Disposal of Dredged Material and Other Waste on the Continental Shelf and Slope

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Summary and Introduction

The history of waste disposal in the Gulf of the Farallones (fig. 1) is directly linked with the history of human settlement in the San Francisco Bay region. The California Gold Rush of 1849 triggered a massive influx of people and rapid, chaotic development in the bay region. Vast quantities of contaminated sediment and water from mining in the Sierra Nevada were carried by rivers into San Francisco Bay, and some was carried by currents through the Golden Gate and into the gulf. The burgeoning region's inhabitants also contributed to the waste that flowed or was dumped into the bay. Eventually, waste began to be dumped directly into the gulf.

Hundreds of millions of tons of waste has been dumped into the Gulf of the Farallones. Since the 1940's, this has included sediment (sand and mud) dredged from shipping channels, waste from oil refineries and fruit canneries, acids from steel production, surplus munitions and ships from World War II, other unwanted vessels, and barrels of low-level radioactive waste (fig. 1).

Because of navigational errors and inadequate record keeping, the location of most waste dumped in the gulf is poorly known. Between 1946 and 1970 approximately 47,800 containers of low-level radioactive waste were dumped into the gulf south and west of the Farallon Islands. From 1958 to 1969, the U.S. military disposed of chemical and conventional munitions at several sites in the gulf, mostly by scuttling World War II era cargo vessels.

The hulks of ships, possibly dating as far back as the 17th century, litter the sea floor in the gulf. From 1951 to 1987, many vessels were deliberately sunk there. Most of these probably pose little environmental hazard because they were carefully prepared before sinking. One exception may be the highly radioactive World War II aircraft carrier USS *Independence*, exposed in atomic tests at Bikini Atoll in 1946 and sunk by the U.S. Navy in 1951 at an unspecified location off the California coast, possibly in the gulf.

Since at least 1959, some sediment dredged from San Francisco Bay and from the sandbar outside the entrance to the bay (the Golden Gate Bar) has been dumped onto the Continental Shelf in the gulf. Much of this material is from dredging to maintain shipping channels into and within the bay, but some is from other engineering projects.

Until 1970, ocean disposal of both radioactive and nonradioactive waste was acceptable under government policy. That year, the United States terminated all ocean disposal of radioactive waste materials. In 1972, Congress passed the Ocean Dumping Act, which regulates the dumping of wastes into ocean waters. A global ban on the dumping of radioactive waste in the oceans took effect in 1983.

The Environmental Protection Agency (EPA) is currently responsible for designating ocean disposal sites for the United States. The U.S. Army Corps of Engineers (USACE), with EPA's concurrence, issues permits for ocean disposal of dredged material at designated sites. Only sediments evaluated as "clean" (non-toxic) by EPA standards may be disposed of in the marine environment.

San Francisco Bay's 136 km (85 mi) of navigable waterways require annual maintenance dredging. The bay's average depth is about 6 m (19 ft), but oil tankers and container vessels need

from 12 to 18 m (40 to 60 ft) of water for safe transit. Environmental concerns and limited disposal capacity for dredged material in the bay have made it necessary to find suitable dumping sites in the ocean beyond the Golden Gate.

A new approach for the management of dredging and disposal of dredged material for San Francisco Bay was coordinated under a regional effort begun in 1990 as a Federal-State partnership of four agencies and later joined by about 30 other public and private organizations. This effort was formally called the Long Term Management Strategy (LTMS) for the San Francisco Bay region. The primary task of the LTMS was to develop a long-range plan for meeting the bay region's need to dispose of an estimated 230 million m^3 (300 million yds^3) of dredged material over the next 50 years. The EPA, a leading Federal agency in this effort, had the responsibility for selecting a location for an ocean disposal site for dredged material.

In 1990, the U.S. Geological Survey (USGS) was asked by EPA, USACE, and the Navy to investigate four study areas for locating potential disposal sites for dredged material in the Gulf of the Farallones. This survey also tested the feasibility of using sidescan sonar to locate the radioactive-waste containers in the gulf (see chapter on Search for Containers of Radioactive Waste on the Sea Floor).

Each of the four study areas was evaluated by the USGS for the presence of deposition and erosion, sediment transport pathways, and the likely effect deposited dredged material might have on the stability of the sea floor (see earlier chapters).

Using the results of the USGS studies, EPA in 1994 designated the San Francisco Deep-Ocean Disposal Site. This site is 85 km (55 mi) beyond the Golden Gate and 8 km (5 mi) outside of the Gulf of the Farallones National Marine Sanctuary in 2,500 to 3,000 m (8,200 to 9,800 ft) of water.

History of Waste Disposal in the Gulf of the Farallones

Few if any records exist of waste disposal in the Gulf of the Farallones before the mid-1900's, and until recently, records have been poor. Since the 1940's, waste disposed of in the waters of the gulf has included sand and mud dredged from shipping channels, oil refinery waste, waste materials from fruit canneries, waste acids from steel production, surplus munitions from the Second World War, unwanted vessels and parts of dry docks, barrels of low-level radioactive waste, and possibly even a dangerously radioactive warship.

Because of navigational errors and inadequate record keeping, the location and distribution of most waste dumped in the gulf are poorly known. The major known areas where waste dumped are shown in figure 1. Between 1948 and 1971, U.S. Steel Corporation annually discharged approximately 10 million gallons of waste acids in an area about 22 km (13 mi) southwest of the Golden Gate and 14 km (9 mi) offshore in water 40 m (120 ft) deep. Between 1966 and 1972, Standard Oil Company discharged approximately 45 million gallons of refinery waste into the gulf near the Farallon Islands. Unknown quantities of refinery wastes were also discharged into the gulf by Shell Oil until 1971. Waste pulp generated by six East Bay fruit and vegetable canneries were dumped 32 km (20 mi) offshore of San Francisco in water depths of about 80 m (240 ft); from 1961 to 1972 about 22,000 tons were discharged annually.

Between 1946 and 1965 approximately 47,800 containers of low-level radioactive waste were dumped at three sites in an area that was supposed to cover approximately 650 km^2 (250 mi^2) of the gulf; from 1946 to 1959 this was supervised by the U.S. Navy and after 1959 by the

Atomic Energy Commission. From 1958 to 1969, the U.S. Army and Navy disposed of toxic chemical and conventional munitions at several sites in the gulf. In 1958, the Army towed the SS *William Ralston* carrying 3,500 kg (8,000 lb) of mustard bombs and lewisite containers into the Pacific Ocean 190 km (120 mi) west of San Francisco and scuttled it in 6,500 m (21,000 ft) of water. In the 1960's, several World War II era cargo ships carrying obsolete munitions were sunk in the gulf, including the SS *John F. Shafroth,* which was scuttled 30 km (18 mi) west of the Farallon Islands.

The hulks of numerous ships, possibly dating as far back as the 17th century, litter the sea floor in the Gulf of the Farallones. From 1951 to 1987, several damaged or derelict vessels and dry dock sections were disposed of in the gulf. Most of these probably pose little environmental hazard because they were carefully prepared before sinking; however, there are two notable exceptions. In 1951, the Navy sank the highly radioactive World War II aircraft carrier USS *Independence*, which had been exposed in atomic tests at Bikini Atoll in 1946, at an unspecified location off the California Coast, possibly in the gulf. In 1984, the SS *Puerto Rican* carrying nearly 100,000 barrels of oil was severely damaged by an onboard explosion a few miles off the Golden Gate. To minimize environmental impacts, the vessel was towed seaward, where it broke into two sections. The stern section, carrying 8,500 barrels of oil, sank in 450 m (1,500 ft) of water 25 km (15 mi) due south of Southeast Farallon Island, and oil has been reported to continue to slowly leak from the wreck.

Since at least 1959, some sediment dredged from the floor of San Francisco Bay and from the sandbar outside the entrance to the Bay (the Golden Gate Bar) has been dumped on to the Continental Shelf in the Gulf of the Farallones. Much of this material has been from continued dredging work to maintain shipping channels into and within the Bay, but some has come from other engineering projects. During 1966 and 1967, excavation of the Trans-Bay Tube for the Bay Area Rapid Transit System (BART) produced 1,750,000 m^3 (2.3 million yd^3) of dredged material that was dumped at sea a few miles outside the Golden Gate. Other dredged material dumped in the gulf include a relatively small amount of sediment used by USACE in 1974 to test dispersion of material dumped at the edge of the Continental Shelf and material dredged in the late 1970's from Oakland Harbor that was considered too contaminated to be dumped within the Bay. In the late 1980's, EPA and USACE conducted site designation studies to locate an ocean disposal site for dredged material. EPA designated the B1B site (1 on fig. 1), located off Half Moon Bay, as a permanent site for the disposal of dredged material generated from San Francisco Bay dredging projects, including an approved Port of Oakland deepening project. It was used briefly in 1988, but was shut down by court injunction after disposal of only about 13,750 m^3 (18,000 yd^3) of dredged material.

The Need for Dumping Dredged Material in the Gulf

From 1946 to 1970, it was acceptable governmental policy to dispose of both radioactive and nonradioactive waste in the ocean. The U.S. Atomic Energy Commission first issued licenses for the transport and ocean disposal of radioactive wastes in 1959. Before 1959, however, apparently no official agency kept track of radioactive-waste disposal. In 1972, Congress passed the Ocean Dumping Act, which regulated the dumping of wastes into ocean waters; this act was amended in 1977 to specifically address the disposal of sludge and industrial waste. Since 1983, there has been a global ban on the dumping of radioactive waste in the oceans. At present, EPA

has just over 100 designated ocean dumpsites off the coast of the United States, of which approximately 95 percent are used for the disposal of dredged material.

In San Francisco Bay, the largest estuary on the west coast of the United States, the average water depth is about 6 m (19 ft). However, oil tankers and container vessels that transit the bay's waterways need from 12 to 18 m (39–60 ft) of water depth for safe transit. Should deep-draft vessels run aground or rupture their hulls, the end result could be millions of dollars in damage and untold and largely immeasurable environmental damage to the bay's fragile habitats. San Francisco Bay has 136 km (85 mi) of navigable waterways that require annual maintenance dredging.

If San Francisco Bay is to remain economically competitive, navigable waterways have to be regularly maintained. This maintenance requires the dredging and adequate disposal of millions of cubic yards of dredged material. The Port of Oakland alone, San Francisco Bay's largest maritime shipping center and the Nation's fourth largest port, generates more than $5 billion in regional economic activity. USACE estimates that the recent harbor-deepening project (to 12.8-m [42 ft] water depth) for the Port of Oakland's inner harbor will result in an increase of about 2,200 jobs and economic benefits of $135 million. The USACE further estimates that the annual amount of dredged material for the San Francisco Bay system will be about 5.8 million m^3 (7.6 million yd^3) for existing projects. The capacity of bay-region (nonaquatic) dumping sites, such as near Alcatraz Island (fig. 2), has historically been limited, and disposal is expensive.

A new approach for the management of dredging and dredged material for San Francisco Bay was coordinated under the Long-Term Management Strategy (LTMS), a regional effort begun in 1990 as Federal-State partnership of four agencies, later joined by about 30 other government agencies, environmental and fishing organizations, development interests, and ports. Its task was to develop a comprehensive long-range plan for meeting the San Francisco Bay region's dredging and disposal needs over the next 50 years. The plan was designed to be technically feasible, economically prudent, and environmentally acceptable. The LTMS evaluates all potential disposal options including ocean sites, aquatic sites in the bay, and upland sites, such as the beneficial reuse of dredged material for wetlands creation. The intent of the LTMS is to provide a list of disposal options that accommodates the volume and composition of materials proposed. This coordinated effort helps to provide a framework for the San Francisco Bay estuary related to waterway modification, sediment management, and ecosystem protection and enhancement. Dredging projects and disposal of dredged material cannot proceed unless feasible disposal options are clearly defined by the LTMS. The LTMS is charged with planning for the acceptable disposal of about 230 million m^3 (300 million yd^3) of dredged material over the next 50 years.

The primary aspects of dredging and disposal of sediment are controlled by the Marine Protection, Research, and Sanctuaries Act (title I) and the Clean Water Act (sec. 404), both of which require that several alternative methods, including ocean disposal, be evaluated for environmental acceptability. The EPA had the responsibility, under section 102 of the Marine Protection, Research, and Sanctuaries Act, for designating an acceptable location for a San Francisco Deep-Ocean Disposal Site (SF-DODS) for dredged material. The Marine Protection, Research, and Sanctuaries Act 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 industrial wastes. EPA and USACE share responsibility for the management of ocean disposal of dredged material. USACE, with EPA's concurrence, issues permits for ocean disposal of dredged

material that is suitable under the criteria of the Marine Protection, Research, and Sanctuaries Act. EPA and USACE test sediments proposed for ocean disposal for the presence of specific contaminants, bulk toxicity, leachability, and biological availability. Only sediments determined to be "clean" (non-toxic) by EPA standards after following EPA/USACE testing protocols may be disposed of in the marine environment.

Before designating a site for the SF-DODS by final rulemaking, EPA had to prepare and publish an environmental-impact statement (EIS). This site-designation EIS had to be a formal evaluation of Alternative Sites in accordance with the National Environmental Policy Act (NEPA) where the potential environmental impacts associated with the disposal of dredged material were considered. The EIS needed to demonstrate the necessity for the proposed SF-DODS designation and describe the available or potential aquatic or nonaquatic alternatives and the consequences of not designating a site. Investigations had to be instituted to determine (1) the potential effects of suspended dredged material on aquatic organisms, (2) the potential effects of deposits of dredged material covering or burying benthic organisms on the sea floor, and (3) other sediment-related impacts on organisms elsewhere in the marine food chain. The site with the least potential for adverse environmental effects would then be selected as the preferred alternative site for formal designation. The designation process would be accomplished through the application of rules published in the *Federal Register*.

U.S. Geological Survey Multiple-Agency Cooperative Cruises

The U.S. Geological Survey (USGS) was asked by EPA, USACE, and U.S. Navy (USN) to conduct research to aid them in their task of managing the disposal of dredged material from San Francisco Bay. In response, the USGS undertook a survey of the Continental Shelf and Slope in the Gulf of the Farallones. An additional goal of the survey was to provide the Gulf of the Farallones National Marine Sanctuary (GFNMS), a part of the National Oceanic and Atmospheric Administration (NOAA), with information on the detection and mapping of the low-level radioactive-waste barrels in the gulf (see chapter on Search for Containers of Radioactive Waste on the Sea Floor).

In the summer of 1990, the USGS conducted a preliminary reconnaissance survey of a study area on the Continental Slope in the gulf for EPA and USACE. The survey covered a region of about 3,400 km^2 (1,000 square nautical miles) and ranging in water depth from 200 to 3,200 m (660–10,500 ft). Included within this region were four EPA Study Areas (fig. 1) to be considered for the potential disposal of dredged material from San Francisco Bay. The USGS collected images and profiles of the sea floor, underwater video and photographs, and sediment samples. In addition, the USGS and cooperating agencies conducted a study of the physical oceanography of the slope (see chapter on Current Patterns Over the Continental Shelf and Slope).

The purpose of this reconnaissance survey was to develop a database that would allow USGS scientists to provide EPA and USACE policymakers with credible scientific information about the physical characteristics of the Continental Slope in the gulf before the emplacement of dredged material and to predict how the slope might respond to the addition of dredged material. This database would provide background information for the EIS to designate a disposal site and potential alternative sites in the study area.

Before the USGS reconnaissance survey, the EPA had designated five offshore Study Areas (fig. 1) where a potential site could be located. Upon completion of the USGS survey, the EPA

retained three of these Study Areas to locate potential disposal sites; all of these EPA Study Areas were located on the Continental Slope. The data and interpretations derived from the USGS survey were used to design subsequent investigations involving detailed sediment sampling and oceanographic and biologic studies in site-specific areas. USGS analyses and interpretations focused on indications of sediment transport, delineating environments where sediment accumulated or was eroded, and delineating sediment mass movement and slope stability within EPA Study Areas 3, 4, and 5.

Investigations of Chemical Munitions Dumpsite Within EPA Study Area 5

The USN approached the USGS in 1990, requesting a survey (sidescan-sonar and shallow seismic-reflection profiling) of the former Chemical Munitions Dumpsite (Naval Ocean Dump Site) offshore from San Francisco at 2,400- to 3,000-m (7,870–9,840 ft) water depth. This dumpsite was within the boundaries of EPA Study Area 5 (fig. 1). The eastern part of this Study Area is also within the Farallon Islands Radioactive Waste Dump (FIRWD) (fig. 1) and includes a dumpsite at 1,800-m (5,900 ft) water depth used for the disposal of low-level radioactive waste from 1946 to 1970. The USGS survey was undertaken to enable the USN to complete its project-specific EIS for the EPA. The USN was seeking a temporary special-use permit under the Marine Protection, Research, and Sanctuaries Act (Section 103) to dispose of 1.2 million m^3 (1.6 million yd^3) of sediment dredged from naval facilities in San Francisco Bay.

As part of the multiple-agency cooperative cruises conducted in 1990, the USGS collected images of the sea floor and profiles of the sea-floor topography within and adjacent to the former Chemical Munitions Dumpsite on the Continental Slope in the gulf. Images and profiles show that most of EPA Study Area 5 is composed of rugged topography, including a large submarine canyon that dissects the central part of the area. A thin layer of mud blankets the floor of this submarine canyon. A field of large bedforms (mud waves) detected in the westernmost part of the submarine canyon suggests that a strong current flows downcanyon, at least on an episodic basis, and molds or reforms these large sea-floor features. The rugged topography of the study area is characterized by numerous small submarine canyons and gullies separated by intervening ridges. Thin veneers of sediment drape some of the sea floor, and other areas show bedrock exposed at the sea floor. Little evidence of sediment mass movement was observed in the study area (fig. 3).

Survey of EPA Study Areas 3 and 4

EPA Study Area 3 is located on the north flank of Pioneer Canyon (fig. 4), where relatively soft sediment ranges in thickness from 5 to 30 m (16–98 ft). Locally, sediment appears to be absent, and bedrock crops out at the sea floor. Evidence for sediment mass movement is minimal, mainly occurring on the steep north wall of the canyon and on the walls of small gullies. Laboratory analysis of relatively soft sediment obtained from gravity cores within the Study Area suggests that the uppermost 3 m (10 ft) of sediment is stable under normal sea-floor conditions. Under conditions of seismic loading (such as when a strong earthquake occurs), the uppermost 3 m of sediment becomes marginally stable and may potentially slide downslope. Photographs of the sea floor reveal that it is molded into ripples at a water depth of 700 to 720 m (2,300–2,360 ft), indicating that currents strong enough to transport fine sand do occur, at least episodically, over part of the study area. Most of the rest of the sea floor in Study Area 3 is largely featureless.

EPA Study Area 4 is located along the south flank of Pioneer Canyon (fig. 5), where relatively soft sediment occurs sporadically and is generally thin to absent. The northeasternmost and southern parts of this study area are characterized by extensive outcrops of bedrock, as shown by acoustic imagery and sea-floor photographs. The characteristic morphology is of a gently sloping plain with gullies along the south wall of the canyon. Evidence for sediment mass movement is minimal. Photographs of the sea floor show that it is largely featureless, except where bedrock occurs. Both sedimentary and volcanic rocks were observed on the sea floor in underwater photographs.

Conclusion

The USGS reconnaissance survey of the Continental Slope in the Gulf of the Farallones shows that some areas of the slope are covered by a thin veneer of relatively soft sediment and other areas have bedrock exposed along the sea floor. Some parts of the slope indicate a depositional environment with a slow rate of sedimentation, and other parts either show little or no signs of sediment accumulation or indicate erosion. Additionally, an object that may be the USS *Independence* was discovered on sonar images of the sea floor (fig. 6).

Ideally, the SF-DODS needed to be characterized by slow deposition or nondeposition and by very little or no sediment mass movement. Evidence for sediment mass movement in the EPA Study Areas is minimal, largely restricted to the steeper slopes that border submarine canyons and gullies. Laboratory analyses of sediment in gravity cores indicate that the upper 3 m (10 ft) of relatively soft sediment is stable under normal conditions and becomes marginally stable under conditions of seismic loading, such as during a fairly large earthquake.

The results of the USGS survey were used by the EPA and USACE in preparing the EIS for potential disposal sites for dredged material in the Gulf of the Farallones, which was released in 1993. The USN also used USGS data in their EIS for a special-use permit to dispose of dredged material at the former Chemical Munitions Dumpsite. Using the results of the USGS studies, EPA tentatively selected their a site within Study Area 5 as the preferred alternative for the SF-DODS in the final EIS. In 1994, EPA formally designated the SF-DODS within this area, 88 km (55 mi) beyond the Golden Gate and 8 km (5 mi) outside of the Gulf of the Farallones National Marine Sanctuary in 2,500 to 3,000 m (8,200–9,800 ft) of water. The scientific information collected by the USGS and its cooperators in the Gulf of the Farallones also allows policymakers to make informed decisions regarding the use and preservation of the marine environment in the gulf, both now and in the future.

Further Reading

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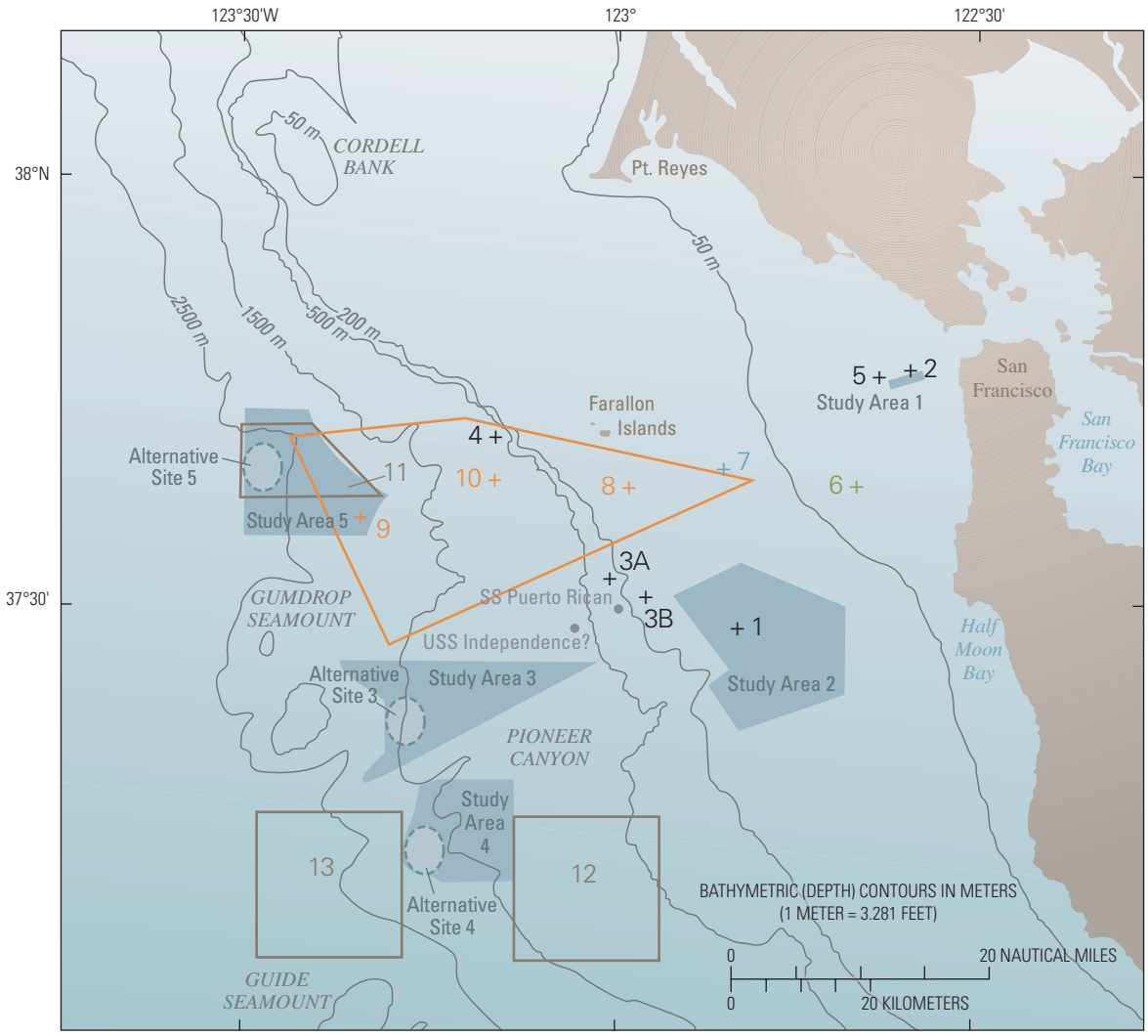


SITES OF HISTORICAL WASTE DISPOSAL

1 +	B1B dredged material disposal site
2 +	BART dredged material disposal site
3A +	100-Fathom dredged material disposal site original location (1975-78)
3B +	100-Fathom site repositioned location
4 +	USACE experimental dredged material disposal site
5 +	Channel Bar ocean dredged material disposal site
6 +	Acid waste disposal site
7 +	Cannery waste disposal site
8 +	Radioactive waste site A
9 +	Radioactive waste site B
10 +	Radioactive waste site C
——	Farallon Islands Radioactive Waste Dump (FIRWD)
11	Chemical munitions dumping area
12	Disused explosives site #1
13	Disused explosives site #2

Figure 1. Map of the Gulf of the Farallones, showing sites of historical waste disposal, as well as locations of U.S. Environmental Protection Agency (EPA) Study Areas (shaded) and Alternative Sites (dotted outlines). Study Areas 2 through 5 and Alternative Sites 3 through 5 were investigated by the U.S. Geological Survey (USGS) for possible designation by the EPA as disposal sites for dredged material. After the USGS reconnaissance survey, Study Areas 3, 4, and 5 on the Continental Slope were retained, and Study Areas 1 and 2 on the Continental Shelf were eliminated from further consideration. In 1994, the EPA designated Alternative Site 5 as the San Francisco Deep-Ocean Disposal Site.

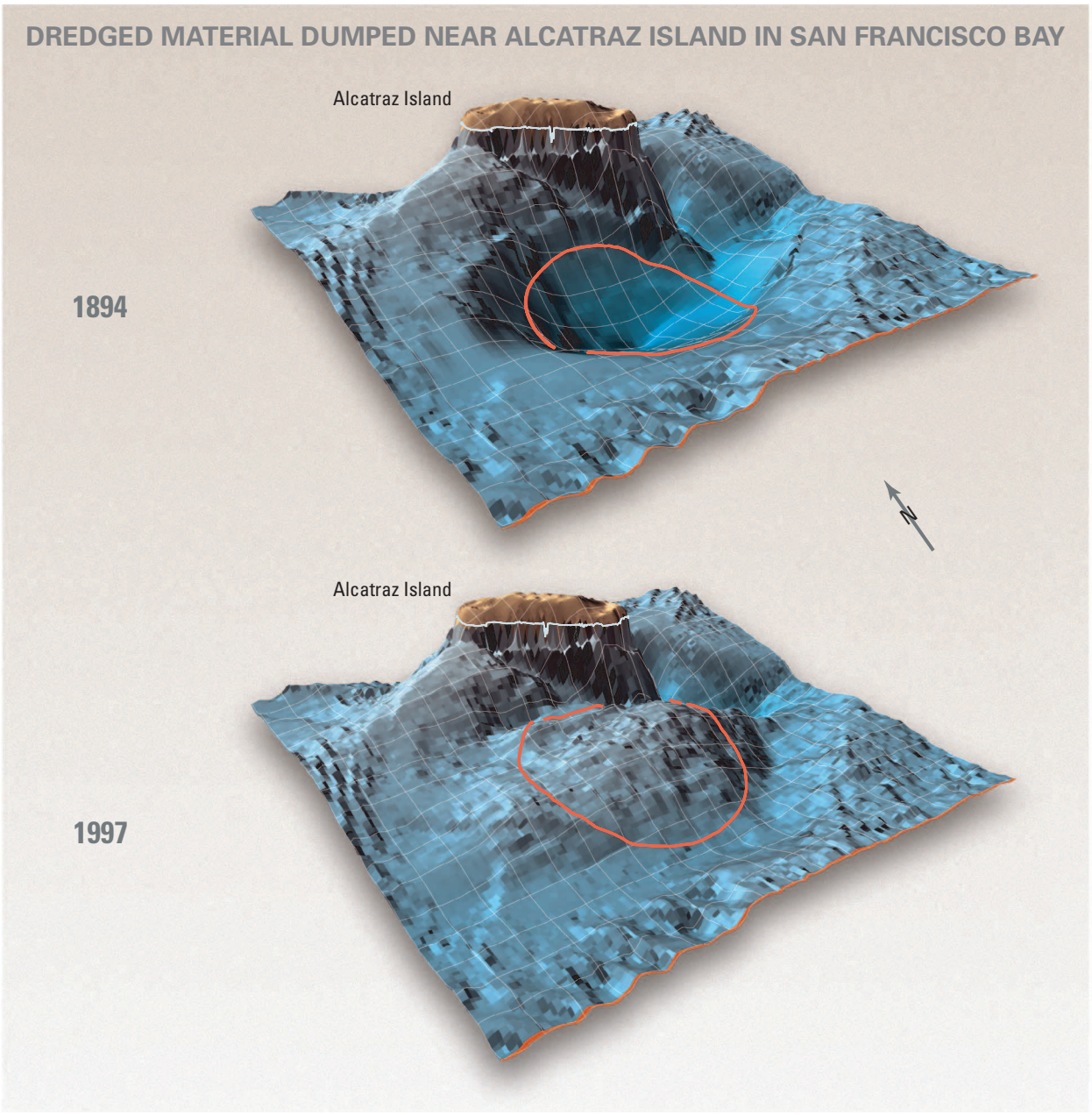


Figure 2. Historically, much of the sediment dredged from the San Francisco Bay to maintain shipping channels has been disposed of in the bay itself, particularly in its deeper parts, such as near Alcatraz Island. These computer generated images of the bay floor south of Alcatraz Island show the effects of dumping more than 6 million m^3 (8 million yds^3) of dredged material between 1894 and the mid-1980's in the area outlined in the red circles. The images were created by the U.S. Geological Survey using historical bathymetric data and recent multibeam (acoustic) mapping

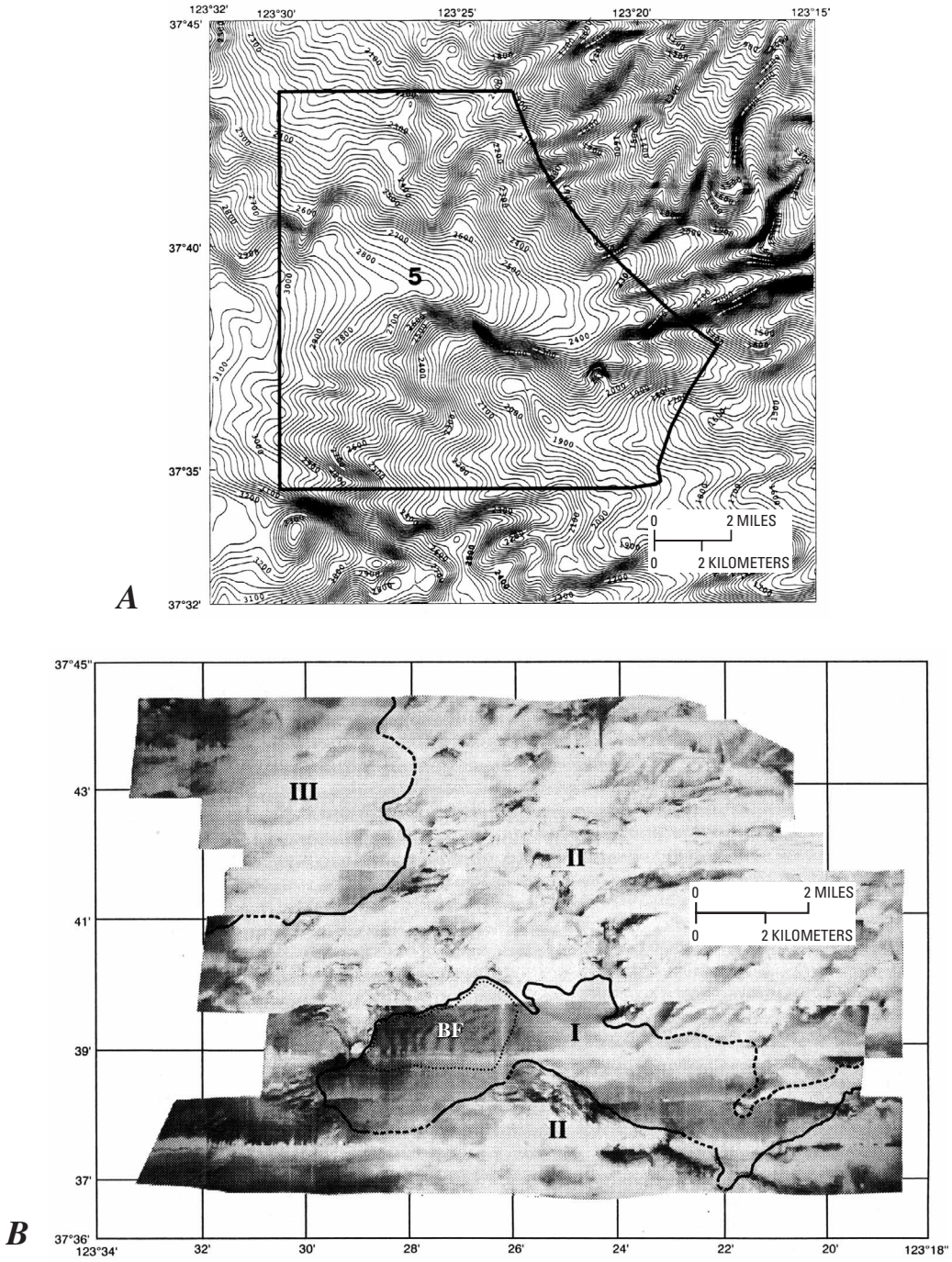


Figure 3. Undersea topography in U.S. Environmental Protection Agency Study Area 5 (see fig. 1). Bathymetric contours (*A*; contour interval, 20 m) that are closely spaced and wavy over most of Study Area 5 indicate rugged sea floor and many submarine canyons and gullies with intervening ridges, as confirmed by sonar image (*B*), which shows light tones with numerous irregular dark-toned patterns. Former Chemical Munitions Dumpsite is in northern part of Study Area 5 (see fig. 1). Area of V-shaped contours that surround "5" in *A* is same area (submarine canyon) in *B* that is marked by "I" and "BF". Light-toned areas are floors and slopes of canyons and gullies, whereas dark-toned areas are intervening ridges. Sediment cover is patchy and irregular, and many ridges are not covered by soft sediment. Area labeled "BF" is a field of large bedforms (mud waves) that rest on floor of submarine canyon to west of area labeled "I". These bedforms are shown by wavy alternating light-and-dark pattern within a dotted line that indicates their extent.

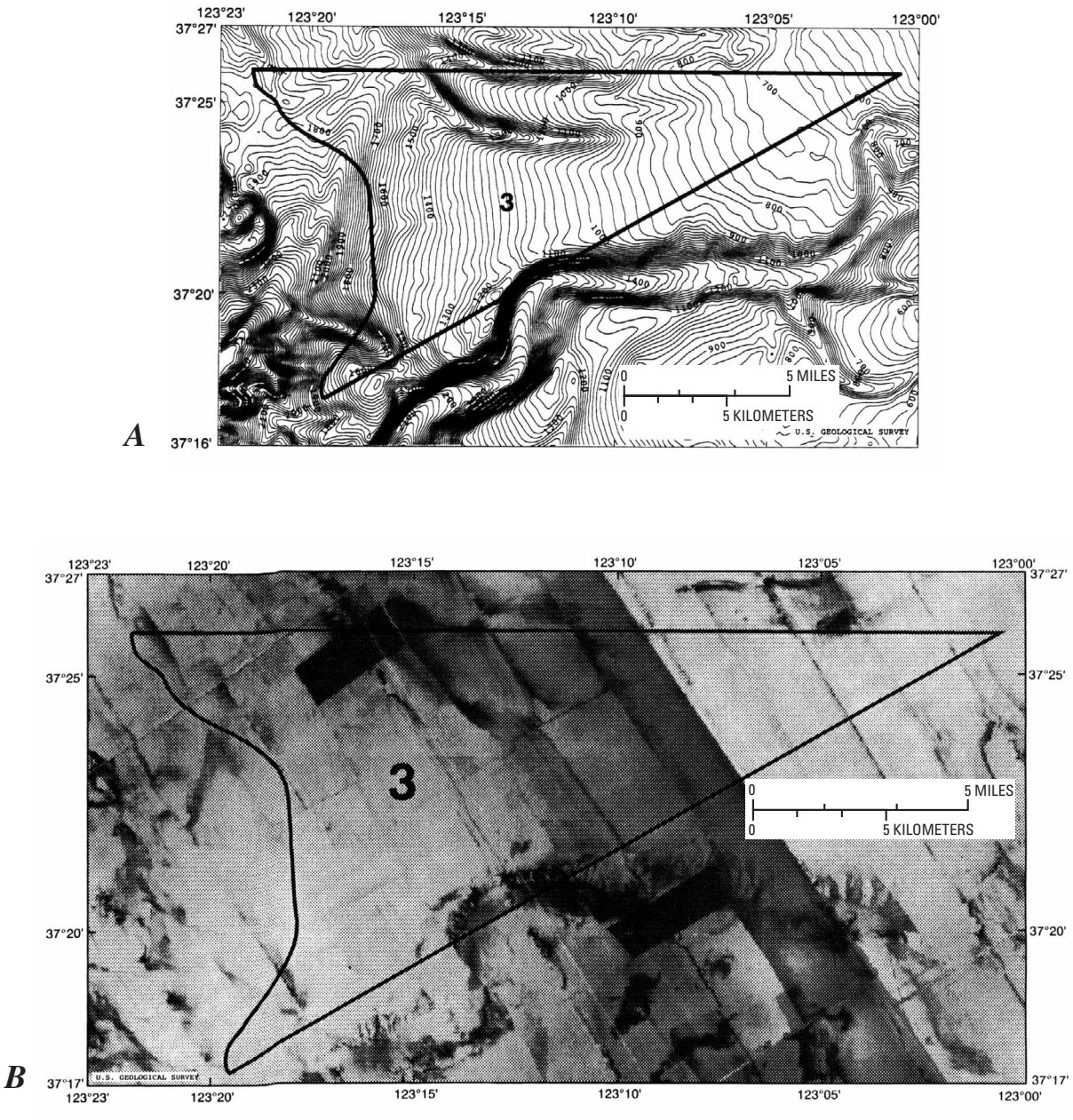


Figure 4. Undersea topography in U.S. Environmental Protection Agency Study Area 3 (see fig. 1), showing bathymetric contours (*A*; contour interval, 20 m) and sidescan-sonar mosaic (*B*). Fairly uniform light tone over most of study area indicates relatively uniform cover of fine sediment and smoothly sloping sea floor. Winding dark pattern near south boundary of study area is Pioneer Canyon. South of study area, dark patches are outcrops of volcanic bedrock within study area 4.

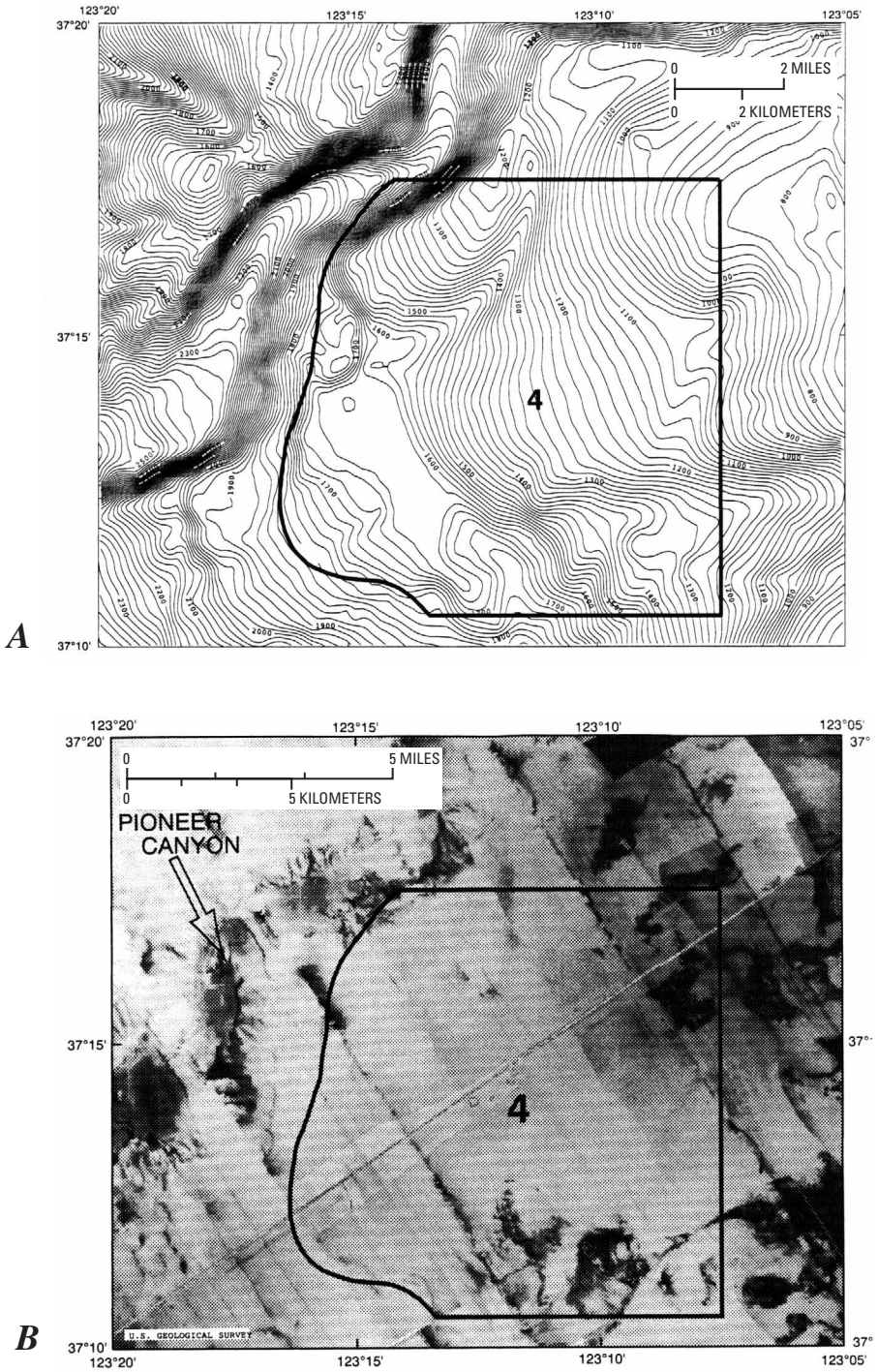
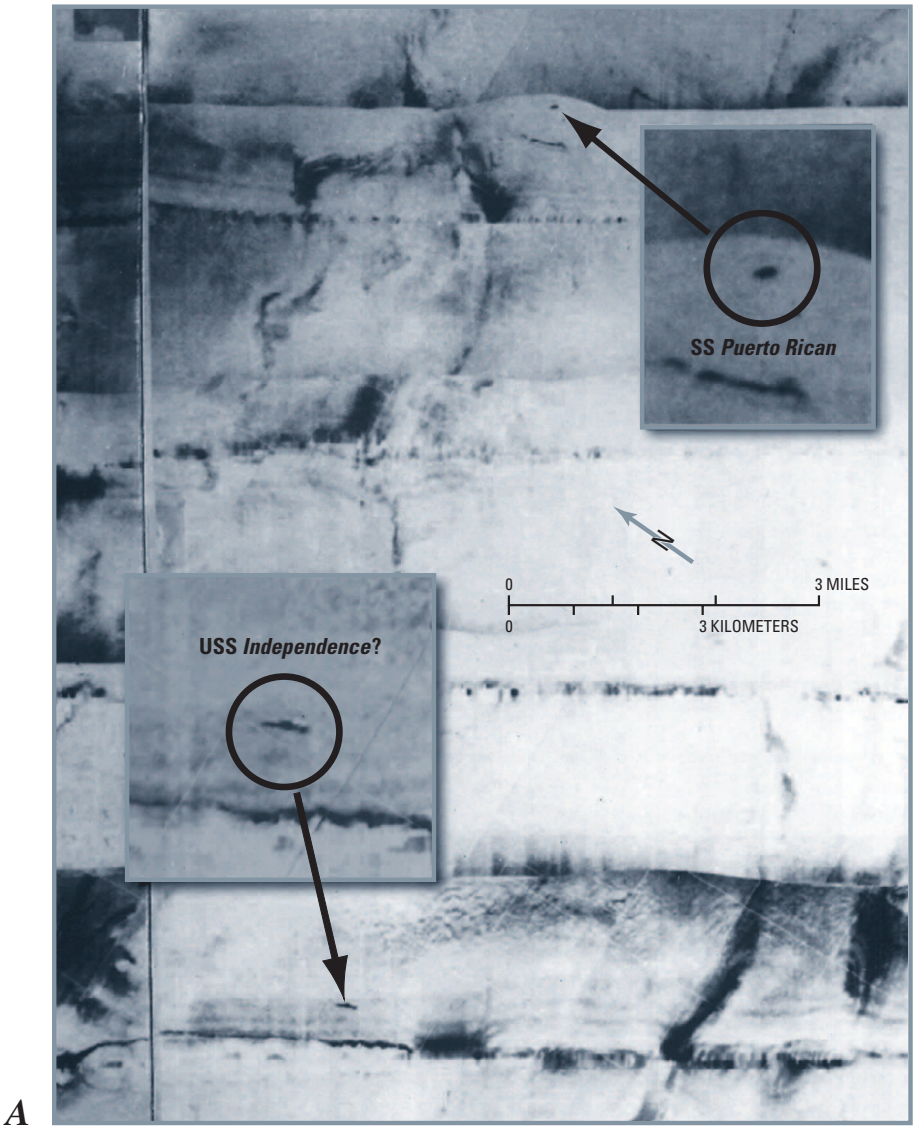
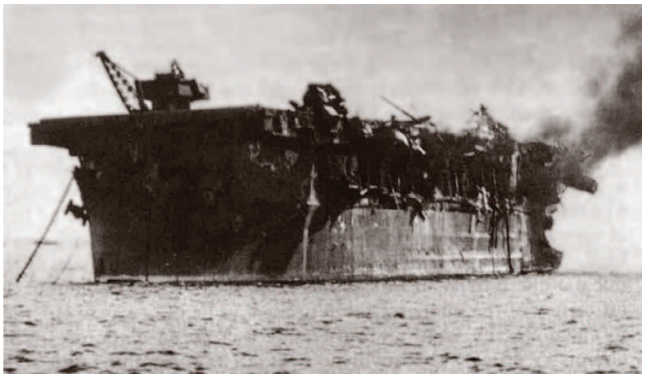


Figure 5. Undersea topography in U.S. Environmental Protection Agency Study Area 4 (see fig. 1), showing bathymetric contours (*A*; contour interval, 20 m) and sidescan-sonar mosaic (*B*). Fairly smooth slope of sea floor is indicated by fairly evenly spaced contours. Two areas where contours form V-shaped patterns are where small submarine canyons or gullies interrupt slope. South boundary of Pioneer Canyon is along northwest boundary of study area. At approximately 1,600-m (5,250 ft) water depth, slope of sea floor flattens out suddenly and forms a flat bench, at 1,600- to 1,700-m (5,250 to 5,580 ft) water depth, that may indicate a submarine-slide deposit originating from slope between two small gullies which bisect study area. Fairly light tones on sidescan-sonar mosaic that dominate study area suggest relatively uniform sediment cover and smooth topography. Dark irregular patches in upper right corner and along lower boundary are outcrops of volcanic rocks that protrude above sea floor with little or no sediment cover.



A

B



C

Figure 6. *A*, Detail of a U.S. Geological Survey sidescan-sonar mosaic from an area of the upper Continental Slope about 32 km (20 mi) southwest of the Farallon Islands. On this image was discovered what is interpreted to be the USS *Independence* (CVL 22), a dangerously radioactive aircraft carrier scuttled in 1951. Also visible is the stern section of the SS *Puerto Rican*, an oil tanker that sank in 1984. U.S. Navy photos show the USS *Independence* while in service (*B*) and after being exposed to atomic tests at Bikini Atoll in 1946 (*C*).