transport Company; Chevron Research; U.S. Naval Radiation Development Laboratory; Atomic Energy Commission; University of California Radiation Laboratory at Berkeley; and Lawrence Livermore Radiation Laboratory (IEC 1974; U.S. Army 1987; Colombo and Kendig 1990). Waste disposal operations were performed by the

U.S. Navy until 1959. After 1959, disposal was conducted by private disposal companies under a license from the Atomic Energy Commission (Colombo and Kendig 1990).

At least three different radioactive waste disposal site locations have been identified. The reported site coordinates and quantities of wastes are listed in Table 3.1-3. Exact coordinates of the actual disposal events are unknown; Joseph (1957) suggested that the disposal area can be defined as an irregular polygon bounded by the coordinates 37° 26'N to 37° 43'N and 122° 48'W to 123° 25'W, representing an area exceeding 650 square kilometers (Figure 3.1-1).

Radioactive Waste Site A was used briefly in 1946 for disposal of three barge-loads (an estimated 150 containers) of material. This site was occupied because the orders supplied to the disposal vessel operators contained a typographical error (IEC 1973). Radioactive Waste Site B was used between late 1946 and 1951 and from 1954 to 1965. Radioactive Waste Site C was used between 1951 and 1954. The majority of the wastes (approximately 44,000 containers) was discharged at Site B. The reason(s) for switching to Site C is unknown, although the concurrent use of Site B for the disposal of chemical munitions waste and the greater distance from shore probably were contributing factors (Colombo and Kendig 1990). Isolated disposal of low-level radioactive wastes also may have occurred closer to shore, due primarily to inclement weather (IEC 1974). Ocean disposal of radioactive wastes was discontinued around 1965 when land disposal sites were licensed to receive the wastes. In 1970, the U.S. terminated all ocean disposal of radioactive waste materials (EPA 1992a).

It is not possible to determine accurately the amounts of low-level radioactive wastes disposed of by these operations because the characteristics of the waste materials and associated radioactivity were poorly documented. Nevertheless, the total quantity of radioactive waste materials disposed of at these sites was estimated at 44,500 to 47,500 containers. The wastes represented a mix of liquid and solid materials, with a wide variety of chemical and physical properties, generated from defense-related, commercial, and medical laboratory activities. The low-level solid wastes included contaminated laboratory equipment and supplies, clothing, rubber gloves, shoes, animal bones, and grease (U.S. Army 1987). Liquid wastes included evaporator

Table 3.1-3. Radioactive Waste Disposal Sites in the Gulf of the Farallones.

SITE	DEPTH (m)	NO. OF WASTE CONTAINERS	DURATION OF USE	LATITUDE, LONGITUDE
Rad. Waste Site A	90	150	1946	37° 38'N, 122° 58'W
Rad. Waste Site B	1,800	44,000	1946-51, 1954-65	37° 37'N, 123° 18'W
Rad. Waste Site C	900	3,600	1951-54	37° 39'N, 123° 09'W

Source: EPA 1975, Dyer 1976

concentrates, solvents, and aqueous solutions (Colombo and Kendig 1990). The wastes contained an estimated total activity of 14,500 curies, primarily associated with thorium, uranium, transuranic and other activation-produced radionuclides, and mixed fission products with half-lives greater than one year (Colombo and Kendig 1990).

The radioactive waste materials were packaged prior to disposal, typically by "encapsulation in concrete" within 55-gallon (210 liter) drums or in large (1.5x2x2.5 m), steel-reinforced, concrete "vaults." Beginning in 1951–1952, the waste containers incorporated a wire-rope or steel bar lifting eye. The ends of the wire rope or steel bar were encased in the concrete end caps, and the exposed portions were shaped into an eye or loop that could be used for lifting and handling the drums. This packaging method was useful for distinguishing and dating individual waste containers during subsequent site surveys. Reports from the post-disposal surveys at these disposal sites (e.g., IEC 1974; EPA 1975; Dyer 1976; Colombo and Kendig 1990) and the testimony of recreational divers, who encountered a package in relatively shallow waters (60 to 165 feet) near the Farallon Islands (Anon. 1980) indicate that the condition of the drums and vaults varied. Some containers were intact, whereas others had imploded, ruptured, or split. Thus, presumably some radioactive waste materials were not completely encapsulated because the packaging was compromised.

3.1.1.6 Chemical and Conventional Munitions Waste

Although there are numerous munitions disposal sites surrounding the Farallon Islands and in the Gulf of the Farallones, most aspects of the military's disposal operations remain classified. The U.S. Army has discharged both chemical and conventional munitions at offshore sites since the late 1950s (Table 3.1-4). From 1958 through 1969, the Army and Navy occupied several ocean sites off San Francisco for the purpose of munitions disposal (U.S. Army 1987). One of the sites used for waste munitions was near radioactive waste disposal Site B and within the present Study Area 5. Munitions waste discharges were made at this site through 1968 and 1969, usually by towing barges of one-ton containers and unloading the containers overboard. Two other munitions sites described as containing both explosive and toxic chemical ammunitions (MMS

Table 3.1-4. Summary of Munitions Discharges in the LTMS Study Region.

Operation	Year	Cargo	Total Cargo	Latitude, Longitude
S.S. WILLIAM RALSTON[1]	1958	M70 bombs (mustard) Containers (lewisite)	301,000 1,497	37°40'N, 125°00'W
SEA LION[1,2] (barge)	1958	M47 bombs (mustard) Containers (lewisite) Containers (mustard) Projectiles (mustard)	6 335 11 2	37°40'N, 125°00'W
S.S. JOHN F. SHAFROTH[3]	1964	40 mm ammunition cartridges Unspecified bombs Torpedo warheads Unspecified mines Unspecified projectiles Fuses, detonators Polaris boosters Contaminated "cake-mix"	— — — — — — — 30,000 lb —	37°40'N, 123°25'W
Chemical Munitions Dumping Area (CMDA)[4]	1968-69	Conventional munitions	510 tons[5]	37°41'N, 123°25'W
Explosives[4] Site #1	NI	Explosive and toxic chemical ammunition	—	37°10'N, 123°03'W
Explosives[5] Site #2	NI	Explosive and toxic chemical ammunition	—	37°10'N, 123°23'W

(-) = Unknown quantity
NI = No information

Sources:
[1] U.S. Army 1988
[2] U.S. Army 1987
[3] EPA 1971
[4] NOAA Chart No. 18680 1984
[5] U.S. Navy 1992

1986) are located to the east and west of Study Area 4 (Figure 3.1-1). No additional information about these sites was available.

In 1958, the Army loaded 8,000 tons of aged mustard and lewisite chemical agents aboard the S.S. WILLIAM RALSTON, which then was towed to a site 190 km off San Francisco and scuttled at a depth of about 6,500 m. Five years later, the Army initiated the "CHASE" (Cut Holes And Sink 'Em) program, similar to the earlier sinking of the RALSTON. The CHASE program used obsolete World War II cargo ships to dispose of large amounts of old munitions at offshore sites. The ships were loaded with munitions, towed offshore, then sunk at deepwater sites (EPA 1971). Chemical weapons were disposed of during only four of the twelve CHASE operations, and none of the vessels were scuttled at any of the Gulf of the Farallones munitions disposal sites. However, the S.S. JOHN F. SHAFROTH, containing approximately 236 tons of explosives and ammunition, was scuttled approximately 30 km west of the Farallon Islands, within the boundaries of Study Area 5.

3.1.1.7 Refinery Waste

Standard Oil Company discharged approximately 45 million gallons of refinery waste annually from 1966 to 1972 in the vicinity of the Farallon Islands (IEC 1973). Specific information on the chemical composition of the waste is not available, although it is likely that it consisted of solvents, petroleum by-products, and residual petroleum fractions. Similarly, specific coordinates for the waste disposal site were not identified. The "site" initially was listed as "at least five miles offshore" (IEC 1973), but then was relocated in 1970 to an area one to three miles beyond (i.e., to the west of) the Gulf of the Farallones. Refinery wastes also were discharged by Shell Oil Company until 1971, although no information on annual discharge volumes or disposal frequency is available. The discharge site was described as an area approximately 81 to 161 km offshore from San Francisco (IEC 1973).

3.1.1.8 Vessel and Dry Dock Sections

From 1951 to 1987, several damaged or derelict vessels and dry dock sections were disposed of in the LTMS study region. A summary of these disposal operations is presented in Table 3.1-5. Discarded items consisted primarily of metal or wooden hulls and associated equipment of the vessels and dry dock sections. As required by EPA Ocean Dumping Regulations issued in 1977 (40 CFR 229.3), the fuel and lube tanks, pipes, pumps, and bilges were emptied and flushed and the other equipment which potentially was capable of resurfacing was removed prior to sinking. Therefore, the environmental consequences of the majority of these vessel disposal operations are expected to be minimal.

In contrast, sinkings of the USS INDEPENDENCE and T/V PUERTO RICAN introduced potentially hazardous materials to the ocean environment. The hull of the USS INDEPENDENCE was characterized as a highly radioactive hulk after serving as a target vessel for the Bikini Atoll atomic bomb testing in 1946 (U.S. Navy 1968). The vessel was sunk in 1951 during further weapons testing at an unspecified location off the coast of California (U.S. Navy 1968). Recent side-scan sonar investigations in the Gulf of the Farallones have identified a structure believed to be the USS INDEPENDENCE at 37° 28.4'N, 123° 7.6'W (north of Study Area 3 and southeast of Study Area 5); positive verification has not yet been made (Karl 1992). The extent of any potential environmental impacts associated with the sinking of the USS INDEPENDENCE is unknown.

The T/V PUERTO RICAN was transporting 91,984 barrels of lubrication oil and 8,500 barrels of bunker fuel when an explosion and fire damaged the vessel approximately 13 km off the Golden Gate in October 1984. The disabled vessel was towed seaward to minimize potential impacts from leaking fuels to sensitive biological habitats within the GOFNMS. However, the vessel later broke into two sections, and the stern section, containing 8,500 barrels of oil, sank at a location approximately 25 km due south of South Farallon Island in a depth of approximately 450 m. The remains have been surveyed using side-scan sonar; and, as of 1989, oil continued to leak slowly from the vessel (Delgado and Haller 1989). Assessments of the environmental

Table 3.1-5. Summary of Vessel and Dry Dock Disposal in the Vicinity of the Gulf of the Farallones.

Date	Vessel/Dry Dock Origin and Responsible Agency/Company	Location	Comments
1951	USS INDEPENDENCE; U.S. Navy.[1]	37°28.4'N; 123°7.6'W (unconfirmed side scan sonar coordinates[2]).	Aircraft carrier whose hull was characterized as highly contaminated from radiation exposures during weapons testing; sunk during further weapons tests.
1980	4 tugboats/towing vessels (M/V SEA KING, M/V SEA PRINCE, M/V SEA ROBIN, M/V SEA CLOUD); Crowley Maritime Corporation.[3]	37°31.0'N; 122°52.0'W (approximately 12.5 miles SE of the Southeast Farallon Light, in approximately 94 m).	Four identical hulls (127' x 29'); vessels taken out of service.
1981	AGGATU; Crowley Maritime Corporation.[3]	37°31.0'N; 122°52.0'W (same location as the site used for disposal of 4 tugboats in 1980).	Rail barge (206' x 99') damaged in "casualty"; the hull was split into 2 sections.
1981	M/V ISLANDER; U.S. Coast Guard.[3]	37°30'N; 122°52.0'W	A vessel in immediate danger of sinking at the San Francisco Coast Guard Base, thus posing a threat to navigation.
1984	T/V PUERTO RICAN; U.S. Coast Guard/Carter and Desmares, Inc.[3]	37°30.6'N; 123°00.7'W	An oil and chemical carrier damaged by an explosion and fire while transporting lubrication oil and bunker oil. The stern section containing bunker oil sank in 450 m.
1985	YFD-19; Todd Shipyards Corporation.[3]	Five sections sunk within area: 37°34.9' - 37°37'N; 123°16.0' - 123°18'W.	Floating dry dock disposed as 77' x 144' sections; weighted with 600 tons of concrete and flooded at locations off the shelf (1,600 m).
1987	LADY ELEANOR; Valley Engineers.[3]	37°23.5'N; 122°53.1'W	Pontoon construction platform with crane (120' x 101' x 100'); scuttled/emergency disposal after capsizing off Half Moon Bay.

Sources: [1]U.S. Navy 1968
[2]Karl 1992
[3]P. Cotter, EPA, pers. comm. 1991

impacts associated with the oil spill were prepared by Herz and Kopec (1985), Robilliard (1985), PRBO (1985), and James Dobbins Associates, Inc. (1986).

3.1.1.9 Summary of Historical Disposal in Relation to the LTMS Study Areas

According to site selection general criteria, EPA will designate ocean dumping sites that have been used historically. A summary of historically used disposal sites indicates that limited dredged material disposal has occurred within Study Area 2 (B1B site), and radioactive and chemical munitions wastes were disposed of in Study Area 5. Study Area 4 lies between two sites previously designated for explosives disposal (Figure 3.1-1); disposal of dredged material within the explosives sites is not desirable. Historically used dredged material disposal sites such as the B1B, COE experimental, and 100-Fathom sites lie within designated National Marine Sanctuary boundaries and therefore cannot be considered for future disposal activities. Similarly, the Channel Bar Site (Study Area 1) is suitable for disposal of sandy materials only, and is not under consideration as an alternative site. Radioactive Waste Sites A, B, and C lie within the boundaries of the GOFNMS.

3.1.2 Types and Quantities of Wastes Proposed To Be Disposed of (40 CFR 228.6[a][4])

The proposed ODMDS will be used for disposal of acceptable sediments from projects in the San Francisco Bay area, including maintenance dredging and new construction projects. Presently planned projects are listed in Table 1.2-1. Site use is expected to extend for fifty years, beginning in 1994; the projected 50-year dredging volume would total 400 million $yards^3$ (COE 1992a). The COE (1991) estimated that six million $yards^3$ per year could be disposed of at the ODMDS. However, the specific volumes will depend on the characteristics of the dredged materials (evaluated on a project-specific basis), potential disposal restrictions in the site management plan, and the range of alternative disposal options developed by the LTMS (see Chapter 2).

The physical and chemical characteristics of the dredged materials planned for ocean disposal are expected to vary considerably depending on the locations of the dredging operations. The possible range in grain-size characteristics of the dredged material is expected to be broad, and specific grain sizes will vary on a project/site-specific basis (Tetra Tech 1992). However, the most prevalent sediment composites planned for disposal are expected to range between two grain size classes: "mostly sand" (76% sand, 21% clay, and 3% silt) and "silt-clay" (74% silt, 5% clay, and 21% sand) (Tetra Tech 1992). Dredged material will not be packaged prior to disposal.

The COE expects that an ODMDS could be used throughout the year, except when wave heights exceed 3 meters and wave periods are 9 seconds or less (approximately 10% of the time, typically from February through May; Tetra Tech 1987). However, seasonal restrictions on dredging activities imposed by biological events such as migration, spawning, and nesting activities may also affect the scheduling of ODMDS use. For example, the California Department of Fish and Game (CDFG) recommends that dredging activities within the Bay be restricted during peak herring spawning periods (December 1 to March 1) (J. Turner, CDFG, pers. comm. 1991). In addition, to ensure high survivorship of Dungeness crab juveniles that utilize the Bay as a nursery ground, CDFG recommends that suction dredging in parts of north San Francisco and San Pablo Bays be prohibited from May 1 to August 1. Mitigation of potential impacts from individual projects will be specified in permit conditions. Specific goals and objectives of the site management and monitoring plan will be published in the FEIS. The complete site management and monitoring plan will be prepared in conjunction with, and referenced in, the Final Rule and Coastal Consistency Determination for the site.

3.1.3 Existence and Effects of Current and Previous Discharge and Dumping in the Area (40 CFR 228.6[a][7])

As discussed in Section 3.1.1, four locations have been used previously for ocean disposal of sediments from San Francisco Bay. However, use of these ocean sites for dredged material disposal has been intermittent, and the disposal volumes have been relatively small (except for the BART site).

The nature and extent of post-disposal effects at these locations are unknown because no systematic baseline and post-disposal studies have been performed. A brief biological survey of an area adjacent to the BART site was conducted prior to disposal of dredged material from the BART construction project (Ebert and Cordier 1966); however, no post-disposal study was conducted. A series of baseline biological and sediment surveys, and a one-year current meter study were initiated at the B1B site before the disposal of Oakland Harbor dredged material (KLI 1991). However, no post-disposal effects studies were conducted at this site other than a continuation of the current meter study. With the exception of a brief qualitative study of the COE experimental site following a small test discharge of approximately 4,000 yd^3 of dredged material (COE 1975), no studies of the environmental impacts of dredged material disposal have been conducted at any of the offshore sites.

Similarly, studies of the environmental impacts from disposal of other waste materials in the vicinity of the Gulf of the Farallones generally have been limited to reconnaissance surveys of the radioactive waste disposal sites (e.g., EPA 1975, Dyer 1976; Noshkin *et al.* 1978; Dayal *et al.* 1979; Schell and Sugai 1980; Melzian *et al.* 1987; Booth *et al.* 1989; Suchanek and Lagunas-Solar 1991), and investigations of potential effects associated with the sinking of the T/V PUERTO RICAN (Robilliard 1985; PRBO 1985; Herz and Kopec 1985). Thus, the specific effects from these previous waste discharges are poorly known, although NOAA and EPA are presently evaluating environmental impacts from disposal of low-level radioactive waste material in the Gulf of the Farallones.

3.1.4 Feasibility of Surveillance and Monitoring (40 CFR 228.5[d] and 228.6[a][5])

3.1.4.1 Surveillance

The United States Coast Guard, EPA, and the COE are responsible for surveillance and enforcement of ocean disposal activities. This includes navigational surveillance and deterrence of unauthorized disposal.

The Coast Guard's marine radar, Offshore Vessel Movement Reporting System, has an operational range of approximately 45 km (27 nmi) from Point Bonita (i.e., the approximate distance to the Farallon Islands). Vessel visibility on the radar screen is affected by the size of the contact, vessel aspect, and weather. Thus, under conditions where distances are greater than 45 km or inclement weather prevails, vessels may not be visible continuously using the radar surveillance system. Portions of Study Area 2 and all of Study Areas 3 through 5 are greater than 45 km from Point Bonita. For these reasons, other methods of navigational surveillance, such as Ocean Dumping Surveillance System (ODSS)-like black boxes, overflights, navigation/operation log audits, or random checks by on-board ship riders would be necessary for surveillance at Alternative Sites 3 through 5.

3.1.4.2 Monitoring

The EPA and the COE are responsible for the development of a site management and monitoring plans for the ODMDS. The purposes of monitoring an offshore disposal site are to:

- Document compliance with all permit requirements;
- Confirm predictions of dredged material dispersion and resuspension; and
- Evaluate the ecological impacts and consequences of dredged material disposal.

Elements of a disposal site monitoring program may include evaluation of: sediment chemistry, demersal fisheries, benthic organisms, bathymetric conditions, bioaccumulation potential, and oceanographic conditions. A site monitoring plan designed to detect and minimize adverse impacts through appropriate management options, will be developed and referenced in the Final Rule and the Coastal Consistency Determination. The goals and objectives of the monitoring plan will be defined in the FEIS, following selection of the preferred alternative.

Assuming appropriate sampling equipment and survey vessels are available, as well as contingencies associated with inclement weather and sea conditions, it is expected that monitoring of environmental effects associated with dredged material disposal operations can be performed at any of the alternative sites. However, depending on specific monitoring requirements, some sites may be significantly more difficult to monitor, particularly for benthic impacts due to greater depths or residual contamination from historical waste disposal. Impacts to benthic communities at deeper sites may be more difficult to assess because less information about benthic community structure and disturbance response is available.

3.2 Physical Environment

This section addresses the physical characteristics of the affected environment: meteorology and air quality (Section 3.2.1); physical oceanography (Section 3.2.2); water column characteristics (Section 3.2.3); geology (Section 3.2.4); and sediment characteristics (Section 3.2.5). These characteristics are addressed in the general and site-specific criteria applied to evaluations of project alternatives Section 2.2.

3.2.1 Meteorology and Air Quality

The primary meteorological and air quality parameters relevant to ODMDS designation are the regional climate, winds, and air quality in the vicinity of the alternative sites.

The coastal environment off San Francisco has a maritime climate characterized by a general lack of weather extremes (Reeves *et al.* 1981), with cool summers and mild, wet winters. The area has experienced drought conditions for at least five years through 1991, which has reduced the frequency and amount of seasonal rainfall. Weather conditions are most stable in summer and autumn, with moderate but persistent winds diminishing to calmer conditions through the mid-autumn period. Variable weather conditions occur during winter when series of storms produce strong winds and high seas in the Gulf of the Farallones. Spring has fewer frontal rainstorms and less extreme conditions, but it usually is the windiest period of the year. Typical meteorological conditions for the coastal area off San Francisco are summarized in Table 3.2-1.

Fog occurs off the coast throughout the year, but it is most persistent during summer. Upwelling in the waters off San Francisco tends to cool the warm, moist air masses moving eastward and results in the formation of fog off the coast. The presence of fog often reduces visibility; for example, the visibility at Southeast Farallon Island is less than 3 km 24% of the time in July, compared to 11% of the time in January (Reeves *et al.* 1981).

Winds are an important influence on water column characteristics and currents over the continental shelf and upper continental slope (Winant *et al.* 1987). For example, the strong north to northwest winds in spring and early summer promote offshore-directed flow of surface waters and upwelling of cool, saline, nutrient-rich waters along the coast. Relaxation periods of weak or calm winds can result in reversals in the surface currents (Halliwell and Allen 1987). The wind field in the region exhibits a seasonal cycle. Summer winds are driven by the pressure gradients of the North Pacific subtropical high pressure and southwestern U.S. thermal low pressure systems (Halliwell and Allen 1987). Coastal atmospheric boundary layer processes modify the wind patterns within 100–200 km of the coast such that wind fluctuations are strongly polarized in directions parallel to the coastline. The cross-shelf component of the winds in the region is weak (Chelton *et al.* 1987). The mean summer winds have an equatorward alongshore component that is relatively strong (approximately 20 knots) along the California coast (Halliwell and Allen 1987). The strongest equatorward winds occur in April and May (Chelton *et al.* 1987). Fluctuations in the winter winds exhibit greater spatial and temporal variability than that which occurs during summer (Halliwell and Allen 1987). The relatively greater variability in the winter winds is due to the passage of atmospheric cyclones and anticyclones moving onshore from over

Table 3.2-1. Meteorological Conditions for the Coastal Area off San Francisco.

Weather Elements	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Wind ≥ 34 knots (%)	1.5	2.5	1.9	2.4	2.5	1.9	0.8	≤ 0.5	1.1	1.7	1.4	2.7	1.7
Wave Height ≥ 10 feet (%)	15.6	13.1	16.4	22.2	18.3	8.7	7.9	4.9	6.2	10.7	14.9	16.0	12.5
Precipitation (%)	9.9	6.9	7.6	4.5	3.2	3.5	3.2	2.7	2.4	2.9	5.4	8.0	4.9
Temperature ≥ 29°C (%)	0	0	0	0	0	0	0	0	0	0	0	0	0
Mean Temperature (°C)	11.7	11.9	11.8	12.0	12.9	14.0	14.8	15.6	16.0	15.4	14.2	13.0	13.7
Temperature ≤ 0°C (%)	0	0	0	0	0	0	0	0	0	0	0	0	0
Mean Relative Humidity (%)	82	82	80	81	82	86	87	88	86	84	83	81	84
Sky Overcast or Obscured (%)	33.2	29.4	28.2	28.9	32.5	37.3	54.3	45.1	34.0	29.2	27.7	28.3	34.5
Mean Cloud Cover (eighths)	4.9	4.6	4.7	4.5	4.7	4.6	5.4	4.9	4.3	3.3	4.5	4.5	4.6
Prevailing Wind Direction	NNW	NNW	NW	NNW	NNW	NW	NNW	NW	NNW	NNW	NNW	NNW	NNW

Boundaries: Between 36°N and 38°N, and from 126°W eastward to coast. These data are based on observations made by ships in passage, and biased towards good weather observations.
Source: U.S. Coast Pilot #7, 1976.

the Pacific Ocean. Storm-driven winds occur approximately 2% of the time with average velocities of approximately 14 m/sec (35 knots; Table 3.2-1).

Recent (1991) wind measurements from four National Data Buoy Center (NDBC) buoys off central California—Bodega Bay (38.2°N, 123.3°W), Gulf of the Farallones (37.8°N, 122.7°W), Halfmoon Bay (37.4°N, 122.7°W), and Monterey Bay (36.8°N, 122.4°W)—were analyzed by Ramp *et al.* (1992). The surface wind vectors for 1991 (Figure 3.2-1) indicated distinct seasonal patterns. From January through early April, the winds were variable in both speed and direction. During the summer months, upwelling-favorable, northwest winds of 10 to 15 m/sec predominated. Winds during autumn were still mainly equatorward, but weaker than those during summer. Some wind reversals occurred, but they usually were weak and lasted only one day. After the beginning of November, winter conditions were similar to those in the beginning of the year, with strong, frequent reversals (Noble and Ramp 1992).

The large-scale wind patterns were similar at the four buoy locations; however, some small-scale differences were apparent that reflect potentially important variations in the mesoscale forcing to the coastal ocean. In particular, the winds measured in the Gulf of the Farallones tended to be weaker and directed more in an eastward direction than the winds to the north and south (Ramp *et al.* 1992). These differences have implications for the location and intensity of upwelling and the subsequent advection of upwelled water along the coast (Schwing *et al.* 1991; see Section 3.2.2).

The air quality in most of central California is considered good. Annual summaries of air pollutants at selected stations in the central San Francisco Bay Area and listings of the corresponding National and California standards are presented in Table 3.2-2. During 1988–1991, concentrations of ozone, carbon monoxide (CO), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2) typically were below the National and California standards, whereas, concentrations of particulate matter (PM) in San Francisco exceeded the California standard up to 15 days per year. Air pollutants were not monitored in the vicinity of the Gulf of the Farallones (M. Basso, BAAQMD, pers. comm. 1992). However, because the offshore regions including Study Areas

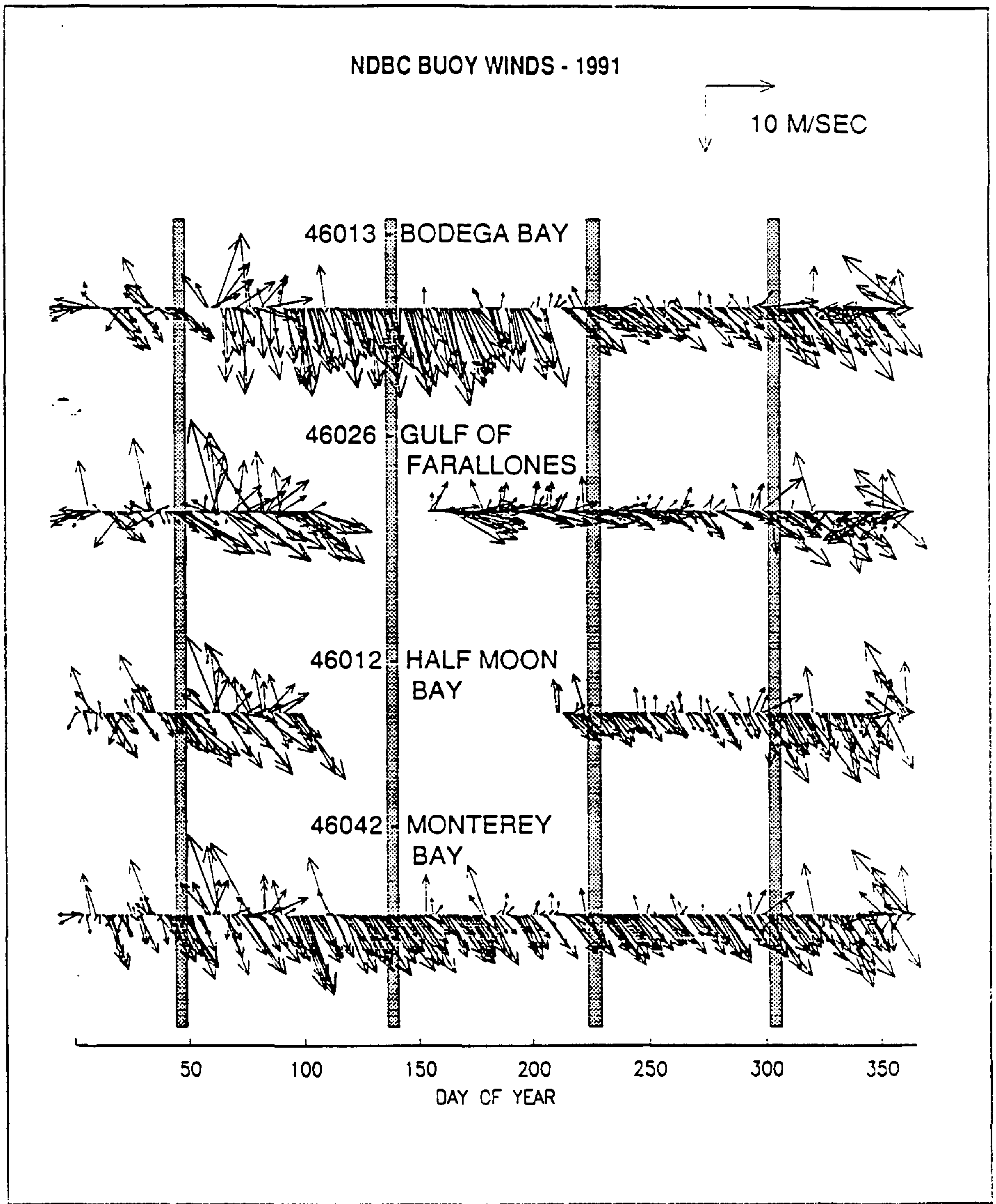

Figure 3.2-1. Surface Wind Vectors at Four NDBC Buoys in the Vicinity of the Gulf of the Farallones During 1991.
Source: Ramp *et al.* 1992.

Table 3.2-2. **A. Annual Air Pollutant Summary for Central San Francisco Bay Stations During 1988–1991; and B. California and National Standards for Individual Pollutants.**

The units and standards for pollutants are described in the Explanatory Notes.

A. Annual Air Pollutant Summary													
	OZONE				CO		NO_2		SO_2		PM_{10}		
Year/Station	Max. Hr.	National Std.	California Std.	3-Yr. Avg.	Max. 8-Hr.	Days National Std.	Max. Hr.	Days California Std.	Max 24-Hr.	Days California Std.	Annual Mean	Days National Std.	California Std.
1991													
San Francisco	5	0	0	0.0	6.5	0	10	0	13	0	29.6	0	15
San Rafael	8	0	0	0.0	5.6	0	9	0	-	-	26.4	0	10
Richmond	5	0	0	0.0	4.6	0	8	0	16	0	24.4	0	9
Oakland	6	0	0	0.0	6.8	0	-	-	-	-	-	-	-
1990													
San Francisco	6	0	0	0.0	5.6	0	11	0	11	0	27.7	1	12
San Rafael	6	0	0	0.0	5.0	0	7	0	-	-	22.5	0	4
Richmond	6	0	0	0.0	4.0	0	8	0	12	0	22.9	0	5
Oakland	6	0	0	0.0	6.1	0	-	0	-	-	-	-	-
1989													
San Francisco	8	0	0	0.0	7.0	0	12	0	15	0	31.8	0	13
San Rafael	8	0	0	0.0	4.0	0	10	0	-	-	27.3	0	8
Richmond	10	0	1	0.0	4.1	0	11	0	14	0	-	-	5
Oakland	8	0	0	0.0	7.5	0	-	-	-	-	-	-	-

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Table 3.2-2. Continued.

A. Annual Air Pollutant Summary														
	OZONE				CO		NO_2		SO_2		PM_{10}			
Year/Station	Max. Hr.	National Std.	California Std.	3-Yr. Avg.	Max. 8-Hr.	Days National Std.	Max. Hr.	Days California Std.	Max 24-Hr.	Days California Std.	Annual Mean	Days National Std.	California Std.
1988													
San Francisco	9	0	0	0.0	12.8	1	12	0	12	0	29.7	0	7
San Rafael	10	0	1	0.0	5.0	0	9	0	7	0	27.6	0	2
Richmond	10	0	2	0.0	5.0	0	11	0	7	0	-	-	-
Oakland	10	0	1	0.0	6.0	0	-	-	-	-	-	-	-

Table 3.2-2. Continued.

B. California and National Standards			
Pollutant	Averaging Time	California Standard	National Standard
Ozone	1 hour	9 pphm	12 pphm
CO	8 hours	9 ppm	9 ppm
	1 hour	20 ppm	35 ppm
NO_2	Annual Avg.	-	5.3 pphm
	1 hour	25 pphm	-
SO_2	Annual Avg.	-	30 ppb
	24 hours	50 ppb	140 ppb
PM	Annual Avg.	30 $\mu g/m^3$	50 $\mu g/m^3$
	24 hours	50 $\mu g/m^3$	150 $\mu g/m$

Explanatory Notes

The units for the maximums and means in the summary table are in parts per hundred million (pphm) for ozone and nitrogen dioxide, parts per million (ppm) for carbon monoxide, parts per billion (ppb) for sulfur dioxide, and micrograms per cubic meter ($\mu g/m^3$) for suspended particulate matter (PM_{10}). "Days" columns give the number of days per year on which an air quality standard was exceeded: National for CO; California for NO_2 and SO_2; and both for Ozone and PM_{10}. The California and National standards vary sharply for ozone and PM_{10}; the California standards are 25% more stringent on ozone and 67% more stringent on 24-hour suspended particulate matter (PM_{10}).

Generally, the particulate measurements are taken on the National systematic 6-day schedule. The 6-day occurrences are reported for days exceeding the California 24-hour standards.

Source: BAAQMD 1988, 1989, 1990, 1991

2, 3, 4 and 5 are upwind from the urbanized areas of San Francisco Bay (Holzworth 1959), the study areas are expected to have relatively lower concentrations of air pollutants than those measured at stations around the central parts of the Bay.

3.2.2 Physical Oceanography 40 CFR 228.6(a)(6)

Physical oceanographic parameters that are important for evaluation of an ODMDS designation are regional and site-specific current patterns, waves, and tides, and the effects of these forces on the transport and dispersion of dredged material. In particular, site-specific current measurements in the vicinity of the alternative sites are used to evaluate the predicted dispersion in the water column, and initial deposition on the seafloor, of dredged material discharged at these sites (Sections 4.2 and 4.4). In this section, the regional current patterns are characterized from historical data, followed by a summary of the results from recent, EPA-sponsored studies of the currents within the LTMS study region.

3.2.2.1 Regional Current Patterns

The LTMS study areas are located within the California Current system, an eastern boundary current that forms the eastern portion of the North Pacific subtropical gyre. The seasonal patterns in the large-scale surface (upper 250 m) currents generally are divided into two seasons: an upwelling period from March to August; and the winter or Davidson Current period from October to February. September is a transition month and may be more like one season or the other depending on the year being studied. The spring and summer upwelling season is characterized by fluctuating flows with a net southward component. During October through November and February through March, nearshore flows over the shelf and upper slope south of Cape Mendocino move northward against weak, northerly, prevailing winds. At the same time, the southward flow of the California Current weakens and moves offshore. Winter is a period of storms that can produce large, storm-generated surface waves and strong fluctuating currents that can last for 2 to 10 days. During any particular month, the flow pattern may differ significantly from the seasonal mean conditions. Much of this variability is attributable to small-scale features (e.g., eddies and filaments) with short time scales and interannual variability with large spatial and temporal scales (Chelton *et al.* 1987).

The California Current is a broad surface flow approximately 100 to 1,000 km from shore. This current is driven primarily by wind stress over the North Pacific Ocean, and it transports cold, low salinity, subarctic waters. The expected mean flow in the upper few hundred meters is equatorward (i.e., towards the southeast) at speeds less than 10 cm/sec. Satellite-tracked drifter observations (Brink *et al.* 1991) show slow, equatorward movement of surface waters that is superimposed on an energetic mesoscale eddy field, displacing the flow 200 to 400 km to the east and west as it moves slowly towards the south.

Within the California Current system are two poleward flows: the Coastal Countercurrent and the California Undercurrent (Hickey 1979; Chelton 1984; Neshyba *et al.* 1989). The Coastal Countercurrent flows northward over the continental shelf, inshore from the California Current. The countercurrent typically is only 10 to 20 km wide, with velocities less than 30 cm/sec (Kosro 1987). It is broader and stronger in the winter (October through early March), when it occasionally covers the entire continental shelf and is referred to as the Davidson Current; however, it remains strongest nearshore (Huyer *et al.* 1978). The Coastal Countercurrent has been observed both north and south of the study region. Observations north of the Gulf of the Farallones were made by the Coastal Ocean Dynamics Experiment (CODE; Lentz 1991) during 1981–1982 along a relatively straight stretch of coast between Point Arena and Point Reyes, California. During the upwelling season, the countercurrent appeared whenever equatorward, upwelling-favorable winds relaxed and disappeared when the winds were unusually strong (Send *et al.* 1987; Winant *et al.* 1987).

The California Undercurrent is a strong poleward flow over the slope. This current has been observed off southern California (Lynn and Simpson 1990), Point Conception and Point Sur (Chelton *et al.* 1988; Tisch *et al.* 1991), Northern California (Freitag and Halpern 1981), Oregon (Huyer *et al.* 1984; Huyer and Smith 1985), Washington (Hickey 1979), and Vancouver Island, British Columbia (Freeland *et al.* 1984). The position, strength, and core velocity of the undercurrent vary spatially and at different times of the year, although a maximum poleward velocity of around 30 cm/sec typically occurs between 150 to 300 m depth in slope waters 500 to 1,000 m deep.

All the currents described above are mean flows that are fairly steady over periods of many months. However, the characteristics of the mean flows are subject to considerable interannual variability. El Niño/Southern Oscillation (ENSO) events can alter the mean current field on a year-to-year basis; evidence from the tropical Pacific indicates that 1991–1992 was an ENSO year. ENSO events can cause anomalous atmospheric conditions and anomolous oceanic conditions in the northeast Pacific. Weakened equatorward or poleward winds may cause weakened upwelling and onshore transport, which leads to warmer than usual water temperature. The ENSO events also can produce very low frequency wave motions at low latitudes which then propagate poleward into the northern hemisphere along the continental shelf and slope. Huyer and Smith (1985) showed that the northward flow over the continental shelf was twice as strong during the El Niño winter of 1982–83 than during the preceding and subsequent "normal" years.

A basic feature of the circulation along the entire central coast is coastal upwelling, which causes continental shelf water to exchange with slope water. An "upwelling front" forms between the upwelled water and the warmer, less dense water further offshore. North of Cape Blanco, Oregon, the upwelling front is fairly straight along the coast, but to the south, large meanders develop and form "cold filaments" of freshly upwelled water that can extend more than 200 km offshore. Filaments are observed most commonly near coastal promontories such as Cape Mendocino, Point Arena, Point Reyes, and Point Sur. The Point Arena filament was observed in six different surveys during July and August 1988 (Huyer *et al.* 1991). Offshore velocities along the northern side of the filament approached 100 cm/sec (2 knots), which is far greater than the large scale mean flow towards the south. The Point Reyes filament is less studied and less well understood, but it is expected that large cross-shore transport is associated with the Point

Reyes feature as well, which potentially can affect suspended particle transport in the vicinity of the alternative sites. Because the filaments are associated with upwelling, they are not commonly seen during winter.

Mixed semidiurnal tides occur on the west coast in the vicinity of San Francisco. The strongest tidal current component is either the principal lunar or the luni-solar diurnal tide, which have periods of 12.4 hours and 23.9 hours, respectively. Diurnal tides are strongest on the shelf in the Gulf of the Farallones (Noble and Gelfenbaum 1990), with tidal amplitudes between 6 and 9 cm/sec. Lunar tidal currents are strongest on the slope adjacent to the Gulf of the Farallones, with amplitudes from 2.3 to 4.4 cm/sec near Study Area 5 (Noble 1990). Semidiurnal and diurnal tides together account for 35 to 60% of the total variability in the current records on the shelf, and from 15 to 33% of the variability on the slope. These tidal currents may promote the resuspension of material deposited on the seabed and dispersion of material suspended in the water column.

Wave observations at a buoy 7 nmi southwest of the Golden Gate Bridge (37.62°N; 122.95°W) are summarized by wave period and wave height in Table 3.2-3. Bottom current motions associated with large, storm waves can affect scouring and resuspension of sediments, particularly on the continental shelf. Also, severe wave conditions (heights greater than 3 m with periods less than 11.7 seconds or wave heights greater than 5 m) can limit or restrict dredged material barge transit to the alternative sites (Section 3.1.2; Tetra Tech 1987).

3.2.2.2 Study Region-Specific Currents

Beginning in 1991, EPA sponsored a one-year study of the circulation in the Gulf of the Farallones and over the adjacent continental slope to develop a better understanding of the physical processes and support predictive modeling of the deposition and fate of dredged material at the LTMS study areas (see Section 4.4). The following, modified from Noble and Ramp (1992), summarizes the information relative to the study area locations.

Table 3.2-3. Wave Observations (Percent Occurrence) Based on U.S. Army Corp of Engineers (COE) Wave Data at Station 20 (Dates Unspecified), Located Approximately 7 nm southwest of the Golden Gate Bridge, San Francisco, California. Bold numbers represent percentage of total observations exceeding criteria (1) wave heights exceed three meters (9.8 ft.) and wave periods are less than 11.7 seconds; and (2) wave height exceeds 5 meters (16.4 ft.) regardless of wave period.

Wave Height (m)	Wave Period (seconds)								
	4.4-6.0	6.1-8.0	8.1-9.5	9.6-10.5	10.6-11.7	11.8-13.3	13.4-15.3	15.4-18.1	18.2-22.2
0-0.9	0.16	0.49	0.52	0.03	0.01	0.01	0.00	0.00	0.00
1.0-1.9	1.73	3.97	8.56	5.35	2.68	0.72	0.04	0.06	0.00
2.0-2.9	2.04	2.71	4.76	7.14	11.01	7.84	1.26	0.10	0.02
3.0-3.9	**0.05**	**0.96**	**1.15**	**1.07**	**3.89**	11.14	4.84	0.35	0.00
4.0-4.9	0.00	**0.17**	**0.46**	**0.32**	**0.58**	3.35	5.48	0.56	0.00
5.0-5.9	0.00	0.00	**0.09**	**0.13**	**0.21**	**0.39**	**1.81**	**0.80**	0.00
6.0-6.9	0.00	0.00	0.00	**0.01**	**0.03**	**0.03**	**0.29**	**0.44**	0.00
7.0-7.9	0.00	0.00	0.00	0.00	0.00	0.00	**0.04**	**0.09**	0.00
8.0-8.9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.04**	0.00
9.0-9.9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.01**	0.00
10.0+	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL%	3.97	8.31	15.54	14.06	18.41	23.48	13.76	2.46	0.02

Source: Modified from COE (1987).

The EPA study included a main line of the moorings, which contained Stations A through D, to monitor the changes with water depth in the physical oceanographic parameters (Figure 3.2-2). Changes in water depth typically cause the largest spatial gradients in the circulation and sediment transport pathways. Station A was on the shelf in 92 m of water, Station B was on the upper slope in 400 m between Study Areas 2 and 3, and Stations C and D were on the mid- and lower-slope at depths of 800 m and 1,400 m adjacent to the southern boundary of Study Area 3. Stations E and F represented a secondary mooring line in the array. Station E was located along the eastern edge of Study Area 5, and Station F was shoreward of Study Area 5. Data from these moorings were used to determine how the circulation patterns change with distance along the isobaths. Each mooring in the array had between three to six instruments that measured current speed, direction, and temperature at specific locations in the water column (Noble and Ramp 1992).

3.2.2.3 Outer Shelf (Study Area 2) Currents

Currents over the outer shelf were measured at Station A, located within Study Area 2 (Figure 3.2-3). Evaluations of currents at Site A are obscured by gaps in the data, but the available data suggest a vertically coherent flow during the first half of the year. Fluctuations in the alongshore component were quite similar and nearly uniform in magnitude with depth, weakening only slightly towards the bottom. There was a tendency for the along-isobath flow at mid-depth to veer toward the coast. The average mid-depth, cross-shelf flow had a mean speed of 2.4 cm/sec. However, shoreward flow was not observed near the surface or 12 m above the seabed.

Tidal currents were the other strong component of the currents measured over the shelf. The principal diurnal tides and the principal semidiurnal tides each can have speeds of 8 to 9 cm/sec (Kinoshita *et al.* 1992). Hence, the tidal and lower frequency (subtidal) currents can combine to generate strong currents. Maximum current speeds over the shelf ranged between 40 to 60 cm/sec, and the maximum speed near the seabed was 47 cm/sec. These currents would be strong enough to move fine sand (see Section 3.2.4.2).

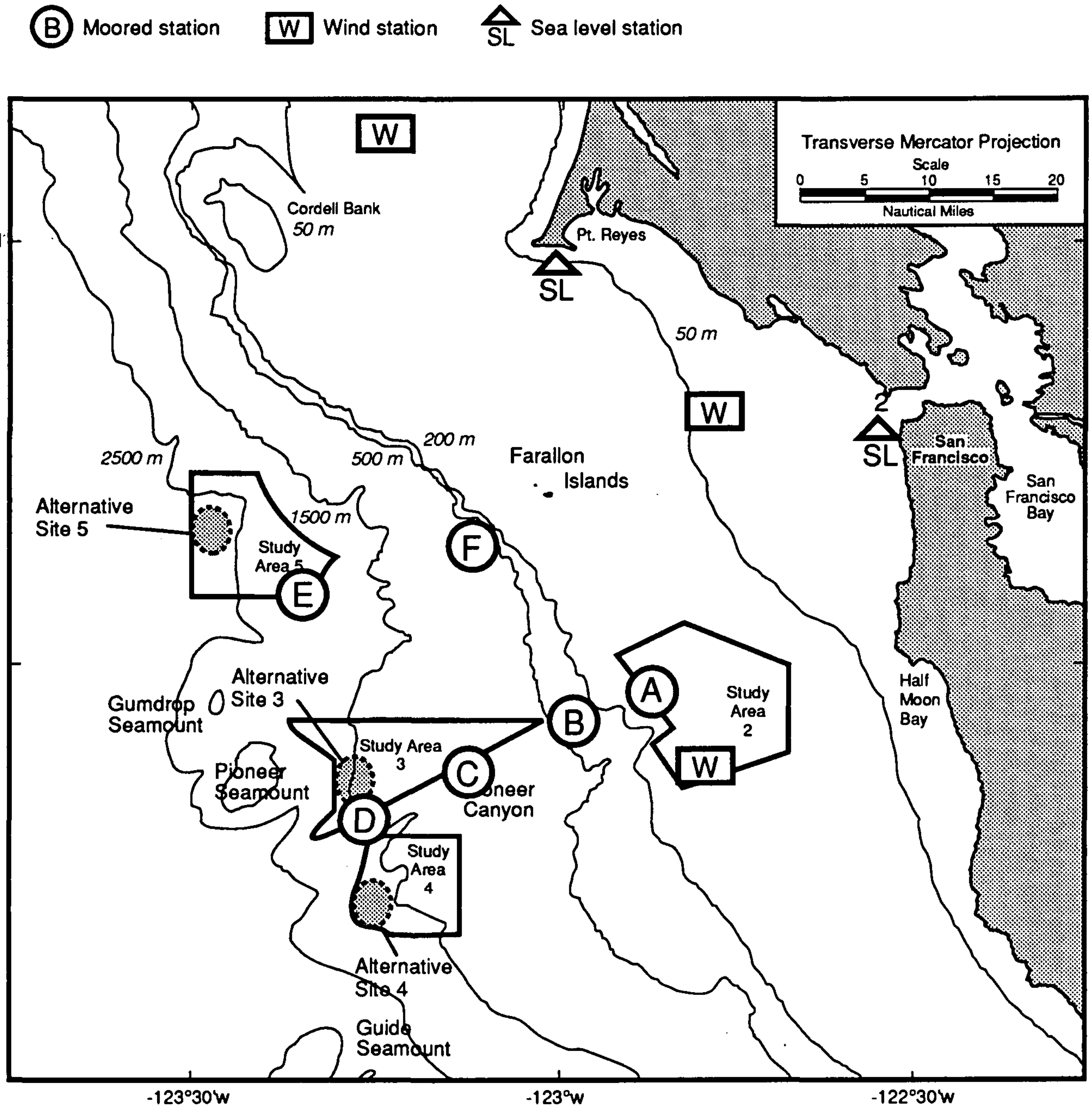

Figure 3.2-2. **Locations of Current Meter Stations A Through F.**
Source: Noble and Ramp 1992.

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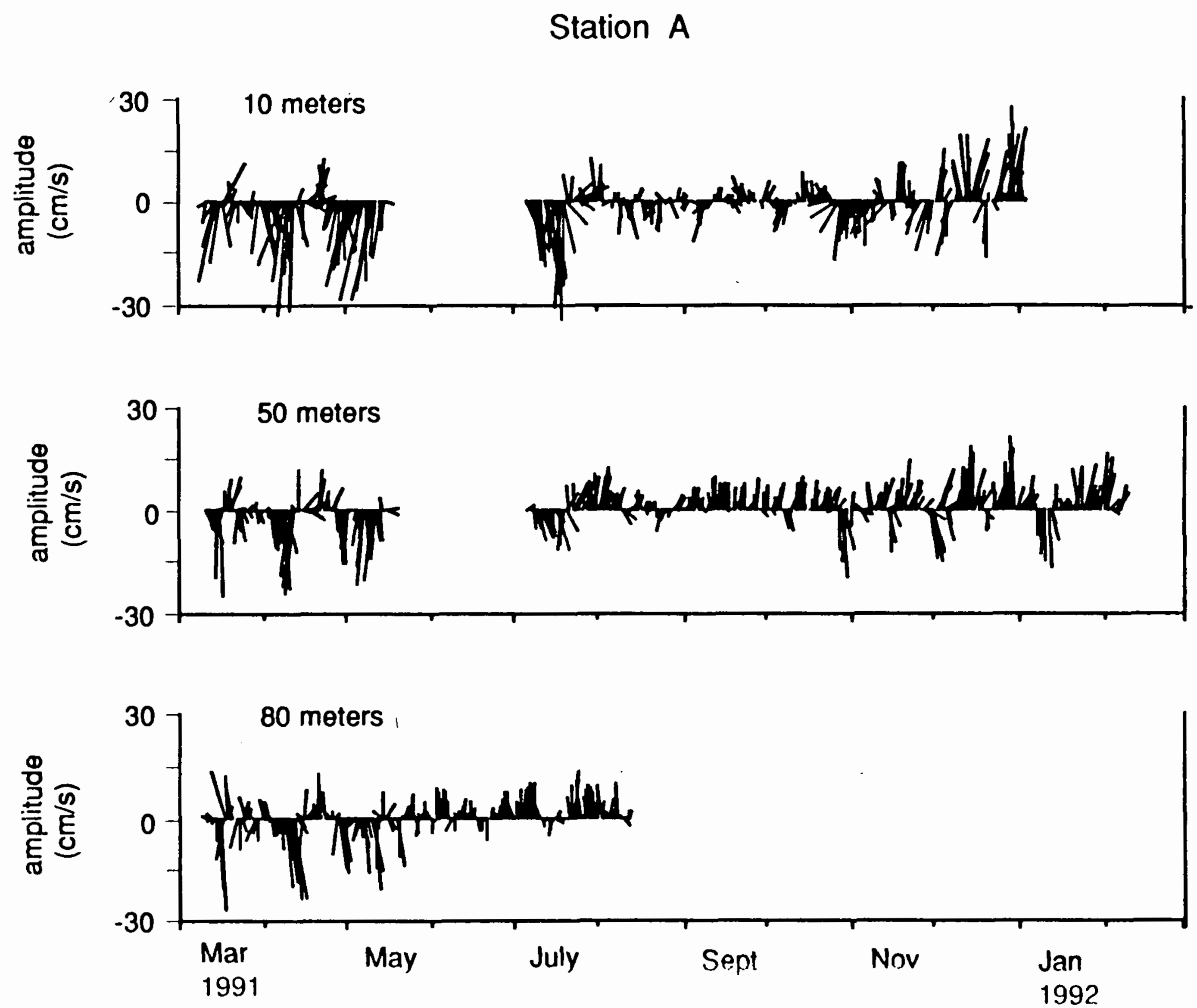

Figure 3.2-3. **Subtidal Currents at Station A.**
Each line represents the magnitude and orientation of the current vector. A line pointing toward the top of the page represents poleward flow along the shelf. Currents flowing toward the coast point to the right.
Source: Noble and Ramp 1992.

3.2.2.4 Slope (Study Areas 3 through 5) Currents

Slope currents in the region of the Gulf of the Farallones during 1991 and 1992 can be grouped by depth ranges. Near-surface currents are those above 75 m depth. Mid-depth currents are between 75 and 800 m and at least 50 m above the seabed. Deep currents are below 800 m and at least 50 m above the seabed, and near-bottom currents are 10 to 15 m above the seabed. The currents within these different depth ranges share similar characteristics, and the coupling among currents is much stronger within discrete depth ranges than the coupling between currents in separate depth ranges.

3.2.2.5 Near-Surface Currents Over the Slope

Near-surface currents over the slope are well studied only at Station C. Spring currents at this station were characterized by a strong equatorward event during April which reached a depth of at least 250 m. This event likely was due to an anticyclonic (clockwise) eddy or a southward flowing upwelling filament, and not attributable to wind. Similar equatorward events also were observed at this time at Stations D and E to depths exceeding 800 m. The strength and duration of the event at 250 m depth was about the same at Stations C and D.

At times, the flow at Station C at 10 m depth was poleward at speeds greater than 30 cm/sec. A portion of this flow likely represented a surfacing of the California Undercurrent which is common during autumn and winter (Section 3.2.2.1). The near-surface diurnal and semidiurnal tidal currents have velocities up to 5 or 6 cm/sec (Kinoshita *et al.* 1992), which are not sufficient to reverse the dominant flow direction of the near-surface currents. The tidal currents can act to disperse materials suspended in the near-surface water, but, being rotational in nature, they would not cause large changes in the fate of those materials in the water column or in the region of deposition (Noble and Ramp 1992).

3.2.2.6 Mid-Depth Currents Over the Slope

A wedge-shaped region, generally including Study Areas 3, 4, and 5, can be described where mid-depth currents along the isobaths are strongly correlated both horizontally and vertically (Figure 3.2-4). The California Undercurrent traditionally has been observed in this region. The offshore boundary of this flow field extended seaward of the study region and was not well delineated.

The persistent patterns in mid-depth currents that flow throughout the wedge-shaped region were not observed at Station F, located shoreward of Study Area 5. Currents at Station F were weak and disorganized, with a much higher variability than currents observed over the continental slope at locations elsewhere along the California coast. Current speeds in 150 m at Station F were slower than the equivalent currents at Station B, even though both flow toward the northwest in the spring and early summer, and the poleward currents at Station F do not extend to 250 m. These characteristics suggest that Station F was just east of the inshore boundary of the correlated, wedge-shaped flow field observed at the other stations on the slope.

The most prominant feature of the mid-depth currents over the slope is a burst of strong poleward flow lasting from mid-April to September. Similar bursts of poleward flow have been observed in three-year records over the slope off Point Sur (Ramp *et al.* 1991). Such burst events are not seasonal. Hence, it is not clear if the poleward bursts observed in the EPA data records are part of a seasonal cycle or if they appear randomly at different times in other years.

Both the persistent poleward flow and the strong vertical correlations in the alongslope currents weakened as the year progressed. The amplitude of the mid-depth flow was reduced at all stations, and the direction became more erratic from mid-August through mid-November. A partial return to the strong poleward flow occurred after mid-November.

The daily, mid-depth, tidal currents have combined amplitudes less than 5 cm/sec (Kinoshita *et al.* 1992). The semidiurnal, mid-depth, tidal currents are slightly stronger, with a combined

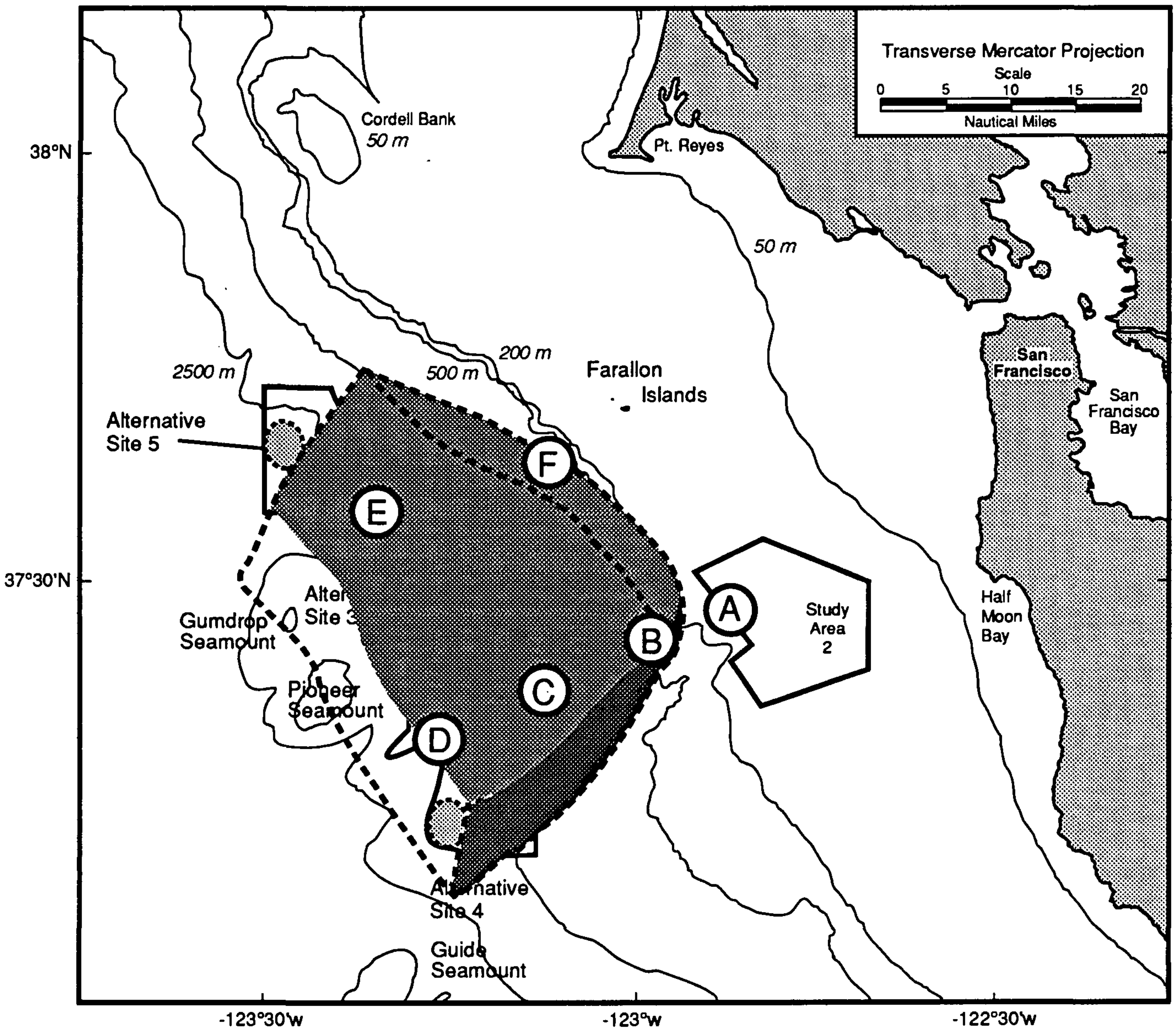

Figure 3.2-4. **Schematic Representation of the Three-Dimensional Structure of the "Wedge-Shaped" Region of Coherent Mid-Depth Flow Over the Slope.**
Source: Noble and Ramp 1992.

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amplitude that can reach 10 cm/sec, but which generally are less than 8 cm/sec. Hence, neither of these tidal constituents can significantly alter the lower frequency current regime described above. The main effect of the tidal components is to increase the cross-slope flow and dispersion of material suspended in the water column across isobaths.

3.2.2.7 Deep Currents Over the Slope

Current measurements in water depths of 1,420 m at Station E suggest that deep currents over the slope are weak and variable (Figure 3.2-5). The deep currents are parallel to bottom contours, but the velocities tend to be less than 10 cm/sec. The mean current speed is 1 cm/sec toward the northwest (Kinoshita *et al.* 1992). The tidal currents have amplitudes less than 4 cm/sec, which are somewhat smaller than those at shallower depths. Because the lower frequency currents also are small, the tidal currents can act to reverse both the net along- and cross-slope flow (Kinoshita *et al.* 1992).

3.2.2.8 Near-bed Currents Over the Slope

Characteristics of currents within 20 m of the seabed cannot be predicted reliably from measurements made above the bed because they are different from the currents in the overlying water column. Near-bed currents also are different from those measured at adjacent sites. For example, near-bed currents at Station B appear unrelated to near-bed currents at Station C even though currents in the overlying water column share similar characteristics. Near-bed currents flow along the isobaths, but their amplitudes are much smaller than flows in the overlying water column at most stations on the slope. Bottom currents at Stations B (400 m) and C (800 m) range from 10 to 15 cm/sec, whereas currents at 250 m depths at these stations reach speeds of 30 cm/sec or more. These differences occur because near-bed currents are more strongly controlled by topographic features than currents higher in the water column.

In contrast to the overlying flow, the near-bed currents at Stations B and D have no definite seasonal or temporal patterns. The mean current directions at Stations B and D are weakly

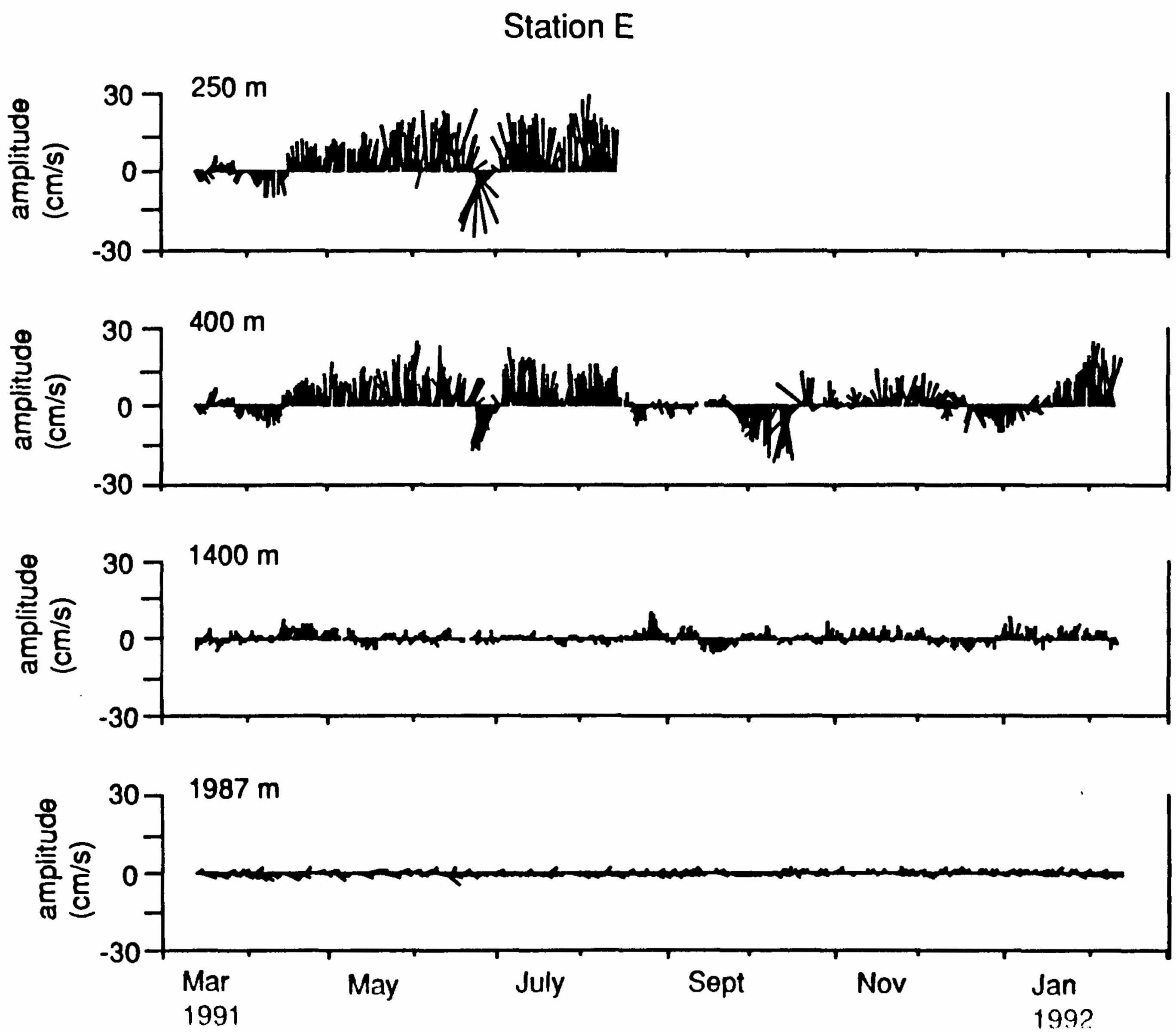

Figure 3.2-5. Subtidal Currents at Station E.
Each line represents the magnitude and orientation of the current vector. A line pointing toward the top of the page represents poleward flow along the shelf. Currents flowing toward the coast point to the right.
Source: Noble and Ramp 1992.

equatorward, at speeds of 0.7 and 0.2 cm/sec, respectively (Kinoshita *et al.* 1992). In addition, particular flow events in the near-bed currents last only a few days, which is much shorter than the duration of events in the overlying water column. Near-bed flow at Station C was poleward for most of the observation period, although current flow to the southeast was observed during a few short periods. Near-bed currents at Station E were small but had a steady flow to the northeast up a small unnamed submarine canyon, and across the striked local isobaths. This shoreward, near-bed flow at Station E may be caused by interactions between the tidal current and local topography (Noble and Ramp 1992).

One of the most notable features of the tidal currents over the slope was the increase in amplitude of both the diurnal and semidiurnal tidal constituents towards the bottom at some locations (Kinoshita *et al.* 1992). Amplification of diurnal and semidiurnal tides can result in tidal currents which are two to three times stronger at the bottom than in overlying waters. This difference may promote resuspension and transport of larger grain sized sediment than would otherwise occur in the absence of "bottom trapping". Enhancement of tides by topographic features also can result in unusually strong mean flows which can result in unidirectional sediment transport. This may occur at Station E, where a steady up-canyon flow was observed. However, amplification of bottom tidal currents was not observed at Station F, possibly due to the relatively steep bottom slope that does not allow this condition to occur. Bottom trapping of the tidal currents has been observed previously over the continental shelf off Point Sur (Sielbeck 1991).

3.2.2.9 Summary of Observed Currents

The observed circulation over the continental shelf and slope near the Farallon Islands can be summarized as follows. The flow over the shelf and slope were not strongly coupled. Over the continental shelf and inshore of the Farallon Islands, the observed flow was coupled closely with the local surface wind stress: equatorward when the wind was equatorward, and poleward when the wind was slack or poleward. The flow also may be affected by outflow from the San Francisco Bay. This aspect of the flow has not been studied previously; hence, the magnitude of the effect is unknown. On average, the mean surface circulation from the shelf break seaward is likely equatorward during the upwelling season, with a velocity less than 10 cm/sec. Surface currents were variable in the other seasons, with speeds and directions changing partially in response to variable surface wind stresses.

Over the continental slope, at depths between 100 and 1,000 m, the flow likely is poleward due to the presence of the California Undercurrent. These currents probably flow poleward throughout the year, but their velocities vary due to conditions not yet fully understood. Strong, persistent bursts (greater than 40 cm/sec) can occur during all seasons for periods of four months or more. The basic flow patterns will be perturbed occasionally by the Point Reyes coastal upwelling jet, which (based on satellite observations of sea surface temperature) sometimes swings southward and crosses the northern corner of the region, and also by mesoscale eddies that move into the area. The frequency of such events is unknown, but at least one such event per year is likely. The upwelling process, which moves water in the upper layers from the slope to the shelf, is weaker here than at other sites on the California coast. The tidal currents over the continental shelf are strongly diurnal and are relatively more important than tidal currents near the continental slope (Noble 1990). Because wave-induced currents generated during winter storms can reach depths of 100 m or more, fine grained material likely will be resuspended over most areas of the shelf (Noble and Ramp 1992). The general absence of fine-grained sediments, and the presence of sand ripples throughout Study Area 2 (SAIC 1992c; see Section 3.2.4.2) support these indications of strong current-sediment interactions. The mean currents will carry suspended materials mainly along the isobaths. The jets, eddies, and tidal currents will disperse the suspended materials across isobaths.

3.2.3 Water Column Characteristics 40 CFR 228.6(a)(9)

Water column characteristics include temperature, salinity, hydrogen ion concentrations, turbidity/light transmittance, dissolved oxygen, and the concentrations of major nutrients, trace metals, and trace organic contaminants.

3.2.3.1 Temperature-Salinity Properties

Recent hydrographic and current measurements indicate that the outer shelf and slope regions of the Gulf of the Farallones are a dynamic area (Ramp *et al.* 1992). Current and water mass variability occurs on time scales from days to months, corresponding to meteorological and mesoscale events and seasonal patterns. Surface waters show a great deal of variability in temperature-salinity (T-S) properties. For example, during recent EPA-sponsored surveys (Ramp *et al.* 1992), near-surface waters represented a mixture of three primary water types: (1) recently upwelled water from a source primarily to the north of Point Reyes; (2) offshore water from the large-scale California Current system; and (3) outflow from San Francisco Bay. The characteristics and importance of each water type in the Gulf vary seasonally and on shorter (i.e., event-related) time scales.

Water discharged from San Francisco Bay into the Gulf of the Farallones has a higher temperature and lower salinity, and therefore lower density, than the water in the Gulf. The long-term average salinity at S.E. Farallon Island is 33.4 ppt, whereas, at Fort Point on the south side of the Golden Gate, the average salinity is 29.9 ppt (Peterson *et al.* 1989). Historically, salinities at both locations are lowest during winter and spring when the Delta outflow is highest. Due to its lower density than ambient waters, the outflow from San Francisco Bay is confined in the Gulf of the Farallones to the surface layer.

In the vicinity of the alternative sites, a typical temperature-versus-depth profile during summer consists of an isothermal surface layer that is tens of meters thick. Beneath the surface mixed layer is a region of rapidly changing temperatures referred to as the thermocline. Below the thermocline, the water temperature changes gradually with depth, becoming nearly isothermal again. The depth of the surface mixed layer and the degree of vertical temperature (density) stratification in the Gulf of the Farallones varies depending on the characteristics and extent of mixing of the various water masses.

Water temperatures below 4.0°C with salinities greater than 34.5 parts per thousand (ppt) are associated with Pacific Common Water, which has a stable T-S relationship throughout the North Pacific. Contrasting T-S properties associated with Subarctic Intermediate Water (found offshore in the California Current) and Equatorial Water (over the continental slope in the California Undercurrent) are found at temperatures between 4.8 and 7.0°C. Subarctic waters also are evident, and although the horizontal scale of this intrusion of Subarctic water was not resolved, it is indicative of the active mixing which must occur in the region at these depths.

Considerable seasonal variability in surface water temperatures and salinites reflect large-scale current patterns, outflow from the Bay, and the presence of mesoscale features. Figure 3.2-6 shows satellite images of surface water temperatures during winter (February 1991) and spring (May 1991) and illustrates the variability in surface temperatures. The presence of numerous mesoscale features in both the water mass distribution and currents demonstrates that there was no overall persistent pattern among the study areas. However, it was apparent that the outflow from San Francisco Bay was confined to the inner continental shelf and did not influence the water column at the study areas (Ramp *et al.* 1992).

3.2.3.2 Hydrogen Ion Concentration (pH)

The pH of seawater within the LTMS study areas was not measured during the recent EPA surveys, but is expected to be within the range of 7.8 to 8.3 measured previously in other areas of the Gulf of the Farallones (e.g., Nybakken *et al.* 1984; IEC 1982). Seawater pH values likely are similar at all of the LTMS study areas, although some minor spatial differences may be related to localized effects from primary production by plankton.

3.2.3.3 Turbidity

Water turbidity or light transmittance properties on the continental shelf near the Golden Gate are affected by seasonal and tidal flows of turbid waters from San Francisco Bay. The location and aerial extent of the outflow plume in the nearshore surface waters off San Francisco change

Color figures follow.

Figure 3.2-6. Satellite Images of Sea Surface Temperatures Within the LTMS Study Region During (A) February and (B) May 1991.

Temperature ranges are indicated by different colors; red to white represents the warmest water; dark blue represents the coldest.

Source: Noble and Ramp 1992.

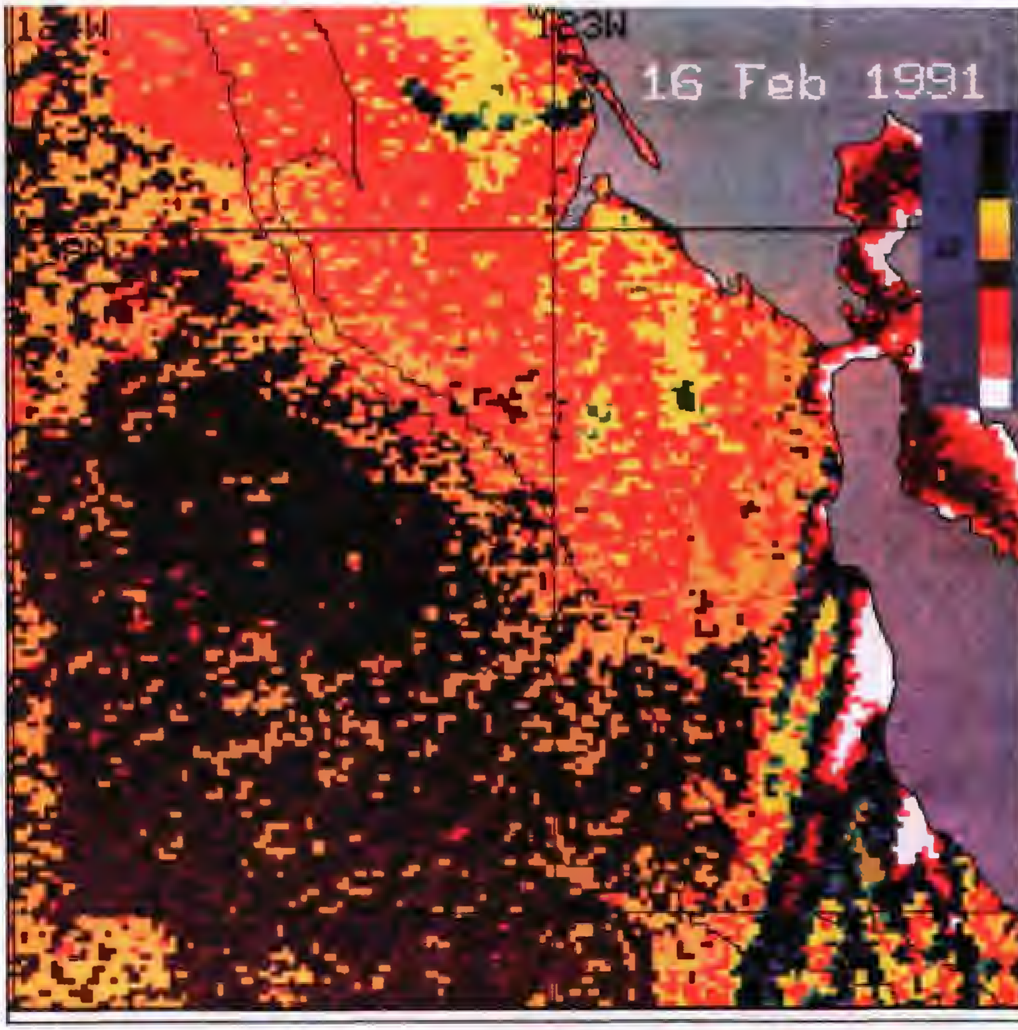

Figure 3.2-6. Satellite Images of Sea Surface Temperatures Within the LTMS Study Region During (A) February 16, 1991.

Temperature ranges are indicated by different colors; red to white represents the warmest water; dark blue represents the coldest.

Source: Noble and Ramp 1992.

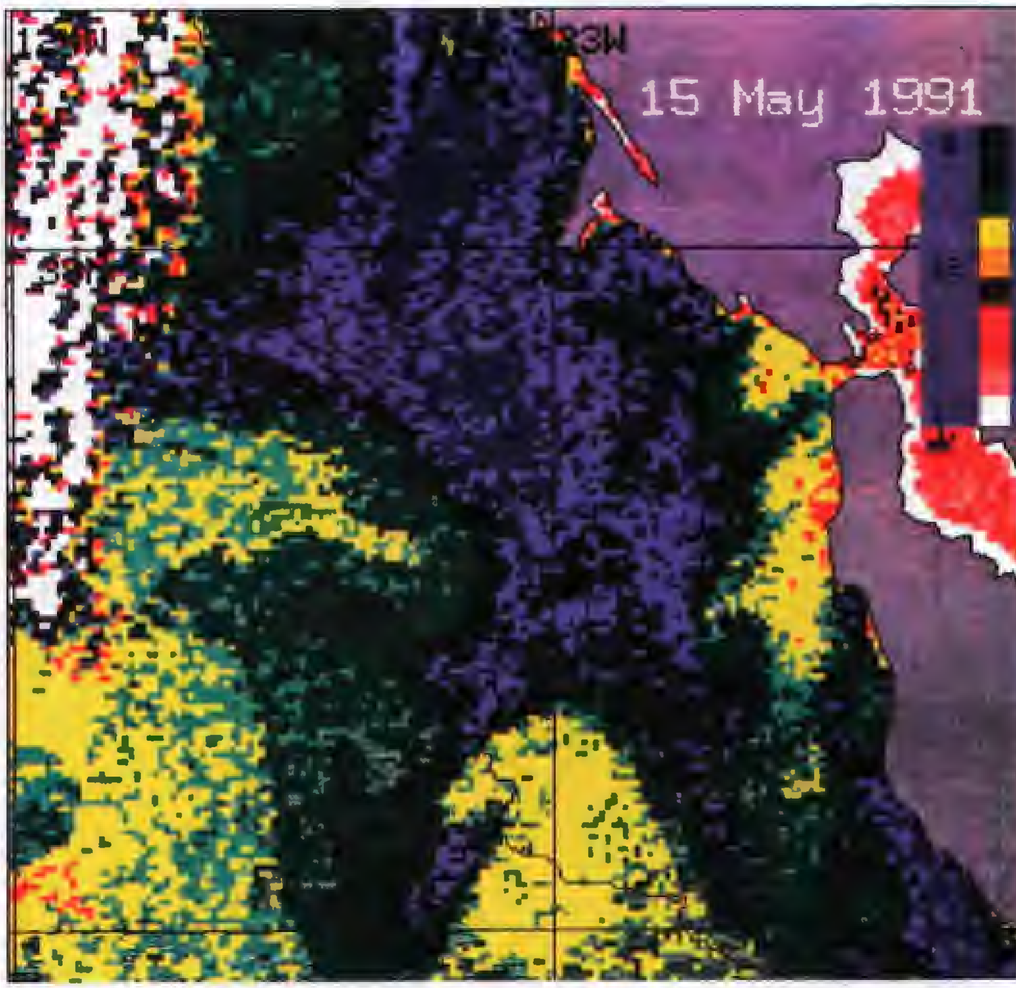

Figure 3.2-6. **Satellite Images of Sea Surface Temperatures Within the LTMS Study Region During (B) May 15, 1991.**

Temperature ranges are indicated by different colors; red to white represents the warmest water; dark blue represents the coldest.

Source: Noble and Ramp 1992.

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Figure 3.2-6. Continued.

seasonally. During recent hydrographic surveys of the region (Ramp *et al.* 1992), outflow from San Francisco Bay was observed to the north of the Golden Gate during August, directly off the Golden Gate during November, and to the south and farther offshore during February 1991. The distribution of the outflow plume may have been influenced by prevailing nearshore wind stress. None of the observed plumes extended very far offshore, likely due to drought conditions. However, previous studies noted a plume of turbid water extending approximately 46 km offshore during peak spring flows from the Bay (Carlson and McCulloch 1974). The relative spatial extent of the plume is reduced in summer when flows from the Bay are minimal.

In waters over the continental shelf off Point Reyes to Point Arena (i.e., the CODE study region), Drake and Cacchione (1987) measured light transmittance values of 65–90 percent transmittance per meter (%/m) throughout the water column. Depth-related patterns in light transmittance suggested the presence of a subsurface lens and bottom layers of turbid (nepheloid) waters. The development of these subsurface lenses may be associated with previously upwelled waters containing high plankton concentrations that sink during periods of relaxation of upwelling-favorable winds. Turbid waters containing high plankton concentrations occur along the front between low density surface water offshore and recently upwelled water over the continental shelf. The location of the front may then move in an onshore or offshore direction in response to local alongshore winds.

Within the LTMS study areas, turbidity probably is affected by seasonal changes in suspended particle concentrations related to primary productivity, surface current patterns and the presence of fronts, and the extent of bottom sediment resuspension on the shelf or at the shelf break. Light transmissivity measurements made at Study Area 5 in September 1991 showed values of 88–90 %/m throughout the water column; there was no evidence of a turbid nepheloid layer in any of the sampled water layers (SAIC 1992a). Similarly, Nybakken *et al.* (1984) measured 80–90 %/m light transmittance throughout the water column at a shelf-edge location (Station 2; see Figure 2.1-3), whereas, relatively lower values of 10–80 %/m were measured at a site over the continental shelf. The low transmittance levels at the continental shelf site may be related to resuspension of sediments near the bottom and inorganic suspended particles or phytoplankton within the near-surface mixed layer (Nybakken *et al.* 1984).

Few measurements of suspended solids concentrations have been made within the region, and no measurements of total suspended solids (TSS) were performed within the LTMS study areas during the EPA surveys. However, IEC (1982) measured TSS concentrations of 0.08 to 2.51 mg/l in waters near the shelf-break (the 100-Fathom disposal site) in April 1980, and Gordon (1980) measured TSS concentrations of 0.3 to 2.9 mg/l within the surface 25 m at two continental shelf sites in the Gulf of the Farallones during March and August 1979. Nearshore areas affected by the plume from San Francisco Bay are expected to have significantly higher water column concentrations of TSS and associated higher turbidity levels than waters further from shore.

3.2.3.4 Dissolved Oxygen

Dissolved oxygen concentrations are important because depressed levels can affect the diversity and abundances of marine organisms. In upwelling areas, such as the central California coastal zone region, organic material associated with high primary production settles through the water column and consumes oxygen as it sinks. The depletion of dissolved oxygen at depths of about 500 to 900 m can produce an oxygen minimum zone (OMZ) (Broenkow and Green 1981). Intersection of the OMZ with the seafloor potentially can affect the distribution of oxygen-sensitive taxa. Whereas the cores of some OMZ are faunally depauperate (Rhoads *et al.* 1991), the edges of the OMZ are known to be highly productive, especially with respect to bacteria (Mullins *et al.* 1985; Rhoads *et al.* 1991).

Composite profiles of dissolved oxygen (DO) concentrations measured in July and September 1991 within Study Areas 3 and 5 are shown in Figure 3.2-7. The DO concentrations in surface waters are approximately 8 mg/l. Concentrations decline through the mixed layer, and reach minimum values of about 0.5 mg/l at a depth of 800 m. Below 800 m, DO concentrations

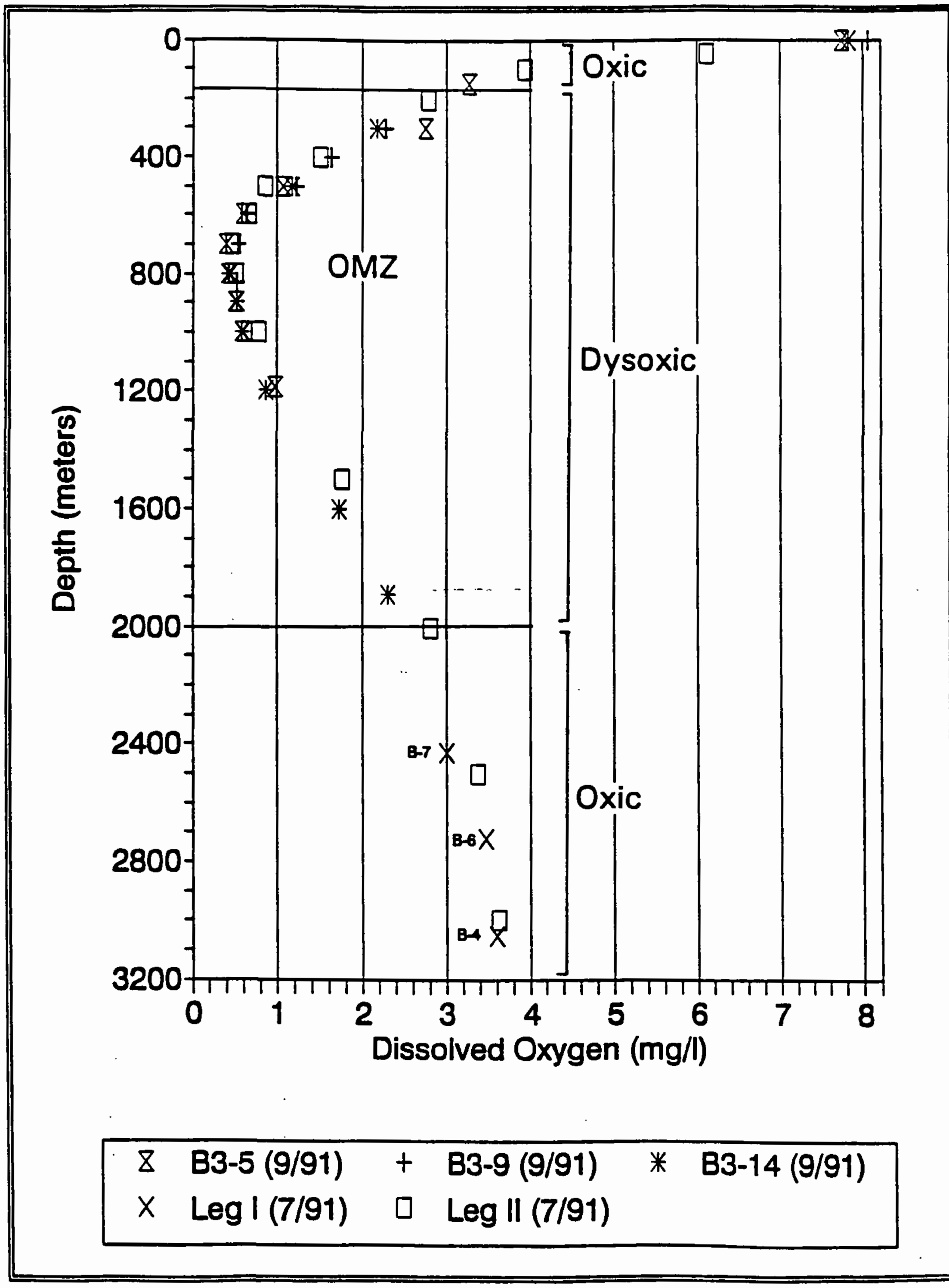

Figure 3.2-7. A Composite Profile of Dissolved Oxygen Concentration in the Water Column Over the Continental Slope off San Francisco and the Gulf of the Farallones.

Data were collected at Study Area 5 in July 1991 and at Study Area 3 in September 1991. Oxygen concentrations in the oxic zones are > 2.8 mg/l and in the dysoxic zone range from 0.28-2.8 mg/l.

Source: SAIC 1992c.

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increase to over 3 mg/l at depths greater than 2,000 m. This DO concentration/depth pattern is similar to those reported for other portions of the central California continental margin (e.g., Thompson *et al.* 1985). Nybakken *et al.* (1984) measured dissolved oxygen concentrations of approximately 5.1–8.6 mg/l over the continental shelf and shelf edge in the Gulf of the Farallones; surface waters were supersaturated with oxygen, while bottom waters were at about 45% saturation. Similarly, dissolved oxygen concentrations averaged over a period of 18 years for CalCOFI Station 60052 (37°51.8N; 123°03.8W; offshore from Point Reyes and north of the Farallon Islands) over the continental shelf ranged from 8.7–10.1 mg/l at the surface to 5.3–7.3 mg/l at 50 m. The higher concentrations typically were measured in January and lower concentrations occurred in October.

3.2.3.5 Nutrients

Nutrient concentrations are influenced by seasonal current patterns, upwelling, and biological uptake by marine plants (phytoplankton). Outflow of water from San Francisco Bay may represent an additional source of nutrients to nearshore waters. Typically, nutrient concentrations increase with depth due to surface depletion by phytoplankton and settling of detritus followed by subsurface remineralization and release of nutrients. However, upwelling of deeper waters transports nutrients into the surface mixed layers.

Measurements from CalCOFI surveys in the vicinity of the Gulf of the Farallones indicate that phosphate concentrations in surface waters (10 m depth) typically range from 0.25 to 2.0 micromoles per liter (µM/liter; which is the mass equal to the molecular weight of the compound per unit volume of seawater). Concentrations increase with depth below the surface mixed layer; concentrations up to about 4 µM/liter occur at depths greater than 1,000 m. Nitrate concentrations in surface (10 m) and mid-depth (100 m) waters range from < 1 to 20 µM/liter and from 10 to 30 µM/liter, respectively. Silicate concentrations in surface and mid-depth waters range from 1 to 40 µM/liter and from 20 to 50 µM/liter, respectively. Profiles of nitrate, phosphate, and silicate concentrations measured at CalCOFI Station 60060 (37°36.8'N, 123°36.5'W; southwest from the Farallon Islands and Study Area 5) over the continental slope during July 1984 are shown in Figure 3.2-8.

No measurements of nutrient concentrations were performed during the EPA surveys of the LTMS study areas. Differences in nutrient concentrations between Study Areas 3 through 5 are expected to be minimal, especially within the subsurface layers, although localized upwelling events and small-scale variability in phytoplankton productivity may result in some short-term spatial differences within surface waters. As mentioned, nutrient concentrations within the shelf region, including Study Area 2, are expected to be influenced to a greater extent by the Point Reyes upwelling filament and outflow from San Francisco Bay than are Study Areas 3 through 5.

3.2.3.6 Trace Metals

Trace metal concentrations in seawater within the LTMS study areas were not measured during the EPA and Navy surveys. However, data from previous measurements of seawater trace metal concentrations in the vicinity of the Gulf of the Farallones are presented in Table 3.2-4. Concentrations of individual trace metals in the surface waters of the Gulf of the Farallones are characterized by pronounced spatial and temporal variability (Nybakken *et al.* 1984). These differences are expected to reflect upwelling patterns, transport and mixing of outflow from San Francisco Bay, resuspension of bottom sediments by currents and wave action, and atmospheric deposition of anthropogenic metals (e.g., lead from gasoline additives). Large differences between Study Areas 3, 4, and 5 in the seawater trace metal concentrations would not be expected. Relatively higher concentrations of selected metals may occur within Study Area 2, depending on the Bay outflow and current conditions.

The NOAA National Status and Trends (NS&T) Program and California "Mussel Watch" Program measured contaminant concentrations in tissues of intertidal mussels (*Mytilus* spp.) as an indicator of water quality trends. Waters near the Farallon Islands typically contain low concentrations of most trace metals as compared to sites along the California coast located near urban areas or discrete sources of pollutants. However, the Farallon Islands mussels historically

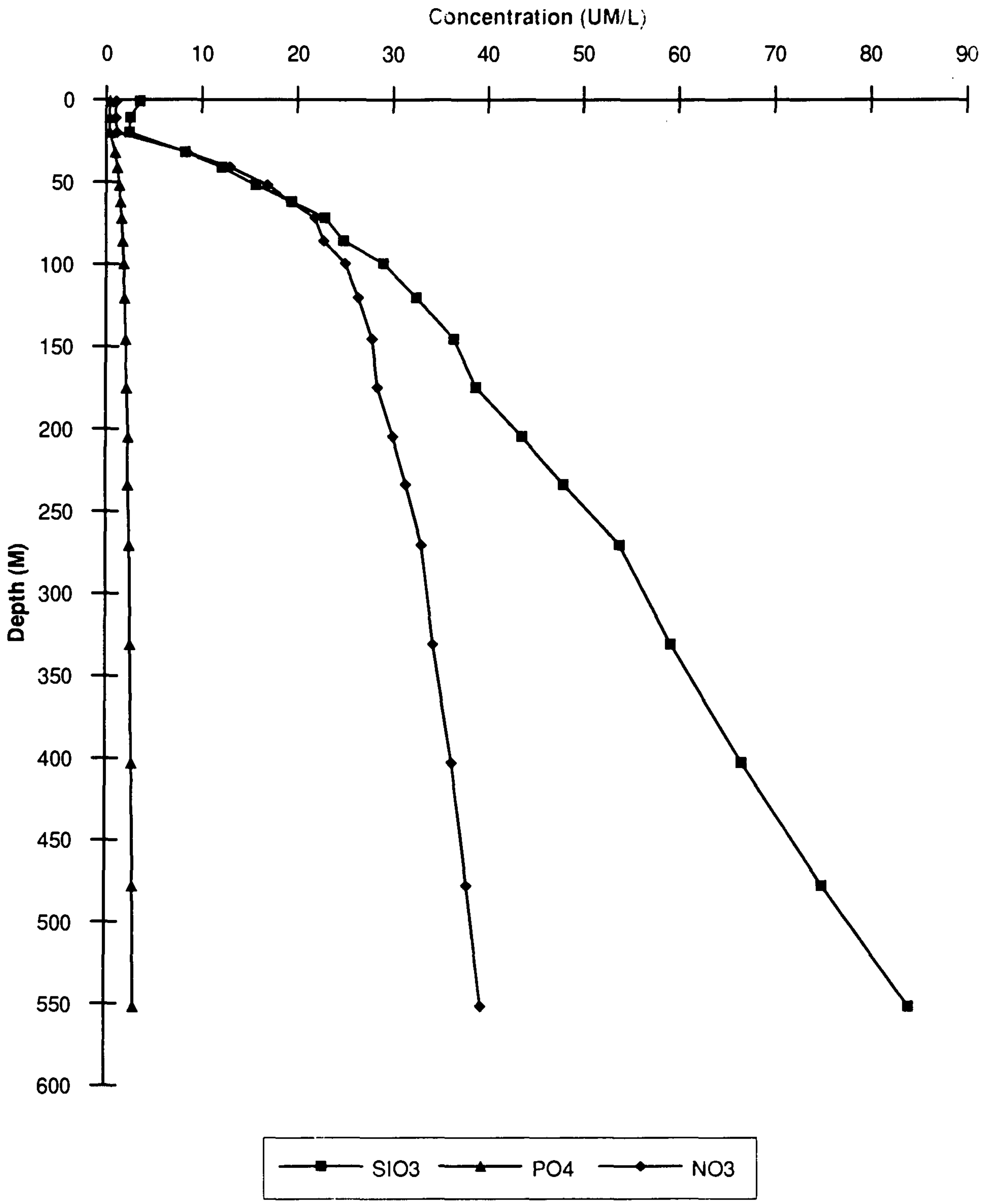

Figure 3.2-8. **Vertical Profiles of Silicate, Phosphate, and Nitrate Concentrations at CalCOFI Station 60060 (37°36.8'N, 123°36.5'W) in July 1984.**
Source: CalCOFI Database (1991).

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Table 3.2-4. Trace Metal Concentrations in Seawater in the Vicinity of the Gulf of the Farallones.

Study Area (Source)	Depth (m)	Concentration (mg/Liter)							
		Cd	Cu	Fe	Mn	Ni	Pb	Zn	Hg
Continental Shelf and Shelf Edge (Nybakken *et al.* 1984)	10	0.02	0.14–0.15	0.51–1.4	< 0.005–0.01	0.42–0.53	< 0.6	0.52–0.53	
	20	0.01–0.04	< 0.005–0.07	0.59–1.1	0.21–0.51	0.17–0.23	< 0.6	< 0.005–0.18	
	40	0.03–0.05	0.03–0.27	1.5–2.7	< 0.005–1.5	0.29–0.48	< 0.6	0.33–2.1	
	100	0.02–0.04	0.07–0.13	0.17–0.59	0.01–0.10	0.23–0.39	< 0.6	< 0.005–0.27	
Continental Shelf (Gordon 1980)[1]	2	0.047	0.16		0.41	0.24	0.15	0.21	
	6	0.030	0.16		0.99	0.34	0.028	0.12	
	20	0.046	0.14		0.39	0.21	0.049	0.095	
	25	0.045	0.10		0.60	0.33	0.020	0.17	
100-Fathom Site (IEC 1982)[1]	55	0.060–0.61					0.22–0.38		0.018–0.019

Table 3.2-4. Continued.

Study Area (Source)	Depth (m)	Concentration (mg/Liter)							
		Cd	Cu	Fe	Mn	Ni	Pb	Zn	Hg
Continental Slope (Bruland 1980)	25	0.0066	0.084			0.217		0.016	
	50	0.0064	0.085			0.207		0.014	
	100	0.037	0.082			0.263		0.054	
	250	0.082	0.081			0.358		0.160	
	750	0.115	0.119			0.522		0.363	
	1,500	0.107	0.135			0.620		0.507	
	3,000	0.100	0.221			0.627		0.574	

[1]Dissolved and particulate fraction concentration

contained high lead concentrations relative to concentrations in mussels from several central California locations. The source of the lead is unknown; however, the location of the Farallon Islands upwind from potential combustion sources would minimize atmospheric deposition sources (Farrington *et al.* 1983; Goldberg and Martin 1983). Elevated concentrations of some elements including cadmium in mussels at the Farallon Islands probably are related to upwelling of subsurface waters that are relatively enriched with these elements (Farrington *et al.* 1983; Bruland *et al.* 1991).

3.2.3.7 Hydrocarbons

Petroleum and synthetic (anthropogenic) hydrocarbon concentrations in waters within the LTMS study areas were not measured during the EPA and Navy surveys. However, concentrations are expected to reflect current transport and mixing with outflow from San Francisco Bay, atmospheric deposition, particularly of combustion-derived compounds, and episodic inputs from oil/petroleum product spills (e.g., the R/V PUERTO RICAN) or discharges. Nevertheless, appreciable differences in hydrocarbon concentrations between Study Areas 3, 4, and 5 would not be expected. Slightly higher concentrations of hydrocarbons may occur within Study Area 2, depending on Bay outflow and current patterns.

Nybakken *et al.* (1984) reported very low concentrations of petroleum hydrocarbons (140–280 ng/liter) in outer continental shelf waters (Station 2; see Figure 2.1-5). Similarly, deLappe *et al.* (1980) reported that the polynuclear aromatic hydrocarbons (PAHs) phenanthrene and pyrene in waters near the Farallon Islands were below analytical detection limits. Organochlorine compounds measured by IEC (1982) in seawater collected at the 100-Fathom site were nondetectable. However, Nybakken *et al.* (1984) measured concentrations of total (dissolved and particulate) polychlorinated biphenyls (PCBs) of 24–105 ng/liter, dichloro-diphenyldichloroethylene (DDE) of 4.6–27 ng/liter, and trace amounts (less than 500 ng/liter) of chlordane, hexachlorocyclohexane, dieldrin, and toxaphene in waters over the continental shelf and shelf edge.

3.2.4 Regional Geology

The regional geology characterization includes bottom topography, presence and location of large geologic structures such as submarine canyons and seamounts, and sediment transport pathways.

3.2.4.1 Topography

The LTMS study region is located in the physiographic province called the Farallones Escarpment. Within this province are two geomorphic areas: a northern segment where the escarpment is about 35 km wide with a slope of six degrees and more, and a southern segment where the width of the escarpment is about 75 km wide with a slope of about two degrees (Karl 1992). The approximate boundary between the northern and southern geomorphic areas is 37°30'N, which also separates Study Areas 2, 3, and 4 to the south from Study Area 5 to the north.

In 1990, the United States Geological Survey (USGS) conducted a geological, geophysical, and geotechnical study of the 3,400 km^2 EPA study region ranging in depths from 200 to 3,200 m. The regional geologic data were used to evaluate bottom stability and sediment transport, as well as other physical and benthic processes, and to identify areas of sediment erosion, bypass, and accumulation (Karl 1992). The regional geological setting as determined from the USGS survey is described below.

The northern segment of the escarpment has the most rugged topographic relief. This relatively narrow part of the escarpment is transected by numerous gullies and canyons that dissect the slope from the shelf-slope break to the lower slope and/or basin floor. These topographic features are oriented roughly perpendicular to the regional trend (generally northwest-to-southeast) of the Farallones escarpment. A canyon within Study Area 5 represents one of these slope features. Between the gullies and canyons are steep intercanyon ridges which consist of barren rock outcrops of consolidated or hardened strata and crystalline basalt (Chin *et al.* 1992). Within the gullies and canyons, unconsolidated muds have accumulated to thicknesses up to 5 m.

Although the northern area has a rugged topography and relatively steep slopes, few examples of massive down-slope movement could be detected from either sidescan or subbottom acoustic records. If slump structures exist in this area, they are of small spatial dimensions and represent only thin intervals of sediment (Chin *et al.* 1992).

The southern segment of the escarpment is wider than the northern segment with a mean slope of one-third that of the northern area. The major topographic features consist of Pioneer Canyon and Pioneer, Guide, and Mulburry Seamounts at the base of the slope. Pioneer Canyon is located between Study Areas 3 and 4, and Pioneer Seamount is immediately west of Study Area 3. Sidescan sonar records show that these features consist of volcanic basement rock covered with hemipelagic (i.e., predominantly from oceanic or planktonic origins with little terrigenous material) sediment.

The topography within both Study Area 3 and Study Area 4 is relatively featureless (Karl 1992). Study Area 3 is located to the north of Pioneer Canyon on a gently sloping, featureless plain that is covered by a thin and variable sediment layer. Study Area 4 is located south of Pioneer Canyon on a gently sloping area where the sediment cover is sparse and patchy. Outcrops of volcanic rock are present within both study areas and in Pioneer Canyon. Subbottom acoustic profiles show a thin, discontinuous layer of unconsolidated sediment covering older sedimentary strata or crystalline bedrock. Soft sediment is 5 to 15 m thick over the southern escarpment. The thin layer of soft sediment makes it difficult to observe small-scale acoustic features that are diagnostic of slumping, soft sediment deformation, and faulting.

Geotechnical analysis of sediment cores collected in both the north and south escarpment areas showed that the upper 3 m of the sediment column appear to be physically stable under conditions of static gravitational loading. A stability model predicted that the equilibrium thickness for sediments deposited on a slope of one to five degrees should be 5 to 15 m thick (Edwards *et al.* 1992). Subbottom profiling results from the USGS survey confirm this prediction, as sediment cover falls within this thickness range. However, the surficial sediment cover becomes marginally stable under conditions of seismic loading as modeled from extreme earthquake events. These slope stability predictions only apply to existing slope sediment, and extrapolation or extension of these conclusions to dredged material that may be rapidly loaded onto the ambient bottom are not warranted (Edwards *et al.* 1992).

3.2.4.2 Sediment Transport

Interactions of strong bottom currents and surface waves can generate bottom shear stresses that are sufficient to suspend and initiate bedload transport of bottom sediments over the continental shelf (Cacchione *et al.* 1987; Grant *et al.* 1984). Mass sediment movement in the form of turbidity currents and submarine avalanches also may occur on the slope in response to downwelling, internal waves, or earthquakes. Some downslope and offshore movement of sediments may be indicated by results from recent EPA surveys showing onshore to offshore gradients in sediment grain size, sediment organic content, and concentrations of some trace sediment chemical parameters (SAIC 1992a,c).

Study Area 2

Of the four areas investigated during the EPA and Navy surveys, Study Area 2 has the greatest potential for resuspension and transport of sediment. The bottom sediments within Study Area 2 are extensively rippled (Figure 3.2-9) indicating active bedload transport of sand. At the shelf-slope transition (180 to 200 m) south of Pioneer Canyon, a coarser sand zone (Figure 3.2-10) lies within a depth zone coincident with the pycnocline (water density stratification layer) (Vercoutere *et al.* 1987). This may represent an area where shoaling internal waves intersect and scour the bottom. The surface component of the California Current and Undercurrent also can affect bottom stresses in this zone, resulting in downslope movement of shelf sands. No low kinetic energy regions are located within Study Area 2. (The low kinetic energy area indicated in Figure 3.2-9 likely is an artifact of high biological activity obscuring sand ripples; SAIC 1992c). Thus, dredged material discharged at this shelf location would not be expected to remain physically stable (i.e., non-dispersed) for any prolonged period of time.

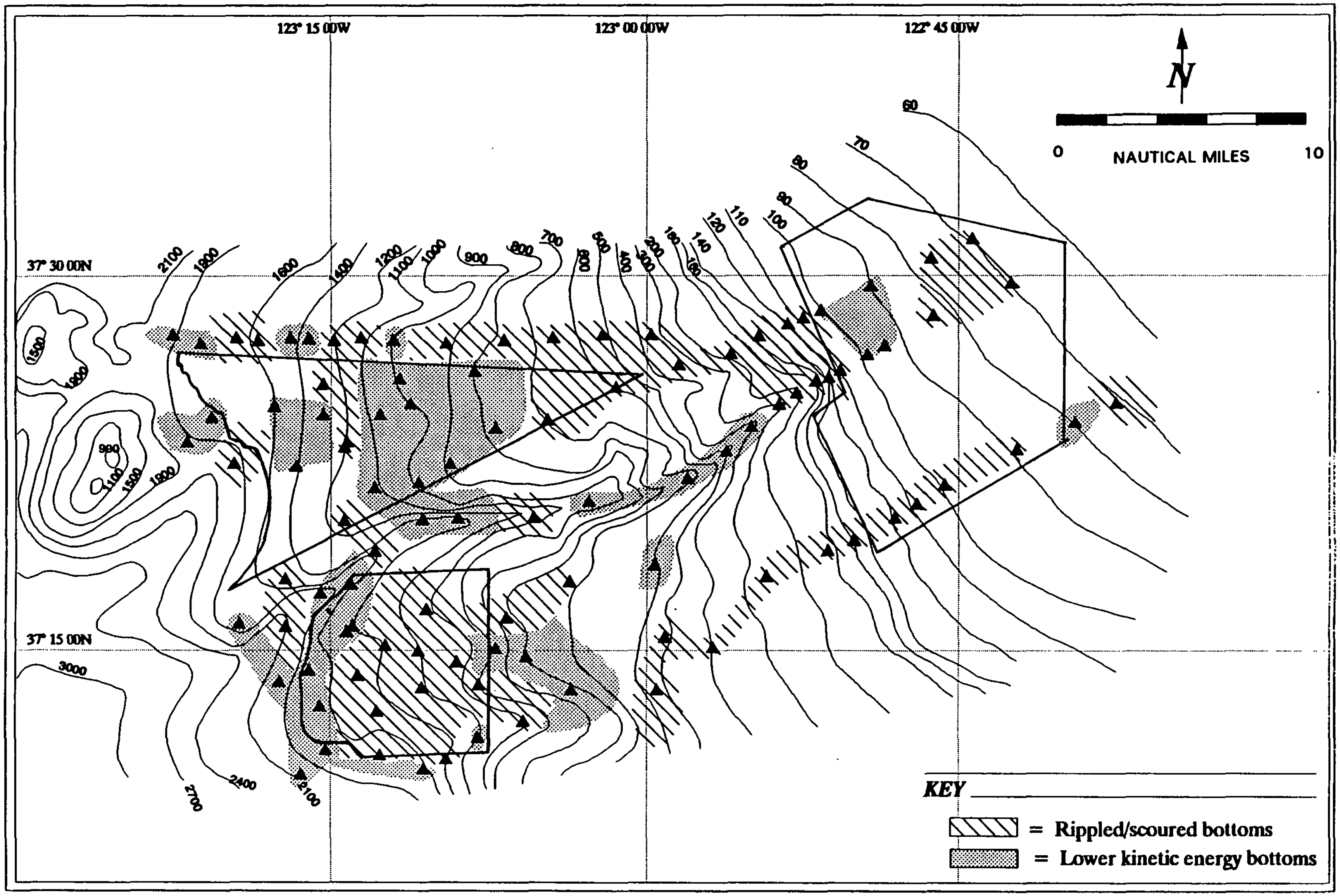

Figure 3.2-9. Mapped Distribution of Ripples and Scour Lag Deposits (High Kinetic Energy Bottoms) and Sediments Dominated by Biogenic Features (Low Kinetic Energy Bottoms).
Source: SAIC 1992c.

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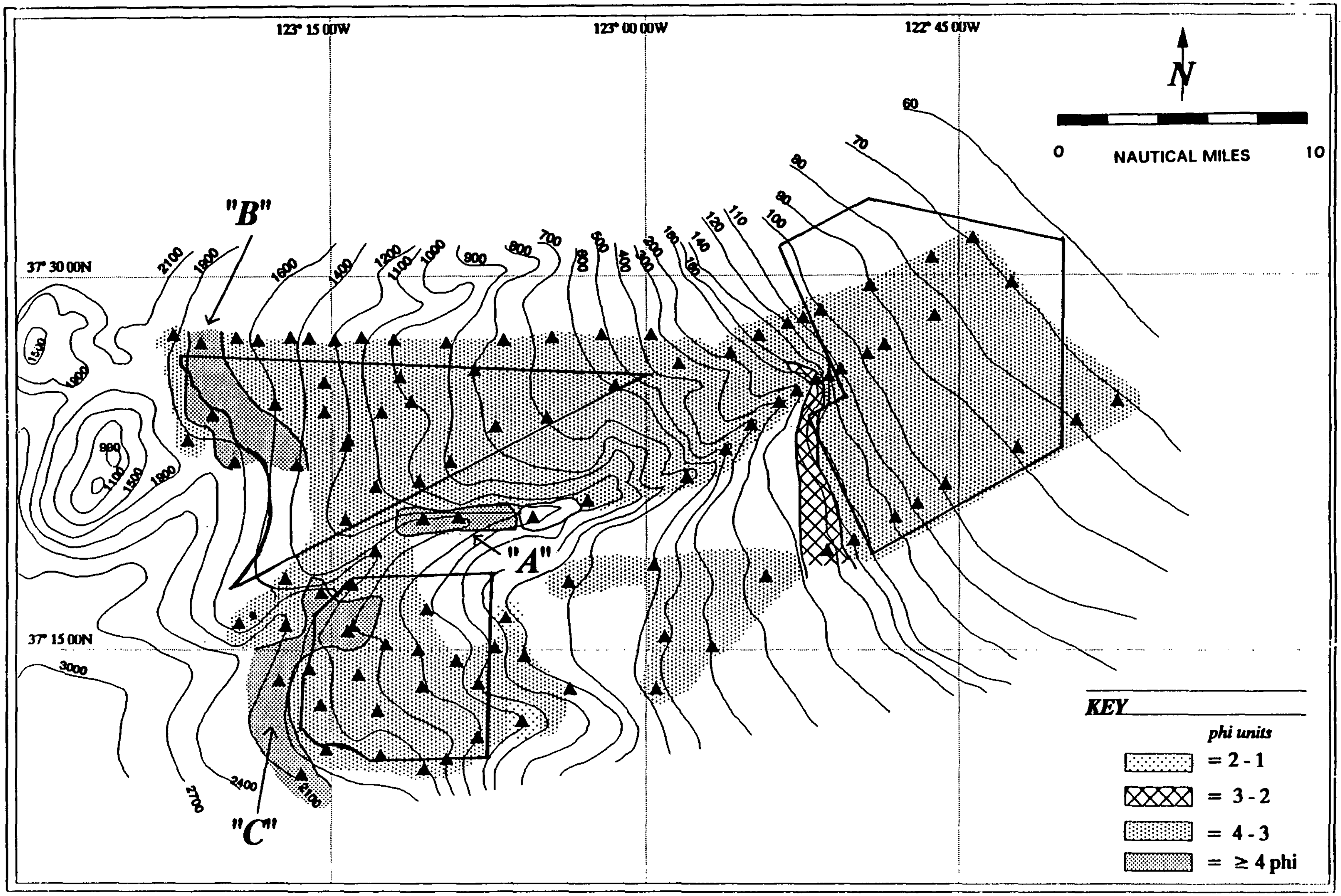

Figure 3.2-10. Mapped Distribution of Major Modal Grain Size (phi units).
Areas A, B, and C identify silt-clay depositional sites.
Source: SAIC 1992c.

Study Areas 3 and 4

Study Areas 3 and 4 share several attributes related to sediment transport. Mapped distributions of rippled and scoured bottoms within the shallower depths of Study Area 3 and regions shoreward of Study Area 4 (Figure 3.2-9) appear to be affected episodically by bottom scour related to occasional "benthic storms" (SAIC 1992c). Between these strong flow events, the bottom may experience low kinetic energy periods when fine-grained sediments and organic "fluff" layers can accumulate until they are resuspended and transported by the next burst event. The periodicity of these benthic storms is not known. These conclusions are based on sediment patterns observed within depth zones of approximately 200 to 500 m which lie within areas affected by the nearshore California Undercurrent. This current has a mean velocity of about 5 to 10 cm/sec (Vercoutere *et al.* 1987). However, "bursts" within this current of up to 40 cm/sec have been measured (see Section 3.2.2). Near-bottom flow velocities of 5 to 10 cm/sec are too weak to erode and transport large quantities of fine-grained sediments, whereas velocities over 25 cm/sec are capable of initiating bed erosion (Rhoads and Boyer 1982).

Within the depth range of 600 to 800 m, where the slope flattens from 8 to 4%, the mud (silt and clay) content of the sediment increases from 12 to 55%. This is called the "mud line" or the mud transition (Vercoutere *et al.* 1987) that generally separates nondepositional or erosional bottoms above this depth range from more depositional regimes below this depth range. However, as noted above, the depositional regimes below 600 to 800 m also may experience episodic scouring.

Depositional, low kinetic sites corresponding to Alternative Sites 3 and 4 are located in Study Areas 3 and 4 (designated as Sites "B" and "C," respectively, in Figure 3.2-10) below depths of approximately 1,400 m. These are the only study area sites that consist of muddy sediments with biogenic features such as fecal mounds, feeding pits, pelletal layers at the sediment-water interface. The presence of these delicate structures is strong evidence that sediment transport is not taking place. Thus, dredged material deposited within these two areas likely will remain undisturbed for relatively longer periods of time than material discharged into the shallower portions of Study Areas 3 and 4 or within Study Area 2.

Pioneer Canyon

The Pioneer Canyon sediments have less evidence of rippling and scouring than the adjacent portions of Study Areas 3 and 4 (Figure 3.2-9). Because Pioneer Canyon is incised into the Farallones escarpment, it apparently is less affected by the California Undercurrent than areas at comparable depths in Study Areas 3 and 4. The major transport direction is along the axis of the canyon. A "pool" of mud has been mapped extending from 1,100 m to deeper than 1,400 m. This low kinetic energy area is designated as Site "A" in Figure 3.2-10.

Study Area 5

Study Area 5 contains a geological environment where sediments entering the escarpment from the continental shelf are flushed through numerous canyons. However, sediments probably do not accumulate over the long term until they reach the continental rise, west of Study Area 5. The floors of gullies and canyons contain unconsolidated sediment, but these deposits may be only temporary repositories. No unequivocal evidence of mass sediment movement within the study area was found (SAIC 1992a). All evidence of slumping is limited to steep slopes and walls of submarine canyons. The intercanyon ridges and sides of gullies and canyons are largely experiencing erosion. However, a low kinetic energy (depositional) area occurs at depths between 2,200 to 3,000 m in the trough axis and extends to the western portion of the study area (Figure 3.2-11). The depositional area within Study Area 5 is at a slightly greater depth than depositional areas within Study Areas 3 and 4 (corresponding to Alternative Sites 3 and 4, respectively).

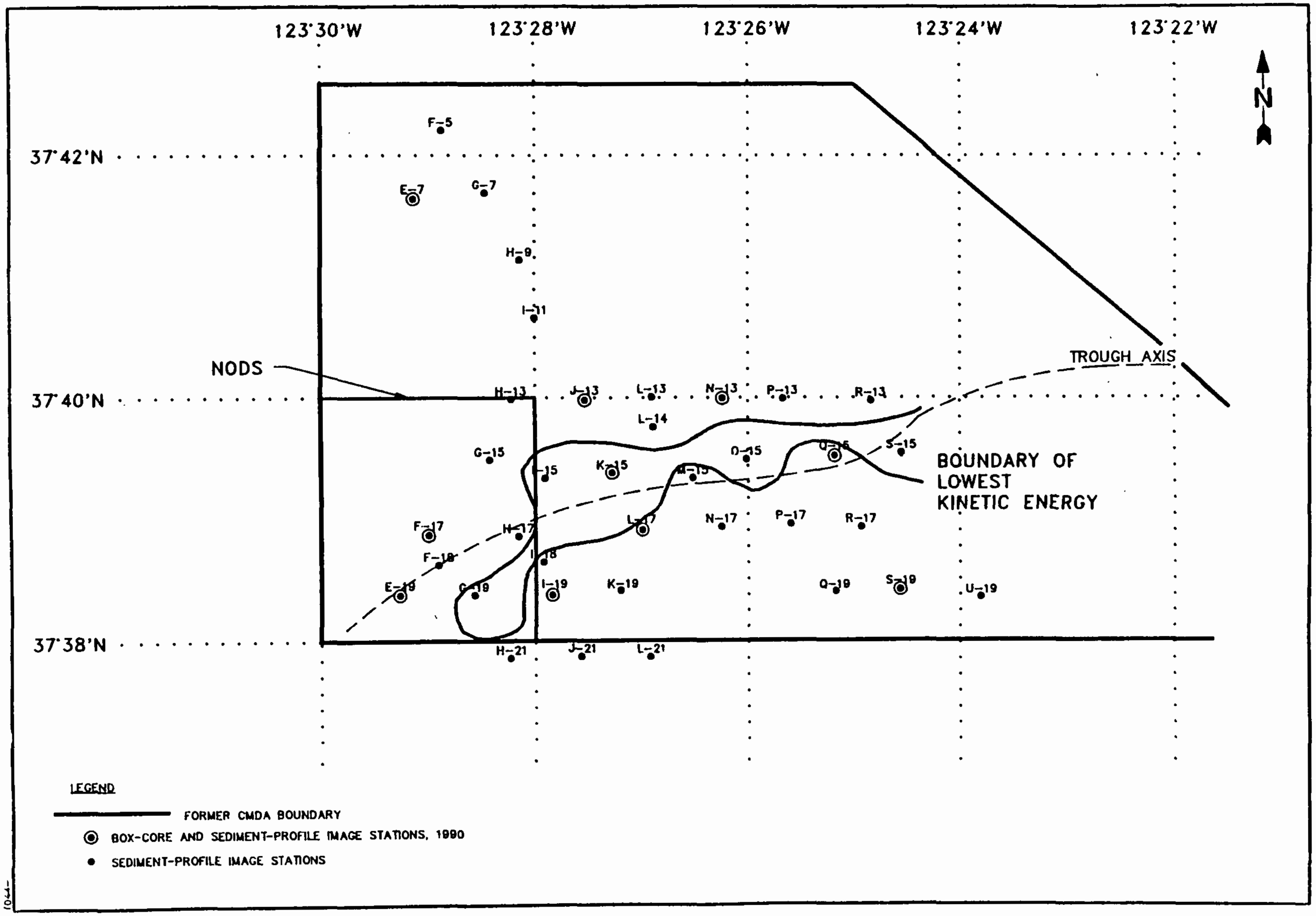

Figure 3.2-11. **Low Kinetic Energy Zones in LTMS Study Area 5.**
Source: SAIC 1992a.

3.2.5 Sediment Characteristics

Sediment characteristics considered for an ODMDS designation include grain size, mineralogy, organic content, and chemical contaminant concentrations. In the Gulf of the Farallones, many of these parameters show depth-related trends (e.g., SAIC 1992a,c; Booth *et al.* 1989) which reflect the sources of sediments and particulate matter, transport pathways, and erosional/depositional characteristics of the specific locations within the region.

3.2.5.1 Grain Size

Sediment grain size generally decreases with increasing depth, from predominantly sand-sized sediments on the continental shelf to fine-grained muds on the continental slope (Figure 3.2-12). The sand-to-sandy mud transition occurs at depths of 600 to 800 m (SAIC 1992c). Above this transition depth, waves and the California Undercurrent scour the bottom, preferentially removing the finer-grained sediments. At depths below this range the scouring effects are attenuated and fine-grained sediments have longer residence times on the bottom (Vercoutere *et al.* 1987). However, some localized areas of relatively coarser and relatively finer grained sediments were observed in Study Areas 3 through 5 which reflect small-scale differences in the kinetic energy or erosional/depositional characteristics of the specific location. Additionally, the Farallon Islands may contribute a local source of relatively coarser sediments to adjacent areas (Hanna 1952).

The results of sediment grain size and organic content measurements from the EPA surveys are listed in Table 3.2-5. Grain size characteristics are summarized for each of the LTMS study areas in the following sections. The mineralogical and organic content of sediments in the study areas are summarized in Sections 3.2.5.2 and 3.2.5.3, respectively.

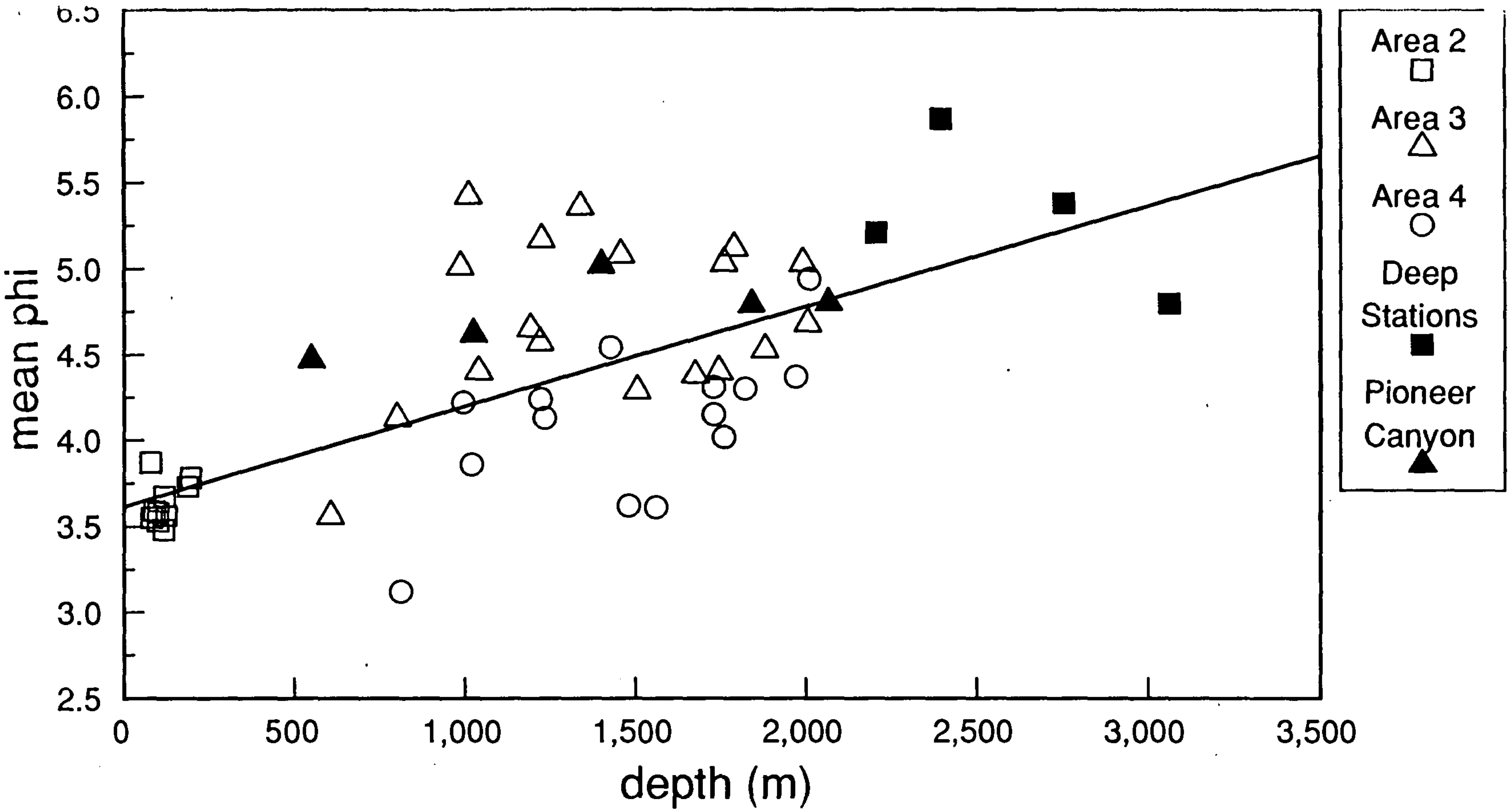

Figure 3.2-12. Patterns in Sediment Grain Size (mean phi) with Depth Within the LTMS Study Region.
Symbols indicate the origins of the composite samples.
Source: SAIC 1992c.

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Table 3.2-5. Descriptive Statistics for Sediment Parameters from Study Areas 2, 3, 4, and 5.

Mean, minimum, maximum, range of values (difference between maximum and minimum), and number of samples are shown for the study areas, deep stations (DS) west of Study Area 4, and Pioneer Canyon. All concentrations are on a dry-weight basis.

Area	Depth (m)	% TS	Avg. Phi	% Gravel	% Sand	% Silt	% Clay	% Carbonate	% C	% N	C/N
All Areas											
Mean	1499	52.4	4.54	0.2	47.10	47.0	5.7	1.5	1.85	0.23	9.26
Minimum	78	32.1	3.12	0	2.1	7.0	0.3	0.2	0.37	0.04	8.48
Maximum	3060	74.9	5.87	6.4	92.2	90.4	14.8	6.1	3.86	0.49	11.01
Range	2982	42.9	2.75	6.4	90.1	83.4	14.5	5.9	3.49	0.45	2.54
No. Samples	64	64	63	63	63	63	63	64	63	63	63
Study Area 2											
Mean	120	72.2	3.63	0.1	88.6	10.3	1.0	0.3	0.43	0.05	9.50
Minimum	78	68.6	3.48	0	80.7	7.0	0.3	0.2	0.37	0.04	8.48
Maximum	196	74.9	3.87	0.4	92.2	18.4	2.8	0.7	0.55	0.07	11.01
Range	118	6.3	0.39	0.4	11.5	11.4	2.5	0.5	0.18	0.03	2.53
No. Samples	10	10	10	10	10	10	10	10	10	10	10
Study Area 3											
Mean	1356	54.7	4.67	0	44.0	49.8	6.2	1.9	1.72	0.21	9.31
Minimum	550	32.1	3.56	0	15.6	20.7	0.8	0.4	0.57	0.07	8.91
Maximum	2005	67.8	5.42	0.2	78.5	80.7	14.1	6.1	3.23	0.40	9.65
Range	1455	35.8	1.86	0.2	62.9	60.0	13.3	5.7	2.66	0.33	0.74
No. Samples	19	19	19	19	19	19	19	10	18	18	18
Study Area 4											
Mean	1421	58.1	4.10	0	62.5	33.4	4.1	1.9	1.33	0.16	9.35
Minimum	545	44.4	3.12	0	31.1	13.8	0.7	0.6	0.66	0.07	9.00
Maximum	2010	72.1	4.94	0.3	84.0	60.5	9.6	4.4	2.58	0.33	9.79
Range	1465	27.7	1.82	0.3	52.9	46.7	8.9	3.8	1.92	0.26	0.79
No. Samples	15	15	14	14	14	14	14	15	15	15	15

Table 3.2-5. Continued.

Area	Depth (m)	% TS	Avg. Phi	% Gravel	% Sand	% Silt	% Clay	% Carbonate	% C	% N	C/N
Study Area 5*											
Mean	2759	30.9	5.33	1.2	13.0	76.1	9.9	1.4	3.50	0.45	9.07
Minimum	2385	21.7	3.95	0.3	2.1	48.5	7.6	1.2	2.70	0.34	8.85
Maximum	3085	43.9	5.78	6.4	37.1	90.3	15.2	1.6	3.86	0.49	9.25
Range	700	22.2	1.83	6.1	35.0	41.8	7.6	0.4	1.16	0.15	0.40
No. Samples	11	11	11	11	11	11	11	11	11	11	11
DS**											
Mean	2604	37.9	5.32	0	16.1	75.4	8.6	1.1	3.13	0.41	8.91
Minimum	2205	35.3	4.80	0	2.1	51.7	2.3	0.9	2.63	0.34	8.75
Maximum	3060	39.5	5.87	0	41.3	90.4	14.8	1.3	3.77	0.48	9.06
Range	855	4.2	1.07	0	39.2	38.7	12.5	0.4	1.14	0.14	0.31
No. Samples	4	4	4	4	4	4	4	4	4	4	4
Pioneer Canyon***											
Mean	1376	45.3	4.74	0.1	32.8	60.8	6.3	1.6	2.06	0.26	9.03
Minimum	550	35.0	4.47	0	19.3	47.0	3.1	0.5	0.98	0.12	8.76
Maximum	2065	60.7	5.02	0.3	47.7	69.2	11.5	2.3	2.81	0.36	9.34
Range	1515	25.7	0.55	0.3	28.4	22.2	8.4	1.8	1.83	0.24	0.58
No. Samples	5	5	5	5	5	5	5	5	5	5	5

* Stations 1-10, 20 (SAIC 1992a).
** Four deep stations west of Study Area 4.
*** Pioneer Canyon.
Source: SAIC (1992a,c).

Study Area 2

Sediment grain size measurements from the EPA surveys show that sediments in Study Area 2 are primarily sandy (89%) with some silt (10%; Figure 3.2-13), a low organic carbon content (0.4%), and low carbonate concentration relative to sediments in Study Areas 3, 4, and 5. Study Area 2 sediments consist of relatively coarse sediments with a mean phi (negative $\log_2$ of particle grain size in mm) of 3.6 and a range of 3.5 to 3.9 phi (SAIC 1992c). Study Area 2 sediments are compact with a high total solids (TS) content (72%), which is related to the large sand fraction. Similar sediment grain size distributions were reported from previous surveys of the continental shelf area by Kinnetics (Parr *et al.* 1988), IEC (1982), and Nybakken *et al.* (1984). Temporal and spatial variability in grain size are expected due to seasonal and annual differences in current velocities, wave conditions, and variations in the input of fine-grained sediments associated with outflow from San Francisco Bay (Parr *et al.* 1988).

Sand waves and ripples that likely extend throughout most of the area indicate that this is a high energy sedimentary regime (Figure 3.2-9). Study Area 2 bottom sediments also are mixed vertically through bioturbation by infaunal organisms. However, in spite of the high mixing by currents and bioturbation, the sediments appear to have a high oxygen demand as no apparent redox potential discontinuity (RPD) depth was observed at most stations located below a depth of 80 m (SAIC 1992c). The high oxygen demand is likely related to a high flux of organic material which is produced in the surface water layer and subsequently sinks as large organic particles to the bottom.

Study Area 3

Sediments in Study Area 3 range from sandy sediments at the eastern edge below the shelf break to silty sediments at the deeper western end. The average sediment composition throughout the study area consists of 44% sand and 50% silt (Table 3.2-5). Organic matter concentrations are quite low in the eastern part of Study Area 3, but are higher in sediments in the deeper western end where finer-grained sediments are more prevalent. Variations in sediment composition from

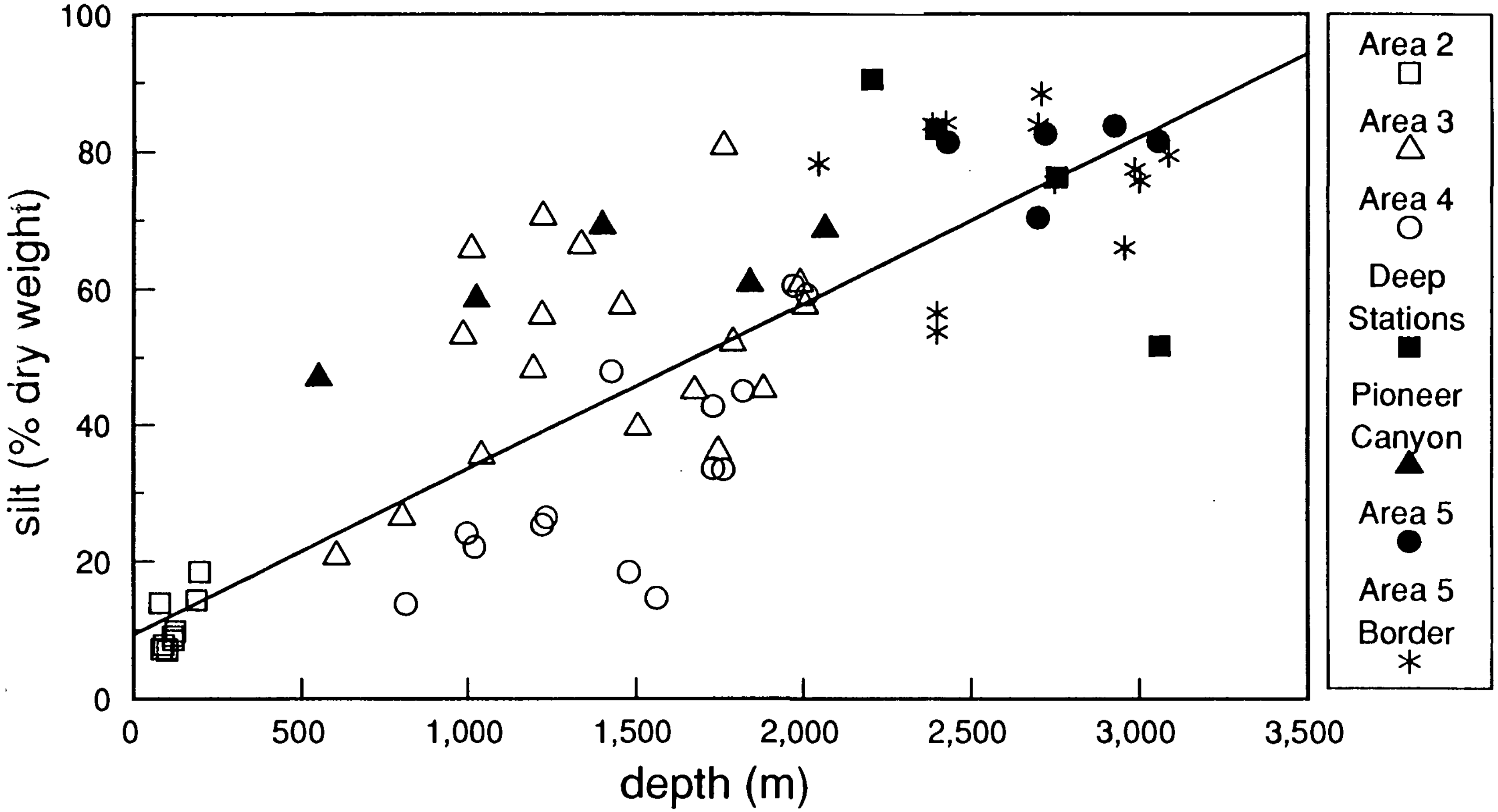

Figure 3.2-13 Patterns in Sediment Silt Content with Depth Within the LTMS Study Region.
Symbols indicate the origins of the composite samples.
Source: SAIC 1992c.

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the northern to the southern parts of the study area also are apparent; sediments along the northern edge of are sandy, rippled, and contain lower organic carbon concentrations than the siltier sediments that occur to the south along the same isobath. A sand outcrop occurs at about 1,400 m depth, and probably continues to the southeast through the center of Study Area 4, crossing Study Area 4 from the northwest to the southeast. The sediment characteristics within Study Area 3 indicate that the average kinetic energy may be intermediate between that noted for shelf depths within Study Area 2 and that indicated for the deeper sites west of Study Area 4 and Pioneer Canyon (SAIC 1992c).

Study Area 4

Overall, Study Area 4 had the second coarsest sediments (Table 3.2-5), with an average 62.5% sand and relatively low silt (33.4%) and organic carbon (1.3%) content. Study Area 4 was ranked between Study Areas 2 and 3 in terms of average kinetic energy based on grain size (SAIC 1992c). Fine-grained sediments and organic matter generally increased as depth increases. A sandy outcrop at about 1,400 m, extending from the southeast to the northwest portion of the study area, may be laterally correlated with a similar outcrop seen in Study Area 3. Below 1,400 m, a low kinetic energy bottom exists with sediment properties characteristic of a depositional zone (Figure 3.2-9).

Study Area 5

Study Area 5 contains the finest sediments (Table 3.2-5) of all the study areas, including those collected from deep sites west of Study Area 4. In addition, Study Area 5 sediments had higher percentages of carbon and nitrogen than sediments from the other areas. Although the high mean phi value corresponds to fine-grained sediments, some gravel sized material occurred on a knoll just south of Study Area 5 that showed other features typical of erosional areas including a high percentage of total solids and low carbon and nitrogen concentrations. In general, the gully area surveyed by SAIC (1992a) in the northern Farallones Escarpment shares many features, although on a smaller scale, with Pioneer Canyon. The characteristics of both features indicate that the axes of the depressions are collecting fine-grained sediments and organic matter. Results from the USGS surveys of the area suggested that sediments accumulating in the axes of the gullies may be temporary, and that the long-term depositional sites for sediments may be the basin floor to the west of these features (Karl 1992). Earthquakes and/or density currents periodically may initiate movement of accumulated sediment in a downslope direction.

3.2.5.2 Mineralogy

The clay mineralogy of the continental shelf sediments off California was described by Griggs and Hein (1980). Booth *et al.* (1989) reported trends with depth in mineralogical patterns; in general, the quantity of clay minerals increased while the nonclay minerals—primarily feldspar, quartz, and heavy minerals (amphibole)—decreased with depth. Smectite is the predominant clay mineral in the continental shelf sediments, with lesser amounts of chlorite, kaolinite, and illite. Booth *et al.* (1989) suggested that there is a similarity between the clay mineral assemblage from the low-level radioactive waste sites and that of the Russian River sediments. This observation strongly suggests that sediment input to the Gulf slope regions is from areas to the north.

Vercoutere *et al.* (1987) described the mineralogical attributes of sediments in the portion of Study Areas 2, 3, and 4 at depths less than 1,200 m. However, mineralogical data for the low kinetic energy depositional areas at depths below 1,400 m (including depositional Sites "A" in Pioneer Canyon, "B" in Study Area 3, and "C" in Study Area 4) are not included in their study. Sediment characteristics at depths corresponding to the core of the OMZ (500 to 900 m) appear to be different from those of the upper and lower edges of the OMZ. The upper boundary has abundant glauconite and foraminiferal carbonate, whereas the lower boundary has abundant fecal pellets, high mica content, high foraminiferal carbonate, low concentrations of quartz and feldspar, and no glauconite. The core of the OMZ has an increased content of mica, lower carbonate, and a higher relative percentage of quartz and feldspar; glauconite and fecal pellets are only minor components (Vercoutere *et al.* 1987).

Sediment mineralogical data are available for Study Area 5 (SAIC 1992a). All sediments contained high organic carbon concentrations (2.7 to 3.8% by wt.), reflecting high productivity of the overlying water. This high surface productivity also is reflected in biogenic carbonate which is contributed mainly by coccolithophores (1 to 2% by wt.); no foraminifera were observed. Biogenic opal also is present in the form of diatom frustules. The bulk of the minerals is contributed by clay (phyllosilicate) minerals, dominated by illite and chlorite. Smectite and kaolinite are present but less common. Clays range from 24 to 73% of the total minerals present. Quartz is the next most abundant mineral (20 to 36% of total minerals), and feldspar ranges from 6 to 52% of total minerals (SAIC 1992a).

3.2.5.3 Sediment Organic Content

Concentrations of organic carbon and organic nitrogen in sediments from the study areas are presented in Table 3.2.5). In general, the concentrations of organic carbon and nitrogen increase with increasing depth (Figure 3.2-14) and with decreasing grain size (i.e., higher phi, Figure 3.2-12). As discussed above for the individual study areas, these trends also are correlated with regional trends in the fine fractions of sediments. Trends in the organic content of the sediments may influence the spatial trends of concentrations of trace metals and trace organic contaminants (Sections 3.2.5.4 and 3.2.5.5). Positive correlations between inventories of metals, organic matter, and grain size are well known (Forstner and Wittman 1983).

3.2.5.4 Sediment Trace Metals

Concentrations of the selected sediment trace metals measured during the EPA and Navy surveys of Study Areas 2, 3, 4, and 5, and Pioneer Canyon (SAIC 1992a,c) are summarized in Table 3.2-6. For comparison, data for sediments from San Francisco Bay and NS&T Program sites, for deep-sea sediments (primarily clay and carbonate sediments) and for local bedrock are presented in Table 3.2-7. The local bedrock of the Franciscan Complex, which consists of basalts and shales, is a likely source of sediments to the offshore region (Yamamoto 1987; Murray *et al.* 1991) and, therefore, represents the natural or background concentrations of sediment metals.

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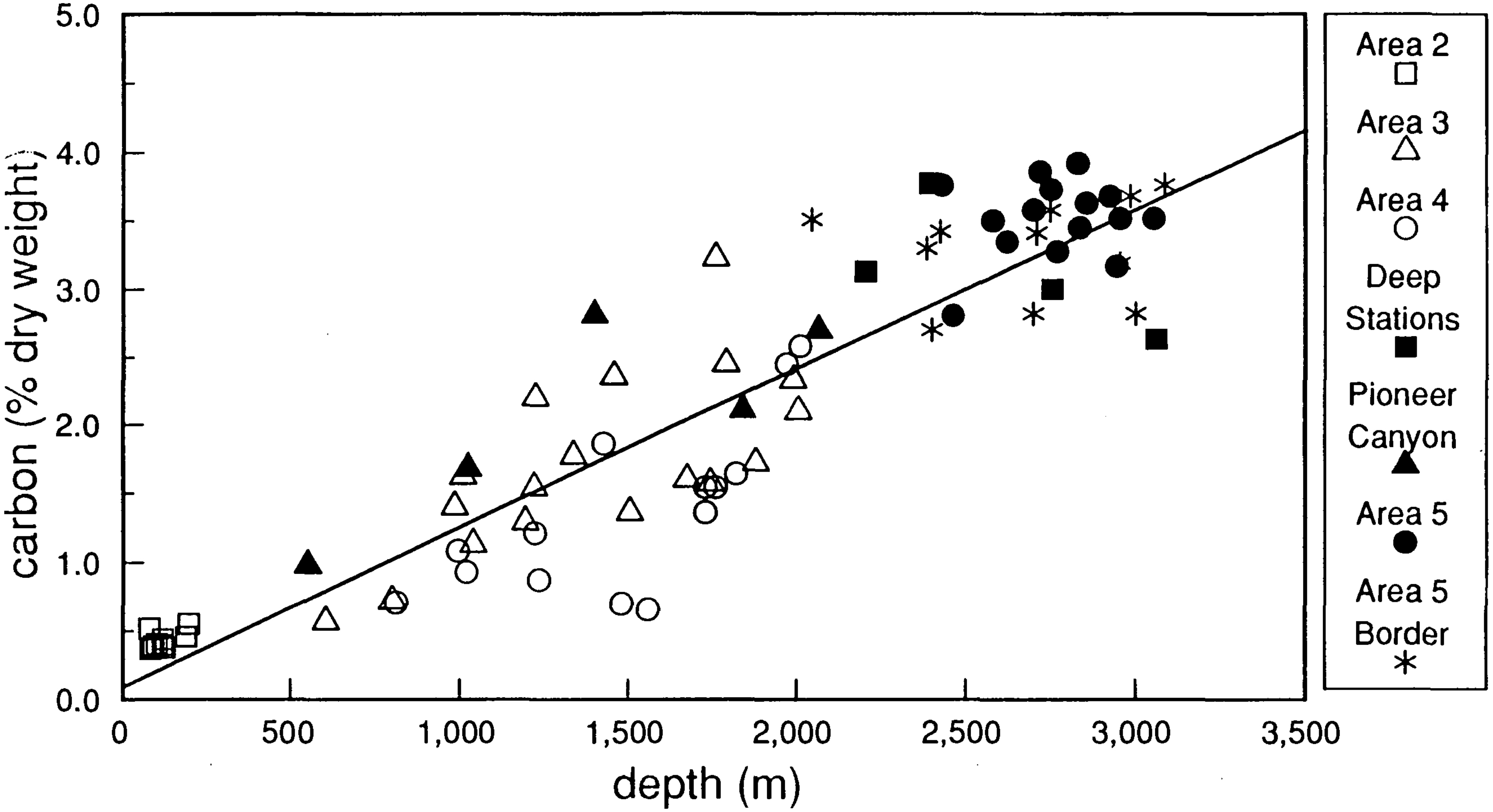

Figure 3.2-14. Patterns in Sediment Total Organic Carbon Concentrations with Depth Within the LTMS Study Region.
Symbols indicate the origins of the composite samples.
Source: SAIC 1992a,c.

Table 3.2-6. **Trace Metal Concentrations in Sediments for Study Areas 2, 3, 4, and 5, and Pioneer Canyon.**
Metal concentrations are in ppm (dry weight) except for aluminum (Al) which is in percent (dry weight). Range is the differences between the maximum and minimum values.

Area	Ag	Al	Cd	Cr	Cu	Hg	Ni	Pb
Study Area 2								
Mean	0.115	6.83	0.854	189	11.7	0.04	54.5	15.7
Minimum	0.101	6.77	0.829	141	11.6	0.03	54.4	15.6
Maximum	0.129	6.89	0.878	236	11.7	0.04	54.5	15.7
Range	0.028	0.12	0.049	95	0.1	0.01	0.1	0.1
No. Samples	2	2	2	2	2	2	2	2
Study Area 3								
Mean	0.518	6.47	0.373	168	24.3	0.08	66.3	13.8
Minimum	0.191	6.17	0.172	156	15.8	0.05	61.0	12.1
Maximum	0.687	6.83	0.770	173	34.1	0.12	73	14.8
Range	0.496	0.66	0.598	17	18.3	0.07	12.0	2.7
No. Samples	5	5	5	5	5	5	5	5
Study Area 4								
Mean	0.403	5.92	0.188	162	27.4	0.06	65.1	15.1
Minimum	0.250	4.85	0.144	117	17.3	< 0.01	54.1	10.3
Maximum	0.526	6.72	0.284	185	42.6	0.12	75.7	24.9
Range	0.276	1.87	0.140	68	25.3	0.12	21.6	14.6
No. Samples	4	4	4	4	4	4	4	4
Study Area 5								
Mean	0.55	6.67	0.31	149	41.9	0.20	92.2	10.4
Minimum	0.45	5.90	0.24	127	19.8	0.13	77.0	9.6
Maximum	0.64	7.61	0.38	168	62.5	0.36	115.0	12.0
Range	0.19	1.71	0.14	41	42.7	0.23	38.0	2.4
No. Samples	4	13	4	13	13	11	13	4

Table 3.2-6. Continued.

Area	Ag	Al	Cd	Cr	Cu	Hg	Ni	Pb
Pioneer Canyon								
Mean	0.713	6.62	0.462	151	28.1	0.06	71.1	12.5
Minimum	0.186	6.24	0.185	143	15.8	< 0.01	55.7	12.0
Maximum	1.070	7.01	1.060	164	38.3	0.10	85.5	13.1
Range	0.884	0.77	0.875	21	22.5	0.10	29.8	1.1
No. Samples	5	5	5	5	5	5	5	5

Source: SAIC (1992a,c).

Table 3.2-7. Trace Metals in Sediments from the Study Areas and Comparison Data.

	Study Areas 2, 3, and 4[1]		NOAA NS&T Program[2]				Deep-Sea Sediments[3]		Average Franciscan Complex[4]	
			San Francisco Bay Sites			All U.S. Sites				
			Fine Seds (> 20% with phi > 4.0)		Coarse Seds (> 20% with phi < 4.0)					
Metals (ppm dry wt):	Mean	Range	Mean	Range		Range	Clay	Carbonate	Chert	Shale
Aluminum (%)	6.42	4.85–7.01	(NA)	(NA)	(NA)	(NA)	8.40	2.00	1.4	12.2
Cadmium	0.41	0.14–1.06	0.42	0.18–0.81	0.28	0.01–11.3	0.42	(NA)	(NA)	(NA)
Chromium	164	117–236	425	185–1,587	259	5.2–3,374	90	11	9.5	90
Copper	24.7	11.6–42.6	69.4	49.9–93.7	13.7	0.4–319	250	30	(NA)	(NA)
Lead	13.9	10.3–24.9	40.8	21.4–84.9	5.2	0.9–280	80	9	25	78
Mercury	0.06	< 0.01–0.12	0.32	0.03–0.54	0.05	0.007–4.31	(NA)	(NA)	(NA)	(NA)
Nickel	66.0	54.1–85.5	151.6	103.4–252.1	72.1	1–252	225	30	16	70
Silver	0.50	0.10–1.07	0.5	0.08–0.87	0.44	0.01–11.6	0.11	(NA)	(NA)	(NA)

[1]Data are from 16 composite samples (SAIC 1992c).
[2]NOAA (1988).
[3]Turekian and Wedepohl (1961).
[4]Data from the Franciscan Complex (Central belt) in Sausalito (CA), 1.5 km north of the Golden Gate Bridge are from Yamamoto (1987).

NA = not available

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The concentrations of aluminum, cadmium, copper, lead, and nickel in sediments from the study areas are comparable to those in deep-sea sediments and to the Franciscan Complex. In contrast, concentrations for chromium and silver are higher in samples from the study areas. Comparative data for silver and mercury concentrations in deep-sea sediments or the Franciscan Complex are limited. However, measured concentrations of these metals generally are comparable to those reported in sediments from other coastal areas (e.g., Bruland *et al.* 1974). Nevertheless, mean concentrations of chromium, copper, lead, mercury and nickel in sediments from the study areas are lower than those in sediments in San Francisco Bay as measured in the NS&T Program.

Trends in concentrations of trace metals with water depth are illustrated in Figure 3.2-15. Values represent the composite sediment samples and the average depth of the locations sampled for each composite sample during the EPA and Navy surveys. In general, concentrations of copper, mercury, nickel, and silver increase with depth over the study region (Figure 3.2-15D). These trends also follow the trends for decreasing TS content and increasing organic carbon and nitrogen concentrations and decreasing sediment grain size. In contrast, cadmium concentrations decrease with increasing depth (Figure 3.2-15B), whereas, distinct trends with depth are not apparent for aluminum, chromium, and lead (Figure 3.2-15A,C).

The association of relatively higher concentrations of metals in sediments with finer grain size has been reported from other geographic regions (Forstner and Wittman 1983). The observed differences between study areas in the sediment trace metal concentrations generally are consistent with spatial patterns of sediment grain size and organic content. There is no evidence of elevated sediment metals concentrations (i.e., unsupported by higher percentages of fine-grained sediments) indicative of significant anthropogenic contaminations over the study region.

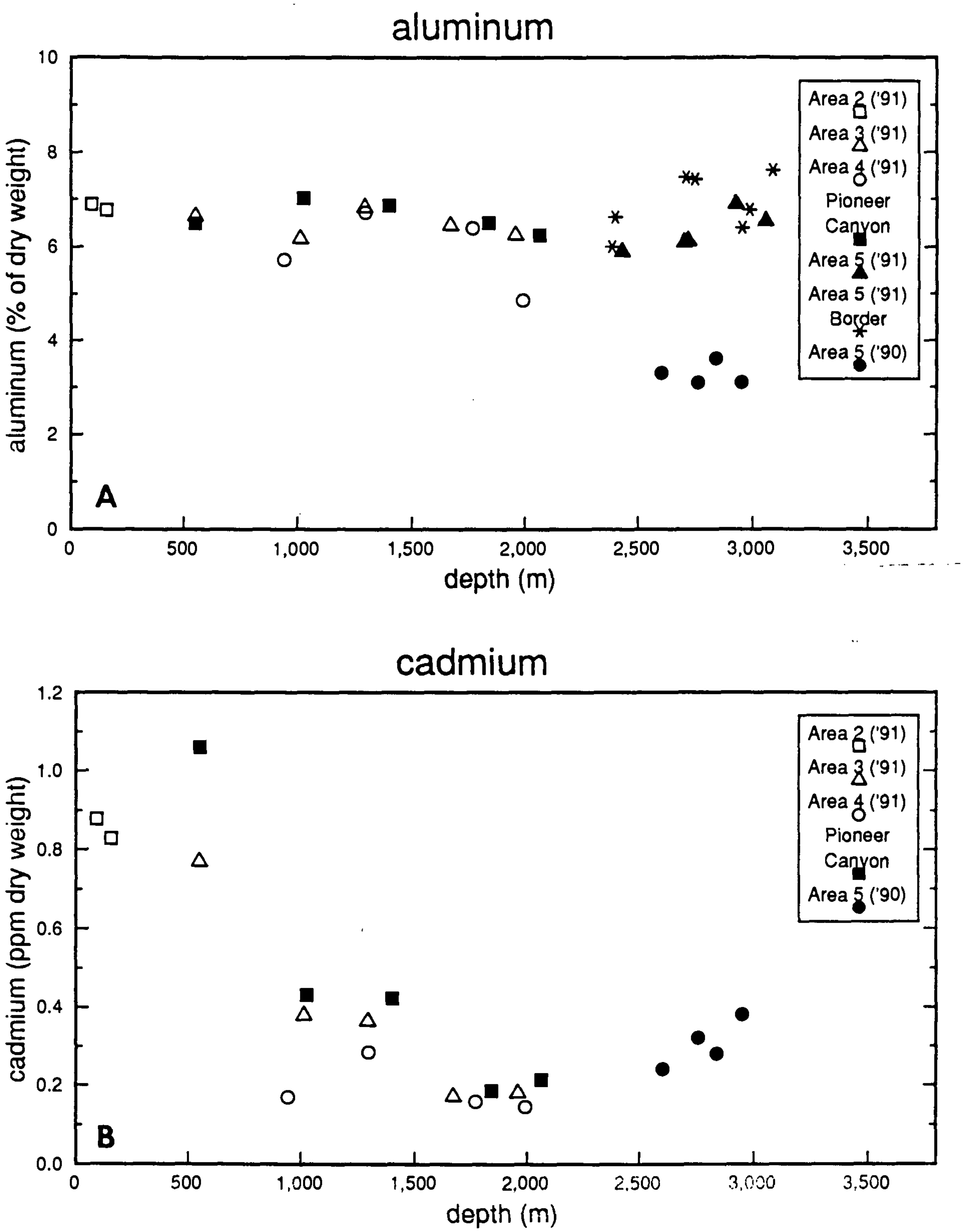

Figure 3.2-15. Sediment Concentrations of: (A) Aluminum; (B) Cadmium; (C) Chromium, and (D) Copper Within the LTMS Study Region.
Symbols indicate the origins of the composite samples.
Source: SAIC 1992a,c.

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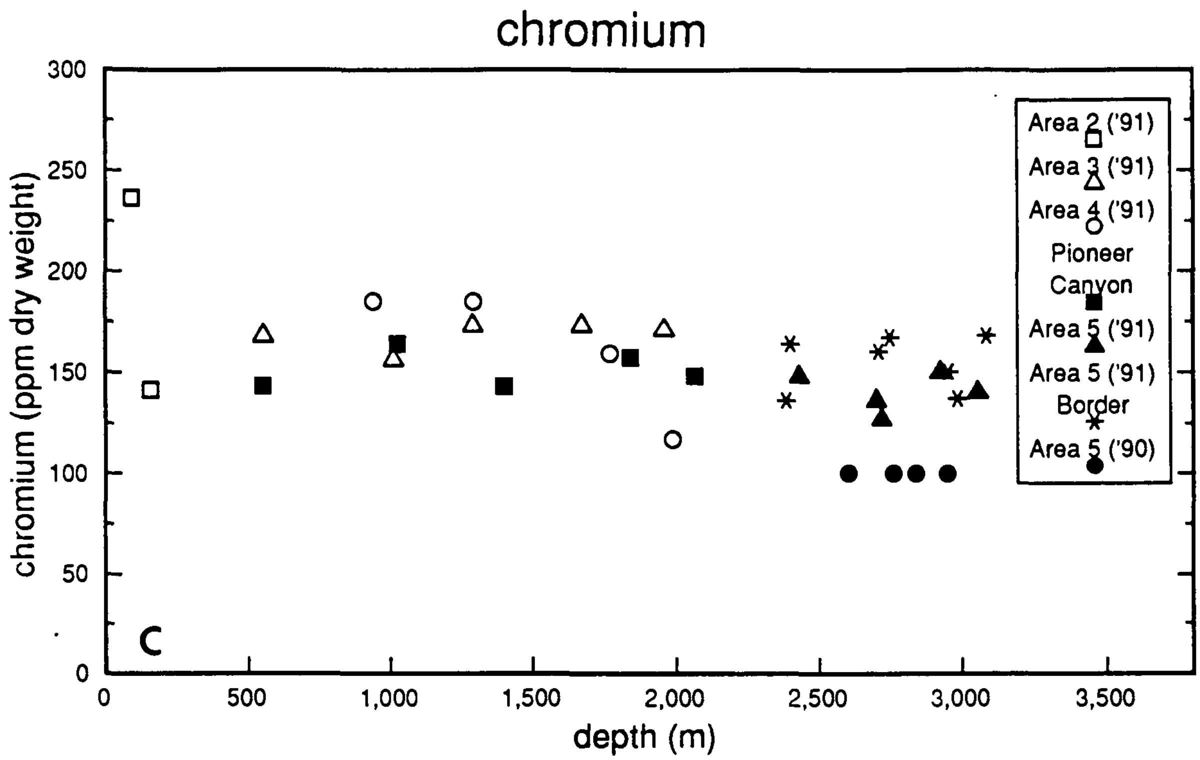

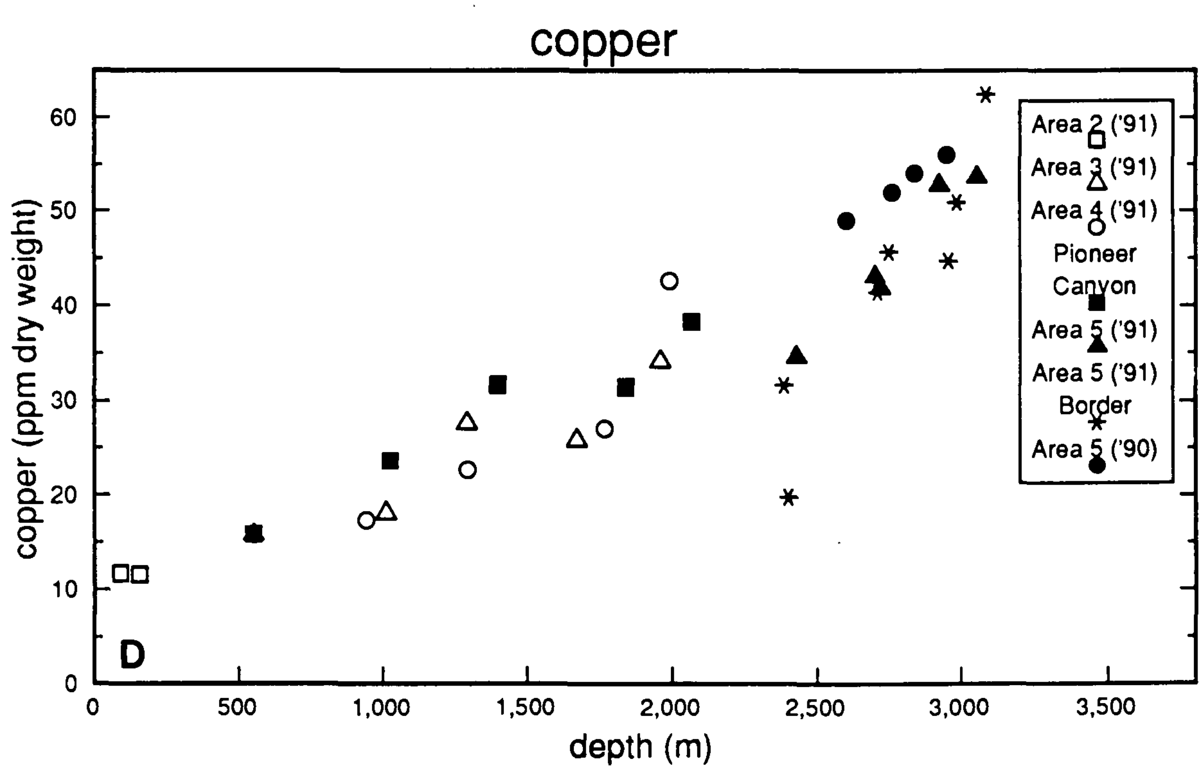

Figure 3.2-15. Continued.

Study Area 2

Sediments from Study Area 2 generally contained high concentrations of cadmium and chromium, but lower concentrations of silver and copper, compared to those in the other study areas (Table 3.2-6). The mean cadmium concentration (0.854 ppm) is approximately two to five times higher than mean concentrations for the other study areas, but comparable to concentrations measured in shelf sediments by Nybakken *et al.* (1984) and to concentrations in sediments at similar depths in a relatively pristine area of the Santa Maria Basin, California (Steinhauer *et al.* 1991). The chromium concentration (mean=189 ppm) was somewhat higher than average concentrations for Santa Maria Basin sediments (45–102 ppm; Steinhauer *et al.* 1991) and concentrations in local source rocks (Table 3.2-7). It is possible that enriched chromium concentrations in the study area sediments are from weathering of bedrock sources containing chromite minerals. Although the mean silver (0.115 ppm) and copper (11.7 ppm) concentrations were relatively low, they were similar to average concentrations in Santa Maria Basin sediments (0.15 and 13 ppm, respectively).

Concentrations of chromium, copper, lead, and mercury measured in shelf sediments by Nybakken *et al.* (1984) were up to several times lower than those measured in the Study Areas 2 sediments during the EPA surveys. The relatively lower concentrations reported by Nybakken *et al.* likely were due to differences in analytical methodologies (sediment digestion procedures) rather than to spatial or temporal changes.

Study Area 3

Concentrations of cadmium in Study Area 3 sediments were lower than those at Study Area 2 and decreased with increasing depth. The concentrations generally were greater than those at Study Area 4, except at depths greater than 1,500 m (region of Alternative Sites 3 and 4), where the concentrations were comparable. All measured cadmium concentrations are less than those found in southern California slope sediments (1.45 ppm) and average deep-sea clays

(Table 3.2-7). Chromium concentrations were relatively uniform but somewhat high (mean=168 ppm). The average silver concentration in Study Area 3 was 0.518 ppm, which is greater than that found in typical southern California slope or shelf sediments, crustal rocks, average shales, and deep-sea clays and carbonates. Concentrations increased with depth to a maximum of approximately 0.7 ppm. The average copper concentration in the study area was 24.3 ppm, which is intermediate to those of the southern California slope (31 ppm) and continental shelf (13 ppm). While the higher copper concentrations occur in deeper water, the range of concentrations in Study Area 3 falls within the values cited above for other California slope and shelf regions.

Study Area 4

The cadmium concentrations in Study Area 4 generally were low and uniform with few exceptions. Concentrations for all other metals were similar to those in Study Area 3.

Pioneer Canyon

Pioneer Canyon sediments contained higher silver concentrations (mean=0.713 ppm) than any of the study areas. The source of the silver, above natural background concentrations, is unknown. Other trace metal concentrations generally were similar to those in Study Area 3.

Study Area 5

Concentrations of silver, chromium, lead, and aluminum in Study Area 5 were similar to those at Study Areas 3 and 4. Cadmium concentrations are similar to those at Study Area 3. Concentrations of copper (mean=41.9 ppm), mercury (mean=0.20 ppm), and nickel (mean=92.2 ppm) were higher than those from the other study areas.

Although some differences between the study areas in the concentrations of individual trace metals were apparent, the trends are well correlated to differences in sediment grain size and organic content. The magnitudes of the concentrations of individual metals generally are comparable to expected natural or background levels. With the possible exception of silver concentrations in Pioneer Canyon sediments and mercury concentration in the Study Area 5 sediments, there is no strong evidence of unusually high or enriched trace metal concentrations suggestive of contamination from historical waste disposal operations or other anthropogenic sources.

3.2.5.5 Sediment Hydrocarbons

Hydrocarbons in sediments include a variety of organic compound classes such as non-chlorinated aliphatics (i.e., saturates), non-chlorinated aromatics, chlorinated pesticides, and PCBs. Many aliphatic and aromatic hydrocarbons may be derived from a variety of natural (e.g., oil seeps), anthropogenic, and biogenic sources. For example, saturated and aromatic hydrocarbons are principal components in residues of both crude and refined petroleum products. In addition to direct inputs from spills of petroleum products and diagenetic sources (i.e., in situ processes associated with marine sediments such as submarine oil seeps), inputs to marine sediments of aliphatic and aromatic compounds of oil-related origin can result from atmospheric fallout of combustion products. Certain hydrocarbons are produced naturally by marine as well as terrestrial biota, although the variety of biogenic compounds is limited relative to oil-derived hydrocarbons. The general composition of these biogenic hydrocarbons is quite different from oil-derived hydrocarbons and these differences can be utilized to distinguish between sources of hydrocarbons. For example, n-alkanes in oil have approximately equal concentrations of compounds with odd and even numbers of carbon atoms (i.e., an odd to even ratio of approximately 1). In contrast, biologically-produced n-alkanes have a predominance of n-alkanes with odd numbers of carbon atoms (i.e., odd to even ratio substantially greater than 1). Consequently, the overall composition of hydrocarbon classes such as n-alkanes can be used to identify the generic source of compounds in sediment samples.

Concentrations of total n-alkanes and PAHs in sediments from the LTMS study areas are summarized in Table 3.2-8 and shown in Figure 3.2-16. The values in the figure are from the

Table 3.2-8. Hydrocarbon Concentrations in Sediments for Study Areas 2, 3, and 4, and Pioneer Canyon.

Hydrocarbon concentrations are in ppb (dry weight) except for the Unresolved Complex Mixture which is in ppm (dry weight). Range is the difference between the maximum and minimum values.

Area	Aliphatic Hydrocarbons Alkanes	Polynuclear Aromatic Hydrocarbons	Unresolved Complex Mixture	Total Pesticides	Total PCBs*
Study Area 2					
Mean	414	127	1.2	1.61	15.0
Minimum	414	123	1.1	1.50	14.8
Maximum	414	131	1.3	1.71	15.1
Range	0.1	8.21	0.2	0.21	0.03
No. Samples	2	2	2	2	2
Study Area 3					
Mean	1,200	317	4.9	3.81	28.4
Minimum	752	211	3.6	2.34	15.5
Maximum	1,440	390	6.3	4.51	68.1
Range	691.2	180	2.7	2.17	52.6
No. Samples	5	5	5	5	5
Study Area 4					
Mean	1,300	349	6.3	3.40	18.8
Minimum	704.5	200	2.4	2.14	14.8
Maximum	2,060	585	13.3	4.84	23.1
Range	1,360	385	10.9	2.70	8.3
No. Samples	4	4	4	4	4
Pioneer Canyon					
Mean	1,745	446	10.1	4.61	18.8
Minimum	964	257	5.0	2.20	15.7
Maximum	2,290	610	16.1	5.98	21.4
Range	1,320	353	11.1	3.78	5.7
No. Samples	5	5	5	5	5

*The method detection limit for total PCB concentrations is approximately 20 ppb; values below 20 ppb should be considered estimates.
Source: SAIC (1992c)

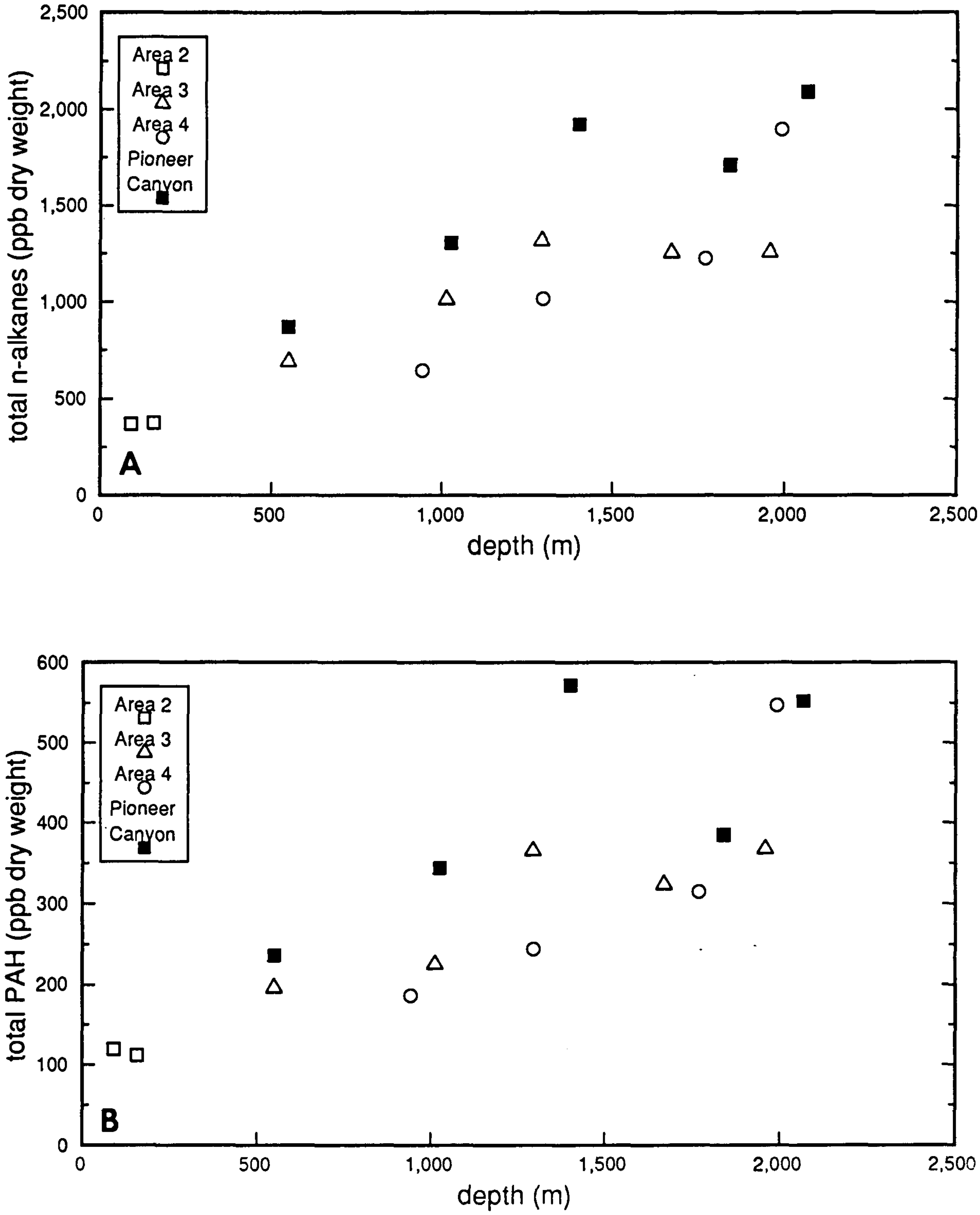

Figure 3.2-16. Sediment Concentrations of: (A) Total n-alkanes and (B) Total PAHs Within the LTMS Study Region.
Symbols indicate the origin of the composite samples.
Source: SAIC 1992c.

sixteen composite samples from Study Areas 2, 3, and 4, and from Pioneer Canyon. Concentrations of both n-alkanes and PAHs generally increase with increasing depth in the study areas. As noted, total organic carbon also increases with depth throughout the study areas (Figure 3.2-14). Figure 3.2-17 shows concentrations for total n-alkanes and PAHs in the individual composites and the corresponding concentrations of total organic carbon, and indicates a close correspondence between these parameters. Consequently, the levels of total n-alkanes and PAHs in sediment samples from the study areas appear to be related to transport processes that also affect the overall organic content of sediments in the study areas. Similar correlations between concentrations for total hydrocarbons and organic carbon content have been reported in surface sediments from the Gulf of Mexico (Boehm 1987).

Chlorinated pesticides and PCBs are synthetic compounds that are not native to the marine environment. These classes of compounds can derive from surface runoff, aerial fallout, and disposal of contaminated wastes. Concentrations of total chlorinated pesticides and total PCBs are summarized in Table 3.2-8, and concentrations of total DDT and total PCBs are plotted in Figure 3.2-18.

Study Areas 2, 3, and 4

Summaries of the concentrations of organic compounds in sediments from Study Areas 2, 3, and 4, and from Pioneer Canyon, are presented in Table 3.2-8. Study Area 3 had two to three times the concentration of organic compounds as Study Area 2. However, except for pesticides and total PCBs, the mean concentrations of other hydrocarbons were less than those in Study Area 4 or in Pioneer Canyon. Except for total PCBs, the concentrations of all organic compounds were highest in the Pioneer Canyon, which probably reflects depositional focusing and transport of sediments at this location.

Although samples from the study areas were analyzed for a variety of chlorinated pesticides, detectable quantities of individual pesticides were measured routinely for only DDT analogs and isomers (particularly 4,4'-DDE, 4,4'-DDD, and 2,4'-DDE); other chlorinated pesticides were not

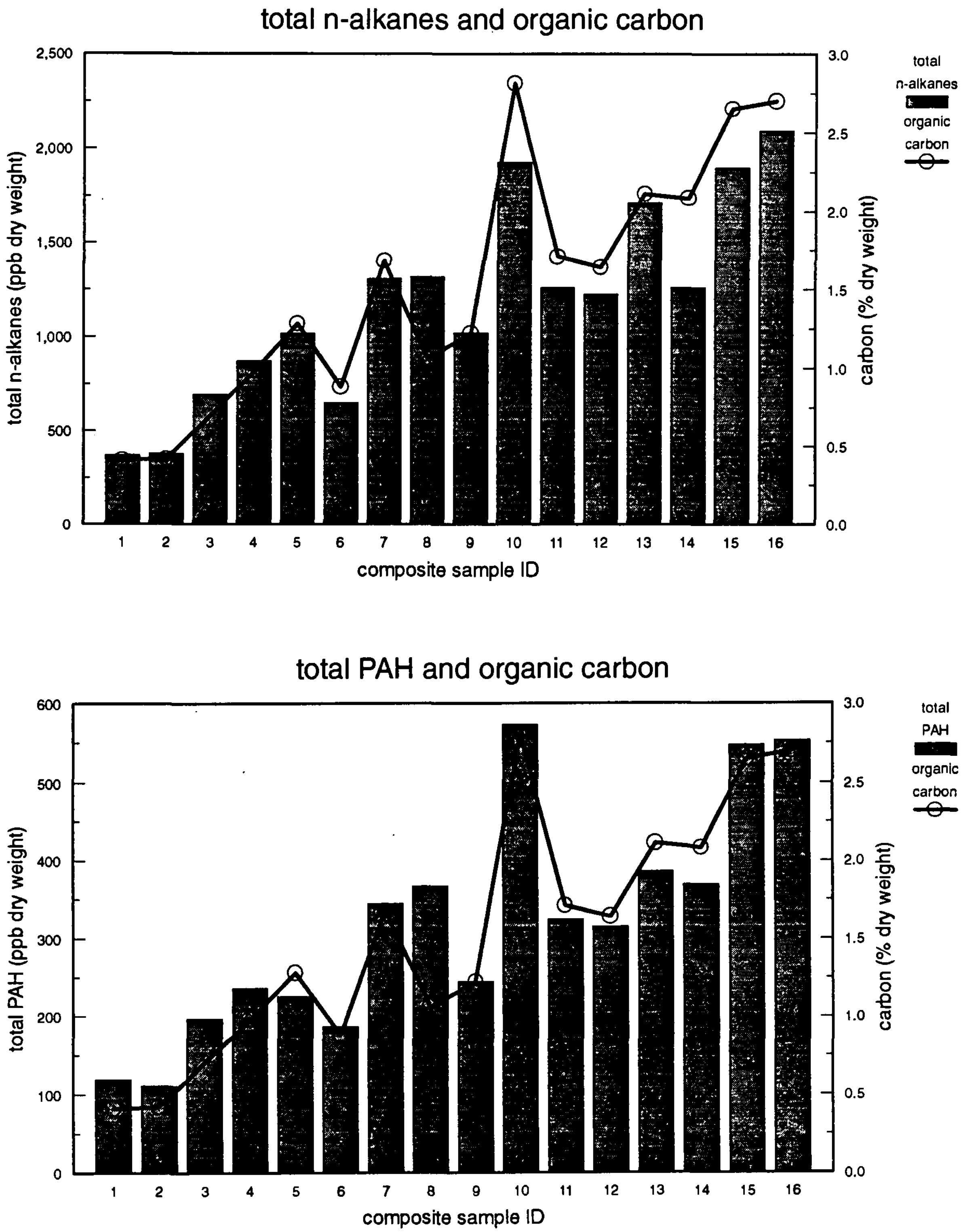

Figure 3.2-17. Sediment Concentrations of: (A) Total n-alkanes and Organic Carbon and (B) Total PAH and Organic Carbon Within the LTMS Study Region.
Source: SAIC 1992c.

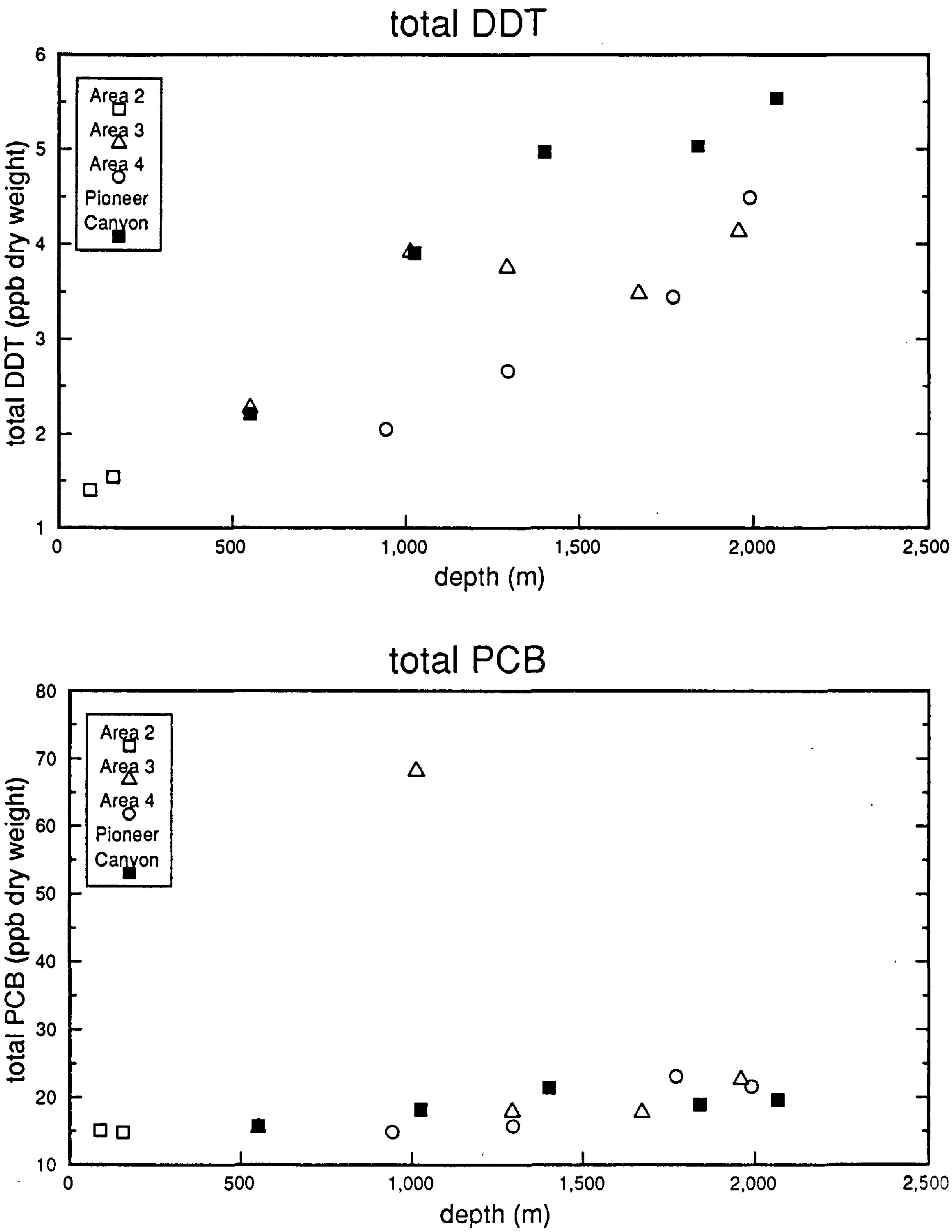

Figure 3.2-18. Sediment Concentrations of Total DDT and Total PCBs Within the LTMS Study Regions.
Symbols indicate the origins of the composite samples.
Source: SAIC 1992c.

detected in the sediments. Individual PCBs (congeners) were detected in the sediments, but at concentrations typically at or near the analytical detection limits. Plots of concentrations for total DDT and total PCBs for the composite samples are presented in Figure 3.2-18. Concentrations of total DDT generally increase with depth along with the organic content of the sediments. These trends indicate that DDT concentrations also are related to transport processes affecting the overall organic content of sediments in the study areas.

Concentrations of total PCBs typically were at or below the analytical detection limits, with the exception of measurable amounts of PCBs in sediments composited from three stations along the 1,000 m isobath in the northern portion of Study Area 3. Consequently, the sediment PCB concentrations appear to be relatively uniform throughout the study areas, and no correlation between PCB concentrations and organic carbon content is evident. The relatively elevated concentration for PCBs in the single composite sample from Study Area 3 presumably reflects a localized input of PCBs to the area.

Study Area 5

Hydrocarbons and other trace organic contaminants were not detected (i.e., less than the analytical detection limits) in sediments collected in Study Area 5 during the Navy surveys (SAIC 1992a). However, these samples were analyzed using different methods, with lower analytical sensitivity (i.e., higher detection limits), than those used for sediments from Study Areas 2, 3, and 4. Also, the concentrations of n-alkanes and many of the PAHs were not analyzed in Study Area 5 sediments. Only the PCB Aroclor 1221 was present in concentrations near the detection limit. The pesticide Lindane (=Gamma-BHC) also was detected in Study Area 5 sediments; whereas, this compound was not found in any of the samples from Areas 2, 3, 4, and the Pioneer Canyon.

Regional Summary

In general, a trend in increasing concentrations of hydrocarbon compounds with depth over the study region is apparent. This relationship likely is not related to historical waste discharges or proximity to source inputs. Rather, the magnitudes, composition, and spatial distributions reflect correlations between sediment hydrocarbons, fine grain size, and higher organic contents as observed in other marine environments.

Hydrocarbon data for sediments from San Francisco Bay and sites from the NS&T Program are summarized in Table 3.2-9 Concentrations of hydrocarbons in sediments from the study areas generally are lower than concentrations in San Francisco Bay sediments, although both substantially lower and higher concentrations for the PAHs, DDT, and PCBs occur in coastal sediments from other locations throughout the U.S.

Previous measurements of sediment hydrocarbons within the region indicated trace concentrations of DDE (2.1–3.2 ng/g), DDD (up to 0.1 ng/g), and chlordane (2.2–2.8 ng/g) in sediments at the 100-Fathom site; PCBs were not detected (IEC 1982). Nybakken *et al.* (1984) reported similar concentrations of DDE (0.2–1.6 ng/g), along with trace quantities of PCBs (0.2–0.5 ng/g), alpha- and gamma-chlordanes (0.01–0.6 ng/g), and selected PAHs (1–74 ng/g phenanthrene, 1–49 ng/g fluoranthene, and 1–56 ng/g pyrene) in sediments from the continental shelf and shelf edge. The PAHs probably are derived primarily from particle discharges from San Francisco Bay and atmospheric deposition of combustion-derived products.

Melzian *et al.* (1987) reported relatively high concentrations of chlorinated hydrocarbons (DDT and PCBs) in the liver tissues of Dover sole (*Microstomas pacificus*) and sablefish (*Anoplopoma fimbria*) collected at depths of 500 m and 1,000 m in the vicinities of the former low-level radioactive and chemical munitions disposal sites. Although the source(s) of the chlorinated organics in the fish liver tissues could not be discerned, Melzian *et al.* suggested that historical wastes may represent a source for one or more of these contaminants.

However, with the exception of the relatively elevated concentration of total PCBs in the one composite sample from Study Area 3, there was no evidence from the EPA surveys of significant anthropogenic sediment contamination within the LTMS study areas.

Table 3.2-9. Hydrocarbons in Sediments from the Study Areas and Comparison Data.

	Study Areas 2, 3, and 4[1]		NOAA NS&T Program[2]			
			San Francisco Bay Sites			All U.S. Sites
			Fine Seds (> 20% with phi > 4.0)		Coarse Seds (> 20% with phi < 4.0)	
Organics (ppb dry wt):	Mean	Range	Mean	Range		Range
Total PAH	318	111–572	2,166	491–5,230	799	2–57,800
Total DDT	3.42	1.40–5.54	15.8	3.0–44.9	0.33	0.04–6,891
Total PCB	21.3	14.8–68.1	62.6	33.3–82.8	10.5	0.3–2,069

[1]Data are from 16 composite samples (SAIC 1992c).
[2]NOAA (1988).

3.2.5.6 Sediment Radionuclides

As discussed in Section 3.1, low-level radioactive wastes were disposed historically at several locations within the Gulf of the Farallones. Several studies (PneumoDynamics 1961; Dyer 1976; Noshkin *et al.* 1978; Shell and Sugai 1980; Suchanek and Lagunas-Solar 1991) have been conducted to determine whether the historical discharges have resulted in elevated radionuclide concentrations in waters, sediments, or organism tissues. NOAA (1990) estimated that studies conducted between 1960 and 1977 have collected over 900 water samples, 30 sediment cores, and 400 biota samples, primarily near disposal sites A, B, and C (see Table 3.1-3).

Detectable amounts of several radionuclides, primarily cesium-137 (^{137}Cs) and plutonium-239/240 ($^{239+240}Pu$), have been measured in the water, sediment, and tissue samples. However, the significance of the measured concentrations, and the contributions to the total concentrations of the waste material relative to inputs from nuclear fallout, are equivocal. For example, Dyer (1976) concluded that the measured concentrations of $^{239+240}Pu$ in sediments near a waste canister cluster were from 2 to 25 times higher than background levels. Suchanek and Lagunas-Solar (1991) calculated that the concentrations measured by Dyer actually were up to 1,064 times above background. Noshkin *et al.* (1978) questioned the reference or background levels used by Dyer and concluded that the total $^{239+240}Pu$ inventory in the Gulf of the Farallones (2.1–3.5 mCi/km^2) is not significantly different from fallout levels in the open Pacific ocean (2.2–4.3 mCi/km^2). Shell and Sugai (1980) also collected sediments near ruptured drums which contained measured quantities (9–137 pCi/kg) of $^{239+240}Pu$. They concluded that the sediment plutonium concentrations at this site were from 2 to 200 times higher than levels expected from fallout sources alone.

Therefore, while the presence of ruptured drums containing low-level radioactive wastes in the Gulf of the Farallones has been well-documented, the contributions of these wastes to the measured sediment radionuclide concentrations, the spatial extent of any contamination, and the environmental impacts and potential human health risks associated with the wastes are problematic. NOAA and EPA presently are evaluating these questions to assess the need for remediation.

3.3 Biological Environment

3.3.1 Plankton Community

This section presents information on plankton and their distributions and abundance in the general vicinity of LTMS Study Areas 2, 3, 4, and 5.

Plankton are free-floating organisms that typically drift with ocean currents, in contrast to actively swimming species such as fish. In general, plankton can be divided into three broad categories: prokaryotic bacterioplankton; phytoplankton, representing single-celled plants that are capable of photosynthesis and which form an important base for many marine systems; and zooplankton, representing animals that are a primary link in many food webs between phytoplankton and larger marine organisms such as fish, sea birds, and marine mammals. Zooplankton includes animals that remain planktonic throughout their life (holoplankton) as well as larval stages of benthic invertebrates (meroplankton) and fish (ichthyoplankton). Plankton distributions are characterized by high spatial patchiness, strong seasonal and inter-annual variation, and direct responses to oceanic circulation (McGowan and Miller 1980). The basic circulation pattern along the central California coast consists of the southward-flowing California surface current and the northward-flowing California Undercurrent, which often becomes a surface current during winter (Noble and Ramp 1992; Hayward and Mantyla 1990). This general pattern for coastal circulation can be modified by local topography and wind fields, and can change considerably on time scales of a few days (Breaker and Mooers 1986).

Satellite imagery indicates that the Gulf of the Farallones is an area of high planktonic activity, due to the combination of seasonal upwelling characteristic of the entire California coast (Barber and Smith 1981), local effects of nutrient inputs from San Francisco Bay (KLI 1991), and such features as the Point Reyes coastal upwelling jet (Noble and Ramp 1992). Detailed information on seasonal patterns of production, abundance, and species composition for the LTMS study areas is not available; however, a general description of the plankton community can be summarized from studies along the central California coast. Bence *et al.* (1992) present a study area-specific review of plankton data available from NMFS, CDFG and CalCOFI research, and from CalCOFI plankton atlases. The NMFS data focus on midwater trawl surveys and one ichthyoplankton survey. The CDFG data consist of zooplankton samples collected between 1975 and 1980 during a study of Dungeness crabs (*Cancer magister*). The CalCOFI data emphasizes ichthyoplankton counts and plankton volume.

3.3.1.1 Phytoplankton

The predominant members of the phytoplankton community are diatoms, silicoflagellates, coccolithophores (Chrysophyta), and dinoflagellates (Pyrrophyta). Three parameters commonly used to describe phytoplankton communities are the following: (1) productivity, reflecting the amount of new plant material formed per unit of time; (2) standing crop, representing the amount of plant material present, usually expressed as concentrations of chlorophyll or cell number; and (3) species composition. Inter-annual variation and seasonal cycles of productivity and standing crop reflect variations in the upwelling regime along the central and northern coast of California, including the general study areas for this program. During the upwelling season, phytoplankton blooms in northern California generally occur between March and August (Welch 1967). Diatom growth is sparse in years of weak upwelling, while intermittent upwelling stimulates diatom growth (Bolin and Abbott 1963).

The combination of seasonal coastal upwelling events and nutrient inputs from San Francisco Bay promotes high primary productivity throughout the study area (KLI 1991). CalCOFI data indicate that both chlorophyll *a* and phaeopigments are highest in continental shelf waters, which suggests that standing stocks of phytoplankton are higher in nearshore areas (e.g., water depths similar to Study Area 2 and the shallow portion of Study Area 3) than in offshore regions (Bence *et al.* 1992). Highest productivity levels between Point Sur and the Gulf of the Farallones occur within approximately 50 km of the coast (Owen 1974). Average productivity values in the latter study ranged from 342 to 586 mg carbon/m^2/day over the course of a year. The maximum productivity (1,300 mg carbon/m^2/day) was reported for a site within 50 km of the Golden Gate during August–September. The minimum productivity (256 mg carbon/m^2/day) was observed during a May–June cruise.

Standing crop lagged behind the cycle of productivity by about two months. Surface chlorophyll concentrations ranged from less than 0.5 mg/m^3 during July–September to 2–8 mg/m^3 during October–December (Owen 1974). Although Garrison (1976) reported similar values from waters near the mouth of Monterey Bay, Ambler *et al.* (1985) measured chlorophyll concentrations ranging from less than 1 mg/m^3 between October and January to nearly 5 mg/m^3 in April and June. Differences in measurements of chlorophyll concentrations among studies may be related to the time lag required for phytoplankton growth (Abbott and Zion 1985). Phytoplankton initially respond to nutrient input with increased primary production, leading to increased population size after a time lag, resulting in a dynamic biological structure (Denman and Abbott 1988).

Species composition of phytoplankton communities also varies seasonally. The spring/summer phytoplankton bloom, coincident with upwelling events, is dominated by diatoms, specifically species of *Chaetoceros* and *Rhizosolenia.* During non-upwelling periods, dinoflagellates of the genera *Ceratium* and *Peridinium* dominate (Bolin and Abbott 1963; Welch 1967). A similar seasonal pattern of species composition was observed along the central coast (Malone 1971) and approximately 200 km south of the study area near Diablo Canyon (Icanberry and Warrick 1978).

In summary, several studies on phytoplankton along the central California coast indicate seasonal cycles of productivity, standing crop, and species composition. It is anticipated that phytoplankton within the LTMS study areas will exhibit the same general cycles, although factors such as upwelling, the complex topography of the Gulf of the Farallones, and nutrient inputs from San Francisco Bay may have significant localized effects. Productivity and standing crop appear to be highest in continental shelf waters including Study Area 2 and the shallow portion of Study Area 3. Potential impacts to phytoplankton communities from dredged material disposal activities are expected to be temporary (Section 4.4).

3.3.1.2 Zooplankton

An estimated 546 invertebrate zooplankton species and approximately 1,000 ichthyoplankton species occur in the California Current system (Kramer and Smith 1972). Copepods and euphausiids, an important food source for many organisms, including juvenile fish, dominate the holoplankton in terms of numbers and biomass, although thalacians (salps), chaetognaths (arrow worms), and pelagic molluscs also are abundant (Table 3.3.1-1). Common species in the California Current include the euphausiid *Euphausia pacifica*, copepods of genera *Calanus*, *Neocalanus*, *Eucalanus*, and *Acartia*, and salps. Based on CalCOFI data, Bence *et al.* (1992) classified 34 holoplankton species that are common to the California Current into nearshore or offshore distribution categories (Table 3.3.1-1). Various species of copepods, euphausiids, and chaetognaths were found in both nearshore and offshore waters, whereas thaliaceans and pelagic molluscs occurred primarily offshore.

The CalCOFI summary was supplemented by results of zooplankton studies conducted by Hatfield (1983) and Tasto *et al.* (1981). These latter samples were collected as part of a CDFG study on Dungeness crabs. Hatfield identified inshore and offshore zooplankton groups of both holoplankton and meroplankton (Table 3.3.1-1) from oblique tows collected in spring 1976, winter and spring 1977, and March 1979. Few of the holoplankton species identified from the CalCOFI atlases were reported by Hatfield, possibly due to different sampling techniques and/or sampling schedules. Further, Hatfield (1983) noted substantial differences in spatial distributions and abundances of a number of zooplankton species associated with upwelling and seasonal and localized current patterns. For example, plankton species that are characteristic of more northerly latitudes were rare in the Gulf of the Farallones. Additionally, in the winter of 1977 when the Davidson Current dominated the area, species typically seen nearshore were found farther offshore and mixed with offshore forms.

Table 3.3.1-1. Dominant Zooplankton in Waters Offshore Central California Based on a Review of CalCOFI Atlases, Hatfield (1983) and Tasto *et al.* (1981; 1975–1977 samples).

Nearshore = continental shelf waters; Offshore = seaward of the continental shelf; summarized from Bence *et al.* (1992).

	Nearshore	Offshore
	CalCOFI (as summarized in Bence *et al.* 1992)	
Holoplankton		
Copepods	*Acartia tonsa*	*Acartia danae*
	Calanus helgolandicus	*Calanus gracilis*
	Clausocalanus pergens	*Clausocalanus arcuicornis*
	Ctenocalanus vanus	*Gaidius pungens*
	Metridia luceus	*Plueromamma abdominalis*
	Tortanus discaudatus	
Euphausiids	*Euphausia pacifica*	*Euphausia gibboides*
	Thysanoessa spinifera	*Euphausia mutica*
	Nyctiphanes simplex[1]	*Euphausia recurva*
		Thysanoessa gregaria
Chaetognaths	*Sagitta enflata*	*Sagitta bierii*
	Sagitta scrippsae[2]	*Sagitta minima*
	Sagitta euneritica[2]	*Eukrohnia hamata*
Thaliaceans	*Dolioletta gegenbauri*	*Thalia democratica*
		Ritteriella pecteti
		Doliolum denticulatum
		Salpa fusiformis[3]
Molluscs		*Carinaria japonica*
		Limacina helicina
		Limacina inflata
		Clio pyramidata
		Corolla spectabilis

Table 3.3.1-1. Continued.

	Nearshore	Offshore
	Hatfield (1983)	
Holoplankton		
Copepods	*Acartia clausi*	*Candacia bipinnata*
	Tortanus discaudatus	*Euchaeta japonica*
	Epilabidocera longipedata	*Euchaeta acuta*
		Neocalanus cristatus
		Neocalanus plunchrus
		Eucalanus bungii
Euphausiids	*Thysanoessa spinifera*	*Nematoscelis difficilis*
		Thysanoessa gregaria
Chaetognath		*Sagitta scrippsae*
Ctenophore	*Pleurobrachia bachei*	
Meroplankton		
	Cancer productus zoeae (stages I-III)	*Cancer productus* zoeae (stages IV-V)
	Cancer antennarius zoeae	*Cancer oregonensis* zoeae (stages IV-V)
	Cancer gracilis zoeae (stages I-III)	
	Pinnotherid zoeae (commensal crab)	
	Pagurid megalopa larvae (hermit crab)	
	Callianassa spp. larvae (ghost shrimp)	
	Grapsid crab zoeae (stages IV-V)	
	Porcellanid larvae (Anomuran decapods)	
	Upogebia pugettensis larvae	
	Xanthid zoeae (stages I-II)	
	Majid zoeae I	

Table 3.3.1-1. Continued.

	Nearshore	Offshore
	Tasto *et al.* (1981)	
Holoplankton		
Copepods	*Acartia clausi*[3]	
	Acartia longiremis[2]	
	Calanus pacificus[3]	
	Calanus tenuicornis[2]	
	Epilabidocera longipedata	
	Eucalanus bungii[2]	
	Metridia lucens[2]	
	Pseudocalanus spp.[2]	
Chaetognath	*Sagitta euneritica*[2]	
Mollusc	*Limacina helicina*[2]	
Ctenophore	*Pleurobrachia bachei*	
Meroplankton		
	Cancer gracilis zoeae (stages I-III)	*Cancer gracilis* zoeas (stages IV-V)
	Cancer spp. larvae	*Cancer oregonensis* (stages I-III)
	Cancer antennarius zoeae (stages I-III)	
	Callianassa spp. larvae	
	Porcellanid larvae	
	Grapsid zoeae (stages I-III)	
	Majid zoeae[3]	

[1]Found only in some years; typically a more southern species.
[2]Nearly uniform distribution between nearshore and offshore areas.
[3]Large concentrations occasionally found nearshore/offshore.

The Bence *et al.* (1992) categorized data for holoplankton and meroplankton from Tasto *et al.* (1981) into nearshore and offshore species (Table 3.3.1-1). Examples of peak densities for certain forms of zooplankton include the following: the copepod *Acartia clausi* (15,000/100m^3), *Cancer* spp. larvae (2,500/100m^3), and zoeae stages I-III for *Cancer antennarius* (1,200/100m^3). There were few holoplankton species common to the CalCOFI, Hatfield, and Tasto *et al.* reports. For example, Table 3.3.1-1 shows that adult euphausiids were present in low abundances in samples from 1975–1977 (Tasto *et al.* 1981), but three species (*Euphausia pacifica*, *Nematoscelis difficilis*, and *Thysanoessa gregaria*) were more abundant in March 1979 samples taken on two transects off San Francisco Bay (Hatfield 1983).

Using differences in species compositions and distributions that could be identified from CalCOFI atlases, Hatfield (1983) and Tasto (1981) noted the following characteristics of zooplankton distributions: (1) the dynamic nature of zooplankton distributions due to the complex hydrography in the California Current system; and (2) the variance between data sets that likely results from differences in sampling schedules, designs, and collection equipment. In addition, taxonomic uncertainties remain for some species. For example, difficulties in the taxonomy of *Acartia* may in part explain why *A. tonsa* and *A. danae* are identified as the most abundant copepods in the CalCOFI atlases, while Tasto *et al.* (1981) identify *A. clausi* and *A. longiremis* as most abundant and do not list *A. tonsa* and *A. danae* at all.

Ichthyoplankton

Ichthyoplankton (larval fish) are an important component of the zooplankton and have been the focus of numerous CalCOFI surveys due to the importance of this group to commercial fishing. Bence *et al.* (1992) summarized data from CalCOFI surveys by season and depth. The highest ichthyoplankton abundances occurred over shallow water in winter, with lowest abundances at deep stations in fall (Figure 3.3.1-1). Seasonal differences in total fish larvae showed some variation among sampling stations, with highest overall values in winter and spring and lowest values in summer and fall (Figure 3.3.1-1). The CalCOFI data are supplemented by data on

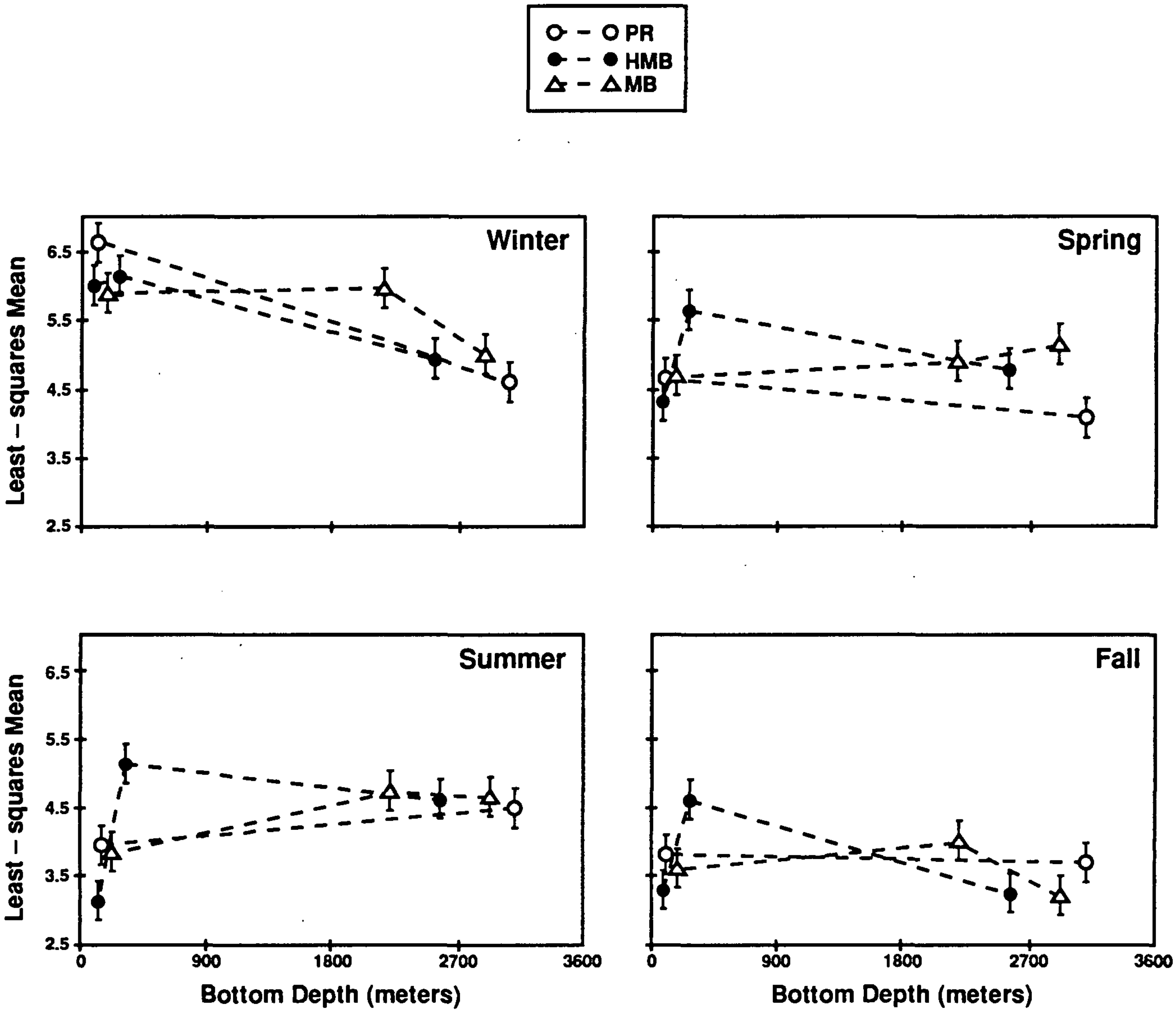

Figure 3.3.1-1 Abundance of Total Fish Larvae Versus Bottom Depth (top panel) and by Season (bottom panel).

Shown are least-squares means (LSMs) for $\log_e$ transformed abundance collected during CalCOFI surveys for individuals sampling stations (top panels) or by season (bottom panels). PR = Point Reyes line, HMB = Half Moon Bay line, MB = Monterey Bay line. Seasons are Dec.-Feb. = winter, March-May = spring, June-Aug. = summer, Sept.-Nov. = fall. Standard errors of LSMs are indicated by vertical bars.

Source: Bence *et al.* 1992.

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larval Pacific hake and shortbelly rockfish from a single ichthyoplankton survey conducted by Bence *et al.* (1992). Preliminary analyses of these data suggest that at the time of the survey Pacific hake larvae were relatively more abundant south of the Farallon Islands at depths greater than 600 m (Figure 21 in Bence *et al.* 1992), with the relative abundance of short belly rockfish being greatest at depths just beyond the shelf break and at depths greater than 1,800 m (Figure 23 in Bence *et al.* 1992).

Due to the inherent variability in plankton populations outlined above, the species composition and distribution of zooplankton can be related to the LTMS study areas only in a general way. Species common in nearshore waters would likely be present in Study Area 2. These include a variety of holoplankton, and perhaps more importantly, most of the identified species of meroplankton and ichthyoplankton, several of which become important to commercial fisheries as adults. Zooplankton in offshore waters in the vicinity of Alternative Sites 3, 4, and 5 are primarily holoplankton and late stages of Dungeness crab with smaller components of meroplankton than occur in nearshore waters. Dominant species contributing to holoplankton populations also are different in nearshore and offshore waters. Zooplankton serve as primary prey items for other carnivorous zooplankton, pelagic invertebrates such as squid, adult fish, seabirds, and marine mammals. Significant disruptions of normal planktonic productivity patterns can negatively impact marine mammal and seabird populations. For example, a reduction in planktonic productivity levels caused by the 1982–83 El Niño event led to high adult mortality and reproductive failure among numerous seabirds and marine mammals in the eastern subtropical Pacific Ocean (Barber and Chavez 1983). This interdependence between lower trophic level organisms and those higher in the food web demonstrates the ecological importance of plankton within marine communities including those in the Gulf of the Farallones. Effects of dredged material disposal on plankton populations are likely to be transitory at most and should not result in impacts to food webs in the Gulf of the Farallones.

3.3.2 Invertebrates

Information on infauna, demersal epifauna, pelagic invertebrates, and commercially important species within the study region is presented in Sections 3.3.2.1 through 3.3.2.4, respectively.

3.3.2.1 Benthic Infauna

Benthic infaunal communities, defined generally as small invertebrates such as polychaete worms and amphipods living within sediments, are described by a number of parameters, such as faunal composition (what species are present), dominant taxa (which species are most abundant), density (number of individuals/m^2), diversity (number of different species relative to the total number of individuals), species richness (number of species), and community assemblage patterns (which species are usually found together in a sample or how similar the samples are to each other). The following sections describe community parameters for Study Areas 2, 3, 4, and 5, including Alternative Sites 3, 4, and 5. These descriptions are based primarily on recent EPA and Navy surveys of the LTMS study region (SAIC 1992a,c).

Study Area 2

The infauna of Study Area 2 was typical of continental shelf habitats along the California coast. The number of species collected from individual grab samples by SAIC (1992c) ranged from 95 to 131 per 0.1 m^2, with a total of 261 species identified from 10 grab samples (Table 3.3.2-1). Polychaete worms represented 48% of the total species and 76% of all individuals. Two genera of surface deposit-feeding spionid polychaetes, *Prionospio* and *Spiophanes*, contributed 50% of the individuals. Amphipod crustaceans and gastropod snails were the next most dominant taxa. Gastropods were much more diverse in Study Area 2 than in any of the other LTMS study areas surveyed. Major infaunal taxa found only in Study Area 2, and absent from the slope areas, included decapods, mysids, ostracods, and phoronids. Taxonomic groups typical of the deep sea, including pogonophorans, aplacophoran molluscs, and isopod and tanaidacean crustaceans, were either absent or collected infrequently in Study Area 2.

Table 3.3.2-1. Total Number of Species Belonging to Each Major Taxonomic Group Collected from Study Areas 2, 3, 4, and 5 (SAIC 1992c,d).

Taxon (Number of Samples)	Study Area 2 (10)	Study Area 3 (18)	Study Area 4 (14)	Study Area 5 (21)
Porifera	—	—	—	1
Coelenterata				
Anthozoa	3	2	2	4
Platyhelminthes	1	1	1	3
Nemertinea	1	8	6	14
Annelida				
Hirudinea	1	1	—	—
Oligochaeta	1	1	1	1
Polychaeta	125	232	234	184
Pogonophora	—	1	1	2
Sipuncula	2	5	3	3
Echiura	1	—	—	0
Mollusca				
Aplacophora	1	13	13	11
Bivalvia	18	25	23	19
Gastropoda	27	9	15	3
Scaphopoda	2	2	—	1
Arthropoda				
Amphipoda	33	33	31	39
Cumacea	13	30	32	21
Decapoda	3	—	—	—
Isopoda	5	45	41	39
Leptostraca	1	1	—	—
Mysidacea	1	—	—	—
Ostracoda	4	—	—	—
Tanaidacea	1	47	43	23
Phoronida	1	—	—	—
Echinodermata				
Asteroidea	—	1	—	1
Echinoidea	1	2	—	1
Holothuroidea	4	2	3	6
Ophiuroidea	10	12	12	8
Hemichordata				
Enteropneusta	—	2	1	1
Urochordata	1	—	—	—
TOTAL	261	475	462	385

Infauna densities (individuals/m^2) were highest in Study Area 2 with spionid and capitellid polychaetes predominant at stations with the highest densities (Table 3.3.2-2). These high densities probably are caused by relatively high productivity in the surface waters in this continental shelf location (see Section 3.2.3). From approximately 75 to 125 m depth, infaunal densities exceeded approximately 20,000 individuals/m^2, decreasing to less than 15,000 near the shelf break (approximately 200 m depth).

Species diversity, measured by Hurlbert's rarefaction (number of expected species per 100 individuals) or by the Shannon-Wiener index (*H'*), also was high, although these measures showed an increase in species diversity with increasing depth within the study area. In contrast, species richness did not show a depth-related pattern (SAIC 1992c). Similarity analysis showed that the two deepest stations were different from the remaining stations, indicating a distinct faunal break between 125 and 180 m depth (SAIC 1992c).

Study Area 3

The number of species collected from individual box core samples within Study Area 3 ranged from 59 to 165 per 0.1 m^2, with a total of 475 species identified from 18 box core samples (Table 3.3.2-1). Subsurface deposit-feeding polychaete worms of the families Paraonidae, Cossuridae, and Cirratulidae each contributed between 9 and 11% of the entire infauna, and represented 49% of the total species collected. Detrital-feeding or scavenging tanaidacean and isopod crustaceans were the next most dominant taxa, each representing 9% of the total number of species collected by SAIC (1992c). The filter-feeding amphipod *Photis* "blind" was extremely abundant at five stations, and by itself accounted for almost 18% of the entire fauna. Because Study Area 3 stations occur over a large depth range (depths from 610 to 2,005 m), half of the dominant species collected were abundant at only a single station. The subsurface deposit-feeding polychaetes *Tharyx* sp. 1, *Cossura pygodactylata, Cossura rostrata,* and *Aricidea ramosa* were the most common species of the taxa that predominated. The most common crustacean was the tanaidacean *Pseudotanais* sp. 7, and the most common mollusc was the aplacophoran Scutopidae sp. 2.

Table 3.3.2-2. Benthic Infaunal Community Parameters for Study Areas 2, 3, 4, and 5 (SAIC 1992a,c).

Data for Alternative Sites 3, 4, and 5 are included in parentheses.

Area (Alternative Site)	Number of Species	Density (Ind./m²)	Hurlbert's rarefraction (Species per 100 Ind.)	Shannon-Wiener Index (H')	Evenness (J')
Study Area 2					
Range	95-131	12,920-42,490	26.3-40.6	4.12-5.37	0.626-0.784
$\bar{x} \pm 1$ SD	114 ±12.7	26,870 ±13,017	32.9 ±4.9	4.67 ±0.43	0.685 ±0.058
No. Samples	10	10	10	10	10
Study Area 3 (Alternative Site 3)[1]					
Range	59-165 (100-165)	3300-19560 (7840-19,560)	22.9-54.9 (34.7-50.5)	3.55-6.24 (4.02-6.05)	0.534-0.855 (0.534-0.822)
$\bar{x} \pm 1$ SD	115 ± 34.6	10,303 ±4590 (14,810 ±5574)	40.2 ±7.6 (39.5 ±7.6)	4.98 ±0.75 (4.64 ±0.98)	0.649 (0.13)
No. Samples	19 (4)	19 (4)	19 (4)	19 (4)	19 (4)
Study Area 4 (Alternative Site 4)[2]					
Range	63-164 (121-143)	4530-13,190 (9310-13,190)	33.2-57.2 (33.2-49.5)	4.28-6.34 (4.28-5.84)	0.619-0.886 (0.619-0.830)
$\bar{x} \pm 1$ SD	118.5 ±27.9 (132 ±11.0)	8446 ±2314 (10,947 ±2010)	44.8 ±6.8 (42.6 ±8.43)	5.46 ±0.53 (5.17 ±0.8)	0.798 ±0.66 (0.734 ±0.107)
No. Samples	14 (3)	14 (3)	14 (3)	14 (3)	14 (3)

Table 3.3.2-2. Continued.

Area (Alternative Site)	Number of Species	Density (Ind./m²)	Hurlbert's rarefraction (Species per 100 Ind.)	Shannon-Wiener Index (H')	Evenness (J')
Study Area 5 (1990) (Alternative Site 5)[3]					
Range	77-131 (90-91)	4970-9870 (4970-5290)	33.3-50.9 (41.9-43.8)	4.35-5.96 (5.31-5.35)	0.694-0.862 (0.818-0.822)
$\bar{X}$ ± 1 SD	105.9 ±16.9 (90.5)	7715 ±1706 (5130)	44.0 ±5.4 (42.9)	4.94 ±1.58 (5.33)	0.810 ±0.51 (.820)
No. Samples	10 (2)	10 (2)	10 (2)	10 (2)	10 (2)
Study Area 5 (Alternative Site 5)[4]					
Range	44-97 (44-73)	750-7540 (750-5790)	27.2-44.5 (29.8-34.5)	3.45-5.23 (3.62-5.23)	0.582 (0.582)
$\bar{X}$ ± 1 SD	74.4 ±15.4 (56 ±15.1)	4450 ±1953 (3123 ±2533)	37.5 ±5.8 (32.2)	4.71 ±0.68 (4.47 ±0.81)	0.582-0.959 (0.638-0.959)
No. Samples	10 (3)	10 (3)	9 (2)	10 (3)	10 (3)

[1] Alternative Site 3 stations were 3-13, 3-17, 3-18, and 3-19 (SAIC 1992c).
[2] Alternative Site 4 stations were 4-4, 4-6, and 4-11 (SAIC 1992c).
[3] Alternative Site 5 stations from the 1990 samples were F-17, K-15, and L-17 (SAIC 1991).
[4] Alternative Site 5 stations from the 1991 samples were B-4, B-5, and B-7 (SAIC 1992a).
* Sample size was too small to calculate this parameter.

Densities (number of individuals/m^2) in Study Area 3 ranged from 3,300 at 800 m to 19,560 at 1,780 m depth, respectively (SAIC 1992c). The highest densities were found at deep stations (depths greater than 1,780 m) due to dense populations of the amphipod *Photis* "blind." Elevated densities at other stations within Study Area 3 were due to dense assemblages of polychaetes in the families Paraonidae, Cirratulidae, and Cossuridae. The lowest densities were observed at stations between 800 and 985 m depth, located within the OMZ. These stations were dominated by oligochaetes, which are frequently associated with low dissolved oxygen, and cossurid or paraonid polychaetes.

Generally, there was a trend toward increasing species diversity and species richness with increasing depth across the continental slope stations. The diversity of infauna in Study Area 3 was high, especially at some of the deepest stations (SAIC 1992c). Low diversity at three deep stations was due to the abundance of *Photis* "blind."

Species richness was lowest at stations ranging in depth from 800 to 985 m and corresponding to the lower edge of the OMZ (Figure 3.3.2-1). The number of species per station increased slightly with depth between 1,000 and 1,500 m, and then showed a pronounced increase at depths greater than 1,600 m. Similarity analysis for Study Area 3 showed two main clusters that are defined by depth, with a distinct break at 1,600 m (SAIC 1992c).

The infauna at four stations (3-13, 3-17, 3-18, and 3-19; SAIC 1992c) located within the depositional area (including Alternative Site 3), was characterized by three predominant species groups, two groups of which were similar to other nearby stations outside the depositional area. The two similar groups were based on the polychaete *Tharyx* sp. 1, and the amphipod *Photis* "blind." All the stations within Alternative Site 3 were variable in species composition, similar to the other stations throughout Study Area 3. This is notable considering the more limited depth range of Alternative Site 3 (1,450–1,900 m) as compared to Study Area 3. The third species group, represented by Station 3-19 within Alternative Site 3, had the most species (165) of any

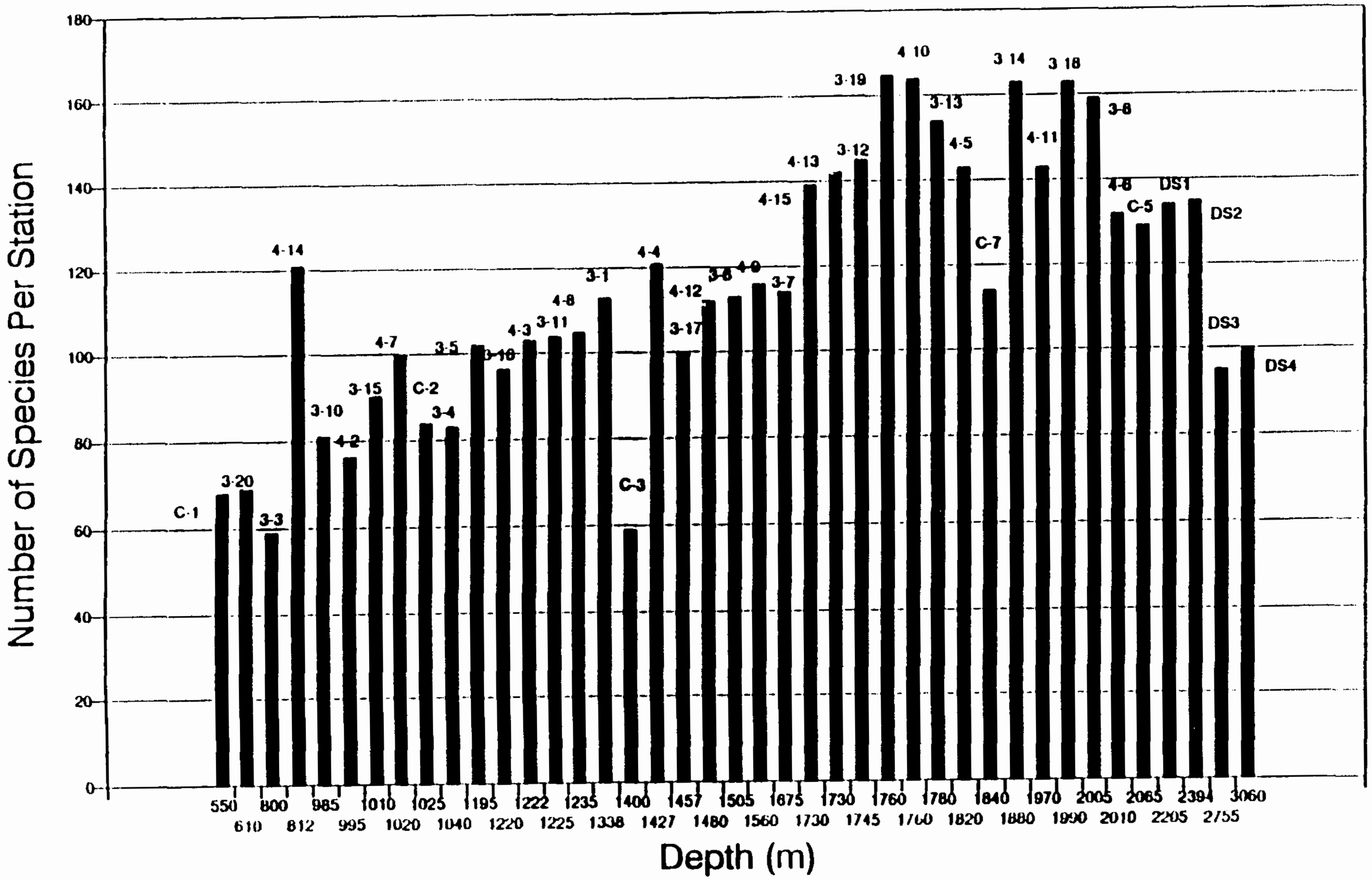

Figure 3.3.2-1. Bar Graph of the Total Number of Species at each Station in LTMS Study Areas 3, 4, and Pioneer Canyon, Arranged by Depth.

station sampled within the entire study region and was characterized by the lack of true dominant species (Figure 3.3.2-1).

Study Area 4

The number of species collected from individual box core samples within Study Area 4 ranged from 63 to 164 per 0.1 m^2 (Table 3.3.2-2), with a total of 462 species identified from 14 samples (Figure 3.2.2-1) (SAIC 1992c). Polychaete worms comprised 51% of the total species collected, while tanaidacean and isopod crustaceans each accounted for 10% (Table 3.3.2-1). Similar to Study Area 3, the filter-feeding amphipod *Photis* "blind" was the most abundant crustacean, accounting for 26% of the individuals collected at Station 4-11 (1,970 m depth). Different dominant species characterized the individual stations within Study Area 4. Subsurface deposit-feeding polychaete species including *Tharyx* sp. 1, *Aricidea simplex*, and *Cossura pygodactylata* were predominant. Three stations (4-5, 4-12, and 4-13) within Study Area 4 lacked a true dominant, with the top ranking polychaete comprising less than 10% of the animals collected.

Densities (number of individuals/m^2) in Study Area 4 ranged from 4,530 (812 m depth) to 13,190 (1,427 m depth) (SAIC 1992c). The overall range in total density was not as great as that noted for Study Area 3 (Table 3.3.2-2) even though high *Photis* densities were observed at Stations 4-10 and 4-11 (1,760 and 1,970 m depth, respectively). Most of the variability observed in densities at individual stations was due to paraonid, cirratulid, and cossurid polychaetes. Similar to Study Area 3, the lowest densities in Study Area 4 were found in the OMZ at Station 4-14 (812 m depth). Station 4-4 (1,427 m depth) exhibited the highest density in Study Area 4, primarily due to high abundances of the polychaetes *Paraonella monilaris* and *Tharyx* sp. 1.

Generally, infaunal diversity in Study Area 4 was comparable to that found in Study Area 3, although both the minimum and maximum values for the Shannon-Wiener index of diversity (H') were somewhat higher than for Study Area 3 (Table 3.3.2-2). Some stations having lower diversities were dominated by exceptionally high numbers of *Tharyx* sp. 1 (Station 4-4, 1,600 m) and *Photis* "blind" (Stations 4-10 and 4-11, 1,900 m).

As in Study Area 3, stations in Study Area 4 located closest to the OMZ (approximately 800 m depth) had a distinctly lower species richness than stations between 1,000 m and 1,600 m. Additionally, a pronounced increase in species richness was noted at stations between 1,700 and 2,000 m depth (Figure 3.3.2-1).

Similarity analysis showed two main species groups defined by proximity to Pioneer Canyon rather than by depth (SAIC 1992c). One group of stations, dominated by the polychaetes *Cossura pygodactylata* and *Aricidea simplex*, occurred in the northern half (closer to Pioneer Canyon) of Study Area 4, while the second group included stations in the southwestern part of this study area (including Alternative Site 4).

Three infauna sampling stations, 4-4, 4-6, and 4-11, ranging in depth from 1,427 to 2,010 m, were included within Alternative Site 4. These stations were relatively dissimilar to one another with respect to infaunal communities in Study Area 4. Station 4-4 was characterized by extremely high numbers of a single species (*Tharyx* sp. 1), and also was the least diverse of any station in the study area. Station 4-6 was the deepest station (2,010 m) and had a low similarity with other stations in its group, due to predominant deep-sea species such as *Levinsenia* sp. 5 and *Aricidea* cf. *catherinae*. Thus, while densities at Station 4-6 were low, diversity was among the highest seen in Study Area 4. In contrast, Station 4-11 (associated with the southwest group away from the Pioneer Canyon) was dominated by *Photis* "blind" and had the greatest number of species (tied with Station 4-5) found in an individual sample in Study Area 4.

Study Area 5

Study Area 5 is located on the lower continental slope/continental rise, with most samples collected deeper than 2,400 m. In 1990 and 1991, 18 box core samples were collected within this study area and another seven were taken in an adjacent area approximately 5 nm to the south (SAIC 1992a,c). Most of the summary information presented in this section refers only to those samples collected within Study Area 5.

Of the 385 species of infauna collected in Study Area 5 (Table 3.3.2-1), polychaetes comprised 48%, crustaceans 32% and molluscs 8%. The remaining 45 species represented a variety of other taxa. Many of these taxa are typical of the deep-sea infaunal communities, including carnivorous or scavenging aplacophoran molluscs, tube-dwelling pogonophorans, and detrital-feeding desmosomatid isopods and tanaidaceans, and were also important faunal elements in Study Areas 3 and 4. The highest infaunal densities (number of individuals/m^2) in Study Area 5 were recorded in 1990, ranging from 4,970 to 9,870. Densities from the 1991 survey were lower and more variable, ranging from 750 to 7,540. Species diversities, like the densities, were higher in 1990 than in 1991.

Similarity analysis indicated that the infaunal community was distributed by depth, with deeper stations (between 2,700 and 3,000 m depth) grouped together and more similar than stations along the 2,400 m isobath (SAIC 1992c). When stations along isobaths were grouped, different dominant taxa became characteristic. For example, stations along the 2,400 m depth contour were dominated by a large paraonid polychaete (*Aricidea simplex*), whereas the stations occurring along the 2,700 m depth were dominated by the polychaetes *Prionospio delta, Chaetozone* sp. 1, and *Aricidea simplex*. Predominant taxa collected at stations on the 3000 m contour included the polychaetes *Prionospio delta*, *Levinsenia* nr. *flava*, and the aplacophoran *Spathoderma* sp. 1.

Alternative Site 5 is in the same approximate location as the Naval Ocean Disposal Site (NODS) described in SAIC (1992a). This encompasses an area of approximately 2 × 2 nm at the southwest corner of the Chemical Munitions Dumping Area (CMDA), at depths ranging from 2,800 to 3,050 m, that was surveyed in part by the Navy (SAIC 1992a). Five box cores were taken within Alternative Site 5: Stations E-19 and F-17 in 1990 and B-1, B-4, and B-5 in 1991 (SAIC 1992a,c).

The values of benthic community parameters in Alternative Site 5 were generally higher in 1990 than in 1991, similar to the overall results for Study Area 5. One station (B-5) within this alternative site had the lowest infaunal densities recorded (750 per m^2) within any study area. In contrast, if Station B-5 is excluded, the remaining 1991 stations averaged 4,310 per m^2 and the two 1990 stations averaged 5,130 per m^2. The most abundant infaunal species in Alternative Site 5 was the spionid polychaete *Prionospio delta*, a surface deposit feeder characteristic of lower slope and rise depths.

Two benthic surveys were conducted in Area 5 (SAIC 1991, 1992a,c). Seven stations sampled in 1991 had lower infaunal densities than any station sampled in 1990. These stations include the deepest stations in the trough of the Chemical Munitions Disposal Area (CMDA) which are mostly within Alternative Site 5, the deepest stations on the southern flank of the CMDA, and the two deepest stations sampled in an adjacent area 10 miles to the south. None of these stations is close to any station sampled in 1990, except for B-5, which is very close to Station F-17 (1990) that had infaunal densities of more than 5,000 individuals per m^2. The reason that the densities at these two stations differ by a factor of 7 may be a disturbance of the environment. Bottom photographs taken as a towed camera sled crossed the coordinates of these stations revealed a lumpy bottom that suggested a local disturbance, possibly related to turbidity flow. It is not known when this disturbance took place, but the low infaunal densities at Station B-5 in 1991 compared with the high values at Station F-17 in 1990 suggest that it occurred after August 1990. The identification of a natural disturbance in Alternative Site 5 is of considerable interest in evaluating the effects of dredged material disposal on benthic infaunal populations. The data derived from the single box core taken from Station B-5 suggest that, although the expected species such as *Prionospio delta* and the typically dominant aplacophorans and deposit-feeding polychaetes are present, they occur in greatly reduced numbers. It is not known whether the resident population at this station is a remnant of the pre-disturbance fauna or a result of specimens that were recruited to the site after the disturbance. (See Section 4.4.2.2 for a general discussion of impacts of burial on the benthos.)

Comparisons Between Study Areas

The most characteristic feature distinguishing Study Area 3 from the other LTMS study areas sampled on the continental slope is the relatively high variability of parameters such as diversity, species richness, and density. The wide ranges in these parameters primarily are related to extremely high abundances of two species, the filter-feeding amphipod *Photis* "blind" and the deposit-feeding polychaete *Tharyx* sp. 1, that make up large percentages of the total infauna at 1,900 and 1,400 m depths, respectively. The most common (frequently occurring) species in Study Area 3 (not necessarily the most abundant) were *Tharyx* sp. 1, *Cossura pygodactylata*, *C. rostrata*, *Aricidea ramosa*, *Pseudotanais* sp. 7, and Scutopidae sp. 2. Similarity analyses revealed that the infaunal community was clearly zoned by depth, with a major faunal break occurring at 1,600 m.

Infaunal community parameters were less variable in Study Area 4 than in Study Area 3 and are within the range of those reported for Study Area 3. This characteristic is related to lower densities of *Photis* "blind" and *Tharyx* sp. 1 found at the same depths as in Study Area 3. In addition, although the most common polychaetes in both areas belong to the same families, the overall faunal composition of Study Area 4 is slightly different from that of Study Area 3, These differences most likely are attributable to differences in sediment characteristics. Similarity among stations within Study Area 4 also is influenced by sediment characteristics. Cluster analysis indicated two main groups of stations that are divided by a narrow band of very sandy sediment crossing Study Area 4 from northwest to southeast.

In a broad sense, Study Area 5 is somewhat less rich in terms of the numbers of species, compared to Study Areas 3 and 4, and has lower infaunal densities. This latter result is expected because of trends of decreasing density with depth in continental slope environments on both coasts of North America (SAIC 1992a; Blake *et al.* 1987). Structurally, the benthic infauna of Study Area 5 are similar to Study Areas 3 and 4 in that the most common speceis belong to the polychaete families Paraonidae, Cirratulidae, and Cossuridae. One important difference is the dominance in Study Area 5 of a surface deposit-feeding spionid polychaete, *Prionospio delta*, in the 2,7000 to 3,000 m depth range. Cluster analysis reveals a faunal break between 2,400 and 2,700 m, and this break can be attributed to this spionid (SAIC 1992a). Spionids are not dominant in Study Areas 3 and 4. *Prionospio delta* is the dominant infaunal species in Alternative Site 5. Available data suggest that spionids would be more susceptible to burial than subsurface deposit-feeders (Jumars 1977), but are, in turn, more likely to rapidly recolonize a disturbed environment.

From a trophic standpoint, differences in the types of organisms at each alternative site are expected to result in differences in their responses to dredged material. For example, Alternative Site 3 is dominated by filter-feeding amphipods, while amphipods are less important in Alternative Site 4, which is dominated by subsurface deposit-feeders. The filter-feeding amphipods would be the most susceptible to dredged material disposal because of their feeding activities and relative inability to burrow out of deposits. It is possible, however, that they might be able to move away from an affected site. Surface deposit-feeders have been shown to be more susceptible to burial than subsurface deposit-feeders (Jumars 1977). All three areas and their alternative sites include numerous species of tanaidaceans and isopods. These small crustaceans are mostly detrivores, feeding on particulate material on the surface of the sediment. It is likely that they will be highly susceptible to dredged material deposits.

Thus, the response of the benthic infauna in each of the areas and alternative sites is mixed from a trophic standpoint. The greatest impact would clearly be in Alternative Site 3, where the populations of highly sensitive filter-feeding amphipods are the most dense. It is likely that the dominant spionids in Alternative Site 5 also would be sensitive, but because overall species richness and density is lower, the composite impact would be less than in Alternative Site 4.

Comparisons With Other Studies

The Continental Shelf—Study Area 2. The occurrence of 261 infaunal species from only ten 0.1 m^2 samples in Study Area 2 is remarkably high when compared with the MMS Monitoring program in Santa Maria Basin where 886 species were collected from 551 0.1-m^2 box core samples over a three-year period (Hyland *et al.* 1991). The diversity estimates from Study Area 2 are similar to those recorded from similar depths in the Santa Maria Basin (Hyland *et al.*, 1991), but higher than those recorded by Parr *et al.* (1987) from stations within and adjacent to Study Area 2 (Table 3.3.2-2). This suggests that the Study Area 2 infauna is very rich and does not differ in that regard from other well-studied shelf and upper slope areas off California.

The lower range of the densities measured in Study Area 2 by SAIC (1992c) is comparable to some stations sampled as part of the MMS Northern and Central California Reconnaissance and Santa Maria Basin programs (SAIC 1989b; Hyland *et al.* 1991). However, the densities (number of individuals/m^2), ranging between 30,000 and 40,000, are among the highest values ever recorded in eastern Pacific waters and comparable to environments such as Georges Bank off Massachusetts (Neff *et al.* 1989).

Parr *et al.* (1987) found much lower total densities (number of individuals/m^2) ranging from 3,400 to 6,200 in Study Area 2. The variation in diversities and densities among the various studies may be due to differences in sampling techniques. For example, samples collected by SAIC (1992c) in Study Area 2 and by Hyland *et al.* (1991) were live-sieved through a 0.3-mm sieve in the field and subsequently resieved through nested 0.3 and 0.5-mm mesh sieves in the laboratory. In contrast, Parr *et al.* (1987) used live-sieving techniques with 0.5-mm screens. Thus, two different methods were used to separate the fauna from the sediments. Although no comparative data are available from samples taken at the same site, it is evident that the 0.3-mm sieve retains many more specimens than a 0.5 mm mesh screen when live-sieved in the field.

The overwhelming dominance of spionid polychaetes noted by SAIC (1992c) was not apparent in the data from a previous study by Parr *et al.* (1987), who reported very different communities at three sites within or adjacent to Study Area 2. The most abundant species from SAIC (1992c) were the paraonid polychaete *Aricidea catherinae* and the bivalve *Axinopsida serricata*, whereas the spionid *Spiophanes missionensis* was predominent at one of the Parr *et al.* stations. The top ranking species of each station in both SAIC (1992c) and Parr *et al.* (1987) accounted for between 7% and 10% of the total fauna. Although similar species composition was found among stations in Study Area 2, almost all the predominant species collected by SAIC (1992c) were rare at stations sampled by Parr *et al.* (1987), and *vice versa.* These differences probably are due to the sieve size differences discussed previously rather than to real year-to-year differences.

The Continental Slope—Study Areas 3, 4, and 5. Infaunal species composition from the eastern Pacific continental slope is very similar to the Western North Atlantic, as identified in a study that used comparable methods, (Blake *et al.* 1987; Maciolek *et al.* 1987a,b). However, some notable differences include the absence of the polychaete family Chrysopetalidae and the lower number of pognophoran species in the Pacific.

The continental slope represents a rich source of biodiversity (Grassle and Maciolek 1992). Species richness estimates from the Navy and EPA samples from the continental slope off San Francisco are very high when compared with the continental shelf environment. However, they are lower overall than those in the western North Atlantic (see Blake *et al.*, 1985). The major difference between the western North Atlantic and eastern Pacific faunas is that infaunal densities are much higher off California. The maintenance of high species richness in deep-sea habitats where certain individual species achieve high densities was first reported by SAIC (1991) and SAIC (1992a) as part of the Navy surveys in Study Area 5.

Although the lack of replicates from the EPA and Navy studies precludes developing site-specific estimates of species accumulation, it is evident that species are continuously added with additional sample collections (Figure 3.3.2-2). However, these estimates must be viewed with some caution since the EPA samples encompassed a much greater depth range and variety of sediment types than the Navy samples. Nevertheless, Figure 3.3.2-2 indicates that leveling-off does not occur after 68 samples from slope depths ranging from 550 to 3,050 m. These results clearly support the concept of high species richness in deep-sea habitats.

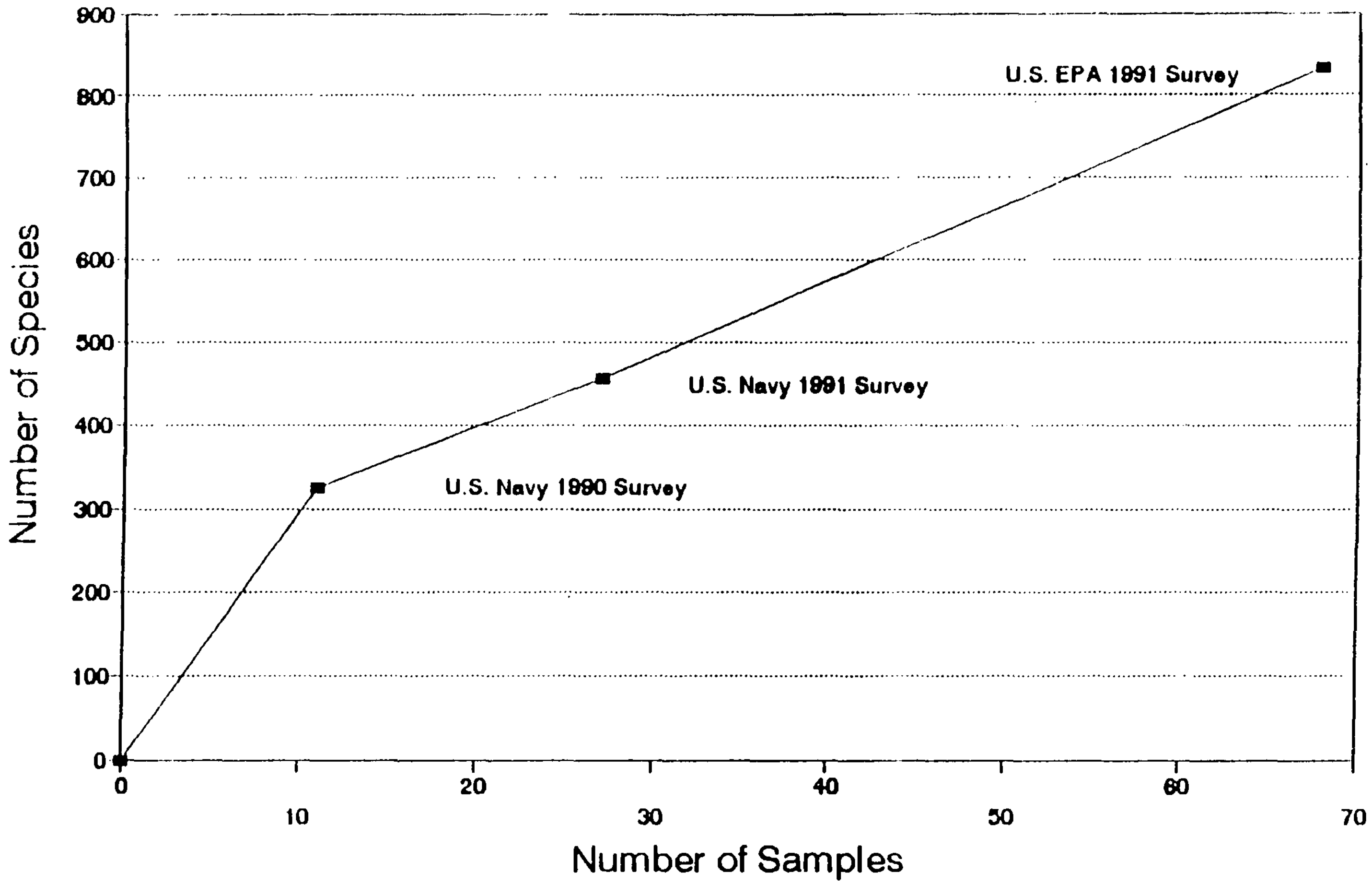

Figure 3.3.2-2. **Species Accumulation Curve for 68 Samples Collected in Study Areas 3, 4, and 5 in 1990 and 1991.**

Figure 3.3.2-3 represents a composite profile of similar depth intervals from the Navy and EPA studies off the Farallones (SAIC 1992a,c), a transect off Cape Lookout, North Carolina (Blake *et al.* 1985), and a transect off Massachusetts (Maciolek *et al.* 1987b). The most obvious difference between transects done on the slope in the LTMS study region and those from the Atlantic is the higher density in samples collected from middle and lower slope depths off California. High benthic productivity in middle and lower slope depths off California very likely is due to a high flux of phytal detritus to the seabed (SAIC 1992c). For example, evidence derived from measurements of carbon-nitrogen ratios, stable isotopes ($\delta^{15}N$, $\delta^{13}C$), and chlorophyll *a* and phaeopigments in the sediments from Study Area 5 suggests that phytodetritus flux is higher than has previously been measured in the deep sea (SAIC 1992c). While phytoplankton is known to impinge on the seabed in the Atlantic (Hecker 1990), the fluxes appear to be more seasonal and irregular than in the eastern Pacific, where surface productivity associated with upwelling extends over longer time intervals (see Sections 3.2 and 3.3). The very marked decrease in densities between 800 and 1,000 m depth off California may be associated with the presence of the OMZ which may vary in depth between 600 and 1000 m. There is no comparable OMZ in the Atlantic, where infaunal densities decline more or less evenly with depth.

Factors Influencing Community Patterns

In typical marine infaunal communities, the dominant taxa are polychaetes. Polychaetes of the families Paraonidae, Spionidae, Cossuridae, and Cirratulidae were predominant at most stations in Study Areas 2, 3, 4, and 5 . However, in Study Area 3, unusually high densities of the amphipod *Photis* "blind" were observed between 1,745 and 2,000 m depth. Filter-feeding amphipods are common in nearshore environments. The amphipods remove particles from the water for food and tube construction. For dense populations of such amphipods to persist, sediment transport mechanisms must be present to move organic materials over the site.

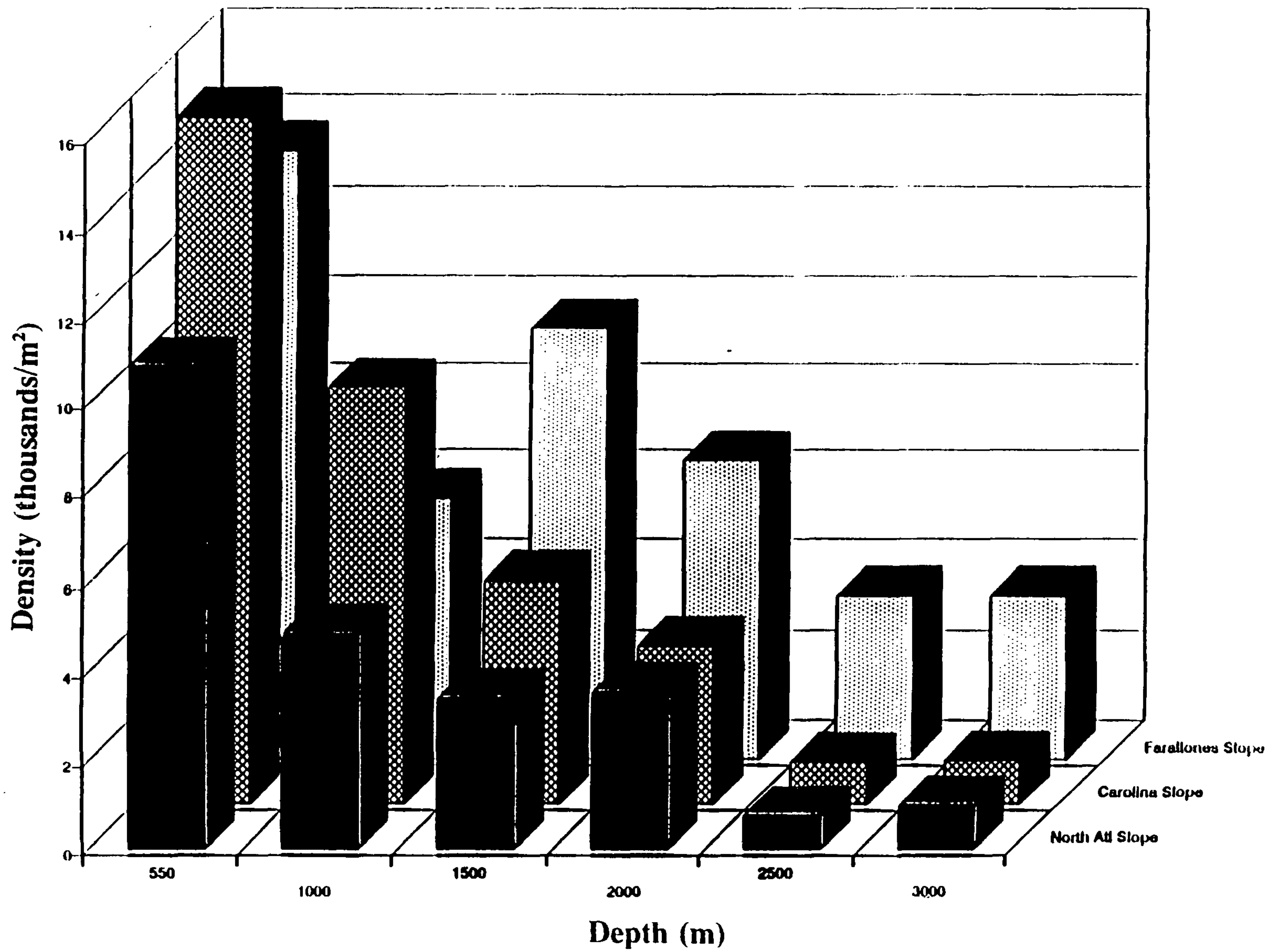

Figure 3.3.2-3. Infaunal Densities at Two Transects on the U.S. Atlantic Continental Slope and Rise and One Transect off the Farallon Islands.

In summary, the infaunal slope communities off San Francisco are clearly zoned by depth (SAIC 1992c). Sediments change from sands to fine silty muds at about 1,800 m, corresponding to one of the faunal breaks observed. The upper slope is influenced by the OMZ, especially between 600 and 1,000 m depth where oligochaetes are present in the fauna and indicative of sites with some partial oxygen stress.

3.3.2.2 Demersal Epifauna

This section describes the demersal epifaunal invertebrate communities found in the study region, including Study Areas 2, 3, 4, and 5. Extensive trawl and remotely operated vehicle (ROV) studies were conducted by the Environmental Protection agency (EPA) in Study Areas 2 through 4 and adjacent sites within Pioneer Canyon and at "Mid-Depth" sites during September and October 1991 (SAIC 1992b). U.S. Navy surveys of Study Area 5 were conducted during July 1991 using beam trawls, otter trawls and camera sled tows (Nybakken *et al.* 1992; SAIC 1992a). Previous trawl studies within Study Area 2 were conducted by KLI (1991).

Similar to general distributional patterns observed for infaunal invertebrate communities (Section 3.3.2.1), megafaunal communities in the study region also are differentiated based on depth or depth-related factors. Types of depth-related factors recognized as influencing megafaunal community structure include differences in the sedimentary environment, the OMZ, and regional current patterns (Wakefield 1990) within the study region. Characterizations of each LTMS study area regarding "low, moderate, or high" parameters are relative comparisons with other SAIC (1992b) transects. These communities are summarized below and discussed in greater detail later in this section.

- A shelf community (from depths of at least 72 m to approximately 200 m), including Study Area 2 and some Mid-Depth locations, was characterized by low numbers of megafaunal species, density, and biomass. This community is characterized by brittlestars, seastars, sea pens, and octopus. Dungeness crab and squid collected infrequently and in low abundances in this study area are the only species which have commercial value.

- Upper and middle slope communities (from depths of approximately 200 m to 500 m and 500 m to approximately 1,200 m), including shallow parts of Study Areas 3 and 4, Mid-Depth, and Pioneer Canyon, were characterized by moderate to high numbers of species. Density and biomass were moderate to high due to species such as Tanner crabs, seastars, brittlestars, snails, and sea cucumbers. Tanner crabs were collected in high numbers but do not appear to be of significant commercial value in the study area.

- A lower slope community (from depths of approximately 1,200 m to at least 1,800 m), including the deeper parts of Study Areas 3 and 4, is characterized by a relatively high number of species including taxonomic groups such as sea cucumbers, brittlestars, seastars, and sea pens. Densities and biomass in these areas also were relatively high and represented primarily by sea cucumbers, brittlestars, and seastars.

- A continental rise community (from depths of approximately 2,000 m to almost 4,000 m), including Study Area 5, is characterized by low numbers of megafaunal taxa, densities, and biomass. However, this area is characterized by similar species composition to Study Areas 3 and 4, with predominant species including sea cucumbers, brittlestars, seastars, and sea pens (Nybakken *et al.* 1992).

Study Area 2

Demersal megafaunal communities within the study region exhibited several distinct patterns in the number and type of species (Figure 3.3.2-4), density (Table 3.3.2-3A), and biomass (Table 3.3.2-3B). The total number of megafaunal species collected during trawl surveys by SAIC (1992b) in Study Area 2 ranged from 8 to 12 (Figure 3.3.2-4). Dominant taxonomic groups in this area typically included echinoderms (particularly seastars and brittlestars), cnidarians (sea pens), and molluscs (octopus). Overall, densities in this study area were low and ranged from 0.29 to 64.6 individuals per hectare (Figure 3.3.2-5). Echinoderm densities (Table 3.3.2-3A) for taxa such as brittlestars and sand stars (*Luidia foliolata*) ranked highest, with sea pen and crustacean densities also ranking in the top five, but often in much lower densities. Biomass in this study area generally was low for individual taxonomic groups, ranging from 0.04 to 2.83 kg per hectare (Figure 3.3.2-6). Biomass was highest for anemones (*Metridium spp.*; between 0.42

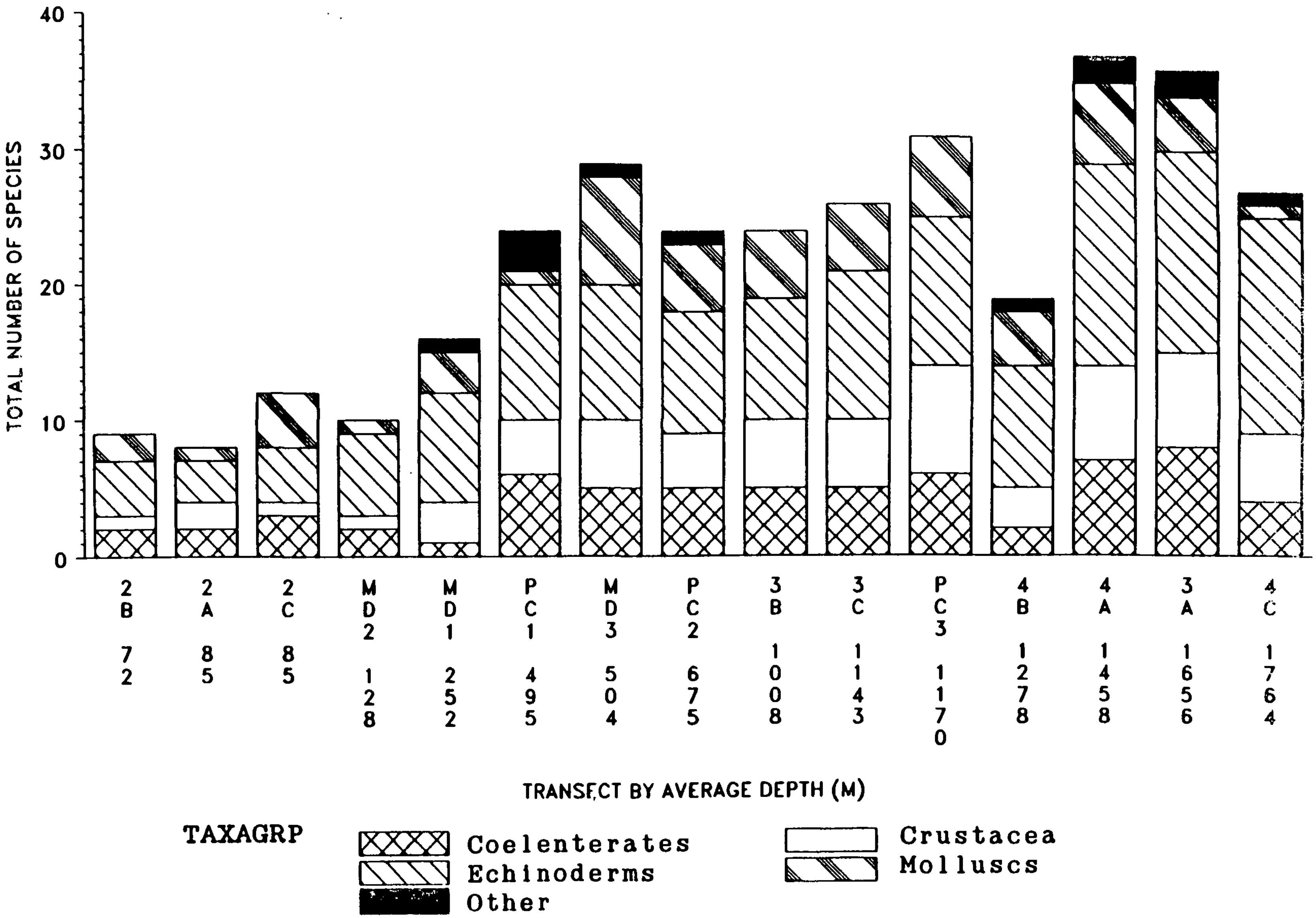

Figure 3.3.2-4. **Number of Benthic Megafaunal Invertebrate Species by General Taxonomic Group Collected During Trawl Surveys by SAIC (1992b) at Each Transect; Transects Sorted in Order of Increasing Depth.**
Average Depth (m) is indicated beneath each transect.

Table 3.3.2-3A. Rank Order of Density for Demersal Megafaunal Invertebrates Collected During Trawl Surveys by SAIC (1992b) in Study Areas 2 through 4 and Adjacent Sites in Pioneer Canyon (PC) and in "Mid-Depth" (MD).

SPECIES (depth in meters)	2A (72)	2B-3 (85)	2C-1 (85)	MD2-1 (128)	MD1-1 (252)	PC1-1 (495)	MD3-1 (504)	PC2-1 (675)	3B-1 (1008)	3C-1 (1143)	PC3-1 (1170)	4B-2 (1278)	4C-1 (1458)	4A-1 (1656)	3A-1 (1764)
Unknown Ophiuroid spp. 1 brittlestar	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Luidia foliata sand star	2	-	2	-	4	-	-	-	-	-	-	-	-	-	-
Stylatula spp. 1 sea pen	3	-	-	3	-	5	-	-	-	-	-	-	-	-	-
Metridium anemone	4	2.5	5	4.5	-	-	-	-	-	-	-	-	-	-	-
Octupus rubescens octopus	5	2.5	3	-	-	-	-	-	-	-	-	-	-	-	-
Asteronyx loveni brittlestar	-	2.5	-	-	-	2	2	3	-	4	-	-	-	2	2
Cancer magister Dungeness crab	-	2.5	-	-	-	-	-	-	-	-	-	-	-	-	-
Hippasteria spinosa seastar	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-
Unknown Ophuiroid, Gray brittlestar	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Pleurobranchia opisthobranch gastropod	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-
Rathbunaster californicus seastar	-	-	-	1	5	-	-	-	-	-	-	-	-	-	-
Gorgonocephalus brittlestar	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-

Table 3.3.2-3A. Continued.

SPECIES (depth in meters)	2A (72)	2B-3 (85)	2C-1 (85)	MD2-1 (128)	MD1-1 (252)	PC1-1 (495)	MD3-1 (504)	PC2-1 (675)	3B-1 (1008)	3C-1 (1143)	PC3-1 (1170)	4B-2 (1278)	4C-1 (1458)	4A-1 (1656)	3A-1 (1764)
Parastichopus simpsoni? sea cucumber	-	-	-	4.5	1	-	-	-	-	-	-	-	-	-	-
Pandalus platyceros spot prawn	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-
Allocentrotus fragilis sea urchin	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-
Myxoderma platyacanthum seastar	-	-	-	-	-	1	1	1	-	-	-	-	-	-	-
Pannychia sea cucumber	-	-	-	-	-	3	5	-	2	-	-	1	1	5	1
Unknown Pagurid Crab Hermit crab	-	-	-	-	-	4	4	-	-	-	-	-	-	-	-
Neptunea lyrata snail	-	-	-	-	-	-	3	2	4	2	2	3	-	-	-
Chionoecetes tanneri Tanner crab	-	-	-	-	-	-	-	4	3	1	4	2	-	-	-
Ophiomusium jollensis brittlestar	-	-	-	-	-	-	-	5	-	-	3	-	-	-	-
Bathybembix bairdii snail	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-
Hormathiidae anemone	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-
Heterozonias alternatus seastar	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-

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Table 3.3.2-3A. Continued.

SPECIES (depth in meters)	2A (72)	2B-3 (85)	2C-1 (85)	MD2-1 (128)	MD1-1 (252)	PC1-1 (495)	MD3-1 (504)	PC2-1 (675)	3B-1 (1008)	3C-1 (1143)	PC3-1 (1170)	4B-2 (1278)	4C-1 (1458)	4A-1 (1656)	3A-1 (1764)
Paractinistola-like anemone	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-
Unknown gastropod #1 snail?	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-
Paralithoides crab	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-
Braided sea pen sea pen	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-
Unknown Ophiuroid spp. 2 brittlestar	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
Lophaster furcilliger seastar	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-
Pteraster tessalatus seastar	-	-	-	-	-	-	-	-	-	-	-	-	4	4	3.5
Actinostola-like anemone	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-
Scotoplanes globosa sea cucumber	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Orange, flat corallimorph anemone	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-
Aphrodita sea mouse	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.5
Stylatula spp 2. sea pen	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5

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Table 3.3.2-3B. Rank Order of Biomass for Demersal Megafauna Collected During Trawl Surveys of Study Areas 2 Through 4 and Adjacent Sites in Pioneer Canyon (PC) and in "Mid-Depth" (MD) (SAIC 1992b).

SPECIES (depth in meters)	2A (72)	2B-3 (85)	2C-1 (85)	MD2-1 (128)	MD1-1 (252)	PC1-1 (495)	MD3-1 (504)	PC2-1 (675)	3B-1 (1008)	3C-1 (1143)	PC3-1 (1170)	4B-2 (1278)	4C-1 (1458)	4A-1 (1656)	3A-1 (1764)
Metridium anemone	1	2	1	1	-	-	-	-	-	-	-	-	-	-	-
Cancer magister Dungeness crab	2	1	3	2	-	-	-	-	-	-	-	-	-	-	-
Octopus rubescens octopus	3	4.5	5	-	-	-	-	-	-	-	-	-	-	-	-
Astropecten verrilli Spiny sand star	4.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Luidia foliata sand star	4.5	-	2	5	4	-	-	-	-	-	-	-	-	-	-
Hippasteria spinosa seastar	-	3	-	-	-	-	-	-	5	-	-	-	-	-	-
Tritonia snail	-	4.5	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurobranchia opisthobranch gastropod	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-
Parastichopus simpsoni? sea cucumber	-	-	-	3	1	-	-	-	-	-	-	-	-	-	-
Gorgonocephalus brittlestar	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-
Allocentrotus fragilis sea urchin	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-
Pandalus platyceros spot prawn	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-

Table 3.3.2-3B. Continued.

SPECIES (depth in meters)	2A (72)	2B-3 (85)	2C-1 (85)	MD2-1 (128)	MD1-1 (252)	PC1-1 (495)	MD3-1 (504)	PC2-1 (675)	3B-1 (1008)	3C-1 (1143)	PC3-1 (1170)	4B-2 (1278)	4C-1 (1458)	4A-1 (1656)	3A-1 (1764)
Rathbunaster californicus seastar	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-
Myxoderma platyacanthum seastar	-	-	-	-	-	1	1	2	-	-	-	-	-	-	-
Pannychia sea cucumber	-	-	-	-	-	2	-	-	2	-	-	3	1	-	1
Paractinistola-like anemone	-	-	-	-	-	3	3	-	4	2	3	-	-	-	-
Asteronyx loveni brittlestar	-	-	-	-	-	4	5	-	-	-	-	-	-	-	2
Chionoecetes tanneri Tanner crab	-	-	-	-	-	5	2	1	1	1	1	1	-	-	-
Neptunea lyrata snail	-	-	-	-	-	-	4	5	-	-	4	5	-	-	-
Octopus dofleini octopus	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-
Moroteuthis robusta octopus	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-
Bathybembix bairdii snail	-	-	-	-	-	-	-	-	3	-	2	-	-	-	-
Thrissacanthias penicillatus seastar	-	-	-	-	-	-	-	-	-	3	-	-	5	-	-
Paralithoides crab	-	-	-	-	-	-	-	-	-	4	-	2	-	-	-

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Table 3.3.2-3B. Continued.

SPECIES (depth in meters)	2A (72)	2B-3 (85)	2C-1 (85)	MD2-1 (128)	MD1-1 (252)	PC1-1 (495)	MD3-1 (504)	PC2-1 (675)	3B-1 (1008)	3C-1 (1143)	PC3-1 (1170)	4B-2 (1278)	4C-1 (1458)	4A-1 (1656)	3A-1 (1764)
Heterozonias alternatus seastar	-	-	-	-	-	-	-	-	-	5	-	-	-	-	5
Opisthoteuthis california octopus	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-
Braided sea pen sea pen	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-
Actinoscyphia-like anemone	-	-	-	-	-	-	-	-	-	-	-	-	2	-	4
Brown "sweet potato" sea cucumber	-	-	-	-	-	-	-	-	-	-	-	-	3	-	3
Pteraster tessalatus seastar	-	-	-	-	-	-	-	-	-	-	-	-	4	3	-
Orange, flat corallimorph anemone	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Scotoplanes globosa sea cucumber	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
Heterozonias-like seastar	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-
Solaster borealis seastar	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-

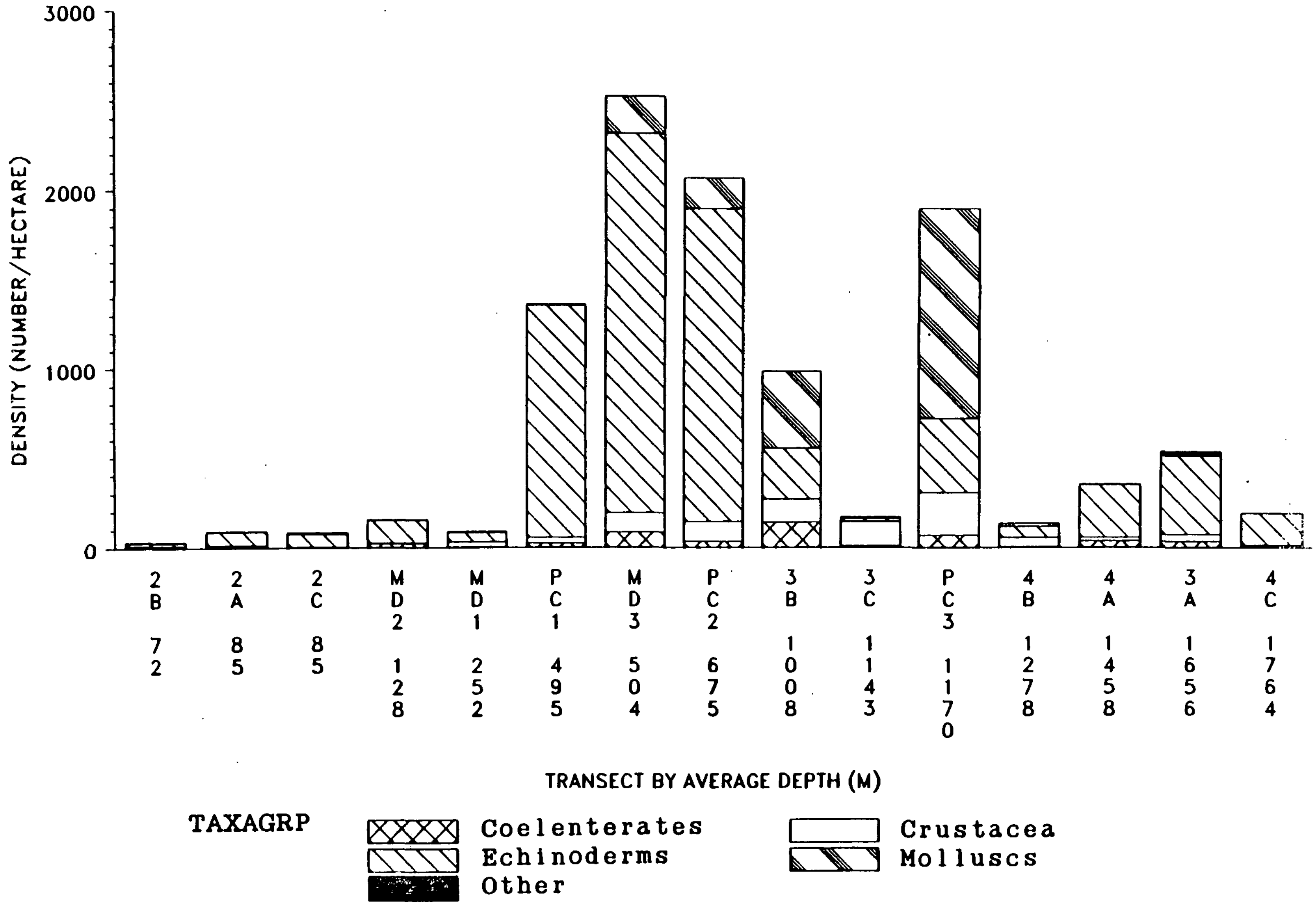

Figure 3.3.2-5. Sum of Densities of Megafaunal Invertebrate Species by General Taxonomic Group Collected During Trawl Surveys by SAIC (1992b) at Each Transect; Transects Sorted in Order of Increasing Depth.
Average Depth (m) is indicated beneath each transect.

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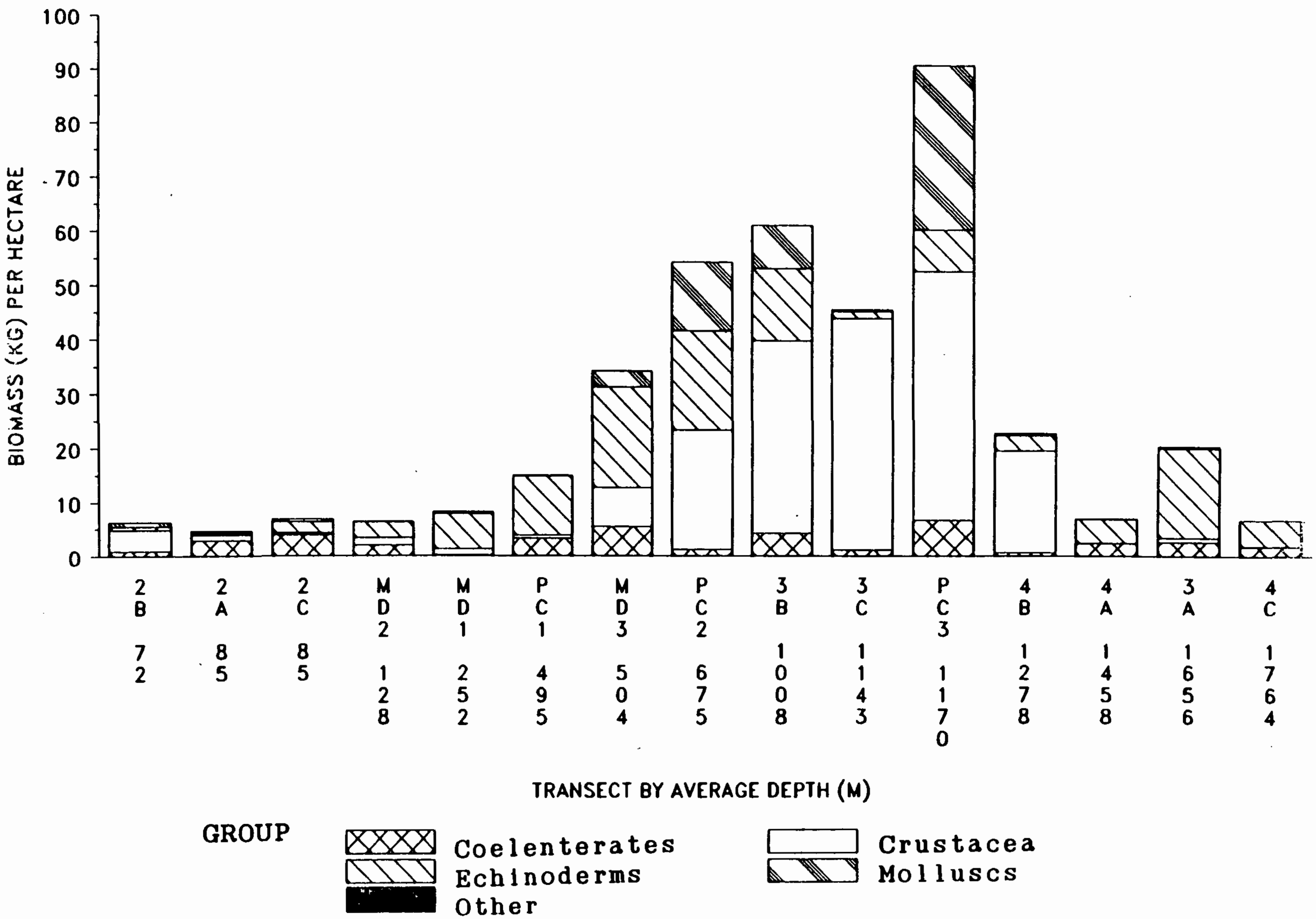

Figure 3.3.2-6. Sum of Biomasses of Benthic Megafaunal Invertebrate Species by General Taxonomic Group Collected During Trawl Surveys by SAIC (1992b) at Each Transect; Transects Sorted in Order of Increasing Depth.
Average Depth (m) is indicated beneath each transect.

and 3.83 kg per hectare), while Dungeness crab, octopus, and seastar biomass ranked in the top five (Table 3.3.2-3B). Some Dungeness crab and market squid (*Loligo opalescens*) were collected by SAIC (1992b) in this study area, and represent the only prominent commercial megafaunal fisheries species. Bence *et al.* (1992) collected market squid in midwater trawls, conducted within 30 m of the surface and over depths shallower than 180 m, which is similar in depth to Study Area 2. Hard-bottom habitats probably occur but were observed infrequently in this study area; however, sparse occurrences of rocks were observed using an ROV on Transect 2C-1 (SAIC 1992b).

Study Area 3

Study Area 3 is characterized by relatively moderate to high numbers of megafaunal species (Figure 3.3.2-4). Densities over the entire study area were low to moderate, ranging from approximately 200 to 1,000 individuals per hectare (Figure 3.3.2-5). Densities and biomass from the shallow parts of Study Area 3 (depths between 1,000 m and 1,200 m) were generally higher than from the deeper part (approximately 1,700 m), including Alternative Site 3, primarily due to the predominance of Molluscs (*Bathybembix bairdii* and *Neptunia amianta*), sea cucumbers (*Pannychia* spp.), brittlestar (*Asteronyx loveni*), seastars, and crustaceans such as Tanner crabs (*Chionoecetes tanneri;* Tables 3.3.2-3A and 3.3.2-3B; SAIC 1992b) In the deeper parts of the study area (Transect 3A-1), *Pannychia, Asteronyx loveni,* and seastar (*Pteraster tessalatus*) were the predominant taxa collected by SAIC (1992b). Hard-bottom substrate (small rock outcroppings) was observed with an ROV by SAIC (1992b) on Transects 3A-1 and 3B-1 with sessile invertebrates such as anemones predominating.

Study Area 4

Study Area 4 is characterized by relatively high numbers of megafaunal invertebrate species, ranging from 19 to 37 (Figure 3.3.2-4). Densities in the shallow parts of this study area (depths between 1,278 m and 1,458 m) were low to moderate, with densities ranging from 100 to 400 individuals per hectare (Figure 3.3.2-5). Biomass in the shallow parts ranged from approximately 10 to 25 kg per hectare (Figure 3.3.2-6). Predominant taxonomic groups in the shallow parts of the study area include echinoderms, cnidarians, and crustaceans (Table 3.3.2-3A). In the deepest part of the study area (Transect 4C), including the vicinity of Alternative Site 4, densities and biomass were relatively low (Figures 3.3.2-5 and 3.3.2-6), with echinoderms (e.g., the seastars *Heterozonias* and *Pteraster* and the sea cucumber *Scotoplanes*) and cnidarians (e.g., anemones) comprising the predominant taxonomic groups. No hard-bottom substrate was observed using an ROV (SAIC 1992b) within this study area.

Study Area 5

Study Area 5, surveyed in part by the Navy in 1991 (Nybakken *et al.* 1992; SAIC 1992a), represents a deeper survey region (depths primarily between 2,300 m and 3,200 m) than Study Areas 2, 3, and 4 (depths between approximately 72 m and 1,800 m) surveyed by SAIC (1992b). Within Study Area 5, (including Alternative Site 5) Nybakken *et al.* (1992) collected 95 taxa of megafaunal invertebrates, of which 71 species were identified, including at least five believed to be species previously unknown to science. Densities in this study area were extremely low (ranging from a mean of near zero to 270 individuals per hectare); however, predominant taxa included sea cucumbers, (*Molpadia intermedia* and *Paelopadites confundeus*), brittlestars (*Amphiura carchara*), seastars, and cnidarians. Biomass was not determined for taxa collected by Nybakken *et al.* (1992) in this study area; however, it most likely was extremely low based on the low densities and small sizes of the organisms.

Primary qualitative differences between results from the EPA study in Study Areas 2, 3, and 4 (SAIC 1992b) and the Navy study (Nybakken *et al.* 1992; SAIC 1992a) reflect depth-related trends between shelf (Study Area 2) and upper to middle slope communities (Pioneer Canyon sites and the shallower portions of Study Areas 3 and 4) compared to lower continental slope communities (the deeper portions of Study Areas 3 and 4), and the continental rise (Study Area 5). This conclusion is based on the predominance of very similar megafaunal taxa

(Nybakken *et al.* 1992; SAIC 1992b) and fish communities (Cailliet *et al.* 1992; SAIC 1992b) at depths from approximately 1,200 m to 3,200 m (i.e., lower slope and rise). For example, echinoderms (sea cucumbers, brittlestars, and seastars) and cnidarians (primarily seapens) were predominant in the deep parts of Study Area 3 and 4 (SAIC 1992b), as well as in Study Area 5 (Nybakken *et al.* 1992). Clearly, these similarities are based partly on upper level taxonomic comparisons and do not account for other potentially important species density and biomass differences. Nonetheless, the relative similarity of the deeper communities suggests a broad-scale pattern that appears to be consistent across the deeper portions of Study Areas 3 and 4 and within Study Area 5.

Comparisons with Other Studies

Prior to recent studies (SAIC 1992 a,b; Nybakken *et al.* 1992), knowledge of benthic megafaunal communities and information concerning the processes that regulate these communities on the continental slope and rise (from depths of approximately 200 m to 4,000 m depth) has been limited. Nearly all studies of deeper slope communities in the northeastern Pacific, as well as those in other continental margins, report depth as a major factor related to changes in the number of species, abundance, biomass, and size structure of populations (Astrahantseff and Alton 1965; Alton 1966, 1972; Carey 1972, 1990; Pereyra 1972; Pereyra and Alton 1972; Carney and Carey 1976). However, it is clear from these studies that depth-associated physical, chemical, and biological changes along these depth gradients, and not depth alone, are collectively responsible for the observed patterns.

SAIC conducted a survey of the northern and central California demersal communities at depths ranging from 30 to 300 m (Lissner *et al.* 1989). This study concluded that substrate type (hard versus soft bottom) and relief were the most important physical factors influencing the biological communities. Depth was next most important while latitude seemed to be least important. The influence of substrate type was illustrated by its effect on the number of species. On transects with 75 to 100% hard substrate, 36–44 taxa were identified. Transects with at least 10% hard substrate still had 23–30 taxa, whereas transects with less than 10% hard substrate contained only

11–14 taxa. Sampling stations were north and south of the LTMS study region and did not overlap the LTMS areas sampled.

Wakefield's (1990) trawl data off Point Sur, California, indicated invertebrates accounted for about 35% to 75% of the total catch, based on individual abundances, for each 200 m depth stratum from 400 m to 1,400 m. This contrasts dramatically with results from SAIC (1992b) where megafauna only contributed from 3% to 13% of the total individuals caught for the same depth strata. Also in contrast, the average total biomass of megafauna collected by SAIC (1992b) at slope depths between 400 m and 1,400 m was approximately 465 kg/ha compared with half that for the Point Sur area (calculated from Wakefield 1990).

Biomass of megafauna collected on the continental slope and near the Columbia River off the Oregon coast differ from results obtained by SAIC (1992b) off the California coast. For example, megafaunal biomass collected by SAIC (1992b) was approximately four times that reported by Pearcy *et al.* (1982) for the continental slope off central Oregon. In contrast, invertebrate biomass in the SAIC (1992b) study was less than 20% of the total near the Columbia River, off the northern Oregon coast (Pereyra and Alton 1972). These differences may be significantly influenced by trawl gear selectivity.

Differences in the number of species, density, and biomass of megafaunal invertebrates off central California (SAIC 1992b) as compared to Oregon (Pereyra and Alton 1972) probably were related to several factors including gear selectivity, inherent latitudinal differences in the faunas, and more limited knowledge of taxonomy for many species groups (e.g., cnidarians) off the central California coast. For example, Pereyra and Alton (1972) noted at least 343 species of megafauna (including infauna), with an estimated 150 additional species unidentified, from their study off the Columbia River. This represents considerably higher megafaunal diversity than the approximately 110 species found by SAIC (1992b).

Factors Influencing Community Patterns

The community differences by depth observed by SAIC (1992a,b) and Nybakken *et al.* (1992) were generally similar to those suggested by Gage and Tyler (1991) and Wakefield (1990), with the exception that the "upper slope" was divided for the SAIC (1992b) study into two parts: upper slope (depths of approximately 200 to 500 m) and middle slope (depths of approximately 500 to 1,200 m).

Sediment Types

In general, sediment types change from relatively coarse-grained in shelf and upper continental slope habitats (approximately < 500 m) to fine-grained muds on the middle to lower slope (> 1,000 m) and can have a significant effect on the distribution and abundance of megafauna (Wakefield 1990; Vercoutere *et al.* 1987). Area-specific studies by SAIC (1992c) concluded that infaunal distribution corresponded to changes in sediment characteristics. Similarly, SAIC (1992b) found taxonomic differences in megafauna (at the Genus level) that may be attributed to broad changes in sediment types within the study region (see Section 3.3.2.1). For example, seastars (*Asteronyx loveni* and *Myxoderma platyacanthum*) were generally predominant at depths corresponding to sedimentary changes from sand to sandy mud (see Section 3.2.5.1), while no distributional trends in epifaunal species composition corresponding to sediment characteristics were evident at depths greater than 1,000 m.

Changes in sediment types in the Gulf of the Farallones are related to several factors including the presence of the California Undercurrent, which reaches to a depth of about 600 m. The California Undercurrent can erode fine-grained sediments (Karlin 1980; Smith 1983) and create favorable habitats for many megafaunal invertebrate species. Thus, due to its role in defining erosional and depositional zones on the slope (Wakefield 1990), the boundary of the California Undercurrent may strongly influence the abundance and distribution of species along this depth gradient. It is notable that the 600 m boundary of the California Undercurrent is close to the approximate boundary between the upper and middle slope communities (combined fish and megafauna) defined by SAIC (1992b).

Results from the ROV video and photographic surveys suggest a generally uniform mud bottom over most transect areas (see Section 3.3.3). Thus, major changes in the sedimentary environment, as might be associated with community differences, were not evident. However, the resolution of sediment grain-size differences from the ROV data may not be sufficient to recognize subtle changes.

The proximity of the study region to waters outflowing from San Francisco Bay also may have an influence on the diversity of the fish and megafaunal communities. Seasonal changes related to river runoff, sediments derived from the estuary, and other factors such as organic fluxes may influence benthic habitat heterogeneity and complexity, leading to changes in species diversity. For example, the differences in species composition noted by Pereyra and Alton (1972) may be attributed to runoff by the Columbia River.

Oxygen Minimum Zone

The presence of gradients such as those produced by the oxygen minimum zone (OMZ) may be responsible for the depth-related patterns of some species on the California continental slope between approximately 600 and 800 m depths (Wakefield 1990). Perhaps the most striking distribution related to the oxygen minimum was that of the sea star *Myxoderma platyacanthum*, which was the most abundant megafaunal invertebrate in the OMZ, where it was found almost exclusively. Although there are no relevant physiological studies that have been performed on this species, it is notable that extensive respiratory structures (papulae), which potentially could be important in low oxygen environments, are present in high densities over the surface of this seastar. Because of the apparent effect of the OMZ on at least some common species, this boundary may strongly influence the patterns of community distribution noted from the cluster analyses (see SAIC 1992b Figure 3-12). SAIC (1992c) also found upper slope infaunal communities to be influenced by the OMZ, especially in the 600 to 800 m depth zones where oligochaetes are present in the fauna and indicative of sites with some partial oxygen stress.

The number of megafaunal invertebrate species tended to increase through the OMZ, perhaps due to reduced movement and activity (and lesser sensitivity to low oxygen conditions) of most species (SAIC 1992b). This pattern of increasing number of megafaunal species from the shelf break towards the middle of the continental slope is similar to general patterns reported from the western Atlantic (Rex 1981, 1983) and for many continental slope communities (Sanders and Hessler 1969; Haedrick *et al.* 1980).

Biological Factors

The majority of studies on biological processes have been conducted in intertidal or shallow subtidal habitats and their applicability to processes influencing deeper water species is unknown. Biological factors, including competition for space or food (Sebens 1986), predation (Paine and Vadas 1969; Lubchenco 1978), and larval selectivity and availability (Crisp 1974; Scheltema 1974) may also influence the distribution and abundance of benthic communities within the study region. Additional studies to evaluate biological processes in deep-water habitats would expand our understanding of the ecology and interactions of these organisms.

3.3.2.3 Pelagic Invertebrates

This section describes the pelagic invertebrates collected by SAIC (1992b), Nybakken *et al.* (1992), and Bence *et al.* (1992) within the study region. Because they were not specifically targeted by the EPA or Navy studies, pelagic invertebrates collected during these surveys represent incidental catches. Midwater trawls by NMFS represent the most comprehensive database for pelagic species within the general study region.

Pelagic invertebrates include those species capable of movement throughout the water column and/or just above the bottom. Examples include euphausiids, squid, pteropods, heteropods, and octopuses. Documentation of pelagic invertebrate populations and abundances in the region is limited. Most of the available information focuses on euphausiids and cephalopods that are either of commercial importance or are prey items for fish, marine birds, and marine mammals.

Midwater surveys in the region (Bence *et al.* 1992) and the analyses of commercial fishery catches (MMS/CDFG Commercial Fisheries Database 1992) indicated that cephalopods were a predominant pelagic invertebrate group in the study region. Market squid collected in midwater trawls at depths of approximately 30 m tended to be most abundant in areas less than 180 m in depth, similar to Study Area 2, while squid abundances in Study Areas 3, 4, and 5 (including Alternative Sites 3, 4, and 5), were uniformly low (Bence *et al.* 1992). In contrast, other squids (not including market squid) had low abundances within Study Area 2 and higher abundances at depths greater than 1,200 m, corresponding to Study Areas 3, 4, and 5 (Bence *et al.* 1992). Euphausiids were patchily abundant throughout the study region and available data do not provide a clear indication that they were more abundant in any particular study area (Bence *et al.* 1992). Because virtually no deep-water pelagic habitats on the Farallon slope have been sampled, information concerning these pelagic species at similar depths off the central California coast is important. For example, a combination of deep-water sampling and monitoring of local commercial fisheries in Monterey Bay resulted in the collection of ten species of previously unreported cephalopods including *Gonatus* spp., *Berryteuthis anonychus*, *Chiroteuthis calyx*, *Octopoteuthis deletron*, *Valbyteuthis danae*, *Japetella heathi*, and *Graneledone* spp. (Anderson 1978). Catches from large midwater trawls and commercial anchovy purse-seine hauls analyzed for pelagic assemblages were dominated by the common market squid *Loligo opalescens* (Cailliet *et al.* 1979). SAIC (1992b) collected seven species of cephalopods, including market squid, *Moroteuthis robusta*, *Vampiroteuthis infernalis*, *Benthoctopus* spp., *Octopus dofleini*, *O. rubescens*, and *Opisthoteuthis californiana*. Cephalopods are also a primary prey item for many marine mammals foraging over the continental shelf (Fiscus 1982; Roper *et al.* 1984) such as whales which feed on squid off the central California coast (Fiscus *et al.* 1989).

3.3.2.4 Commercially Important Species

The offshore coastal regions of central California support fisheries for a number of epifauna species including pink shrimp (*Pandalus jordani*); spot prawn (*Pandalus platyceros*); four crab species of the genus *Cancer*, including Dungeness crab (*C. magister*); and market squid (*Loligo opalescens*; Roper *et al.* 1984).

Commercially and/or recreationally important species collected within the study region by SAIC (1992b) included Dungeness crab, market squid, and various species of shrimp; however, all these species were collected infrequently (primarily as incidentals) and in low abundances. Assessments of local squid populations have been made to determine fishery size and structure (Roper *et al.* 1984; Recksick and Frey 1978) and correlations between oceanographic conditions and squid catches (McInnis and Broenkow 1978). The predominance of squid off the central coast of California, and their importance as a prey species to marine mammals suggest that these species are a major component of the pelagic invertebrate community.

Study Area 2, with a maximum depth of approximately 180 m, is likely to support the most substantial commercial fisheries for both pelagic and demersal invertebrates within the study region, with species such as pink shrimp, spot prawn, *Cancer* crabs, and market squid predominating. Dungeness crab, a significant bottom fishery resource in shallow inshore depths along the west coast of North America from central California to Southern Alaska (Botsford *et al.* 1989), was collected infrequently within Study Area 2 by SAIC (1992b) and Parr *et al.* (1988). Market squid populations were most abundant in midwater trawls in the top 30 m of the water column, over depths less than approximately 180 m, corresponding to similar depths within Study Area 2 (Bence *et al.* 1992), although crabs and urchins were the primary megafaunal species being targeted in Study Area 2, according to the MMS/CDFG Commercial Fisheries Database (1992). Although MMS/CDFG Commercial Fisheries Database (1992) data also indicated abalone were taken in Study Areas 2 and 3, these data may be inaccurate and a result of reporting or database tabulation error. Abalone are usually limited to shallow intertidal or subtidal (less than 30 m) hard-bottom substrate.

In contrast to fishery resources in Study Area 2 and shallower inshore areas, little information exists regarding commercial invertebrate fisheries in Study Areas 3, 4, or 5. This may be due to lower fishing effort for invertebrates within Study Areas 3, 4, or 5 by commercial fishermen.

3.3.3 Fish Community

This section describes the fish communities in the study region. Separate sections are included on demersal fishes (those which live on or near the bottom; Section 3.3.3.1) and pelagic fishes (those that spend all or part of their life in the water column; Section 3.3.3.2). Also, information is presented on commercially and/or recreationally important species that inhabit the study region (Section 3.3.3.3).

3.3.3.1 Demersal Species

This section describes the demersal fishes found in the study region, including Study Areas 2, 3, 4, and 5. Specifically, information is presented on predominant species, density, and biomass within each study area. Also, details are presented on the rank order of density (Table 3.3.3-1A) and biomass (Table 3.3.3-1B) for the top five fishes collected during trawl surveys by SAIC (1992b) in each study area. A summary overview of demersal fish community characteristics by study area is presented in Table 3.3.3-2. Because a number of fish species (e.g., rockfishes) possess both pelagic juvenile and demersal adult stages, juvenile stages of these fishes collected by SAIC (1992b) and Bence *et al.* (1992) are discussed in Section 3.3.3.2.

Extensive trawl and remotely operated vehicle (ROV) biological surveys were conducted for the Environmental Protection Agency (EPA) in Study Areas 2 through 4, at adjacent transects within Pioneer Canyon, and at "Mid-Depth" transects during September and October 1991 (SAIC 1992b) and by the Navy in Study Area 5 during July 1991 (Cailliet *et al.* 1992). Previous trawl studies

Table 3.3.3-1A. **Rank Order of Density (number of individuals/hectare) by Increasing Trawl Depth for Demersal Fishes Collected by SAIC (1992b) During Surveys in Study Areas 2 Through 4 and Adjacent Sites in Pioneer Canyon (PC) and at "Mid-Depth" (MD).**

SPECIES (depth in meters)	2A (72)	2B-3 (85)	2C-1 (85)	MD2-1 (128)	MD1-1 (252)	PC1-1 (495)	MD3-1 (504)	PC2-1 (675)	3B-1 (1008)	3C-1 (1143)	PC3-1 (1170)	4B-2 (1278)	4C-1 (1458)	4A-1 (1656)	3A-1 (1764)
Citharichthys sordidus Pacific Sanddab	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—
Errex zachirus Rex Sole	2	4	3	2	—	2	—	—	—	—	—	—	—	—	—
Porichthys notatus Plainfin Midshipmen	3	—	—	5	—	—	—	—	—	—	—	—	—	—	—
Zalembius rosaceus Pink Surfperch	4	2	4	—	—	—	—	—	—	—	—	—	—	—	—
Pleuronectes vetulus English Sole	5	—	2	—	—	—	—	—	—	—	—	—	—	—	—
Genyonemus lineatus White Croaker	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—
Peprilus simillimus Pacific Butterfish	—	5	—	—	—	—	—	—	—	—	—	—	—	—	—
Microstomus pacificus Dover Sole	—	—	5	—	1	1	1	2	2	2	4	2	—	—	—
Sebastes jordani Shortbelly Rockfish	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—
Lyopsetta exilis Slender Sole	—	—	—	3	3	—	—	—	—	—	—	—	—	—	—
Sebastes saxicola Stripetail Rockfish	—	—	—	4	2	—	—	—	—	—	—	—	—	—	—
Anoplopoma fimbria Sablefish	—	—	—	—	4	—	—	3	4	—	5	—	—	—	—

Table 3.3.3-1A. Continued.

SPECIES (depth in meters)	2A (72)	2B-3 (85)	2C-1 (85)	MD2-1 (128)	MD1-1 (252)	PC1-1 (495)	MD3-1 (504)	PC2-1 (675)	3B-1 (1008)	3C-1 (1143)	PC3-1 (1170)	4B-2 (1278)	4C-1 (1458)	4A-1 (1656)	3A-1 (1764)
Sebastes diploproa Splitnose rockfish	—	—	—	—	5	—	—	—	—	—	—	—	—	—	—
Sebastolobus altivelis Longspine Thornyhead	—	—	—	—	—	3	2	1	1	1	1	4	4	4	—
Sebastolobus alascanus Shortspine Thornyhead	—	—	—	—	—	4	5	4	—	—	—	—	—	—	—
Lycodes cortezianus Bigfin Eelpout	—	—	—	—	—	5	3	—	—	—	—	—	—	—	—
Nezumia stelgidolepis California Grenadier	—	—	—	—	—	—	4	—	—	—	—	—	—	—	—
Merluccius productus Pacific Hake	—	—	—	—	—	—	—	5	—	—	—	—	2.5	—	—
Alepocephalus tenebrosus California Slickhead	—	—	—	—	—	—	—	—	5	5	2	5	—	5	—
Coryphaenoides acrolepis Pacific Grenadier	—	—	—	—	—	—	—	—	3	3	3	1	1	1	1
Albatrossia pectoralis Giant Grenadier	—	—	—	—	—	—	—	—	—	4	—	3	2.5	3	5
Antimora microlepis Finescale Codling	—	—	—	—	—	—	—	—	—	—	—	—	5	2	2
Lycenchelys jordani Shortjaw Eelpout	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3
Coryphaenoides filifer Threadfin Grenadier	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4

Table 3.3.3-1B. Rank Order of Biomass by Increasing Trawl Depth for Demersal Fishes Collected by SAIC (1992b) During Surveys in Study Areas 2 Through 4 and Adjacent Sites in Pioneer Canyon (PC) and at "Mid-Depth" (MD).

SPECIES (depth in meters)	2A (72)	2B-3 (85)	2C-1 (85)	MD2-1 (128)	MD1-1 (252)	PC1-1 (495)	MD3-1 (504)	PC2-1 (675)	3B-1 (1008)	3C-1 (1143)	PC3-1 (1170)	4B-2 (1278)	4C-1 (1458)	4A-1 (1656)	3A-1 (1764)
Citharichthys sordidus Pacific Sanddab	1	1	2	—	—	—	—	—	—	—	—	—	—	—	—
Errex zachirus Rex Sole	2	4	3	4	5	3	—	—	—	—	—	—	—	—	—
Pleuronectes vetulus English Sole	3	5	1	—	—	—	—	—	—	—	—	—	—	—	—
Raja binoculata Big Skate	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Porichthys notatus Plainfin Midshipmen	5	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Genyonemus lineatus White croaker	—	2	4	—	—	—	—	—	—	—	—	—	—	—	—
Zalembius rosaceus Pink Surfperch	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—
Microstomus pacificus Dover Sole	—	—	5	2	1	1	1	2	1	1	4	1	—	—	—
Sebastes jordani Shortbelly Rockfish	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—
Sebastes goodei Chilipepper	—	—	—	3	—	—	—	—	—	—	—	—	—	—	—
Sebastes saxicola Stripetail Rockfish	—	—	—	5	3	—	—	—	—	—	—	—	—	—	—
Anoplopoma fimbria Sablefish	—	—	—	—	2	2	2	1	2	2	1	4	—	—	—
Lyopsetta exilis Slender Sole	—	—	—	—	4	—	—	—	—	—	—	—	—	—	—

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Table 3.3.3-1B. Continued.

SPECIES (depth in meters)	2A (72)	2B-3 (85)	2C-1 (85)	MD2-1 (128)	MD1-1 (252)	PC1-1 (495)	MD3-1 (504)	PC2-1 (675)	3B-1 (1008)	3C-1 (1143)	PC3-1 (1170)	4B-2 (1278)	4C-1 (1458)	4A-1 (1656)	3A-1 (1764)
Merluccius productus Pacific Hake	—	—	—	—	—	4	—	4	—	—	—	—	—	—	—
Sebastolobus alascanus Shortspine Thornyhead	—	—	—	—	—	5	—	5	5	4	—	—	—	—	—
Sebastolobus altivelis Longspine Thornyhead	—	—	—	—	—	—	3	3	3	5	5	—	—	5	—
Raja rhina Longnose Skate	—	—	—	—	—	—	4	—	—	—	—	—	—	—	—
Lycodes cortezianus Bigfin Eelpout	—	—	—	—	—	—	5	—	—	—	—	—	—	—	—
Coryphaenoides acrolepis Pacific Grenadier	—	—	—	—	—	—	—	—	4	—	3	2	2	1	1
Albatrossia pectoralis Giant Grenadier	—	—	—	—	—	—	—	—	—	3	—	3	1	2	2
Alepocephalus tenebrosus California Slickhead	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—
Antimora microlepis Finescale Codling	—	—	—	—	—	—	—	—	—	—	—	5	4	3	3
Bathyraja trachura Black Skate	—	—	—	—	—	—	—	—	—	—	—	—	3	—	—
Bathyraja abyssicola Deepsea Skate	—	—	—	—	—	—	—	—	—	—	—	—	5	4	—
Bathyraja rosispinus Flathead Skate	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4
Coryphaenoides filifer Threadfin Grenadier	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5

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Table 3.3.3-2. Summary by Study Area of Demersal Fish Community Characteristics.

Survey Location	Depth Range (m)	Total Species	Density (individuals per hectare)	Biomass (kg per hectare)	Predominant Species	Commercially Important Species
Study Area 2 [1]	72-85	29	1500-2500	100-250	Sanddabs Rex Sole English Sole Pink Surfperch	yes yes yes no
MD	128-504	19	500-14,000	220-1200	Shortbelly Rockfish Flatfishes Sablefish Skates	yes yes yes no
PC	495-1170	19	1500-2500	550-1150	Flatfishes Rockfishes Sablefish	yes yes yes
Study Area 3 [1]	1008-1656	16	500-1500	80-400	Rattails Thornyheads Dover Sole Finescale Codlings	potential yes yes no
Study Area 4 [1]	1278-1764	14	< 100-500	20-400	Rattails Thornyheads Eelpouts	potential yes no
Study Area *5 [2]	2300-3065	15	~ 14	Data not collected	Rattails Finescale Codlings Eelpouts Snailfishes	potential no no no

[1] SAIC 1992b
[2] Cailliet *et al.* 1992
* Data are not directly comparable to SAIC (1992b) since different trawl methods were used (beam and small otter trawl versus large otter trawl for SAIC 1992b).

within Study Area 2 also were conducted by KLI (1991). Additional information from midwater and bottom trawls is summarized in Bence *et al.* (1992).

Similar to general distributional patterns observed in the study region for invertebrate communities (see infauna, Section 3.3.2.1; and epifauna, Section 3.3.2.2), demersal fish communities were differentiated based on depth or depth-related factors in the study region (Figures 3.3.3-1 and 3.3.3-2). These communities are summarized below:

- A shelf community (from depths of at least 72 to approximately 200 m), including Study Area 2 and some Mid-Depth transects (Figure 3.3.3-2), was characterized by relatively high numbers of fish species and abundances (including commercially/recreationally important species) but relatively low biomass (Table 3.3.3-2). This community is dominated by sanddabs, English sole, rex sole, rockfishes (not including thornyheads), pink surfperch, plainfin midshipman, and white croakers (Table 3.3.3-1A). Of these, all except pink surfperch have important commercial value. Figure 3.3.3-1 depicts a typical shelf community assemblage.

- Upper and middle slope communities (from approximately 200 to 500 m and 500 to 1,200 m depth, respectively), including shallow parts of Study Areas 3 and 4, Mid-Depth, and Pioneer Canyon (Figure 3.3.3-2), were characterized by moderate numbers of fish species and densities and the highest relative biomass (including commercially/recreationally important species; Table 3.3.3-2). Fishes collected using trawls and/or observed from ROV records on the upper slope include rockfishes, flatfishes, sablefish, eelpouts, and thornyheads (Figure 3.3.3-1). Rockfishes, thornyheads, flatfishes, sablefish, hake, slickheads, and rattails were collected and observed on the middle slope. Figure 3.3.3-1 depicts typical upper and middle slope fish assemblages.

- Lower slope communities (from depths of approximately 1,200 m to at least 3,200 m), including the deeper parts of Study Areas 3 and 4 and Study Area 5 (including Alternative Sites 3, 4, and 5), were characterized by relatively low numbers of fish species, abundance, and biomass (Table 3.3.3-2). This community is characterized by rattails, thornyheads, finescale codling, and eelpouts (Figure 3.3.3-1).

Types of depth-related factors recognized as influencing community structure include differences in the sedimentary environment, the OMZ, and regional current patterns (e.g., summarized in Wakefield 1990). These factors are discussed in greater detail below.

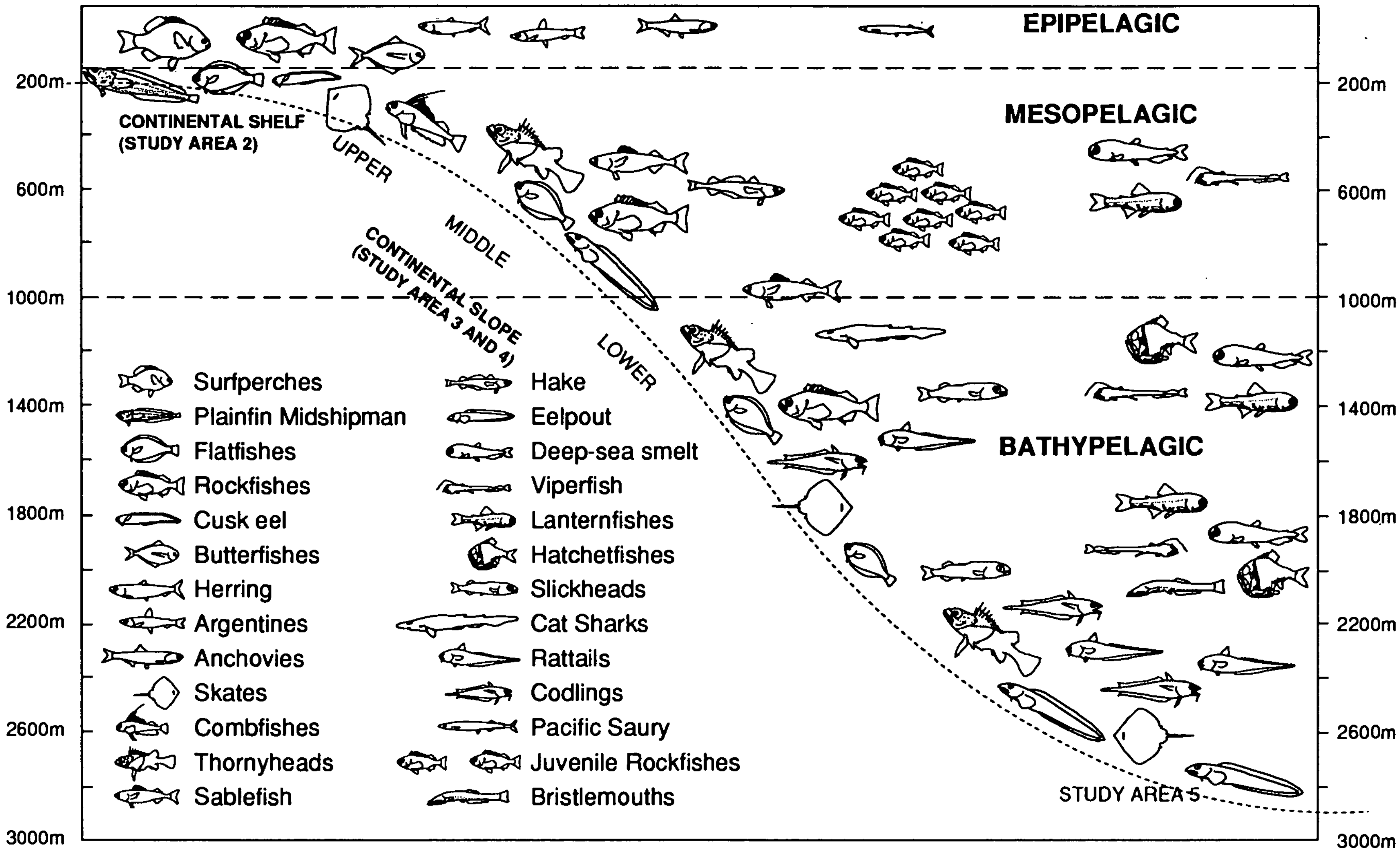

Figure 3.3.3-1. Community Assemblages on Continental Shelf and Slope off San Francisco, California, for Common Fishes Collected in Trawls by SAIC (1992b), Cailliet et al. (1992), and NMFS (1992) in LTMS Study Areas 2, 3, 4, and 5.

Taxonomic groups (e.g., families) may represent more than one species. Fishes do not accurately reflect size differences. Drawings taken from Miller and Lea (1972).

Demersal fish communities within the study region exhibited several distinct patterns related to the number and type of species, density, and biomass (Tables 3.3.3-2, 3.3.3-1A, and 3.3.3-1B; Figures 3.3.3-3 through 3.3.3-5). The numbers of species collected from transects in Study Area 2 by SAIC (1992b) ranged from 18 to 29 (Figure 3.3.3-3), with flatfishes (such as Pacific sanddab, *Citharichthys sordidus,* English sole, *Pleuronectes vetulus* and rex sole, *Errex zachirus*), rockfishes (*Sebastes*, spp.), and species such as pink surfperch (*Zalembius rosaceus*) being abundant (Table 3.3.3-1A). Similar results were obtained by Bence *et al.* (1992) and KLI (1991) in Study Area 2, with Pacific sanddabs, plainfin midshipmen, and pink surfperch predominating. Fish densities (number of individuals per hectare) were high in Study Area 2 (Figure 3.3.3-4). Flatfish densities (Table 3.3.3-1A) and biomass (Table 3.3.3-1B) for species such as Pacific sanddabs and English sole were highest in Study Area 2. However, biomass (kg/ha) in this area was relatively low (less than approximately 250 kg/ha) due to the presence of numerous small flatfishes such as Pacific sanddabs and rex sole (Figure 3.3.3-5). Rockfishes (*Sebastes* spp.), as a group were most abundant from depths of approximately 180 to 270 m (Bence *et al.* 1992), which corresponds to similar depths adjacent to Study Area 2. Pelagic juvenile Dover sole and adult Pacific hake were collected in midwater trawls within 30 m of the surface and had higher abundances in Study Area 2 (Bence *et al.* 1992).

Study Area 3 was characterized by moderate numbers of species (Table 3.3.3-2; Figure 3.3.3-3). Fish densities (Figure 3.3.3-4) from the shallow parts of Study Area 3 (at depths of approximately 1,000 to 1,200 m; Transects 3B-1 and 3C-1) were higher than the deeper part (at depths of approximately 1,700 m; Transect 3A-1) and Alternative Site 3 (SAIC 1992b). Rockfishes such as thornyheads (*Sebastolobus* spp.) and flatfishes such as Dover sole, comprised the highest densities in the shallower parts of this study area, while rattails and finescale codling represent characteristic species at deeper depths (SAIC 1992b; Bence *et al.* 1992). Densities of both thornyheads and Dover sole were high in this study area (Table 3.3.3-1A). Biomass decreased in the shallowest to deepest parts of this study area, from 400 to 80 kg/ha, with Dover sole and sablefish contributing the highest proportion of biomass (Table 3.3.3-1B; Figure 3.3.3-5).

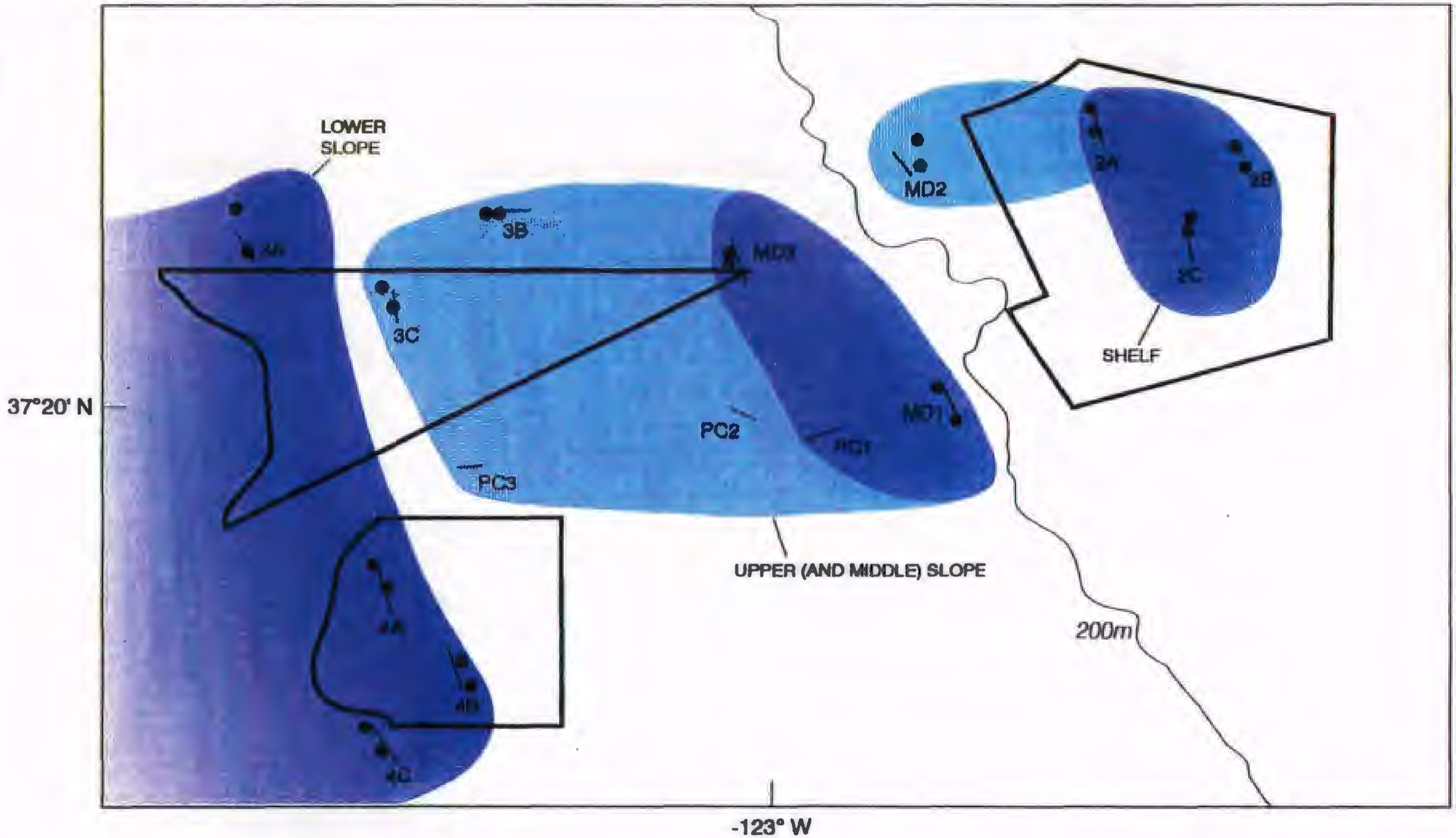

Figure 3.3.3-2 Summary of Distribution Patterns of Benthic Communities (Fishes and Megafaunal Invertebrates) from Trawl and ROV Studies Conducted in September and October 1991.

Transect start and end coordinated are indicated for trawls (solid lines) and ROV (dots mark coordinates). Study Areas 2, 3, and 4 locations are shown by "2", "3", and "4"; MD=Mid-depth; PC=Pioneer Canyon. Shelf communities are less than or equal to 200 m; upper slope is 200-500 m; middle slope is 500-1,200 m; and lower slope is greater than 1,200 m. Shades of blue correspond to areas with similar species composition (dark blue) and areas with less similar species composition (light blue) based on cluster analysis by SAIC (1992b).

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Figure 3.3.3-2. Continued.

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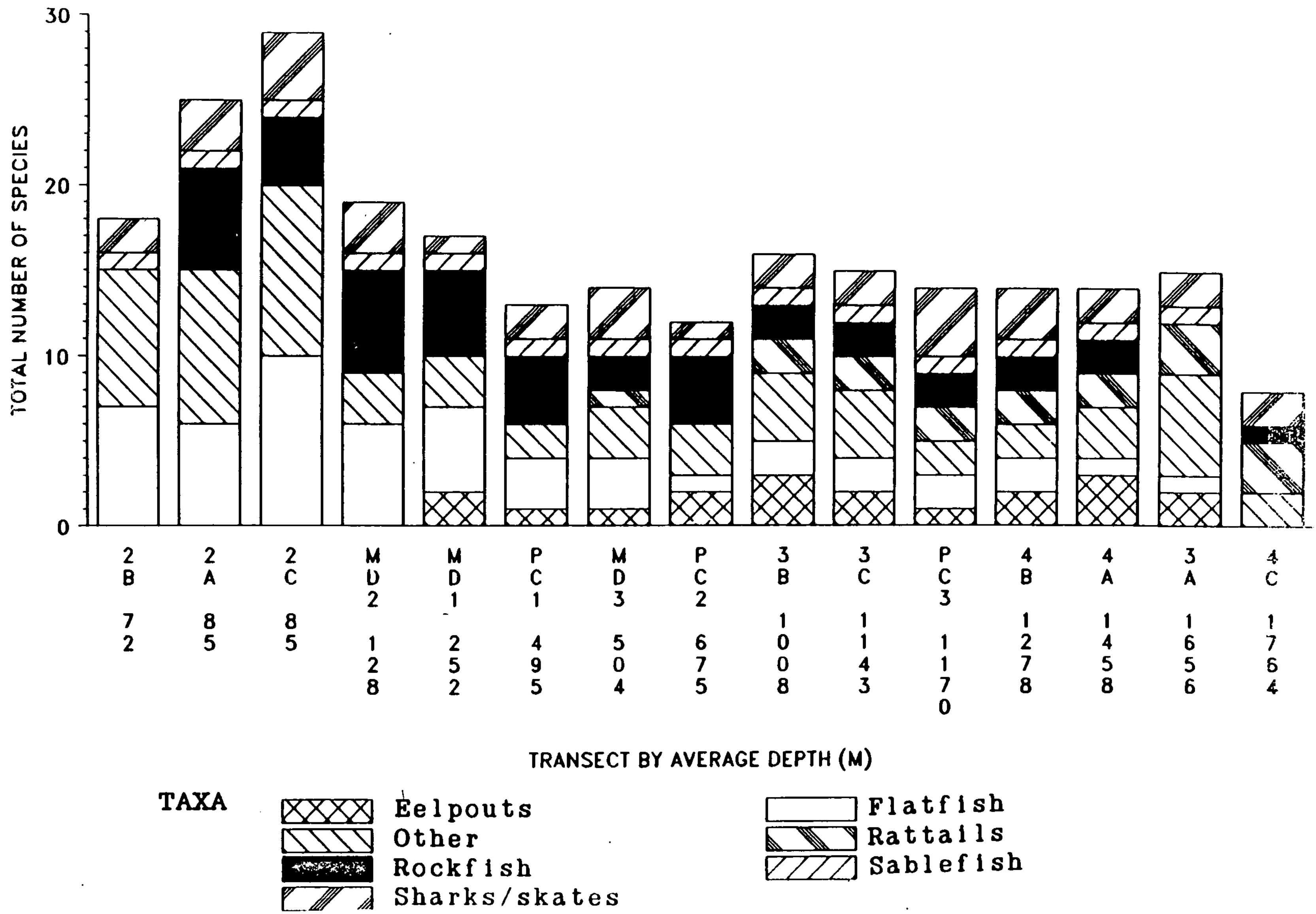

Figure 3.3.3-3. Number of Benthic Fish Species by General Taxonomic Group Collected During Trawl Surveys by SAIC (1992b) by Each Transect; Transects Sorted in Order of Increasing Depth.
Average depth (m) is indicated beneath each transect.

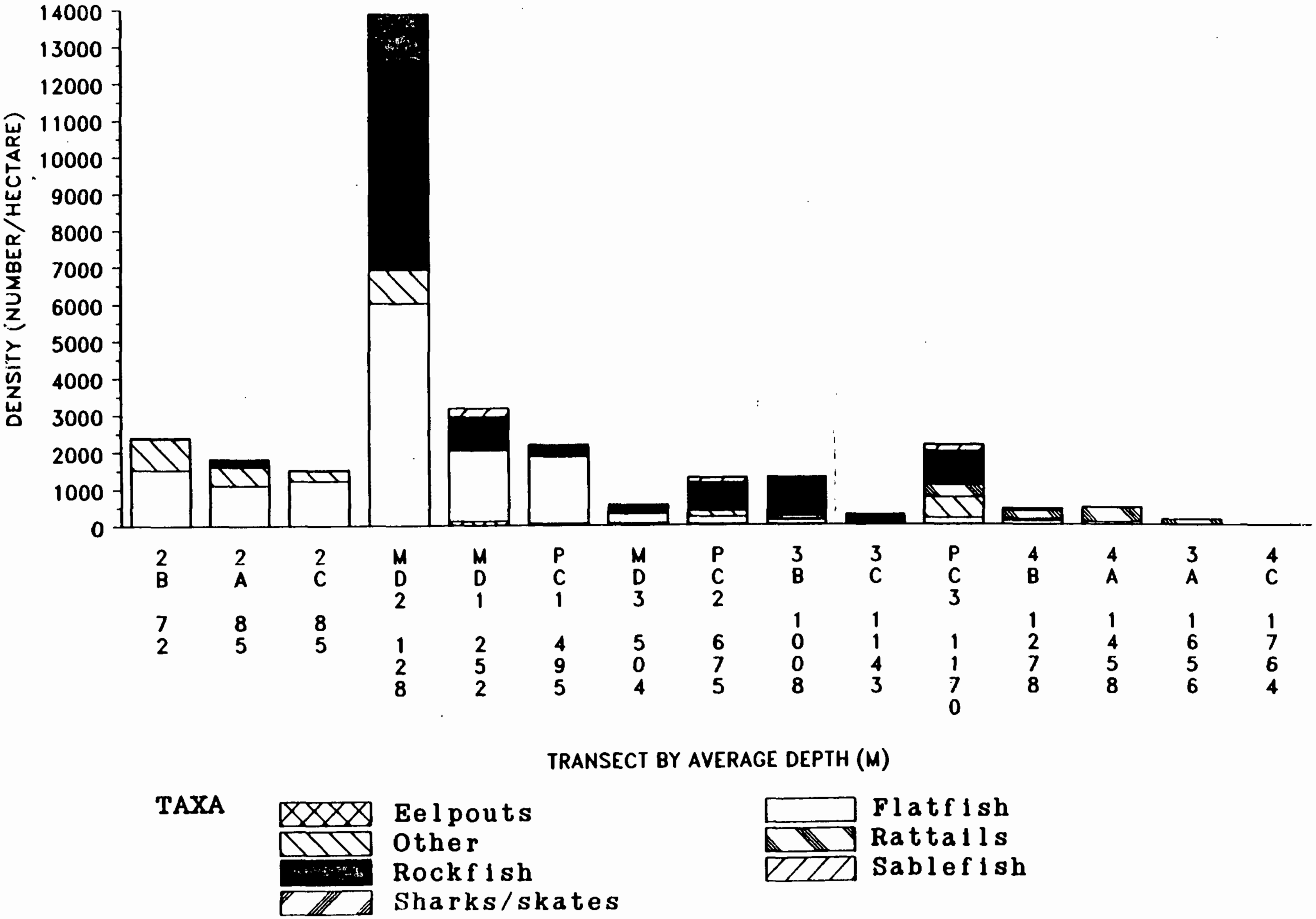

Figure 3.3.3-4. **Sum of Densities of Benthic Fish Species by General Taxonomic Group Collected During Trawl Surveys by SAIC (1992b) at Each Transect; Transects Sorted in Order of Increasing Depth.**
Average depth (m) is indicated beneath each transect.

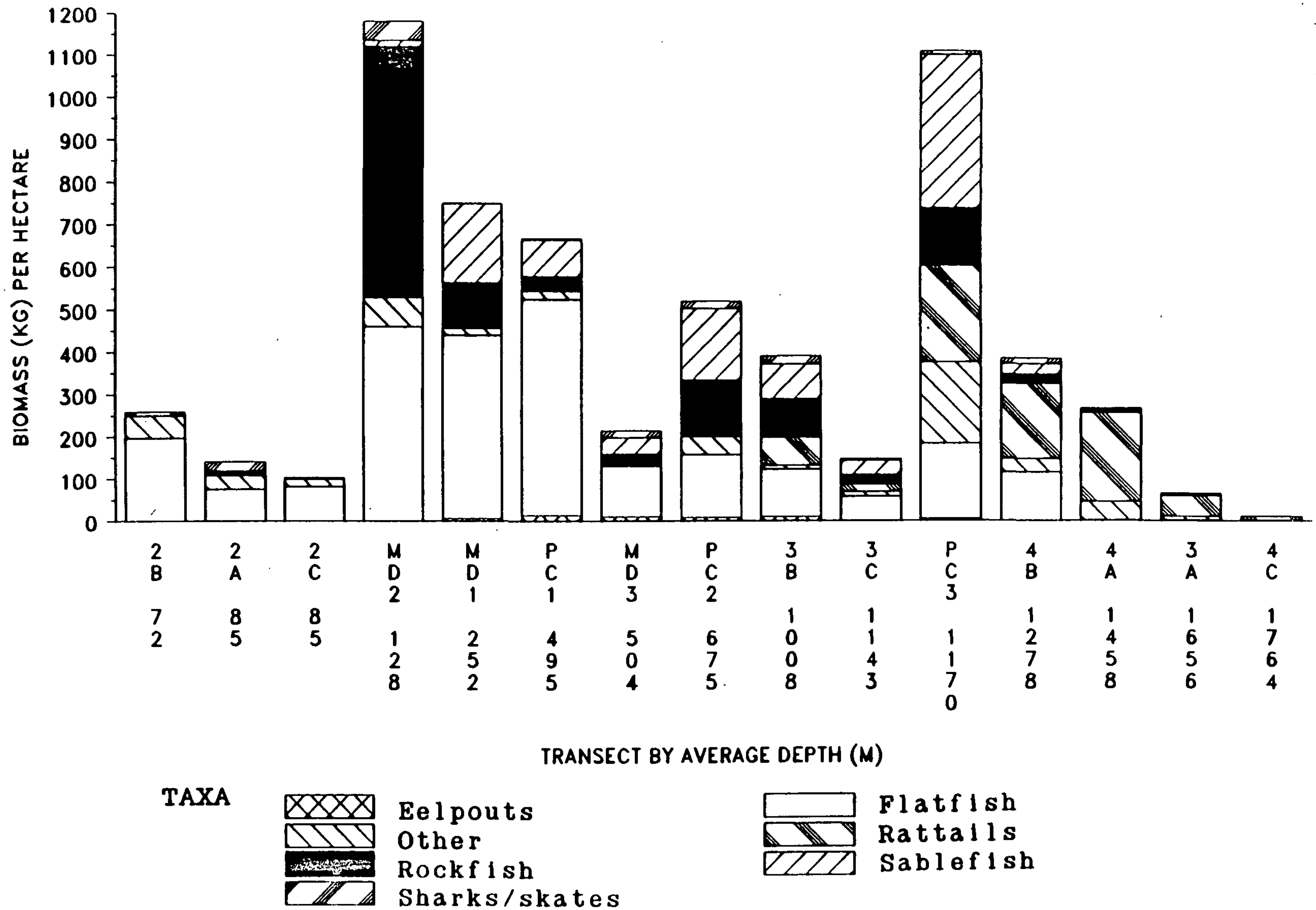

Figure 3.3.3-5. Sum of Biomasses of Benthic Fish Species by General Taxonomic Group Collected During Trawl Surveys by SAIC (1992b) at Each Transect; Transects Sorted in Order of Increasing Depth.
Average depth (m) is indicated beneath each transect.

Slender sole (*Lyopsetta exilis*) and spotted ratfish (*Hydrolagus colliei*) were abundant at depths of approximately 270 to 360 m, suggesting they also might be common in the shallowest parts of this study area (Bence *et al.* 1992).

SAIC (1992b) collected the lowest number of species in the deepest part of Study Area 4 and Alternative Site 4, although this may have been due to problems with sampling gear on one of the three trawls. In the entire study area, rattails (*Coryphaenoides* spp.) comprised the majority of the trawl fish catch. Densities of fishes varied, but were usually less than 500/ha (Figure 3.3.3-4). At depths greater than approximately 1,500 m (e.g., Transect 4C), the numbers of fish species, densities, and biomass were extremely low. The highest biomass contribution at these deeper depths was from rattails and slickheads (Table 3.3.3-1B; Figure 3.3.3-5). Bence *et al.* (1992) indicated thornyheads (*Sebastolobus* spp.) were most abundant at depths between 700 to 900 m. This suggests thornyheads might be common in the shallow parts of Study Area 4 (Bence *et al.* 1992), while rattails were most abundant in the deep portions of Study Areas 3 and 4 and in Study Area 5 (including Alternative Sites 3, 4, and 5).

Study Area 5, surveyed by the Navy in 1991 (Cailliet *et al.* 1992), was dominated by rattails, eelpouts (Zoarcidae), and morids (*Antimora microlepis*). Fish density in this study area was low (e.g., 207/ha). These general results are very similar to those observed for the deep slope communities in Study Areas 3 and 4 at depths greater than approximately 1,200 m, even though the trawl used by SAIC (1992b) was a large commercial-sized otter trawl, while Cailliet *et al.* (1992) used a small beam trawl and a small otter trawl. Within Study Area 5, Cailliet *et al.* (1992) collected 15 species of fishes, of which rattails, eelpouts, and finescale codling were predominant.

Based on the differences in sampling methods, as noted above, quantitative comparisons between Study Areas 2 through 4 and Study Area 5 do not appear to be appropriate. Primary qualitative differences between results from SAIC (1992b) surveys in Study Areas 2, 3, 4, Mid-Depth, and Pioneer Canyon and Cailliet *et al.* (1992) surveys in Study Area 5 reflect depth-related trends between shelf (Study Area 2) and upper to middle slope communities (Pioneer Canyon sites and the shallower portions of Study Area 3) compared to lower slope communities (Study Area 4, the deeper portion of Study Area 3, and Study Area 5). This conclusion is based on the predominance of very similar fish taxa from depths of approximately 1,200 to 3,200 m (i.e., lower slope) as compared to the shallower communities. For example, lower slope fish communities from both studies are characterized by rattails, eelpouts, and finescale codlings. Clearly, these similarities and differences are based partly on upper level taxonomic comparisons and do not account for other potential species density and biomass differences. Nonetheless, the relative "sameness" of the deeper communities suggests a broad-scale pattern that is consistent across the deeper portions of Study Areas 3 and 4 and within Study Area 5. This similarity is also evident from Bence *et al.* (1992) surveys. Although both midwater and demersal trawls were used, results similar to SAIC (1992b) and Cailliet *et al.* (1992) in species composition were obtained by the NMFS surveys.

Comparisons With Other Studies

Several studies from California to the Pacific Northwest show variations with depth among major fish groups. For shallow depths on the continental shelf and upper continental slope, flatfishes, including Bothidae (e.g., sanddabs) and Pleuronectidae (e.g., rex sole and Dover sole), account for the greatest biomass in most studies. Fishes such as flatfishes, including Dover sole, rex sole, and in some cases Pacific sanddabs (SAIC 1992b; Bence *et al.* 1992), were also dominant on the shelf and upper slope off Point Sur (Wakefield 1990), offshore from the Columbia River (Pearcy *et al.* 1982), and over most trawl locations along the coast of central California which were sampled by NMFS (Butler *et al.* 1989). Smaller individuals of these flatfish species usually were most abundant at the shallowest depths and larger individuals were most abundant on the continental slope (SAIC 1992b, Figures C-6 , C-5 , and C-2).

Comparisons of shelf fish communities based on abundance data from SAIC (1992b) and KLI (1991) indicated that flatfishes, pink surfperch, plainfin midshipman, and rockfishes made up the top species or taxonomic groups collected by both studies within the study region. Comparisons of upper slope fish communities at depths between approximately 300 to 600 m with studies by Wakefield (1990) and Cross (1987) at depths between 600 to 1,600 m indicated that flatfishes, rockfishes, and eelpouts ranked in the top five, suggesting that species compositions were similar between both of these studies over the same depth intervals. Finally, on the lower slope (at depths greater than 1,200 m) thornyheads, rattails, eelpouts, and finescale codling ranked high in all studies (SAIC 1992b; Wakefield 1990).

Factors Influencing Community Patterns

Fish community structure within the study region can be influenced by depth or depth-related factors such as the sedimentary environment, regional current patterns, and the OMZ.

Several factors, including the presence of the California Undercurrent, which reaches to a depth of about 600 m, may contribute to changes in sediment types in the Gulf of the Farallones. Thus, due to its role in defining erosional and depositional zones on the slope (Wakefield 1990), the boundary of the California Undercurrent may also influence the abundance and distribution of demersal fishes along this depth gradient. It is notable that the 600 m boundary of the California Undercurrent is close to the approximate boundary between the upper and middle slope communities defined by SAIC (1992b).

The proximity of the study region to the outflow from San Francisco Bay also may have an influence on the diversity of the fish communities within the study region. Seasonal changes related to river runoff, sediments derived from the estuary, and other factors such as organic fluxes, may influence benthic habitat heterogeneity and complexity, leading to changes in species diversity. The only other west coast study of slope fishes offshore of a large estuary or river is Alton's (1972) study off the Columbia River.

In addition to sedimentary effects on fish communities, the presence of gradients such as those produced by the OMZ may be responsible for the depth-related patterns of some species found on the California continental slope at depths between approximately 600 m and 800 m (Wakefield 1990). Oxygen minima usually underlie surface waters having high primary production or other high inputs of organic material (e.g., upwelling zones along the coast of California). Active species, such as many types of fishes, may be unable to withstand low oxygen concentrations. Although few studies have been conducted, there is some evidence which indicates that species inhabiting the OMZ are well adapted to low oxygen environments. Some mid-water species in this zone have the ability to regulate oxygen consumption (Childress 1975); dominant species of demersal fishes, such as thornyheads, have several biochemical adaptations which allow them to thrive on the continental slope (reviewed in Wakefield 1990). All of these physical factors may contribute to the overall structure of fish communities within the study region.

3.3.3.2 Pelagic Species

This section describes pelagic species of fishes collected primarily using midwater and plankton trawls by NMFS in the study region. Because surveys by SAIC (1992b) and Cailliet *et al.* (1992) targeted demersal fish species, most of the pelagic fishes collected during these surveys represented incidental species. However, the families of pelagic fish species collected by SAIC (1992b) and Bence *et al.* (1992) are similar to other studies in comparable marine zones (Moyle and Cech 1988). Bence *et al.* (1992) is the most comprehensive data available on pelagic fish species in the study region. Results from Bence *et al.* (1992) are from evaluated CalCOFI ichthyoplankton surveys (mainly the upper 210 m of the water column), NMFS ichthyoplankton surveys (maximum 200 m wire out) and NMFS midwater trawls for juvenile rockfishes (depths to 30 m).

The surface waters of the ocean to depths of approximately 200 m (epipelagic zone) represent an enormous, although relatively featureless, habitat for fishes (Moyle and Cech 1988). Epipelagic zone waters are typically well lighted, well mixed, and capable of supporting actively photosynthesizing algae. At depths between 200 and approximately 1,000 m (mesopelagic zone), light decreases rapidly as does temperature and dissolved oxygen concentrations, while pressure increases. At depths greater than 1,000 m (bathypelagic zone), conditions are characterized by complete darkness, low temperature, low oxygen levels, and great pressure. Each of these zones is distinguished by characteristic fish assemblages.

Epipelagic fishes can be distinguished based on two ecological types. Oceanic forms are those that spend all or part of their life in the open ocean away from the continental shelf, while neritic forms spend all or part of their life in water above the continental shelf (Moyle and Cech 1988). Typical epipelagic species include fast-moving swimmers such as tunas, mackerels, and salmon, as well as schooling baitfish such as herring, anchovy, and juvenile rockfishes. To date, information exists for epipelagic fishes over the continental shelf; however, little information exists for epipelagic fishes collected in Study Areas 3, 4, or 5. Epipelagic species collected by SAIC (1992b) included the Pacific herring, Northern anchovy, medusafish, Pacific sardine, Pacific mackerel, Pacific saury, Pacific argentines, and juvenile rockfishes, while Bence *et al.* (1992) collected approximately 140 species in midwater trawls including juvenile rockfishes, Pacific herring and Northern anchovy. Although these studies did not target epipelagic fishes, all of these species were collected in Study Area 2 and most are commercially important. Juvenile rockfishes represent an important part of both commercial and recreational fisheries along the entire Pacific coast (Bence *et al.* 1992). Juvenile rockfishes, such as the shortbelly rockfish (*Sebastes jordani*) have been shown to be an important prey item for many seabirds (Ainley and Boekelheide 1990), and for fishes such as chinook salmon, lingcod, and other rockfish species (Chess *et al.* 1988). Some of the pelagic species collected by SAIC (1992), Cailliet *et al.* 1992, and Bence *et al.* (1992) are shown by depth zone in Figure 3.3.3-1.

Mesopelagic fishes comprise the majority of incidental fishes collected by SAIC (1992b) and Cailliet *et al.* (1992) in the study region. Most of these species undergo vertical migrations, often moving into the epipelagic zone at night to prey on plankton and other fishes (Moyle and Cech 1988). Typical mesopelagic species collected in Study Areas 3 and 4 at depths between 100 to 1,000 m by SAIC (1992b) and Bence *et al.* (1992) included deep-sea smelts (Bathylagidae), lanternfishes (Myctophidae), and viperfishes (Chauliodontidae; Figure 3.3.3-1). In Study Area 5, Cailliet *et al.* (1992) also collected six species of mesopelagic fishes, most of which were from the same families Bathylagidae, Myctophidae, Chauliodontidae, and Sternoptychidae.

Bathypelagic species, in contrast to mesopelagic fishes, are largely adapted for a sedentary existence in a habitat with low levels of food and no light (Moyle and Cech 1988). SAIC (1992b) collected bathypelagic fishes such as blackdragons (Idiacanthidae), dragonfish (Melanostomiidae), and tubeshoulders (Searsiidae) primarily in the deeper parts of Study Areas 3 and 4 at depths greater than 1,000 m, while bathypelagic fishes collected by Cailliet *et al.* (1992) in Study Area 5 included lanternfishes (Myctophidae), deep-sea smelts (Bathylagidae), hatchetfishes (Sternoptychidae), and viperfishes (Chauliodontidae). Most of the species found to occupy the bathypelagic zone also can be collected in the mesopelagic zone during vertical migrations. A typical bathypelagic fish assemblage is shown in Figure 3.3.3-1. Bathypelagic fishes collected by Bence *et al.* (1992) included deep-sea smelts (Bathylagidae) and lanternfishes (Myctophidae).

3.3.3.3 Commercially and Recreationally Important Species

This section describes the commercially and recreationally important species of fishes in the study region including those collected by trawls from EPA (SAIC 1992b) and Navy studies (Cailliet *et al.* 1992), as well as information summarized in Bence *et al.* (1992), unpublished California Department of Fish and Game (CDFG) Catch Block Data as provided by the Minerals Management Service (MMS) and Battelle (1989). Although some information is presented from recreational fisheries within the study region, the majority of fish species discussed in this section represent commercial landings.

Several of the abundant species collected within the study areas are of commercial importance. In particular, SAIC (1992b) collected various species of flatfishes (Dover sole, rex sole, sanddabs, English sole, and Pacific halibut), rockfishes (splitnose, shortbelly, chilipepper, boccacio, and thornyheads) and sablefish, that are currently targeted by commercial fisheries. The most common fishes taken by recreational fishermen within the study region include salmon, tunas, mackerel, and rockfishes (CDFG Recreational Fisheries Database 1992). A summary of common commercially and recreationally important species within the LTMS study areas is presented in Table 3.3.3-3. Additional information concerning commercial and recreational fisheries is presented in Section 3.4.1.

Flatfishes

In Study Area 2, commercially important species of flatfishes collected by SAIC (1992b), Bence *et al.* (1992), and KLI (1991) collected Dover sole, rex sole, Pacific sanddabs, English sole, petrale sole, and Pacific halibut (Table 3.3.3-3). However, it is notable that Pacific halibut were collected only rarely and primarily in Study Area 2. Bence *et al.* (1992) indicate that slender sole were most abundant between 270–360 m depth, suggesting they might be abundant in the shallowest portions of Study Area 3. In the shallow parts of Study Areas 3 and 4, two species of flatfishes (Dover sole and deep-sea sole) were collected by SAIC (1992b). Of these two species, only Dover sole represents a commercially important flatfish species. No flatfishes were collected by SAIC (1992b) in the deeper part of Study Areas 3 and 4. Dover sole collected commercially at depths greater than 800 m have high water content which makes them less valuable to commercial fishermen under current conditions (Bence *et al.* 1992).

Rockfishes

Rockfishes such as splitnose rockfish, shortbelly rockfish, boccacio, chilipepper, stripetail rockfish, and thornyheads are commercially or recreationally important. Rockfishes (not including thornyheads), found primarily in Study Area 2 by SAIC (1992b) and Bence *et al.* (1992), were one of the most abundant and species-rich groups collected on the continental shelf. Juvenile rockfishes had relatively high seasonal abundances inshore (Study Area 2) and in the deep parts of Study Area 5, while lower seasonal abundances were found in the deep parts of Study Areas 3 and 4 (Bence *et al.* 1992). MMS/CDFG Commercial Fisheries Database (1992) indicated rockfishes (not including thornyheads) were the predominant species collected

Table 3.3.3-3. Summary of Common Commercially and Recreationally Important Fishes Within the LTMS Study Areas. Information is Based on SAIC (1992b), Cailliet et al. (1992), Bence *et al.* (1992), MMS/CDFG Commercial Fisheries Database (1992), CDFG Recreational Fisheries Database (1992), and KLI (1991). Adults are indicated by (A), Juveniles by (J), and Not Specified as A or J by (NS).

Common Name	2 (72-85 m)	3 "Shallow" (1,008-1,143 m)	3 "Deep" (1,656 m)	4 (1,278-1,764 m)	5 (2,300-3,065 m)
Northern Anchovy	A/J	J	J	J	
Pacific Herring	A				A
Pacific Sardine	A				
Pacific Hake	A/J	A/J	A/J	A/J	A/J
Shortbelly Rockfish	A/J	J	J	J	J
Chilipepper Rockfish	A/J	J	J	J	
Boccacio	A/J	J	J	J	J
Widow Rockfish	A				
Yellowtail Rockfish	A	J	J	J	J
Thornyheads		A/J	A/J	A/J	
Sablefish	A/J	A		A	
Lingcod	A/J				
Pacific Sanddab	A/J				
Rex Sole	A/J	J	J	J	J

Table 3.3.3-3. Continued.

Common Name	2 (72-85 m)	3 "Shallow" (1,008-1,143 m)	3 "Deep" (1,656 m)	4 (1,278-1,764 m)	5 (2,300-3,065 m)
California Halibut	A				
English Sole	A				
Dover Sole	A/J	A		A	J
Petrale Sole	A				
Rattails (potential fishery)		A	A	A	A
Salmon	NS				
Tunas	NS				
Sharks/Skates/Rays	A				
Hagfish		A	A	A	
White Croaker	A				

commercially in Study Area 2, while rockfishes (including thornyheads) were targeted in the shallow parts of Study Areas 3 and 4. Of the 16 species of rockfishes collected by SAIC (1992b), only two species, the thornyheads *Sebastolobus altivelis* and *S. alascanus*, were abundant on the middle and lower continental slope (Study Areas 3 and 4). However, thornyheads accounted for approximately 25% to 50% or more of the total abundance or biomass of the upper to middle slope fishes collected by SAIC (1992b) and other studies (Wakefield 1990; Butler *et al.* 1989; Pearcy *et al.* 1982; Alton 1972). Thornyheads collected by Bence *et al.* (1992) were most abundant at depths between 700 and 900 m, corresponding primarily to the shallow parts of Study Area 3 (Table 3.3.3-3).

Sablefish

Sablefish commonly ranked third in biomass of the trawl-collected fishes, both along the California coast (SAIC 1992b; Wakefield 1990; Butler *et al.* 1989) and offshore Oregon and Washington (Pearcy *et al.* 1982; Alton 1972). Sablefish adults and juveniles occur on the continental shelf (Study Area 2 and adjacent sites; Table 3.3.3-3), but adults tend to be highest in abundance and biomass on the upper to middle slope (at depths from approximately 200 to 1,200 m; shallow parts of Study Areas 3 and 4), particularly off the Oregon coast where they accounted for approximately 75% of the total fish biomass at depths between approximately 500 to 1,000 m (Alton 1972). Their abundance is somewhat lower (10% to 25% of the total fish biomass) off California at middle slope depths (SAIC 1992b; Wakefield 1990; Butler *et al.* 1989). SAIC (1992b) found that sablefish densities were highest at depths between 200 to 500 m. Sablefish are known to inhabit depths of up to 1,800 m (Miller and Lea 1972) and can reach lengths to one meter. Juvenile sablefish can often be found at or near the surface, while larger adults occupy deeper depths (Cailliet *et al.* 1988).

Rattails

Rattails, such as the Pacific grenadier and the giant grenadier (*Albatrossia pectoralis*), dominated the deepest sampling depths (at depths greater than approximately 1,200 m) within Study Areas 3 and 4 and Study Area 5 (SAIC 1992b; Cailliet *et al.* 1992; Bence *et al.* 1992; Eschmeyer and Herald 1983). Rattails are commercially important in many parts of the world; however, these fishes have been lightly exploited along the Pacific Coast due to the difficulties of deep-water trawling in the region. (Matsui *et al.* 1990). For example, some rattails are landed in California which are caught as part of the deep-water Dover sole fishery (Oliphant *et al.* 1990). Rattails are currently fished in Alaska as an alternative fishery to the declining pollock fishery (Jacobson 1991; Matsui *et al.* 1990).

Other Species

Other fishes with commercial value (Table 3.3.3-3), including hagfish, are utilized primarily for their skin. In Study Area 3, SAIC (1992b) collected only a few black hagfish (*Eptatretus deanii*). Low abundances of hagfish collected by SAIC (1992b) is probably due to gear selectivity and avoidance of nets due to their burrowing. Additional information concerning commercially and recreationally targeted species such as tunas, mackerels, and salmon are discussed in Section 3.4.1.

3.3.4 Marine Birds

This section presents information on marine birds of the study region. Information on the distribution, abundance, and ecology of key representative species is presented in Section 3.3.4.1. A summary of the birds' usage of the LTMS study areas is presented in Section 3.3.4.2.

Marine birds are defined as those species that obtain most of their food from the ocean and are found over water for more than half of the year (Briggs *et al.* 1987). The Gulf of the Farallones is the most important marine bird breeding area on the West Coast of the United States (Sowls *et al.* 1980). Many of the 74 species of birds recorded by Briggs *et al.* (1987) off the California coast occur in the Gulf of the Farallones during their migration and/or breeding seasons. The Farallon Islands and vicinity are used throughout the year by some 350,000 marine birds of 122 species (Ainley and Boekelheide 1990). The islands support the world's largest breeding colonies of ashy storm-petrels (*Oceanodroma homochroa*, 85% of the world population), Brandt's cormorants (*Phalacrocorax pennicilatus*, 10% of the world population), and western gulls (*Larus occidentalis*, 50% of the world population) (DeSante and Ainley 1980; Ainley and Boekelheide 1990). Additionally, an estimated one million sooty shearwaters (*Puffinus griseus*) use the Gulf of the Farallones, especially during their breeding season from March to July (DeSante and Ainley 1980; Ainley *et al.* 1987).

Studies of marine birds near the Farallon Islands have been conducted for over a century. More recent studies emphasize the biology of twelve species that nest on the Farallon Islands (Ainley and Boekelheide 1990) and the distributions of birds that forage in the Gulf of the Farallones (Briggs *et al.* 1987). In June of 1985 through 1991, the Point Reyes Bird Observatory (PRBO) conducted surveys that covered the general study region, including LTMS Study Areas 2 through 5 (Ainley and Allen 1992). Data from these surveys provide a long-term record of the distribution of marine birds during the breeding season, although no comparable studies were conducted during other seasons. Five additional surveys were conducted by EPA (Jones and Szczepaniak 1992) during all seasons over a one year period, using methods similar to those used by PRBO. However, this study was limited in duration. Neither study provided uniform coverage of the four LTMS study areas. However, collectively they provide sufficient data to characterize the marine bird communities of the region.

Ainley and Allen (1992) list a total of 63 marine bird species which occur regularly in the study region (i.e., are present each year, either year-round or seasonally) or have special status (i.e., species that are threatened, endangered, or of special concern) (Table 3.3.4-1). Of these 63 species, 14 are breeding species, 37 are seasonal visitors, and 12 are passage migrants.

Table 3.3.4-1. Species and General Characteristics of Marine Birds Observed Off California in the Vicinity of the Gulf of the Farallones.

Those Species Having Legal Status (Special Concern*, Threatened**, or Endangered***) Are Shown in Bold.
Species are listed according to their occurrence within the study region, such as breeding, seasonal visitor, or passage migrant, and alphabetically by common name within these groups. Relative abundances refer to the following: Abundant = over 25,000 individuals, Common = between 1,000–25,000 individuals, Uncommon = between 100–1,000 individuals, and Rare = up to 99 individuals. Habitat areas refer to occurrences over the following water depths: shelf = < 200 m, slope = 200–1999 m, pelagic = > 1999 m.
Primary source: Ainley and Allen (1992)

Scientific Name	Common Name	Occurrence Within Study Region	Seasonal Status	Relative Abundance	Predominant Habitat
Pandion haliaetus*	**American Osprey**	**Breeding**	**Year-round**	**Uncommon**	**Shelf**
Oceanodroma homochroa	Ashy Storm-petrel	Breeding	Year-round	Common	Pelagic
Phalacrocorax penniciliatus	Brandt's Cormorant	Breeding	Year-round	Abundant	Shelf
Ptychoramphus aleuticus	Cassin's Auklet	Breeding	Year-round	Abundant	Slope
Uria aalge	Common Murre	Breeding	Year-round	Abundant	Shelf, slope
Phalacrocorax auritus	Double-crested Cormorant	Breeding	Summer	Uncommon	Shelf
Oceanodroma leucorhoa	Leach's Storm-petrel	Breeding	Summer	Uncommon	Pelagic
Brachyramphus marmoratus*	**Marbled Murrelet**	**Breeding**	**Year-round**	**Rare**	**Shelf**
Phalacrocorax pelagicus	Pelagic Cormorant	Breeding	Year-round	Common	Shelf
Falco peregrinus***	**Peregrine Falcon**	**Breeding**	**Year-round**	**Rare**	**Shelf, slope**
Cepphus columba	Pigeon Guillemot	Breeding	Summer	Common	Shelf
Cerorhinca monocerata	Rhinoceros Auklet	Breeding	Year-round	Abundant	Shelf, slope, pelagic

Table 3.3.4-1. Continued.

Scientific Name	Common Name	Occurrence Within Study Region	Seasonal Status	Relative Abundance	Predominant Habitat
Fratercula cirrhata	Tufted Puffin	Breeding	Year-round	Uncommon	Slope
Larus occidentalis	Western Gull	Breeding	Year-round	Abundant	Shelf, slope
Brachyramphus antiguus	Ancient Murrelet	Seasonal Visitor	Winter	Uncommon	Shelf
Mellanita nigra	Black Scoter	Seasonal Visitor	Winter	Uncommon	Shelf
Oceanodroma melania	Black Storm-petrel	Seasonal Visitor	Winter	Irregular (numerous at sporadic intervals)	Pelagic
Diomedea nigripes	Black-footed Albatross	Seasonal Visitor	Summer	Common	Slope, pelagic
Rissa tridactyla	Black-legged Kittiwake	Seasonal Visitor	Winter	Common	Slope, pelagic
Puffinus opisthomelas	Black-vented Shearwater	Seasonal Visitor	Winter	Irregular (numerous at sporadic intervals)	Shelf, slope
Pelecanus occidentalis*	**Brown Pelican**	**Seasonal Visitor**	**Winter**	**Common**	**Shelf**
Larus californicus	California Gull	Seasonal Visitor	Winter	Abundant	Shelf, slope
Sterna caspia	Caspian Tern	Seasonal Visitor	Winter	Uncommon	Shelf
Gavia inmer	Common Loon	Seasonal Visitor	Winter	Uncommon	Shelf
Pterodroma cooki	Cook's Petrel	Seasonal Visitor	Summer	Uncommon	Pelagic
Podiceps aechmophorus	Eared Grebe	Seasonal Visitor	Winter	Uncommon	Shelf

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Table 3.3.4-1. Continued.

Scientific Name	Common Name	Occurrence Within Study Region	Seasonal Status	Relative Abundance	Predominant Habitat
Sterna elegans	Elegant Tern	Seasonal Visitor	Winter	Common	Shelf
Oceanodroma furcata	Fork-tailed Storm-petrel	Seasonal Visitor	Winter	Irregular (numerous at sporadic intervals)	Pelagic
Sterna forsteri	Forster's Tern	Seasonal Visitor	Year-round	Common	Shelf
Larus glaucescens	Glaucous-winged Gull	Seasonal Visitor	Winter	Common	Shelf, slope
Larus heermanni	Heermann's Gull	Seasonal Visitor	Winter	Common	Shelf
L. argentatus	Herring Gull	Seasonal Visitor	Winter	Common	Slope, pelagic
Fratercula corniculata	Horned Puffin	Seasonal Visitor	Summer	Uncommon	Slope, pelagic
Podiceps nigricollis	Horned Grebe	Seasonal Visitor	Winter	Uncommon	Shelf
Diomedea immutabilis	Laysan Albatross	Seasonal Visitor	Winter	Uncommon	Slope, pelagic
Larus canus	Mew Gull	Seasonal Visitor	Winter	Uncommon	Shelf
Pterodroma ultima	Murphy's Petrel	Seasonal Visitor	Summer	Uncommon	Pelagic
Fulmarus glacialis	Northern Fulmar	Seasonal Visitor	Winter	Abundant	Slope, pelagic
Stercorarius parasiticus	Parasitic Jaeger	Seasonal Visitor	Winter	Uncommon	Shelf, slope, pelagic
Puffinus creatopus	Pink-footed Shearwater	Seasonal Visitor	Summer	Common	Shelf, slope
Stercorarius pomarinus	Pomarine Jaeger	Seasonal Visitor	Winter	Uncommon	Shelf, slope, pelagic

Table 3.3.4-1. Continued.

Scientific Name	Common Name	Occurrence Within Study Region	Seasonal Status	Relative Abundance	Predominant Habitat
Mergus serrator	Red-throated Merganser	Seasonal Visitor	Winter	Uncommon	Shelf
Gavia stellata	Red-throated Loon	Seasonal Visitor	Winter	Uncommon	Shelf
Larus delawarensis	Ring-billed Gull	Seasonal Visitor	Winter	Common	Shelf
Diomedea albatrus*	**Short-tailed Albatross**	**Seasonal Visitor**	**Winter**	**Rare**	**Shelf, slope**
Puffinus tenuirostris	Short-tailed Shearwater	Seasonal Visitor	Winter	Uncommon	Shelf, slope
Puffinus griseus	Sooty Shearwater	Seasonal Visitor	Summer	Abundant	Shelf, slope
Catharacta maccormicki	South Polar Skua	Seasonal Visitor	Summer	Rare	Shelf, slope, pelagic
Larus thayeri	Thayer's Gull	Seasonal Visitor	Winter	Uncommon	Slope, pelagic
Aechmophorus occidentalis	Western Grebe	Seasonal Visitor	Winter	Abundant	Shelf
*Endomychura hypoleuca**	Xantus' Murrelet	Seasonal Visitor	Winter	Rare	Slope, pelagic
Gavia pacifica	Arctic (Pacific) Loon	Passage Migrant	Winter	Abundant	Shelf, slope
Sterna paradisaea	Arctic Tern	Passage Migrant	Winter	Common	Slope, pelagic
Branta bernicla	Black Brant	Passage Migrant	Winter	Abundant	Shelf
Larus philadelphia	Bonaparte's Gull	Passage Migrant	Winter	Abundant	Shelf
Puffinus bulleri	Buller's Shearwater	Passage Migrant	Winter	Common	Slope, pelagic
Sterna hirundo	Common Tern	Passage Migrant	Winter	Uncommon	Shelf, slope
Stercorarius longicaudus	Long-tailed Jaeger	Passage Migrant	Winter	Rare	Slope, pelagic

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Table 3.3.4-1. Continued.

Scientific Name	Common Name	Occurrence Within Study Region	Seasonal Status	Relative Abundance	Predominant Habitat
Phalaropus fulicarius	Red Phalarope	Passage Migrant	Winter	Abundant	Shelf, slope, pelagic
Phalaropus lobatus	Red-necked Phalarope	Passage Migrant	Winter	Abundant	Shelf
Larus sabini	Sabine's Gull	Passage Migrant	Winter	Uncommon	Pelagic
Mellanita perspicilata	Surf Scoter	Passage Migrant	Winter	Abundant	Shelf
M. fusca	White-winged Scoter	Passage Migrant	Winter	Abundant	Shelf

The distribution, abundance, and ecology of ten key species is described in this section as representative of the range of natural history patterns that occur within the four study areas and which potentially could be affected by dredged material disposal activities. Special status species are discussed in more detail in Section 3.3.6. Because of the importance of the Gulf of the Farallones to many marine bird species, one or more of the following criteria were used to select these ten key species:

- Species that breed in the area or which occur year-round or are common to abundant within the study region;
- Species having a narrow geographical range with population centers located in the Gulf of the Farallones; and
- Species which forage in shelf, slope, or pelagic areas similar to those of the LTMS study areas.

Based on these criteria, the following ten species were selected: ashy storm-petrel, Brandt's cormorant, western gull, common murre (*Uria aalge*), pigeon guillemot (*Cepphus columba*), sooty shearwater, Cassin's auklet (*Ptychoramphus aleuticus*), rhinoceros auklet (*Cerorhinca monocerata*), pink-footed shearwater (*Puffinus creatopus*), and tufted puffin (*Fratercula cirrhata*) (Table 3.3.4-2). With the exception of the sooty and pink-footed shearwaters, which occur in high abundances within the LTMS study areas during the summer (Briggs *et al.* 1987; Jones and Szczepaniak 1992), all of these species breed within the Gulf of the Farallones. Other marine bird species recorded in the Gulf of the Farallones, including seasonal visitors and passage migrants, are listed with their estimated densities in Jones and Szczepaniak (1992) and Ainley and Allen (1992).

Density estimates of all marine bird species surveyed during June are presented for the years 1986, 1987, and 1991 (Figures 3.3.4-1 through 3.3.4-3) (Ainley and Allen 1992). These years represent a broad range in different foraging conditions, based on pelagic juvenile rockfish abundance, from poor (1986) to good (1987) to intermediate (1991) rockfish years. Ainley and

Table 3.3.4-2. Relative Densities of the Ten Key Marine Bird Species Within the Four LTMS Study Areas.

Data from A (Ainley and Bockelheide 1990); B (Ainley and Allen 1992); and C (Jones and Szczepaniak 1992).

	Study Area 2			Study Area 3			Study Area 4			Study Area 5		
	A	B	C	A	B	C	A	B	C	A	B	C
Ashy storm-petrel	N	N	N	L to H	L	L	*	L	N	M	L	N
Brandt's cormorant	N	L	N	N	N	N	*	N	N	N	N	N
Western gull	L	M	L to M	L	L	L	*	N	L	L	L	L to M
Common murre	L to M	L	L	L to M	L	N	*	N	N	M to H	M	N
Pigeon guillemot	N	N	N	N	L	N	*	N	N	N	N	N
Sooty shearwater	L to H	L to H	L	L to H	L	L to H	*	L	L	M to H	M	L
Cassin's auklet	L	M	L	L to H	L	L	*	L	L	L to H	M	L
Rhinocerus auklet	H	M	M	H	L	L	*	L	L	L to M	L to M	L
Pink-footed shearwater	*	L to H	N	*	L	M	*	N	L	*	N	L
Tufted puffin	N	L	N	N	N	N	*	N	N	L	N	N

N = No birds observed
L = Low density
M = Moderate density
H = High density
* = No data collected

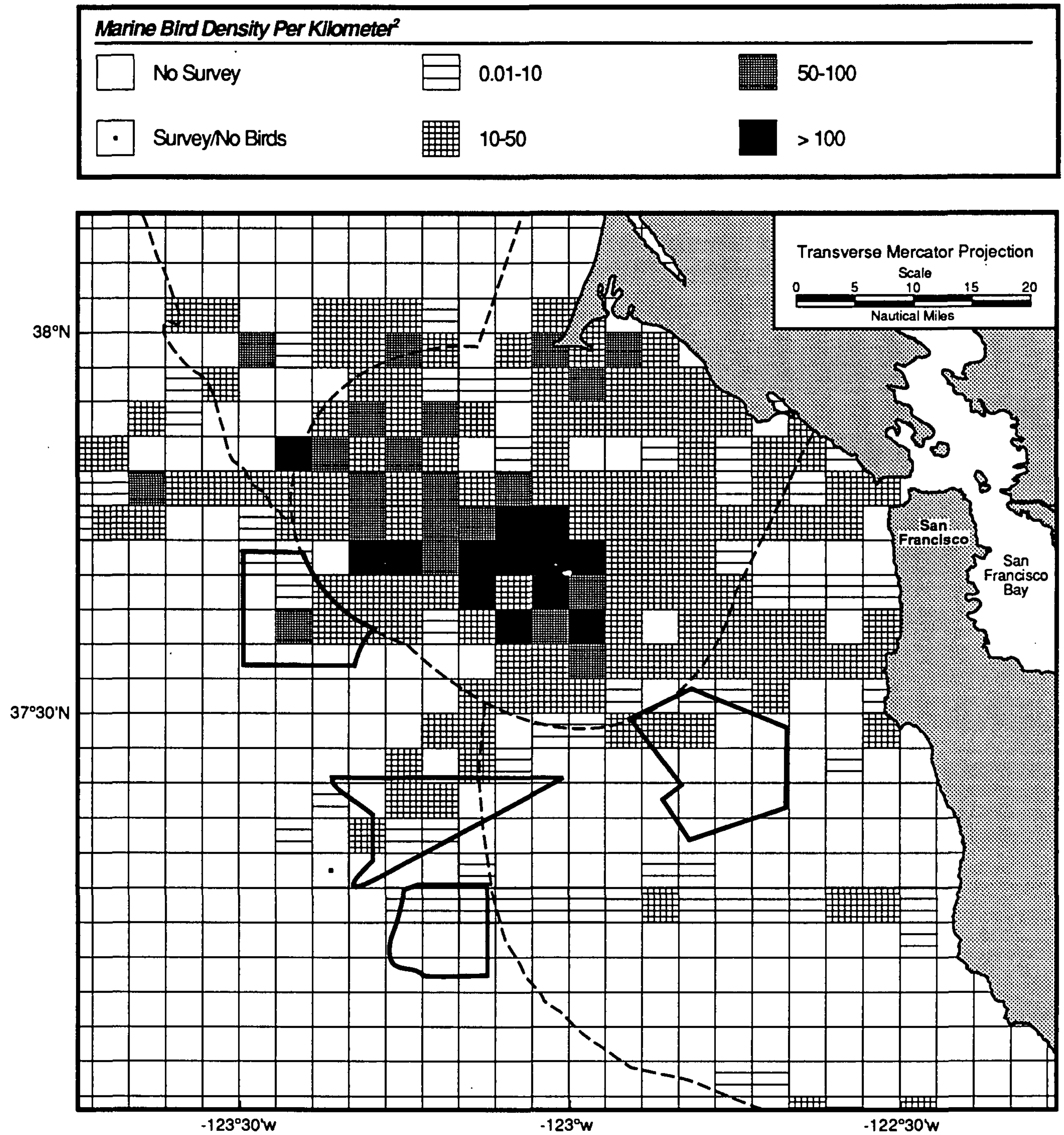

Figure 3.3.4-1. **Density Estimates for all Marine Bird Species During June 1986, a Poor Rockfish Year.**
Source: Ainley and Allen (1992)

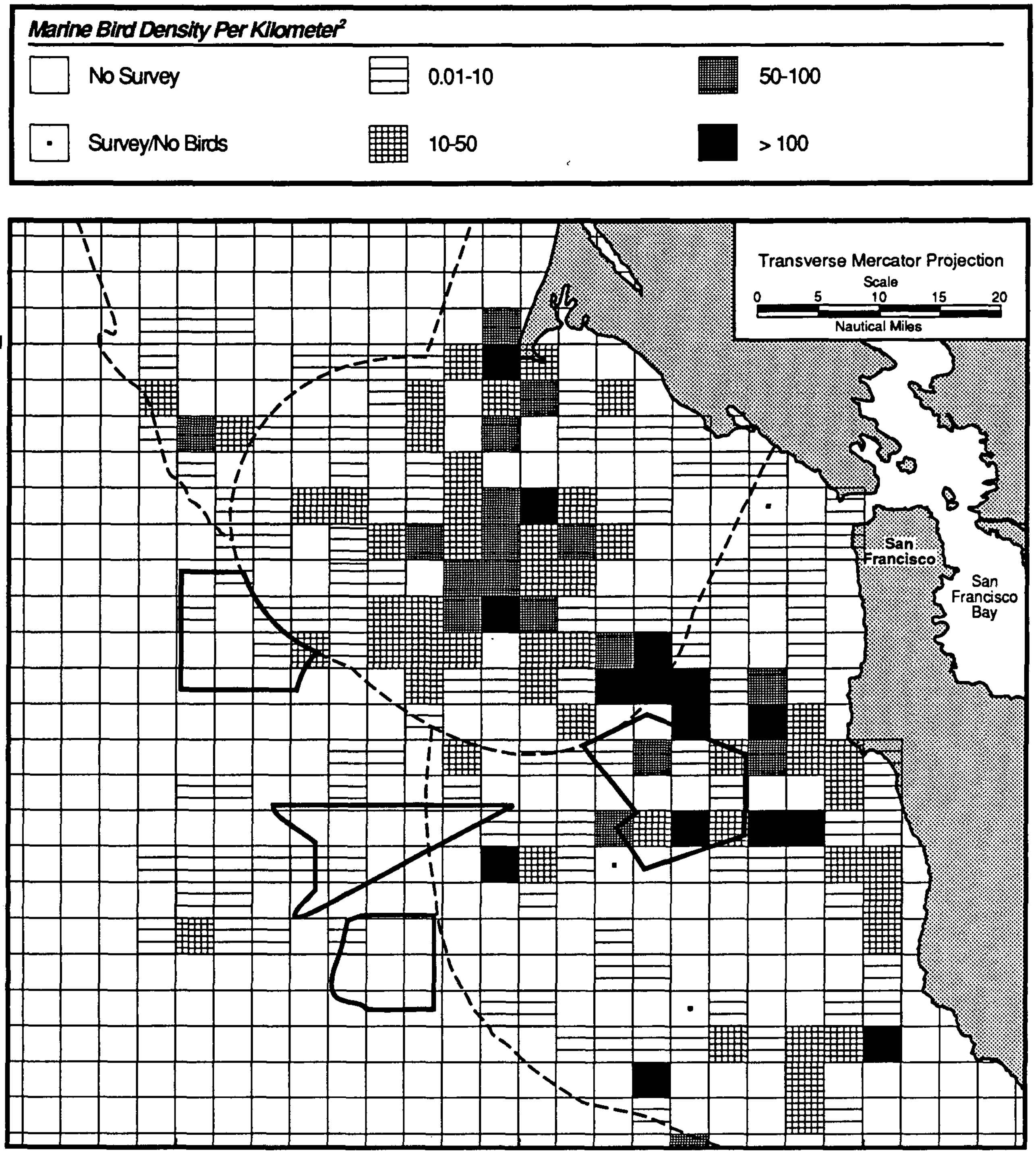

Figure 3.3.4-2. **Density Estimates for all Marine Bird Species During June 1987, a Good Rockfish Year.**
Source: Ainley and Allen 1992.

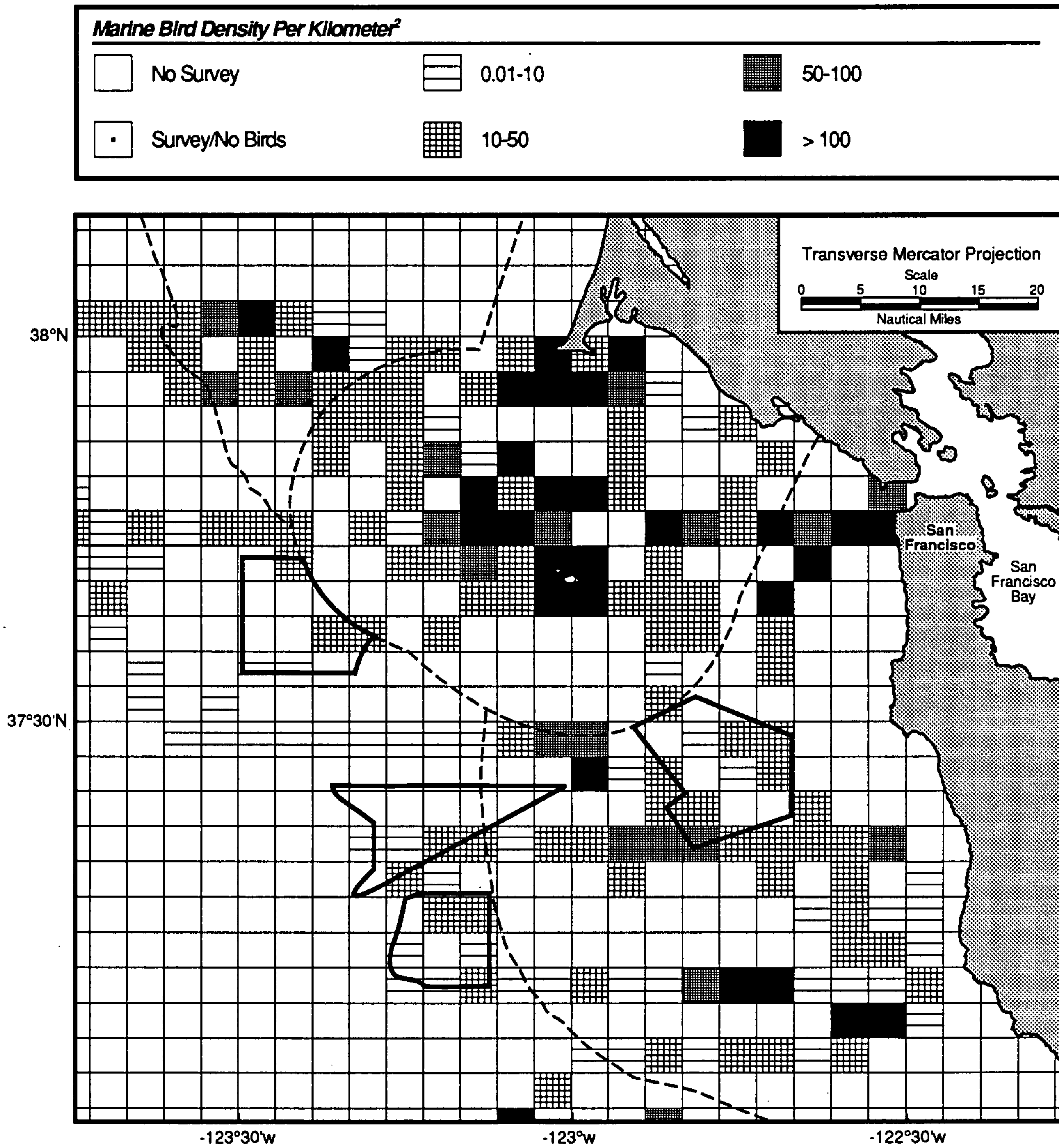

Figure 3.3.4-3. Density Estimates for all Marine Bird Species During June 1991, an Intermediate Rockfish Year.
Source: Ainley and Allen 1992.

Boekelheide (1990) concluded that the feeding range of pigeon guillemots, Cassin's and rhinocerus auklets, tufted puffins, sooty shearwaters, and many other resident species primarily is a response to food availability as opposed to nesting activities. Further, at least in the summertime, the natural history of breeding marine birds of the Gulf of the Farallones, including visitors such as the sooty shearwater, is based on a "juvenile rockfish economy." When juvenile rockfish are available, foraging habits, behaviors, and diets of many species overlap extensively. The dominant juvenile rockfishes used as prey are yellowtail rockfish (*Sebastes flavidus*) and shortbelly rockfish (*S. jordani*). When rockfish are unavailable or in lower abundance (e.g., during warm-water years), they are replaced in the diet of many species by anchovies and a variety of other prey including cephalopods and zooplankton. Additional prey species include hake, smelt, and squid, all of which are considered either midwater-schooling species or species that avoid the surface. The distribution, abundance, and size classes of many fish species, including shortbelly rockfish, within the LTMS study areas are presented in Section 3.3.3. Figure 3.3.4-1 indicates that during a poor rockfish year (e.g., 1986) marine bird densities are spread relatively evenly throughout the Gulf of the Farallones. During a good rockfish year (e.g., 1987) densities are concentrated around breeding sites, such as the Farallon Islands (Figure 3.3.4-2). Marine bird densities for an intermediate rockfish year (1991) are more scattered over the region, with highest densities occurring within the GOFNMS (Figure 3.3.4-3).

Estimated densities of the ten marine bird species were relatively greatest in LTMS Study Areas 2 and 5 (Ainley and Boekelheide 1990; Ainley and Allen 1992; Jones and Szczepaniak 1992). Tufted puffins were observed too rarely to derive density estimates for the three representative years; the only sighting of this species within a study area during the 1985–1991 surveys was recorded in 1985 within Study Area 2. The following sections provide detailed discussion of distributions, densities, and ecology of the ten representative species.

3.3.4.1 Distribution, Abundance, and Ecology of Representative Breeding Species

Ashy Storm-Petrel

Ashy storm-petrels are year-round residents that breed in the Gulf of the Farallones (Table 3.3.4-1). Eighty-five percent of the world population of ashy-storm petrels breed and reside there (Ainley and Allen 1992). They typically feed over pelagic waters at least 25 km from the Farallon Islands, but they also may feed over waters near the shelf break (~ 200 m) where upwelling events are more frequent (Ainley and Boekelheide 1990). However, they often occur over mid-slope waters (Jones and Szczepaniak 1992), and are presumed to eat fish and crustaceans (Center for Marine Studies 1985). A comparison of density estimates for this species within the Gulf of the Farallones indicates that of the four LTMS study areas, Study Areas 3 and 5 contain greatest abundances of ashy storm-petrels (Table 3.3.4-2).

Brandt's Cormorant

The Brandt's cormorant population in the Gulf of the Farallones represents approximately ten percent of the world population of this species (Ainley and Allen 1992). This species also is a breeding resident of the Gulf of the Farallones. Brandt's cormorants feed in San Francisco Bay in early spring, up to 80 km from nesting sites on the Farallon Islands. However, they may shift later in the season to feed near the Islands or in coastal waters (Ainley and Boekelheide 1990). Estimated densities of this species within the LTMS study areas are low (Table 3.3.4-2), probably due to their preferred feeding habitat in shallow waters over flat sand or mud. Populations of greater than 100 individuals/km^2 can be found in the immediate vicinity of the Farallon Islands (Ainley and Allen 1992). Brandt's cormorants often occur over shelf and upper slope waters where water depths range from a few hundred to 1,000 m (Jones and Szczepaniak 1992). Nearshore feeding areas range from 10–60 m in depth over flat sand or mud substrate to offshore rocky bottom sites up to 120 m. Their prey items include demersal fish species such as rockfish (*Sebastes flavidus* and *S. jordani*), flatfishes, tomcod (*Microgradus proximus*), midshipman (*Porichthys notatus*), and cusk eels (*Chilara taylori*) (Ainley and Boekelheide 1990).

Western Gull

Western gull populations are widespread throughout the study region and utilize the Gulf of the Farallones as an important breeding area (Ainley and Boekelheide 1990). Approximately 50 percent of the world population of this species nests in the Gulf of the Farallones (Ainley and Boekelheide 1990). Historic studies reported low densities in the vicinity of Study Areas 2, 3, and 5; no observations were made in Study Area 4 (Ainley and Boekelheide 1990). Recent censuses of all of the study areas recorded the highest densities in Study Areas 2 and 5 (Ainley and Allen 1992; Jones and Szczepaniak 1992). This probably is due to the relative proximity of these two study areas to nesting sites on the Farallon Islands in comparison to Study Areas 3 and 4. Jones and Szczepaniak (1992) observed the highest species densities near Southeast Farallon Island; low to moderate densities were observed in or near Study Areas 2, 3, 4, and 5. Western gulls have a wide diet which includes fish, predominantly juvenile rockfish (Ainley *et al.* 1987), but they also consume marine invertebrates; to a lesser extent, marine bird eggs and young, seal placenta, and other organic materials are scavenged by the gull.

Common Murre

The common murre, a resident breeding species, occurs primarily over the continental shelf (Jones and Szczepaniak 1992; Ainley and Allen 1992). Breeding populations show considerable fluctuations, ranging from approximately 400,000 individuals in 1850 to a few hundred individuals in the early 1900s. The 1986 breeding population consisted of approximately 39,000 birds (Ainley and Boekelheide 1990). Observations of this species during the breeding seasons of 1986, 1987, and 1991, consistently indicated low densities (0.01–10 individuals/km^2) within Study Area 2 (Ainley and Allen 1992). Common murres also were observed at low densities (0.01-10 individuals/km^2) within Study Area 3 in 1986 (a poor rockfish year) and at moderate densities (10–50 individuals/km^2) during the same year within Study Area 5. This species was not observed within Study Area 4 during the three survey years. Similar densities (low to moderate in the region of Study Areas 2 and 3 and moderate to high in Study Area 5) were observed by Ainley and Boekelheide (1990). Seasonal surveys (Jones and Szczepaniak 1992) indicated that low densities of this species were observed over Study Area 2; no common murres were observed in any of the other LTMS study areas. Common murres exhibit great variation in feeding habitats. In early spring, they occur over the outer continental shelf. In the spring and summer of cool-water (i.e., good rockfish years), their feeding range is somewhat constricted to shallower water closer to the Farallon Islands. At that time, murres feed heavily on rockfish, northern anchovy (*Engraulis mordax*), market squid (*Loligo opalescens*), and euphausiids. In warmer years, they occur farther from the Farallon Islands, especially over the shelf towards the mainland, where they feed heavily on anchovies, and secondarily over slope waters (e.g., Study Area 5). By July, they begin to move toward the coast. However, when juvenile rockfish are abundant, they remain offshore longer (Ainley and Boekelheide 1990).

Pigeon Guillemot

The pigeon guillemot is a common (estimated population of 1,000 to 25,000 individuals) summer-breeding species within the Gulf of the Farallones (Ainley and Allen 1992). The majority of the resident population appears to occur around the Farallon Islands and in areas to the north. This species forages in relatively shallow waters over rocky substrate, and rarely feeds in waters farther than 15 km from the Farallon Islands (Ainley and Boekelheide 1990). Recent surveys conducted by the PRBO during the spring of 1986, 1987, and 1991 indicated that no pigeon guillemots were observed within Study Areas 2, 4, or 5; however, low densities occurred in Study Area 3 in June 1991 (Ainley and Allen 1992). EPA surveys (1992) recorded sightings in February, May, and August of 1991, although no sightings were made within any of the LTMS study areas and actual counts or densities were not reported.

Sooty Shearwater

Sooty shearwaters typically are non-breeding, summer visitors to the study region, and occur throughout the shelf and slope waters of the Gulf of the Farallones (Table 3.3.4-1). An estimated one million sooty shearwaters are present between May and August of cool-water (high productivity) years (KLI 1991). Of the four LTMS study areas, Study Area 2 supported the highest densities of sooty shearwaters, especially during 1987, a good rockfish year (Ainley and Allen 1992). However, in May 1991, high densities of sooty shearwaters were reported in the vicinity of Pioneer Canyon (between Study Areas 3 and 4) (Jones and Szczepaniak 1992). Surveys conducted by Ainley and Boekelheide (1990) recorded low to high densities of sooty shearwaters in Study Areas 2 and 3, and moderate to high densities in the region of Study Area 5. Sooty shearwaters are pursuit divers, preying on anchovies, market squid, euphausiids, and juvenile rockfish.

Cassin's Auklet

Cassin's auklets are year-round, breeding residents of the Gulf of the Farallones, typically foraging over slope waters (Table 3.3.4-1). They are the most abundant marine bird on the Farallon Islands (Sowls *et al.* 1980), and are distributed widely throughout the study region. Cassin's auklets occurred at low densities (0.01–10 individuals/km^2) in Study Area 3 and moderate densities (10–50 individuals/km^2) in Study Areas 2 and 5 (Ainley and Allen 1992). No birds were observed in Study Area 4 during the three survey years, except in 1991, when low densities (0.01–10 individuals/km^2) were recorded (Ainley and Allen 1992). Surveys conducted by EPA (1992) indicated an absence or low densities of 0.01–10 individuals/km^2 within all study areas. Ainley and Boekelheide (1990) reported that Cassin's auklets occurred in low densities near Study Area 2, and from low to high densities in the region of Study Areas 3 and 5. No surveys were conducted in Study Area 4. Cassin's auklets can dive to depths of 35 m for their prey. Ninety percent of their diet is composed of euphausiids (*Thysanoessa* sp. and *Euphausia* sp.) and larval fish.

Rhinoceros Auklet

Rhinoceros auklets also are year-round, breeding residents of the Gulf of the Farallones and are found over shelf, slope, and pelagic waters. The highest overall species densities (10–50 individuals/km^2) occurred within Study Area 2 (Ainley and Allen 1992; Jones and Szczepaniak 1992) although similar densities were recorded for Study Area 5 during 1987 (Ainley and Allen

1992). Rhinoceros auklets occurred at relatively low densities over Study Areas 3 and 4. Ainley and Boekelheide (1990) reported similar results, except for Study Area 3: rhinoceros auklets were observed in relatively high densities in Study Areas 2 and 3, and low to moderate densities in Study Area 5. Rhinoceros auklets are pursuit divers (KLI 1991) that feed primarily on fish (Briggs *et al.* 1987).

Pink-footed Shearwater

Pink-footed shearwaters are non-breeding, summer visitors to the region, occurring over shelf and slope waters (Table 3.3.4-1). Point Reyes Bird Observatory surveys indicated a relatively low occurrence of this species in all of the study areas, except for Study Area 2 where high densities of over 100 individuals/km^2 were recorded in 1987 (Ainley and Allen 1992). Similarly, EPA surveys conducted during August 1990 recorded low densities (0.01–10 individuals/km^2) within LTMS Study Areas 4 and 5. However, no sightings of pink-footed shearwaters were made within Study Area 2 and moderate densities (10–50 individuals/km^2) were observed over Study Area 3 (Jones and Szczepaniak 1992).

Tufted Puffin

Tufted puffins are breeding residents of the Gulf of the Farallones; less than 50 breeding pairs occur on the Farallones (Table 3.3.4-1). Breeding season censuses conducted from 1985 through 1991 indicated that tufted puffins rarely occurred within any of the study areas (Ainley and Allen 1992). Only a single individual was recorded within Study Area 2 (Figure 3.3.4-4); no tufted puffins were observed within any of the other study areas during the seven survey years. These surveys also indicated that the majority of tufted puffins occurred to the north and west of the Farallon Islands, close to the eastern boundary of Study Area 5 (Figure 3.3.4-4). Although Jones and Szczepaniak (1992) recorded sightings of tufted puffins during four of five surveys, counts were determined to be too low for inclusion in species density estimates. Ainley and Boekelheide (1990) recorded low densities of tufted puffins in Study Area 5. Tufted puffins

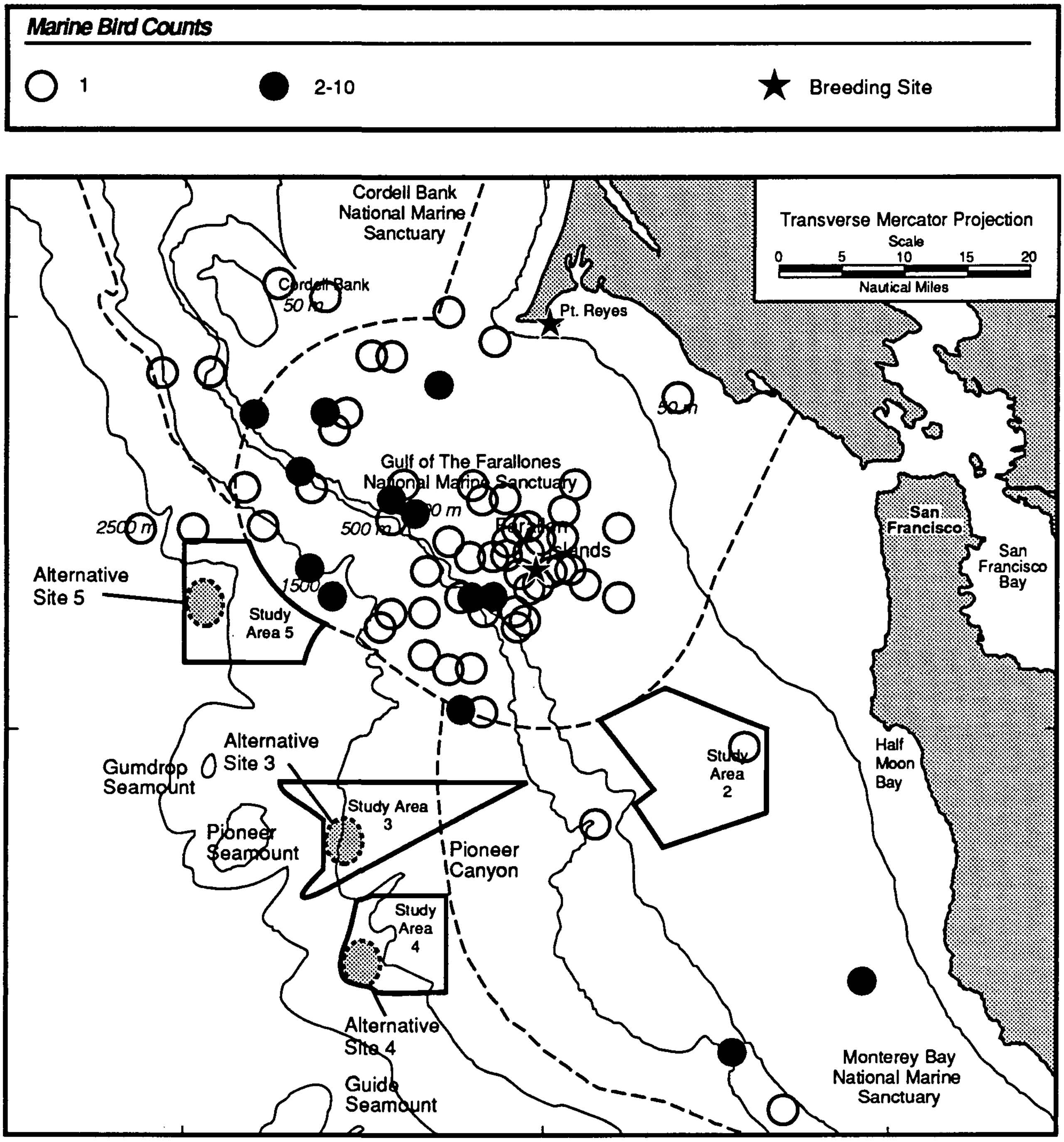

Figure 3.3.4-4. Tufted Puffin Counts in the Gulf of the Farallones Region, 1985-1991.
Source: Ainley and Allen 1992.

forage in deeper waters of the continental shelf (Ainley and Boekelheide 1990). Juvenile blackcod are an important prey item (Ainley and Allen 1992).

Brown Pelican

In addition to the ten representative breeding species considered, one migratory species, the brown pelican (*Pelecanus occidentalis*), occurs in significant numbers within the region and is listed by both State and Federal agencies as endangered. The nesting range for brown pelicans extends from the Santa Barbara Channel to Mexico. Two major roosting sites are Año Nuevo Island and Southeast Farallon Island (Briggs *et al.* 1983). Daytime surveys of these areas recorded 500 animals, whereas nocturnal censuses recorded several thousand individuals (Briggs *et al.* 1983). Surveys conducted from 1985–1991 indicated that California brown pelican populations were centered along the coastline and over shelf waters including Study Area 2 (Figure 3.3.4-5) (Ainley and Allen 1992). EPA surveys (1992) also recorded the highest numbers of brown pelicans over the continental shelf, particularly near the periphery of Study Area 2. Brown pelicans typically forage in shallow waters, and feed primarily on the northern anchovy (*Engraulis mordax*) (Anderson *et al.* 1980; Anderson *et al.* 1982), but they can be found during calm weather in waters over the continental slope (Briggs *et al.* 1983; Jones and Szczepaniak 1992).

3.3.4.2 Summary of Study Area Usage by Marine Bird Species

In general, assessments of densities of the ten representative species indicate that of the four areas, Study Areas 2 and 5 support the largest number of marine birds (Table 3.3.4-2). Study Area 2 is the only site located over shelf waters; these waters represent a more productive area for foraging marine birds (Ainley and Allen 1992; Jones and Szczepaniak 1992). Of the remaining three study areas, Study Area 5 is located closest to nesting sites of breeding species on the Farallon Islands, and thus is likely to be a more convenient feeding ground for breeding individuals. Ainley and Allen (1992) suggested that due to limited prey availability and

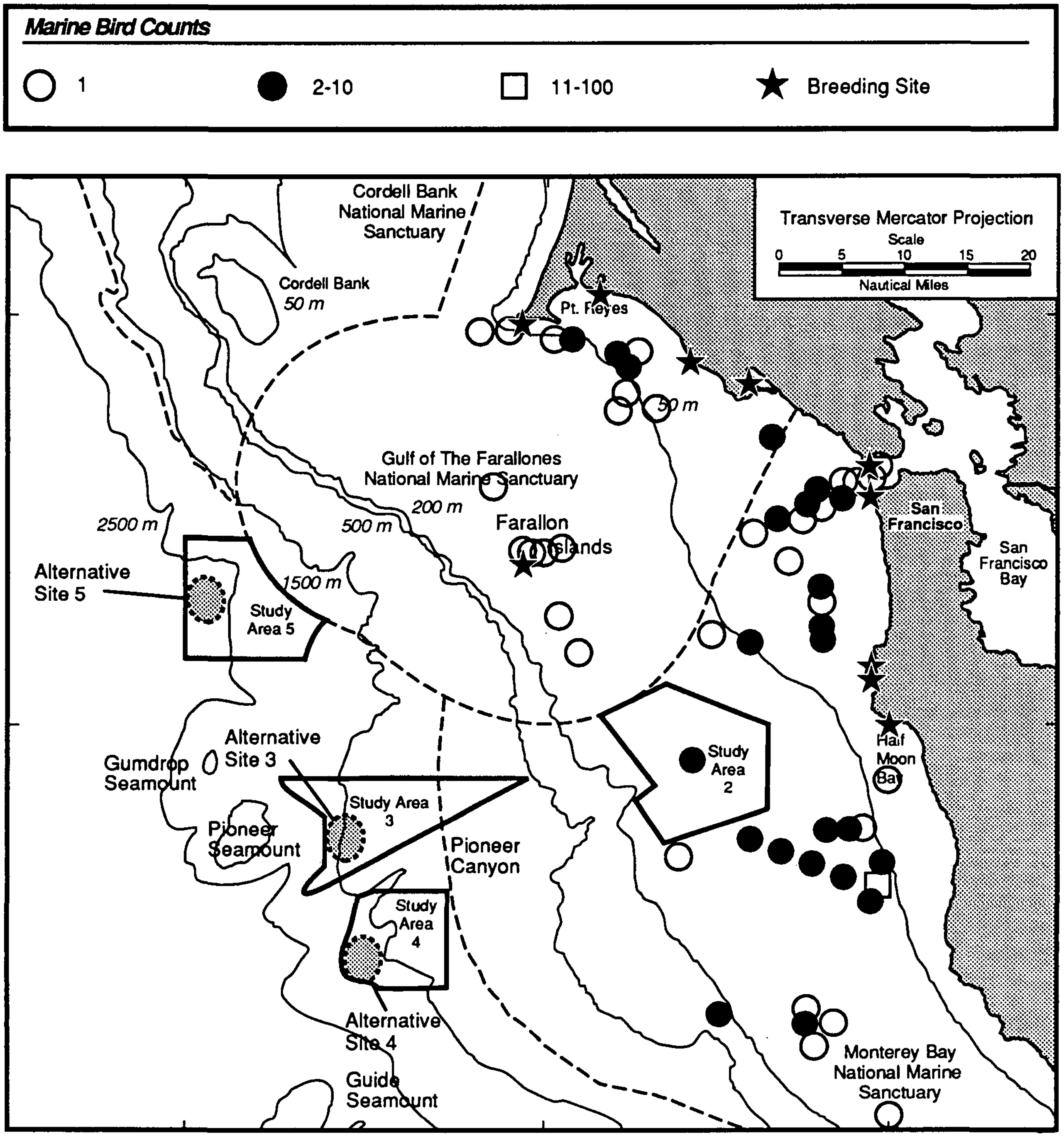

Figure 3.3.4-5. California Brown Pelican Counts in the Gulf of the Farallones Region, 1985-1991.
Source: Ainley and Allen 1992.

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prevailing northerly winds, marine birds forage less often to the south than to the north, west, or east of the Farallon Islands. An upwind return flight for an adult bird with prey is estimated to be relatively more difficult energetically. Thus, during the May/June breeding season, regions south of the Farallon Islands (such as Study Areas 3 and 4) may be less preferred as feeding grounds due to relatively lower prey availability (as compared to shelf waters) and the higher energy expenditure required to return to upwind nesting sites rather than downwind sites (e.g., Study Area 5) (Ainley and Allen 1992). Density estimates of all marine birds during poor, good and intermediate rockfish years (Figures 3.3.4-1 through 3.3.4-3, respectively) also indicate that the greatest abundances of marine birds are found within Study Areas 2 and 5 (Ainley and Allen 1992).

Based on known habitats from the literature, the total number of bird species potentially utilizing the different study areas decreases as the distance from shore increases (Briggs *et al.* 1987). This trend is consistent for breeding species, seasonal visitors, and passage migrants and tends to indicate that offshore areas such as LTMS Study Area 5 should have low utilization as bird habitats. Although Study Area 5 is far from shore, it lies in close proximity to a land source: the Farallon Islands. The relatively close distance between Study Area 5 and the Farallon Islands may explain the higher use of this area by marine birds. Thus, based on actual surveys (Ainley and Boekelheide 1990, Ainley and Allen 1992, Jones and Szczepaniak 1992), LTMS Study Areas 2, 3, and 5 show the highest utilization by species which breed in the Gulf of the Farallones, are common residents, are geographically limited, and/or have legal status.

3.3.5 Marine Mammals

This section presents information on marine mammals of the study region including cetaceans (Section 3.3.5.1), pinnipeds (Section 3.3.5.2), and fissipeds (Section 3.3.5.3).

Twenty-one species of cetaceans (dolphins, porpoises, and whales), six species of pinnipeds (sea lions and seals), and one species of fissiped (sea otter) comprise the marine mammal fauna of central California (KLI 1991). Twenty-six of these species (twenty cetaceans, five pinnipeds, and the fissiped) are frequently observed in the Gulf of the Farallones region (Table 3.3.5-1). All marine mammals are protected by the Marine Mammal Protection Act (MMPA 1972, amended 1988), administered by the National Oceanic and Atmospheric Administration/National Marine Fisheries Service (NOAA/NMFS) and the United States Fish and Wildlife Service (USFWS). In addition, gray, humpback, blue, finback, sei, right, and sperm whales are Federally listed as endangered species and thereby protected by the Endangered Species Act (ESA 1973, amended 1978). Recently, NOAA/NMFS has recommended that the eastern Pacific stock of gray whales be removed from the endangered species list because current estimates suggest the population has recovered from commercial whaling (IWC 1990). Formal action on the recommendation to de-list gray whales is expected by 1993 (MMS 1991). The northern fur seal, northern sea lion, and the sea otter are designated as threatened species under Federal law and fully protected under California law. Because marine mammals are protected, evaluation of the study areas for this EIS includes consideration of the extent to which the areas are used by marine mammals for breeding, weaning, feeding, or migration. Seasonal patterns of distribution in the LTMS study areas may suggest alternative disposal strategies that would minimize impacts to these species.

Broad-scale surveys of marine mammals off central and northern California, including the Gulf of the Farallones and the Farallon Islands, were conducted by Dohl *et al.* (1983) and Bonnell *et al.* (1983). Dohl *et al.* focused on the seasonal occurrence of cetaceans while Bonnell *et al.* studied pinnipeds and sea otters during a three-year (1980–1983) research program. Both of these historic studies provide seasonal estimates of the relative abundance of marine mammals for waters encompassing each of the study areas. In addition, a three-year (1986–88) photo-identification study on humpback and blue whales within and near the Gulf of the Farallones provides information on movements and site fidelity for these two endangered whale species common to the region (Calambokidis *et al.* 1990a, 1990b). More recent marine mammal surveys have focused on the LTMS study region (Ainley and Allen 1992; Jones and Szczepaniak 1992). The PRBO surveys (Ainley and Allen 1992) provide information on study area use by marine mammals; this information was collected during seven cruises conducted each June from 1985–91. Thus, seasonal events within the study region, such as the spring and fall migrations of gray whales and the late summer concentrations of humpback whales, are not represented in

Table 3.3.5-1. **Marine Mammals Observed in the Vicinity of the Gulf of the Farallones.**

Those species having legal status (special concern*, threatened**, or endangered***) are shown in bold. Species are listed according to their occurrence within the study region, such as breeding (breed in area), seasonal visitor (seasonal residents, feed in area), migrant (migrate through area but may feed as moving through area), or incidental. Relative occurrences refer to the following: Abundant = over 5,000 individuals, Common = between 1,000-5,000 individuals, Uncommon = between 100-1,000 individuals, and Rare = less than 100 individuals. Habitat areas refer to occurrences over the following water depths: shelf = < 200 m, slope = 200-1999 m, pelagic = > 1999 m. Species are listed according to their activity within the study region, such as breeding, seasonal visitor, or migrant.

Primary source: Ainley and Allen (1992)

Scientific Name	Common Name	Activity Within Study Region	Seasonal Status	Relative Occurrence	Predominant Habitat
Cetaceans					
(Approx 4 spp.)	Beaked Whale	?	Year-round	Rare	Pelagic
Balaenoptera musculus*	**Blue Whale**	**Seasonal Visitor**	**Summer**	**Uncommon**	**Shelf, slope**
Delphinus delphinus	Common Dolphin	Seasonal Visitor	Summer	Rare	Shelf
Phocoenoides dalli	Dall's Porpoise	Breeding	Year-round	Abundant	Shelf, slope
B. physalus*	**Finback Whale**	**Migrant**	**Summer**	**Rare**	**Shelf, slope, pelagic**
Eschrichtius robustus*	**Gray Whale**	**Seasonal Visitor/ Migrant**	**Year-round**	**Common**	**Shelf, slope**
Phocoena phocoena	Harbor Porpoise	Breeding	Year-round	Common	Shelf
Megaptera novaeangliae*	**Humpback Whale**	**Seasonal Visitor**	**Summer**	**Common**	**Shelf, slope**
Orcinus orca	Killer Whale	?	Year-round	Uncommon	Shelf, slope
B. acutorostrata	Minke Whale	Seasonal Visitor	Summer	Common	Shelf, slope

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Table 3.3.5-1. Continued.

Scientific Name	Common Name	Activity Within Study Region	Seasonal Status	Relative Occurrence	Predominant Habitat
Lissodelphis borealis	Northern Right Whale Dolphin	Breeding	Year-round	Common	Shelf, slope
Lagenorhyncus obliquidens	Pacific White-sided Dolphin	Breeding	Year-round	Abundant	Slope, pelagic
Globicephala spp.	Pilot Whale	Migrant	Winter	Uncommon	Slope, pelagic
Eubalaena gracialis*	**Right Whale**	**Incidental**	**?**	**Rare**	**?**
Grampus griseus	Risso's Dolpin	Seasonal Visitor	Year-round	Abundant	Shelf, slope
B. borealis*	**Sei Whale**	**Incidental**	**Summer**	**Rare**	**Pelagic**
Physeter macrocephalus*	**Sperm Whale**	**Incidental**	**Year-round**	**Common**	**Slope, pelagic**
Pinnipeds					
Zalophus californianus	California Sea Lion	Seasonal Visitor	Year-round	Abundant	Shelf
Phoca vitulina	Harbor Seal	Breeding	Year-round	Common	Shelf
Mirounga angustirostis	Northern Elephant Seal	Breeding/Seasonal Visitor	Year-round	Common	Shelf, slope, pelagic
Callorhinus ursinus*	**Northern Fur Seal**	**Seasonal Visitor**	**Year-round**	**Abundant**	**Slope, pelagic**
Eumetopias jubatus*	**Northern Sea Lion**	**Breeding**	**Year-round**	**Uncommon**	**Shelf**
Fissipeds					
Enhydra lutris*	**Sea Otter**	**Seasonal Visitor**	**Year-round**	**Common**	**Shelf**

these survey results. In contrast, EPA (Jones and Szczepaniak 1992) conducted five cruises between August 1990 and November 1991 on marine mammal use of the region. Although coverage of the four study areas was not uniform, these surveys supply incidental information on seasonal occurrence. Therefore, site-specific data (historic and recent) exist for marine mammals of the region and may be used to determine relative marine mammal use of the four study areas.

3.3.5.1 Cetaceans

In general, cetaceans are most common in continental slope (slope) waters (e.g., over water depths of 200–2,000 m). Dohl *et al.* (1983) recorded five times as many sightings in slope waters as in continental shelf (shelf) waters (less than 200 m), and three times the numbers sighted in deep waters (greater than 2,000 m).

During the 1980–83 surveys, Dohl *et al.* (1983) counted 116,800 cetaceans comprising 18 species. The most abundant odontocetes (i.e., toothed cetaceans) were the Pacific white-sided dolphin, followed by the northern right whale dolphin, Risso's dolphin, Dall's porpoise, and the harbor porpoise. The most common baleen whales were the California gray whale followed by the humpback whale. Sperm, blue, minke, and killer whales also were sighted, although their abundances were lower. Overall, the highest densities of cetaceans occurred in autumn and winter.

Results from Dohl *et al.* (1983) indicate that for all cetaceans combined, abundance estimates were highest near the Gulf of the Farallones. According to this study, all slope and deep-water study areas contained cetaceans during March through May with moderate to high densities (0.301–1.2/km^2) in Study Area 5, moderate densities (0.301–0.60/km^2) in Study Area 3, and low densities (0.01–0.15/km^2) in Study Areas 2 and 4.

Recent censuses indicated similar marine mammal occurrences and species within the Gulf of the Farallones region (Ainley and Allen 1992; Jones and Szczepaniak 1992). Similar to results from

Dohl *et al.* (1983), during the June 1985–91 surveys (Ainley and Allen 1992), a higher incidence of cetaceans was reported in slope and deep waters. Of the four study areas, the deep waters of Study Area 5 had the highest counts for a single species (22 Pacific white-sided dolphins) (Ainley and Allen 1992). However, the highest number of cetacean species and the highest counts for some species, including 15 Pacific white-sided dolphins, 7 humpback whales, 2 Risso's dolphins, and 1 minke whale, were reported for the slope waters of Study Area 4. Cetaceans observed within Study Area 3 included 12 Risso's dolphins, 3 Pacific white-sided dolphins, and 1 Dall's porpoise. In contrast, only three cetaceans (2 harbor porpoises and 1 humpback whale) were observed in shelf waters within Study Area 2.

In surveys during June 1985–91, Dall's porpoise, Pacific white-sided dolphin, and harbor porpoise were the most abundant odontocetes within the study region (Ainley and Allen 1992). Of the larger cetaceans, humpback whales were the most abundant, followed by minke and gray whales. Seasonal surveys conducted by the EPA (Jones and Szczepaniak 1992) also reported Dall's porpoise and Pacific white-sided dolphins as the most frequently observed cetaceans, although only two harbor porpoises were observed during the entire study. In contrast to the findings of Dohl *et al.* (1983), no gray whales were observed during EPA surveys; instead, humpback whales were the most frequently sighted baleen whales (Jones and Szczepaniak 1992).

Ainley and Allen (1992) suggest that Study Area 5 may have the relatively greatest importance to marine mammals based on the number of individuals observed there. However, seasonal surveys suggested that marine mammal abundances within Study Area 3 were greater than expected (Jones and Szczepaniak 1992). Also, during these surveys, numbers observed within Study Area 5 were less than expected and no marine mammals were observed within Study Area 4.

The seven species of large whales that occur within the study region are classified as seasonal visitors or migrants (Table 3.3.5-1). Gray, humpback, and blue whales are listed as seasonal visitors because they likely feed opportunistically in, as well as migrate through, the Gulf of the Farallones region. Conversely, finback, sperm, sei, and right whales are listed as migrants or incidentals because they appear to pass through the area during seasonal migrations, rarely stopping to feed. Periods of likely occurrence in the Gulf of the Farallones region for the seven species are shown in Figure 3.3.5-1. The occurrence of these seven species within the study areas warrants special attention because all are Federally listed as endangered (see Section 3.3.6, Endangered Species).

Pacific White-Sided Dolphins

Pacific white-sided dolphins were the most abundant cetacean observed off the central California coast, comprising 40% of all animals sighted (Dohl *et al.* 1983). These dolphins generally occur in waters over and seaward of the continental slope, except during spring when they occur in continental shelf waters from Half Moon Bay to Monterey Bay (Dohl *et al.* 1983). They feed on northern anchovy, whiting, saury, and squid at depths in excess of 120 m (Dohl *et al.* 1983). Juvenile animals were observed from July through October with the highest number of sightings between Point Conception and Point Reyes and with heavy use of the Gulf of the Farallones region (Dohl *et al.* 1983). Counts of this species over five years indicated moderate numbers (11–100 individuals) observed within Study Area 4 and in close proximity to Study Areas 3 and 5 (Figure 3.3.5-2) (Ainley and Allen 1992). During the EPA surveys, this species was seen in low to moderate abundances Study Area 3 and low abundances in Study Area 5 during August 1990 and 1991 (Jones and Szczepaniak 1992). These results verify that slope and deep-water habitats are used more often than shelf waters, as reported by Dohl *et al.* (1983).

Northern Right Whale Dolphin

Northern right whale dolphins comprised 35% of all animals sighted by Dohl *et al.* (1983), and usually were observed over deep waters. They feed primarily on squid, lanternfish, and other mesopelagic fishes at depths greater than 250 m (Leatherwood and Reeves 1982; Dohl *et al.* 1983). Sixty-two percent of all juveniles were sighted between Point Piedras Blancas and Point Piños, south of the Gulf of the Farallones (Dohl *et al.* 1983). There was a tendency for northern

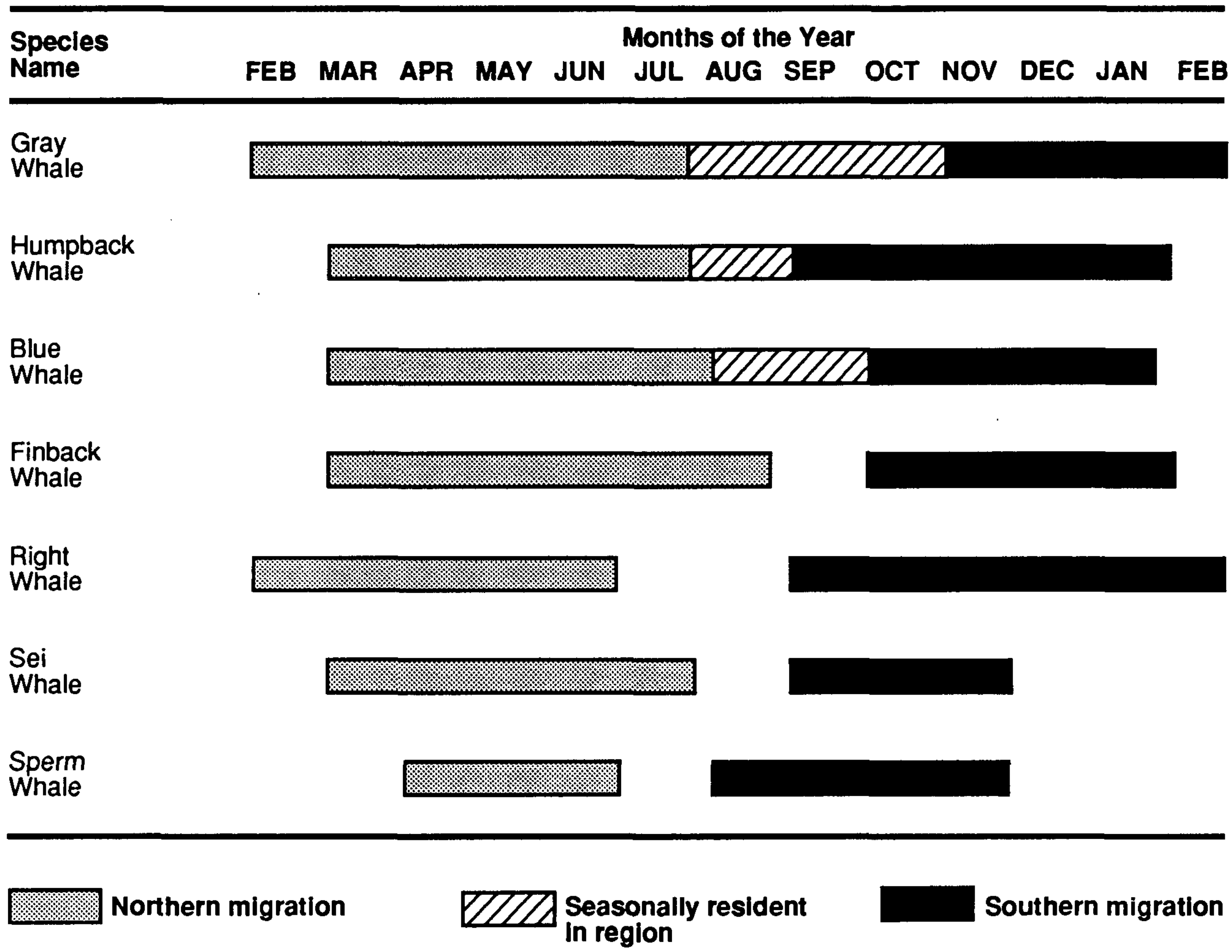


Figure 3.3.5-1. Whale Migrations (Northern and Southern) and Times During Which Each Species May Occur in the Study Region.
Modified from Dohl et al., 1983.

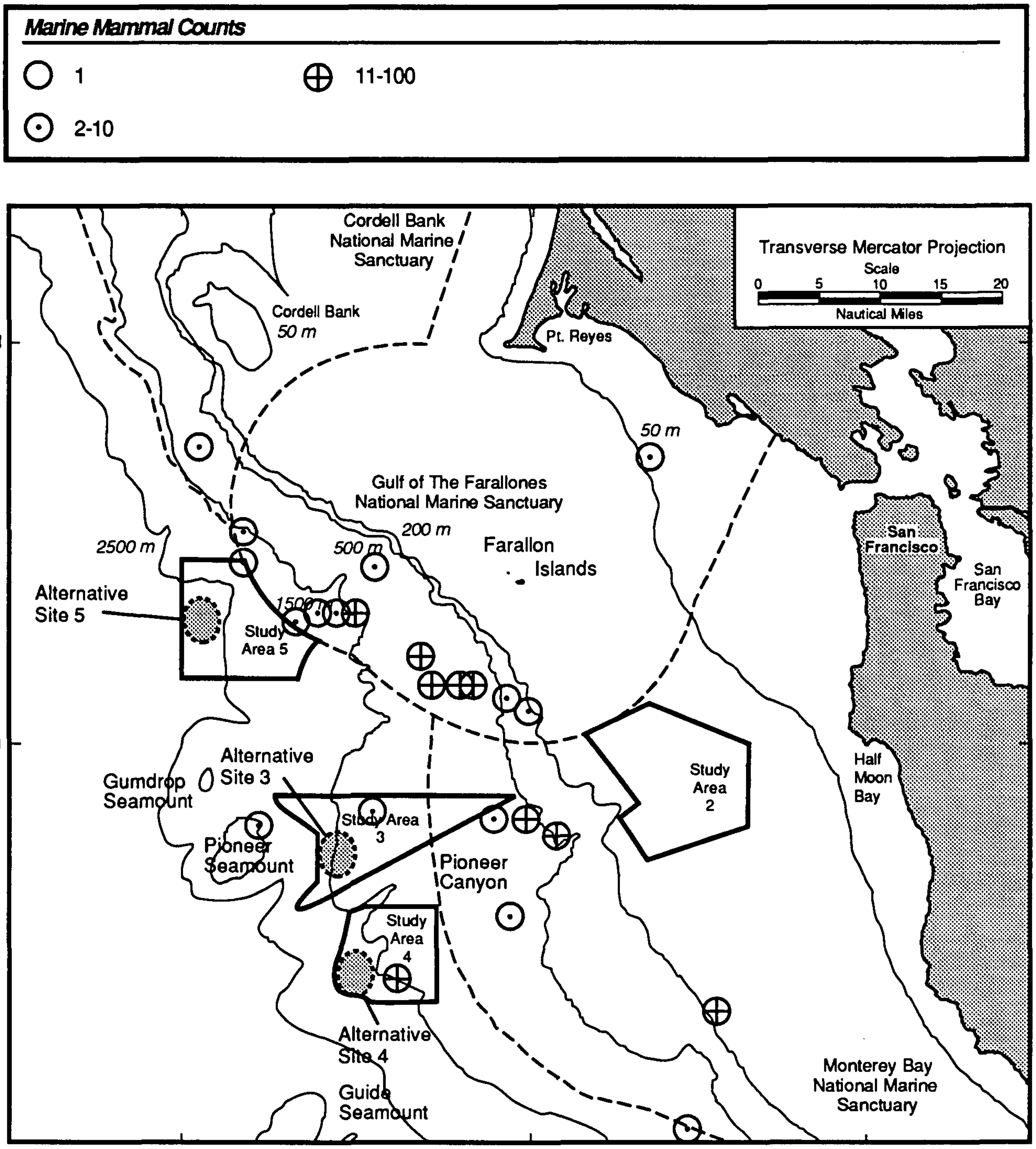


Figure 3.3.5-2. Pacific White-Sided Dolphin Counts in the Gulf of the Farallones Region, 1985-1991.
Source: Ainley and Allen 1992.

right whale dolphins to be found over deeper waters in autumn (1,440 m) than in spring (862 m), although this pattern was not consistent from year to year (Dohl *et al.* 1983). Overall, the species' distribution appears to shift south and inshore from October through June, then north and offshore from July through September (Leatherwood and Reeves 1982). During the PRBO (1992) surveys, most northern right whale dolphins were seen near the eastern boundary of Study Area 5, with fewer sighted near Study Area 3 (Figure 3.3.5-3). EPA sightings of this species were over slope waters between Study Areas 3 and 4 (Jones and Szczepaniak 1992). All EPA sightings occurred during August and October surveys, confirming the suggestion by Dohl *et al.* (1983) that northern right whale dolphins tend to be found over slope waters during autumn. Thus, like Pacific white-sided dolphins, with which they commonly co-occur, northern right whale dolphins prefer slope and deep-water habitats over continental shelf waters.

Risso's Dolphin

Risso's dolphins comprised 18% of the cetaceans sighted by Dohl *et al.* (1983). This species often is found offshore in deep temperate and tropical waters where it feeds primarily on squid (Leatherwood and Reeves 1982). The few Risso's dolphin that were seen within the study region during the PRBO surveys were near or within Study Areas 3 and 4 (Ainley and Allen, 1992) (Figure 3.3.5-4). Although Risso's dolphins occur regularly in the Gulf of the Farallones, the population reportedly is concentrated in southern California waters (Dohl *et al.* 1983). Jones and Szczepaniak (1992) recorded a single sighting of Risso's dolphins within Study Area 4.

Dall's Porpoise

Dall's porpoise numerically represented only 2% of the cetaceans seen, but were the most frequently encountered species during the 1980–83 surveys (Dohl *et al.* 1983). Abundance indices were highest from mid-summer through autumn, and lowest in winter.

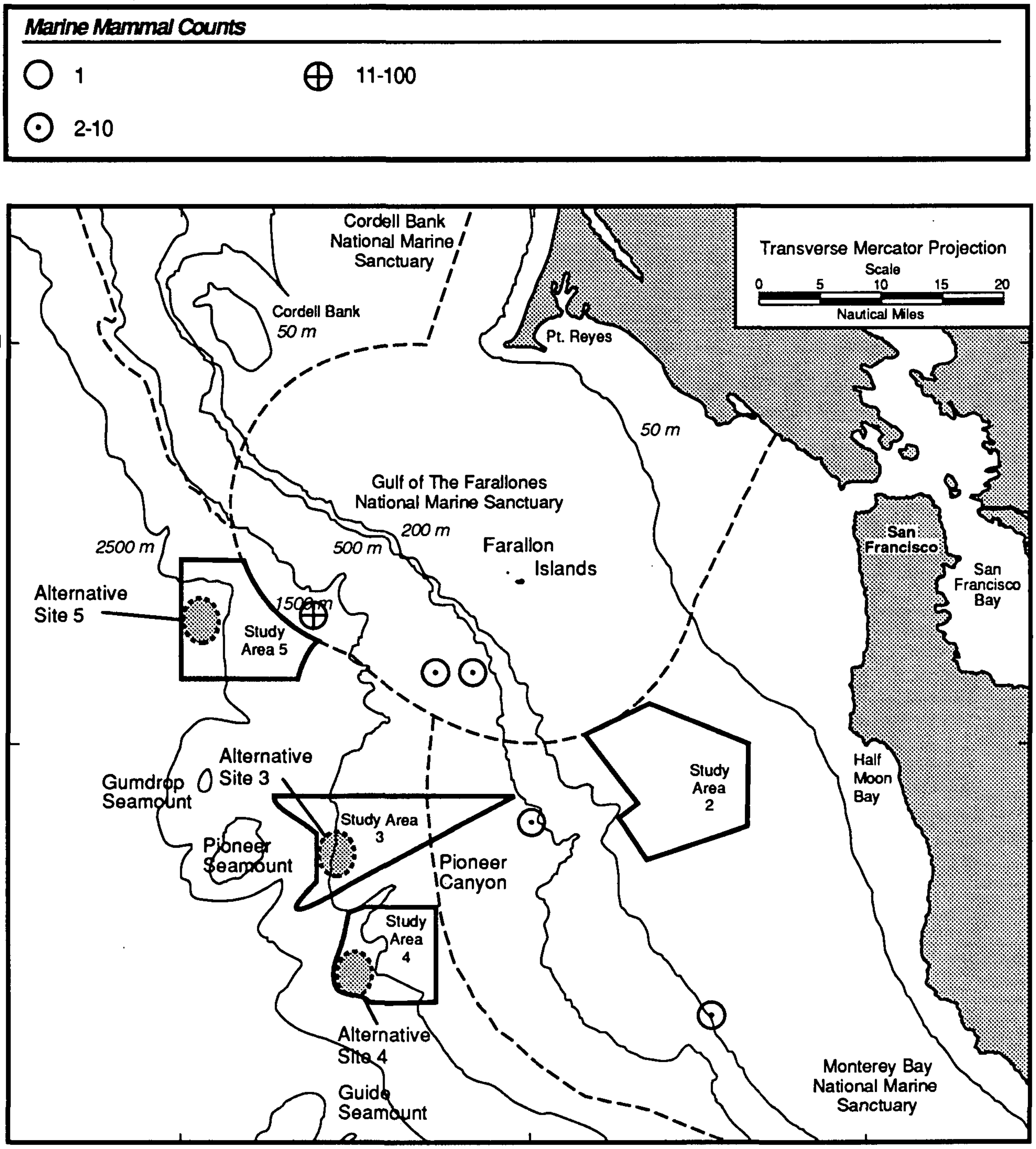


Figure 3.3.5-3. **Northern Right Whale Dolphin Counts in the Gulf of the Farallones Region, 1985-1991.**
Source: Ainley and Allen 1992.

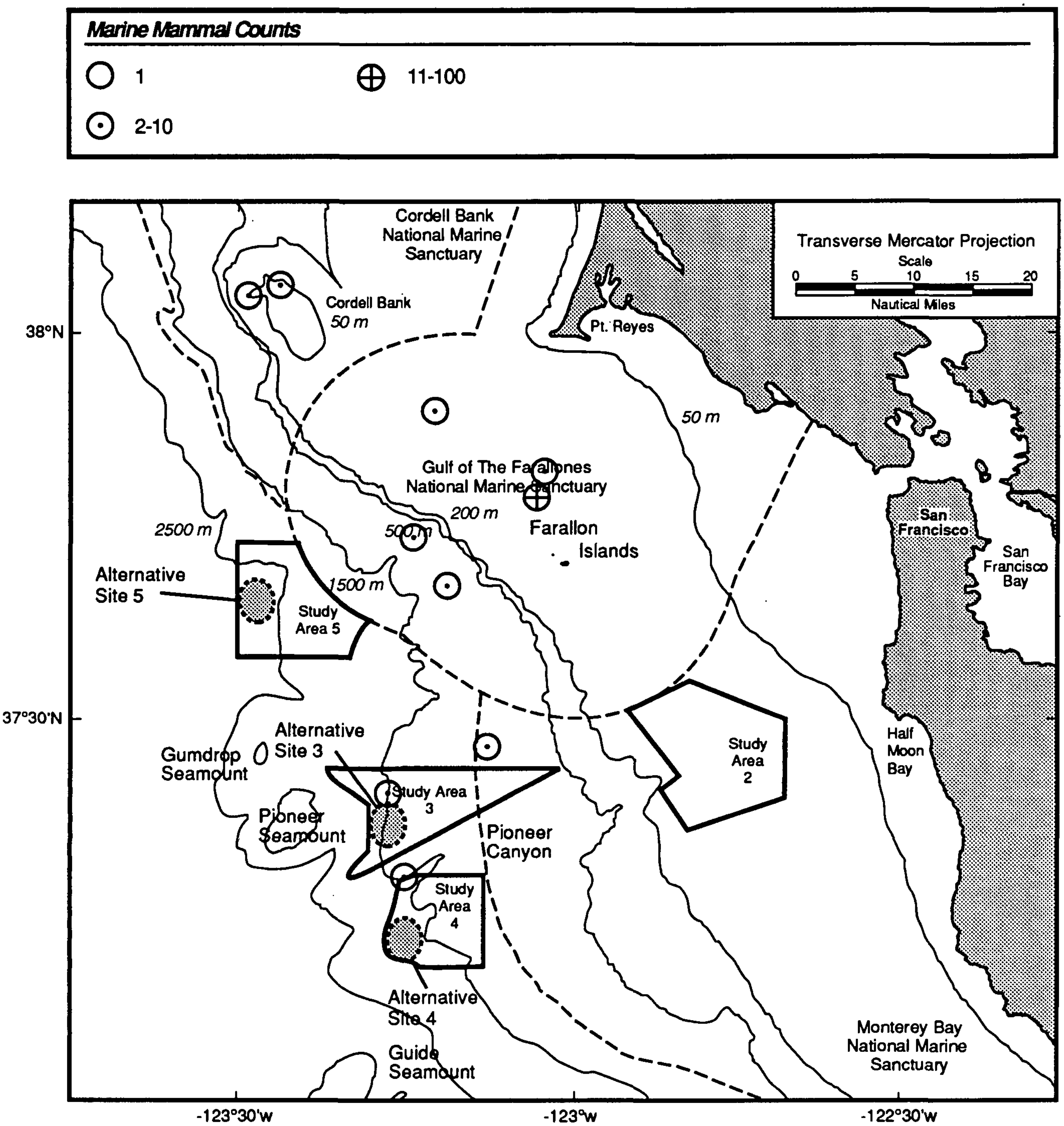


Figure 3.3.5-4. Risso's Dolphin Counts in the Gulf of the Farallones Region, 1985-1991.
Source: Ainley and Allen 1992.

Similarly, Dall's porpoises were the cetaceans observed most often within the study region during the PRBO (1992) surveys, although sightings within specific study areas were rare (Figure 3.3.5-5). During the EPA (1992) surveys, this species occurred in the study region region most often in summer, especially within Study Area 3 (Jones and Szczepaniak 1992). The greatest numbers occurred along the seaward edge of the continental shelf and slope waters (Ainley and Allen 1992; Jones and Szczepaniak 1992). Dall's porpoises are nocturnal feeders, primarily consuming anchovies, squid, crustaceans, and deep-water fishes (Morejohn 1979; Jones 1981; Ainley and Allen 1992). Preferred prey abundance may significantly affect the species foraging range. For example, the highest densities of Dall's porpoises were observed around the Farallon Islands coincident with unusually high numbers of anchovies (Ainley and Allen 1992).

Harbor Porpoise

Harbor porpoise are the most common nearshore cetaceans in the central California region (Leatherwood *et al.* 1982; Dohl *et al.* 1983). Seasonal movements seem to be inshore-offshore rather than north-south and may be determined by prey availability. Harbor porpoise feed on juvenile rockfish, herring, mackerel, sardines, pollack, and whiting (Leatherwood and Reeves 1982). Dohl *et al.* (1983) estimated a peak central California population of 3,000 porpoises in the fall season, although recent observations suggest the species is present year-round in the Gulf of the Farallones (Szczepaniak and Webber 1985). Harbor porpoise rarely are seen in waters deeper than 180 m, and usually occur within the 18 m isobath (Caldwell and Caldwell 1983). Sightings during the PRBO and EPA (1992) surveys support this observation. All animals were seen in continental shelf waters with only one animal in Study Area 2 (Ainley and Allen 1992) (Figure 3.3.5-6).

Gray Whales

The eastern Pacific population of gray whales is currently estimated at 21,113 individuals and is considered to be essentially recovered from historical reductions attributable to commercial whaling (IWC 1990). Migrations occur twice annually between winter breeding lagoons in Baja

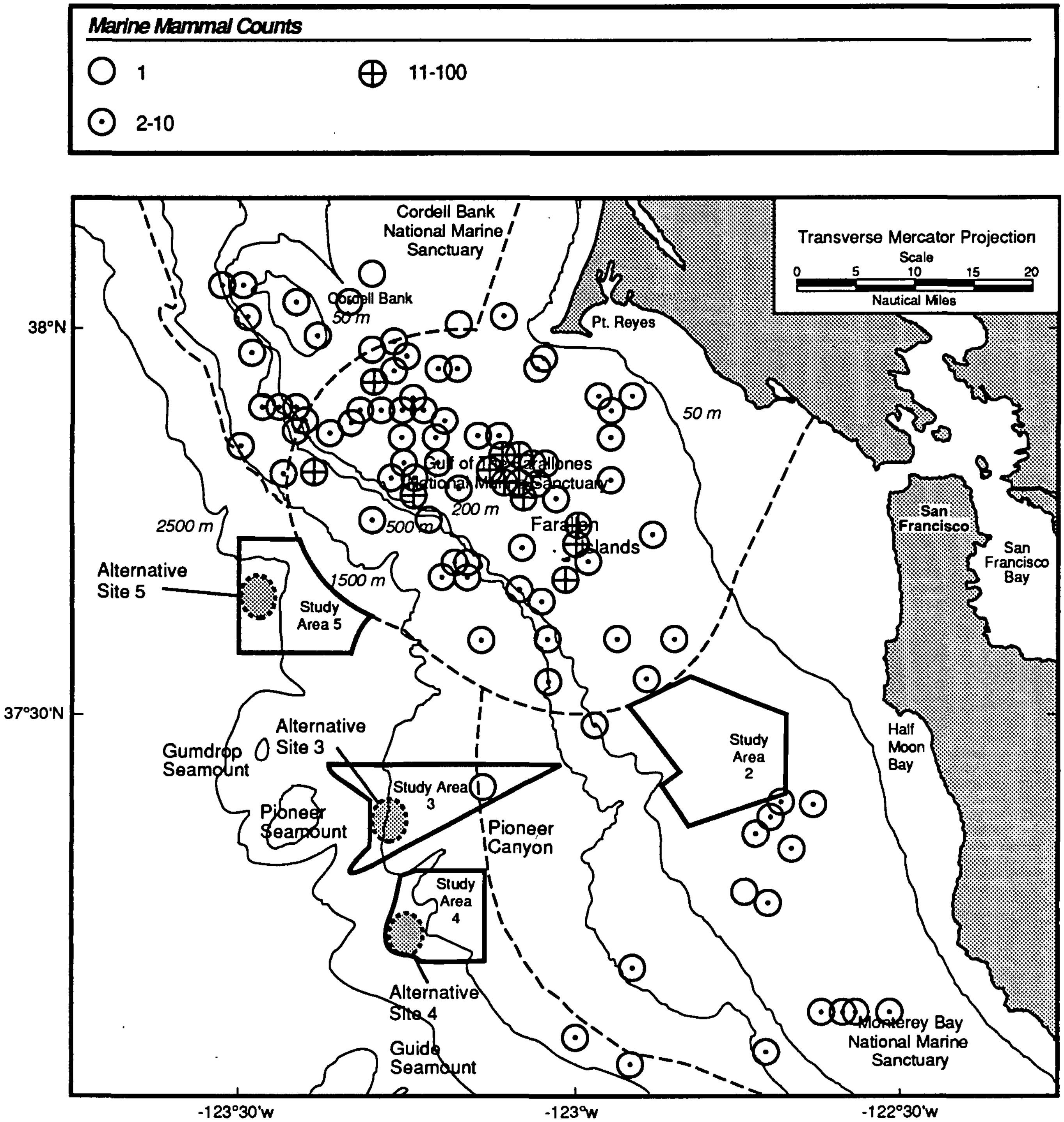


Figure 3.3.5-5. Dall's Porpoise Counts in the Gulf of the Farallones Region, 1985-1991.
Source: Ainley and Allen 1992.

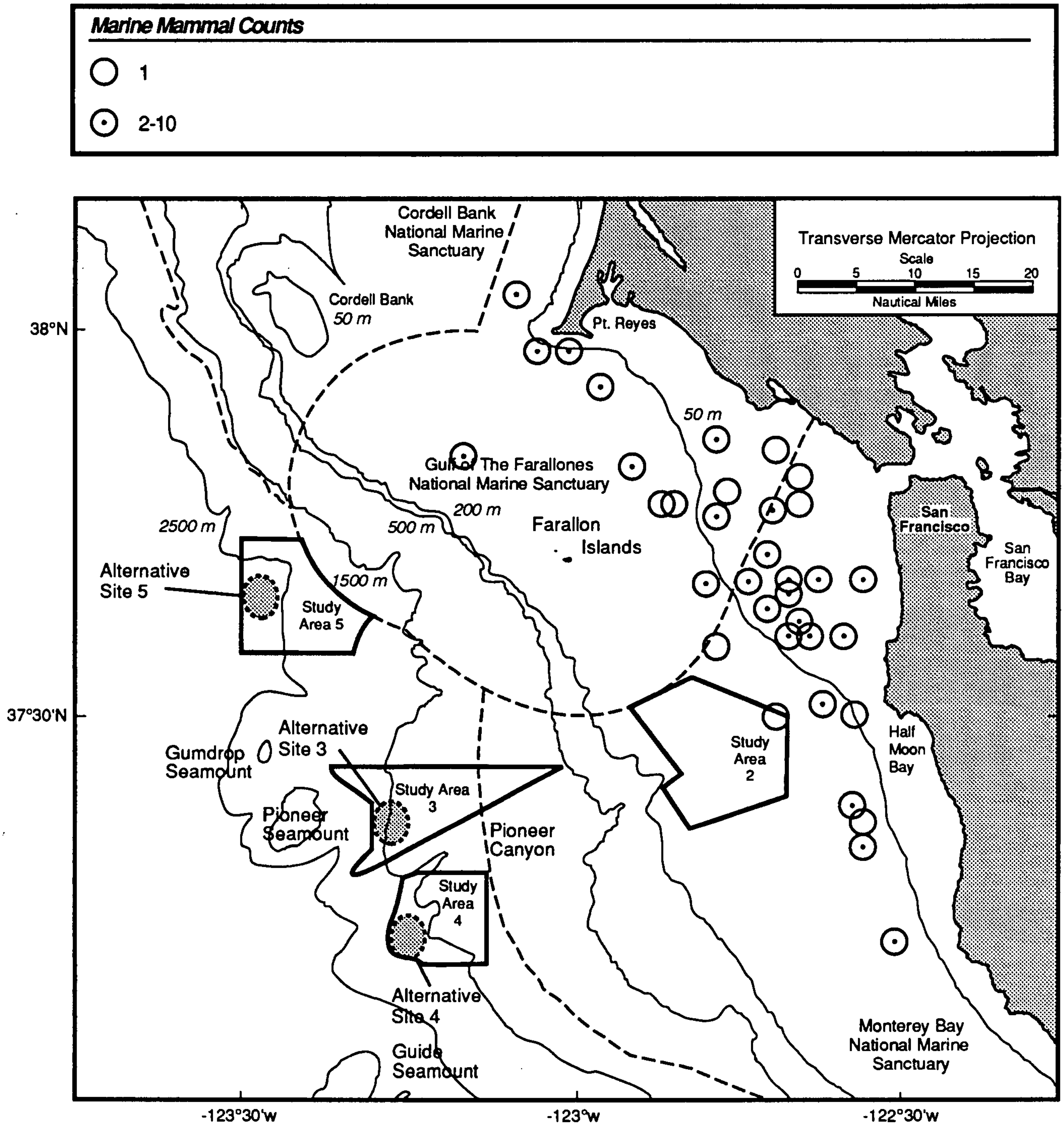


Figure 3.3.5-6. Harbor Porpoise Counts in the Gulf of the Farallones Region, 1985-1991.
Source: Ainley and Allen 1992.

California and summer feeding grounds in the Bering and Chukchi seas (Clarke *et al.* 1989; Moore *et al.* 1986; Swartz 1986). There is recent evidence of year-round residency of some gray whales in the Gulf of the Farallones (PRBO, unpubl. data).

Southbound whales may appear as early as October, with the majority of animals occurring in late December-early January (Dohl *et al.* 1983). Individuals generally tend to avoid turbid waters, such as those receiving run-off following extensive rainfall, and usually pass west of the Farallon Islands on their way south from Point Reyes (Dohl *et al.* 1983). Newborn whales have been observed in northern, central, and southern California waters (Jones and Swartz 1990), suggesting that whales do not calve solely in the lagoons of Baja California. In addition, the year-round residency of some gray whales in the Gulf of the Farallones indicates that some breeding/calving of gray whales may occur in the study region.

The northward migration period is less well defined, but generally occurs from mid-January through June (Dohl *et al.* 1983; Herzing and Mate 1984). Northbound animals tend to stay closer to shore. Poole (1984) described two migration corridors for northbound whales off San Simeon (Piedras Blancas): a route 200 m to 3.2 km offshore used by whales not accompanied by calves, and a route less than 200 m from shore used primarily by females with calves. The cow/calf pairs closely followed the coastal contour, while whales using the "offshore" route often followed a nearly straight line from one coastal promontory to the next. The route(s) used by northbound whales in the Gulf of the Farallones region is unknown.

Few gray whale sightings were recorded during the PRBO surveys, although moderately high counts were made near the northeast boundary of Study Area 5 (Figure 3.3.5-7) (Ainley and Allen 1992). This overall scarcity of sightings could be due to limitation of the field effort (May/June surveys only). However, no gray whales were observed during the EPA seasonal surveys (Jones and Szczepaniak 1992). In recent years, 3 to 8 gray whales summered in the vicinity of the Farallon Islands (Dohl *et al.* 1983; Huber *et al.* 1986). Gray whales feed on infaunal crustaceans, primarily ampeliscid amphipods, and there are incidental reports of gray

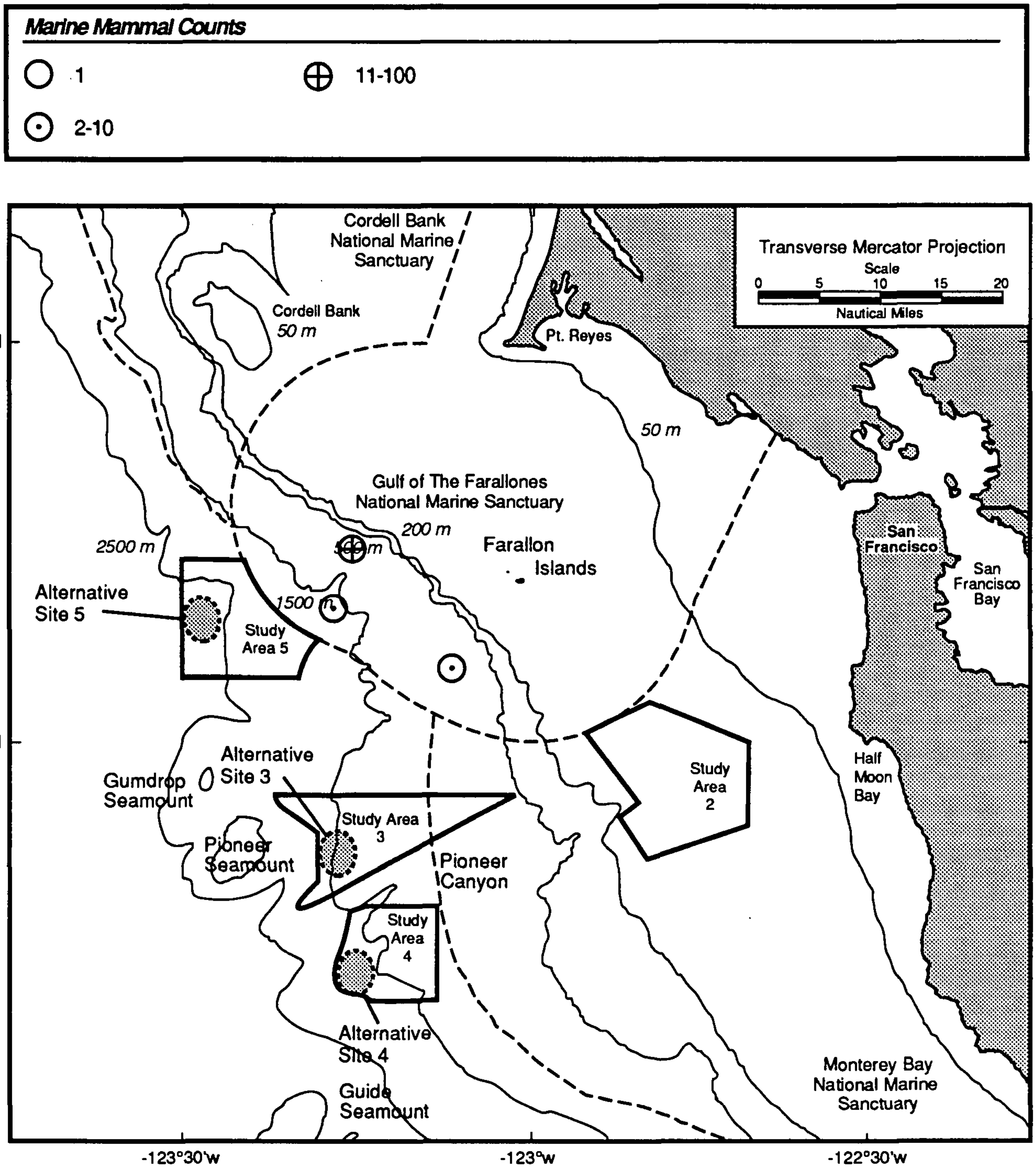


Figure 3.3.5-7. **Gray Whale Counts in the Gulf of the Farallones Region, 1985-1991.**
Source: Ainley and Allen 1992.

whales associated with sediment trails (which indicate feeding) near the Farallon Islands and off Point Reyes (Nerini 1984; PRBO, unpubl. data). Gray whales summering off Vancouver Island are principally engaged in feeding (Oliver *et al.* 1984), and there is some evidence that gray whales feed opportunistically near the Farallon Islands as well (P. Jones, EPA, pers. comm. 1992).

Humpback Whales

The eastern north Pacific population of humpback whales migrates from summer feeding areas in southern Alaskan waters to winter breeding areas in waters near Hawaii and Mexico (Johnson and Wolman 1984; Baker *et al.* 1986). Humpbacks occur along northern and central California from March through January, with the greatest numbers in waters near the Farallon Islands from mid-August through October (Dohl *et al.* 1983; Calambokidis *et al.* 1990a). During summer months, central California populations may reach 500 animals (Dohl *et al.* 1983). Annual local populations have been estimated at roughly 150–200 whales in the region for the years 1986–88 (Calambodikis *et al.* 1990a). Humpbacks feed on baitfish, euphausiids, pelagic crabs, and a variety of other prey in the Gulf of the Farallones in summer and early fall. Highest abundance was observed in August between Study Areas 2 and 3 during EPA (1992) surveys (Figure 3.3.5-8a), while data from the multi-year June surveys (Ainley and Allen 1992) suggested higher relative abundance further south between Study Areas 3 and 4 (Figure 3.3.5-8b). Calambokidis *et al.* (1990a) describe movement of humpbacks between feeding aggregations in the Gulf of the Farallones and along the California coast, particularly Monterey Bay. Differences in sighting distributions from the PRBO and EPA surveys could result from differences in survey timing, or movement of the whales between Monterey Bay and Gulf of the Farallones feeding areas.

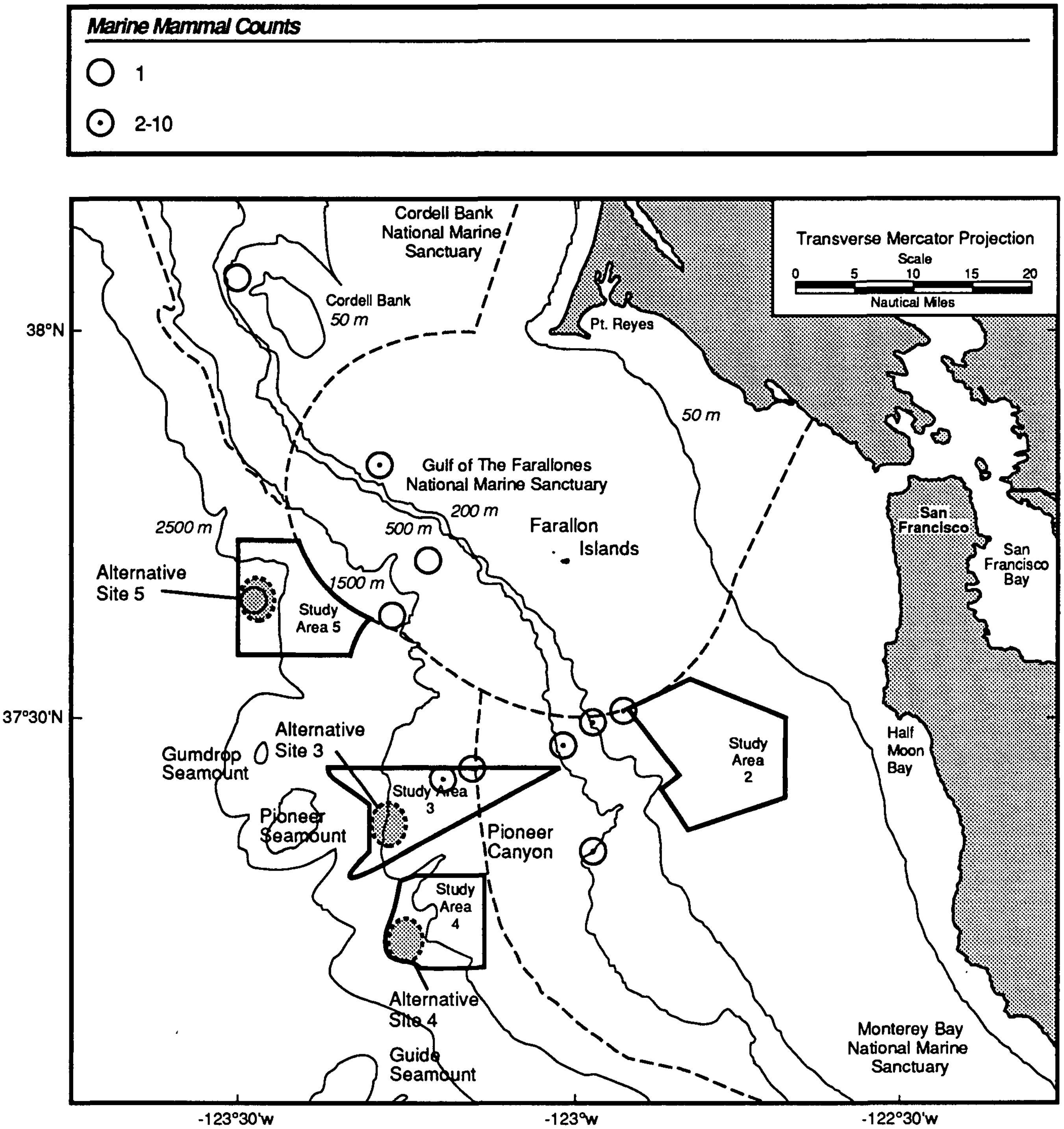
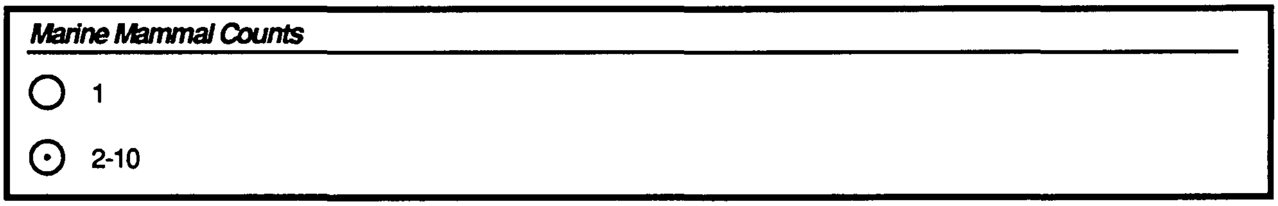


Figure 3.3.5-8a. Humpback Whale Counts in the Gulf of the Farallones Region, August 1990 and 1991.

Source: Jones and Szczepaniak 1992.



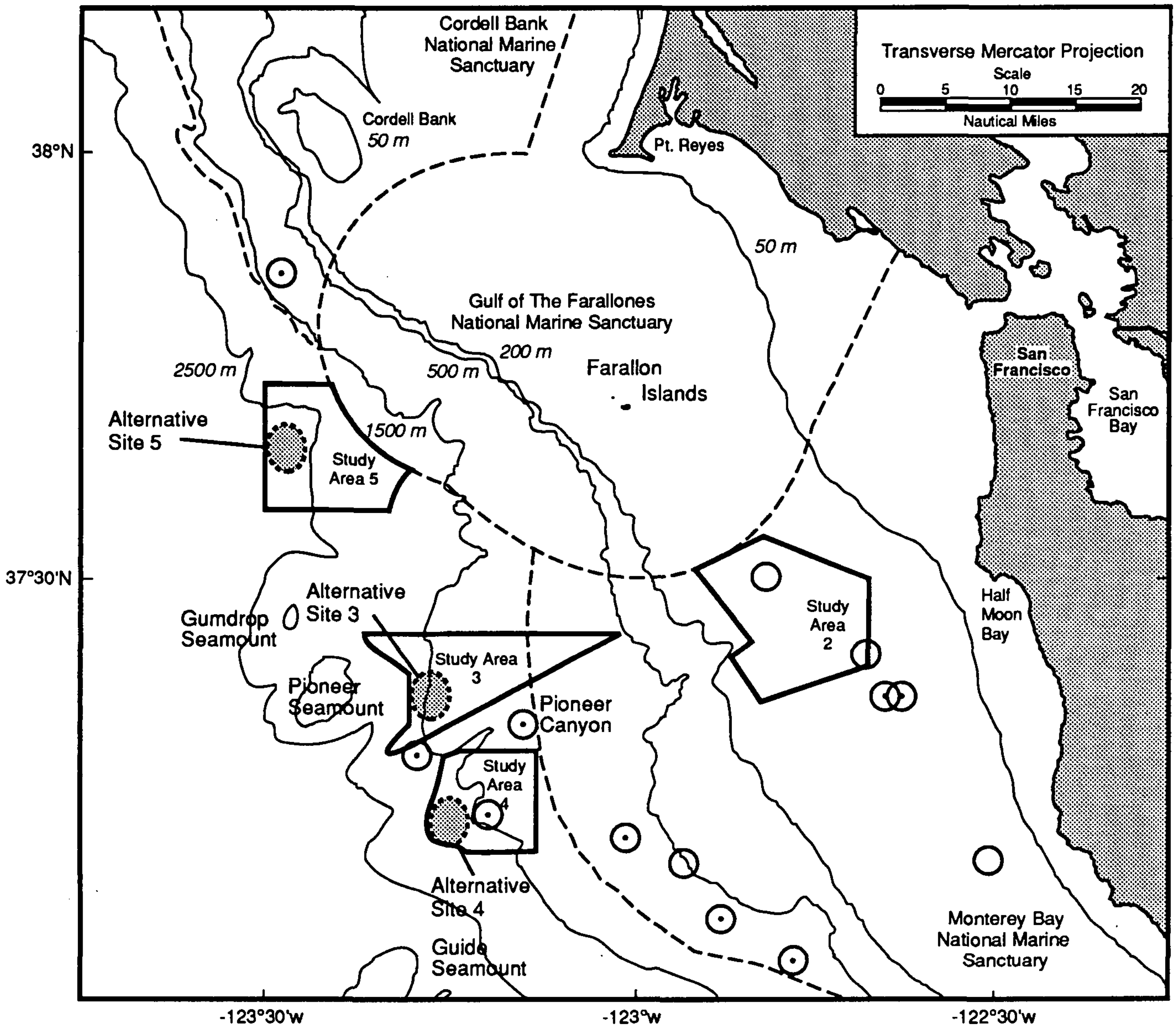


Figure 3.3.5-8b. Humpback Whale Counts in the Gulf of the Farallones Region, 1985-1991.
Source: Ainley and Allen 1992.

Blue Whales

Blue whales occur from the Chukchi Sea to waters off Costa Rica in the eastern north Pacific, although specific migration patterns and feeding areas are poorly defined (Mizroch *et al.* 1984). Like humpbacks, blue whales use the Farallon Basin for feeding in summer and early fall, but occur in lower numbers (Dohl *et al.* 1983). A total of 179 blue whales were identified photographically in the Gulf of the Farallones over three years (1986–88), with some movement of individual whales between the Farallones and feeding aggregations in Monterey Bay documented in 1987 and 1988 (Calambokidis *et al.* 1990b). In 1986, a single sighting of 41 blue whales was recorded near Southeast Farallon Island (PRBO, unpubl. data), the same year that unusually large aggregations of blue whales fed on euphausiids in Monterey Bay (Schoenherr 1991). During the EPA (1992) surveys, blue whales were seen in Study Area 3 and near Study Area 2 in August, with most seen along the continental shelf break (Figure 3.3.5-9). No blue whales were observed within survey transects during the June 1985–91 surveys (Ainley and Allen 1992).

Minke Whales

Minke whales are widely distributed in tropical, temperate, and polar waters (Leatherwood and Reeves 1982). In the north Pacific, minkes winter from central California to near the equator, with distribution shifting northward in summer from central California to waters off Alaska. Minke whales appear to segregate by age/sex classes in all areas, which limits attempts to make unbiased estimates of population size. There is evidence that minke whales are year-round residents in Monterey Bay (Stern 1990) and the Gulf of the Farallones (PRBO, unpubl. data). The sexes of resident populations in the Gulf and off Monterey migrate separately (Stern 1990). Dohl *et al.* (1983) sighted 16 minke whales over 3 years, with only one animal seen near the Farallon Islands in 1981. A single minke whale was observed within Study Area 4 during the June PRBO (1992) surveys. The majority of minke whales observed during these surveys were along the northern coastline of the study region (Ainley and Allen 1992) (Figure 3.3.5-10). EPA

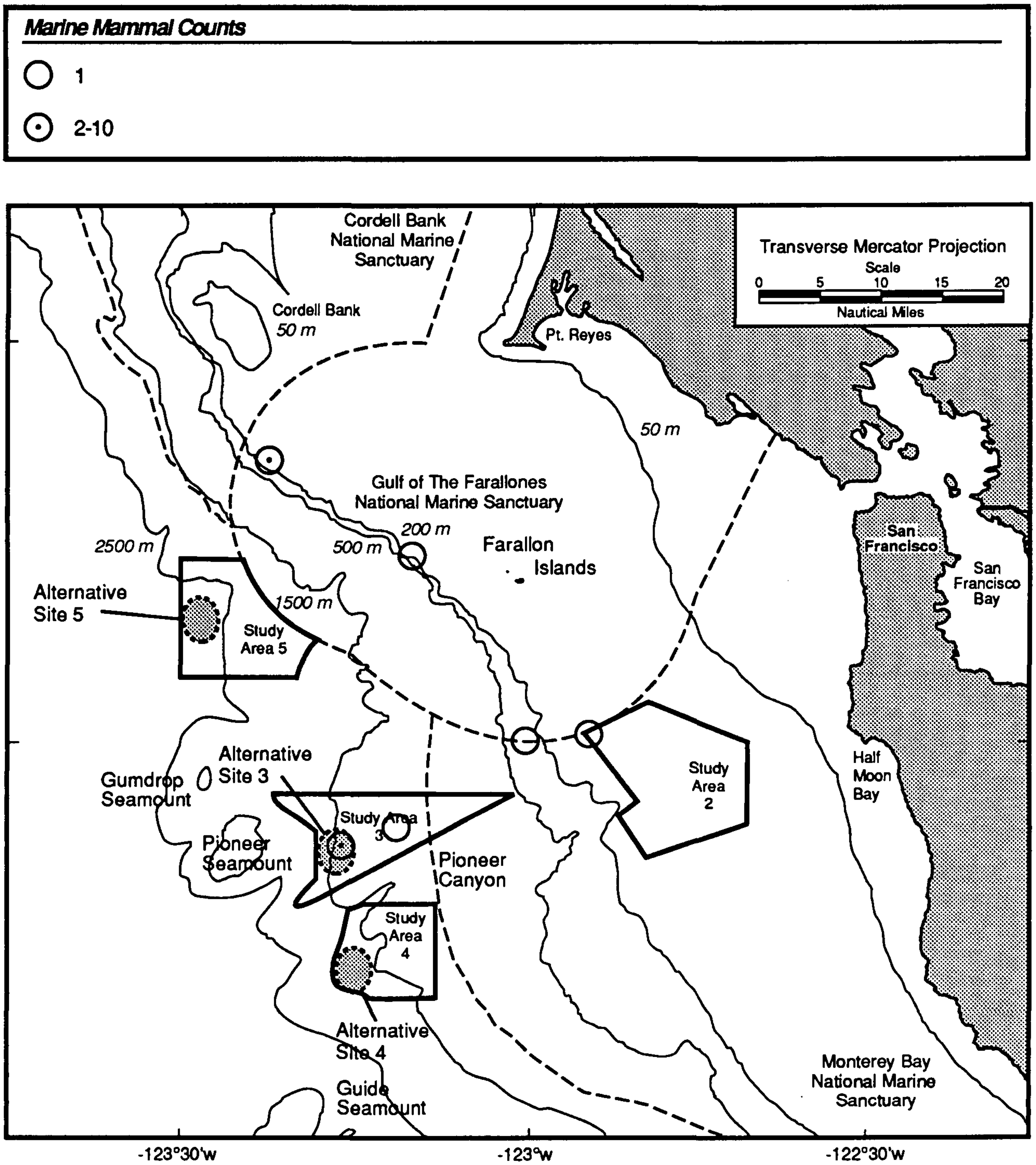


Figure 3.3.5-9. **Blue Whale Counts in the Gulf of the Farallones Region, August 1990 and 1991.**
Source: Jones and Szczepaniak 1992.

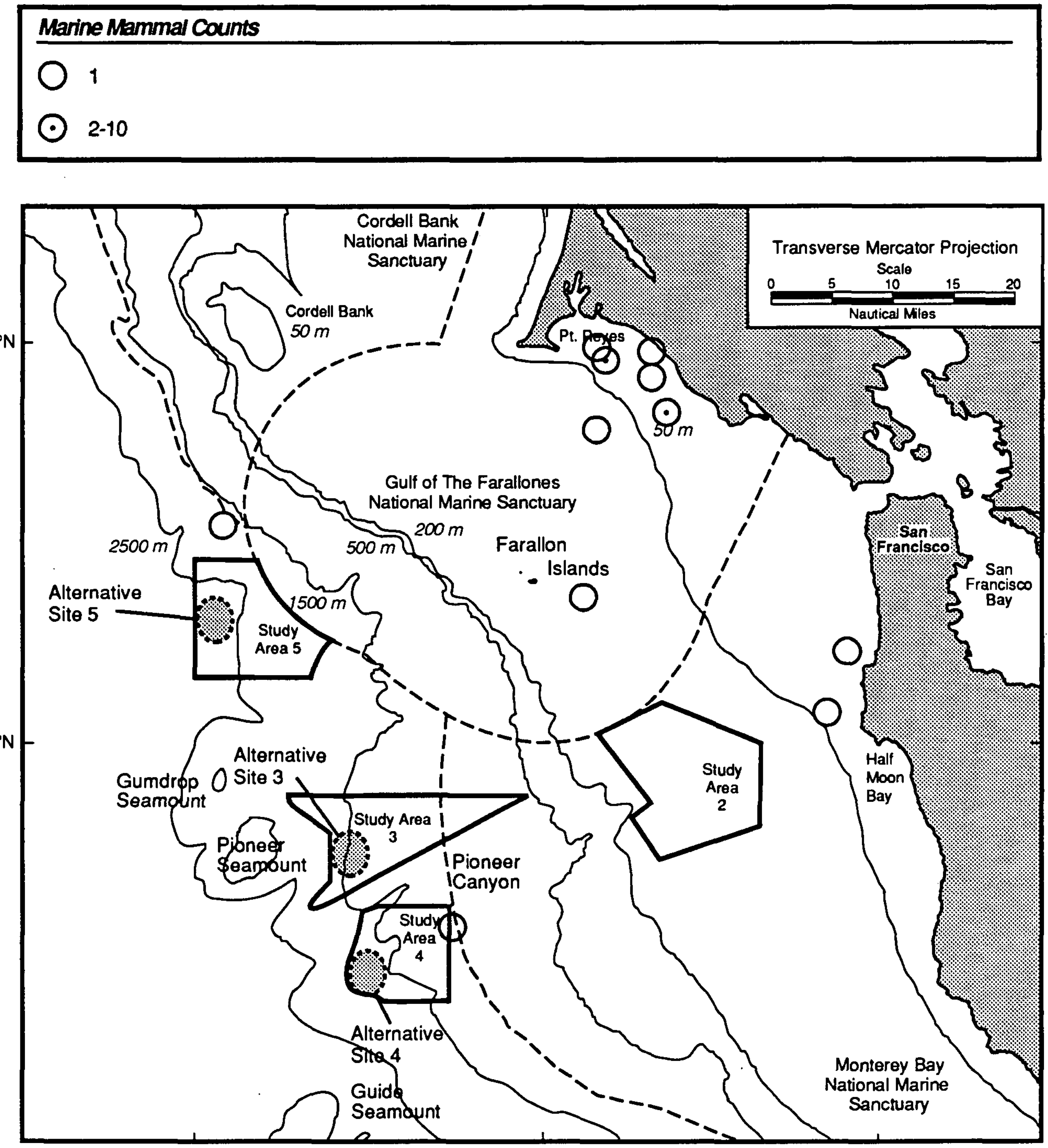


Figure 3.3.5-10. Minke Whale Counts in the Gulf of the Farallones Region, 1985-1991.

Source: Ainley and Allen 1992.

surveys observed only two minke whales shoreward of the 100-m isobath (Jones and Szczepaniak 1992).

Finback, Sperm, Sei, and Right Whales

Endangered finback, sperm, sei, and right whales rarely occur in the study region (Dohl *et al.* 1983), and none were observed during the PRBO (1992) and EPA (1992) surveys. Thirty sightings of a total of 56 finback whales were recorded from 1980–83 (Dohl *et al.* 1983), with 70% of the sightings in continental shelf and slope waters. One finback whale was seen about 20 km west of Point Reyes, and a group of 5 to 8 whales were observed just south of the Farallon Islands in 1981. Sperm whales are commonly found off central California, with peaks of abundance in mid-May and mid-September suggesting a northward migration in the spring and a southward migration in fall. From November to April, breeding groups are sighted over the continental slope off California between 33° to 38°N latitude (Gosho *et al.* 1984). There were 66 sightings of a total of 218 sperm whales from 1980–83 (Dohl *et al.* 1983), with 68% of the sightings in waters greater than 1,700 m deep. Four sperm whales were observed in Study Area 5 in 1983. Although the Gulf of the Farallones lies within the distributional range of sei and right whales (Caldwell and Caldwell 1983), none were recorded during recent (Ainley and Allen 1992; Jones and Szczepaniak 1992) or historic (Dohl *et al.* 1983) surveys.

Other Cetaceans

Other species of cetaceans either have been sighted in the region, stranded along the mainland coast, or have the potential for occurring in the region (Dohl *et al.* 1983). Killer whales are widespread throughout the eastern north Pacific (Leatherwood and Reeves 1982). Dohl *et al.* (1983) reported that killer whales ranged along the entire California coastline, occurring most frequently over the continental slope north of Monterey Bay. A group of 5 to 8 killer whales was seen west of the Farallon Islands near Study Area 5 in 1981 (Dohl *et al.* 1983). Beaked whales, including *Mesoplodon* spp. and *Berardius bairdi*, are oceanic and occur worldwide.

There are at least three species of *Mesoplodon* that could occur in the area: Hubb's beaked whale (*M. carlhubbsi*), Blainville's beaked whale (*M. densirostris*), and Stejneger's beaked whale (*M. stejneger*). Some species of *Mesoplodon* are recognized as deep divers (*M. carlhubbsi* in particular) and feed on squid and midwater fishes. Baird's beaked whales (*B. bairdi*) occur from the Bering Sea to Baja California, Mexico. Dohl *et al.* (1983) suggested that Baird's beaked whales move onto the continental slope off central and northern California during June, then move offshore in November; none were seen near the Gulf of the Farallones during the 1980–83 surveys. This species also is deep-diving and feeds on squid and octopuses as well as crustaceans, sea cucumbers, and a variety of deep-sea and midwater fishes (Caldwell and Caldwell 1983). Beaked whales generally avoid vessels, which may in part explain their reduced numbers during surveys.

In summary, results from historic surveys (Dohl *et al.* 1983) indicated that for all cetaceans combined, highest species densities occurred in Study Area 5. Moderate species densities occurred in Study Area 3, and low densities were found in Study Areas 2 and 4. In contrast, results from long-term marine mammal censuses (Ainley and Allen 1992) and recent seasonal surveys (Jones and Szczepaniak 1992) indicated that more cetaceans occurred in Study Areas 3 and 4 (Table 3.3.5-2). In general, cetacean abundances within the study region appear highest in slope and deeper waters.

3.3.5.2 Pinnipeds

Bonnell *et al.* (1983) censused the pinnipeds and southern sea otters of central and northern California by means of monthly aerial transects and quarterly coastal censuses. They estimated that the five predominant pinniped species, the California sea lion (*Zalophus californianus*), harbor seal (*Phoca vitulina*), northern elephant seal (*Mirounga angustirostis*), northern fur seal (*Callorhinus ursinus*), and northern sea lion (*Eumetopias jubatus*), had combined populations of approximately 50,000 animals. Peak numbers at sea occurred in winter and spring with the arrival of migrant northern fur seals from the Bering Sea. Northern sea lions, northern elephant

Table 3.3.5-2. Relative Densities of Marine Mammal Species Within the Four LTMS Study Areas.

Data from A (Ainley and Allen 1992) and B (Jones and Szczepaniak 1992).

	Study Area 2		Study Area 3		Study Area 4		Study Area 5	
Cetacean Species	A	B	A	B	A	B	A	B
Pacific white-sided dolphin	N	N	L	M	M	N	L	L
Northern right whale dolphin	N	N	N	N	N	N	N	N
Risso's dolphin	N	N	L	N	L	L	N	N
Dall's porpoise	L	L	L	M	N	N	N	L
Harbor porpoise	L	N	N	N	N	N	N	N
Gray whale	N	N	N	N	N	N	N	N
Humpback whale	L	L	N	L	L	N	N	N
Blue whale	N	L	N	L	N	N	N	N
Minke whale	N	N	N	N	L	N	N	N
Pinniped Species								
California sea lion	L	N	N	M	N	N	N	L
Northern elephant seal	L	N	L	N	N	N	L	N
Northern sea lion	N	N	N	L	N	N	N	L
Northern fur seal	L	N	L	L	L	N	L	N
Harbor seal	L	N	N	N	N	N	N	N

N = No mammals observed
L = Low density
M = Moderate density

seals, and harbor seals had large populations of approximately 3,000, 4,000, and 12,000 individuals, respectively.

The Farallon Islands are among the most important pinniped haul-out grounds in California (Bonnell *et al.* 1983). The primary pinniped foraging grounds are the shallow shelf waters from Point Reyes south in summer and fall, and deeper continental slope waters in winter and spring. California sea lions and northern fur seals are present seasonally either along the coast or offshore, and the northern elephant seal, harbor seal, and northern sea lion breed in the area (Table 3.3.5-1). The Guadalupe fur seal (*Arctocephalus townsendi*) is considered an occasional visitor to the area (Bonnell *et al.* 1983).

California Sea Lion

The California sea lion is the most common pinniped at California haul-out areas and in continental shelf waters (KLI 1991). A few pups have been born on Southeast Farallon Island (Pierotti *et al.* 1977; Huber *et al.* in prep.) and on Año Nuevo Island (Keith *et al.* 1984) but viable rookeries have not been established at either site. At sea, California sea lion relative abundance is characterized by two peaks (May-June and September-October) which correspond to peaks in abundance in haul-out areas. These peaks are due to the arrival and subsequent departure of transient northern populations, with the highest at-sea mean seasonal density ($0.18/km^2$) recorded in fall (Bonnell *et al.* 1983). During this period, California sea lions feed over Pioneer Canyon (between Study Areas 3 and 4) and Cordell Bank. Primary prey items include crabs, squid, herring, hake, and mackerel (Ainley and Allen 1992). During the EPA (1992) surveys, California sea lions were the most abundant pinniped in all seasons; the greatest number of individuals were observed during August in slope waters near Study Area 3 (Figure 3.3.5-11a). PRBO (1992) reported California sea lions as the second most common pinniped of the region (following northern fur seals) occurring primarily along the continental shelf including Study Area 2 (Figure 3.3.5-11b).

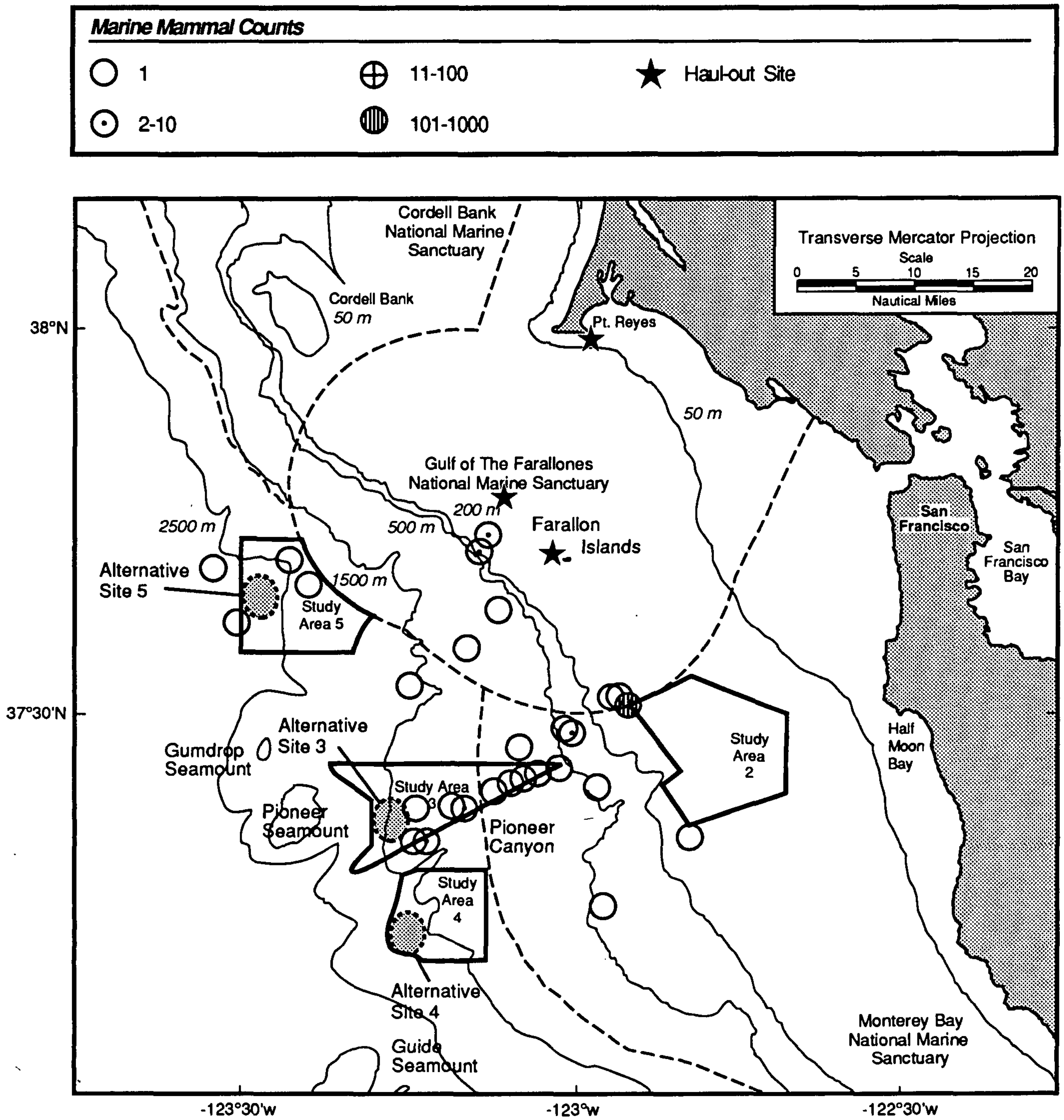


Figure 3.3.5-11a. California Sea Lion Counts in the Gulf of the Farallones Region, August 1990 and 1991.
Source: Jones and Szczepaniak 1992.

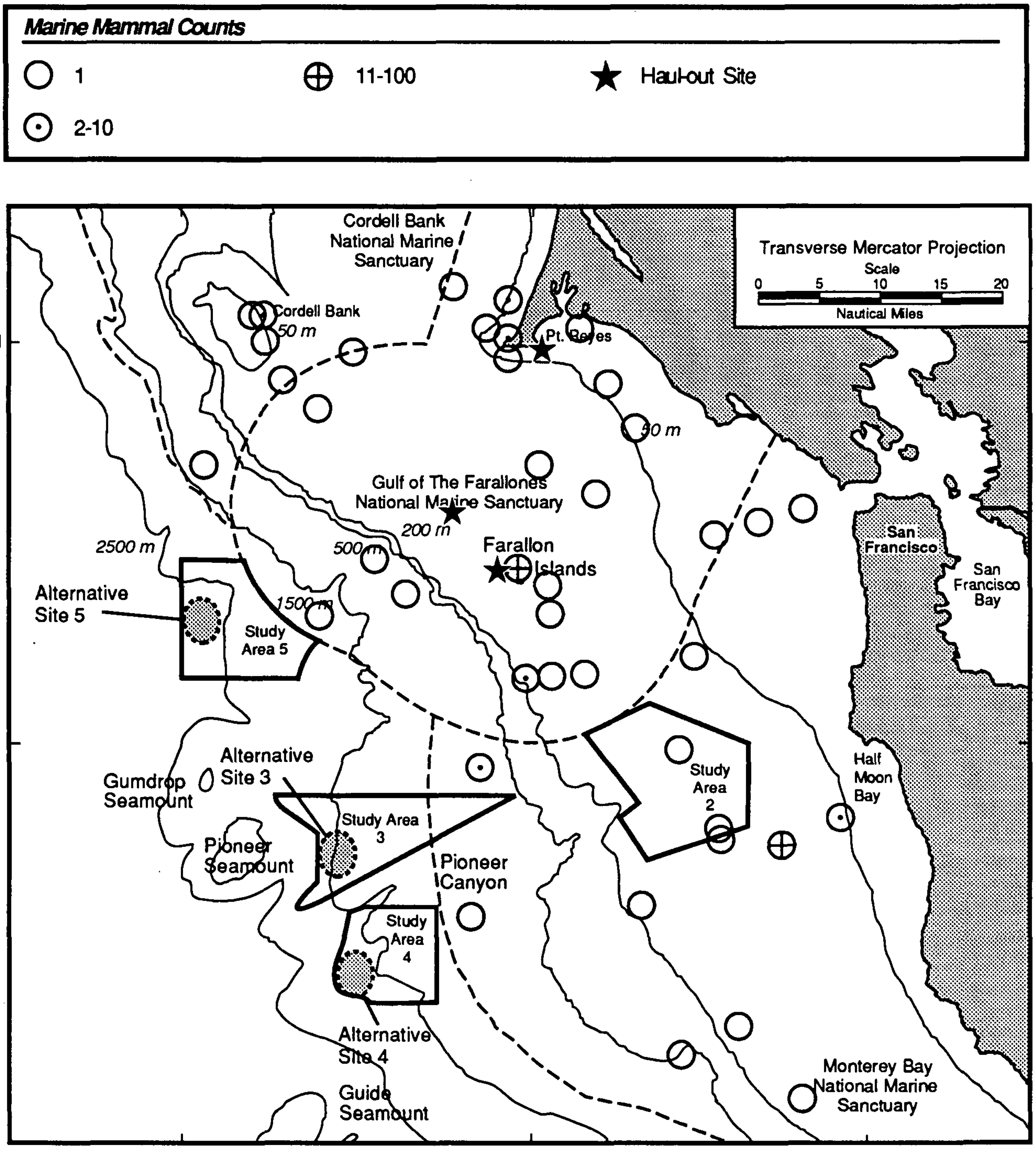


Figure 3.3.5-11b. California Sea Lion Counts in the Gulf of the Farallones Region, 1985-1991.
Source: Ainley and Allen 1992.

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Northern Elephant Seals

Northern elephant seals are present year-round in the study region and reach peak numbers in haul-out areas during the spring (Bonnell *et al.* 1983). Their breeding range extends from Point Reyes to Isla Cedros in Baja California (Le Boeuf *et al.* 1978) and includes a breeding colony on Southeast Farallon Island. The greatest numbers of elephant seals near the study areas were sighted near the Año Nuevo and Farallon rookeries and in areas over the continental slope from Point Reyes to Monterey Bay (Bonnell *et al.* 1983) where they feed primarily on squid, octopus, hagfish, anchovies, and rockfish (Ainley and Allen 1992). The few northern elephant seals seen during PRBO (1992) surveys were primarily over slope waters (Figure 3.3.5-12); EPA (1992) censuses recorded five sightings over slope waters although no northern elephant seals were observed in the LTMS study areas. Northern elephant seals may dive to depths of 1,500 m (Ainley and Allen 1992) and often remain at the surface for less than one minute when feeding. This may account for the few species sightings within the region (Le Boeuf *et al.* 1978). Conversely, other pinniped species such as northern fur seals may rest at the surface for hours (Gentry and Kooyman 1986) making them more likely to be observed during censusing.

Northern Sea Lion

Northern sea lion populations have declined since the 1940s and currently include about 3,000 individuals statewide (KLI 1991). They are currently listed as a threatened species by the Federal government. Northern sea lions usually are sighted in shallow waters from less than 1 km to 55 km offshore. Most are found in four areas within 45 km of the coast: (1) Cape Mendocino to the Klamath River; (2) Cordell Bank; (3) north of Point Arena; and (4) the continental slope between the Farallon Islands and Año Nuevo Island. The largest northern sea lion rookery in California is on Año Nuevo Island and includes over 1,000 animals. A rookery of about 200 animals exists on Southeast Farallon Island; however, fewer than 30 pups are reported born per year (Huber *et al.* in prep.). There is a minor haul-out area at Point Reyes Headland. Northern sea lions feed primarily on squid, octopus, and fish such as smelt, flatfishes, and rockfishes

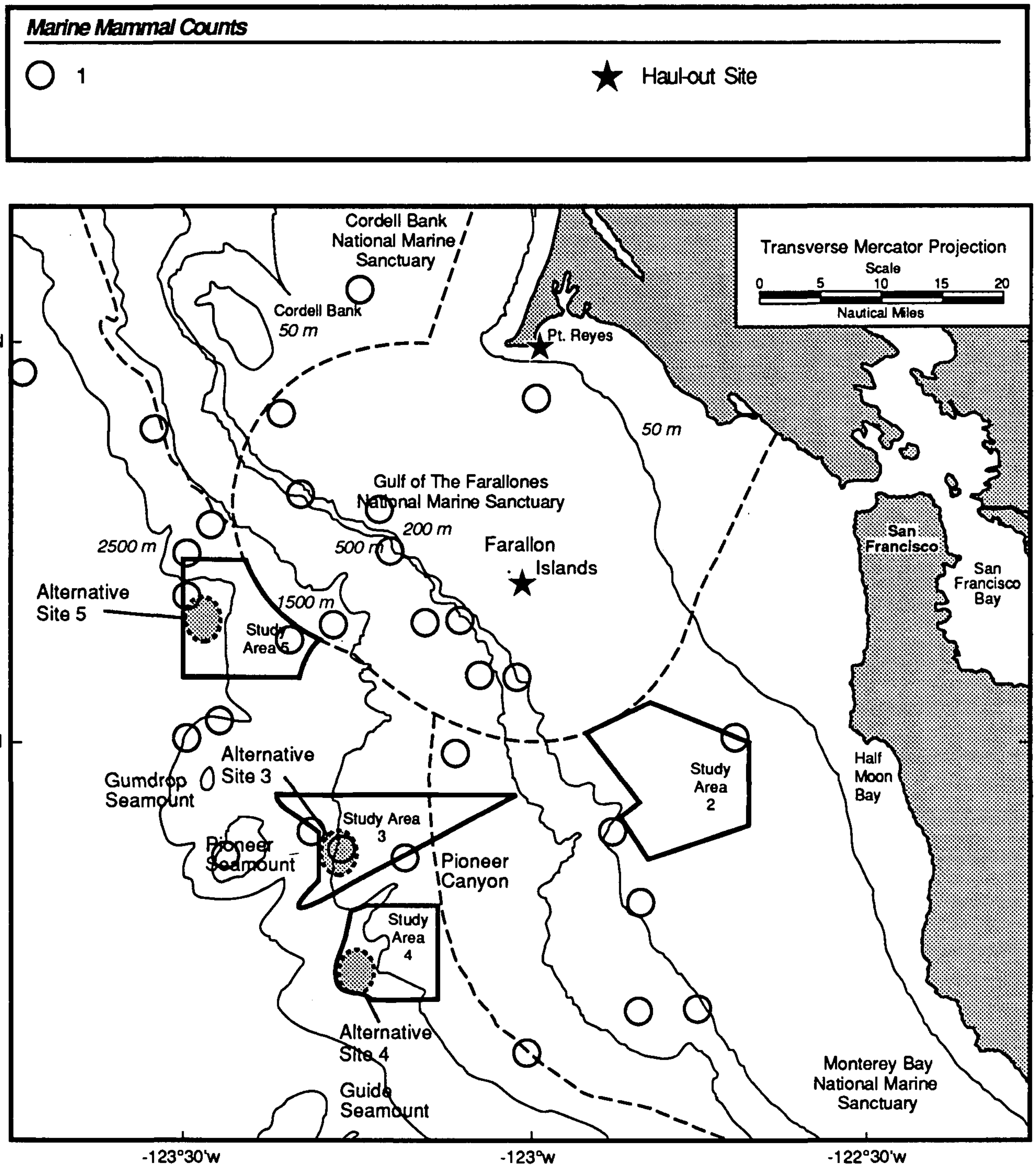

Figure 3.3.5-12. Northern Elephant Seal Counts in the Gulf of the Farallones Region, 1985-1991.
Source: Ainley and Allen 1992.

(Ainley and Allen 1992). Northern sea lions were observed twice during seasonal studies: once each in Study Areas 3 and 5 (Figure 3.3.5-13a) (Jones and Szczepaniak 1992). Two individuals were observed during the PRBO (1992) surveys, one northwest of the Gulf of the Farallones National Marine Sanctuary and one along the coast south of Point Reyes (Figure 3.3.5-13b) (Ainley and Allen 1992).

Northern Fur Seals

Northern fur seals are the predominant pinnipeds in waters seaward of the continental shelf (greater than 200 m) in winter and spring, with an estimated 25,000–30,000 animals present off central and northern California (Bonnell *et al.* 1983). They are designated as a depleted species by the Marine Mammal Commission. A few individuals haul out on Año Nuevo Island and the Farallon Islands (Le Boeuf and Bonnell 1980; Huber *et al.* in prep.). Although the species occurs year-round in the study region, it is considered primarily a winter-spring pelagic visitor to the area (Bonnel *et al.* 1983; KLI 1991). Their numbers increase in abundance offshore with the arrival of northern migrants in the winter. Most return to their Bering Sea rookeries in late spring (York 1987) or to rookeries on San Miguel Island in southern California. Northern fur seals consume a variety of prey including crabs, squid, sablefish, anchovies, and rockfish (Ainley and Allen 1992). Within the study region, northern fur seals were the second most frequently observed pinniped during seasonal surveys (Jones and Szczepaniak 1992) and the most common pinniped during June 1985–91 surveys (Ainley and Allen 1992). Northern fur seals were seen within Study Area 3 and near Study Areas 4 and 5 during EPA (1992) surveys (Figure 3.3.5-14a). During June 1985–91, northern fur seals were seen in low numbers within all of the study areas, although the greatest concentrations were found north and west of Study Area 5 (Figure 3.3.5-14b).

In general, pinniped sightings were rare within the study areas (Ainley and Allen 1992; Jones and Szczepaniak 1992). Table 3.3.5-2 presents a summary of pinniped occurrences within the four study areas. These results in conjunction with actual sightings as shown in Figures 3.3.5-11a through 3.3.5-15 indicate that the slope waters of Study Areas 3 and 5 support the highest

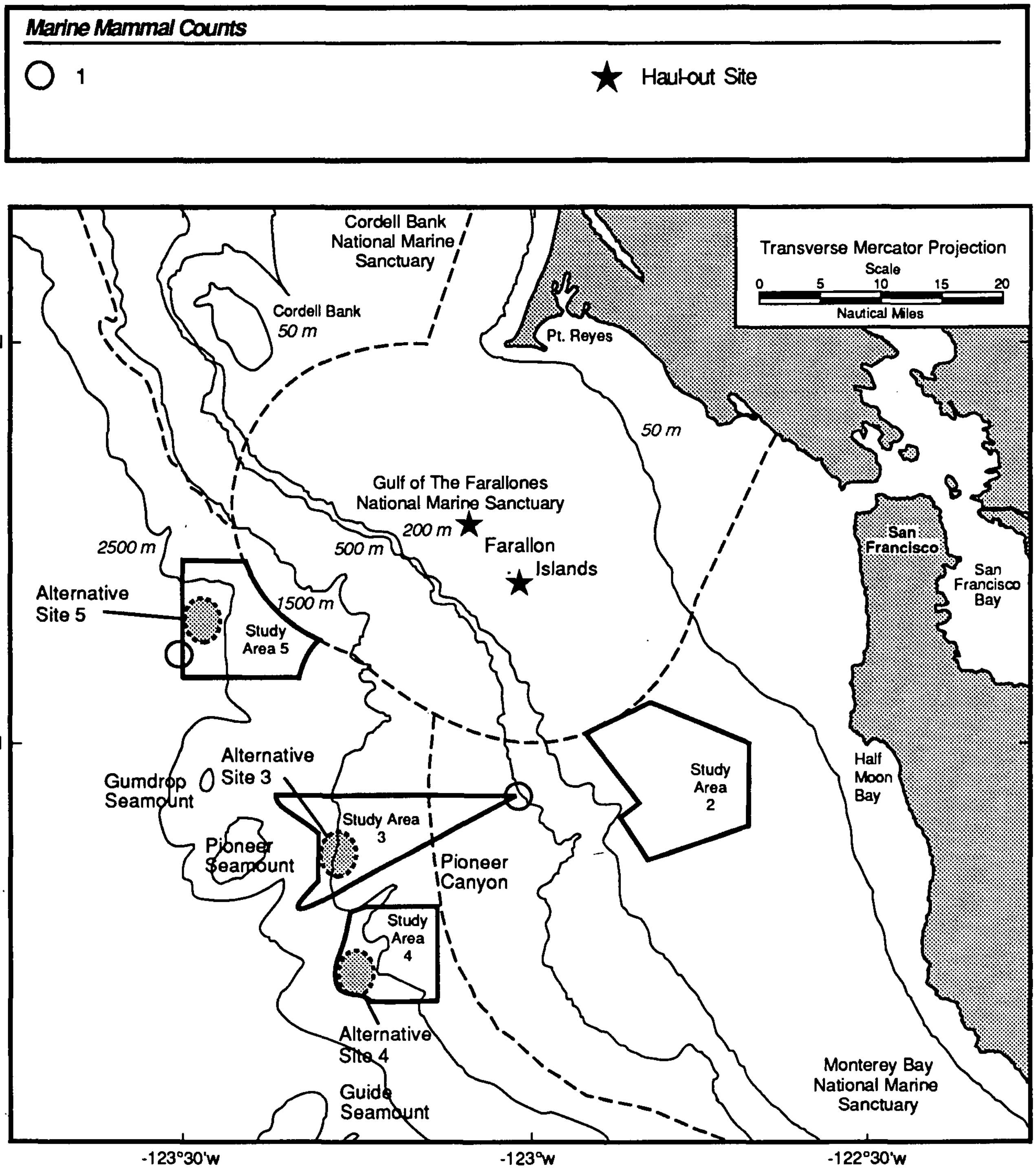

Figure 3.3.5-13a. Northern Sea Lion Counts in the Gulf of the Farallones Region, August 1990 and 1991.
Source: Jones and Szczepaniak 1992.

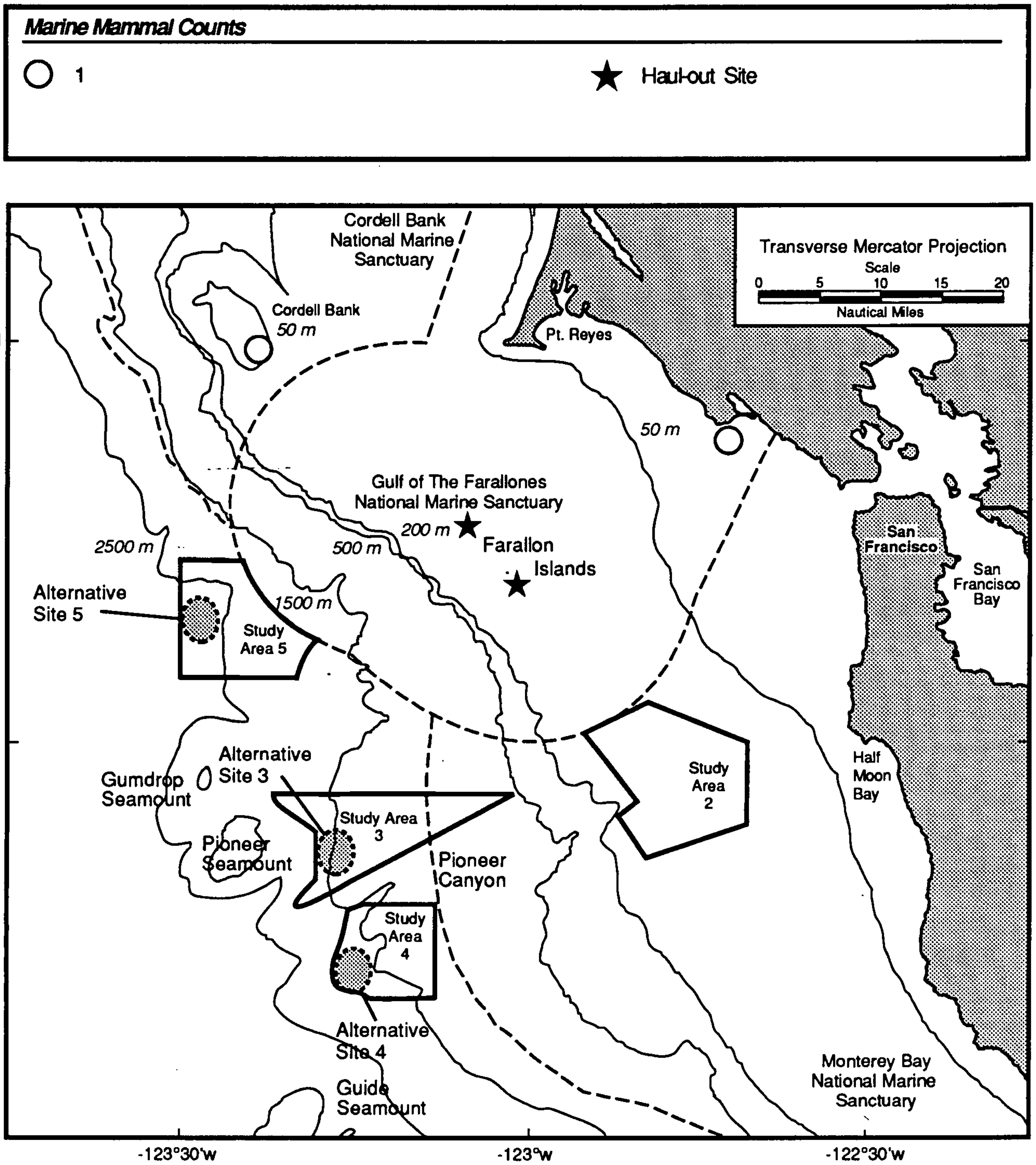

Figure 3.3.5-13b. Northern Sea Lion Counts in the Gulf of the Farallones Region, 1985-1991.
Source: Ainley and Allen 1992.

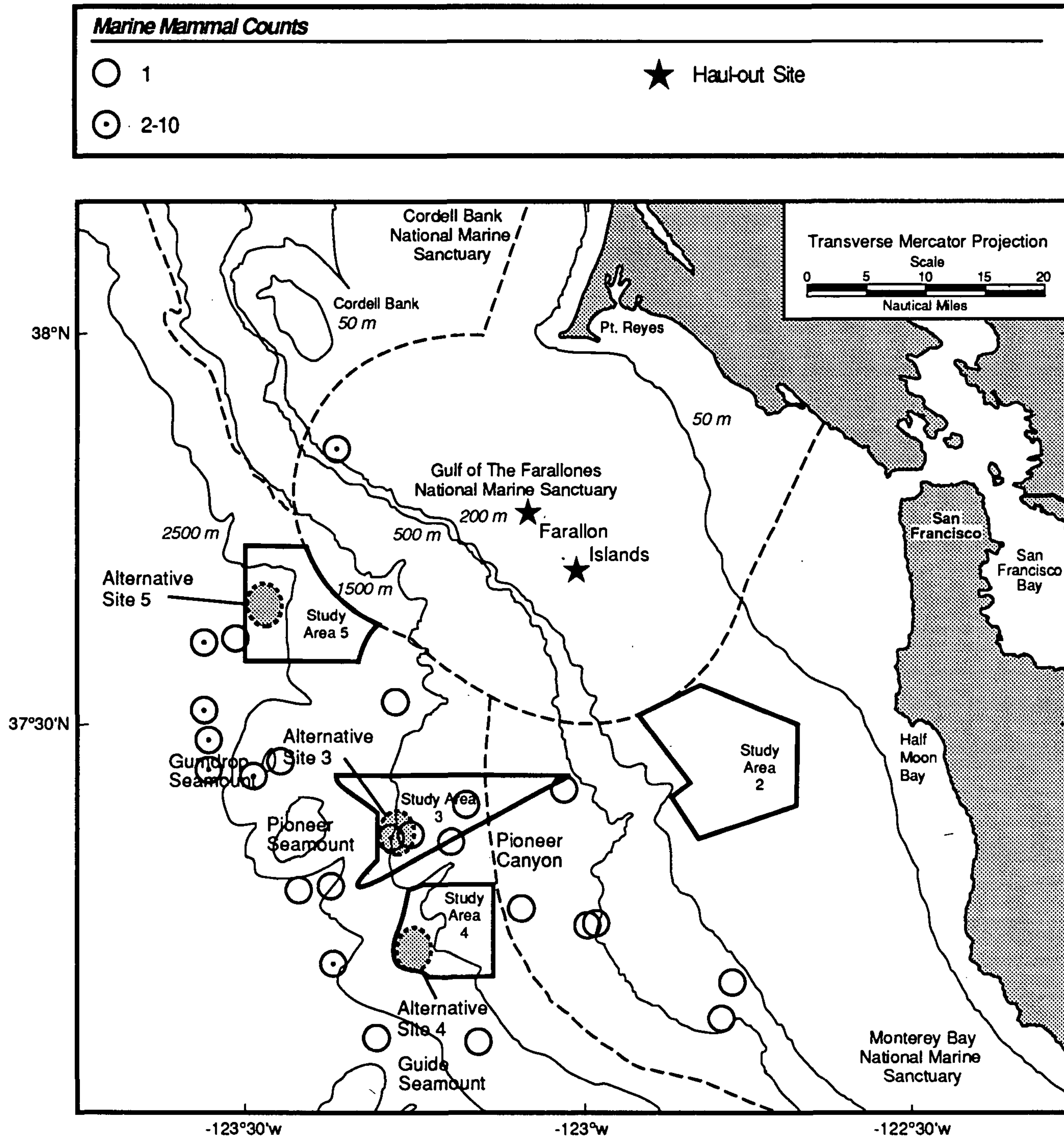

Figure 3.3.5-14a. Northern Fur Seal Counts in the Gulf of the Farallones Region, August 1990, February, May, August, November 1991.
Source: Jones and Szczepaniak 1992.

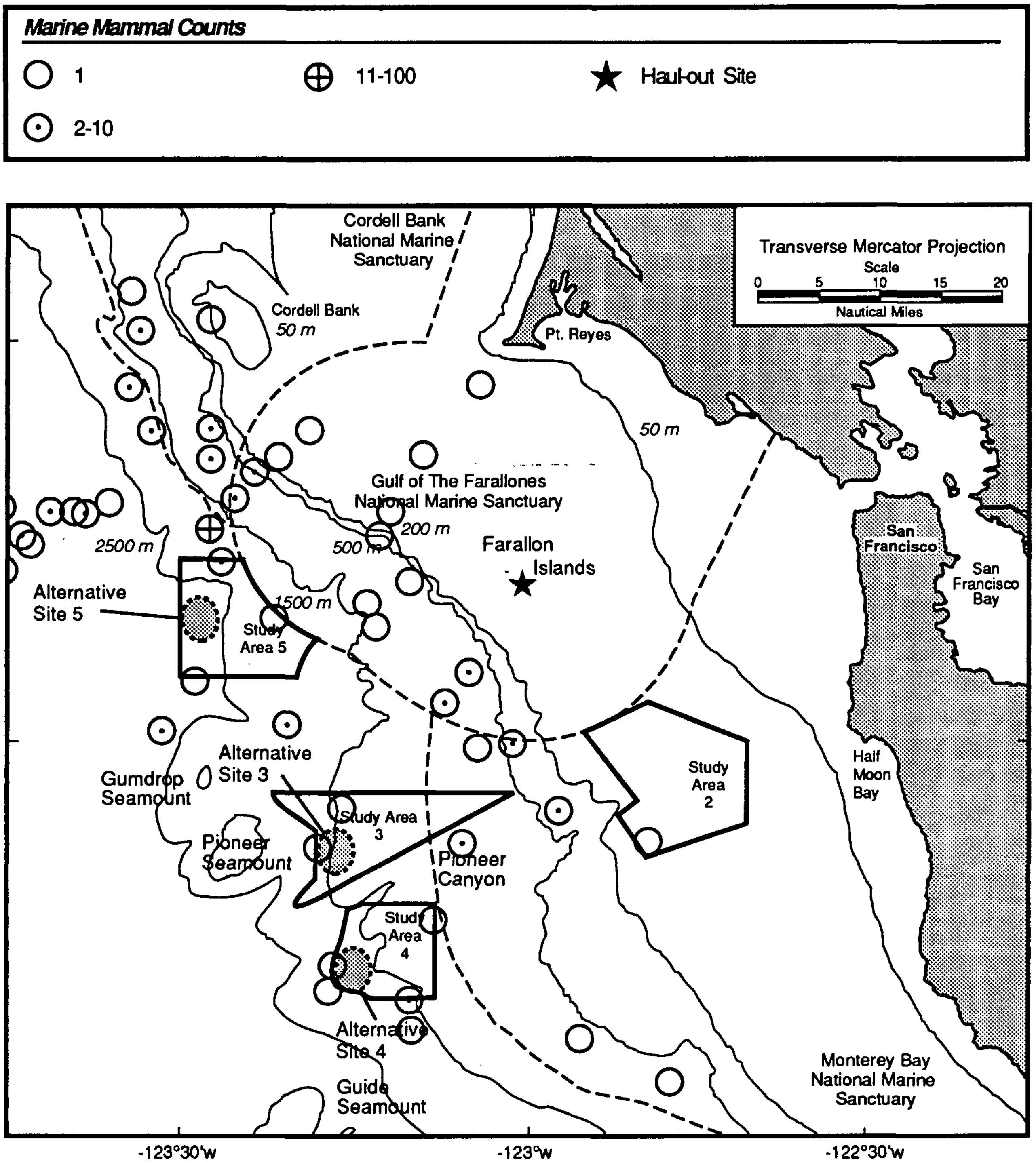

Figure 3.3.5-14b. Northern Fur Seal Counts in the Gulf of the Farallones Region, 1985-1991.
Source: Ainley and Allen 1992.

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concentration of pinnipeds. Of the five pinnipeds cited, four occurred most often in Study Area 3. The remaining pinniped was the harbor seal which is rarely seen in deeper, slope waters (KLI 1991).

Harbor Seals

Harbor seals are year-round residents of the central California coast, and haul out at islands, secluded beaches, estuaries, and offshore rocks between Año Nuevo and Point Reyes (Allen and Huber 1983, 1984; Bonnell *et al.* 1983; Allen *et al.* 1986; Hanan *et al.* 1987). They forage close to shore, feeding on crabs, squid, smelt, mackerel, and rockfish (Ainley and Allen 1992), and rarely are seen in water deeper than 180 m (KLI 1991). Harbor seals are locally migrant and are seasonally most abundant onshore during the spring breeding season (March–June) and the summer molt (June–August). They rest onshore almost daily but spend more time on land during early spring and winter months, averaging 17 hours per day on land (Allen *et al.* 1987). During PRBO (1992) surveys, most harbor seals (80%) were seen over continental shelf waters, in and around Study Area 2 (Figure 3.3.5-15). No harbor seals were observed during the seasonal survey effort (Jones and Szczepaniak 1992).

3.3.5.3 Fissipeds

Southern sea otters are common to the general study region, but occur primarily along the mainland south of Point Año Nuevo to Point Conception (Bonnell *et al.* 1983). Sea otters normally reside nearshore (within 2,000 feet of shore) and feed on shellfish and fish (Siniff and Ralls 1988). Recently, there have been major, unpredictable shifts in their distribution along the coast. According to the California Department of Fish and Game (CDFG), a group of 11 to 25 otters was observed several times north of Año Nuevo between September 1986 and April 1987. In October 1986, a single sea otter was observed for a four-day span at the Southeast Farallon Island (PRBO, unpubl. data). Incidental sightings also occur annually along the Point Reyes peninsula (PRBO, unpubl. data). Sea otters were not observed near any of the proposed study areas during recent survey efforts (Ainley and Allen 1992; Jones and Szczepaniak 1992). Their

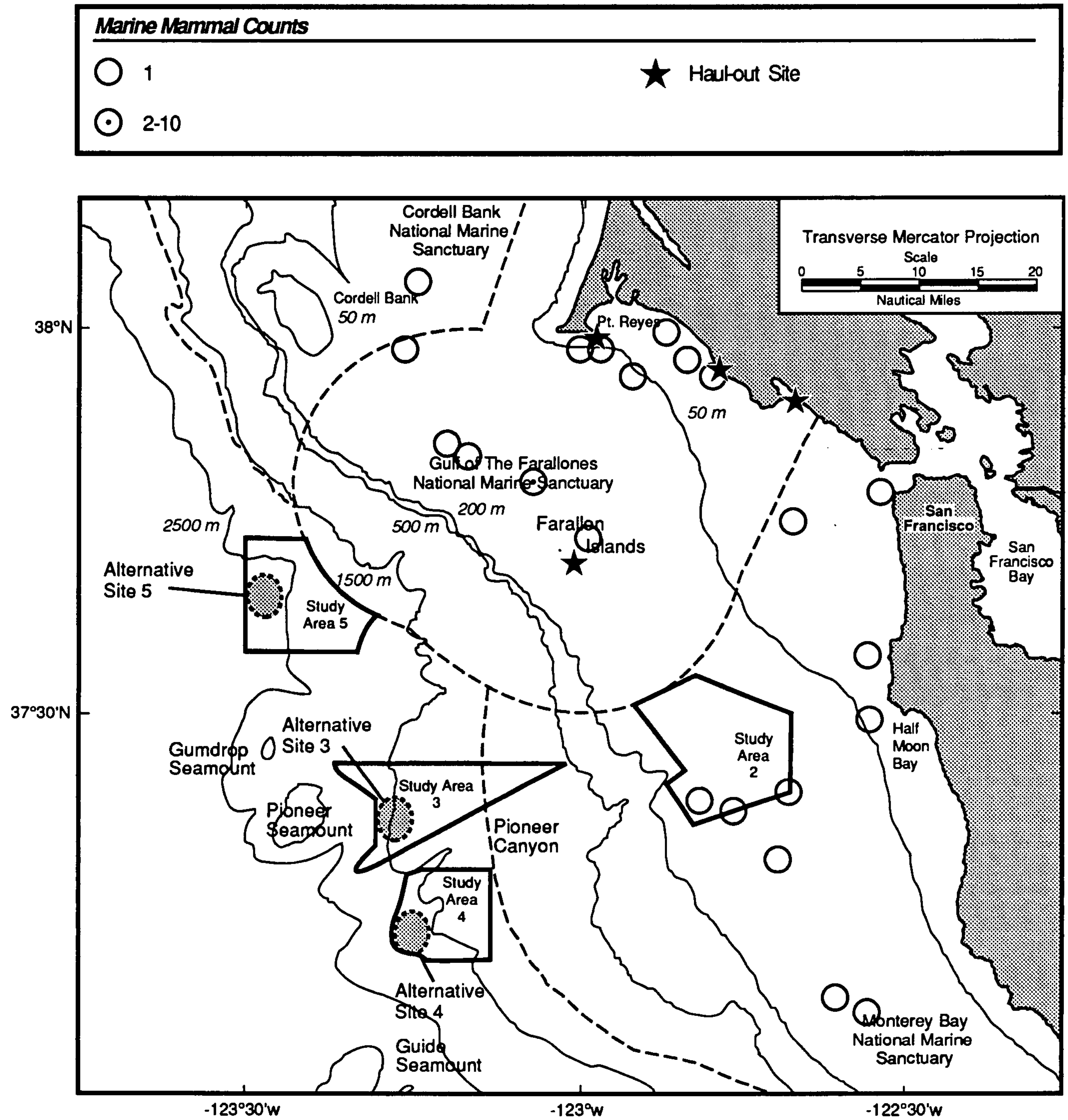


Figure 3.3.5-15. Harbor Seal Counts in the Gulf of the Farallones Region, 1985-1991.
Source: Ainley and Allen 1992.

typical habitat is rocky intertidal and kelp bed areas (Ainley and Allen 1992) which suggests that their presence is unlikely within any of the deep, slope waters of the LTMS study areas.

3.3.6 Threatened, Endangered, and Special Status Species

This section presents information on threatened, endangered, and special status species that occur within the LTMS study region. Species that occur regularly, and species that occur rarely in the study region are discussed in separate sections.

3.3.6.1 Species Observed Regularly Within the Study Region

Nine known threatened or endangered species regularly occur in the general study region. These include five whale species (gray, humpback, blue, finback, and sperm), one pinniped (northern sea lion), two bird species (Peregrine falcon and California brown pelican), and one fish species (winter-run chinook salmon). The current status of these species under the Federal Endangered Species Act (ESA) and the State of California endangered or protected species list is summarized in Table 3.3.6-1. The ESA coordination process will occur concurrently with the review of the draft EIS and the preparation of the final EIS. Coordination information will be included in the final EIS. Formal consultation letters (see Chapter 5) requesting advisement of (1) the presence of any listed or candidate, threatened, or endangered species, and (2) any critical habitat of these species that may be impacted by dredged material disposal, within the four LTMS study areas were submitted to the Fish and Wildlife Service, National Marine Fisheries Service, and the California Department of U.S. Fish and Game as required by the Endangered Species Act Section 7(c).

The species listed in Table 3.3.6-1 are subject to full protection under the Federal ESA (see Section 1.6.2.7). The ESA prohibits the take of any listed species, generally defined as prohibiting any harassment, harm, pursuit, hunting, shooting, wounding, killing, trapping, capture, collection, or attempts at such conduct. In addition to the ESA, marine mammals are protected by the Marine Mammal Protection Act which established a moratorium on the taking or

Table 3.3.6-1. **Threatened or Endangered Species Occurring in the Study Areas (modified from KLI 1991).**

Common Name	Scientific Name	Status
Cetaceans		
Gray Whale	*Eschrichtius robustus*	FE
Humpback Whale	*Megaptera novaeangliae*	FE
Blue Whale	*Balaenoptera musculus*	FE
Finback Whale	*Balaenoptera physalus*	FE
Sperm Whale	*Physeter macrocephalus*	FE
Pinnipeds		
Northern Sea Lion	*Eumotopias jubatus*	FT
Marine Birds		
Peregrine Falcon	*Falco peregrinus*	SE, FE
California Brown Pelican	*Pelecanus occidentalis californicus*	SE, FE
Marine Fishes		
Winter-run Chinook Salmon	*Oncorhyncus tshawytscha*	SE, FT

FE = Federally listed endangered
ST = State listed threatened
FT = Federally listed threatened
SE = State listed endangered

Note: Additional threatened, endangered, or candidate species that occur rarely within the study region are discussed later in Section 3.3.6.

importing of marine mammals or marine mammal products. One of the Act's management requirements seeks to attain an "optimum sustainable population" for all marine mammal species, including additional protection of those populations considered depleted.

NMFS is responsible for the protection of cetaceans, pinnipeds, and fishes, while FWS is charged with responsibility for protection of birds. CDFG has jurisdiction over endangered or threatened species in State waters.

Details on the biology and distributions of the eight species observed within the study region are provided in Sections 3.3.5 (Marine Mammals), 3.3.4 (Marine Birds), and 3.4.1. (Commercial Fisheries). A brief summary of species occurrence (based on historic surveys and recent annual and seasonal censuses) within the four Study Areas is presented below.

Cetaceans

Gray whales generally migrate twice annually through the study region (Table 3.3.5-2), although currently they are observed year-round in central California (Ainley and Allen 1992) and have been observed summering (Dohl *et al.* 1983; Huber *et al.* 1986) and overwintering (PRBO unpubl. data) around the Farallones. Three sightings of gray whales were made during annual surveys conducted during late spring from 1985–91 (Ainley and Allen 1992). All of the sightings occurred within the GOFNMS; highest counts (11–100 individuals) were observed near the northeast border of Study Area 5 (Figure 3.3.5-7) (Ainley and Allen 1992). No gray whales were observed during similar surveys conducted over four seasons in 1990–91, although this was likely due to the fact that most of the areas surveyed during the months of high migratory activity were over deep waters, where gray whales are rarely seen (Jones and Szczepaniak 1992).

Humpback whales typically are found in the study region from March through January with greatest concentrations occurring from mid-August through October (Dohl *et al.* 1983; Baker *et. al.* 1986; Calambokidis *et al.* 1990a). Annual surveys conducted June 1985–1991 (Ainley and Allen 1992) recorded the greatest abundances (2–10 individuals) near the southeast corner of

Study Area 2 and between Study Areas 3 and 4 (Figure 3.3.5-8b). In contrast, August surveys (Jones and Szczepaniak 1992) recorded similar numbers of individuals within Study Area 3 and the region between Study Areas 2 and 3 (Figure 3.3.5-8a).

Similar to humpback whales, the greatest abundances of blue whales within the Farallon Basin occur in summer and early fall, although overall numbers are lower than those of humpback whales (Dohl *et al.* 1983). Studies conducted from 1986–1989 identified a total of 179 blue whales within the Gulf of the Farallones (Calambokidis 1990b). In 1986, an aggregation of 41 blue whales was sighted near Southeast Farallon Island (National Marine Sanctuary Program 1987). Recent seasonal studies (Jones and Szczepaniak 1992) recorded blue whales between Study Areas 2 and 3 and within Study Area 3, with greatest abundances along the continental shelf break (Figure 3.3.5-9).

During their 1980–83 survey, Dohl *et al.* (1983) recorded 30 sightings of 56 finback whales, primarily over continental shelf and slope waters. In addition, this survey observed a group of five to eight finbacks just south of the Farallon Islands, and a single individual approximately 20 km west of Point Reyes. No finback whales were sighted within the region during recent annual (Ainley and Allen 1992) and seasonal surveys (Jones and Szczepaniak 1992).

Dohl *et al.* (1983) characterized sperm whales as regular visitors to the Gulf of the Farallones, with records of 66 sightings for a total of 218 individuals from 1980–83. Most of the sightings occurred in deeper waters (> 1700 m); four individuals were sighted in Study Area 5. Although sperm whales historically were listed as the sixth most common cetacean in the region, recent surveys recorded no sightings of this species (Ainley and Allen 1992; Jones and Szczepaniak 1992).

Pinnipeds

Due to a recent reduction in their numbers, northern sea lions were listed as threatened under the ESA. Although this species is one of three pinniped species that breeds in the region, few sightings were made during recent surveys (Ainley and Allen 1992; Jones and Szczepaniak 1992). Ainley and Allen (1992) recorded two sightings of single individuals, one near Cordell Bank and one nearshore within the eastern boundary of the GOFNMS. Similarly, Jones and Szczepaniak (1992) sighted only two individuals, one on the eastern boundary of Study Area 3 and one at the western boundary of Study Area 5.

Although currently not listed as endangered or threatened, the northern fur seal is considered depleted under the Marine Mammal Protection Act. It is found primarily over the continental slope and was the most abundant pinniped species in the study region during June surveys (Ainley and Allen 1992). During these surveys, low densities of northern fur seals (0.01–10 seals/km^2) were observed in all of the study areas, but mostly in Study Areas 3 and 5. Jones and Szczepaniak (1992) listed northern fur seals as the second most frequently sighted pinniped. Similar to Ainley and Allen (1992), most sightings occurred over the continental slope, although almost half of the sightings occurred west of the study areas (Jones and Szczepaniak 1992).

Birds

Peregrine falcons are Federally and State listed as endangered species. They are considered rare in the region, but historically bred on the Farallon Islands (DeSante and Ainley 1980). Currently, a relatively high number of individuals (5–8) continue to winter on the Islands (PRBO, unpubl. data). During winter/spring NMFS cruises, two Peregrine falcons were observed foraging over waters north and west of the Farallon Islands (PRBO, unpubl. data). No Peregrine falcons were observed during annual or seasonal surveys (Ainley and Allen 1992; Jones and Szczepaniak 1992).

Although currently Federally and State listed as endangered, California brown pelican populations appear to be recovering (Ainley and Allen 1992). Large numbers of pelicans roost at various sites within the general study region including the Farallon Islands (Pyle and Henderson 1991) and coastal mainland sites (Shuford *et al.* 1989). Recent annual surveys (Ainley and Allen 1992) suggest that pelican populations are concentrated nearshore, over waters shallower than 180 m

(Figure 3.3.4-5). Seasonal surveys (Jones and Szczepaniak 1992) also concluded that abundances were greatest over continental shelf and upper slope waters.

Fishes

A dramatic reduction in winter-run chinook populations over the past two decades has led to its listing as a threatened species by the Federal government and as an endangered species by the State of California.

Winter-run chinook salmon are an anadromous species that pass through the Delta, San Pablo Bay, and San Francisco Bay during their upstream and downstream migrations (J. Turner, CDFG, pers. comm. 1991). Although this species is the least abundant Pacific salmon, it has the highest value per pound and is fished commercially in North America from Kotzebue Sound, Alaska, to Santa Barbara, California (Emmett *et al.* 1991). Juveniles of the species are ocean-dwelling and occur primarily over continental shelf waters (Fredin *et al.* 1977). Commercial fish block data for the study region (MMS/CDFG Commercial Fisheries Database 1992) indicate highest abundances of salmon including winter-run chinook are caught within shelf regions such as Study Area 2 (Figure 3.4-3).

3.3.6.2 Species Occurring Irregularly Within the Study Region

In addition to the species listed in Table 3.3.6-1, several other species that are currently listed as endangered, threatened, or are candidates for special legal status occur irregularly within the study region.

Cetaceans

Sei and right whales currently are listed as endangered under the Federal ESA. Although the Gulf of the Farallones lies within the distributional range of both species (Caldwell and Caldwell

1983), neither were observed during historic surveys (Dohl *et al.* 1983) or during recent survey efforts (Ainley and Allen 1992; Jones and Szczepaniak 1992).

Pinnipeds

The Guadalupe fur seal (*Arctocephalus townsendi*) is considered a threatened species by Federal and State agencies. Currently, this species is known to breed only at Guadalupe Island, Baja, Mexico; sightings have been restricted to waters south of the Channel Islands (Bonnell *et al.* 1978). Historic estimates include approximately 2,000 individuals (Fleischer 1978). Guadalupe fur seals are believed to be pelagic throughout most of the year except during the summer breeding season. Although this species was not observed during recent annual and seasonal surveys (Ainley and Allen 1992; Jones and Szczepaniak 1992), it may be a rare visitor to regional waters (KLI 1991).

Fissipeds

The Southern sea otter is a geographic variant of the Alaskan otter (Kenyon 1987), and was Federally listed as threatened in 1977. Its distribution ranges from Point Año Nuevo south to Pismo Beach (Jameson 1989). Although no sightings of the Southern sea otter were made within any of the study areas (Ainley and Allen 1992; Jones and Szczepaniak 1992), one was recorded near Point Año Nuevo, the northern extent of its range (Ainley and Allen 1992). Southern sea otters typically inhabit rocky intertidal and kelp bed areas (Ainley and Allen 1992). Thus, it is unlikely that they would be present within any of the deep, slope waters of the LTMS study areas.

Birds

The short-tailed albatross is also a Federally endangered species. According to Ainley and Allen (1992), only two individuals have been sighted in the study region, although historically the short-tailed albatross was a common species in offshore waters of the North American West

Coast. Of the two individuals sighted within the region, one was seen at Cordell Bank and the other in Monterey Bay (PRBO, unpubl. data).

In addition, the American osprey (*Pandion haliaetus*) is Federally and State listed as endangered. This species is a breeding, year-round resident of the general coastal region (Ainley and Allen 1992). A small population (approximately 100 individuals) of American osprey nest at a coastal site in Marin County (Ainley and Allen 1992). Osprey typically forage close to shore, and thus are rarely observed farther than a few kilometers from the coast (Ainley and Allen 1992). No osprey were observed within any of the study areas during recent annual and seasonal surveys (Ainley and Allen 1992; Jones and Szczepaniak 1992).

The marbled murrelet (*Brachyramphus marmoratus*) has special status within California as a candidate threatened species. Similar to the osprey, this species rarely forages farther than three to five kilometers offshore (Ainley and Allen 1992) and was not observed within any of the study areas during annual or seasonal surveys (Ainley and Allen 1992; Jones and Szczepaniak 1992).

Turtles

The leatherback sea turtle (*Dermochelys coriacea*) is the most frequently sighted marine turtle within northern and central California (Dohl *et al.* 1983). This species currently is Federally listed as endangered. During recent seasonal surveys (Jones and Szczepaniak 1992), two sightings, each of a single leatherback turtle, were made. The first sighting occurred in shallow water (54 m depth) north of Study Area 2, while the second observation was at approximately 1,000 m depth, northeast of Study Area 4. Both sightings occurred in August, consistent with Dohl *et al.* (1983) findings of highest leatherback abundances during summer and fall months.

3.3.7 Marine Sanctuaries and Special Biological Resource Areas

Six areas are designated as marine sanctuaries, refuges, or special biological resource areas within the vicinity of the LTMS study areas. Four of these are Federally protected (GOFNMS, CBNMS, MBNMS, and the Farallon National Wildlife Refuge), and two are protected by the State of California (Farallon Islands ASBS and the Farallon Islands Game Refuge) (Figures 3.3.7-1 and 3.3.7-2). Collectively, these six areas contain a wide diversity of sensitive habitats and biological resources, including threatened or endangered species.

3.3.7.1 Federally Protected Areas

Sanctuaries

The Marine Protection, Research, and Sanctuaries Act of 1972 (MPRSA) was designed to protect and manage discrete areas having special ecological, recreational, historical, and aesthetic resources. The Gulf of the Farallones, Cordell Bank, and Monterey Bay National Marine Sanctuaries (Figure 3.3.7-1) are three of eleven designated national marine sanctuaries. All national marine sanctuaries are administered by NOAA's Sanctuaries and Reserves Division (NOAA 1992).

Gulf of the Farallones National Marine Sanctuary. The GOFNMS encompasses 948 nmi^2 of nearshore and offshore waters, most of which lie in the Gulf of the Farallones. The Sanctuary extends from approximately the western edge of the continental shelf (35 nmi offshore) to the coasts of Marin and Sonoma Counties. Alternative Site 3 is over 10 nmi southwest of the Sanctuary and more than 25 nmi southwest of the nearest Farallon Island. While Study Area 5 adjoins the western boundary of the Sanctuary, Alternative Site 5 lies nearly 25 nmi west of the Farallon Islands. Study Area 2 begins at the southern boundary of the Sanctuary and lies entirely within the MBNMS (Figure 3.3.7-1).

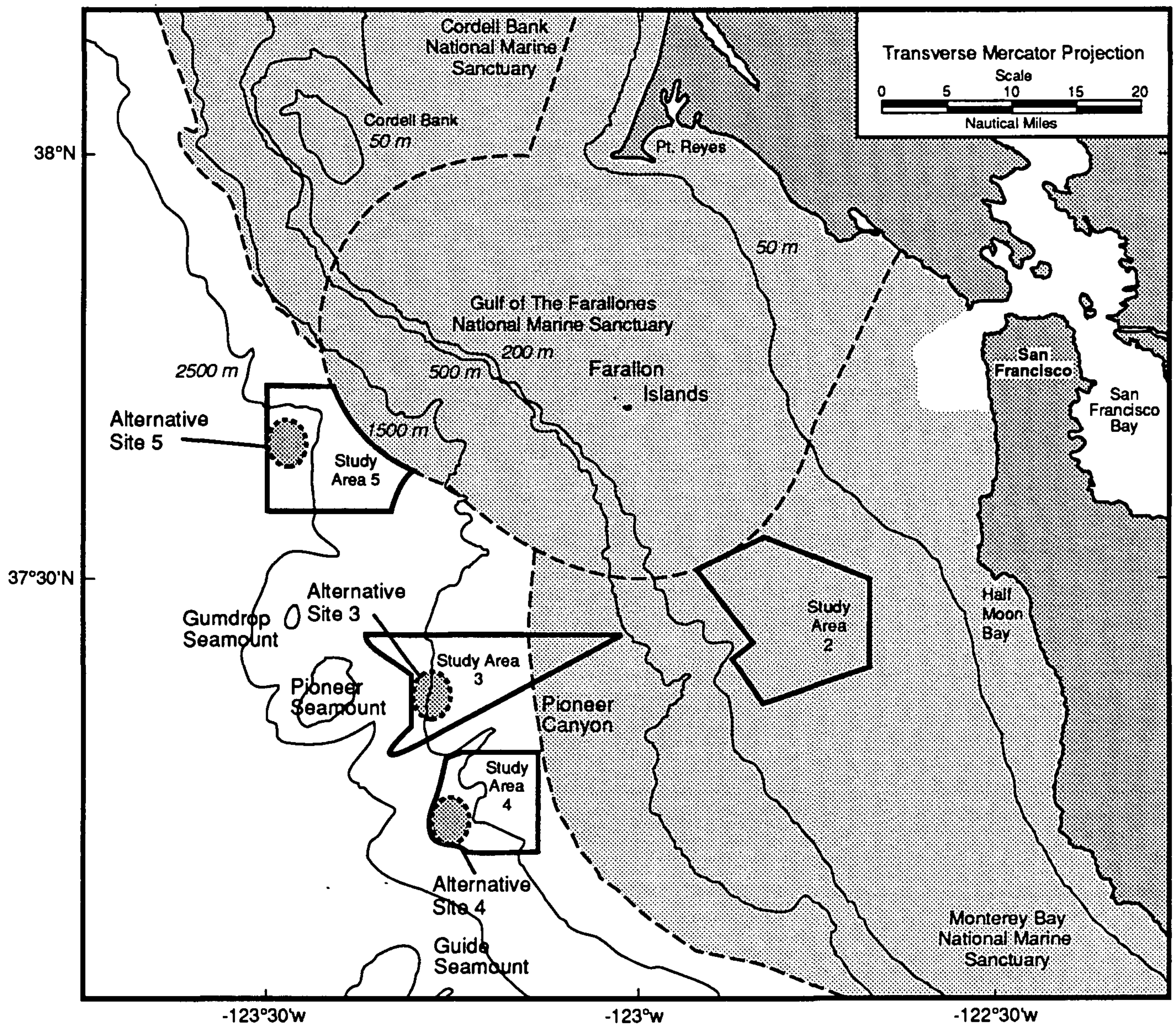
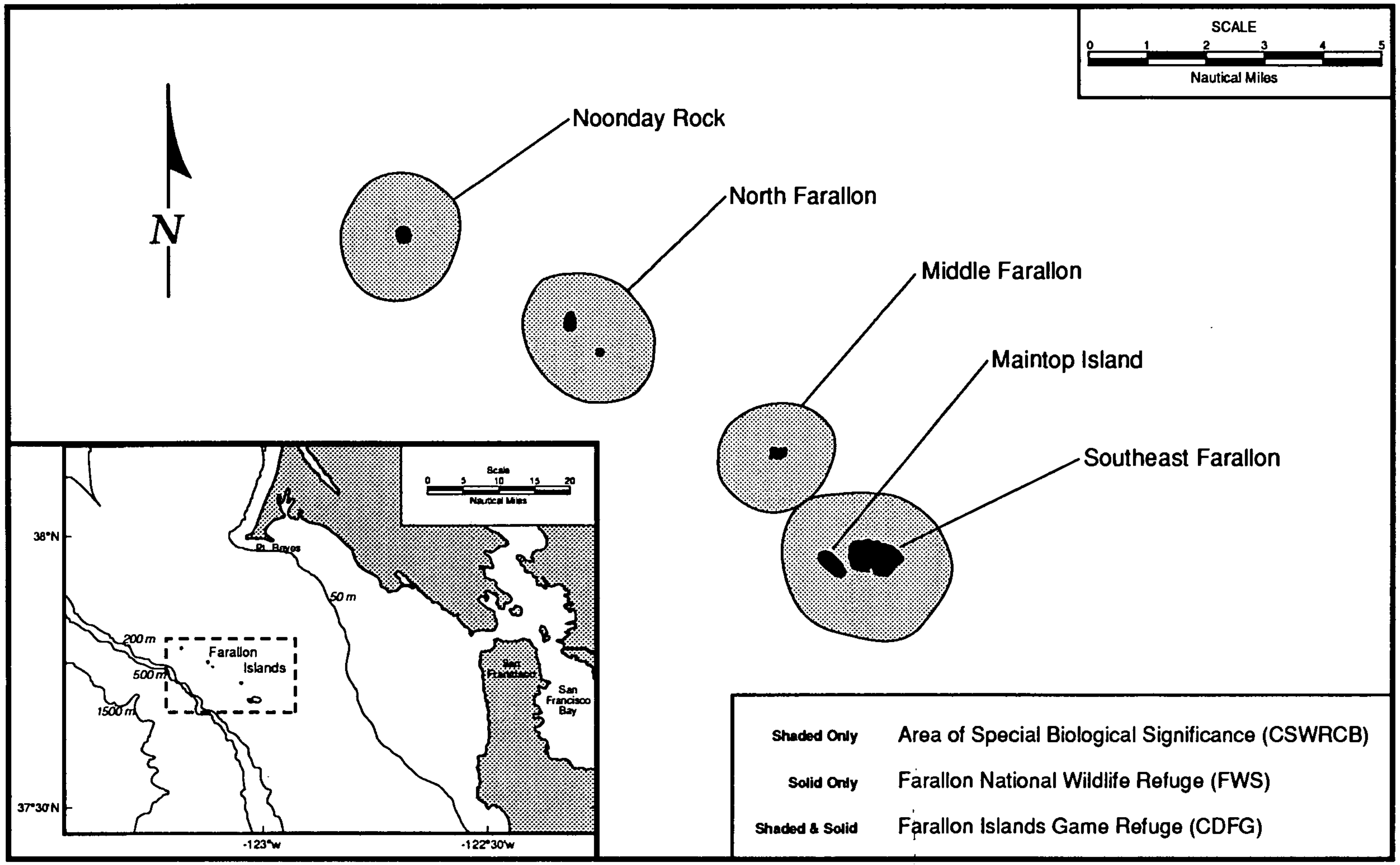


Figure 3.3.7-1. National Marine Sanctuaries in the LTMS Study Region.



Source: Smith and Johnson 1989.

Figure 3.3.7-2. Farallon National Wildlife Refuge, Farallon Islands Area of Special Biological Significance, and Farallon Islands Game Refuge.

The selection of the GOFNMS as a sanctuary (January 26, 1981; 46 FR 7936) was based on the high concentration of biological resources living within or migrating through its boundaries. These resources include: (1) marine vegetation (particularly kelp, eelgrass, and salt marsh species); (2) benthic fauna; (3) fish; (4) marine birds; and (5) marine mammals (NOAA 1980).

One of GOFNMS' most extensive resources is its marine bird population. The Farallon Islands are the most important marine bird breeding site on the west coast of the continental United States (Sowls *et al.* 1980; Briggs *et al.* 1987). There are sixteen species of marine birds known to breed along the Pacific coast and twelve of these species have colonies on the Farallon Islands. This group is comprised of the American black oystercatcher, Ashy storm-petrel, Brandt's cormorant, Cassin's auklet, common murre, double-crested cormorant, Leach's storm-petrel, pelagic cormorant, pigeon guillemot, rhinoceros auklet, tufted puffin, and western gull (Ainley and Lewis 1974). The Farallon Islands serve as the nesting grounds for a significant portion (up to 85%) of the world populations of Ashy storm-petrels, Brandt's cormorants, and western gulls (Ainley and Allen 1992) as well as eighty percent of California's nesting Cassin's auklets (California Coastal Commission 1987). In addition, California brown pelicans roost on the Farallon Islands regularly and abundantly during summer and autumn. Endangered peregrine falcons winter on the islands (NOAA 1980; Ainley and Allen 1992).

Aquatic birds also are found within the Sanctuary's lagoon, coastal bay, and four estuaries. Breeding species include the American coot, cinnamon teal, gadwall, great blue heron, great egret, killdeer, mallard, pied-billed grebe, and snowy plover. An additional twenty aquatic bird species summer in the region, and seven species occur as spring and fall migrants (KLI 1991).

Marine mammals also are a significant part of the Sanctuary's biological resources. Twenty species of whales and dolphins have been sighted in the Sanctuary, occurring either as migrants or regular inhabitants (Table 3.3.5-1). Of these, Dall's porpoise, harbor porpoise, and Pacific white-sided dolphin are considered common resident species (Ainley and Allen 1992). Large baleen cetaceans such as endangered blue, gray, and humpback whales are important migratory species (Dohl *et al.* 1983).

The Farallon Islands also serve as one of the most important pinniped haul-out grounds in California (Bonnell *et al.* 1983). California's largest mainland breeding population of harbor seals occurs within the Sanctuary, along with breeding herds of northern elephant seals and northern sea lions (Ainley and Allen 1992). The threatened southern sea otter is an occasional visitor to the Sanctuary (KLI 1991).

Cordell Bank National Marine Sanctuary. CBNMS encompasses 397 nmi^2 of ocean water overlying the northernmost submerged seamount on the California continental shelf. The CBNMS was designated a National Marine Sanctuary on December 4, 1990 (55 FR 4994). Ocean depths within the Sanctuary range from 35 m (at the peak of the Bank) to 1,830 m. Alternative Site 5 is located within approximately 10 nmi of Sanctuary boundaries (Figure 3.3.7-1); however, the Bank itself is located over 20 nmi from the Site. Alternative Site 3 is located 30 nmi to the south of the Sanctuary.

The combination of upwelling, underwater topography, and the wide range of depths at Cordell Bank provides for a highly productive environment with unique associations between subtidal and deep-water species (NOAA 1989). Further, endangered or threatened marine mammal and reptile species, including gray, blue, right, finback, sei, sperm, and humpback whales, Guadalupe fur seals, northern sea lions, and green, loggerhead, leatherback, and Pacific Ridley sea turtles, as well as the depleted northern fur seal, often are found at Cordell Bank. Due to its rich biological diversity, Cordell Bank is used frequently by divers and fishermen (NOAA 1989).

Monterey Bay National Marine Sanctuary. The MBNMS (Figure 3.3.7-1) encompasses 4,024 nmi^2, ranging from Marin County to Cambria (NOAA 1992). Portions of Study Area 3 and all of Study Area 2 lie within the Sanctuary boundaries.

The MBNMS supports a high diversity of marine resources. Monterey Canyon and its associated topographic features promote seasonal upwelling of nutrient-rich waters which support diverse biological assemblages of plankton, algae, invertebrates, fishes, marine birds, sea turtles, and marine mammals. Monterey Bay provides abundant prey items for many species of migratory marine birds. This area is an important habitat for winter populations of Ashy storm-petrel and Cassin's auklet, among others. Several endangered species are observed regularly within the Sanctuary. The endangered California brown pelican is observed throughout the Sanctuary and along the coastline (Figure 3.3.4-5) (Ainley and Allen 1992; Jones and Szczepaniak 1992). Right whales, with a world-wide population estimated near 200, have been seen in waters off Half Moon Bay. In addition, the endangered gray whale has been found in high abundances in the northernmost limits of the proposed sanctuary (NOAA 1992), including the vicinity of Study Areas 2 and 3. A complete list of species present in the Sanctuary can be found in the Final Environmental Impact Statement and Management Plan for the Proposed Monterey Bay National Marine Sanctuary (NOAA 1992).

Highly sensitive nearshore and offshore resources within the Sanctuary include: commercial fisheries, aquaculture operations, kelp harvesting, estuaries, sloughs, sandy beaches and rocky intertidal habitats, and nearshore littoral habitats (NOAA 1992). The commercially important Dungeness crab is harvested in local waters.

Wildlife Refuges

Farallon National Wildlife Refuge. The Farallon National Wildlife Refuge is maintained by the U. S. Fish and Wildlife Service (FWS) and includes Noonday Rock, North, Middle, and Southeast Farallon Islands, and Maintop Island (Figure 3.3.7-2). It is primarily a migratory refuge for 12 species of marine birds (including auklets, cormorants, guillemots, murres, puffins, and storm-petrels) but also serves as an important habitat for 5 species of pinnipeds (KLI 1991). The Wildlife Refuge is approximately 20 nmi due east of Alternative Site 5 and 25 nmi northeast of Alternative Site 3.

3.3.7.2 State Protected Areas

Areas of Special Biological Significance

Areas of Special Biological Significance (ASBSs) were designated under the California State Water Resources Control Board Resolution No. 74-28 to provide special protection for biological communities and important marine species. Waste discharges within these areas are prohibited in order to preserve and maintain natural water quality.

Farallon Island Area of Special Biological Significance. The Farallon Island ASBS includes 2.2 nmi^2 of waters surrounding but not including Noonday Rock, North, Middle, and Southeast Farallon Islands (Figure 3.3.7-2), and Maintop Island (CSWRCB 1976). Within the ASBS are a highly diverse intertidal community and abundant marine mammal populations, including California and northern sea lions, elephant seals, and harbor seals. Rare and endangered species such as the California brown pelican, peregrine falcon, blue, gray, finback, humpback, sei, and sperm whales also occur in the area (KLI 1991). The Farallon Island ASBS is approximately 20 nmi due east of Alternative Site 5.

Game Refuges

Farallon Islands Game Refuge. The Farallon Islands Game Refuge, under California Department of Fish and Game (CDFG) jurisdiction, encompasses the Farallon Islands and Noonday Rock and their surrounding waters extending 1 nmi from the coastline of each island (Smith and Johnson, 1989). It has an area similar to the combined areas of the Farallon National Wildlife Refuge and Farallon Islands ASBS (Figure 3.3.7-2). The regulations governing the use of the Game Refuge are coincident with those of the Wildlife Refuge and ASBS. The Farallon Island Game Refuge lies 20 nmi east of Alternative Site 5 (Figure 1.3-1).

Mainland Resource Areas

Other mainland coastal resource areas are located at least 30 nmi from the nearest alternative site. Results from modeling the dispersion of dredged material (see Section 4.4) indicate that sediments discharged at the alternative sites would not reach the mainland shore in detectable quantities.

3.3.8 Potential for Development or Recruitment of Nuisance Species

Some changes in the distribution and abundance of local biological communities are expected following any environmental disturbance, including dredged material disposal. Recolonization and recovery of a disturbed area and the resultant species assemblage will depend on numerous physical and biological interactions, including the size of the impacted area, the availability of larvae and adults, biological interactions among colonizers, and the severity and frequency of disturbance (Connell and Keough 1985; Lissner *et al.* 1991). Typically, recolonization of an altered environment begins with opportunistic species and proceeds through time to more stable communities typical of the surrounding area (EPA 1986).

Some organisms that may be present in dredged material or that may be favored after a disturbance can be considered nuisance species. EPA defines nuisance species as "organisms of no commercial value, which, because of predation or competition, may be harmful to commercially important organisms; pathogens; or pollution tolerant organisms present in large numbers that are not normally dominant in the area" (EPA 1986). These species can include viruses, pathogenic bacteria, protozoans, fungi, invertebrates, and fish, or they may include the eggs or spores of parasites that infect local fauna. In addition, in some environments dredged material disposal may alter water quality or local sediments so that pollution-tolerant organisms, normally occurring in low numbers, become the dominant species.

Dredged material disposal is unlikely to promote the development of nuisance species at any of the alternative sites due to: (1) significant differences between dredging and disposal site depths and habitat characteristics and (2) permit restrictions for ocean disposal of dredged material. The environment of the alternative sites consists of deep waters (depths > 1400 m) and thus is expected to be very different, particularly in terms of dissolved oxygen, temperature, salinity, pressure, food availability, and larval availability, than the relatively shallow dredging sites. Therefore, the placement of shallow-water dredged material at sites of significantly greater depths is not expected to result in colonization or propagation of shallow water nuisance species. All dredged material proposed for disposal at the designated ODMDS must conform to MPRSA's permitting criteria for acceptable quality. The acceptability of the material will be determined by physical, chemical, and bioassay/bioaccumulation testing (EPA and COE 1991)

3.4 Socioeconomic Environment

This section presents information on the socioeconomic environment of the study region, including commercial and recreational fisheries (Section 3.4.1), mariculture (Section 3.4.2), shipping (Section 3.4.3), military usage (Section 3.4.4), mineral or energy development (Section 3.4.5), recreational activities (Section 3.4.6), and cultural and historical areas (Section 3.4.7).

3.4.1 Commercial and Recreational Fisheries

3.4.1.1 Existing Fisheries

The continental shelf and slope off San Francisco support a variety of commercial fisheries including purse seine, dip net, trawl, hook and line, trap, gill net, and troll methods (Battelle 1989). The principal market species in this region include Dungeness crab, market squid, salmon, tuna, flatfishes (Dover sole, petrale sole, and English sole), a variety of rockfishes (*Sebastes* spp.; including shortbelly, widow, boccacio, chilipepper, splitnose and yellowtail), thornyheads (*Sebastolobus* spp.), and sablefish (MBC 1989; Tetra Tech 1987). In addition to primary market species, a number of other species including various species of sharks, tunas, mackerels, and baitfishes such as Pacific herring (*Clupea pallasii*) have commercial value (MMS/CDFG Commercial Fisheries Database 1992). Within the entire San Francisco region (from Point Arena to Point San Pedro, offshore to a distance of 200 nm; some of the most productive commercial fisheries areas are in the Gulf of the Farallones, including the vicinity of Study Areas 2 and 3 (MBC 1989; Oliphant *et al.* 1990). The estimated value of all major commercial fisheries within the San Francisco region in 1986 totaled over $23,680,000 (Oliphant *et al.* 1990; COE 1988). Figures 3.4-1 through 3.4-3 show the fisheries areas and describe the commercially important megafaunal invertebrates and fishes collected in CDFG catch blocks corresponding to each LTMS study area (including alternative sites).

Battelle (1989) concluded that fisheries resources of the continental shelf are of greater economic value than those in deeper areas. SAIC (1992b) and MMS/CDFG Commercial Fisheries Database (1992) found that some of the most productive areas were located in the deeper parts of Study Area 2 and the shallow part of Study Area 3 (Figure 3.4-1).

Battelle (1989) indicated that three catch block groups had trawl landings in excess of 0.4 million pounds (MP) in 1985. The first group (catch blocks 455 to 458 in depths less than approximately 100 m) had reported landings in 1985 of 0.58 MP, while the second group (catch block 475 in depths between 200 and 600 m) had trawl landings of 0.40 MP (Battelle 1989). The third catch block group (catch blocks 480, 481, and 482 at depths between 200 and 1,000 m) had reported landings in 1985 of 1.5 MP.

Based on analysis of MMS/CDFG Commercial Fisheries Database (1992) information from 1970 through 1986, Study Area 2 lies entirely within an area of moderate to high fisheries resources (0.5–72.5 MP; Figure 3.4-1), while the eastern (i.e., shallow) part of Study Area 3, on the upper continental slope, is represented by highly productive fisheries resources (> 2.5 MP; Figure 3.4-1). Study Area 4 represents an area of low to intermediate fisheries resources, with between 0.5 and 2.5 MP taken from 1970 to 1986, while the least productive area within the study region in terms of fisheries resources was Study Area 5 (0.5–1 MP).

The landings and catch block data must be interpreted with some caution because they represent reported areas where fish were taken, and the accuracy of these data is difficult to verify. Fish

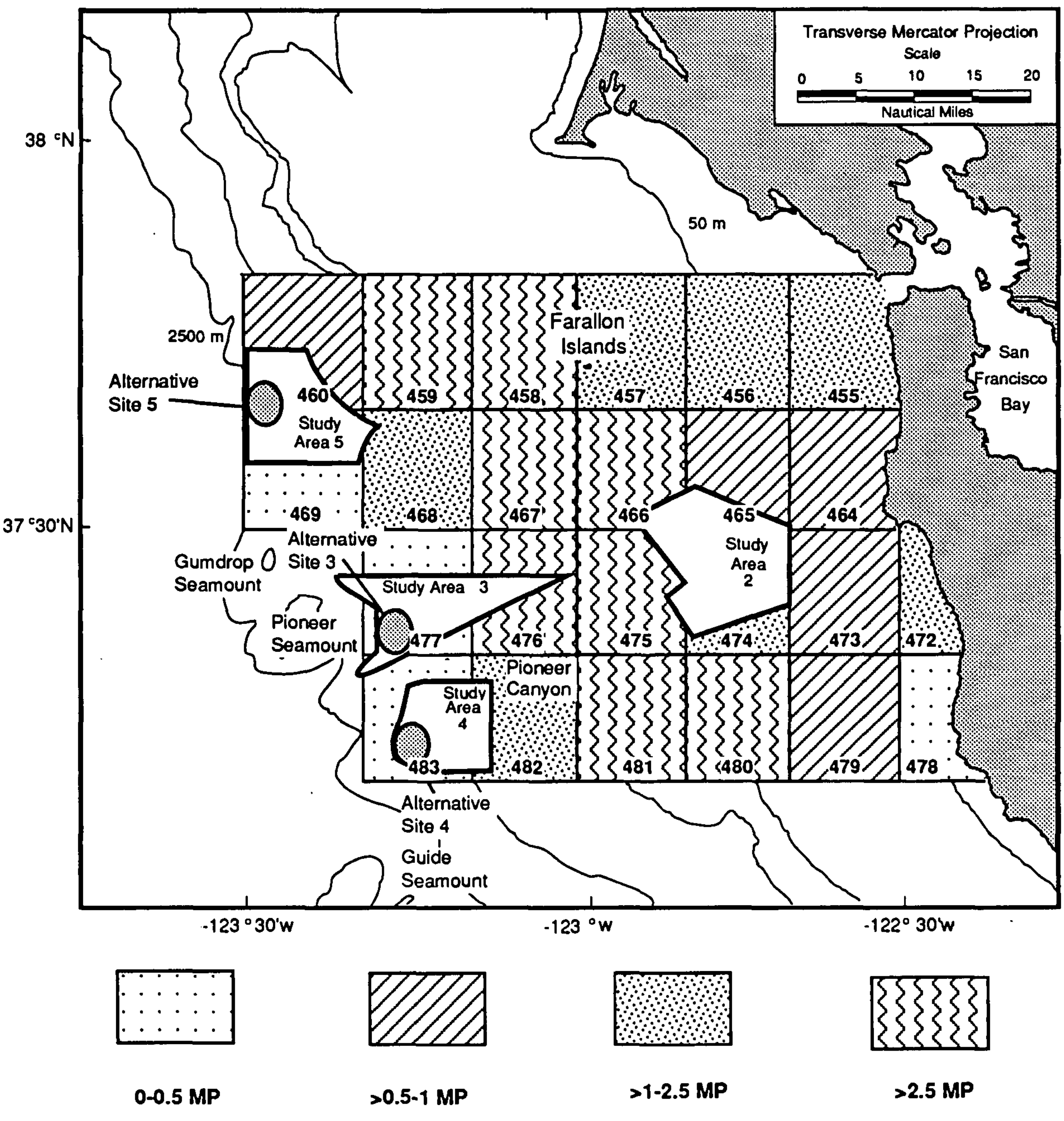


Figure 3.4-1. CDFG Commercial Fisheries Catch Blocks Showing Locations of Blocks and Total Catches of Fishes and Invertebrates From 1978 to 1986 Within the LTMS Study Areas. Total Catches are Given in Millions of Pounds (MP).
Source: MMS/CDFG Commercial Fisheries Database 1992.

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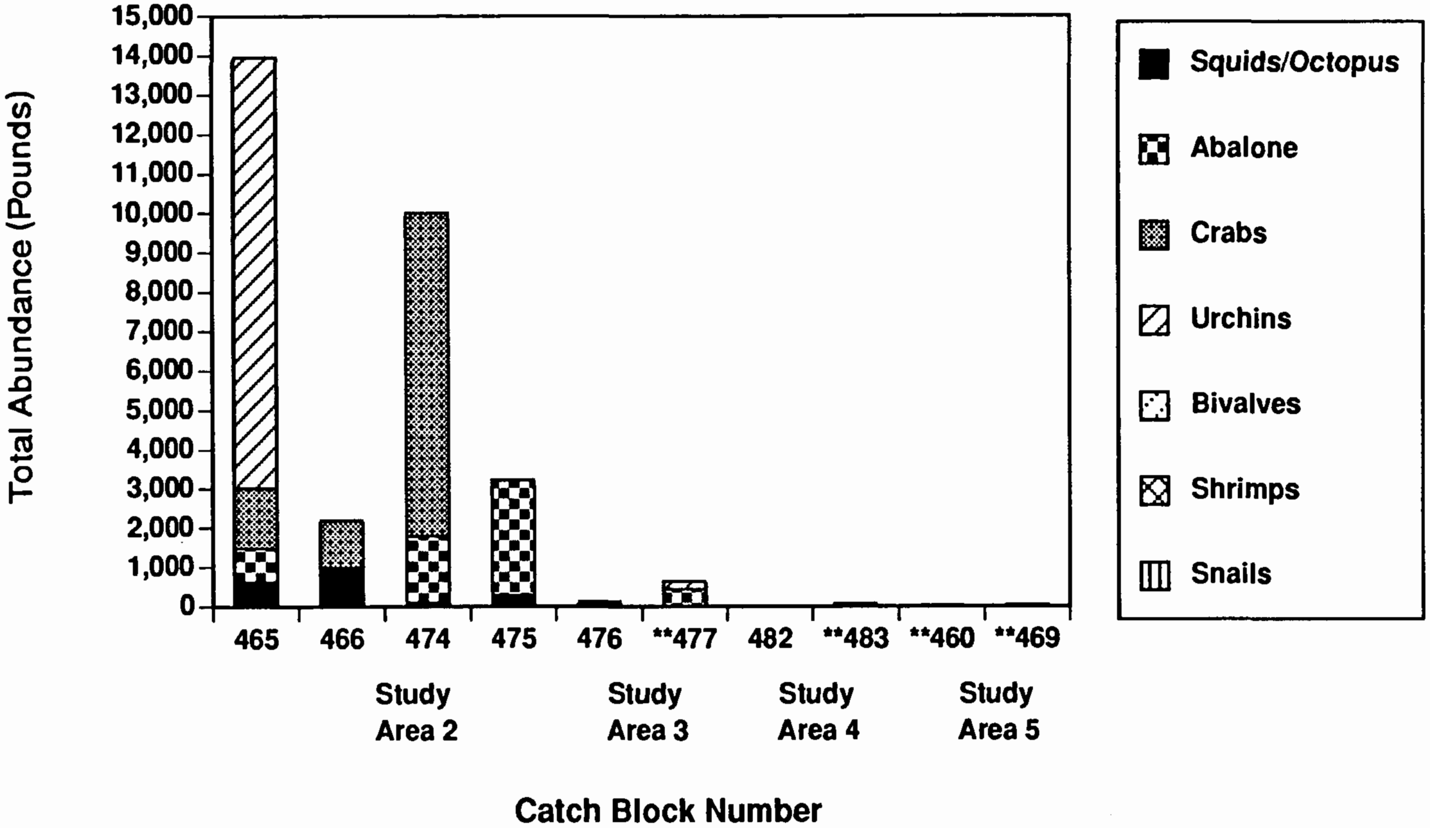

Figure 3.4-2. **Commercially Collected Megafaunal Invertebrates (By Catch Block in Pounds) Within the LTMS Study Areas between 1970 and 1986.**
**Location of the Alternative Site.
Source: MMS/CDFG Commercial Fisheries Database 1992.

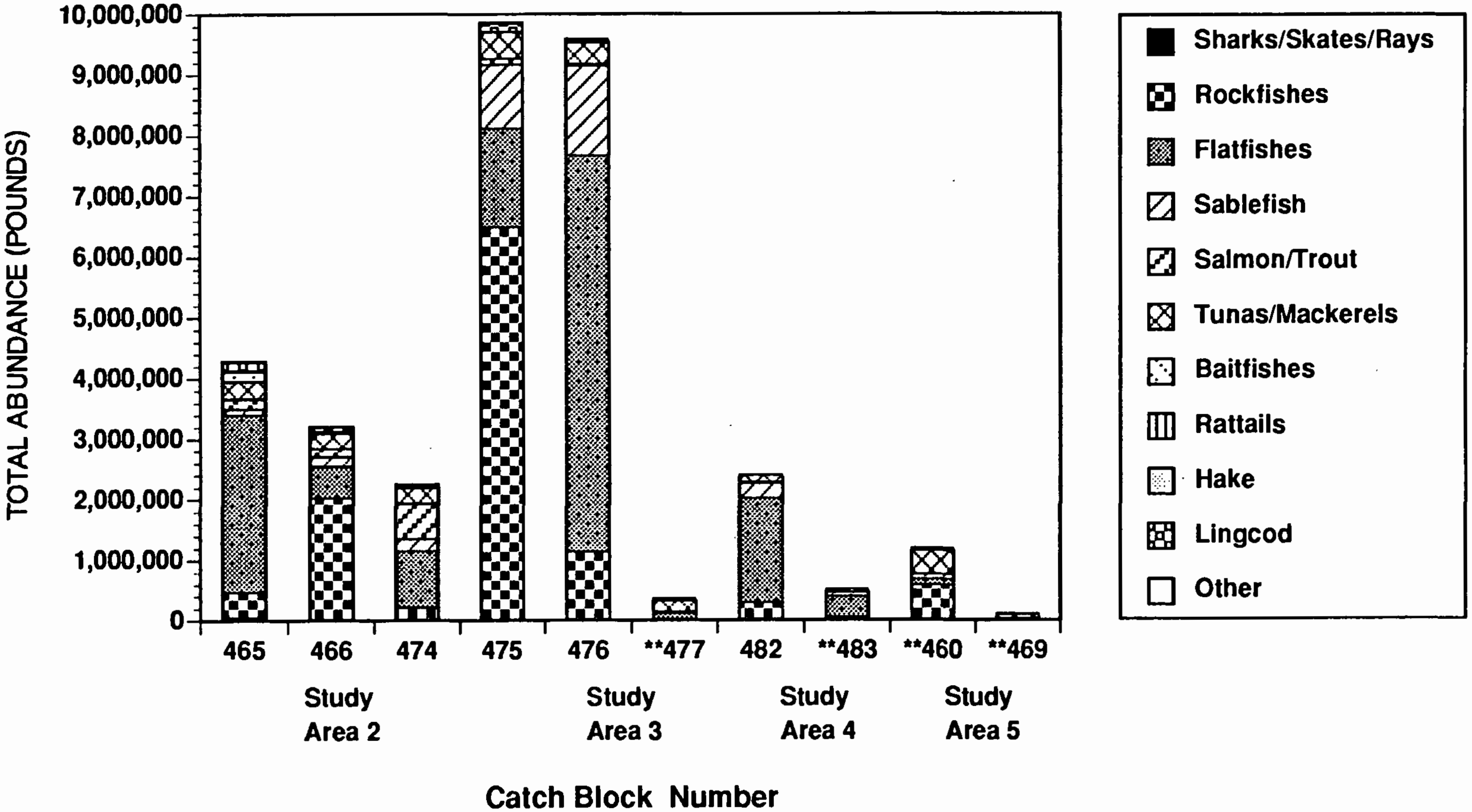

Figure 3.4-3. Commercially Collected Fishes (By Catch Block in Pounds) Within the LTMS Study Areas between 1970 and 1986.
**Location of the Alternative Site.
Source: MMS/CDFG Commercial Fisheries Database 1992.

landed in a small portion of a given block may be extrapolated to the entire block or to groups of blocks. Apparently unusual increases in the landings of a given species may actually represent the first time a particular area was fished for that species. Another limitation is that the fishing effort associated with the landings is not known for each catch block. For example, high catches of flatfishes could represent high abundances from a few trawls or moderate catches from many trawls.

The fishery resources for each study area are summarized in the following sections.

Study Area 2

Of the four LTMS study areas, the most significant commercial and recreational fisheries exist on the continental shelf within Study Area 2. The total amount of all megafaunal invertebrates collected commercially in the four primary catch blocks corresponding to Study Area 2 between 1970 and 1986 was over 29,000 pounds (Figure 3.4-2).

Commercially collected megafaunal invertebrates in these catch blocks include red urchins (*Strongylocentrotus franciscanus*), market squid (*Loligo opalescens*), a variety of crabs (*Cancer* spp; presumably including Dungeness crab, *C. magister*, although not specifically identified in MMS/CDFG Commercial Fisheries Database 1992), abalone (*Haliotis* spp.), and various species of bivalves including clams, mussels, and scallops (SAIC 1992b; MMS/CDFG Commercial Fisheries Database 1992; Bence *et al.* 1992). Wild and Tasto (1983) also reported that a significant fishery for Dungeness crab exists at depths centered between 36–64 m. The CDFG Recreational Fisheries Database (1992) lists Dungeness crab as the only megafaunal invertebrate taken in Study Area 2, although few individuals were collected.

Commercially collected fishes within the study area include lingcod (*Ophiodon elongatus*), baitfishes such as Pacific herring, salmon, tuna, sablefish, various species of rockfishes, and a variety of flatfish species including Pacific sanddabs (*Citharichthys sordidus*), Dover sole

(*Microstomus pacificus*), rex sole (*Errex zachirus*), English sole (*Pleuronectes vetulus*), and petrale sole (*Eopsetta jordani*; SAIC 1992b; MMS/CDFG Commercial Fisheries Database 1992; Bence *et al.* 1992; Battelle 1989). The total amount of fish commercially taken in the four catch blocks comprising Study Area 2 between 1970 and 1986 exceeded 19 million pounds (Figure 3.4-3). Of these commercially targeted species, flatfishes, rockfishes, salmon, and tunas represented the most important fisheries. Predominant fishes taken by recreational fishermen in the same two catch blocks included rockfishes, salmon, tunas, and lingcod (CDFG Recreational Fisheries Database 1992).

Study Area 3

Study Area 3 contains moderate to high commercial fisheries for both megafaunal invertebrates and fishes in the shallow areas (Catch Block 476) but very limited fisheries in the deeper portions (catch block 477) including Alternative Site 3 (Figures 3.4-2, and 3.4-3). Commercially collected megafaunal invertebrates were virtually nonexistent within the entire study area (including Alternative Site 3), with a total of less than 1,000 pounds taken from the two catch blocks corresponding to this study area from 1970 through 1986 (Figure 3.4-2). Based on the MMS/CDFG Commercial Fisheries Database (1992), a limited abalone fishery exists in the deeper part of the study area, (catch block 477; Figure 3.4-2), although this may reflect reporting or tabulation errors in the database. No megafaunal invertebrates were taken by recreational fishermen in this study area (CDFG Recreational Fisheries Database 1992).

Commercially collected fishes included flatfishes (primarily Dover sole, rex sole, English sole, and petrale sole), sablefish, rockfishes, and tunas. The total amount of fish taken in the shallow parts of this study area exceeded 9 million pounds between 1970 and 1986 (Figure 3.4-3), with flatfishes being the most predominant. Catches in the deeper part of the study area comprised migrating pelagic species such as tunas and mackerels (Battelle 1989). However, mackerels may be caught in high numbers inshore using roundhaul nets (Jow 1992).

Study Area 4

Very limited commercial fisheries for megafaunal invertebrates existed in Study Area 4, including Alternative Site 4, from 1970 through 1986 (Figure 3.4-2), probably due to difficulties with fishing gear at these greater depths. No megafaunal invertebrates were taken by recreational fishermen (CDFG Recreational Fisheries Database 1992). Commercial catches of fishes in the shallow part of Study Area 4 (catch block 482, located shoreward of Alternative Site 4) were represented by several species including flatfishes, sablefish, rockfishes, tunas, and mackerels (Figure 3.4-3). In the deeper part of Study Area 4 (catch block 483), including Alternative Site 4, catches were substantially lower, with a total of approximately 600,000 pounds being taken from 1970 through 1986. Flatfishes comprised almost 80% of this total. Very few species of fishes such as sharks and tunas were taken by recreational fishermen in this study area (CDFG Recreational Fisheries Database 1992).

Study Area 5

Based on available data, Study Area 5 is characterized by no megafaunal invertebrate fisheries and a low to moderate commercial fisheries area for fishes (Figures 3.4-2 and 3.4-3). Predominant fishes taken commercially include rockfishes, flatfishes, tunas and mackerels, and sablefish (Figure 3.4-3). However, the region of Alternative Site 5 (Catch Block 469) is characterized by the substantially lower fisheries resources. The primary recreational fisheries in this study area are for pelagic species such as certain rockfishes, salmon, and tunas (CDFG Recreational Fisheries Database 1992).

Detailed information on key existing fisheries species is presented below.

Dungeness Crab

Because of its economic importance to commercial fisheries in central and northern California (as well as Oregon, Washington, British Columbia, and Alaska), the population dynamics of the Dungeness crab have been studied extensively (summarized in MBC 1987). Dungeness crabs typically occur in depths from low tide to approximately 180 m, although they are most abundant in inshore coastal waters (MBC 1987). Dungeness crab catches in the San Francisco region have varied substantially over the years, with a peak catch of 8.9 million pounds in 1956–57 and a sharp decline to a total of 700,000 pounds from 1980 to 1985 (COE 1988). In 1986, over 1.2 million pounds were taken in the San Francisco region, for a total value of over $2.3 million (Oliphant *et al.* 1990). The Dungeness crab fishery continued to show a substantial recovery in 1987–1988 when 3.1 million pounds were taken in the San Francisco region. However, 1988–89 catch results indicated a decline of more than 50% from the previous year (CALCOFI 1990). Pollution stress to juvenile stages has been suggested as a possible cause for such substantial declines (Wainwright *et al.* 1992). Other suggested causes for population fluctuations may include oceanographic factors (temperature and currents), overfishing, parasitism, predation, and environmental degradation (Wild and Tasto 1983). Consequently, water quality monitoring and habitat protection measures have been recommended by CDFG to protect this resource (Wild and Tasto 1983). It is notable that Dungeness crab were uncommon in recent EPA trawl and ROV surveys conducted in Study Area 2 (SAIC 1992b), primarily because they were not targeted by bottom trawls. The MMS/CDFG Commercial Fisheries Database (1992) indicated market crabs were collected in low numbers in catch blocks corresponding to Study Area 2 (Figure 3.4-2).

Market Squid

Market squid are fished commercially from Baja California to British Columbia, with major fishing grounds located off central California (MBC 1989, 1987). Market squid typically are collected using small purse-seines and dip nets. Historically, market squid have been an important commercial fishery, representing one of the top five in California in terms of weight harvested (MBC 1987). Between 1983 and 1985, an average of 467,000 pounds per year was harvested off California, while 1.8 million pounds were taken in 1986, representing a value of almost $215,000 (Oliphant *et al.* 1990). Although the amount of market squid harvested is large, the overall dollar value is low due to low market prices. Based on analysis of the MMS/CDFG Commercial Fisheries Database (1992), market squid (combined with other squids and octopus) represent a limited fishery in the general study region, occurring only at continental shelf depths including Study Area 2 (Figure 3.4-2). Similarly, Bence *et al.* (1992) suggests that market squid abundances are highest inshore, at depths less than 180 m. Market squid were collected as incidental catch in Study Area 2 by SAIC (1992b); however, none were collected in any of the other study areas or alternative sites.

Pelagic Fishes

The predominant pelagic fishes, defined as those species which spend all or part of their life in the water column (Moyle and Cech 1988), of commercial importance are anchovies, herring, juvenile rockfishes, and hake. Some species such as salmon and tuna can occur in large numbers seasonally while migrating through the general study region (Oliphant *et al.* 1990).

Northern anchovy (*Engraulis mordax*) are distributed from British Columbia to the tip of Baja California at the surface to depths greater than 300 m (Love 1991). Northern anchovies are a major component of the commercial and baitfish fisheries in California. For example, anchovy harvests have varied from 508,772 pounds in 1977 to over one million pounds in 1980 (Oliphant *et al.* 1990). Between 1983 and 1985 an average of almost 830,000 pounds were taken, while in 1986 approximately 865,000 pounds representing a total value of almost $92,000 were collected in the San Francisco region (Oliphant *et al.* 1990). Bence *et al.* (1992) indicated that juvenile northern anchovy were clearly most abundant in the shallow inshore areas such as Study Area 2.

Pacific herring catches within the San Francisco region were consistently high from 1983 through 1985, averaging over 16 million pounds per year (Oliphant *et al.* 1990). The 16.4 million pounds collected in 1986 represented a value of almost $5.3 million. Pacific herring were collected by SAIC (1992b) in low numbers in Study Area 2, representing incidental catch. Similarly, the MMS/CDFG Commercial Fisheries Database (1992) suggests that baitfishes (including Pacific herring) were collected only in low numbers in the catch blocks corresponding to Study Area 2 (Figure 3.4-3).

Pacific hake (*Merluccius productus*) can occur in dense midwater schools and range in distribution from the Bering Sea to Baja California at depths between 10 to 1,000 m (Love 1991). However, this species is not normally targeted by recreational fishermen because of their deep distributions, and is a smaller component of commercial fisheries in the San Francisco region. SAIC (1992b) collected Pacific hake in low numbers using bottom trawls in Study Area 2 and in adjacent Mid-Depth and Pioneer Canyon locations. Bence *et al.* (1992) concluded that Pacific hake had their highest abundances at intermediate depths corresponding to depths such as the shallow portions of Study Area 3 (i.e., not including Alternative Site 3). Although this species is not currently taken in high numbers, it represents a valuable potential fishery.

Other pelagic species having considerable commercial value are salmon and tuna. Salmon (chinook and coho) in the San Francisco region are a popular partyboat and commercial species, normally trolled for at depths of up to 600 m (MBC 1989). In 1986, over 2.7 million pounds of salmon were taken in the San Francisco region, accounting for a value of approximately $5.6 million. Albacore tuna (*Thunnus alalunga*), a valuable gamefish for recreational and sport fishermen (MBC 1987), are most abundant from August through October (Squire and Smith 1977). In 1986, over 500,000 pounds of albacore, representing an estimated value of $326,000 (Oliphant *et al.* 1990), were taken in the San Francisco region.

Roundfishes

Roundfish fisheries in the San Francisco region are comprised primarily of lingcod, sablefish and hake (discussed above). Lingcod (*Ophiodon elongatus*) typically occur in nearshore coastal environments from the Gulf of Alaska to Ensenada, Mexico (Love 1991). Juvenile lingcod are primarily pelagic and distributed nearshore (Bence *et al.* 1992), while larger juveniles live near the bottom over a variety of habitats including sand and gravel and eelgrass beds. Adults typically are found on soft bottoms, moving into rocky areas as they grow older (Love 1991). Lingcod are taken by sport and recreational fishermen as well as commercially. Between 1983 and 1985 an average of almost 860,000 pounds were taken in the San Francisco region. In 1986, over 400,000 pounds representing a total value of almost $140,000 were taken in the San Francisco region (Oliphant *et al.* 1990). During trawl surveys by SAIC (1992b), lingcod were only collected in Study Area 2; however, these represented only low abundances of juveniles.

Sablefish (*Anoplopoma fimbria*) occur from the inner shelf to depths of almost 3,000 m (Miller and Lea 1972). Juvenile sablefish occur on the upper slope and shelf, while spawning adults occur deeper than 1,000 m. The highest reported densities of sablefish are at depths between 324 and 990 m (Allen and Smith 1988). Sablefish are fished using trawls at depths between 73 and 1,000 m, while traps and longlines are used at deeper depths (between 384 to 1,262 m). Between 1983 and 1985 an average of almost 1.9 million pounds were taken in the San Francisco region, while approximately 3.4 million pounds (a value of almost $1.4 million) were collected in 1986 (Oliphant *et al.* 1990). Sablefish were collected during trawl surveys by SAIC (1992b) in Study Areas 2, 3, and 4; however, their abundances were highest in adjacent Mid-Depth and Pioneer Canyon locations at depths between 252 to 1,170 m. No sablefish were collected by Cailliet *et al.* (1992) in Study Area 5, including the Alternative Site 5 region.

Groundfishes

Landing data for groundfishes have a number of limitations including how certain groups are classified. For example, chilipepper rockfish may be grouped in "rockfish", "chilipepper", or "chilipepper/boccacio" categories. The accuracy of many of these landing reports must be considered because numerous databases are available for analysis of commercial landings, and there may be conflicting information contained within these databases.

Groundfish fishery resources in the study region are diverse and comprised of a number of rockfishes (primarily including shortbelly, widow, boccacio, canary, chilipepper, yellowtail, and thornyheads), and flatfishes (Dover sole, petrale sole, English sole, rex sole, and sand sole). In 1987, commercial groundfish landings of more than 20,000 metric tons were recorded within the Monterey International North Pacific Fisheries Commission (INPFC) Region, exclusive of foreign fishing and joint ventures (Battelle 1989). Data on commercial groundfish resources for Study Areas 2 through 5 primarily are taken from the MMS/CDFG Commercial Fisheries Database (1992), while recreational catches are from the CDFG Recreational Fisheries Database (1992).

Rockfishes. The rockfish complex consists of a number of species (*Sebastes* spp. and *Sebastolobus* spp.) collected from the middle continental shelf to areas deeper than 1,400 m; however, most rockfishes are taken commercially at depths between 100 to 400 m (MBC 1987). Most deepwater species of thornyheads (*Sebastolobus* spp.) are taken at depths between 90 to 800 m, although some have been fished at depths as great as 1,400 m (Allen and Smith 1988). The most important rockfish species in terms of annual revenues to commercial fisheries are chilipepper (*Sebastes goodei*), boccacio (*S. paucispinis*), splitnose (*S. diploproa*), yellowtail (*S. flavidus*) and widow rockfish (*S. entomelas*). Widow rockfish catches reached their highest total in 1982, with almost 12 million pounds collected representing a value of approximately $1.6 million (Oliphant *et al.* 1990). Oliphant *et al.* (1990) presents combined data for chilipepper and boccacio. Chilipepper/boccacio catches from 1983 through 1985 averaged over 3.4 million pounds, while in 1986 approximately 1.8 million pounds representing a value of $570,000 were taken (Oliphant *et al.* 1990). SAIC (1992b) collected 12 species of rockfishes throughout the study region. Chilipepper and shortbelly (*S. jordani*) had the highest abundances in Study Area 2, as well as in adjacent Mid-Depth and Pioneer Canyon locations. Midwater trawls conducted by Bence *et al.* (1992) indicated juvenile rockfish as a group were consistently most abundant inshore, including depths similar to Study Area 2, but also were relatively abundant in some offshore locations including the region of Study Area 5 and Alternative Site 5. In contrast, abundances in Study Areas 3 and 4 were somewhat less, representing moderate to high numbers (Bence *et al.* 1992).

Flatfishes. Dover sole (*Microstomus pacificus*) comprise the largest flatfish fishery in the San Francisco region. They are collected from the Bering Sea and Aleutian Islands southward to central Baja California on the inner continental shelf to depths greater than 900 m, but primarily are taken commercially in trawls at depths between approximately 300 and 900 m (Love 1991; MBC 1987). In 1986, Dover sole landings in the San Francisco region totaled almost 6.3 million pounds representing a value of over $1.6 million (Oliphant *et al.* 1990). Dover sole primarily were collected by SAIC (1992b) within Study Areas 2 and the shallow parts of Study Areas 3 and 4 (not including Alternative Sites 3 or 4). The highest numbers of Dover sole collected by SAIC (1992b) were in the Mid-Depth and Pioneer Canyon locations at depths ranging from 252 to 500 m.

Petrale sole occur from the Bering Sea southward to northern Baja California, but are most abundant from southern California northward (Love 1991). They are taken at depths ranging from intertidal to greater than 600 m, but are collected most often between 100 to 300 m. This species is taken by sport and recreational fishermen, as well as by commercial trawlers. From 1983 to 1985, an average of nearly 400,000 pounds of petrale sole were taken in the San Francisco region, while in 1986, almost 400,000 pounds representing a value of over $302,000 were taken in the same region (Oliphant *et al.* 1990). Bence *et al.* (1992) suggests that the highest abundance of this species is at depths less than 180 m, corresponding to similar depths as Study Area 2. SAIC (1992b) collected this species infrequently and in low numbers in Study Area 2.

English sole are found from the Aleutian Islands to southern Baja California, with their distribution centered from the Gulf of Alaska to southern California, at depths ranging from intertidal to almost 600 m (Love 1991). Historical population centers of English sole in California are located off San Francisco, Eureka, Fort Bragg, Monterey, and Santa Barbara (MBC 1987; Frey 1971). From 1983 to 1985 an average of over 700,000 pounds of English sole were taken in the San Francisco region, while nearly 900,000 pounds representing a value of almost $327,000 were taken in 1986. SAIC (1992b) collected this species in moderate numbers within

Study Area 2. Consistent with their relatively shallow depth distribution, English sole were not observed in Study Areas 3, 4, and 5.

Rex sole have a similar distribution as Dover sole and English sole and are taken at depths ranging from intertidal to at least 900 m, but are most frequently collected at depths between 100 to 150 m (Love 1991). Although this species does not comprise a major part of the commercial flatfish catch in the San Francisco region, an average of over 300,000 pounds were taken between 1983 and 1985, while over 400,000 pounds representing a value of almost $152,000 were taken in 1986. Rex sole were collected by SAIC (1992b) in Study Area 2, as well as at adjacent Mid-Depth and Pioneer Canyon locations. This species was not collected in any of the other study areas. Bence *et al.* (1992) indicates that juvenile rex sole collected in midwater trawls had the highest abundances in Study Area 5 relative to the other study areas. In contrast, bottom trawls indicated adult rex sole were most abundant at depths between 100 to 500 m, corresponding to depths such as Study Area 2 and the shallow part of Study Area 3 (Bence *et al.* 1992).

3.4.1.2 Potential Fisheries

In general, limited fisheries currently exist in depths greater than 900 to 1,440 m (R. Lea, CDFG, pers. comm. 1991). However, data on deep demersal fishes with fisheries potential are available from studies conducted in other areas at similar depths (Pearcy *et al.* 1982; Stein 1985; Wakefield 1990). Currently, the only deep demersal species being targeted are various grenadiers (rattails).

Several fish species represent a potential future fishery resource. Potential or currently underutilized species include shortbelly rockfish, Pacific sanddab, jack mackerel, ocean sunfish, Tanner crab, king crab, rock crabs, krill, giant Pacific octopus, spiny dogfish, sea cucumber, sheep crab, grenadier (rattails), hagfish, sharks, and skates (NMFS 1983; S. Kato, NMFS, pers. comm. 1991). Shortbelly rockfish have been identified by NMFS Tiburon as an unexploited fishery with major potential (Chess *et al.* 1988; Lenarz 1980). Bence *et al.* (1992) indicated high abundances of certain species of juvenile rockfishes in Study Area 5 which are an important potential component to the commercial fishery in that area. Other less heavily fished species include hagfish (*Eptatretus* spp.), for which a substantial trap fishery exists for their skins even though these skins are of poor quality, fishing is difficult, and pay for fishermen is low. Wakefield (1990) found black hagfish (*E. deani*) to be predominant along camera sled transects off Point Sur from depths between 400 and 1,200 m, with a strong peak in abundance within the 600 m depth zone. Wakefield (1990) estimated that 82% of the total population of black hagfish resided in this depth zone. Hagfish were collected infrequently within the entire study region and only in Study Area 3 by SAIC (1992b) at approximately 1,000 m depth.

In summary, of the four LTMS study areas, Study Area 2 contains the most substantial commercial fisheries resources and is considered by commercial fishermen to be a very significant area (P. Parravano, Halfmoon Bay Fisherman's Association, pers. comm. 1991). The area is dominated by market fishes such as rockfishes, flatfishes, salmon, and tuna. The shallow parts of Study Areas 3 and 4 (not including Alternative Sites 3 and 4) contain some commercially important species such as flatfishes, rockfishes, salmon, and tuna. The deeper parts of Study Areas 3 and 4 (including Alternative Sites 3 and 4) and Study Area 5 have limited commercial fisheries resources.

3.4.2 Mariculture

Several mariculture operations exist in nearshore embayments of the San Francisco Bay region. These consist primarily of oyster culturing operations in Tomales Bay and Drakes Estero sites leased from CDFG. However, these operations are located over 20 nmi from the nearest study area (Study Area 2) and over 50 nmi from the alternative sites, and therefore are very unlikely to be affected by use of any of the sites.

Mariculture activities in Tomales Bay consist of relatively small lease areas (4–120 hectares). The majority of oysters raised and marketed are giant Pacific oysters (*Crassostrea gigas*) with a commercial value in 1990 of over $800,000 (T. Moore, CDFG, pers. comm. 1992). The remaining mariculture species in Tomales Bay consist of European oysters valued at over $5,000/yr and mussels valued at $18,000/yr in 1990 (T. Moore, CDFG, pers. comm. 1992). Oyster culture in Drakes Estero represented approximately 30% of California's total commercial crop in 1990 (T. Moore, CDFG, pers. comm. 1992). The primary lease in Drakes Estero covers 425 hectares and runs until 2015 (U.S. National Park Service 1976). The giant Pacific oyster is the principal species cultured.

3.4.3 Shipping

Ships from six publicly used ports, 11 military installations, and several proprietary installations use the 11 navigable waterways in the San Francisco Bay and Delta. It is estimated that $5.4 billion of economic activity is directly dependent on deep and shallow draft navigation channels in the San Francisco Bay and Delta regions (Ogden Beeman 1990). Commercial shipping supports up to 35,000 full-time jobs, exclusive of jobs supported by Navy activities.

Movements of all types of vessels within the Bay have exceeded 61,000 per year since 1980, and annual vessel movements in 1991 exceeded 86,000 (Table 3.4-1). A vessel movement is defined as any occasion when a vessel enters San Francisco Bay from the Pacific Ocean, moves within the Bay, or departs the Bay for the Pacific Ocean. The majority (81%) of these movements are by small vessels such as ferries, tugs, and dredge barges and primarily involve transits within the Bay.

The Coast Guard has established a Vessel Traffic Service (VTS) to reduce vessel collisions and groundings and potential environmental or other resource damage that could result from such incidents. As a safety measure, VTS has established precautionary zones and vessel traffic lanes around major traffic intersections (see Figure 2.1-3). A precautionary zone 22.1 km in diameter is located west of San Francisco Bay and facilitates safe vessel turning movements into and out of the Golden Gate. VTS serves in an advisory capacity, coordinating and monitoring vessel movements using commercial and surveillance radar as well as closed circuit television, and utilizes a radio network to communicate information to inbound, outbound, and within the Bay

Table 3.4-1. Total Vessel Transits in the San Francisco Bay Region, 1980-1991.

Vessel Types	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Commercial	8102	7191	6516	6633	7225	6653	5982	6298	6090	5761	5877	5876
Hazardous	58	93	87	81	93	85	52	83	79	95	83	97
Navy, Surface vessels	669	847	850	892	840	796	866	1227	1359	2236	1913	1823
Coast Guard	1173	4275	4266	2999	3578	3567	3411	5697	2096	2572	1907	1788
Navy, Submarines	83	139	112	1333	146	87	97	71	67	67	70	69
Foreign Navy	34	28	17	60	30	34	26	25	40	45	59	49
Tugs without Tows	4176	5076	4919	5207	4326	3267	2804	1611	1070	868	525	517
Tugs with Tows	13386	16003	17792	15812	14978	13504	14139	14091	13507	13790	14553	13081
Deep Draft	185	159	103	135	152	158	180	194	219	248	205	700
Ferries	26467	24993	24008	28710	28306	31307	41605	45564	45520	56036	58343	56100
U.S. Government	0	0	0	0	344	771	659	830	906	935	1081	904
Non-Channel 13 (Large Vessels Not Using VTS)	1201	1348	1945	1415	1735	2036	2061	1787	722	532	310	236
Dredges	2669	2309	2638	2804	2780	7544	6943	5270	2813	2819	2390	1914
Tankers	3404	3401	2939	2904	2664	2374	3194	3206	3644	3907	3684	3570
Passenger Ships	0	0	0	0	100	146	213	119	83	65	70	157
TOTAL	61607	65862	66192	67785	67297	72329	82232	83073	78215	89976	91070	86891

SOURCE: Lt. Cdr. Gibson, USCG VTS, pers. comm. 1992.

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vessels (Ogden Beeman 1991). Traffic data are maintained by vessel type for movements within the Bay, but are not maintained for movements through the Golden Gate, in the precautionary zone, or in the vessel traffic lanes. Approximately 38% of arriving and departing vessels use the Northern Traffic Lane, 20% the Western, and 42% the Southern. The majority of tanker traffic uses the Western Traffic Lane. The Coast Guard does not specifically track vessel traffic within any of the LTMS study areas (Lt. Cmdr. Gibson, USCG VTS, pers. comm. 1992).

Movements through the Golden Gate account for only a small percentage (6.9%) of all vessel traffic, although they represent a large percentage of the commercial cargo, Coast Guard, Navy, tanker, and other large vessel movements. A summary by vessel type of the percentage of total vessel movements that include transiting through the Golden Gate is presented in Table 3.4-2. These movements represent approximately 99% of all military and commercial traffic, but very few recreational vessel movements. Accurate transit data on recreational and small vessel, including fishing vessel, movements is unavailable since they do not participate in the Coast Guard's VTS (Lt. Cmdr. Gibson, USCG VTS, pers. comm. 1992). However, they are estimated to be about 25 to 50 times the number of large commercial and military vessel movements. This summary is based on the professional judgment of Coast Guard personnel, and reflects traffic conditions during a typical year in the 1980's.

Vessels transporting dredged materials to a disposal site would traverse the traffic lanes shown in Figure 2.1-3 and contribute to total traffic volume. Based on conservative assumptions of approximately one barge-load every 12 hours (see Section 4.4), this would equate to approximately 730 additional vessel transits. Given the rough or foggy conditions that may be common in the study region (see Section 3.2.1), there is some small risk of collisions by towed barges and hopper dredges within the Bay and the traffic lanes leaving the Bay. However, historically the number of collisions or near collisions among vessels within and near San Francisco Bay has been small. Collisions occurred an average of three times per year during that time period, and represent a comparatively small number given the high overall traffic volume. Overall, incidents of all types, including collisions, occurred an average of six times per year.

Table 3.4-2. Percentage by Category of Total Vessel Movements That Include Transiting Through the Golden Gate.

Vessel Category	Percentage
Commercial	95%
Hazardous	80%
Navy, Surface vessels	20%
Coast Guard	5%
Navy, Submarines	100%
Foreign Navy	100%
Tugs without Tows	45%
Tugs with Tows	5%
Deep Draft	95%
Ferries	0%
U.S. Government	25%
Non Channel 13 (Large vessels not using VTS)	5%
Dredges	5%
Tankers	45%
Passenger ships	95%

SOURCE: Lt. Cdr. Gibson, USCG VTS, pers. comm. 1992.

Incidents involving tugs with barges or self propelled barges as recorded by VTS between 1980 and 1989 are presented in Table 3.4-3.

3.4.4 Military Usage

The San Francisco Bay region and adjacent Gulf of the Farallones represent a major area of military usage, primarily by the U.S. Navy. Within the Bay, the Oakland Naval Supply Center and Alameda Naval Air Station are major facilities (Navy 1992). The Alameda Naval Air Station currently is used for homeporting two aircraft carriers, three cruisers, and one destroyer tender. The Oakland Naval Supply Center is homeport to two replenishment oilers, one combat replenishment ship, one naval hospital ship, and 28 Military Sealift Command Pacific ships. Maintenance dredging of these facilities is needed to ensure that the berths are accessible to large Naval vessels. The Navy's Third Fleet regularly utilizes the Gulf of the Farallones region for offshore air, surface, and submarine operations. Naval activity within San Francisco Bay averaged approximately 157 vessel movements (including submarines) per month in 1991 (Lt. Cmdr. Gibson, USCG VTS, pers. comm. 1992).

The Navy maintains five submarine operating areas (U1–U5), located 45 to 56 km from the Golden Gate (see Figure 2.1-4). Area U-1 is not used regularly, while the remaining areas receive moderate use (an average of 10 days per month). Submarine operating area use typically is associated with trial diving exercises and equipment checkouts. The Navy would consider dredged material disposal in these areas to be incompatible with submarine operations (E. Lukjanowicz, U.S. Navy, pers. comm. 1991). Submarine transit lanes vary in width from 13 to 18.5 km and run parallel to the mainland and west of Bodega Head. The exact locations of active transit lanes are periodically designated by the Navy in advisories to the Coast Guard (E. Lukjanowicz, U.S. Navy, pers. comm. 1991). When lanes are active, other vessels in the vicinity are warned against towing submerged objects within traffic lanes. The Navy also conducts aircraft and surface vessel exercises, often in conjunction with submarine operations, in an area that encompasses North Farallon Island and Noonday Rock along its southern boundary. Activities include anti-submarine warfare training, air-intercepts, surface vessel

Table 3.4-3. Incidents Involving Tugs, Barges, and Self Propelled Dredges Within and Near San Francisco Bay, 1980-1989.

NATURE OF INCIDENT	NUMBER OF OCCURRENCES	PERCENT
Collision	25	40.9
Grounding	13	21.3
Material Failure	8	13.1
Foundering or Flooding	5	8.2
Barge Breakaway	4	6.6
Steering Failure	3	4.9
Disabled	2	3.3
Weather Damage	1	1.7
	___	___
TOTAL	61	100.0

SOURCE: Ogden Beeman 1991.

coordination, and dropping inert ordinance. These exercises typically represent 15 use-days per quarter per year.

In addition to the Navy's activities, the USCG supports infrequent aerial overflight missions throughout the area. The USCG conducts approximately five helicopter sorties per week around the Farallon Islands for serial offshore enforcement purposes, and search and rescue missions are conducted to a variety of destinations along the coast. The USCG also maintains a lighthouse on Southeast Farallon Island, thus requiring regular flights of maintenance personnel from San Francisco to the lighthouse post.

3.4.5 Mineral Or Energy Development

Large repositories of oil and gas reserves are located in several areas along and offshore of the California coast (F. White, MMS, pers. comm. 1992). However, there are no oil and gas development activities or structures within the general study region, and all the potential lease areas are over 200 miles from the alternative sites. This is due to current moratorium schedules and technological constraints which have limited oil and gas development to depths less than approximately 300 to 400 m. Therefore, no significant mineral or energy development activities are likely in the vicinity of the study areas and alternative sites. In addition, it is unlikely that any mineral or energy development will take place within any of the marine sanctuaries that cover a large area of the Gulf of the Farallones or in State waters (waters up to three miles from the coast) (Kirk Walker, California State Lands Commission, pers. comm. 1992). The future of outer continental shelf lease sales has been addressed recently by a Presidential Task Force on oil and gas development (KLI 1991) but the results have not yet been published nor any recommendations implemented.

1987). Predominant fishes taken by recreational fishermen include rockfishes, king and chinook salmon, tuna, and Dungeness crabs (CDFG Recreational Fisheries Database 1992).

Weather permitting, offshore tours to the GOFNMS are operated by Oceanic Society Expeditions on each weekend day through the summer and fall months (June–September). Nature organizations visit the Farallon Islands infrequently, conduct other commercial ventures, or operate whale watching trips during the winter and spring migrations. On the average, over 10,000 people per year have participated in these tours between 1984 and 1992 (M.J. Schramm, Oceanic Society Expeditions, pers. comm. 1992). Large numbers of bird watchers also made boat trips to the GOFNMS and adjacent areas (greater than 2,500 people per year) to observe the rookeries (M.J. Schramm, Oceanic Society Expeditions, pers. comm. 1992). The majority of recreational traffic occurs on weekends. An average of five sailboats per month, mostly originating from San Francisco Bay, have been observed in the vicinity of the Farallon Islands (M.J. Schramm, Oceanic Society Expeditions, pers. comm. 1992). In addition, several motor boat and sailing clubs use the Farallon Islands as a turning point during sponsored races that can occur throughout the year (M.J. Schramm, Oceanic Society Expeditions, pers. comm. 1992).

3.4.7 Cultural and Historical Areas

Designation of the GOFNMS, the CBNMS, and the MBNMS is intended to preserve the natural environment and to recognize the increasing "cultural" value placed on areas that are free from the effects of technology. Wildlife tours are popular cultural events around the Farallon Islands. Naturalist and zoological societies, such as the Audubon Society, conduct one or two tours annually, and Oceanic Society Expeditions conducts a tour every Saturday and Sunday from June to mid-November (M.J. Schramm, Oceanic Society Expeditions, pers. comm. 1992). Use of any of the alternative sites should not significantly affect these activities beyond normal navigational precautions.

No known man-made cultural or historical resources are located in the study areas and alternative sites, based on a file review conducted of the California Archaeological Inventory, and a review of listings in the National Register of Historic Places and the California Inventory of Historic Resources. Further, no known shipwrecks of cultural or historical significance are reported within the study areas. According to the "Submerged Cultural Assessment" (which includes the California region), published jointly by NOAA and the National Park Service, only one vessel is located near Study Area 3. This is the aft portion of the PUERTO RICAN, which sank in 1984 one mile inside the boundary of the GOFNMS near the historical 100 Fathom site (located at 37°30.3' N, 123°00.3' W). However, this vessel has little historic value (Delgado and Haller 1989).

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CHAPTER 4
ENVIRONMENTAL CONSEQUENCES

4.1 Introduction

This chapter assesses the significance of potential impacts of the proposed and alternative actions on the physical, biological, and socioeconomic environments at the preferred and alternative sites. Environmental consequences are evaluated separately for the preferred alternative (Section 4.2), the No-Action Alternative (Section 4.3), and other ocean disposal alternatives (Section 4.4). Site-specific impacts associated with dredged material disposal at the alternative sites are also summarized and compared in Chapter 2 according to the five general and eleven specific criteria.

The significance of potential environmental impacts associated with each of the alternatives is classified according to the following scheme (modeled after EPA 1988):

- Class I: Significant adverse impacts that cannot be mitigated to insignificance. No measures can be taken to avoid or reduce the adverse impacts to insignificant or negligible levels.
- Class II: Significant adverse impacts that can be mitigated to insignificance. These impacts potentially are similar in magnitude to Class I impacts, but the severity can be reduced or avoided by implementation of specific mitigation measures.
- Class III: Adverse but insignificant impacts or no effects anticipated. No mitigation measures are necessary to reduce the magnitude or severity of these impacts.
- Class IV: Beneficial effects. These effects could improve conditions relative to existing or pre-project conditions. These can be classified further as significant or insignificant beneficial effects.

The term "significant" is used to characterize the magnitude of potential impacts; a significant impact is defined as a substantial or potentially substantial change to resources in the vicinity of or adjacent to a proposed ODMDS. In the following sections, the rationale for characterizing potential impacts as significant or insignificant, distinctions between localized and regional spatial scales of impacts, and the duration (short-term versus long-term) of these potential impacts are identified. Associated mitigation measures are discussed where appropriate.

A summary of potential impacts on important resources of the physical, biological, and socioeconomic environments of each alternative site is presented in Table 4.1-1. Resources for which comparisons can be made among the alternative sites are addressed separately by site in Sections 4.2 and 4.4. Resources or environmental conditions, such as ocean currents, which are not affected by the proposed action are addressed generically for all sites within each respective section.

4.2 Preferred Alternative

This section describes the potential impacts of the proposed actions on the physical, biological, and socioeconomic environments of the preferred alternative, Alternative Site 5. Potential impacts of these actions on the environments of the other ocean disposal alternatives, Alternative Sites 3 and 4, are addressed in Section 4.4.

Neither the preferred nor the alternative sites have been used previously for dredged material disposal, and no specific data on the actual effects of disposal operations are available. Thus, evaluation of potential effects on sea bottom and water column environments at the preferred and alternative sites relies on modeling the initial deposition of dredged material and dispersion of suspended particles and on information from studies conducted at existing ODMDSs. Where possible, differences between the preferred and alternative sites in the magnitude of expected or model-predicted spatial and temporal impacts are specified in this section and in Section 4.4.

Table 4.1-1. Summary of Potential Environmental Impacts at the Preferred Alternative and Alternative Sites 3 and 4.

Description	PREFERRED ALTERNATIVE				OTHER OCEAN ALTERNATIVES							
	Alternative Site 5				Alternative Site 3				Alternative Site 4			
	Impact Class[1]	Spatial Extent[2]	Temporal Extent[3]	Comment	Impact Class	Spatial Extent	Temporal Extent	Comment	Impact Class	Spatial Extent	Temporal Extent	Comment
Physical Environment												
Air Quality	III	R	S		III	R	S		III	R	S	
Water Quality												
- Turbidity	III	R	E		III	R	E		III	R	E	
- Dissolved Oxygen	III	L	E		III	L	E		III	L	E	
- Pollutants	III	L	S	Given that material is suitable quality	III	L	S	Given that material is suitable quality	III	L	S	Given that material is suitable quality
Geology												
- Grain Size	I	L	E		I	L	E		I	L	E	
- Sediment Quality	III	L	E	Given that material is suitable quality	III	L	E	Given that material is suitable quality	III	L	E	Given that material is suitable quality

[1] Impact Class: I = Significant; II = Significant, but can be reduced by mitigation; III = Insignificant or none; IV = Beneficial.
[2] Spatial Extent: S = Confined within site boundaries; L = Localized (up to 1 nmi outside of site boundaries); R = Regional (beyond 1 nmi from site boundaries).
[3] Temporal Extent: S = Short term (less than or equal to 5 hours); E = extended (greater than 5 hours).
[4] Potential interferences mitigated by specifying barge transit areas/Benefit of enhanced access in dredging areas.
[5] NA = No known resources: Spatial and temporal extent of impacts not applicable.
[6] Potential interferences near Farallon Islands mitigated by specifying barge transit areas.

Table 4.1-1. Continued.

Description	PREFERRED ALTERNATIVE				OTHER OCEAN ALTERNATIVES							
	Alternative Site 5				Alternative Site 3				Alternative Site 4			
	Impact Class[1]	Spatial Extent[2]	Temporal Extent[3]	Comment	Impact Class	Spatial Extent	Temporal Extent	Comment	Impact Class	Spatial Extent	Temporal Extent	Comment
Biological Environment												
- Plankton	III	L	S		III	L	S		III	L	S	
- Benthic Infauna	I	L	E		I	L	E		I	L	E	
- Benthic Epifauna	I	L	E		I	L	E		I	L	E	
- Demersal Fish	III	L	E		III	L	E		III	L	E	
- Pelagic Fish	III	L	S		III	L	S		III	L	S	
- Birds	III	L	S		III	L	S		III	L	S	
- Mammals	III	L	S		III	L	S		III	L	S	
- Threatened/ Endangered	III	L	S		III	L	S		III	L	S	

[1] Impact Class: I = Significant; II = Significant, but can be reduced by mitigation; III = Insignificant or none; IV = Beneficial.
[2] Spatial Extent: S = Confined within site boundaries; L = Localized (up to 1 nmi outside of site boundaries); R = Regional (beyond 1 nmi from site boundaries).
[3] Temporal Extent: S = Short term (less than or equal to 5 hours); E = extended (greater than 5 hours).
[4] Potential interferences mitigated by specifying barge transit areas/Benefit of enhanced access in dredging areas.
[5] NA = No known resources: Spatial and temporal extent of impacts not applicable.
[6] Potential interferences near Farallon Islands mitigated by specifying barge transit areas.

Table 4.1-1. Continued.

	PREFERRED ALTERNATIVE				OTHER OCEAN ALTERNATIVES							
	Alternative Site 5				Alternative Site 3				Alternative Site 4			
Description	Impact Class[1]	Spatial Extent[2]	Temporal Extent[3]	Comment	Impact Class	Spatial Extent	Temporal Extent	Comment	Impact Class	Spatial Extent	Temporal Extent	Comment
- Sanctuaries	II or III	L	S	Potential effects from spills mitigated by specifying barge transit areas	II or III	L	S		II or III	L	S	
Socioeconomic Environment												
- Fisheries												
Commercial	III	L	E		III	L	E		III	L	E	
Recreational	III	L	E		III	L	E		III	L	E	
- Shipping	III or IV	R	E	Footnote 4	III or IV	R	E		III or IV	R	E	
- Mineral	III	NA	NA	Footnote 5	III	NA	NA		III	NA	NA	

[1] Impact Class: I = Significant; II = Significant, but can be reduced by mitigation; III = Insignificant or none; IV = Beneficial.
[2] Spatial Extent: S = Confined within site boundaries; L = Localized (up to 1 nmi outside of site boundaries); R = Regional (beyond 1 nmi from site boundaries).
[3] Temporal Extent: S = Short term (less than or equal to 5 hours); E = extended (greater than 5 hours).
[4] Potential interferences mitigated by specifying barge transit areas/Benefit of enhanced access in dredging areas.
[5] NA = No known resources: Spatial and temporal extent of impacts not applicable.
[6] Potential interferences near Farallon Islands mitigated by specifying barge transit areas.

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Table 4.1-1. Continued.

Description	PREFERRED ALTERNATIVE				OTHER OCEAN ALTERNATIVES							
	Alternative Site 5				Alternative Site 3				Alternative Site 4			
	Impact Class[1]	Spatial Extent[2]	Temporal Extent[3]	Comment	Impact Class	Spatial Extent	Temporal Extent	Comment	Impact Class	Spatial Extent	Temporal Extent	Comment
- Military Usage	III	S	S		III	S	S		III	S	S	
- Recreational Usage	II	R	S	Footnote 6	III	R	S		III	R	S	
- Cultural/Historical	II	R	E	Footnote 6	III	L	E		III	L	E	
- Public Health/Welfare	III	L	E		III	L	E		III	L	E	

[1] Impact Class: I = Significant; II = Significant, but can be reduced by mitigation; III = Insignificant or none; IV = Beneficial.
[2] Spatial Extent: S = Confined within site boundaries; L = Localized (up to 1 nmi outside of site boundaries); R = Regional (beyond 1 nmi from site boundaries).
[3] Temporal Extent: S = Short term (less than or equal to 5 hours); E = extended (greater than 5 hours).
[4] Potential interferences mitigated by specifying barge transit areas/Benefit of enhanced access in dredging areas.
[5] NA = No known resources: Spatial and temporal extent of impacts not applicable.
[6] Potential interferences near Farallon Islands mitigated by specifying barge transit areas.

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Other sources of information concerning environmental impacts of dredged material disposal are based almost exclusively on research and monitoring of nearshore, shallow-water sites. Effects from dredged material disposal at deep-water sites are not well known. Of the more than 150 dredged material disposal sites in U.S. coastal waters, most are in water depths of less than 20 m (EPA 1989). Some limited information on environmental consequences of dredged material disposal in deep water areas is available. For example, information exists for the Yabucoa Harbor, Puerto Rico, dredged material disposal site at depths between 377 and 914 m (Stoddard *et al.* 1985) as well as sites located off southern California in 100 to 300 m of water (SAIC 1990a,b).

The following discussions of potential impacts are therefore based primarily on results of shallow water disposal site studies and the environmental characteristics of the preferred and alternative sites (see Chapter 3). Some of the impacts and processes occurring at these shallow water sites can be extrapolated to deep water environments. However, the deep continental slope and rise environment, within which the preferred and alternative sites are located, represents a unique combination of geological, hydrographic, and biological features that must be considered when evaluating the consequences of ocean disposal of dredged material in these environments. Therefore, as appropriate, limits of present knowledge are identified along with the uncertainties of extrapolating this information to the deep water environments of the LTMS study region.

4.2.1 Effects on the Physical Environment

These sections address potential effects of dredged material disposal at the preferred alternative site on regional meteorology and air quality, physical oceanography, water quality, geology, and sediment quality.

4.2.1.1 Air Quality

Potential impacts to regional air quality associated with dredged material disposal operations at the preferred alternative site were evaluated using an EPA air quality model. The model assumptions and results are summarized in the following section.

Initial screening modeling was performed for carbon monoxide (CO), volatile organic compounds (VOC), and oxides of nitrogen (NO_x) to determine impacts to air quality. Effects from the emissions of diesel engines on barge tugs were calculated using an EPA model (ISCST2) that was designed to compute air pollutant concentrations from various types of emission sources. EPA guidelines (EPA 1992b) were followed for the modeling analysis.

Air pollutant emissions from barges during transit between the Oakland inner, outer, and middle harbors and the preferred alternative site were modeled as eight, one km^2 volume sources grouped into one line source. The line source stretched from south of Treasure Island to a point 15 km southwest of the Golden Gate Bridge and followed a path along the deep water shipping channel. Initial dispersion coefficients and other related variables were determined following EPA guidance (EPA 1992b).

Emission factors for barge tugs were taken from "AP-42, Compilation of Air Pollutant Emission Factors" (EPA 1985). Other assumptions for barge tugs included a draft of 12 to 18 feet, 900 horsepower diesel engine, speed of 8 km/hr (4.3 knots), fuel consumption of 44 gal/hr, and 2 trips per day. Meteorological data were obtained from EPA's Office of Air Quality, Planning and Standards Technology Transfer Network Bulletin Board System (OAQPS TTN). The surface meteorological data were from San Francisco International Airport data for 1989 and the mixing height data was from Oakland International Airport data for the same year.

The model calculated concentrations for a receptor grid that covers all of San Francisco and parts of Sausalito, Berkeley, Alameda, and western Oakland. Concentrations of pollutants were averaged for one hour, 24 hours, and one year. The model output tabulated the highest concentrations for each receptor and the highest ten concentrations within the grid for each averaging period. These concentrations are compared to State and Federal ambient standards. Table 4.2-1 presents the modeled concentrations and the regulated limits. Based on these model results, no significant effects to air quality were indicated along the presumed route of the barges transporting dredged material to the preferred alternative site. Therefore, effects from barge tug emissions on air quality within the general LTMS study region are considered negligible, and use of an ODMDS for dredged material disposal is estimated to represent a Class III impact.

4.2.1.2 Physical Oceanography

The proposed use of an ODMDS for dredged material disposal is not expected to have any measurable effect on the regional or site-specific physical oceanographic conditions (Class III). Instead, the prevailing oceanographic processes will strongly influence the dispersion and long-term fate of dredged material discharged at the preferred alternative site. In particular, currents will affect the dispersion of particles in the water column and subsequent water quality conditions (discussed in Section 4.2.1.3), as well as settling and initial deposition of dredged material on the sea floor (discussed in Section 4.2.1.4). Those oceanographic conditions that are important to assessments of impacts on the physical, biological, and socioeconomic environments are summarized below.

Although the circulation patterns over the continental shelf and slope areas of the study region share some similarities with other regions of the California coast, there are specific current patterns that are unique to this region (Section 3.2). These patterns include: (1) near-surface flow over the slope that is more poleward than expected; (2) tidal effects which can be larger and amplified at different frequencies than those in other areas; (3) the unique spatial pattern of the California Undercurrent; and (4) a non-local source for the upwelled waters occurring on the shelf (Section 3.2). All of these characteristics would affect the resuspension, dispersal, and ultimate fate of dredged material deposited at the preferred and the alternative sites.

Table 4.2-1. Model-Predicted Maximum Concentrations of Air Pollutants in Central San Francisco Bay and the Corresponding Air Quality Standards.
The predicted maximum concentration represents the highest concentration within a receptor grid from ambient concentrations plus project-related (dredged material barge transit) operations.

Pollutant	Averaging Period	Predicted Maximum Concentration	Standard California	Standard Federal
CO	1 hour	14.2 $\mu g/m^3$ (0.012 ppm)	20 ppm	35 ppm
	24 hour	0.62 $\mu g/m^3$ (0.0005 ppm)		
	Annual	0.03 $\mu g/m^3$ (0.00003 ppm)		
NO_x	1 hour	115 $\mu g/m^3$ (0.06 ppm)	0.25 ppm[1]	
	24 hour	5.0 $\mu g/m^3$ (0.0027 ppm)		
	Annual	0.27 $\mu g/m^3$ (0.0001 ppm)		0.053 ppm
VOC	kg/day	2.6 kg/day	68 kg/day	

[1]Standard for NO_2; the comparison assumes that all of the NO_x is NO_2.

On the outer shelf, tidal and low frequency (subtidal) currents combine to generate currents near the sea bottom with speeds greater than 45 cm/sec (Noble and Ramp 1992). These currents are powerful enough to resuspend and transport fine sands. Therefore, any material containing fine sand or smaller grain sizes can be moved by currents within this region in the direction of predominant current flow. In addition, large currents from surface waves are expected to reach the sea bed over the outer shelf. When surface wave currents combine with lower frequency flows near the bottom, the erosive potential of the currents over the outer shelf is greatly enhanced (Grant and Madsen 1979). The tendency for currents near the bottom to flow poleward, especially during winter when large surface waves are generated by winter storms, suggest that any fraction of dredged material deposited on the shelf eventually could move along the isobaths into the GOFNMS.

Persistent poleward flow occurs in the upper 1,000 m of the water column over most of the year (Section 3.2.2). This poleward flow is interrupted by equatorward events which can last as long as a month. A strong seasonal pattern in the current regime was not apparent from recent EPA studies (Noble and Ramp 1992). However, there was an abrupt transition to a less energetic regime with more variable current directions from approximately the middle of August until November, after which more energetic but intermittent poleward flow persisted through the winter. There is evidence that the poleward flow is strongest over the inner slope at about 100 m depth near Alternative Sites 3 and 4 but moves offshore to the north in the region of the preferred alternative site. The inner slope currents offshore of the Farallon Islands are particularly weak below the shallow surface layer. Currents below 800 to 1,000 m depth are small magnitude, low frequency flows and are dominated by tides. Flows on the outer shelf appear to be separated and unrelated to flows over the slope (Noble and Ramp 1992). The time and space varying current field has a major influence on dispersion and deposition in deep water.

The local topography of a site is expected to cause enhanced flow and veering in the currents near the bottom. Because enhanced tidal flows generally are stronger than subtidal near-bottom currents, tidal movements represent the largest contributor to the erosive characteristics at the different sites. The near-bottom currents at mooring Stations B and C, located near the southern boundary of Study Area 3, and mooring E, located in deeper water near the eastern boundary of Study Area 5, had maximum current speeds between 37 and 43 cm/sec (Figure 3.2-2). Mooring D, located to the south of Alternative Site 3, and F, located on the upper slope inshore from Study Area 5, had relatively lower near-bottom tidal currents (see Section 3.2.2; Figure 3.2-2). Thus, material deposited near Stations B, C, or E would be eroded more easily than material deposited at Stations D or F. The near-bottom subtidal flow direction suggests that resuspended material at Station B will be dispersed in both directions along the isobaths. Resuspended material at Station C would be carried poleward, and resuspended material at Station E would be carried eastward up the axis of a small, unnamed submarine canyon. However, because Station E is in 2,000 m of water, it is not expected that resuspended material would move onto the shelf, but rather would remain in the deeper portion of the canyon.

Upwelling processes can affect the dispersal of material suspended in the water column; however, recent data from EPA surveys indicate that the local upwelling in the Gulf of the Farallones is weaker than at other sites along the California coast (Ramp *et al.* 1992). The majority of the cold saline water on the shelf during summer is advected horizontally into the region from a strong upwelling center north of Point Reyes. Therefore, it is very unlikely that material, including dredged material, suspended in the waters over the slope would be transported via locally upwelled water onto the shelf. Further, water quality modeling results indicate that significant transport of suspended material to shelf areas from disposal activities at the preferred or alternative sites would be very unlikely (Section 4.2.1.3).

4.2.1.3 Water Quality

This section discusses dredged material settling behavior and water quality effects.

Dredged Material Settling Behavior

Dredged material disposal may have a short term (several hours to days) impact on the water column following discharges of solids and solutes from a barge (e.g., Gordon 1974). The greatest proportion of dredged material consists of negatively buoyant solids that sink as a turbid suspension through the water column to the seabed. Dissolved constituents of dredged material are entrained in the turbulent water associated with the convective descent. Predictions of the impacts of the descending plume on the ambient water column depend on the settling velocity of component particles or particle aggregates, particle concentrations, particle chemistry, water depth, and the presence and strength of water density stratification (i.e., pycnocline). The fate of dissolved components depends on their solubility and reactivity with the entrained ambient water and particles, and mixing properties of the ambient flow field.

The proposed ODMDS is expected to receive dredged sediment of two general types: "mostly sand" (76% sand, 21% clay, and 3% silt) and "silt-clay" (74% silt, 5% clay, and 21% sand) (Section 3.1). The settling velocities of the medium sand and coarser material have been measured in the laboratory. These measurements can be used to estimate the theoretical transit time in a motionless water column. However, the actual (in situ) settling velocities of individual particles may vary depending on changes in the density of the water column and water column turbulence. Sediment dispersion models are most accurate in predicting the transit time and dredged material footprint of these coarse fractions because of the availability of empirical data (e.g., Koh and Chang 1973).

The settling behavior of very fine sand and smaller particles is more difficult to estimate because these fractions rarely consist of discrete particles. Very large aggregates (mud clasts up to a meter in diameter) may form the bulk of disposed material, particularly when mechanical clam shell dredges are used to excavate cohesive clay and mud from channels and basins. Smaller aggregates (up to about 1 mm in size) also dominate the muddy slurry associated with dredged muds and fine sands. The high surface areas and surface charges associated with fine particles, particularly clay minerals, promote particle-to-particle aggregation in marine waters. Also, the presence of biogenic films, which coat the surfaces of small particles, serve to bind fine particles into low density organic-mineral aggregates. Zooplankton grazing also has been shown to result in repackaging of suspended particles into rapidly settling fecal pellets (Capuzzo 1983). The settling velocities of aggregates can be much higher than their component particles. No empirical data, with the exception of the information on zooplankton pellets, exist for accurately estimating the settling velocities of such aggregates (Komar *et al.* 1981). Therefore, the behavior of these aggregates or clumps is the most difficult to predict in dispersion models. The rate of convective descent of typical estuarine (e.g., from San Francisco Bay) dredged material consisting of large, cohesive mud clasts has been measured as approximately 1 m/sec (Bokuniewicz *et al.* 1978); the exception was the 3 to 5% (by weight) of the material that comprises the fine silt fraction, which had a sedimentation rate of about 0.7 cm/sec.

Coarse sand (and larger) size fractions and large, cohesive, silt-clay mud clasts settle rapidly to the bottom and accumulate close to the point of discharge. Slower settling fractions decelerate as the descending plume experiences dynamic collapse. This is the point of nearly neutral buoyancy for settling particles, when passive dispersion of this fine fraction takes place. The depth at which convective descent changes to neutral buoyancy is largely a function of volume of the barge load (Stoddard *et al.* 1985). The relationship between buoyancy depth and depths of pycnoclines and the bottom is important for predicting water column exposures. In deep water environments, such as the preferred and alternative sites, the buoyancy depth may be much shallower than the bottom. In this case, the neutrally buoyant plume may intersect a pycnocline, and slowly settling particles can accumulate and spread laterally along this density interface with the potential for farfield dispersion by horizontal advection. Therefore, the greatest potential for long-term, water column impacts and farfield dispersion is associated with slowly settling, organic-mineral aggregates within the region of neutral particle buoyancy and along pycnoclines.

Disposal Plume Modeling

Effects on water quality from dredged material disposal at the preferred and alternative sites were evaluated using a computer model to determine dispersion and dilution of suspended particles at varying distances and times following a disposal event (SAIC 1992e). The model calculated the probability or visitation frequency of particle clouds moving over specific locations in the vicinity of the sites. This approach was based on models used by Csanady and Churchill (1986) and Churchill (1987) to assess environmental impacts at ocean disposal sites. The model was adapted for the present application to simulate discrete discharge events and the predicted behavior of material that settles according to individual particle size classes. The assumptions used in the model and the model results are described in the following section.

The model assumed that dredged material disposal would occur as discrete events, representing releases from a barge of 6,000 yd^3 of sediments every 12 hours, over a period of one year, for a total annual volume of 4.38 million yd^3. The dredged material was assumed to consist of seven particle size classes, with class-specific sinking rates. The initial disposal cloud was modeled as a circular "slab" with a diameter of 100 m and a thickness of 50 m. The "mostly sand" type material, as modeled, contained a maximum concentration of 5,290 mg/l of fine sand class particles. In the "clay-silt" type material, a portion of this fine sand is replaced in the model by 2,500 mg/l of fine silt particles. These initial particle concentrations would be approximately 1,000 times higher than background or ambient suspended particle concentrations of approximately 1 to 5 mg/l (see Section 3.2.3).

The model assumed that the initial cloud separated due to differential sinking and differing rates of horizontal transport into seven clouds comprising the different size class particles (Table 4.2-2). Over time and distance from the release point, clouds would spread due to turbulent diffusion. Under the assumption of constant diffusion, concentrations of particles in these separate clouds would decrease approximately linearly with time following release. The model predicted that the average particle concentration within the clouds would decrease to background concentration (conservatively assumed to be approximately 1 mg/l), or particles would be deposited on the seabed, within about two days for most particle size classes. During this time, if the cloud remained in the water column, the cloud diameter would increase by a factor of 30 or more. Primary exceptions to these time limits (known as the cloud age limit) were clouds of fine silt (class 6) with high initial concentrations that would remain in the upper water column for many days. Using small values (1 m^2/sec) for the horizontal diffusion coefficient, it was calculated that clouds of fine silt particles would require about five days to reach ambient concentrations. However, these calculated times to reach ambient suspended particle concentrations are sensitive to the assumed value of the horizontal diffusion coefficient.

Table 4.2-2. **Particle Size Classes and Sinking Velocities Used in the Sediment Deposition Model.**

Class	Name	Particle Diameter (µm)	Sinking Velocity (m/sec)	Time to Sink 1,000 m (hours)	Horizontal Distance Traveled at 0.1 m/sec (km)	Percent by Weight*
1	Coarse Sand	1,000	0.086	3.2	1.15	1.1
2	Medium Sand	500	0.041	6.8	2.45	23.9
3	Fine Sand	250	0.016	17.4	6.26	43.4
4	Very Fine Sand	125	0.0052	53.4	19.22	7.6
5	Coarse Silt	62	0.0014	198.4	71.42	3.3
6	Clay-Silt	31	0.0005	556	200.0	10.4**
7	Clay-Silt Clumps	—	0.15	1.85	0.67	10.3**

* Material Composition Oakland NSC Site.
**Assumes 50% clumping of Clay-Silt Material.

Source: SAIC (1992e).

Values used for the model are smaller than have been measured directly in the deep ocean (Ledwell and Watson 1991), but are consistent with the turbulent scales associated with the characteristic sizes of the clouds. Using diffusion coefficients closer to those measured by Ledwell and Watson (1991) would reduce the cloud age limit by factors of 5 to 10 times (i.e., the time required for particle concentrations to reach background concentrations would be reduced from five days to 12 to 24 hours.

The model estimated the probability over a one-year period that the water column above individual "grid" locations on the sea floor would experience the passage of the particle cloud associated with a discrete discharge event within 48 hours of release. The results are expressed as a percentage of disposal events contacting a grid location, and are termed the "visitation frequency." For example, a visitation frequency of 5% for a class 4 (very fine sand) particle corresponds to a probability of 5 out of every 100 disposal plumes containing very fine sand particles passing over a specific location. The model also calculated the average depth in the water column of the cloud as it passed over the grid point (i.e., cloud depth) and the time required for the cloud to pass over a location (exposure time). Because vertical diffusion is considered minimal as compared to horizontal diffusion, the modeled cloud maintains a vertical thickness of 50 m as it passes through the water column (Figure 4.2-1).

In the model, individual particle size clouds separate due to different sinking velocities and would not be expected to contact each other after disposal. Average cloud depths increase in proportion to average cloud age and particle concentration due to the constant sinking speed for each class of particles. Thus, a cloud of coarse sand (class 1) would descend to the bottom within a few hours and would affect only the water column within a few kilometers of the discharge point. In contrast, coarse silt particles (class 5) would descend only a few hundred meters within a period of two days, and would be dispersed greater distances from the discharge point. Characterizing the dredged material as consisting of discrete particle size classes is appropriate for the purposes of a practicable model, although it is more likely that actual particle sizes and sinking speeds would represent a continuum.

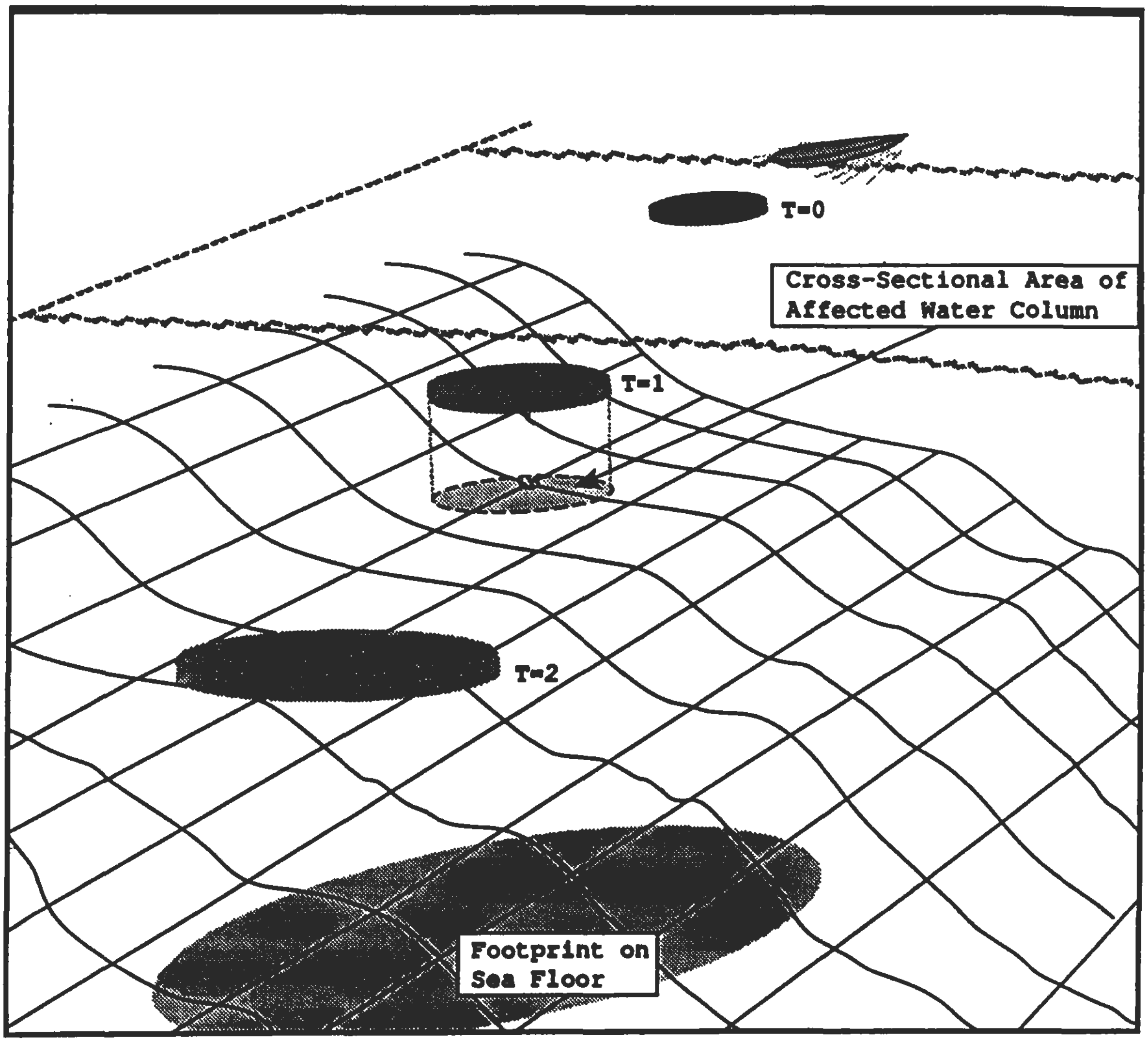

Figure 4.2-1. Schematic of a Particle Cloud Sinking Through the Water Column.
T=O, T=1, and T=2 correspond to time at the initial disposal and subsequent intervals during cloud descent through the water column.
Particle concentrations are indicated by relative shades of grey.
Source: SAIC 1992e.

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The calculated visitation frequencies and average suspended particle concentrations associated with discharges from the preferred and alternative sites are summarized in Table 4.2-3 and plotted in Figures 4.2-2 through 4.2-4 for Class 6 (clay-silt) particles. (Alternative Sites 3 and 4 are discussed further in Section 4.4.) This particle class contained the smallest diameter particle considered, with the corresponding lowest sinking rate, longest water column residency time, and thus the largest horizontal dispersion or affected area. Larger particles would have relatively shorter water column residency times and smaller dispersion areas. The fastest falling particles of the high concentration classes (fine sands and clay-silt clumps) would only spread a few kilometers from the disposal site, and reach the bottom in 2,000 m water depths within 4 to 24 hours of release. Clouds of particles that settle within the dispersion period (i.e., 48 hours) affect an area similar to that predicted by the sediment deposition (footprint) model (Section 4.2.1.4) for a particular size class. The slower settling particles (classes 4 through 6) are the exception because they do not reach the bottom within 48 hours.

Model results indicated that clouds of coarse to very fine sands and coarse silts (particle classes 1 through 5 and class 7) likely would not be transported across the GOFNMS, CBNMS, or MBNMS boundaries (i.e., probabilities less than 0.2%). Clay-silt particles (class 6) represent the only size class of material with a predicted likelihood of being transported across sanctuary boundaries under the conservative assumptions of high initial concentrations, low dispersion rates (D = 1 m^2/sec), and ambient suspended particle concentrations of 1 mg/l. Based on the model, plumes of fine grained sediments, representing only a fraction of disposed material, were estimated to cross the GOFNMS and MBNMS boundaries from only 0.2 to 5% of the disposal events regardless of which of the sites was used for dredged material disposal. The predicted particle concentrations within plumes crossing the sanctuary boundaries would be approximately 1 to 2 mg/l and within the range of presumed background or ambient levels (Figures 4.2-2 through 4.2-4). The calculated average depths of the plumes at the sanctuary boundaries would range from approximately 60 to 800 m. Using higher dispersion rates (e.g., D = 10 m^2/sec) in the model would result in relatively lower visitation frequencies and particle concentrations in the vicinity of the sanctuary boundaries (Figure 4.2-5).

Table 4.2-3. Model-Predicted Disposal Plume Visitation Frequencies, Mean Depth, and Exposure Times for Simulated Discharges at the Preferred Alternative (Alternative Site 5) and Alternative Sites 3 and 4.

Area affected corresponds to the area defined by the 1 mg/l suspended particle concentration contour (i.e., the assumed background concentration). Visitation frequency represents the probability or percentage of the total number of disposal events in which a cloud of individual size classes of particles would pass over a particular location on the seafloor. Cloud depth is the average (mean) and standard deviation (SD) of the depths in the water column of the cloud as it passes over a location. Exposure is the length of time that a position in the water column would experience higher concentrations of particles relative to background levels. Cloud age is the time required since disposal for particle concentrations within the cloud to reach background levels or for particles to settle on the bottom. Model-predicted values based on current data for the period March 15, 1991 through February 15, 1992.

Preferred Alternative (Alternative Site 5)							
Particle Size Class	Area Affected (km^2)	Visitation Frequency		Cloud Depth		Maximum Exposure (hrs)	Maximum Cloud Age (hrs)
		Mean (%)	Maximum (%)	Mean (m)	± SD (m)		
1: Coarse Sand	48	6.0	49.2	2393	370	2.6	10
2: Medium Sand	102	8.2	62.7	2237	388	5.5	21
3: Fine Sand	336	8.0	64.0	1902	398	13.2	48
4: Very Fine Sand	932	4.1	54.1	725	113	14.0	48
5: Coarse Silt	603	2.1	28.4	112	17	7.7	24
6: Clay-Silt	3681	3.8	37.2	166	36	43.9	120
6*: Clay-Silt*	1245	5.2	74.4	54	5	6.7	24
7: Clay-Silt Clumps	23	5.2	39.3	2335	360	1.5	5

*Diffusion coefficient increased from 1 m^2/sec to 10 m^2/sec.
Source: SAIC (1992e).

Table 4.2-3. Continued.

Alternative Site 3

Particle Size Class	Area Affected (km^2)	Visitation Frequency		Cloud Depth		Maximum Exposure (hrs)	Maximum Cloud Age (hrs)
		Mean (%)	Maximum (%)	Mean (m)	± SD (m)		
1: Coarse Sand	30	3.4	21.3	1237	241	1.4	6
2: Medium Sand	96	3.9	28.6	1326	233	3.3	14
3: Fine Sand	414	4.2	35.1	1315	265	9.8	41
4: Very Fine Sand	1227	3.0	22.8	675	122	16.0	48
5: Coarse Silt	1082	1.4	20.3	115	32	7.0	24
6: Clay-Silt	7855	2.2	19.7	168	28	42.0	120
6*: Clay-Silt*	1717	4.3	62.2	54	5	6.1	24
7: Clay-Silt Clumps	13	2.7	18.7	1073	244	1.0	3

Alternative Site 4

Particle Size Class	Area Affected (km^2)	Visitation Frequency		Cloud Depth		Maximum Exposure (hrs)	Maximum Cloud Age (hrs)
		Mean (%)	Maximum (%)	Mean (m)	± SD (m)		
1: Coarse Sand	32	3.7	29.6	1404	284	1.6	6
2: Medium Sand	98	4.7	35.3	1505	298	3.4	16
3: Fine Sand	457	4.8	35.6	1511	315	10.9	43
4: Very Fine Sand	1321	3.0	24.9	694	128	15.4	48
5: Coarse Silt	1217	1.3	16.0	115	15	6.9	24
6: Clay-Silt	7708	2.3	19.7	164	29	42.8	120
6*: Clay-Silt*	1913	3.9	55.4	55	5	6.1	24
7: Clay-Silt Clumps	13	4.3	23.9	1378	328	1.0	3

*Diffusion coefficient increased from 1 m^2/sec to 10 m^2/sec.
Source: SAIC (1992e).

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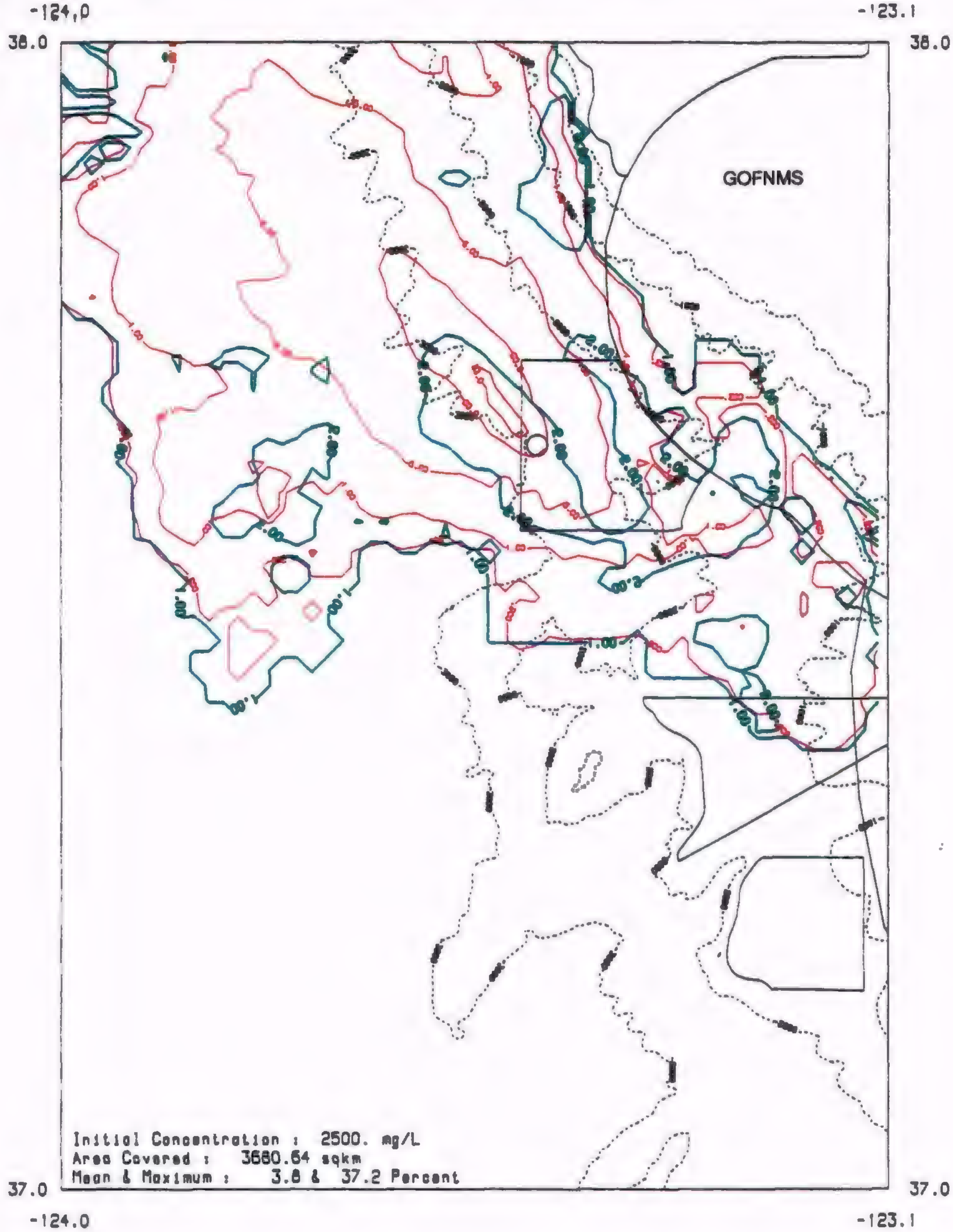

Figure 4.2-2. Model-Predicted Visitation Frequencies (red) and Average Particle Concentrations (green) for Clay-Silt (Class 6) Sediments Discharged at the Preferred Alternative Site.

Visitation frequencies (in percent) represent the probability of the total number of disposal events in which a cloud of particles would pass over a location on the seafloor. The concentration contour represents the suspended particle concentration (mg/l) within a cloud as it passes a location. Results were based on current data for the period March 15, 1991 through February 15, 1992, and used a diffusion coefficient of D=1 m^2/sec.

Source: SAIC 1992e.

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Figure 4.2-2. Continued.

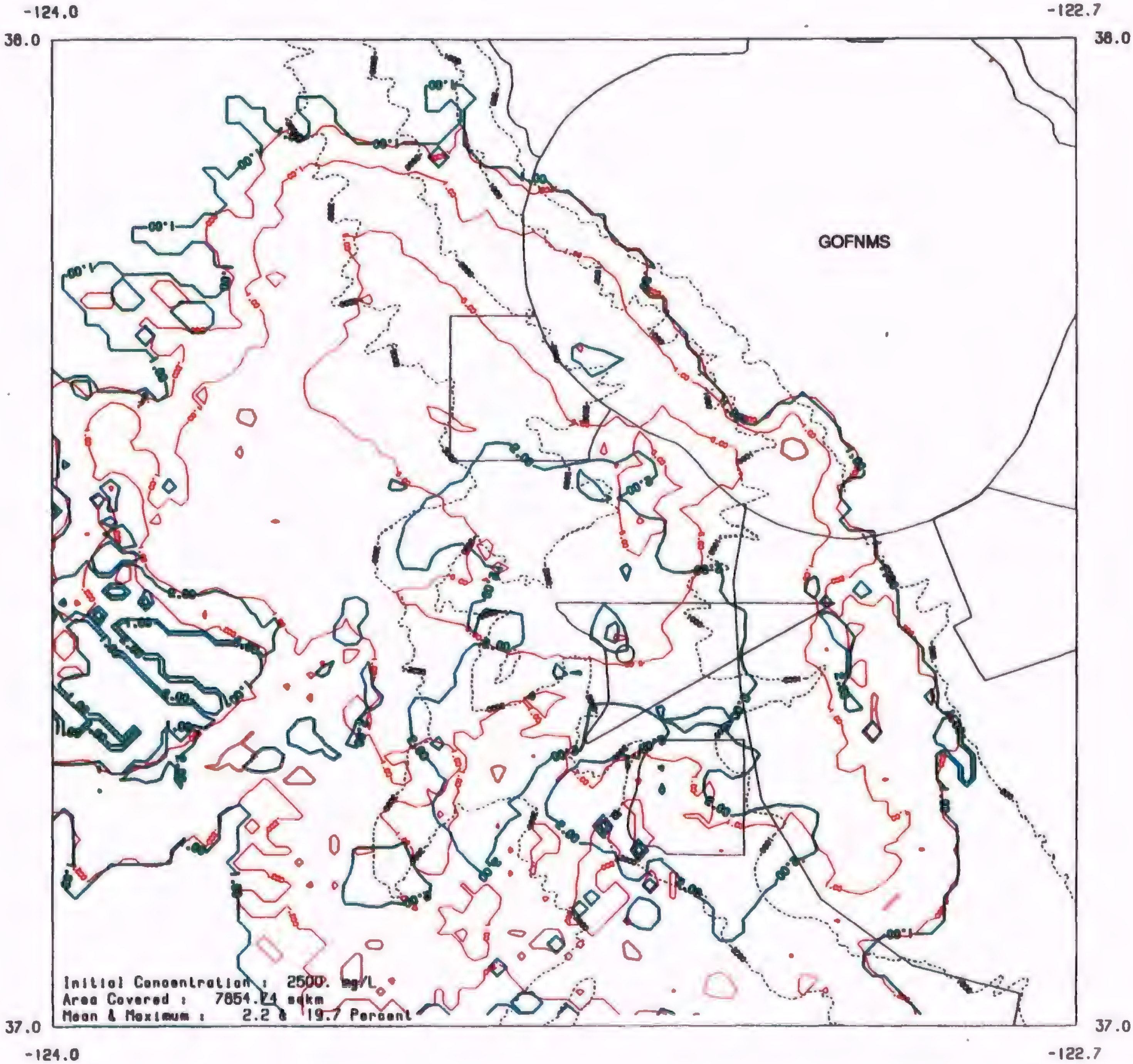

Figure 4.2-3. Model-Predicted Visitation Frequencies (red) and Average Particle Concentrations (green) for Clay-Silt (Class 6) Sediments Discharged at Alternative Site 3.

Visitation frequencies (in percent) represent the probability of the total number of disposal events in which a cloud of particles would pass over a location on the seafloor. The concentration contour represents the suspended particle concentration (mg/l) within a cloud as it passes a location. Results were based on current data for the period March 15, 1991 through February 15, 1992 and used a diffusion coefficient of $D=1m^2/sec$.
Source: SAIC 1992e.

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Figure 4.2-3. Continued.

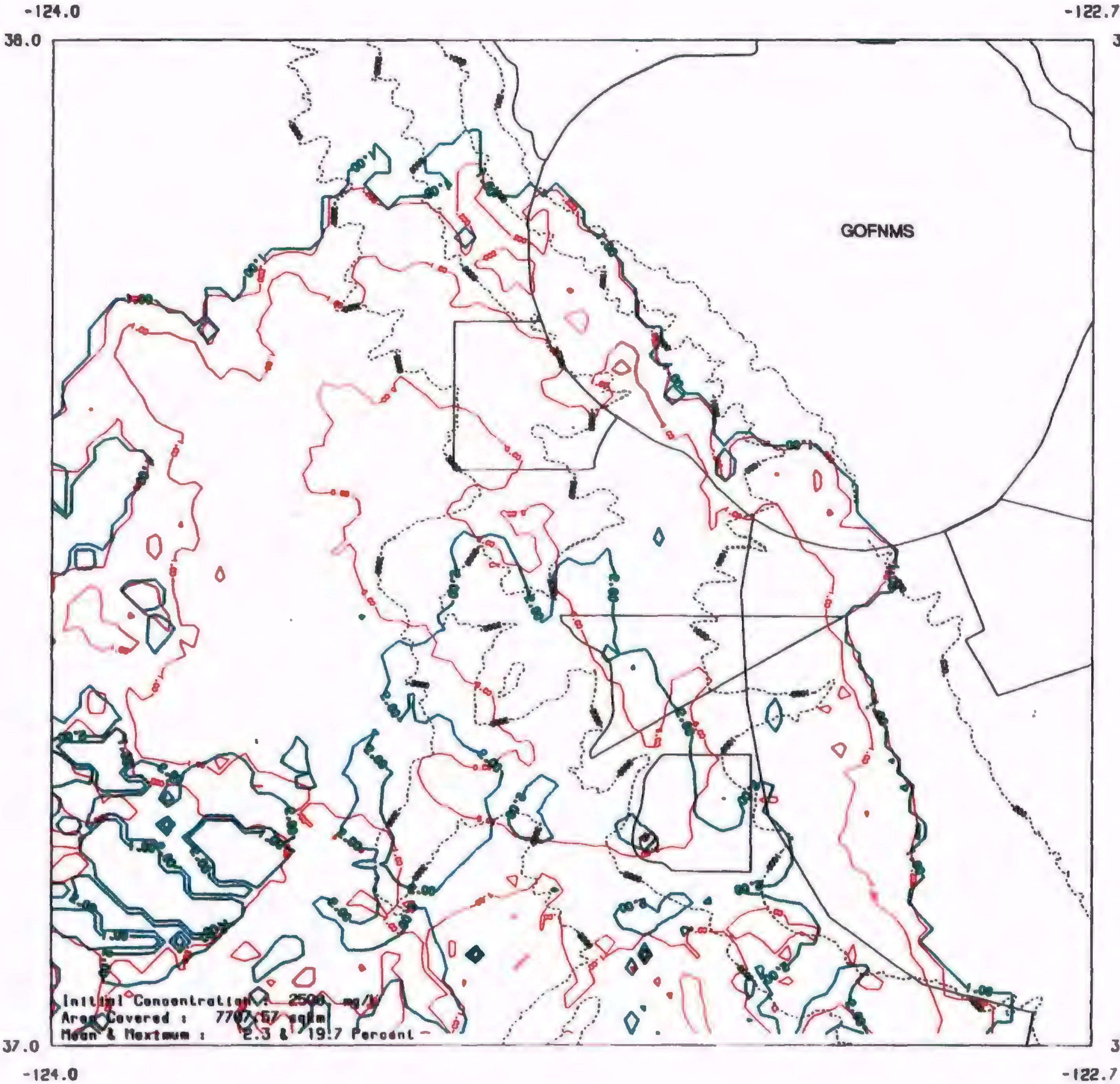

Figure 4.2-4. Model-Predicted Visitation Frequencies (red) and Average Particle Concentrations (green) for Clay-Silt (Class 6) Sediments Discharged at Alternative Site 4.

Visitation frequencies (in percent) represent the probability of the total number of disposal events in which a cloud of particles would pass over a location on the seafloor. The concentration contour represents the suspended particle concentration (mg/l) within a cloud as it passes a location. Results were based on current data for the period March 15, 1991 through February 15, 1992 and used on diffusion coefficient of D=$1m^2$/sec. Source: SAIC 1992e.

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Figure 4.2-4. Continued.

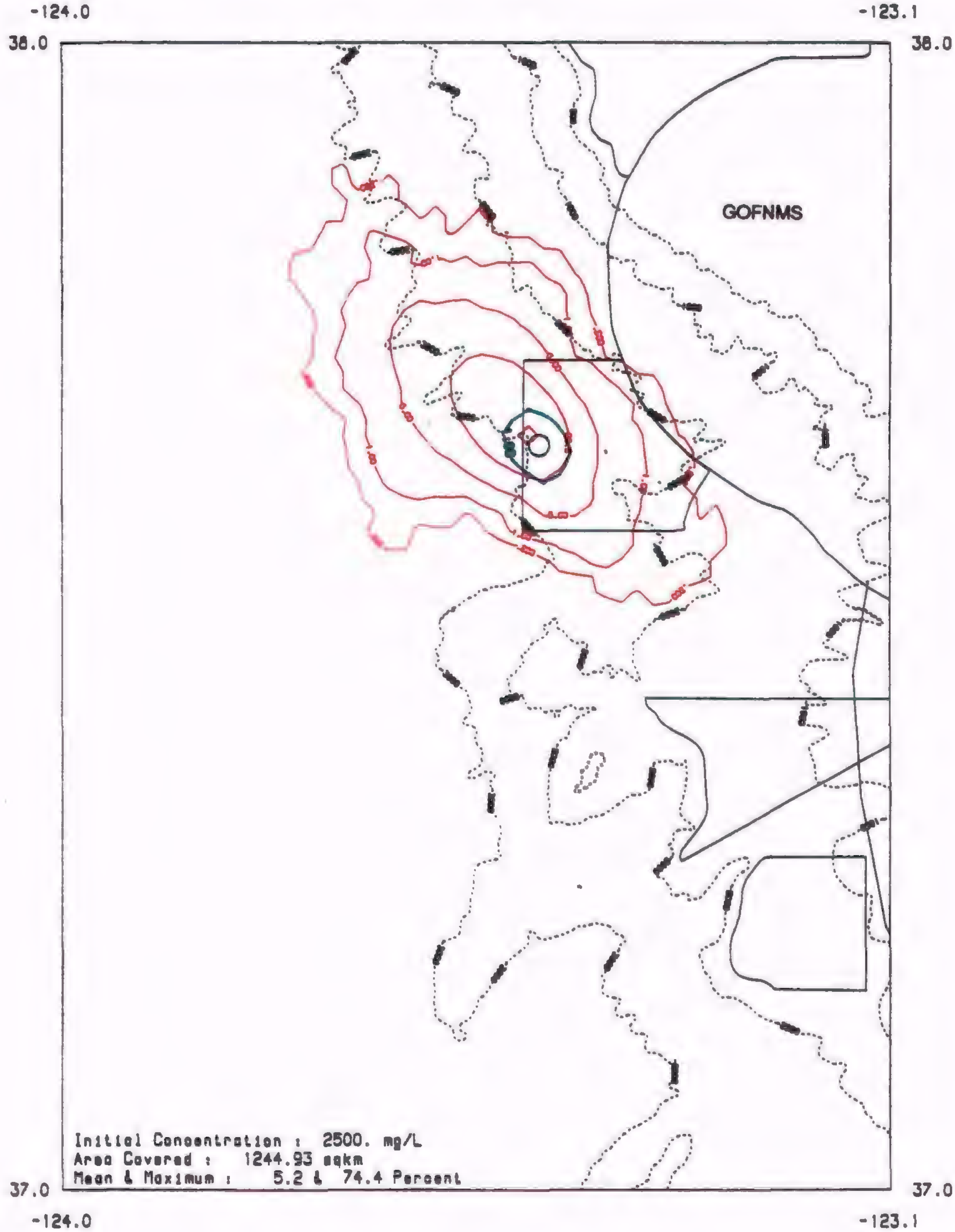

Figure 4.2-5. Model-Predicted Visitation Frequencies (red) and Average Particle Concentrations (green) for Clay-Silt (Class 6) Sediments Discharged at the Preferred Alternative Site Using a Diffusion Coefficient of $D=10m^2/sec$.

Visitation frequencies (in percent) represent the probability of the total number of disposal events in which a cloud of particles would pass over a location on the seafloor. The concentration contour represents the suspended particle concentration (mg/l) within a cloud as it passes a location. Results were based on current data for the period March 15, 1991 through February 15, 1992.
Source: SAIC 1992e.

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Figure 4.2-5. Continued.

The duration of turbid plumes near the discharge site would vary with the frequency and location of disposal events. Although the model assumed that disposal would occur every 12 hours, the actual frequency of disposal events at an ODMDS is unknown but is likely to be less frequent than assumed by the model. As a result, impacts on water quality associated with dredged material plumes are expected to be transitory when site use is intermittent. Furthermore, disposal likely will take place at various locations within the approved disposal site and, consequently, the plumes would not originate from the same location. The direction of transport for individual plumes also would vary depending on the prevailing current patterns.

Specific results from the water quality model of discharges at the preferred alternative site suggested that disposal plumes corresponding to individual particle size classes would affect areas from 23 to 3,681 km^2, with mean visitation frequencies from 2.1 to 8.2% (Table 4.2-3). Higher visitation frequencies calculated for the preferred alternative site, as compared to Alternative Sites 3 and 4 (see Section 4.4.1.3), are due to the greater water depth and longer descent times, which would allow the clouds to increase in size and affect a larger percent of the region immediately adjacent to the preferred alternative site. For individual particle classes, mean cloud depths ranged from 54 to 2,393 m. Maximum exposure times, defined as the time during which background concentrations of suspended particles are exceeded at a particular point, ranged from approximately 1.5 to 44 hours. Use of the preferred alternative site would result in concentrations from 1 to 2 mg/l of suspended particles at the boundaries of the GOFNMS and MBNMS for 0.2 to 1% of the disposal events, (i.e., 2 to 10 occurrences per 1,000 discharge events, Figure 4.2-2). These concentrations are within the presumed range of normal ambient values for suspended particles and would not be expected to result in measurably elevated concentrations within the sanctuaries. Concentrations at the CBNMS boundary would not be expected to be elevated above background concentrations at any time.

Water Quality Effects

Potential impacts on water quality from dredged material disposal are expected to be transient at the preferred alternative site, therefore representing Class III impacts. These changes correspond to localized increases in turbidity, reductions in light transmittance, and increases in dissolved and particulate concentrations of trace chemical constituents contained in the dredged material. The following is a discussion of generic effects; expected effects for the preferred alternative are summarized below.

Chemically reduced inorganic compounds associated with particles sinking through the upper water column (generally above a depth of 400 m) may be oxidized, causing a transient increase in the chemical oxygen demand. Oxidation of labile organic material consequently may reduce dissolved oxygen concentrations in the water. However, because the upper water column in the study region is well oxygenated, this effect may be more pronounced at depths corresponding to the oxygen minimum zone (OMZ) where dissolved oxygen concentrations are naturally low (i.e., less than 2.8 mg/l; Figure 3.2-7).

Similarly, depending on the chemical composition of the dredged material, elevated concentrations of sinking particles may cause changes in the concentrations of trace chemical constituents in the water column. Because the bulk chemical composition of the dredged material is not known, assessments of the contributions of suspended particles to changes in water quality at the preferred and alternative sites, and subsequent comparisons to marine water quality criteria, presently are not possible. However, these chemical concentrations are expected to be low because dredged material must be tested and the results meet established criteria in order to be acceptable for disposal (see Section 4.6). Evaluations of changes in water quality due to a specific disposal event will be made during the permitting process for individual dredging projects.

Dredged material disposed at an ocean site also can introduce dissolved solutes or gases, such as hydrogen sulfide, methane, manganese, iron, ammonia, and phosphorus, that occur naturally in estuarine sediments such as San Francisco Bay. These may be introduced in solution or subsequently released into ambient waters by desorption from particles and/or release of trapped interstitial gas from the break-up of falling cohesive mud clasts. Material deposited on the bottom represents a second source of dissolved compounds (Salomons *et al.* 1987). Once solid particles reach the seafloor, changes in pH and redox potential (Eh), and benthic organism and microbial activity, can redissolve metals and organic compounds. Remobilized, dissolved compounds can accumulate in sediment porewaters or in water overlying deposited material or sediments (Forstner and Wittman 1983; Bryan 1984; Graybeal and Heath 1984; Landner 1986; Salomons *et al.* 1987).

The chemical fate of dissolved contaminants in seawater will be affected by a variety of physical, chemical, and biological processes. These factors include: (1) circulation and mixing processes; (2) the presence of organic matter, clays, iron and manganese oxides and hydroxides; (3) salinity; (4) biological uptake processes; (5) chemical conditions (Eh, pH) in the sedimentary and water environment; and (6) the properties of the compound itself. Water circulation may be the most important factor affecting dispersal of contaminants in the oceans (Bryan 1984). Dissolved constituents also are diluted as the discharged material settles through a deep water column. In the deep ocean, near-bottom currents are capable of dispersing dissolved materials that have diffused out of deposited sediments. Conversely, local topographic depressions, such as submarine valleys or troughs, have the potential to trap finer-grained sediments which often contain relatively higher concentrations of trace chemical constituents.

Organic matter, clays, and iron oxides all have the ability to adsorb dissolved organic compounds, metals, and salts due to the ion-adsorptive properties (Lee 1975; Stumm *et al.* 1976; Hem 1977; Kerndorf and Schnitzer 1980; Leckie *et al.* 1980; Davis and Gloor 1981; Tipping 1981; Forstner and Wittman 1983; Hunter 1983; Balistrieri and Murray 1986; Landner 1986). Present evidence suggests that cycling and residence times of dissolved and particulate metals in the oceans are controlled by a combination of biological scavenging and uptake by surface-reactive particles (Fisher *et al.* 1991). Bio-concentration of metals through uptake by zooplankton may result in the production of metal-rich zooplankton fecal pellets. These particles serve as an important vehicle for the rapid removal and sedimentation of contaminants to the seafloor (Capuzzo 1983), and affect the residence times of elements in the ocean (Fowler 1977; Cherry *et al.* 1978; Fisher *et al.* 1991).

Adsorption and scavenging of metals by organic particles or organic coatings on particles is another important process that removes metals from the water column (Brewer and Hao 1979; Balistrieri *et al.* 1981; Forstner and Salomons 1982; Balistrieri and Murray 1983, 1984; Hunter 1983; Bryan 1984; Collier and Edmond 1984; Honeyman *et al.* 1988). Particle concentrations in the water column may be the most important variable affecting metal removal (Capuzzo 1983; Honeyman *et al.* 1988). Organic matter appears to have greater ability to form complexes with metals than with inorganic minerals (Balistrieri *et al.* 1981). Desorption of metals may be driven by interactions with particulate or dissolved ligands (or both) in seawater (Erel and Morgan 1991). Thus, the fate of metal contaminants, even in the dissolved phase, is strongly affected by the number and kinds of particles that are present in the descending or dispersing plume and in the ambient water column.

Once particles have reached the sea floor, reducing conditions may develop again beneath the oxidized surface sediment layer, particularly if concentrations of labile organic carbon are greater than about 1%. Thus, remobilization of metals from particles could occur in both the water column (OMZ) and in the sediment column, resulting in a release of dissolved metals to the overlying water or to porewater.

The mobility of certain metals is strongly affected by pH and the Eh of the environment. Metals which become soluble under reducing conditions include iron, manganese, and mercury (Bothner *et al.* 1980), whereas oxidizing conditions favor the release of cadmium, nickel, lead, and zinc (Bryan 1984). Dissolution of certain metals under anoxic conditions is balanced by their precipitation as metal sulfides. The dissolution of iron or manganese oxides releases other metals, such as zinc, copper, cobalt, nickel, and lead, and organic compounds which were adsorbed to these compounds (Elderfield and Hepworth 1975; Bryan 1984).

Biological activity, including bioturbation and microbial activities, in sediments also can remobilize contaminants in deep-sea surface sediments (Graybeal and Heath 1984). Microbial decomposition of organic matter, including organic compounds, can transform compounds from one form to another, potentially affecting their toxicity, mobility, and release to the water column (Metcalf 1977; Colwell and Saylor 1978; Bryan 1984).

Effects to water quality from dredged material disposal at the preferred alternative site are considered Class III potential impacts because plumes are expected to disperse within 48 hours of discharge, no build-up or accumulation of particles within the water column is expected, and changes to water quality parameters (e.g., turbidity, light transmittance, dissolved oxygen concentrations) are expected to be transient and localized within the discharge plume. Disposal operations should have insignificant effects on concentrations of contaminants in the water column, given that only dredged material of suitable quality will be permitted for disposal.

4.2.1.4 Geology and Sediment Characteristics

Dredged material disposal operations at the preferred alternative site are not expected to result in any significant changes in regional bottom topography or sediment transport processes, although minor accumulations of sediments to depths of a few to several centimeters could occur within the sites (discussed below). In the vicinity of the alternative sites, where depths are greater than 1,600 m and slope angles are small, mounding of bottom sediments or slight changes in sediment stability conditions are not a primary concern (Class III impact). Accumulation of dredged material, and associated changes in the sediment characteristics may cause impacts to benthic-dwelling organisms (Sections 4.2.2.2 and 4.2.2.3).

Particle Deposition (Footprint) Model

The spatial extent of effects at the preferred and alternative sites were evaluated using a sediment deposition (footprint) model to predict the horizontal transport of theoretical dredged material particles and cumulative deposit thicknesses on the seafloor (SAIC 1992e). The assumptions and the results of the model predictions are summarized below.

The deposition of dredged material was assumed to result from a continuous release from the surface to increase the statistical confidence for modeling long-term deposition. This was accomplished by simulating the release of approximately 16,000 discrete particles for each size class over a one-year period. The source material was divided into independent particle size classes which could be tracked as the material sinks through the water column. The locations of particles for each size class were estimated using the model which incorporated all influences on particle movement. These influences included tidal and non-tidal currents sampled during a one-year period (March 1991 through February 1992). The model advected (transported) particles horizontally according to estimates of the local current velocity at each time step. One-year current records from measurements described in Section 3.2.2 were used to calculate the velocities. Linear interpolation between velocity positions on the current meter moorings was used to estimate current velocities at specific locations and depths; this accounted for vertical and horizontal spatial variability of the current field experienced by a sinking particle. The vertical distance traveled was determined by the sinking velocity.

Standard particle sizes and their associated sinking speeds are listed in Table 4.2-2. The table also lists the calculated time to sink to 1,000 m depth for seven size classes of particles or clumps under horizontal current speeds of 10 cm/sec. Water depths at the preferred and alternative sites vary from approximately 1,400 to 3,000 m, and maximum current speeds vary from 30 cm/sec on the slope to 20 cm/sec in the layers below 1,000 m (Section 3.2). As noted in the table, the larger and heavier particles would be displaced only a few kilometers, whereas very fine sands and fine and coarse silts would be transported tens of kilometers before reaching the bottom.

The particle size composition of the dredged material planned for disposal at the ODMDS presently is unknown because of the wide variety of sediment types occurring at potential dredging sites within the Bay. As noted for the water quality model (Section 4.2.1.3), two cases were assumed for the average composition of material discharged at each alternative site: a silt-clay type and a mostly sand type. It is likely that the majority of the material to be disposed at an ODMDS would be dredged using a clam shell dredge. This type of dredging equipment does not add much water to the dredged material, as opposed to a suction-type dredge. Therefore, the dredged material likely would retain the clumped character of the original Bay muds. The extent to which cohesive materials become fluidized by the dredging operations and transit to the disposal site presently is unknown. Therefore, an assumption of 50% clumping of the clay-silt material was made for the purposes of the model. Smaller clumping factors (i.e., less than 50%) would result in smaller maximum deposit thicknesses, but little or no change in the area covered with deposits thicker than 1 mm. This is because fine silt material would be dispersed so widely that effects to the predicted deposit thickness would be negligible. In contrast, sandy materials contained in the dredged sediments are not cohesive and would act as individual particles following disposal from a barge. Therefore, these particles' behavior would not be expected to change as factors influencing clumping were varied.

The measurements made by the EPA study (Section 3.2.2.2) provided the first long-term, deep-water current data for this region. Because few current measurements have been made over the continental slope off San Francisco, there was no definitive basis for determining the representativeness of these current measurements relative to long term climatology or interannual variability (see Section 3.2.2.1). Modeling was performed using segments of the data that could represent the seasonal and inter-annual variability of the region.

The distinct changes in the current characteristics between the first and second portions of the study prompted the modeling of deposition over a one-year period as well as two six month periods. The first time period coincided with the complete period of the current measurements (March 15, 1991 through February 15, 1992). The second and third periods corresponded to the first and second six-month segments of these current records. The first six-month period was characterized by a strong poleward flow, whereas, the second six-month period was characterized by weak, intermittent flows followed by episodic poleward events. The mean and maximum deposition decreased and the areas of deposition increased with increasing current speeds.

The model simulations assumed that the momentum from the initial release dissipated at a depth of 20 m, and particles acted independently at depths below 20 m. Other simulations were performed which varied this depth between 20 and 250 m for a continuous discharge over a one year period in 1,000 m of water. The results did not change significantly despite this depth variation. The model also assumed that discharges did not occur at the same location each day. Instead, the discharge positions were randomized on a daily basis over a region defined by a watch circle having a diameter of 2 km and centered in the southern to central portion of the western boundary for each site. This area corresponds to the proposed site of the discharge area for the ODMDS. However, should the size of this area be changed in the final designation of the site, this model's assumption would represent a conservative estimate of predicted impacts. The bathymetric data used in the model simulations were from NOAA's EEZ side scan surveys; these data provided the highest resolution grid available for the study region and resolved bathymetric features to an accuracy of a few meters.

Table 4.2-4 presents the mean and maximum cumulative deposit thicknesses for the two material types, accounting for all particle size classes. For all alternative sites, the silt-clay material would produce the greatest thickness near the disposal site because of the contribution from rapidly-sinking clumps. In contrast, the maximum thickness of sand is only 60 to 70 mm. The table also lists the areas covered by deposits with thicknesses exceeding 1 mm at the end of the period. The quantities of material that would be advected or lost outside of the boundaries of the model also were calculated. The total percent loss consisted entirely of coarse and fine silts. This material would be deposited far from the disposal site, with respective accumulation thicknesses of less than 1 mm for the modeled discharge volumes (6 million yd^3).

Comparisons between the two six-month periods generally indicated higher amounts of deposition and less area covered for the less energetic August to February period than for the more energetic spring period. The 12-month period showed deposition amounts and areas that were intermediate between the two six-month periods.

The simulated depositional footprints for the mostly sand and silt-clay materials at the preferred and alternative sites are shown in Figures 4.2-6 and 4.2-7. The contour lines correspond to deposit thicknesses of 1 mm, 10 mm, and 100 mm. The predicted bottom deposits were

Table 4.2-4. Model-Predicted Deposit Thicknesses, Areal Coverage, and Material Losses Due to Transport Outside of the Model Boundaries

Based on current data for the period March 15, 1991 through February 15, 1992.

Alternative Site	Material Type[1]	Mean Deposit Thickness (mm)[2]	Maximum Deposit Thickness (mm)	Percent Loss	Area Covered (km^2)[3]
3	C-S M-S	7.94 4.46	727.2 62.0	19.3 11.4	362.8 624.4
4	C-S M-S	9.78 5.25	788.3 69.4	21.4 12.7	283.8 500.1
5*	C-S M-S	9.75 5.87	493.2 65.5	27.1 16.2	278.6 449.1

[1]C-S = Clay-Silt Mixture, M-S = Mostly Sand Mixture.
[2]For deposits with thicknesses greater than 1 mm.
[3]Area covered by deposits with thicknesses greater than 1 mm.
*Preferred Alternative Site.

Source: SAIC (1992e).

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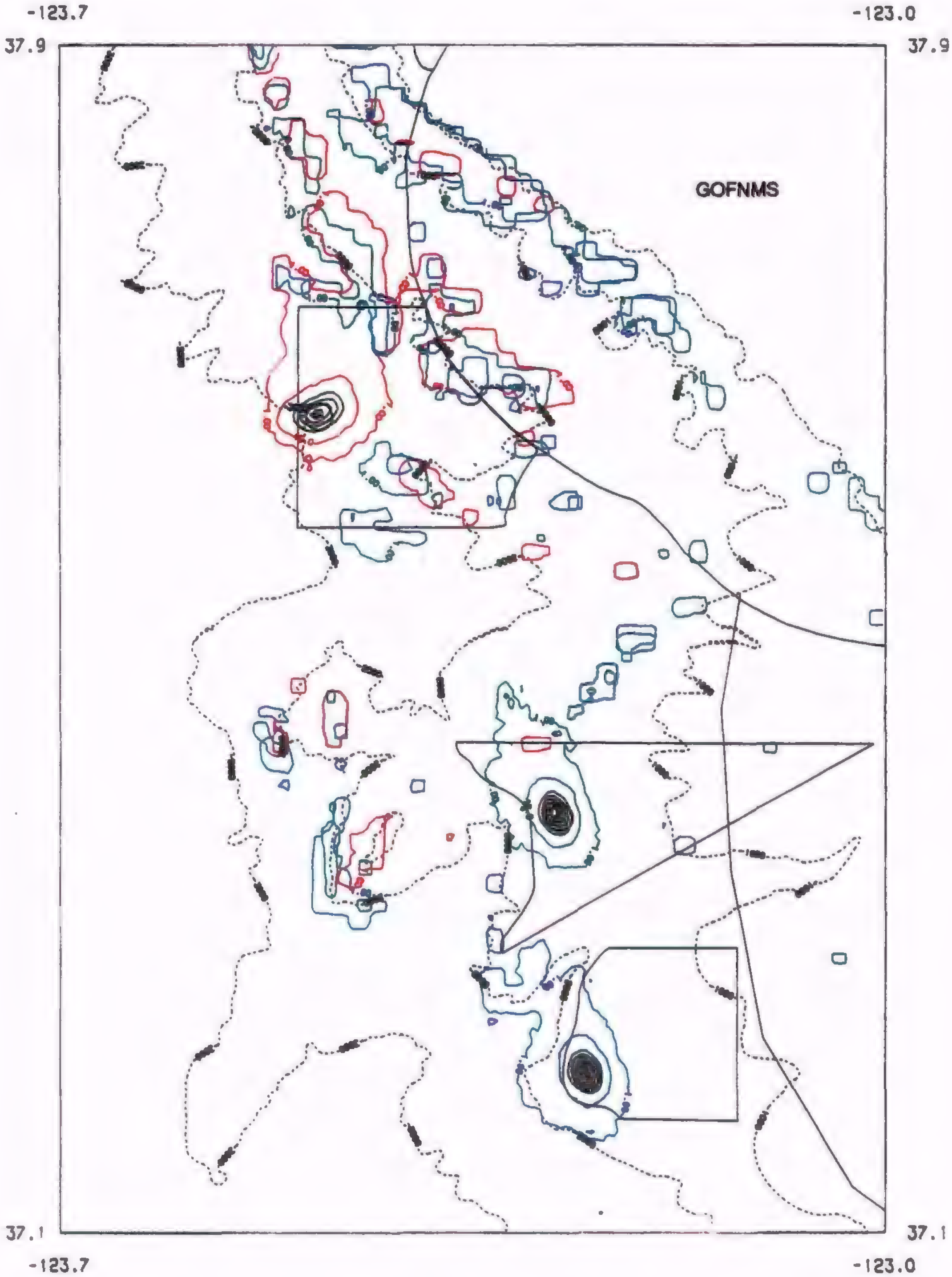

Figure 4.2-6. **Model-Predicted Bottom Deposit Thicknesses (in mm) From Discharges of Six Million yd^3 of Clay-Silt Type Material Over a One-Year Period at the Preferred Alternative Site (red), Alternative Site 3 (green), and Alternative Site 4 (blue).**

The solid black lines near the respective 2 km watch circles (i.e., discharge point) correspond to deposit thicknesses of 100 mm, 200 mm, etc. Results are based on current data for the period March 15, 1991 through February 15, 1992 and used a diffusion coefficient of $D=1\ m^2/sec$.

Source: SAIC 1992e.

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Figure 4.2-6. Continued.

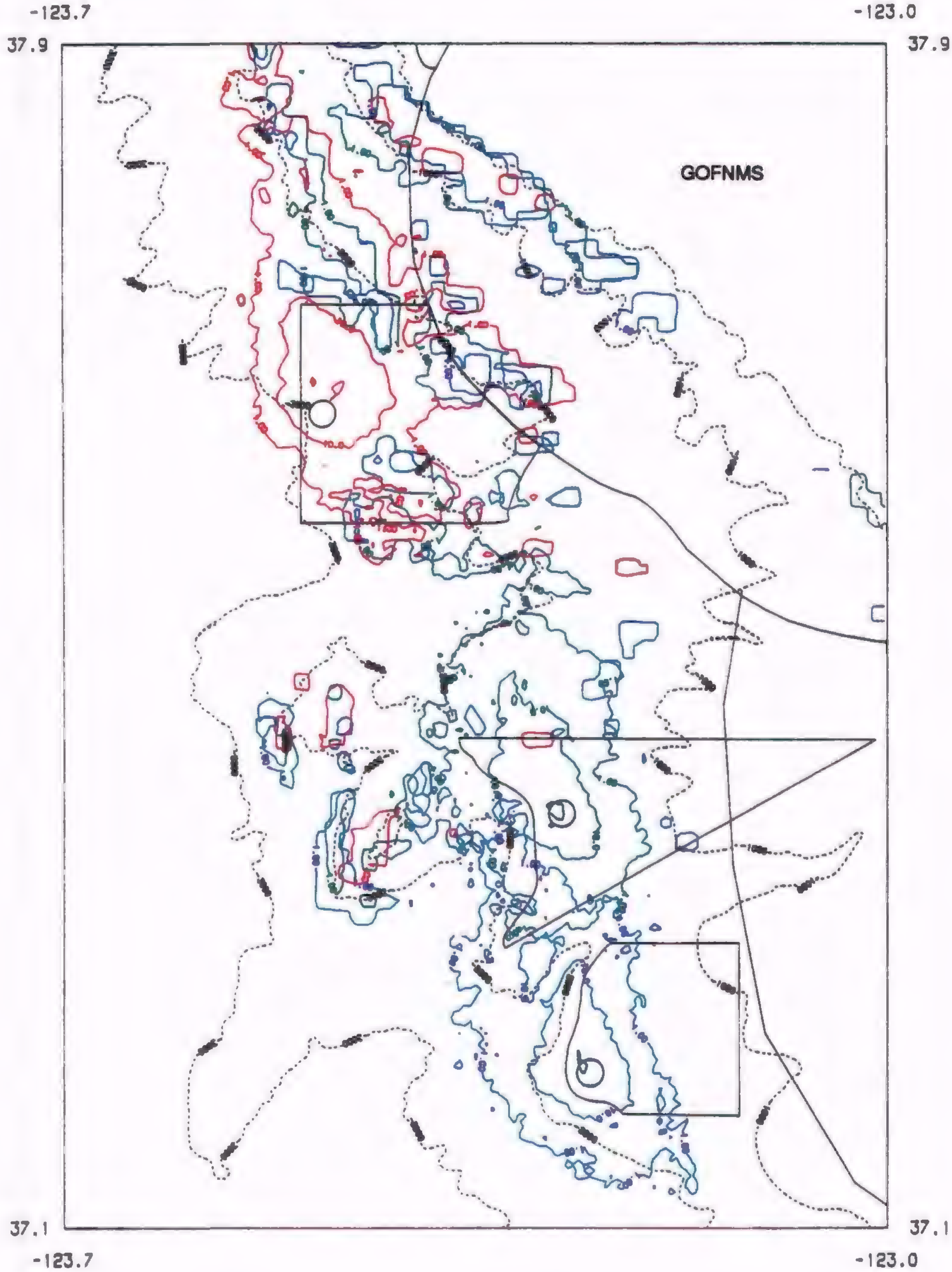

Figure 4.2-7. Model-Predicted Bottom Deposit Thicknesses (in mm) From Discharges of Six Million yd^3 of Mostly Sand Type Material Over a One-Year Period at the Preferred Alternative Site (red), Alternative Site 3 (green), and Alternative Site 4 (blue).

Results are based on current data for the period March 15, 1991 through February 15, 1992 and used a diffusion coefficient of $D = 1 m^2/sec$.

Source: SAIC 1992e.

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Figure 4.2-7. Continued.

discontinuous in some areas because of the effects of topographic irregularities on the deposition patterns. Significant impacts to bottom-dwelling organisms from smothering would be most likely in areas where the thickness of recently-deposited material exceeded 100 mm (10 cm) (Rhoads and Germano 1990; see Section 4.2.2.2). The 1 mm deposit represents the minimum thickness that might be measured practically using existing technologies, and does not correspond to any known or predicted adverse impact to the benthic environment. The 10 mm deposit represents an intermediate reference thickness that was used as the basis for defining the size and shape of the preferred and alternative sites (Section 2.2). Modeling the 1 mm and 10 mm deposit thicknesses was intentionally conservative for predicting potential effects, but was considered useful for possible monitoring purposes to determine where measurable amounts of dredged material would be deposited. These deposit thicknesses are much lower than 100 mm thicknesses where significant impacts to benthic organisms would be expected. Also, impacts associated with 100 mm thicknesses would result from instantaneous deposition, whereas, the modeled deposits were accumulated over a period of one year.

The deposition model predicted that disposal of six million yd^3 per year of clay-silt and mostly sand type material at the preferred alternative site would result in bottom deposits with thicknesses greater than 1 mm covering areas of approximately 280 and 450 km^2, respectively. The maximum deposit thicknesses for these material types would be approximately 490 and 66 mm, respectively, and the mean deposit thicknesses over these areas would be 9.8 and 5.9 mm, respectively. The model-predicted bottom deposits with thicknesses greater than or equal to 100 mm would cover an area of 7.29 km^2 based on discharges of 6 million yd^3 of silt-clay materials over a one-year period.

The 1 mm and 10 mm deposit thickness contours for the clay-silt type material for all alternative sites do not extend into any of the National Marine Sanctuaries. The 1 mm deposit thickness for the mostly sand type material discharged at Alternative Site 5 extends into the GOFNMS, whereas, the bottom deposits corresponding to Alternative Sites 3 and 4 do not cross the sanctuary boundaries.

The model assumed that deposition of material is cumulative. It does not account for losses due to sediment transport processes such as bottom current resuspension and transport and/or mass movement, which would reduce the estimated thickness of the deposit but also increase the bottom area affected. The preferred alternative site is located within a depositional zone characterized by low kinetic energy and fine grain size sediments with a relatively high organic content (Section 3.2). It is expected that the depositional characteristics of the site will minimize the bottom current-induced dispersion of deposited dredged material. Use of the site over a period of 50 years would increase the predicted deposit thicknesses as well as the areas covered by deposits with thicknesses exceeding 1 mm. However, over time physical processes (e.g., mass wasting) and biological processes (e.g., bioturbation) may transport and mix the dredged material with existing and recently-deposited sediments, thus, reducing differences between the physical characteristics of the dredged material and those of existing sediments and reducing potential impacts.

Because the grain size and chemical characteristics of sediments potentially discharged at the ODMDS are unknown, the specific effects of dredged material disposal on long-term changes to the properties of the bottom sediments cannot be evaluated or quantified accurately. Sediments must be evaluated using testing procedures for dredged material described in EPA/COE (1991) to ensure that chemical constituents are not present at concentrations that would be toxic to, or bioaccumulated by, marine organisms. Only material deemed acceptable under these protocols would be approved for disposal at an ODMDS.

Effects from dredged material disposal at Alternative Site 5 on sediment grain size are expected to represent a Class I impact. This impact also would be localized and would persist for the duration of site use assuming a continuous disposal schedule. Effects to sediment chemical quality are considered a Class III impact.

4.2.2 Effects on Biological Environment

The following sections discuss the potential consequences of the proposed action on the biological environments associated with the preferred alternative site.

4.2.2.1 Plankton

Any significant water column impacts to the pelagic ecosystem would most likely involve those planktonic organisms that come in contact with slower-settling particles, such as silts, in regions of neutral buoyancy, such as the pycnocline. The impact of suspended particles from dredged material disposal on planktonic organisms is expected to be minimal for the rapidly settling size fractions, including sand and clay-silt aggregates, that reach the bottom within a few minutes to hours (see Section 4.2.1.4).

Some effects of water column turbidity on open ocean planktonic species have been addressed experimentally by a study designed to predict the impact of surface discharges of deep-sea muds simulating a manganese mining operation (Hirota 1985). These results indicated increased mortality and lower recruitment rates in 12 species of epipelagic copepods and one species of mysid exposed in the laboratory. However, mortality of copepods collected in the field from a simulated plume showed only slightly higher mortality relative to reference populations collected from outside the plume (Hirota 1985).

A laboratory study of exposure of the copepod *Calanus helgolandicus* to fine-grained red bauxite muds showed lower survival, growth rates, and body weight at concentrations above 6 mg/l (Paffenhofer 1972). This same type of mud resulted in decreased egg hatching success and lowered survival of larval Atlantic herring (*Clupea harengus*) and adversely affected embryo development and larval feeding at concentrations in the range of 600 to 7,000 mg/l (Rosenthal 1971).

The results from these studies cannot be extrapolated directly to dredged material disposal because most of the adverse biological effects were related to organisms ingesting mineral-rich and nutrient-poor deep-sea ooze or bauxite "red mud". These nutrient-poor suspensions resulted in starvation of the exposed species. Because dredged material plumes will typically consist of relatively organic-rich muds, and will be transient in nature, similar impacts to planktonic organisms are unlikely.

Potential effects of disposal-related turbidity on planktonic organisms are difficult to assess due to the transient nature of the dredged material plume and the free-floating or mobile characteristics of the organisms. Turbid plumes associated with dredged material disposal can temporarily attenuate light penetration into the water column, thereby reducing primary production by phytoplankton. Measurements of primary production in a disposal plume showed 50% reduction in productivity compared to that of ambient phytoplankton populations (Chan and Anderson 1985). However, this effect lasted only a few hours until the plume dissipated. Additional factors which complicate these assessments are seasonal and annual variations in plankton productivity, standing stock, and species composition (Section 3.3.1).

Since the duration of potential plume exposure is short and of limited spacial extent, the overall effect of disposal on plankton communities at the preferred alternative site is expected to be insignificant (Class III; Table 4.1-1). This conclusion also is based on significant, natural variation in plankton communities throughout the general study region. The highest plankton abundences are inshore of the preferred and alternative sites and there are no distinguishable differences between the sites.

4.2.2.2 Infauna

Impacts of Burial

As dredged material accumulates on the seafloor, benthic organisms in the area of initial deposition may be impacted. However, information on the response of deep-water organisms to burial or smothering is limited. The ability of buried infauna (or epifauna) to reestablish normal depths and orientations within bottom sediments is an adaptation for surviving burial from natural events such as storm-related changes in sedimentation or slumping. In deep water, particularly on the continental slope and rise, turbidity currents, submarine slumps, and debris flows can be major natural causes of burial (Hollister *et al.* 1984). The frequency of disturbance and depth of burial are also critical for determining the response of infauna to burial. Frequencies of disturbance that are less than one year tend to keep the colonizing benthos in an early successional stage while burial frequencies much greater than one year allow colonization of higher order successional species with longer mean life-spans and more conservative reproductive strategies (e.g., Rhoads *et al.* 1978).

Impacts to bottom-dwelling organisms from burial by either natural processes or dredged material disposal can vary from negligible to localized mortality, depending on the rate of accumulation, burial depth, textural and mass properties of the deposited sediment, burial time, water temperature, and the species experiencing burial. This type of impact has been quantified for several species in estuarine environments. For example, Kranz (1974) determined the depth of burial that caused mortality of several bivalve species. The critical burial depth for epifaunal suspension feeders was less than 5 cm, while infaunal deposit-feeders could survive and burrow through as much as 50 cm of overburden. *In situ* burial experiments by Nichols *et al.* (1978) indicated that overburden thicknesses of 5 to 10 cm did not cause significant mortality to "mud-dwelling" invertebrates as most of these motile infauna could initiate "escape" responses by burrowing upward, while organisms covered with overburdens of 30 cm could not initiate escape responses. Similar results for estuarine organisms were documented in a laboratory study by Maurer *et al.* (1978), who also noted critical overburden thicknesses of 5 to 10 cm. The critical burial depth for estuarine infauna therefore appears to range from 5 to 30 cm. The response of a species to a specific overburden thickness can be estimated from how frequently a species population experiences natural sediment burial. For example, species living on rippled bottoms or sediments subjected to resuspension are better able to withstand burial by relatively thick sediment layers than species living in low kinetic energy, low sedimentation rate areas.

Generalizations about critical burial depths based on shallow water data noted above are directly applicable to Study Area 2 and perhaps the shallower part of Study Area 3. However, care must be exercised in extrapolating these observations to deep water as comparable data on critical burial depths for deep-sea benthos have not been fully investigated. The present information comes from observations of the burial of benthos by "accidental" sedimentation events. Jumars (1977) reported an accidental burial of benthos in the San Diego Trough (1,200 m depth) by a small avalanche of sediment (2 to 10 cm thick) produced by a submersible. The next day, the site was revisited and the submersible took cores through the new sediment layer. Organisms were beginning to migrate upward through layers 1 cm thick, while deeper burial resulted in increased mortality. The polychaete *Prionospio spp.* was noted to be an important casualty in this experiment, suggesting that surface deposit feeders might be most affected by burial (Jumars 1977). *Prionospio delta* is present in water depths of ≥ 2,000 m in the Farallones region. These observations suggest that deposition of shallow layers of sediment at these depths might allow deep water species to recover from burial, but that disposal layers substantially deeper than 10 cm might cause high local mortality. Support for this inference is presented from Study Area 5, sampled in 1990 and 1991 (SAIC 1991; SAIC 1992c). In 1990, high densities of infauna were recorded at Station F-17, while in 1991 densities near Station F-17(B-5) were lower by a factor of seven (see Section 3.3.2.1). Bottom photography showed a "hummocky" surface typical of sedimentation deposits. One explanation for the change in density between 1990 and 1991 is partial mortality related to an intervening depositional (burial) event.

Rapid burial of a benthic community by 30 to 100 cm thick, natural turbidity flows in the Cascadia Channel (2,900 to 3,000 m depth) off the Oregon and Washington coast resulted in a "no escape" response of the buried species. An inference of total mortality was based on the absence of escape burrows across the contact zone between the buried and basal layers of the overlying sediments (Griggs *et al.* 1969). There are no direct studies on the ability of slope-dwelling infauna to escape from thinner deposits of sediments. However, based on the considerable abilities of many species to burrow through and modify natural sediments (Hecker 1982), it is likely that many slope infaunal species would have the ability to survive periodic burial by submarine slumping or moderate amounts of dredged material.

In summary, available information on shallow-water infaunal invertebrates indicates that the rapid accumulation of sediments (either natural sediments or dredged material) in thicknesses exceeding approximately 5 to 30 cm can result in significant mortality of the buried species. Sessile or otherwise immobile species are the most sensitive to burial while mobile deposit-feeding infauna have the greatest ability to escape upward through newly deposited sediments.

Colonization after Deposition

Colonization by infaunal organisms of deposited dredged material has been well documented in shallow water environments, but equivalent studies at deeper depths are lacking. In most cases, the colonization process in shallow water begins within a few days following cessation of discharges (Germano and Rhoads 1984; Scott *et al.* 1987). The mode of colonization is sensitive to the thickness of the deposit. For thin overburden layers (less than or equal to 10 cm), buried adults have an upward escape response, with selective survival based on the ability of different species to reestablish their natural vertical depth positions within the new sediments. When dredged material accumulates in a thick mound, only the thin, distal edges of the deposit may be colonized by this means. The thicker part of the deposit primarily is colonized through larval recruitment or immigration of organisms from adjacent, undisturbed areas.

In shallow water (less than 50 m depth), colonization by adults (reburrowing) and larval recruitment normally is very rapid, taking only a few days to weeks to establish a low diversity but abundant pioneering community. Rapid colonization is attributed to the presence of competition-free space and the availability of detrital organic food that commonly is in greater concentration in dredged material than on the ambient seafloor. In addition, the diffusion of sedimentary sulfides from dredged material into the water column may serve as a larval settlement cue and as a nutritional factor for opportunistic species such as *Capitella* (Cuomo 1985; Tsutsumi 1992).

In shallow water disposal site studies, three phases of macrofaunal recolonization have been described (Rhoads and Germano 1982, 1986, 1990; Scott *et al.* 1987). This successional paradigm is based on "...the predictable appearance of macrobenthic invertebrates belonging to specific functional types following a benthic disturbance" (Rhoads and Boyer 1982). The first organisms (Stage I) to colonize a disposal site by larval recruitment are usually small opportunistic polychaetes, such as Spionidae and Captellidae. Species within these families are commonly associated with frequently disturbed and/or organically enriched areas (Pearson and Rosenberg 1978). The worms form dense tube mats and feed at, or near, the sediment surface. Within one or two years, these dense polychaete assemblages may be replaced by dense aggregations of tubiculous amphipods and tellinid bivalves (Stage II). Densities of pioneering species on dredged material often are significantly higher than densities on the ambient bottom. Disposal sites can exceed the secondary productivity measured on the natural seafloor by a factor of six fold or more (Rhoads *et al.* 1978). The degree of enhancement of secondary productivity is proportional to the amount of labile organic matter in the dredged material because organic detritus serves as food for many resident benthos. This high secondary productivity may account for intensive foraging by mobile predators observed at many disposal sites (Becker and Chew 1983; SAIC 1989a).

Larval recruitment and establishment of Stage III species on a disposal site requires several years because these organisms tend to have more conservative reproductive strategies, slower population and developmental growth rates, and longer mean life spans (Pearson and Rosenberg 1978; Rhoads *et al.* 1978; Hecker 1982). Stage III species are "head-down" deposit feeders and are commonly encountered as part of the equilibrium community on ambient mud bottoms adjacent to disposal sites. Stage III species typically consist of deep burrowing polychaetes (e.g. Maldanidae, Pectinariidae), caudate holothurians, infaunal ophiuroids, or burrowing urchins. Deep burrowing is accompanied by vertical bioturbation of both particles and pore-water fluids to depths of 10 to 20 cm or more. Bioturbation modifies sediment chemistry through oxidation of the sediment column and advective exchange of sulphate, ammonia, or nitrate across the sediment water interface (Aller 1982; Rice and Rhoads 1989). Similarly, bioturbation can change the chemical properties of dredged material and its associated constituents (Rhoads *et al.* 1977).

A series of biological, physical, and chemical changes occur over a period of several months to years after disposal operations cease. The changes include gravitational compaction and biological modifications as well as the reshaping of the deposit in relation to current-mound interactions. Small-scale boundary roughness of cohesive materials is reduced over time as surficial bioturbation and surface current scour reduce elevations and fill in depressions. Diversion of flow over a mound can result in a local change in mound texture as fine-grained sediments are eroded, leaving a coarser surface layer. Long-term bioturbation by Stage III species can result in a progressive increase in fluidization and oxidation of the surface of a dredged material deposit. Furthermore, bioturbation can cause pelletization and repackaging of organic-mineral aggregates which decreases the overall cohesiveness of fine-grained sediments (Rhoads 1991) and often results in the surface becoming physically destabilized (Rhoads and Boyer 1982). Such biogenic processes can contribute to destabilization of the bottom over the long term, especially on slope environments (Hecker 1982).

The successional changes described above for shallow water disposal sites applies only to sites that experience "normal" succession. Normal succession involves rapid initial colonization progressing to Stage III within one to two years. Such a progression can be retarded or stopped if disposal operations are continuous or frequent, if the disposed material experiences erosion and dispersal, or if the disposal area is seasonally or permanently affected by low dissolved oxygen. The relationship between near bottom dissolved oxygen and the successional model indicates that mobile epifauna or demersal species avoid regions with dissolved oxygen concentrations below approximately 3 mg/l. Dissolved oxygen concentrations below about 1.4 mg/l appear to prevent successful colonization of Stage III taxa (Tyson and Pearson 1991). The ecological and physiological effects of low oxygen conditions can be compounded by hydrogen sulfide and/or methane gas associated with organically enriched hypoxic habitats. These compounds may further stress benthic species. Additionally, if pollutants are present, the ability of an oxygen-stressed organism to survive exposure may be significantly reduced. These synergistic effects are poorly known. The shallow portions of Study Areas 3 and 4 are within or near the OMZ (Section 3.2), but the preferred and alternative disposal sites are located in waters deeper than the OMZ. Disposal at any of the sites is unlikely to result in reduced colonization due to low oxygen tensions.

The successional patterns described above for shallow-water disposal sites have been compared to results from studies at deeper water dredged material disposal sites off Los Angeles (LA-2) in 110 to 320 m of water (SAIC 1990a) and off San Diego, CA (LA-5) in 100 to 220 m of water (SAIC 1990b). The dredged material disposed at these sites was from their respective metropolitan harbors and comprised a wide range of textures including sandy material and cohesive mud clasts overlying ambient silt-clays and very fine sands. Presumably due to the relatively deep water at these two sites, the dredged material footprints were in the form of thin deposits. All parts of the dredged material mounds were colonized by benthic organisms, and relatively fresh dredged material could be distinguished from older dredged material by the degree of bioturbation, depth of oxidation of the sediment column, and successional status. Stage I and III species were present both on and off the dredged material.

Studies of colonization of experimental sediment trays deployed in the deep-sea, and research on the effects of natural disturbances such as submarine slumping on the rate of colonization, diversity, abundance, and biomass of benthic communities provide some information on rates of recolonization as compared to shallow water systems. Some studies of deep-sea colonization indicate that early colonies may occur in lower densities than the natural communities, even after two years (Grassle and Morse-Porteous 1987). These observations suggest that deep-sea recruitment rates and succession may operate very differently than those in shallow water. In contrast, observations of repopulation at depths greater than 2,000 m in the Bay of Biscay show rapid colonization within six months by opportunistic species resulting in abundances in experimental trays that were five times higher than on the ambient bottom (Desbruyeres *et al.* 1980). These observations suggest that some deep-water colonization shares attributes with shallow-water succession. However, when organic-rich, shallow-water sediments were introduced into an oligotrophic deep-water environment, some studies indicated inhibition of colonization (Desbruyeres *et al.* 1980) while others showed a stimulatory or enhancement effect (Griggs *et al.* 1969; Jumars and Hessler 1976).

Predicting the responses of infaunal communities to disposal within the preferred and alternative sites is difficult because of the wide range of results from the few relevant studies on recolonization in deep-water environments. However, the dispersion modeling results indicate that the impact of disposing 6 million yd^3 of sand, silt, and clay over a period of one year at all sites will result in most of the dredged material footprint being less than 10 cm thick. The only part of the footprint that might be thick enough to cause extensive burial and mortality is the relatively small central mound formed by rapidly settling cohesive material (see Figure 4.2-6). Therefore the impact class for the central mound is estimated to be Class I for the preferred and alternative sites (Table 4.1-1) and is expected to persist throughout the duration of site use.

Infaunal communities at the preferred alternative site are expected to be significantly impacted (Class I) in a localized area by dredged material disposal. It is likely that the dominant spionid polychaetes at the site would be more sensitive to sedimentation caused by burial, but because overall species richness and density is lower (Section 3.3.2.1), the composite impact should be less than at Alternative Sites 3 and 4. However, recovery or recolonization of the benthic populations at the preferred alternative site following dredged material disposal might be slower than in Alternative Sites 3 and 4 because the flux of organic material needed to provide food and stimulate reproductive processes in benthic invertebrates is generally lower with increasing depth. The preferred alternative site is approximately 1,200 m deeper than Alternative Sites 3 and 4.

4.2.2.3 Epifauna

Predicting the effects of dredged material disposal on pelagic and deep-water demersal megafauna is difficult because most studies on the impacts of dredged material have focused on infaunal species assemblages and community characteristics in estuarine environments (Wainwright *et al.* 1992). Few studies have been conducted on megafaunal invertebrates, especially deep-sea species such as those occurring in the preferred and alternative sites.

Following dredged material disposal, it is likely that fast-swimming pelagic megafauna, such as euphausiids, siphonophores, and various gelatinous species (cnidarians), would be most affected by suspended sediments causing displacement through avoidance of, or escape behavior from, the disposal plume. Although limited information is available concerning pelagic megafauna within the general study region, some information can be extrapolated from midwater trawls conducted by Bence *et al.* (1992) and from incidental catches in bottom trawls by SAIC (1992b). In general, some pelagic species of cephalopods (not including market squid) were found by Bence *et al.* (1992) at depths greater than 1,200 m, corresponding to depths similar to those of the preferred and alternative sites. Other pelagic species including euphausiids are patchy in their distributions within the sites (Bence *et al.* 1992). However, as noted above, potential impacts to these pelagic species probably would be insignificant due to their apparent ability to avoid disposal plumes and distribution over broad depth and geographic ranges.

Similar to the potential impacts noted for infauna (Section 4.2.2.2), slow-moving epifaunal invertebrates such as seastars and sea pens may become buried and smothered as dredged material is deposited on the bottom, while more motile benthic taxa such as some crustaceans may be displaced as an escape response. Also similar to the infauna, recovery and recolonization of an impacted area will depend on the frequency and severity of the disturbance and the species involved. Thus, recolonization is expected by individuals able to escape burial, larval recruitment, and immigration from adjacent, undisturbed areas (e.g., Lissner *et al.* 1989). Based on uncertainties and variability in the timing of these events, some recovery may occur within hours to days, but full recovery could require a few years. However, accumulation of dredged material should be localized, and there are no known epifaunal species of limited geographic distribution within the preferred or alternative sites. Therefore, based on an assumption of significant but localized impacts, particularly to some slow-moving epifauna, potential impacts (worst case) are projected to be Class I (Table 4.1-1).

There are few differences between the preferred alternative site and Alternative Sites 3 and 4 in the taxonomic composition, density, and biomass of epifauna (Section 3.3.2.2). The predominant species within the site (e.g., sea cucumbers, seastars, and brittlestars) are slow-moving and have the greatest potential for burial and possible mortality. Therefore, potential, localized impacts from dredged material disposal at the preferred alternative site are expected to be significant and designated as Class I, persisting throughout the duration of site use.

4.2.2.4 Fishes

Information on direct impacts of dredged material disposal on fish communities is extremely limited. Most studies on the effects of dredging and dredged material disposal on fish communities have focused on larvae and eggs in estuarine environments (Auld and Schubel 1978; Johnston and Wildish 1981). However, results from these studies suggest that if disposal of dredged material does not significantly affect these sensitive life stages, then plankton, fishes, or commercial fisheries also should be unaffected by disposal events.

Pelagic Species

During a disposal event, the greatest impact to pelagic fish species may be from increased turbidity within the disposal plume, which may limit the feeding efficiency of visually-oriented predators. However, most of the near-surface pelagic species characteristic of the preferred and alternative sites are highly mobile species, such as juvenile rockfishes, salmon, tunas, and mackerels (Section 3.3.3), which may actively avoid the disposal plume. Additionally, some of these species may be attracted to various prey items (e.g., polychaete worms) which may be dispersed from the dredged material. Deep-water mesopelagic and bathypelagic species such as deep-sea smelts and lanternfishes characteristic of the region also should be able to avoid the disposal plume, although there are no specific studies on avoidance behavior in these fishes. Therefore, it is estimated that potential impacts of dredged material disposal on pelagic fishes will be insignificant, and classified as Class III.

Demersal Species

The number of demersal fish species, density, and biomass at the preferred and alternative sites is relatively low (Section 3.3.3). Impacts from dredged material disposal are expected to be insignificant, particularly due to the relatively high mobility of most species. Some relatively sedentary demersal species such as eelpouts (Zoarcidae) may be less able to avoid burial from rapidly accumulating sediments than more mobile species such as rattails (Macrouridae), which may escape disposal areas entirely. These species also may be displaced from primary deposition areas, but following recolonization by prey species, eventually may return to areas affected by disposal. Therefore, because the preferred and alternative sites are located in relatively deep water and have similar species composition with low fish densities and biomass, potential impacts are estimated to be localized and insignificant (Class III) (Table 4.1-1).

The preferred alternative site has similar numbers and types of fishes as Alternative Sites 3 and 4 (Section 3.3.3). These include pelagic, offshore species such as salmon, tunas, and mackerels. Pelagic species are expected to be least impacted by dredged material disposal due to their high mobility. Alternatively, demersal species within the site such as codling and eelpouts, have lower mobility, and thus are expected to be more impacted by disposal than pelagic species. However, the relatively low numbers of demersal fish species and abundances found within the preferred alternative site (Section 3.3.3) suggest that impacts will be minimal. Some feeding habitat may be lost temporarily following disposal activities. However, demersal species should return to the affected areas following recolonization by prey species. Overall potential impacts of dredged material disposal on fishes at the preferred alternative site are expected to be insignificant and designated as Class III.

4.2.2.5 Marine Birds

Information concerning impacts of dredged material disposal to resident and migrating bird populations is limited. Potential impacts may include ship-following behavior, temporary reductions in prey items, and visual impairment of marine birds foraging in the vicinity of the disposal plume.

It is common for many species of birds to follow ships. The regular occurrence of dredged material barges and tugs transiting to and from the preferred alternative site may potentially distract some marine birds from their normal feeding activities and/or passage routes. However, the increase in vessel traffic created by dredged material barges is considered insignificant when compared to existing ship traffic (Commander S. Tiernan, U.S. Coast Guard, pers. comm. 1992).

It is anticipated that many pelagic prey organisms will exhibit various escape behaviors in response to dredged material disposal. Thus, following a disposal event the immediate area may contain temporarily reduced populations of some organisms, including juvenile rockfish, anchovies, euphausiids, and squid, that are important prey items for marine birds that breed and nest on the Farallon Islands (Ainley and Boekelheide 1990; Ainley and Allen 1992). Therefore, foraging success of marine birds may be reduced temporarily following disposal activities. However, since these prey species characteristically are patchy in their distribution (see Sections 3.3.1 and 3.3.3), localized reductions in prey densities may not significantly affect feeding behavior of marine birds in the region.

Similarly, it has been suggested that reductions in water clarity following disposal operations may temporarily inhibit feeding activities of marine birds that typically forage in surface waters (Navy 1992). Computer model results indicated that the finer silt-clay components of dredged material may require up to approximately 48 hours to reach presumed background concentrations of 1 mg/l, and particle clouds could affect an area over 3,600 km^2 (Section 4.2.1.4), thereby potentially limiting the foraging efficiency of deeper water bird predators. In addition, attraction of marine birds to positively buoyant particles remaining at the surface following disposal suggests that some marine birds may expend substantial energy with limited prey acquisition. However, dispersion modeling results indicated that mean plume depths increase with distance from the disposal site. Thus, significantly reduced clarity in surface waters likely is restricted to the immediate release site. Further, permit conditions will ensure that dredged material contains negligible quantities of buoyant (floatable) debris. Therefore, these potential impacts should be localized and of relatively short duration; consequently, they are not expected to affect significantly the breeding, feeding, or passage of marine birds that occur broadly throughout the study region.

Dredged material proposed for ocean disposal will be tested for bioaccumulation potential according to "Green Book" (EPA/COE 1991) protocols. Material that exhibits a potential for contaminant bioaccumulation will not be discharged at an ODMDS. Therefore, it is assumed that dredged material disposal at any of the alternative sites will not affect bioaccumulation or biomagnification of contaminants.

Based on the above information, dredged material disposal impacts on marine birds are classified as Class III. The types of impacts are expected to be similar at the preferred and alternative sites; therefore differences in disposal consequences to marine birds should be related primarily to differences in the relative abundance of marine bird species within each site (see Section 3.3.4).

The preferred alternative site is located approximately 25 nmi from the breeding and nesting grounds of the Farallon Islands. As compared to Alternative Sites 3 and 4, survey results suggest that the preferred alternative site receives the highest use by marine birds (Section 3.3.4). Thus, potential impacts (Class III) to marine birds are expected to be greatest but still insignificant at the preferred alternative site as compared to Alternative Sites 3 and 4.

4.2.2.6 Marine Mammals

The potential impacts of dredged material disposal to marine mammals are expected to be similar to those of marine birds. These impacts include temporary impairment of foraging activities attributable to disturbances caused by disposal and subsequent reductions in water clarity (see Section 4.2.2.5).

An additional potential impact may be alteration of marine mammal passage routes to avoid noise from ship traffic or from increased water turbidity during or following disposal activities. Further, noise may influence non-auditory physiology (Fletcher 1971), increasing the stress response and lowering resistance to disease. Because ship noise levels correlate generally with vessel size, speed, and load, larger, faster ships underway with full loads (or towing/pushing loads) may emit more sound than smaller, slower, and lighter ships (Richardson 1991). In addition, ships with older auxiliary equipment such as generators and compressors radiate more noise than modern, well-maintained vessels (Richardson 1991). Some studies have suggested that the noise associated with increased vessel traffic may affect marine mammal migration routes. Specifically, it has been suggested that increased ship traffic in Japanese waters disturbed migration routes of minke and Baird's beaked whales (Nishiwaki and Sasao 1977). Baleen whales such as grays, humpbacks, and blues sometimes move quickly away from approaching vessels, although there is little evidence that they are affected after the vessel has passed. However, based on limited data, Richardson (1991) suggests that ship noise has little impact on pinnipeds. Although vessel traffic may potentially impact marine mammals, the increase in ship traffic attributable to dredged material barges is considered insignificant in relation to existing traffic (Commander S. Tiernan, U.S. Coast Guard, pers. comm. 1992).

Dohl *et al.* (1983) indicated that gray whales may change their course to avoid turbid plumes caused by run-off from rivers and bays. Similarly, experiments with dolphins (*Tursiops truncatas*) suggested that they were able to detect and avoid oil patches using echolocation, especially if air bubbles were present in the patch (Geraci and St. Aubin 1987). Thus, it is possible that marine mammals capable of detecting differences in water turbidity may alter their route to avoid a disposal area.

However, vessel noise and plume impacts to marine mammals are temporary and localized to the immediate vicinity of the disposal site, and are not expected to affect breeding, nursery, or feeding areas for adults or juveniles. Thus, potential impacts to marine mammals are characterized as Class III (Table 4.1-1). These potential impacts are similar for the preferred and alternative sites. As described for marine birds, differences in potential disposal effects on marine mammals are based on comparisons of their relative abundances within each of the sites (see Section 3.3.5).

Survey results suggest that the preferred alternative site receives the highest use by marine mammals (Section 3.3.5) as compared to Alternative Sites 3 and 4. Thus, impacts to marine mammals are expected to be greatest but still insignificant at the preferred alternative site as compared to Alternative Sites 3 and 4.

4.2.2.7 Threatened, Endangered, and Special Status Species

As described in Section 3.3.6, nine known threatened or endangered species occur somewhat regularly in the general study region. These include five whale species (gray, humpback, blue, finback, and sperm), one pinniped species (northern sea lion), two bird species (Peregrine falcon and California brown pelican), and one fish species (winter-run chinook salmon).

Potential impacts of dredged material disposal on whale and pinniped species may include temporary impairment of feeding activities and avoidance of barge vessels and the disposal plume, as described in Section 4.2.2.6. Impacts to Peregrine falcon include the potential for ship following behavior which may affect normal feeding or passage activities. California brown pelican and winter-run chinook salmon populations occur primarily over the continental shelf (see Section 3.3.6), and thus are not expected to be impacted by disposal activities within any of the sites.

Due to the temporary nature and localized spatial distribution of disposal activities, potential impacts are estimated to be insignificant (Class III). The types of potential impacts are expected to be similar at the preferred and alternative sites. However, differences in disposal consequences between sites can be identified based on the relative abundances of threatened or endangered species (See Section 3.3.6) as described below.

Compared to Alternative Sites 3 and 4, the preferred alternative site is a relatively high use area for threatened or endangered marine bird and mammal species (Section 3.3.6). Therefore, potential impacts to threatened or endangered species are expected to be higher but still insignificant at the preferred alternative site than at Alternative Sites 3 and 4.

4.2.2.8 Marine Sanctuaries

Six designated national marine sanctuaries, refuges, or special biological resource areas occur within the study region. One or more of these areas lies within 5 nmi of the preferred and alternative sites (Section 3.3.7). These areas contain a wide variety of sensitive habitats and biological resources including threatened and endangered species.

Disposal of dredged material from San Francisco Bay will not occur within the boundaries of any of the national marine sanctuaries, refuges, or areas of special biological significance. However, because the dredged material barges must transit through one or more of the marine sanctuaries to reach any of the sites, accidents or overflow from the barges could result in inadvertent releases of dredged material within sanctuary boundaries.

The volumes of dredged material released by single or isolated incidences likely would be small (e.g., 6,000 yd^3 for a single barge load) and environmental consequences would depend on location of the discharge, rate and direction of plume dispersion, and specific resources in the path of dispersing material. Dredged material released within or immediately adjacent to a sensitive habitat, and repeated discharges over a longer time period, could result in more significant environmental impacts. However, the probability of these circumstances can be reduced or mitigated by specifying that barges use specific transit routes that avoid sensitive habitats (Class II impact).

The Farallon Islands lie in the direct route of barges transiting from San Francisco Bay to the preferred alternative site. Accidental discharge or overflow of dredged material near the Islands should be avoided. Mitigative measures as discussed above indicate that potential disposal impacts at the preferred alternative site are Class II (i.e., significant adverse impacts that can be mitigated to insignificant levels).

4.2.3 Effects on Socioeconomic Environment

The following sections discuss the potential consequences of the proposed action on the socioeconomic environment associated with the preferred and alternative site. Resources addressed include commercial fishing, commercial and recreational shipping, mineral and oil and gas development, military usage, recreational activities, cultural resources, and public health and welfare.

4.2.3.1 Commercial and Recreational Fishing

Analysis of the MMS/CDFG Commercial Fisheries Database (1992) and CDFG Recreational Fisheries Database (1992) indicated that the majority of commercial and recreational fisheries are located predominantly in the continental shelf region. Extremely limited fishing activity occurs over the slope areas corresponding to the preferred and alternative sites (Section 3.4.1). The commercial fishery data suggest that some minor catches of tunas, mackerels, and some flatfishes were taken from the region of Alternative Sites 3 and 4, while tunas and mackerels were taken in low numbers in the region of the preferred alternative site (MMS/CDFG Commercial Fisheries Database 1992).

Most species targeted by commercial or recreational fishermen in offshore areas such as the alternative sites are fast-moving pelagic fishes such as salmon, tunas, and mackerels. According to Bence *et al.* (1992), juvenile rockfishes are abundant offshore in the preferred and alternative sites but are somewhat more abundant in the region of the preferred alternative site. However, because all the sites are located far offshore (e.g., 45 to 55 nmi), where most commercial and recreational fishing is limited, and because these species are mobile and should be able to avoid the disposal plumes, there should not be any significant impacts on these fisheries at any of the sites. Therefore, impacts are estimated to be Class III.

Historical catches within the region of the preferred alternative site are somewhat lower than those for the regions of Alternative Sites 3 and 4. Thus, potential fishery impacts at Alternative Site 5 may be relatively lower as compared to Alternative Sites 3 and 4.

4.2.3.2 Commercial Shipping

The preferred and alternative sites are located outside of designated commercial vessel traffic lanes and away from any restricted passage areas, precautionary zones, or anchorages for commercial shipping. Dredged material barges using an ODMDS would represent additional vessel traffic within the study region. However, the magnitude of this additional ship traffic is expected to be negligible (Section 3.4.3), representing a Class III impact that is not expected to vary significantly between sites. Furthermore, because the ultimate purpose of dredging operations is to provide adequate water depths and access to vessel traffic for channels and berths within the Bay, the proposed action could be considered a Class IV (beneficial effect) impact.

4.2.3.3 Mineral or Energy Development

As discussed in Section 3.4.5, no oil and gas development activities occur within the general region of the preferred or alternative sites, and the closest potential lease blocks are more than 200 miles from the sites. This is based on current moratoriums on development, and technological limitations which restrict these activities to depths shallower than approximately 300 to 400 m (Section 3.4.5). The average depth at the preferred alternative site is over 2,000 m. Further, because of the deep bottom depths at the sites, no other mineral development activities are likely to occur. Therefore, use of any of the sites for dredged material disposal will not interfere with or impact existing mineral resources or energy development operations in the foreseeable future (Class III impact).

4.2.3.4 Military Usage

Military usage of the LTMS study region, including areas in the vicinity of the preferred and alternative sites, is considered to be significant (Section 3.4.4). In particular, submarine operating areas are delineated near but outside of Alternative Sites 3, 4, and 5 (Figure 2.1-5). With exception of operating area U1 which is used infrequently, submarine operating areas U2 through U5 are used by the Navy an average of 10 days per month for trial diving exercises and post-overhaul checkouts. However, because the preferred and alternative sites are located outside of the operating areas, dredged material disposal at any of the sites is expected to have negligible impacts (Class III) on military operations in the region. Use of an ODMDS is not expected to interfere with any other military vessel traffic or training exercises. Although the preferred alternative lies near submarine operating area U4, use of the site for dredged material disposal is not expected to adversely impact military activities (Class III impact).

4.2.3.5 Recreational Activities

Recreational activities in the general vicinity of the preferred and alternative sites are centered around the Farallon Islands. Although specific data are unavailable, recreational activities such as sailing, fishing, or whale watching, within the boundaries of the alternative sites are generally infrequent (Section 3.4.6). Therefore, potential impacts from use of the alternative sites for dredged material disposal are considered insignificant. Potential effects of dredged material barge traffic on recreational boating or fishing within the vicinity of the Farallon Islands could be mitigated by requiring barges to stay within defined traffic lanes and avoid the areas immediately around the Farallon Islands.

Of the three alternative sites, the preferred alternative lies closest to the Farallon Islands. Thus, relative to Alternative Sites 3 and 4, potential impacts to recreational activities may be greatest at the preferred alternative site. However, as noted, restricting dredged material barges to specified traffic lanes could mitigate potential impacts (Class II).

4.2.3.6 Cultural and Historical Resources

As discussed in Section 3.4.7, no known shipwrecks of cultural or historical importance, or other man-made cultural or historical resources, are located within the immediate vicinity of the preferred or alternative sites. Therefore, designation of an ODMDS is not expected to have any significant effect on historical resources. Oceanic tours or expeditions by wildlife and naturalists groups are concentrated around the Farallon Islands and Cordell Banks. Potential interferences from dredged material disposal operations would be limited to minor navigational conflicts with dredged material barges in the vicinity of the Farallon Islands. However, these potential interferences could be mitigated by specifying barge transit lanes that avoid the vicinity of the Islands. Therefore, these potential impacts are considered Class II.

4.2.3.7 Public Health and Welfare

There are no obvious impacts on public health and welfare associated with the designation of an ODMDS (Class III). Collisions between a dredged material barge and a commercial or recreational vessel, or operation of a dredged material barge in the Gulf of the Farallones during extreme weather conditions, could endanger human lives. However, these events are expected to be rare (Section 3.4.3). Conversely, maintenance dredging of navigational channels within San Francisco Bay supports the continued operation of several ports and, consequently, promotes local and regional commerce.

Potential impacts on public health and welfare associated with disposal at the preferred alternative site are insignificant (Class III) due to the projected rare occurrence of vessel collisions near the site.

4.3 No-Action Alternative

As stated in the Purpose of and Need for Action (Section 1.2), it is the intent of this EIS to identify and designate an ODMDS that is suitable for approved Federal and permitted dredging projects. Selection of the No-Action alternative would not fulfill the LTMS goal of providing a long-term, multi-user ODMDS for disposal of dredged material from San Francisco Bay. In the absence of a designated ODMDS, or Section 103 interim ODMDS, other disposal options, such as within the Bay or at nonaquatic sites, would be required for dredged material. Alternatively, planned dredging would have to be delayed until a suitable disposal option is identified.

Selection of the No-Action Alternative per se would result in no impacts or changes to the existing environmental conditions at the preferred or alternative sites due to dredged material disposal operations. However, the consequences of the No-Action Alternative may cause varying environmental impacts. For example, non-ocean disposal options, such as the use of sites within the Bay or nonaquatic sites also would result in location-specific environmental impacts. At this time, the ability of non-ocean sites to receive the volume of dredged material planned for the next 50 years is not known. However, the nature and extent of potential impacts at nonaquatic sites and sites within the Bay presently are being evaluated by the In-Bay and Nonaquatic/Reuse LTMS Work Groups.

Disposal of dredged material at a Section 103 ocean disposal site would result in some impacts on conditions at the Section 103 Site, although the magnitude of these impacts would depend on the volume and characteristics of the dredged material and the physical and biological conditions at the particular site. Cessation of dredging would result in shoaling within the main shipping channels, thus impairing and potentially endangering shipping operations within the Bay, with associated impacts on the economy of the region and the logistical needs of the Navy (COE 1990b).

Selection of the No-Action Alternative would preclude the use of ocean disposal as a long-term management option. Selection of this alternative would result in a failure to meet LTMS objectives and would have unknown consequences (COE 1992a). Therefore, EPA proposes to designate an ODMDS based on the preferred alternative described in this DEIS.

4.4 Other Ocean Disposal Alternatives

This section describes the potential environmental consequences of dredged material disposal at Alternative Sites 3 and 4.

4.4.1 Effects on the Physical Environment

These sections address potential effects of dredged material disposal at the other ocean disposal alternatives on regional meteorology and air quality, physical oceanography, water quality, and sediment quality.

4.4.1.1 Air Quality

Potential impacts to regional air quality associated with dredged material disposal at Alternative Sites 3 and 4 were evaluated using the same EPA air quality model and assumptions as summarized in Section 4.2.1.1 for the preferred alternative site. As noted for the preferred alternative site, no significant effects on air quality were indicated along the preferred route of the barges transporting dredged material to Alternative Sites 3 and 4 (Table 4.2-1), therefore representing a Class III impact.

4.4.1.2 Physical Oceanography

Similar to the preferred alternative site, the use of Alternative Sites 3 and 4 would not have any measurable effect on the regional or site-specific physical oceanographic conditions, and therefore is predicted to represent a Class III impact. The prevailing oceanographic processes will strongly influence the dispersion and long-term fate of dredged material discharged at the alternative sites. The overall circulation patterns that would affect disposal activities are as summarized in Section 4.2.1.2.

In general, poleward current flows are typical of the upper 1,000 m of the water column over most of the year, with the strongest flows over the inner slope region, including the general area of Alternative Sites 3 and 4 (Section 3.2.2). Near-bottom currents in the vicinity of Alternative Site 3 (Mooring D) were characterized by relatively low speeds and thus were less likely to erode sediments than currents measured at Station E near the eastern boundary of Study Area 5 (Section 3.2.2). No specific information from the current meter program is available for Alternative Site 4. Based on the data presented in Section 3.2.2, it is very unlikely that upwelling would be a significant mechanism at either of the alternatives to transport dredged material from slope to shelf environments.

4.4.1.3 Water Quality

Potential impacts on water quality from dredged material disposal at Alternative Sites 3 and 4 were addressed by disposal plume modeling (SAIC 1992e), as discussed in Section 4.2.1.3 for the preferred alternative. Similar to the preferred alternative, changes in water quality such as localized increases in turbidity, reductions in light transmittance, and increases in dissolved and particulate concentrations of trace contaminants that could result from dredged material disposal are expected to be transient, and therefore represent Class III impacts.

Alternative Site 3

Results from the water quality model (SAIC 1992e) indicated that dredged material plumes comprising class 1 through class 6 particles would disperse over areas of 13 to 7,855 km^2 in the vicinity of the site, (assuming a conservative background suspended particle concentration of 1 mg/l, conservative dispersion rates, and conservative initial and background concentrations (Table 4.2-3). The mean plume visitation frequencies over these affected areas would range from approximately 1 to 4%, and the predicted maximum exposure times would range from 1.0 to 42 hours for individual particle size classes. The mean cloud depth over the affected area for individual particle size classes would range from 54 m for clay-silt particles to approximately 1,300 m for fine and medium sand particles (Table 4.2-3). The areas affected and the water column residence times would be expected to vary as a function of the particle size. Larger particles with higher sinking rates would have shorter residence times and deeper cloud depths, whereas smaller particles with lower sinking rates would have longer residence times and shallower cloud depths because stronger and more variable near-surface currents would disperse the plumes over relatively larger areas. Dredged material disposal at Alternative Site 3 would be expected to result in concentrations from approximately 1 to 2 mg/l of fine-grained (class 6) suspended particles at the MBNMS boundary for 0.2 to 5% of the discharge events, and concentrations from approximately 1 to 2 mg/l of fine-grained particles at the GOFNMS boundary for 1 to 5% of the discharge events. Particle concentrations at the CBNMS boundary were not expected to be elevated above background concentrations (Figure 4.2-3). Clouds of larger dredged material particles would not be expected to cross any of the Sanctuary boundaries.

Based on the above information, effects on water quality from dredged material disposal at Alternative Site 3 are considered Class III because the plumes are expected to disperse within 48 hours of discharge, no build-up or accumulation of particles within the water column is expected, and changes to water quality parameters (e.g., turbidity, light transmittance, dissolved oxygen concentrations) are expected to be transient and localized within the discharge plume. Disposal operations should have insignificant effects on concentrations of contaminants in the water column, given that only dredged material of suitable quality will be permitted for disposal at the ODMDS.

Alternative Site 4

The water quality model results (SAIC 1992e) indicated that disposal plumes comprising class 1 through class 6 particles would affect areas up to 7,708 km^2, although the mean visitation frequency over this area would range from approximately 1 to 5% (Table 4.2-3). The mean cloud depth would vary from 55 to 1,511 m, and the maximum exposure time would range from approximately 1.0 to 43 hours. Use of Alternative Site 4 would result in concentrations from approximately 1 to 2 mg/l of fine-grained particles at the GOFNMS and MBNMS boundaries for approximately 0.2 to 1.0% of the discharge events (Figure 4.2-4). Clouds of coarser particles would not be expected to reach the sanctuary boundaries. Effects on water quality from dredged material disposal at Alternative Site 4 are considered Class III, similar to those discussed for Alternative Site 3.

4.4.1.4 Geology and Sediment Characteristics

Potential impacts on sediment characteristics from dredged material disposal at Alternative Sites 3 and 4 were evaluated by deposition modeling (SAIC 1992e) as discussed in Section 4.2.1.4 for the preferred alternative site. Specific effects of dredged material disposal on long-term changes to the grain size and chemical characteristics of the bottom sediments cannot be determined quantitatively. Although localized and extended impacts to grain size may be expected, significant effects on sediment quality would not be anticipated, given that only dredged material of suitable quality will be approved for disposal at an ODMDS.

Alternative Site 3

The deposition model (SAIC 1992e) calculated that disposal of six million yd^3 over a one-year period at Alternative Site 3 would result in bottom deposits of clay-silt and mostly sand material with thicknesses greater than 1 mm covering areas of approximately 360 and 620 km^2, respectively. The maximum deposit thicknesses for these material types would be approximately 730 and 62 mm, respectively, and the mean deposit thicknesses over these areas would be 7.9 and 4.5 mm, respectively. The model-predicted bottom deposit with thicknesses greater than or equal to 100 mm would cover an area of 5.91 km^2 based on a discharge of 6 million yd^3 of silt-clay materials over a one-year period.

Clay-silt material would produce the greatest thickness (approximately 70 cm) near the disposal site center due to deposition of rapidly-settling clumps. The maximum thickness of mostly sand material is an order of magnitude lower (approximately 60 mm). Because the alternative site boundaries were defined to encompass the 10 mm deposit thickness contour for clay-silt material

(Section 2.2), deposits of both clay-silt and mostly sandy material with thicknesses greater than 10 mm would, by definition, be contained within site boundaries.

Deposition of dredged material could result in a significant localized alteration of the bottom sediment grain size properties (Class I impact; Table 4.1-1). The extent of this alteration would depend on the grain size distribution of the dredged material. Although it is desirable to minimize these differences, it is likely that some of the material disposed at the ODMDS would contain sand-sized sediments that do not occur naturally at the site. This impact would be expected to persist at least for the duration of the site use assuming continuous disposal schedules. Subsequent return to pre-disposal conditions could result from extended interruption of disposal operations and natural particle deposition, dispersion, and mixing processes (Section 4.2.2.2). Contours for the model-predicted 1 mm and 10 mm deposit thicknesses extended towards the northwest (Figure 4.2-6), but there was no indication that these deposits would affect Pioneer Seamount (to the west of Alternative Site 3) or other hard-bottom features that might occur in the vicinity of the site.

Effects from dredged material disposal on the chemical characteristics of the site sediments cannot be determined accurately because the organic content and trace contaminant concentrations in the dredged material are not known. Conclusions that disposal operations at Alternative Site 3 would represent a Class III impact on sediment quality assume that the dredged material has satisfied testing criteria designed to establish that the material is of suitable quality for ocean disposal (EPA/COE 1991).

Alternative Site 4

The deposition model (SAIC 1992e) predicted that disposal of six million yd^3 per year of clay-silt and mostly sand type material at Alternative Site 4 would result in bottom deposits with thicknesses greater than 1 mm covering areas of 280 and 500 km^2, respectively. The maximum deposit thicknesses for these material types would be approximately 790 and 69 mm, respectively, and the mean deposit thickness over these areas would be 9.8 and 5.2 mm, respectively. The model-predicted bottom deposit with thicknesses greater than or equal to 100 mm would cover an area of 5.88 km^2 based on a discharge of 6 million yd^3 of silt-clay materials over a one-year period.

Effects from dredged material disposal at Alternative Site 4 on sediment grain size also are expected to represent a Class I impact. This impact also would be relatively localized (i.e., corresponding approximately to the 10 mm footprint contour), but would persist for the duration of site use assuming a continuous disposal schedule. Deposits with thicknesses between 1 and 10 mm would extend in a northwest direction beyond the site boundaries (Figure 4.2.6). The extent of hard-bottom features in the adjacent portion of Pioneer Canyon presently is not known. Regardless, it is unlikely that deposition of dredged material at a rate of 1 to 10 mm per year on a hard substrate would have a significant impact on an attached epifaunal community which might occur within the area (e.g., Lissner *et al.* 1991). Effects on sediment quality are considered a Class III impact, as noted above for Alternative Site 3, and similar to the magnitude of effects at Alternative Sites 3 and 5.

4.4.2 Effects on Biological Environment

The following sections discuss the potential consequences of the proposed action on the biological environments of Alternative Sites 3 and 4.

4.4.2.1 <u>Plankton</u>

As noted for the preferred alternative (Section 4.2.2.1), impacts on plankton from rapidly settling dredged material particles such as sand and clay-silt aggregates are expected to be minimal because of relatively limited exposure times (minutes to hours). Longer exposure times and potentially greater impacts would be expected from slower-settling, fine-grained particles which may concentrate more in regions of neutral buoyancy, such as the pycnocline. However, based on the transient nature of the dredged material plume and the characteristically high seasonal and annual variability in plankton communities, overall impacts are expected to be insignificant and classified as Class III.

Alternative Site 3

Significant seasonal and annual variations in productivity, standing crop, and species composition of plankton communities are evident from existing data of the general study region (Section 3.3.1). Phytoplankton and zooplankton (including ichthyoplankton) abundances vary seasonally, but are highest inshore of Alternative Site 3 and the lower slope environment. Therefore, for plankton, no significant effects (Class III) on plankton from the proposed action are expected at this site (Table 4.1-1).

Alternative Site 4

Based on existing data on plankton communities of the general study region, no differences can be distinguished in the productivity, standing crop, or species composition between Alternative Sites 3 and 4. Therefore, potential impacts to plankton at this site also are classified as insignificant (Class III).

4.4.2.2 Infauna

As described in Section 4.2.2.2, potential impacts to infauna following dredged material disposal include burial and smothering and will be influenced by the frequency and severity of disturbance and the capacity for species recolonization after the disposal event. Extensive burial would be expected within a relatively small, central mound at each of the sites regardless of which alternative was selected. Thus, relative differences in potential impacts are based on differences in infaunal compositions and densities within each of the sites.

Alternative Site 3

Burial and mortality of infauna at Alternative Site 3 are expected to be significant (Class I) within the boundary of the 10 cm depositional area (e.g., up to 5.91 km^2 for a discharge of 6 million yd^3 per year) as noted above (Table 4.1-1 and Figure 4.2-6). No species that are known to be unique to the area or geographically limited in distribution are found at this site or at Alternative Sites 4 or 5. However, the high abundances of filter-feeding amphipods found in Alternative Site 3, among other deep-water parts of Study Area 3, were not found at any other sampled locations within the study region. Overall infaunal densities are similar to Alternative Site 4, but slightly higher than Alternative Site 5 (Section 3.3.2.1). Therefore, the impacts of dredged material disposal at Alternative Site 3 are expected to be similar to those at Alternative Site 4 but somewhat greater than those at Alternative Site 5 due to the relative differences in infaunal densities.

Alternative Site 4

Similar to Alternative Site 3, impacts of dredged material disposal at Alternative Site 4 are expected to be significant (e.g., up to 5.88 km^2 for a discharge of 6 million yd^3 per year) (Class I) but localized. Based on infaunal densities (Section 3.3.2.1) the impacts at Alternative Sites 3 and 4 are expected to be similar but somewhat higher than at Alternative Site 5. However, Alternative Site 4 does not contain the high abundances of filter-feeding amphipods found at Alternative Site 3.

4.4.2.3 Epifauna

Disposal impacts to slow-moving epifaunal species such as seastars and sea pens are expected to be more significant as compared to impacts on more mobile species (e.g., crustaceans) which may respond to disposal events with various escape behaviors (see Section 4.2.2.3). The taxonomic composition, density, and biomass of epifaunal species are similar at the preferred alternative site and Alternative Sites 3 and 4. Localized burial of epifauna would occur at each of the sites within the 10 cm depositional contour. Thus, potential impacts are projected to be Class I at each alternative site.

Alternative Site 3

Alternative Site 3 contains moderate numbers of species, abundances, and biomass of epifaunal organisms (Section 3.3.2.2). Predominant species, including sea cucumbers, seastars, and brittlestars, are all slow-moving and would have the greatest potential for burial and possible mortality. Based on this assumption and the conservative nature of the modeling, impacts are estimated to be significant (Class I), and localized within the 10 cm depositional boundary at this site, but are expected to persist throughout the duration of site use.

Alternative Site 4

Similar to Alternative Sites 3 and 5, impacts of dredged material disposal at Alternative Site 4 are expected to be significant (Class I) but localized. This is based on similar epifaunal species and densities at these sites (Section 3.3.2.2).

4.4.2.4 Fishes

As discussed in Section 4.2.2.4, potential impacts to pelagic fishes following disposal activities could include a decrease in feeding efficiency and avoidance behaviors. Potential disposal impacts to demersal species could include burial (for relatively sedentary species), displacement, and temporary habitat loss. However, because fish densities and biomass within the alternative sites are low, potential impacts are estimated to be insignificant (Class III).

Alternative Site 3

Pelagic fishes such as salmon, tunas, and mackerels that occur in offshore areas such as Alternative Site 3 should not be impacted due to their high mobility (Class III). Moreover, this site contains relatively low numbers of demersal fish species and abundances (Section 3.3.3). Although some feeding habitat may be temporarily lost following a disposal event, demersal fishes are expected to return to these affected areas after a disposal event. Most species at this site should be able to avoid impacted areas and would not be affected significantly by dredged material disposal. Therefore, potential impacts are classified as Class III.

Alternative Site 4

The number of species, densities, and biomass of fishes in Alternative Site 4 is similar to Alternative Site 3 (Section 3.3.3); therefore, potential impacts of dredged material disposal at Alternative Site 4 also are expected to be insignificant and classified as Class III.

4.4.2.5 Marine Birds

Potential impacts on marine birds from dredged material disposal are discussed in Section 4.2.2.5. These impacts are expected to be similar and insignificant at the preferred and alternative sites. Therefore, the discussion of differences in disposal consequences to marine birds focuses on abundances of marine bird species within each site (see Section 3.3.4).

Alternative Site 3

Alternative Site 3 is located approximately 25 nmi from the Farallon Islands, an important breeding, nesting, and feeding area for marine birds (Section 3.3.4). The combined results from recent survey efforts (Ainley and Boekelheide 1990; Ainley and Allen 1992; Jones and Szczepaniak 1992) indicate that Alternative Site 3 receives relatively higher use by marine birds as compared to Alternative Site 4 but relatively lower use than the preferred alternative site

(Section 3.3.4). Thus, the extent of potential impacts to marine birds occurring at Alternative Site 3 may be relatively greater than at Alternative Site 4 and relatively less than at the preferred alternative site. However, based on the transient nature of potential impacts, overall effects are estimated to be insignificant and classified as Class III.

Alternative Site 4

Of the three alternative sites, Alternative Site 4 is located the greatest distance (approximately 30 nmi) from the Farallon Islands breeding and nesting grounds. In contrast to Alternative Site 3 and the preferred alternative site, survey results for Alternative Site 4 indicate that it is a relatively low use area for marine birds (Section 3.3.4). Therefore, it is expected that fewer potential impacts (Class III) to marine birds would occur at Alternative Site 4 than at the preferred alternative or Alternative Site 3.

4.4.2.6 Marine Mammals

Potential impacts on marine mammals from dredged material disposal are discussed in Section 4.2.2.6. These impacts are expected to be similar and insignificant at the preferred and alternative sites. Thus, as for marine birds, differences in potential disposal effects on marine mammals are based on relative abundances of marine mammal species within each site (see Section 3.3.5).

Alternative Site 3

Alternative Site 3 does not appear to be within an important marine mammal passage area, although it may be important as a feeding ground for some marine pinnipeds (Section 3.3.5). The combined results from historic (Bonnell *et al.* 1983; Dohl *et al.* 1983) and recent marine mammal surveys (Ainley and Allen 1992; Jones and Szczepaniak 1992) indicate that Alternative Site 3 receives intermediate use by marine mammals as compared to lower use of Alternative Sites 4 and higher use of the preferred alternative (Section 3.3.5). Therefore, although impacts at the alternative sites can be classified as Class III, based on the transient nature of potential effects, disposal impacts on marine mammals are expected to be greater at Alternative Site 3 than at Alternative Site 4, but less than at the preferred alternative site.

Alternative Site 4

Alternative Site 4 is not located in close proximity to marine mammal breeding or feeding grounds or important passage areas (Section 3.3.5). In contrast to Alternative Site 3 and the preferred alternative, survey results indicate that Alternative Site 4 is a low use area for marine mammals (Section 3.3.5). Thus, potential impacts on marine mammals are expected to be lower (Class III) within Alternative Site 4 as compared to Alternative Site 3 and the preferred alternative site.

4.4.2.7 Threatened, Endangered, and Special Status Species

As discussed in Section 4.2.2.7, the types of potential impacts on threatened and endangered species are expected to be similar at each of the alternative sites. Thus, differences in disposal consequences to these species are based on their relative abundances within each site.

Alternative Site 3

Compared to Alternative Site 4 and the preferred alternative, Alternative Site 3 is an intermediate use area for the endangered cetacean and threatened pinniped species; it is a relatively low use area for endangered marine bird and fish species (Section 3.3.6). Therefore, the magnitude of potential impacts at Alternative Site 3 is expected to be greater than at Alternative Site 4 but less than at the preferred alternative site. However, as noted for marine birds and mammals, the transient nature of potential effects represents insignificant impacts (Class III).

Alternative Site 4

Alternative Site 4 is a relatively low use area for threatened or endangered marine mammals, birds, and fish (Section 3.3.6). Therefore, the magnitude of potential impacts on threatened or endangered species is expected to be lowest at Alternative Site 4 (Class III) as compared to Alternative Site 3 and the preferred alternative site.

4.4.2.8 Marine Sanctuaries

As discussed in Section 4.2.2.8, there are six national marine sanctuaries, refuges, or special biological resource areas within the study region. These areas contain sensitive habitats in addition to some biological species that are threatened or endangered (Section 3.3.7). Although disposal of dredged material will not occur within any of these sensitive areas, there is some concern that accidental overflow or discharge of dredged material in the vicinity of sensitive areas may occur as dredged material barges transit to the disposal site. EPA and COE will address these concerns through the site management plan and special conditions on permits for individual dredging projects. Therefore, potential impacts at the alternative sites are expected to be Class II (significant adverse impacts that can be mitigated to insignificance).

Alternative Site 3

Alternative Site 3 is located south of the GOFNMS and west of MBNMS. Dredged material barges must pass through one or both of these sanctuaries in route to and from this site. To reduce or mitigate potential impacts caused by accidental overflow of dredged material from the barges, specific transit routes can be identified that avoid sensitive areas within the sanctuaries (e.g., Farallon Islands). Therefore, impacts at Alternative Site 3 are considered Class II.

Alternative Site 4

Alternative Site 4 is located in a similar position as Alternative Site 3 (i.e., south of the GOFNMS and west of MBNMS). Therefore, potential impacts on sensitive habitats within sanctuaries from use of Alternative Site 4 also are designated Class II because specific transit routes can be identified that avoid sensitive areas.

4.4.3 Effects on Socioeconomic Environment

4.4.3.1 Commercial and Recreational Fishing

As discussed in Section 4.2.3.1, the potential impacts of dredged material disposal on pelagic and demersal fisheries are limited due to the high mobility of pelagic fishes that may avoid disposal plumes, location of many demersal fish species inshore of the alternative sites, and overall historical record of limited catches within any of the sites.

Alternative Site 3

In the vicinity of Alternative Site 3, most of the commercially and recreationally important pelagic fishes, such as tunas and mackerels, are expected to be able to avoid dredged material disposal sites. Therefore, the impacts on fisheries for pelagic species would be negligible (Class III). Similarly, fisheries for demersal fishes, including some flatfishes, are located primarily inshore of Alternative Site 3 (Section 3.4.1), indicating that potential impacts to these species also would be insignificant (Class III).

Alternative Site 4

Commercial and recreational fishery resources in the region of Alternative Site 4 are very similar to those of Alternative Site 3. Therefore, potential impacts are expected to be Class III, because targeted pelagic species should be able to avoid disposal plumes, and the majority of demersal fishery resources are located inshore of the alternative sites.

4.4.3.2 Commercial Shipping

All of the alternative sites lie outside of designated commercial vessel traffic lanes (see Section 4.2.3.2). The additional vessel traffic represented by dredged material barges transiting to and from an ODMDS is expected to be negligible (Cmdr. Tiernan, USCG, pers. comm. 1992) (Class III) and is expected to vary only slightly among sites.

Alternative Site 3

Alternative Site 3 is located outside of commercial vessel traffic lanes. Therefore, impacts to commercial shipping activities created by use of an ODMDS are considered to be Class III.

Alternative Site 4

Alternative Site 4 also is located outside of commercial traffic lanes. Therefore, similar to Alternative Site 3, potential impacts on commercial shipping activities are considered to be Class III.

4.4.3.3 Mineral or Energy Development

Mineral or energy development activities are currently restricted to depths less than approximately 400 m, whereas bottom depths at the alternative sites are greater than approximately 1,400 m (Section 3.4.5). In addition, the closest potential oil and gas lease block is located over 200 miles from the alternative sites. Therefore, use of either of the alternative sites for dredged material disposal is not expected to interfere with existing mineral resources or energy development activities (Class III impact).

Alternative Site 3

Due to its deep depths (approximately 1,500 m) and its distant location (over 200 miles) from the closest potential lease block, impacts on mineral or energy development attributable to dredged material disposal at Alternative Site 3 are considered to be Class III.

Alternative Site 4

Alternative Site 4 also is located in deep water (greater than 1,500 m) and is over 200 miles from the nearest potential lease block. Therefore, impacts on potential mineral or energy development activities also are considered to be Class III.

4.4.3.4 Military Usage

As discussed in Section 4.2.3.4, military activities within the study region are primarily focused on exercises conducted within five submarine operating areas. All of these areas lie outside of the alternative site boundaries. Thus, use of an ODMDS site is not expected to interfere with military activities (Class III).

Alternative Site 3

Alternative Site 3 is located over 10 nmi from the nearest submarine operating area (U2). Therefore, impacts on military activities related to dredged material disposal at Alternative Site 3 are considered to be Class III.

Alternative Site 4

Alternative Site 4 also is located over 10 nmi from the nearest submarine operating area (U5). Similar to Alternative Site 3, impacts of disposal operations on military activities are considered to be Class III.

4.4.3.5 Recreational Activities

Most of the recreational activities (sailing, whale watching, and fishing) within the study region occur around the Farallon Islands (see Section 4.2.3.5). Such activities are infrequent within any of the alternative sites. In addition, the restriction of dredged material barges to specified traffic lanes would ensure that interferences between barges and recreational users of the Farallon Islands will be minimized. Thus, potential disposal impacts on recreational activities are considered negligible (Class III).

Alternative Site 3

Alternative Site 3 is located over 20 nmi from the Farallon Islands. Therefore, as noted above, potential disposal impacts on recreational activities are considered to be Class III.

Alternative Site 4

Alternative Site 4 is located over 30 nmi from the Farallon Islands. Thus, similar to Alternative Site 3, potential impacts are classified as Class III.

4.4.3.6 Cultural and Historical Resources

No known cultural or historical resources exist within the alternative sites. Wildlife and naturalist tours are concentrated around the Farallon Islands and Cordell Bank (at least 20 nmi from the alternative sites). Therefore, potential impacts should be limited to possible navigational conflicts between dredged material barges and naturalist vessels. However, these conflicts can be mitigated by specification of barge traffic lanes that avoid the Farallon Islands region, thus representing a Class III impact.

Alternative Site 3

Alternative Site 3 is located over 20 nmi from the Farallon Islands. Therefore, potential disposal impacts on cultural and historical resources are considered insignificant (Class III).

Alternative Site 4

Alternative Site 4 is located over 30 nmi from the Farallon Islands. Thus, similar to Alternative Site 3, potential disposal impacts are considered insignificant (Class III).

4.4.3.7 Public Health and Welfare

As discussed in Section 4.2.3.7, disposal impacts on public health and welfare are associated with the potential for interferences between dredged material barges and commercial and recreational vessels. The potential for such events is considered to be insignificant because navigational interferences can be minimized by specifying that barge transit lanes and the overall increase in vessel traffic is considered negligible (Section 4.2.3.7) (Class III).

Alternative Site 3

The potential for vessel interferences at Alternative Site 3 is expected to be negligible, as discussed above. Therefore, potential impacts from disposal are considered to be Class III.

Alternative Site 4

Similar to Alternative Site 3, the potential for vessel interferences at Alternative Site 4 also is expected to be insignificant. Therefore, potential impacts from disposal also is considered to be Class III.

4.5 Other Alternatives

The environmental consequences associated with other general dredged material disposal options, such as disposal at sites within the Bay, disposal at nonaquatic sites, or treatment/reuse, are being evaluated by the LTMS In-Bay, Nonaquatic/Reuse, and Implementation Work Groups. Therefore, detailed evaluations and comparisons of the potential impacts associated with these options are not addressed by this EIS. The specific environmental consequences of each of the alternative disposal options will be evaluated, relative to the potential impacts from use of the ODMDS, during the assessment of permit applications for individual dredging projects.

4.6 Management of the Disposal Site

The primary goal of site management is to assure that the continued use of the disposal site will not cause significant adverse impacts on the marine environment. Site management is accomplished, in part, through the evaluation of ocean dumping permit applications and the development and implementation of a Site Management and Monitoring Plan. Ocean dumping permits and site management and monitoring are discussed in the following sections. The objectives of a proposed Site Management and Monitoring Plan will be issued as an appendix to the Final EIS.

4.6.1 Ocean Dumping Permits

Permits are required for dredging projects which propose to use an ODMDS (except for COE projects that do not require permits but require EPA approval). In general, the permit application must demonstrate the need, other than for short-term economic reasons, to use the ODMDS. Ocean disposal is permitable only if there are no practical alternatives. Some of the factors evaluated in this process are the environmental risks, impacts, and costs of ocean disposal compared to those of other feasible alternatives. Therefore, permit applications may be required to contain the following information:

- Written documentation of the need to dispose dredged material in the ocean;

- A description of historical dredging and activities at or adjacent to the proposed dredging site that may represent sources of contamination to the site;

- The type and quantity of the dredged material proposed for disposal at the ODMDS;

- The existing condition of the proposed dredging area, including the proposed dredging depths, overdredge depths, and depths adjacent to the boundary of the proposed dredging area;

- Composition and characteristics of the proposed dredged material, including the results from physical, chemical, and biological testing. These data will be used to determine whether the proposed dredged material is suitable for disposal at the ODMDS; An estimate of the planned start and completion dates for the dredging operation; this information is needed to avoid potential resource conflicts and may be used to schedule inspections at the dredging site and/or the disposal site;

- A debris management plan that addresses the disposal of materials other than the dredged sediment (e.g., pilings or metal debris) to ensure that these other materials are not discharged at the ODMDS.

The need for ocean disposal is demonstrated when other, feasible alternatives have been evaluated, and no practicable alternative locations, methods of disposal, or treatment technologies exist to reduce adverse impacts from disposal.

The suitability of dredged material proposed for disposal at the ODMDS must be demonstrated through appropriate physical, chemical, and biological testing according to the requirements and procedures defined in EPA's Ocean Dumping Regulations (40 CFR Parts 220, 225, 227, and 228). Section 227.6 of the Ocean Dumping Regulations prohibits the disposal of certain contaminants as other than trace chemical constituents of dredged material. Regulatory decisions rely on assessments of the potential for unacceptable adverse impacts based on persistence, toxicity, and bioaccumulation of the constituents, instead of specific numerical limits (EPA/COE 1991).

The present technical guidance for determining the suitability of dredged material involves a tiered-testing procedure (EPA/COE 1991). This procedure includes four levels of testing: Tiers I and II apply existing or easily obtained information and limited chemical testing to predict effects. If these predictions indicate that the dredged material has any potential for significant adverse effects, higher tiers are activated. Tiers III and IV utilize water column and benthic bioassay and bioaccumulation tests to determine effects on representative marine organisms.

Management decisions concerning the use of the ODMDS in lieu of disposal sites within the Bay, at nonaquatic sites, or other, approved treatment/reuse options, will be made according to guidance presently being developed by the LTMS. Decisions regarding the suitability of dredged material for ocean disposal will be guided by criteria contained in MPRSA and EPA's Ocean Dumping Criteria (40 CFR Parts 220, 225, 227, and 228). MPRSA authorizes the COE to administer the permit program for dredged material. The COE, San Francisco District will prepare the Public Notice concerning the proposed disposal operation, and EPA Region IX as well as other Federal and State agencies, will participate in the review of the application. EPA Region IX, will approve, disapprove, and propose conditions on a draft of the MPRSA Section 103 permit as specified in 40 CFR section 220.4(c). EPA Region IX will not approve the ocean disposal of material which has the potential for significant adverse biological impacts.

Dumping permits subsequently issued for individual dredging projects may impose additional conditions on the disposal operations to preclude or minimize potential interferences with other activities and/or uses of the ocean. Management options for the permitting process may include: full or partial approval of dredged material proposed for ocean disposal; limits on disposal volumes; seasonal restrictions (see Section 3.1.2); disposal within a spatially-limited portion of the disposal site; or requirements, for example, for dredged material barge operators to stay within specified transit paths, utilize navigation equipment with specified accuracy, and maintain appropriate ship logs.

Measures to ensure that disposal occurs reliably within the boundaries of the designated ODMDS are being developed jointly by EPA Region IX and the COE for incorporation into disposal permits. Two conditions now being considered are: (1) use of a precision navigation system to ensure accurate positioning of the disposal barge, together with formal certification of the accuracy of the on-board equipment; and (2) a requirement for continuous plotting of vessel paths once inside the central disposal zone, with plots of all disposal trips submitted to and maintained by the COE for later inspection. EPA Region IX will work with the COE, San Francisco District and the U.S. Coast Guard to inspect, monitor, and conduct surveillance of disposal operations in the San Francisco area. If violations of the permit(s) are detected, EPA Region IX may take appropriate enforcement actions.

4.6.2 Site Management and Monitoring

Site management is the joint responsibility of EPA and COE. Site management actions could include restrictions on the location, time, rate or method of disposal, restrictions on the composition and quantity of material to be disposed of, modification of site boundaries, or de-designation of the site.

The primary purpose of the monitoring program will be to evaluate the impact of disposal on the marine environment. The goal of site monitoring may include assessment of the following:

- The potential for movement of material into estuaries or marine sanctuaries, onto beaches or shorelines, or toward geographically-limited fishery or shellfishery areas.
- Significant, progressive changes in sediment accumulation outside the disposal site, to determine whether these changes are attributable to material disposed at the site.
- Significant accumulation of dredged material contaminants in marine biota near the site.
- Significant changes in benthic biological resources as a result of dredged material disposal at the site.

EPA and the LTMS Ocean Studies Work Group will develop a monitoring program to detect and minimize significant adverse impacts. The determination of positive or negative impacts will be based on an evaluation of data collected as part of the monitoring program.

Specific questions to be addressed by the monitoring program will be based on outstanding issues and concerns in the site designation process. For example, these questions may include:

- Is the area affected by disposal of dredged material restricted to the disposal site? (Impacts may be measured by changes in grain size, sediment chemistry, and biological communities, including benthic invertebrates and fish).
- Does the model used to simulate the dispersal of dredged material accurately predict movement of material through the water column and to the bottom?
- Is there significant bioaccumulation of chemical contaminants in local organisms at the site?
- Do disposal operations have a significant impact on biological resources?
- Do disposal operations have a significant impact on the distribution or feeding habits of seabirds or mammals?

Site management action, such as disposal volume or timing restrictions, will be initiated if monitoring data indicate nonconformance with permit conditions or if disposal activities have caused any of the following conditions:

- Significant accumulation of waste constituents at or within any shoreline, marine sanctuary, or critical area;
- Biota, sediments, or the water column are adversely affected to the extent that there are significant decreases in populations of valuable commercial or recreational species, or in other species essential to the propagation of such species;
- Significant adverse effects to populations of seabirds or marine mammals, including threatened and endangered species of limited distribution;

- Material has accumulated to the extent that major uses of the site are impaired;
- Adverse effects to the taste or odor of valuable commercial or recreational species; or
- Dredged material is identified consistently in toxic concentrations outside the disposal site more than 4 hours after disposal [40 CFR 228.10 (c)(1)(i)-(v)].

4.7 Cumulative Impacts as a Result of the Project

Ongoing and historical discharges in the LTMS study region are described in Sections 1.7 and 3.1.1. These discharges include disposal of dredged material at the Channel Bar ODMDS (5.6 km from shore) and discharges of treated wastewaters from several coastal outfalls, including San Francisco Southwest Ocean Outfall (10.2 km from shore), City of Pacifica Outfall (0.8 km from shore), and Northern San Mateo County Outfall (0.8 km from shore). Additional dredged material disposal activities also may occur near or within Alternative Site 5 as part of an MPRSA Section 103 Permit requested by the Navy. Discontinued historical waste discharges in the LTMS study region include dredged material disposal, acid waste, cannery waste, low-level radioactive waste, munitions, refinery waste, and vessel and dry dock disposal (Figure 3.1-1).

Due to the large distances (greater than 45 nmi) from shore to the alternative sites, discharges of treated wastewaters from nearshore outfalls are unlikely to cause any cumulative effects with regard to designation or use of an offshore ODMDS. Ocean disposal of acid waste, cannery waste, and refinery waste was discontinued approximately 20 years ago (in 1971–1972), and the presence of residual wastes which could interact with discharged dredged material to produce cumulative, adverse, environmental effects has not been detected (Section 3.2.5). Similarly, the majority of the dredged material disposal activities were discontinued 14 to 25 years ago (BART in 1967, COE Test Site in 1974, and the 100-Fathom Site in 1978,). Present dredged material disposal activities at the Channel Bar ODMDS are too far (approximately 45 to 55 nmi) from the alternative sites to produce cumulative effects. Also, the sandy material from the entrance channel discharged at the site is not expected to contain chemical contaminants which could contribute to cumulative effects. In contrast, other discharge activities discussed below may have some effect on the proposed actions due to the proximity of these historical discharge operations to one or more of the alternative sites and the likelihood of residual contamination.

4.7.1 Radioactive Waste Disposal Sites

One of three radioactive waste sites (Site B in 1,800 m of water) is located in the vicinity of Study Area 5 (Figure 3.1-1). The other two sites (Site A at 90 m depth and C at 900 m depth) are within the GOFNMS and located approximately 20 nmi or more from the alternative sites. However, the precise locations of the majority of the waste containers are unknown, and the wastes may be spread over a large area within the general region. All known disposal of containerized, low-level radioactive wastes at Sites A, B, and C was suspended by 1965. Due to the expected residual radioactivity associated with this waste, some potential exists for contamination of bottom sediments and organisms. The magnitude of the contamination, and potential risks to environmental resources and human health, presently are being evaluated by NOAA and EPA.

It is unlikely that dredged material disposal would cause cumulative effects in conjunction with these low-level radioactive waste containers. In fact, deposition of dredged material could have the effect of burying and further isolating some containers. However, it would not be practical at this time to use dredged material specifically for burying waste containers because, according to best available information, most of the containers are close to the Farallon Islands and within the GOFNMS. The primary concern related to ODMDS designation is the potential for accidental recovery of radioactive waste material during baseline and monitoring surveys of the ODMDS. Inadvertent collection of some radioactive material has occurred in the southeastern portion of Study Area 5, but outside of Alternative Site 5 (Lissner, SAIC, pers. obs. 1992). Therefore, while cumulative effects are not a significant concern, it is important to address the feasibility of monitoring an ODMDS situated in the vicinity of the radioactive waste disposal sites.

4.7.2 Munitions Waste Sites

The Chemical Munitions Dumping Area (CMDA) is located within Study Area 5 (Figure 3.1-1). Two other disused munitions disposal areas are adjacent to Study Area 4. As with the radioactive waste sites, disposal operations at the munitions waste disposal sites were terminated over 20 years ago (by 1969). The potential exists for regional environmental contamination and/or human health concerns from historically disposed chemical agents and explosives. However, cumulative impacts from dredged material disposal are unlikely, and deposition of dredged material could bury some munitions. The primary concern associated with designation of an ODMDS would be accidental recovery of munitions wastes during baseline or monitoring surveys of the ODMDS. Inadvertent collection of munitions near Alternative Site 5 has occurred (Lissner, SAIC, pers. obs. 1992). Thus, while cumulative impacts are not considered significant, it is important to evaluate the feasibility of monitoring an ODMDS which lies in vicinity of the historical munitions disposal sites.

4.7.3 Navy Section 103 Dredged Material Disposal

The Navy currently is conducting studies in support of an MPRSA Section 103 interim site designation for the Naval Ocean Disposal Site (NODS), which corresponds approximately to Alternative Site 5. If granted, the dredged material disposed at the site could contribute to cumulative effects associated with any subsequent use of the site for other dredged material disposal operations. As required under MPRSA, any dredged material, whether disposed of at a Section 102 or a Section 103 site, must meet all applicable criteria to be eligible for ocean disposal. Assessment of any cumulative effects will be part of the site monitoring plan. Data collected by the Navy, required as part of their monitoring program as specified in a Section 103 permit, could be used to assess cumulative effects from subsequent disposal operations at Alternative Site 5.

4.7.4 B1B Dredged Material Disposal Site

The B1B site is located within the boundary of LTMS Study Area 2 (Figure 3.1-1). The site was used briefly in 1988 for disposal of approximately 18,000 yd^3 of dredged material from the Port of Oakland. In general, this volume of material is very small, and residual effects at the site, including cumulative effects related to the proposed action, are unknown. Results from recent EPA surveys (SAIC 1992b,c) indicate that the shelf area is a high-energy zone and fine-grained material appears readily dispersed (Noble and Ramp 1992; SAIC 1992c). Therefore, detectable quantities of dredged material from the Port of Oakland may no longer exist in the vicinity of the BIB site.

4.8 Relationship Between Short-Term Use and Long-Term Resource Uses

The proposed designation of any of the alternative sites as an ODMDS is not expected to produce significant, long-term, adverse impacts to resources, including the physical, biological, and socioeconomic environments, within the LTMS study region. Impacts to benthic invertebrates within the site are expected to persist as long as the site is used for disposal. However, cessation of disposal should result in gradual recovery over time. Deep sites generally are expected to require longer recovery times than shallow-water sites due to the slow rates of change that typically are associated with more stable conditions (Sanders and Hessler 1969).

Use of the proposed ODMDS is not expected to interfere with uses of resources outside of the boundaries of the alternative sites. These resources include commercial and sport fishing, seabird and mammal observation, and use of the region by commercial, military, and recreational vessels (Sections 3.4 and 4.4). No significant mineral or oil and gas resources occur within any of the alternative sites (Sections 3.4 and 4.4). Therefore, use of ODMDS does not represent a potential conflict with the long-term use of resources.

Any impacts or restricted uses of resources within the site boundaries would represent a very small percentage of these resources within the LTMS study region. This marginal loss of some resources is balanced by the significant benefit that would be derived from the proposed action. In contrast, lack of a designated ocean disposal site capable of receiving large quantities of dredged material could have a significant adverse effect on the economic productivity and national defense activities associated with San Francisco Bay (COE 1990a,b, 1991).

4.9 Irreversible or Irretrievable Commitment of Resources

Irreversible or irretrievable resources that would be committed if an ocean disposal site is designated will include:

- Energy resources used as fuel for dredges, pumps, and disposal vessels, and for research vessels involved in any subsequent monitoring studies;
- Economic resources associated with ocean disposal including monitoring and surveillance;
- Unavailability of sediments disposed at the ODMDS for potential marsh restoration or other beneficial use projects; and
- Some loss or degradation of the benthic habitat and associated benthic communities at the site for at least the duration of site use.

The commitment of energy and economic resources will increase with increased distance of a site from dredging areas. However, the three alternative sites are similar distances from the Golden Gate Bridge, and no significant differences in the resources contained within the alternative sites are evident. Therefore, the magnitude of any long-term commitment of irreversible or irretrievable resources that can be determined from the existing information is essentially the same for each of the three alternative sites.

CHAPTER 5
COORDINATION

This chapter contains information on public involvement and interagency activities related to the Draft Environmental Impact Statement (DEIS) for designation of the San Francisco Deep Water Ocean Dredged Material Disposal Site (Sections 5.1 and 5.2, respectively); evidence of formal consultation (Section 5.3); and requested reviewers and public distribution of the DEIS (Sections 5.4 and 5.5, respectively).

5.1 Notice of Intent and Public Scoping Meeting

The Notice of Intent (NOI) to prepare an environmental impact statement related to designation of an ocean dredged material disposal site (ODMDS) was published in the *Federal Register* on March 31, 1989 (Exhibit 1).

A public scoping meeting was held in Sausalito, California on April 11, 1989 to identify affected public and agency concerns and to define the issues and alternatives to be examined in detail in the EIS. At this scoping meeting, EPA explained the need for and process of site designation and identified several geographic areas for further evaluation. These areas included the continental shelf to a depth of 100 fathoms (183 m), the shelf break from 100 to 300 fathoms (183 to 550 m), the continental slope from 300 to 500 fathoms (550 to 914 m), the deep slope area from 500 to 1,000 fathoms (914 to 1,829 m), Pioneer Canyon from 300 to 1,000 fathoms (550 to 1,829 m), and areas deeper than 1,000 fathoms (1,829 m).

[ER-FRL-3549-3]

Designation of an Ocean Dredged Material Disposal Site (ODMDS) off San Francisco, CA; Intention To Prepare an Environmental Impact Statement

AGENCY: U.S. Environmental Protection Agency (EPA), Region 9.

ACTION: Notice of Intent to prepare an Environmental Impact Statement (EIS) on the designation of an ODMDS off San Francisco, California.

Purpose: The U.S. EPA, Region 9, in accordance with section 102(2)(c) of the National Environmental Policy Act (NEPA) and in cooperation with the San Francisco District of the U.S. Army Corps of Engineers, will prepare a Draft EIS (DEIS) on the designation of an ODMDS for dredged material off San Francisco, California. An EIS is needed to provide the information necessary to designate a suitable site. This Notice of Intent is issued pursuant to Section 102 of the Marine Protection, Research and Sanctuaries Act (MPRSA) of 1972, and 40 CFR Part 228 (Criteria for the Management of Disposal Sites for Ocean Dumping).

For Further Information and to be Placed on the Mailing List Contact: Patrick Cotter, Oceans and Estuaries Section (W-7-1), U.S. Environmental Protection Agency, Region 9, 215 Fremont Street, San Francisco, California 94105, telephone number (415) 974-0257, or FTS 454-0257.

SUMMARY: Designation of the San Francisco ODMDS is needed to provide a suitable disposal site for dredged material removed from San Francisco Bay and other locations in the vicinity. Disposal of dredged material at any ODMDS is not permitted unless EPA and the Corps determine that the material is acceptable for disposal under EPA's Ocean Dumping criteria at 40 CFR 225 and 40 CFR 227. The Corps issues permits under Section 103 of MPRSA subject to EPA review.

EPA and the Corps are evaluating several geographical areas for suitable disposal sites. These geographical areas include continental shelf to a depth of 100 fathoms (fm), the shelf break from 100-300 fm, the continental slope 300-500 fm, the deep slope area 500-1,000 fm, Pioneer Canyon 300-1,000 fm, and areas deeper than 1,000 fm.

The Corps will complete all environmental and economic studies related to the San Francisco site in support of EIS preparation. EPA is responsible for reviewing the information used in preparation of the DEIS and publishing the document. The Corps will assist EPA in responding to any comments received on the DEIS and subsequent site designation work.

Need for Action: The Corps of Engineers, San Francisco District has requested that EPA designate an ODMDS offshore of San Francisco, California. An EIS is required to provide the necessary information to evaluate disposal alternatives and to designate the preferred ODMDS. If the proposed dredged material from San Francisco Bay and other locations in the vicinity meets the criteria for ocean disposal at 40 CFR Parts 225 and 227 then the material may be disposed at the designated site.

Alternatives: The EIS will characterize environmental parameters, assess environmental impacts and evaluate a reasonable range of alternatives to determine whether designation of an ocean disposal site is acceptable. The alternatives include: (1) No Action; (2) Existing In-Bay Disposal Sites, (3) New In-Bay Disposal Sites, (4) Upland Disposal, (5) Historical Ocean Dumping Sites, and (6) Ocean Disposal at any of the geographical areas described above.

Scoping: Preliminary scoping meetings were held on January 18, 1989 and March 1, 1989 to develop thise NOI. Two scoping meetings for the general public are scheduled on April 11, 1989, from 1:00 to 4:00 p.m., and from 7:00 to 10:00 p.m. The meetings will be held at the Bay Motel, 2100 Bridgeway, Sausalito, California, 94965. Written comments on this Notice of Intent should be sent to the contact person listed above no later than 45 days after the date of publication.

Estimated Date of Release: The DEIS will be made available in March 1991.

Responsible Official:

Daniel W. McGovern,

Regional Administrator, Region 9.

Date: March 28, 1989.

Richard E. Sanderson,

Director, Office of Federal Activities.

[FR Doc. 89-7742 Filed 3-30-89; 8:45 am]

BILLING CODE 6560-50-M

[ER-FRL 3543-1]

Intention To Prepare a Draft Environmental Impact Statement (EIS); City of San Diego Wastewater Treatment Facilities, California

AGENCY: U.S. Environmental Protection Agency (EPA) Region IX.

ACTION: Preparation of a Draft Environmental Impact Statement on the conversion of San Diego's wastewater treatment facilities from advanced primary treatment to secondary treatment and water reclamation.

Purpose: In accordance with section 511(c) of the Clean Water Act (CWA) and section 102(2)(c) of the National Environmental Policy Act (NEPA), EPA has identified a need to prepare an EIS and therefore issues this Amended Notice of Intent.

For Further Information and to be Placed on the Project Mailing List Contact: Mr. Enio Sebastiani, Construction Grants Branch, U.S. EPA, (W-2-2), 215 Fremont St., San Francisco, CA 94105, Telephone: (Commercial) 415-974-8316 or (FTS) 454-8316.

SUMMARY: The City of San Diego has initiated a new program, the Clean Water Program for Greater San Diego, with a goal of attaining full compliance with the CWA and NEPA. The program is currently in the facilities planning stage. The resulting plan will recommend both secondary treatment and water reclamation facilities of sufficient size to serve the San Diego metropolitan area through the middle of the twenty-first century. Facilities covered by the plan will include an upgrade of the City's Point Loma wastewater treatment plant, one or two other secondary treatment plants, a number of water reclamation plants, sludge handling and disposal facilities, and associated pump stations and pipelines.

Need for Action: On September 30, 1988, EPA announced its decision to tentatively deny the City of San Diego's 1979 and 1983 applications for a waiver under Section 301(h) of the CWA. On November 3, 1986, the City Council authorized the City Manager to send EPA a letter of intent to file a revised waiver application. On February 17, 1987, the City Council decided to discontinue waiver efforts and to pursue secondary treatment.

Alternatives: Six alternatives plus the No Project alternative are presently under consideration for providing secondary treatment in the San Diego area. The alternatives involve variations in the size and extent of treatment facilities in the North City area, at the existing Point Loma treatment site, at locations near Lindbergh Field, and at sites along the U.S./Mexico border. Alternative sites are also being considered for a number of reclamation plants throughout the San Diego metropolitan area.

Comments made during the scoping meeting covered the following general topics:

- Proximity of the ocean disposal site to the Gulf of the Farallones National Marine Sanctuary, Cordell Bank National Marine Sanctuary, hard-bottom areas, and Pioneer Canyon;

- Potential interferences with existing and/or future fishery resources, and feeding, breeding, and migratory activities of marine birds and mammals;

- Potential impacts to other water column organisms should dredged material particles remain suspended;

- Potential problems predicting the area affected by disposal operations; and

- Potential problems monitoring short- and long-term effects from disposal operations at a deep-water site.

5.2 San Francisco Bay Long-Term Management Strategy for Dredged Material

The Long-Term Management Strategy (LTMS) program began in January 1990 as a Federal/State partnership between the four agencies which have regulatory authority for dredged material in the San Francisco Bay area. The LTMS is designed to provide a regional plan for the disposal of up to 400 million yd^3 of dredged materials from the San Francisco Bay over the next 50 years. As the lead agencies for the LTMS, the U.S. Army Corps of Engineers (COE), the Environmental Protection Agency Region IX (EPA), the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB), and the San Francisco Bay Conservation and Development Commission (BCDC), share responsibility for managing the various components of the LTMS.

Within the LTMS structure are several committees (Figure 5.2-1). The Executive Committee is composed of the COE South Pacific Division Commander, the EPA Regional Administrator, the SFBRWQCB Chairperson, the BCDC Chairperson, and a state coordinator. This committee provides management and policy guidance and retains principal decision-making authority for LTMS program issues. However, overall LTMS coordination and technical direction is delegated to the Management Committee. This committee, consisting of the COE South Pacific Division

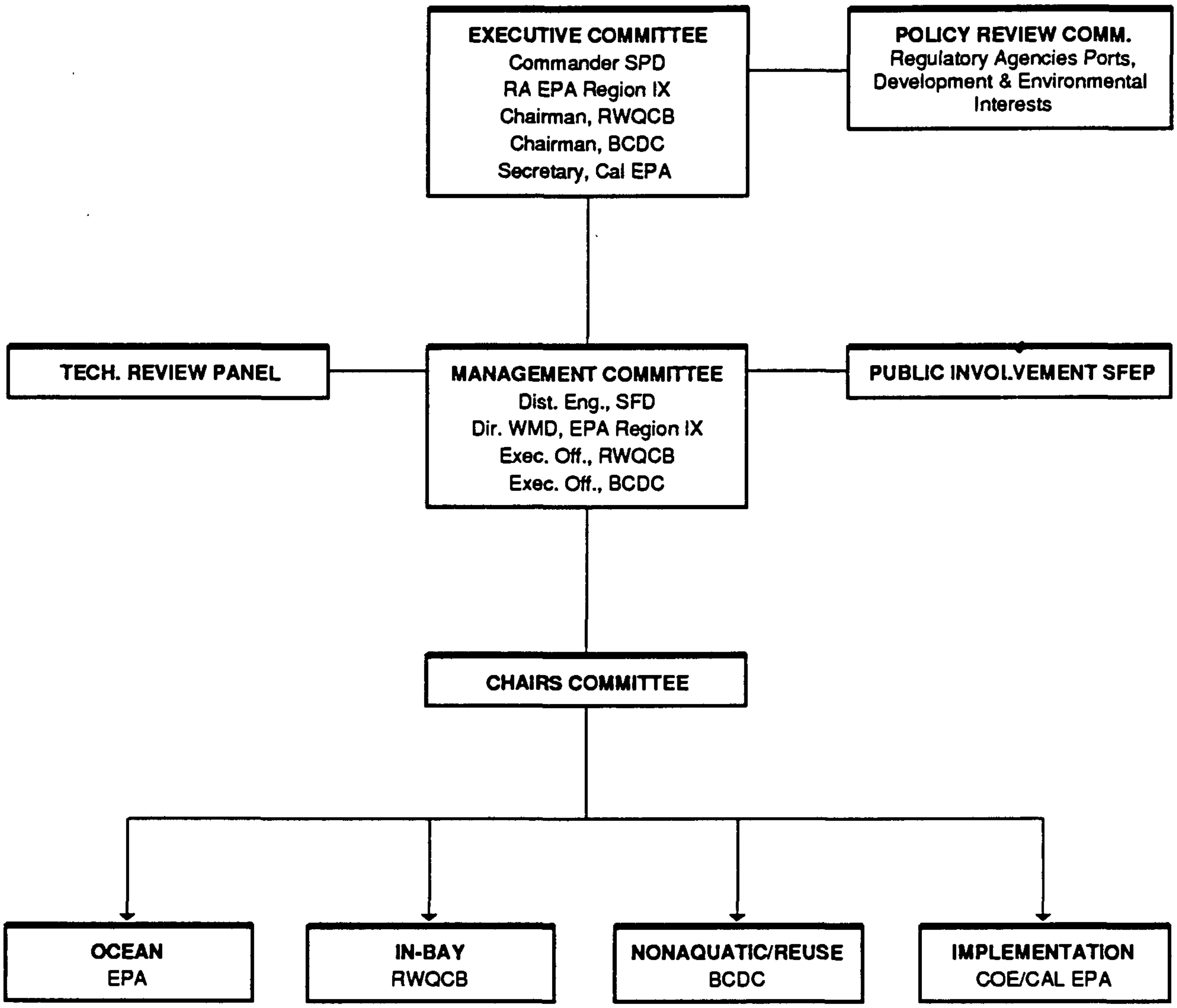

Figure 5.2-1 **Long-Term Management Strategy (LTMS) Management and Implementation Structure.**

LTMS Program Manager, the EPA Water Management Division Director, the SFBRWQCB Executive Officer, and the BCDC Executive Director, oversees the LTMS work groups and the Technical Review Panel.

There are four LTMS work groups including the Ocean Studies Work Group (OSWG), the In-Bay Work Group, the Nonaquatic/Reuse Work Group, and the Implementation Work Group. Each of these work groups has its own structure, public involvement strategy, and specific objectives. The Ocean, In-Bay, and Nonaquatic/Reuse Work Groups are responsible for conducting the tasks described in the LTMS Study Plan (COE 1991). The Implementation Work Group is the newest of the work groups. The Steering Committee of this work group has recently proposed a series of subcommittees to deal with the issues of siting framework, sediment quality, financing and ownership, containment sites, a programmatic management document, and project coordination.

The Technical Review Panel is composed of five scientific experts who provide critical reviews of technical issues that lie outside of the LTMS program's broad conceptual approach. The members of the Technical Review Panel are shown in Table 5.2-1.

The LTMS structure also includes an advisory group, the Policy Review Committee, which is comprised of a broad range of Federal and State agencies, ports, development, environmental, and fishing interests (Table 5.2-2). This committee meets quarterly and provides an important forum for public involvement in, and review of, LTMS development and implementation. Another mechanism for public involvement in the LTMS is the San Francisco Estuary Project, which serves to disseminate information to the general public through its outreach programs.

5.3 LTMS Ocean Studies Work Group

The LTMS OSWG, led by EPA, meets periodically to allow EPA and others to present preliminary or final study findings and to solicit comments from group members. The members of the OWSG, commentors on OSWG products, and attendees of the OSWG meetings are shown

Table 5.2-1. Members of the LTMS Technical Review Panel.

Name	Specialty	Organization
Don F. Boesch	Benthic Community Analysis	University of Maryland
R. Risebrough	Chemistry	University of California—Santa Cruz
Hsieh W. Shen	Physical Processes	University of California—Berkeley
Tom Ginn	Sediment Toxicology	PTI, Inc.
David R. Stoddart	Wetland Geomorphology	University of California—Berkeley

Table 5.2-2. Members of the LTMS Policy Review Committee

Category	Member Organization
Federal Agencies	Gulf of the Farallones National Marine Sanctuary National Marine Fisheries Service National Oceanic and Atmospheric Administration U.S. Army Corps of Engineers U.S. Coast Guard U.S. Environmental Protection Agency U.S. Fish and Wildlife Service U.S. Geological Survey U.S. Navy
California State and Regional Agencies	Coastal Commission Department of Boating and Waterways Department of Fish and Game Department of Water Resources Integrated Waste Management Board San Francisco Bay Conservation and Development Commission Secretary for Environmental Protection Secretary of Business, Transportation, and Housing State Lands Commission State Water Resources Control Board The Resources Agency
Special Interest Groups	Bay Planning Coalition California Marine Affairs and Navigation Conference Citizens for a Better Environment Golden Gate Ports Association Half Moon Bay Fisherman's Marketing Association Ocean Alliance Pacific Coast Federation of Fisherman's Associations Port of Oakland Port of Redwood City Port of Richmond Port of San Francisco Save San Francisco Bay Association Sierra Club United Anglers of California

in Tables 5.3-1, 5.3-2, and 5.3-3, respectively. Under the LTMS program, EPA first convened representatives of interested agencies and groups on February 20, 1990, to present an outline of the LTMS Ocean Studies Plan (OSP). The purpose of this document was to define objectives and identify studies necessary to address the site selection general and specific criteria (see Table 1.1-1). At a meeting of the LTMS Policy Review Committee on February 27, 1990, interested reviewers were asked to submit comments on the OSP outline.

Using comments received at the February 1990 meeting and written comments from members of the Policy Review Committee, EPA prepared a response to comments and developed the OSP outline into a detailed plan. This draft OSP was presented and distributed to the Ocean Studies Work Group at its first official meeting on November 8, 1990. At this meeting, attendees were asked to submit comments on the draft OSP by early December. EPA prepared responses to comments and presented those responses at another OSWG meeting held December 17, 1990.

Since one of the major issues for the site designation process was the methodology used in assessing fish communities, EPA convened a special work group meeting at NMFS (Tiburon) on January 8, 1991 to discuss these issues. Afterward, another OSWG meeting was held on February 20, 1991. At this meeting, the COE presented a draft Zone of Siting Feasibility determination which included all of the study areas identified by EPA in the draft OSP. Other topics discussed at this meeting included preliminary footprint modeling and proposed changes to the OSP based on comments received at the previous two meetings.

EPA released a draft final OSP on March 8, 1991. This document contained a detailed description of each of the site selection criteria and defined specific objectives for four study elements: Physical Oceanography, Benthic Infauna and Sediments, Epifauna and Fisheries, and Marine Birds and Mammals. In addition, the document provided an assessment of existing information for the study areas, a description of specific studies to be conducted, and a cost estimate. EPA received written comments on the draft final OSP and revised it into a final OSP which was released at a Policy Review Committee meeting on June 7, 1991.

Table 5.3-1. LTMS Ocean Studies Work Group (OSWG) Members.
Members listed alphabetically by affiliation.

Name	Organization
Bill Boland	independent
Tom Jow	independent
Ellen Johnck	Bay Planning Coalition
Mark Delaplaine	California Coastal Commission
Jim Raives	California Coastal Commission
George Armstrong	California Department of Boating and Waterways
Pete Phillips	California Department of Fish and Game
Robert Tasto	California Department of Fish and Game
Tracy Wood	California Integrated Waste Management Board
Mary Bergen	California State Lands Commission
Alan Ramo	Citizens for a Better Environment
Kathleen van Velsor	Coastal Advocates
Marie White	Entrix
Jeffrey Cox	Evans-Hamilton, Inc.
Jan Roletto	Gulf of the Farallones National Marine Sanctuary
Ed Ueber	Gulf of the Farallones National Marine Sanctuary
Pietro Parravano	Half Moon Bay Fisherman's Association
Cynthia Koehler	Heller, Ehrman, White and McAuliffe
Robert Battalio	Moffatt and Nichol
Greg Cailliet	Moss Landing Marine Laboratories
James Nybakken	Moss Landing Marine Laboratories
Herb Curl	National Oceanic and Aeronautical Administration Hazardous Materials
Alec MacCall	National Marine Fisheries Service
Chris Mobley	National Marine Fisheries Service
Don Pearson	National Marine Fisheries Service
Gail Blaise	Office of Congresswoman Barbara Boxer
Lynelle Johnson	Office of Congressman George Miller
Catherine Courtney	PRC Environmental Management Inc.
David Cobb	PTI Environmental Services

Table 5.3-1. Continued.

Name	Organization
Zeke Grader	Pacific Coast Federation of Fish Association
David Ainley	Point Reyes Bird Observatory
Sarah Allen	Point Reyes Bird Observatory
Jim McGrath	Port of Oakland
Charles Schwarz	Port of Oakland
Jody Zaitlin	Port of Oakland
Steve Goldbeck	San Francisco BCDC
Scott Rouillard	San Francisco Bay Keeper
Michael Carlin	San Francisco Regional Water Quality Control Board
Paul Jones	San Francisco Regional Water Quality Control Board and U.S. Environmental Protection Agency
Andrew Lissner	Science Applications International Corporation
John Lunz	Science Applications International Corporation
David Nesmith	Sierra Club
Kim Brown	Tetra Tech
John Beuttler	United Anglers of America
Commander Scot Tiernan	U.S. Coast Guard Marine Safety Office
Rod Chisholm	U.S. Corps of Engineers
Bill McCoy	U.S. Corps of Engineers
Lynn O'Leary	U.S. Corps of Engineers
Richard Stradford	U.S. Corps of Engineers
Tom Wakeman	U.S. Corps of Engineers
William Allen	U.S. Department of the Interior
Jean Takakawa	U.S. Fish and Wildlife Service
Herman Karl	U.S. Geological Survey
Marlene Noble	U.S. Geological Survey
Curt Collins	U.S. Naval Postgraduate School
Steven Ramp	U.S. Naval Postgraduate School
Sherman Seelinger	U.S. Navy Western Division

Table 5.3-2. Agencies and Organizations that Provided Written Comments on LTMS Ocean Studies Plan, February 1990 to June 1991.

California Coastal Commission
California Department of Fish and Game
California Environmental Protection Agency
Golden Gate Ports Association
Gulf of the Farallones National Marine Sanctuary
Half Moon Bay Fisherman's Marketing Association
National Marine Fisheries Service, Santa Rosa
National Marine Fisheries Service, Tiburon
Point Reyes Bird Observatory
Port of Oakland
San Francisco Bay Conservation and Development Commission
San Francsico Bay Regional Water Quality Control Board
Save San Francisco Bay Association
State Lands Commission
United States Army Corps of Engineers, San Francisco District
United States Army Corps of Engineers, South Pacific Division
United States Army Corps of Engineers, Waterways Experiment Station
United States Coast Guard
United States Environmental Protection Agency, Office of Research and Development
United States Geological Survey
United States Naval Postgraduate School
United States Navy

Table 5.3-3. Attendance at LTMS Ocean Studies Work Group Meetings, February 1990 to September 1992.

Organization	2/20/90	11/8/90	12/17/90	1/8/91	2/26/91	7/29/91	12/12/91	2/13/92	5/4/92	8/14/92	9/29/92
Bay Conservation and Development Commission		N/A	X			X	X		X	X	X
Bay Planning Coalition	X	N/A							X		
Bill Boland		N/A								X	
California Coastal Commission	X	N/A	X			X	X	X	X	X	X
California Department of Boating and Waterways		N/A	X		X	X	X	X	X		X
California Department of Fish and Game		N/A	X	X	X	X	X	X	X	X	
California Marine Affairs and Navigation Conference (CMANC)		N/A	X								
Citizens for a Better Environment	X	N/A									
Coastal Advocates		N/A									X
Congresswoman Boxer's Office		N/A			X						
Corps of Engineers	X	N/A	X	X	X	X	X	X	X	X	X
Department of the Interior		N/A								X	
Golden Gate Ports Association	X	N/A									
Gulf of the Farallones National Marine Sanctuary	X	N/A		X		X					
Half Moon Bay Fisherman's Marketing Association	X	N/A	X		X	X	X	X		X	
Integrated Waste Management Board		N/A				X					
Moss Landing Marine Laboratories		N/A		X							
National Marine Fisheries Service	X	N/A	X	X	X	X	X	X	X	X	X
National Oceanic and Atmospheric Administration (NOAA)		N/A					X	X			
Naval Postgraduate School		N/A	X			X		X		X	

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Table 5.3-3. Continued.

Organization	2/20/90	11/8/90	12/17/90	1/8/91	2/26/91	7/29/91	12/12/91	2/13/92	5/4/92	8/14/92	9/29/92
Point Reyes Bird Observatory	X	N/A	X			X	X			X	X
Port of Oakland		N/A			X	X	X	X		X	X
San Francisco Bay Regional Water Quality Control Board	X	N/A	X							X	
Sierra Club	X	N/A									
State Lands Commission		N/A			X						
U.S. Fish and Wildlife Service		N/A						X			
U.S. Geological Survey	X	N/A	X		X					X	
U.S. Navy		N/A	X	X	X	X	X	X	X	X	X
University of California at Davis		N/A		X							

Since some commentors felt that the final OSP had not resolved all of the outstanding issues, EPA prepared responses to comment letters from the Gulf of the Farallones National Marine Sanctuary and the California Environmental Protection Agency and held an OSWG meeting on July 29, 1991 to address these issues. Other presentations at this meeting included additional preliminary footprint modeling and the scope of services for the OSP biological studies.

At the next Ocean Studies Work Group meeting held on December 12, 1991, EPA presented preliminary results of the benthic infauna and sediments, trawl, and remotely-operated vehicle studies to the OSWG. Preliminary results of database analyses performed by the National Marine Fisheries Service and the Point Reyes Bird Observatory under contract to EPA were also presented. Other topics of discussion included the need for a second season of biological sampling and the compatibility of EPA field work with studies conducted by the Navy in LTMS Study Area 5.

In order to address concerns about compatibility between EPA and Navy studies, EPA made the Navy studies the focus of an OSWG meeting held on February 13, 1992. At this meeting, the Navy described the types of studies conducted and their preliminary findings. The topic of the May 4, 1992 OSWG meeting also related to this issue. Since the OSWG was very concerned about comparison of data collected with different gear types, EPA presented a synopsis of data types and recommended approaches for analyzing and comparing EPA and Navy data. Following the recommendation of the OSWG, EPA has avoided quantitative comparisons between certain data sets.

On August 14, 1992, EPA held another OSWG meeting to present results from each of the OSP components and to propose alternative sites within the OSP study areas. OSWG members agreed on the locations of alternative sites and voiced their opinions and concerns regarding the comparison of these alternative sites to the EPA site selection criteria (40 CFR Sections 228.5 and 228.6). At an OSWG meeting held on September 29, 1992, EPA presented its tentative selection of Alternate Site 5, within Study Area 5, as the preferred alternative for site designation. The members of the OSWG who attended the meeting (Table 5.3-1) did not react negatively to

EPA's selection of Alternative Site 5. While some concerns were raised regarding seabirds and marine mammals, the balance of information did not lead the OSWG members to call for selection of another alternative site.

EPA will continue to hold OSWG meetings to address comments on the DEIS, develop the site management and monitoring plan, and prepare the FEIS and proposed rule.

5.4 Formal Consultation

The Endangered Species Act requires formal consultation with Federal and State agencies to identify any threatened, endangered, or special status species occurring within the region that may be affected by the proposed action. The formal consultation process with the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, and the California Department of Fish and Game was initiated on July 22, 1992 (Exhibits 2, 3, and 4). Further consultation documentation, including responses from these agencies and concurrence certification, will be included in the FEIS.

The National Historic Preservation Act requires consultation with the State Historic Preservation Officer to identify any areas within the study region of architectural, archeological, historic, or cultural value that are currently listed or eligible for listing on the National Register of Historic Places. Coordination with the California State Historic Preservation Officer also was initiated on July 22, 1992 (Exhibit 5). Further documentation of this consultation will also be included in the FEIS.

5.5 Public Distribution of the Draft Environmental Impact Statement

The list of agencies, organizations, and individuals to whom the DEIS will be distributed is shown in Table 5.5-1. A Notice of Availability will be sent to the approximately 1,000 agencies, companies, and organizations on the Corps of Engineers San Francisco District Environmental Branch's mailing list. Additional copies of the EIS may be requested from EPA or the document

EXHIBIT 2

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, Ca. 94105-3901

22 JUL 1992

Mr. William Lehman
Endangered Species Coordinator
U.S. Fish and Wildlife Service
2800 Cottage Way, Room E-1823
Sacramento, CA 95825

Dear Mr. Lehman:

The Environmental Protection Agency Region IX (EPA) is preparing an Environmental Impact Statement (EIS) for the designation of an ocean dredged material disposal site off San Francisco, California. The site will be selected as part of the Long-Term Management Strategy (LTMS) for San Francisco Bay and will have the capacity to accomodate an estimated 400 million cubic yards of dredged material over a 50-year period. The proposed action will involve only the designation of the site itself; before disposal is permitted, dredged material must be evaluated in accordance with the Marine Protection, Research and Sanctuaries Act of 1972 and its implementing regulations and guidance.

EPA began the site designation process by evaluating four study areas on the Farallon Shelf and Slope at distances of 20 to 55 miles offshore and at depths of 300 to 6000 feet. The four study areas are delineated on the enclosed map (areas 2-5) and coordinate list. With the recent designation of the Monterey Bay National Marine Sanctuary Study Areas 2 and the eastern third of Study Area 3 are no longer being considered as potential sites. However, since data have been collected for all four study areas, a characterization of each area is being developed. In the draft EIS, which is scheduled for release in November 1992, EPA will identify candidate sites within Study Areas 3, 4 and 5 and will choose a preferred alternative site.

In accordance with Section 7(c) of the Endangered Species Act, please advise EPA of the presence of any listed, or candidate, threatened or endangered species in the vicinity of the four study areas identified above. In addition, please advise EPA of any critical habitat for these species which may be impacted by the proposed action. Similar requests have been forwarded to the National Marine Fisheries Service and the California Department of Fish and Game. EPA would appreciate your response prior to October 1, 1992. Please direct any questions or requests for further information to Shelley Clarke at (415) 744-1162.

Sincerely,

Janet Y. Hashimoto

Janet Y. Hashimoto, Chief
Marine Protection Section

Enclosures (2)

EXHIBIT 3

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION IX

75 Hawthorne Street
San Francisco, Ca. 94105-3901

22 JUL 1992

Mr. James Bybee
Environmental Coordinator, Northern Area
National Marine Fisheries Service
777 Sonoma Avenue, Room 325
Santa Rosa, CA 95404

Dear Mr. Bybee:

The Environmental Protection Agency Region IX (EPA) is preparing an Environmental Impact Statement (EIS) for the designation of an ocean dredged material disposal site off San Francisco, California. The site will be selected as part of the Long-Term Management Strategy (LTMS) for San Francisco Bay and will have the capacity to accomodate an estimated 400 million cubic yards of dredged material over a 50-year period. The proposed action will involve only the designation of the site itself; before disposal is permitted, dredged material must be evaluated in accordance with the Marine Protection, Research and Sanctuaries Act of 1972 and its implementing regulations and guidance.

EPA began the site designation process by evaluating four study areas on the Farallon Shelf and Slope at distances of 20 to 55 miles offshore and at depths of 300 to 6000 feet. The four study areas are delineated on the enclosed map (areas 2-5) and coordinate list. With the recent designation of the Monterey Bay National Marine Sanctuary Study Areas 2 and the eastern third of Study Area 3 are no longer being considered as potential sites. However, since data have been collected for all four study areas, a characterization of each area is being developed. In the draft EIS, which is scheduled for release in November 1992, EPA will identify candidate sites within Study Areas 3, 4 and 5 and will choose a preferred alternative site.

In accordance with Section 7(c) of the Endangered Species Act, please advise EPA of the presence of any listed, or candidate, threatened or endangered species in the vicinity of the four study areas identified above. In addition, please advise EPA of any critical habitat for these species which may be impacted by the proposed action. Similar requests have been forwarded to the U.S. Fish and Wildlife Service and the California Department of Fish and Game. EPA would appreciate your response prior to October 1, 1992. Please direct any questions or requests for further information to Shelley Clarke at (415) 744-1162.

Sincerely,

Janet Y. Hashimoto

Janet Y. Hashimoto, Chief
Marine Protection Section

Enclosures (2)

EXHIBIT 4

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, Ca. 94105-3901

22 JUL 1992

Mr. John Turner, Acting Chief
Environmental Services Division
California Department of Fish and Game
1416 Ninth Street
Sacramento, CA 95814

Dear Mr. Turner:

The Environmental Protection Agency Region IX (EPA) is preparing an Environmental Impact Statement (EIS) for the designation of an ocean dredged material disposal site off San Francisco, California. The site will be selected as part of the Long-Term Management Strategy (LTMS) for San Francisco Bay and will have the capacity to accomodate an estimated 400 million cubic yards of dredged material over a 50-year period. The proposed action will involve only the designation of the site itself; before disposal is permitted, dredged material must be evaluated in accordance with the Marine Protection, Research and Sanctuaries Act of 1972 and its implementing regulations and guidance.

EPA began the site designation process by evaluating four study areas on the Farallon Shelf and Slope at distances of 20 to 55 miles offshore and at depths of 300 to 6000 feet. The four study areas are delineated on the enclosed map (areas 2-5) and coordinate list. With the recent designation of the Monterey Bay National Marine Sanctuary Study Areas 2 and the eastern third of Study Area 3 are no longer being considered as potential sites. However, since data have been collected for all four study areas, a characterization of each area is being developed. In the draft EIS, which is scheduled for release in November 1992, EPA will identify candidate sites within Study Areas 3, 4 and 5 and will choose a preferred alternative site.

EPA is requesting an endangered species consultation pursuant to the State Endangered Species Act. Therefore, please advise EPA of the presence of any listed, or candidate, threatened or endangered species, or species of special concern, in the vicinity of the four study areas identified above. In addition, please advise EPA of any critical habitat for these species which may be impacted by the proposed action. EPA will use this information in the preparation of the Draft Environmental Impact Statement and will forward this information to the California Coastal Commission as part of the site

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designation coastal consistency package we will prepare. Similar Federal consultations have been initiated with the U.S. Fish and Wildlife Service and the National Marine Fisheries Service. EPA would appreciate your response prior to October 1, 1992. Please direct any questions or requests for further information to Shelley Clarke at (415) 744-1162.

Sincerely,

Janet Y. Hashimoto

Janet Y. Hashimoto, Chief
Marine Protection Section

Enclosures (2)

EXHIBIT 5

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, Ca. 94105-3901

22 JUL 1992

Mr. Steade Craigo
Acting State Historic Preservation Officer
P.O. Box 942896
Sacramento, CA 94296-0001

Dear Mr. Craigo:

The Environmental Protection Agency Region IX (EPA) is preparing an Environmental Impact Statement (EIS) for the designation of an ocean dredged material disposal site off San Francisco, California. The site will be selected as part of the Long-Term Management Strategy (LTMS) for San Francisco Bay and will have the capacity to accomodate an estimated 400 million cubic yards of dredged material over a 50-year period. The proposed action will involve only the designation of the site itself; before disposal is permitted, the dredged material must be evaluated in accordance with the Marine Protection, Research and Sanctuaries Act of 1972 and its implementing regulations and guidance.

EPA began the site designation process by evaluating four study areas on the Farallon Shelf and Slope at distances of 20 to 55 miles offshore and at depths of 300 to 6000 feet. The four study areas are delineated on the enclosed map (areas 2-5) and coordinate list. With the recent designation of the Monterey Bay National Marine Sanctuary Study Areas 2 and the eastern third of Study Area 3 are no longer being considered as potential sites. However, since data have been collected for all four study areas, a characterization of each area is being developed. In the draft EIS, which is scheduled for release in November 1992, EPA will identify candidate sites within Study Areas 3, 4 and 5 and will choose a preferred alternative site.

In accordance with section 106 of the National Historic Preservation Act and Executive Order 11593, please advise EPA of any sites of historic, architectural, archeological or cultural value listed on, or eligible for listing on the National Register of Historic Places in the vicinity of the four study areas identified above. EPA would appreciate your response prior to October 1, 1992. Please direct any questions or requests for further information to Shelley Clarke at (415) 744-1162.

Sincerely,

Janet Y. Hashimoto

Janet Y. Hashimoto, Chief
Marine Protection Section

Enclosures (2)

Table 5.5-1. Distribution List for Draft Environmental Impact Statement (DEIS).
Members listed alphabetically by affiliation.

Name	Organization
Federal Agencies	
	Federal Maritime Commission
	Fort Point National Historic Site
Nancy Homor	Golden Gate National Recreation Area
Edward Ueber	Gulf of the Farallones National Marine Sanctuary
Herb Curl	National Oceanic and Aeronautical Administration Hazardous Materials, NOAA/N/OMA34
Martin Eckes	National Oceanic and Aeronautical Administration Headquarters, N/SPA
James Bybee	National Marine Fisheries Service
Dr. Alec MacCall	National Marine Fisheries Service
Don Pearson	National Marine Fisheries Service
Michael Thaubault	National Marine Fisheries Service
Lt. Col. Len Cardoza	San Francisco District, U.S. Corps of Engineers
Roderick Chisholm	San Francisco District, U.S. Corps of Engineers
Calvin Fong	San Francisco District, U.S. Corps of Engineers
Richard Stradford	San Francisco District, U.S. Corps of Engineers
Thomas Wakeman	San Francisco District, U.S. Corps of Engineers
	South Pacific Division, U.S. Corps of Engineers
	South Pacific Division, U.S. Corps of Engineers
William McCoy	South Pacific Division, U.S. Corps of Engineers
	U.S. Coast Guard Marine Safety Office
Commander Scot Tiernan	U.S. Coast Guard Marine Safety Office
	U.S. Department of the Interior
Patricia Sanderson Port	U.S. Department of the Interior
Marvin Plenert	U.S. Fish and Wildlife Service
Wayne White	U.S. Fish and Wildlife Service
Michael Field	U.S. Geological Survey
Herman Karl	U.S. Geological Survey
Marlene Noble	U.S. Geological Survey
John Kennedy	U.S. Naval Facilities Engineering Command
Curt Collins	U.S. Naval Postgraduate School
Steven Ramp	U.S. Naval Postgraduate School
Sherman Seelinger	U.S. Navy Western Division

Table 5.5-1. Continued.

Name	Organization
Interest Groups	
Don Anderson	independent
Bill Boland	independent
Lou Drake	independent
Tom Jow	independent
Margaret Johnson	Aquatic Habitat Institute
	Audubon Society, Golden Gate Chapter
	Bay Institute of San Francisco
Michael Herz	Bay Keeper
Ellen Johnck	Bay Planning Coalition
George Plant	Benicia Port Terminal
Philip Plant	Benicia Industries, Inc.
	Bodega Marine Laboratory
Lloyd Dodge	California Association of Harbormasters and Port Captains
Mike Cheney	California Maritime Affiliation and Naval Conference (CMANC)
Ray Krone	California Maritime Affiliation and Naval Conference (CMANC)
Robert Langner	California Maritime Affiliation and Naval Conference (CMANC)
	California Academy of Sciences
Laurel Marcus	California Coastal Conservancy
	California Marine Mammal Center
Mike Corker	California Waterfowl Association
Jill Kauffman	Center for Marine Conservation
	Chevron U.S.A., Inc.
Alan Ramo	Citizens for a Better Environment
Kathleen van Velsor	Coastal Advocates
William Dorresteyn	Dredge Rep Operating Engineers Local #3
	Dutra Construction Company
Levia Stein	EXXON Refining Company
	Earth Island Institute
	Environmental Defense Fund
	Environmental Forum of Marin
James Robertson	Golden Gate Fisherman's Association
John Karas	Great Lakes Dredging Company

Table 5.5-1. Continued.

Name	Organization
Karen Topakian	Greenpeace Action
Pietro Parravano	Half Moon Bay Fisherman's Association
	Headlands Foundation
Cynthia Koehler	Heller, Ehrman, White and McAuliffe
Dr. Victor Jones	Intra-Governmental Studies, University of California at Berkeley
	Latitude 38 Magazine
	League for Coastal Protection
	League of Women Voters, Bay Area
	Manson Construction and Engineering Company
Barbara Salzman	Marin Audubon Society/Conservation League
Karen Urquhart	Marine Conservation League
	Marine Science Institute
	Moss Landing Commercial Fisherman's Association
J. Martin	Moss Landing Marine Laboratory
	National Audubon Society, Marin Chapter
	National Audubon Society, Sequoia Chapter
	Nature Conservancy, California Field Office
Daniel Bacher	Northern California Angling Publication
	Oakland Chamber of Commerce
Margaret Elliot	Ocean Alliance
	Ocean Research Institute
Leonard Long	PICYA/RBOC
Zeke Grader	Pacific Coast Federation of Fishermen's Association
Miles Butler	Pacific Refinery Company
David Ainley	Point Reyes Bird Observatory
Sarah Allen	Point Reyes Bird Observatory
John Lunz	Science Applications International Corporation
Captain A.J. Thomas	San Francisco Bar Pilots
	San Francisco Bay Bird Observatory
Dr. Doug Segar	San Francisco State University
James Haussener	San Leandro Marina
Barry Nelson	Save San Francisco Bay Association
Daniel Glaze	Shell Oil Co.

Table 5.5-1. Continued.

Name	Organization
David Nesmith	Sierra Club
	Sierra Club, San Francisco Bay Chapter
Wendy Eliot	State Coastal Conservancy
	Stuyvesant Dredging Company
Kim Brown	Tetra Tech
	Tiburon Center for Environmental Studies, San Francisco State University
Roger Lockwara	Tosco Refining Co.
Leo Cronin	Trout Unlimited
Ken Guziak	UNOCAL, San Francisco Refinery
John Beuttler	United Anglers of America
Richard Peterson	United Surf Riders
Richard Bailey	Water Quality Association
	Western Pacific Dredging Company
Local Agencies	
Sally Germain	ABAG Clearinghouse
Steven Szalay	Alameda County
	Association of Bay Area Governments
	Board of Port Commissioners, Oakland
	City and County of San Francisco
	City of Redwood City
	City of Richmond
	Contra Costa County
	Marin County
	Napa County
James McGrath	Port of Oakland
Charles Roberts	Port of Oakland
Floyd Shelton	Port of Redwood City
M. Powers	Port of Richmond
Eugene Serex	Port of Richmond
Michael Huerta	Port of San Francisco
Veronica Sanchez	Port of San Francisco
	Port of Stockton

Table 5.5-1. Continued.

Name	Organization
Gail Louis	San Francisco Estuary Project
	San Mateo County
	Santa Clara County
James Harberson	Sonoma County
Libraries	
	ABAG/MTC Library
	Alameda County Library
	Bancroft Library, University of California
	Berkeley Public Library
	Daly City Public Library
	Environmental Information Center, San Jose State University
	Half Moon Bay Library
	Marin County Library, Civic Center
	North Bay Cooperative Library System
	Oakland Public Library
	Richmond Public Library
	San Francisco Public Library
	San Francisco State University Library
	San Mateo County Library
	Santa Clara County Free Library
	Sausalito Public Library
	Stanford University Library
U.S. Representatives	
Honorable Ronald Dellums	U.S. House of Representatives
Honorable Vic Fazio	U.S. House of Representatives
Honorable Wally Herger	U.S. House of Representatives
Honorable Tom Lantos	U.S. House of Representatives
Honorable George Miller	U.S. House of Representatives
Honorable Nancy Pelosi	U.S. House of Representatives
Honorable Fortney Stark	U.S. House of Representatives

Table 5.5-1. Continued.

Name	Organization
U.S. Senators	
Honorable Barbara Boxer	U.S. Senate
Honorable Dianne Feinstein	U.S. Senate
State Agencies	
	Bay Area Air Quality Management District
Bob Potter	California Department of Water Resources
	CALTRANS
George Larsen	California Integrated Waste Management Board
Wes Ervinh	California Commerce Department
	California Coastal Commission
Mark Delaplaine	California Coastal Commission
Peter Douglas	California Coastal Commission
	California Department of Boating and Waterways
George Armstrong	California Department of Boating and Waterways
Robert Tasto	California Department of Fish and Game
John Turner	California Department of Fish and Game
	California Department of Health Servics
Michael Kahoe	California Environmental Protection Agency
Douglas Wheeler	California Resource Agency
	California State Air Resources Board
John Geoghegan	Department of Business, Transportation, and Housing
Michael Carlin	San Francisco Bay Regional Water Quality Control Board
Paul Jones	San Francisco Bay Regional Water Quality Control Board
Marion Otsea	San Francisco Bay Regional Water Quality Control Board
Steven Ritchie	San Francisco Bay Regional Water Quality Control Board
Jeptha Wade	San Francisco Bay Regional Water Quality Control Board
Steve Goldbeck	San Francisco BCDC
Alan Pendleton	San Francisco BCDC
Linda Martinez	State Lands Commission
Charles Warren	State Lands Commission
Fred La Caro	State Water Resources Control Board

Table 5.5-1. Continued.

Name	Organization
California Representatives	
Honorable Tom Bates	California State Assembly
Honorable Willie Brown, Jr.	California State Assembly
Honorable John Burton	California State Assembly
Honorable Robert Campbell	California State Assembly
Honorable Barbara Lee	California State Assembly
Honorable Ted Lempert	California State Assembly
Honorable Jackie Speier	California State Assembly
James Alford	State of California Assembly, Speaker's Office
California Senate	
Honorable Barry Keene	California State Senate
Honorable Quentin Kopp	California State Senate
Honorable Milton Marks	California State Senate
Honorable Rebecca Morgan	California State Senate
Honorable Nicholas Petris	California State Senate

can be viewed at any of the libraries listed in Table 5.5-2. Comments received from reviewers and responses to these comments will be included in the Final Environmental Impact Statement.

Table 5.5-2. Locations Where the DEIS Can Be Reviewed or Requested.

Copies of this DEIS may be reviewed at the following locations:	
ABAG/MTC Library 101 - 8th Street Oakland, CA 94607	Oakland Public Library 125 - 14th Street Oakland, CA 94612
Alameda County Library 3121 Diablo Avenue Hayward, CA 94545	Richmond Public Library 325 Civic Center Plaza Richmond, CA 94804
Bancroft Library University of California Berkeley, CA 94720	San Francisco Public Library Civic Center, Larkin and McAllister San Francisco, CA 94102
Berkeley Public Library 2090 Kittredge Street Berkeley, CA 94704	San Francisco State University Library 1630 Holloway Avenue San Francisco, CA 94132
Daly City Public Library 40 Wembley Drive Daly City, CA 94015	San Mateo County Library 25 Tower Road San Mateo, CA 94402
Environmental Information Center, San Jose State University 125 South 7th Street San Jose, CA 95112	Santa Clara County Free Library 1095 N. 7th Street San Jose, CA 95112
Half Moon Bay Library 620 Correas Half Moon Bay, CA 94019	Sausalito Public Library 420 Litho Street Sausalito, CA 94965
North Bay Cooperative Library System 725 Third Street Santa Rosa, CA 95404	Stanford University Library Stanford, CA 94035
Marin County Library, Civic Center 3501 Civic Center Drive San Rafael, CA 94903	
Copies of this DEIS may be requested by writing to the following address: U.S. Environmental Protection Agency Region IX Marine Protection Section, W-7-1 ATTN: Shelley Clarke 75 Hawthorne Street San Francisco, CA 94105	

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CHAPTER 6
PREPARERS AND CONTRIBUTORS

This chapter provides a list of EIS preparers (Table 6-1) and contributors (Table 6-2).

Table 6-1. List of EIS Preparers.

NAME	EXPERTISE	EXPERIENCE	RESPONSIBILITY
U.S. Environmental Protection Agency			
Shelley Clarke, M.S.	Fisheries Marine Policy	Seven years conducting research and preparation and review of technical reports.	Technical Program Manager and EIS review.
Allan Ota, M.S.	Biological Oceanography	Twelve years conducting research and preparation and review of technical reports.	Field Studies Manager and EIS review.
Contractor: Science Applications International Corporation			
James Blake, Ph.D.	Benthic Biology/Ecology	Over 20 years conducting ecological research in benthic environments.	Preparation and review of EIS section: Affected Environment
John Clayton, Ph.D.	Biological Oceanography Environmental Chemistry	Over 20 years research in environmental chemistry and marine sciences.	Preparation of EIS section: Affected Environment
Debra Davison, M.S.	Marine Biology	Seven years conducting research and preparation of technical reports.	Preparation of EIS sections: Affected Environment Environmental Consequences Coordination EIS review
Joseph Germano, Ph.D.	Marine Sciences Dredged Material Impacts	Over 15 years conducting environmental studies focusing on dredged material impacts.	EIS review
Peter Hamilton, Ph.D.	Physical Oceanography	20 years conducting research in physical oceanography.	Preparation of EIS section: Environmental Consequences

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NAME	EXPERTISE	EXPERIENCE	RESPONSIBILITY
Mike Hart (M.S., in Progress)	Environmental Chemistry	Over four years conducting research and preparation of technical reports.	Preparation of EIS section: Affected Environment
Daniel J. Heilprin, M.S.	Marine Sciences Ichthyology Fisheries Biology	Over five years conducting ecological studies and preparation of technical reports.	Preparation of EIS sections: Affected Environment Environmental Consequences List of Preparers and Contributors EIS review
Robert Kelly, Ph.D.	Marine Sciences Dredged Material Impacts EIS Preparation	Over 15 years conducting environmental studies, including EIS preparation and impact assessment.	Preparation of EIS sections: Introduction Affected Environment Environmental Consequences
Andrew Lissner, Ph.D.	Marine Biology Dredged Material Impacts EIS Preparation	Over 15 years conducting environmental studies, including EIS preparation and impact assessment.	Work Assignment Manager Preparation of EIS sections: Affected Environment Environmental Consequences EIS review
John Lunz, M.S.	Marine Sciences Dredged Material Impacts	Over 15 years conducting dredged material research studies and impact assessment.	Preparation of EIS section: Affected Environment EIS review
Joann Muramoto, Ph.D.	Marine Geochemistry	Over 10 years conducting geochemical research.	Preparation of EIS section: Affected Environment
Charles Phillips, M.A.	Biology Chemistry EIS Preparation	15 years conducting environmental studies, including EIS preparation and impact assessment.	EIS Task Manager Preparation of EIS sections: Introduction Alternatives Affected Environment Environmental Consequences EIS review

NAME	EXPERTISE	EXPERIENCE	RESPONSIBILITY
William J. Reynolds, Ph.D.	Coastal Geomorphology	Almost 30 years conducting research in coastal geomorphology, project management, and teaching.	Preparation of EIS section: Affected Environment EIS review
Donald Rhoads, Ph.D.	Benthic Processes	More than 30 years conducting benthic studies and assessing marine environmental impacts.	Preparation of EIS sections: Affected Environment Environmental Consequences EIS review
Bo Shmorhay	Technical Editing	Over 10 years performing editing and production of technical reports and studies.	Editing and Production of EIS
Sridhar Srinivasan, M.A.	Economics Political Science	Two years environmental and institutional analyses.	Preparation of EIS sections: Affected Environment Environmental Consequences
Isabelle Williams, M.S.	Marine Biology	More than 20 years in marine sciences.	Preparation of EIS section: Affected Environment

Table 6-2. List of EIS Contributors.

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Sarah Allen	Point Reyes Bird Observatory
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Brian Edwards	U.S. Geological Survey
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CHAPTER 7

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