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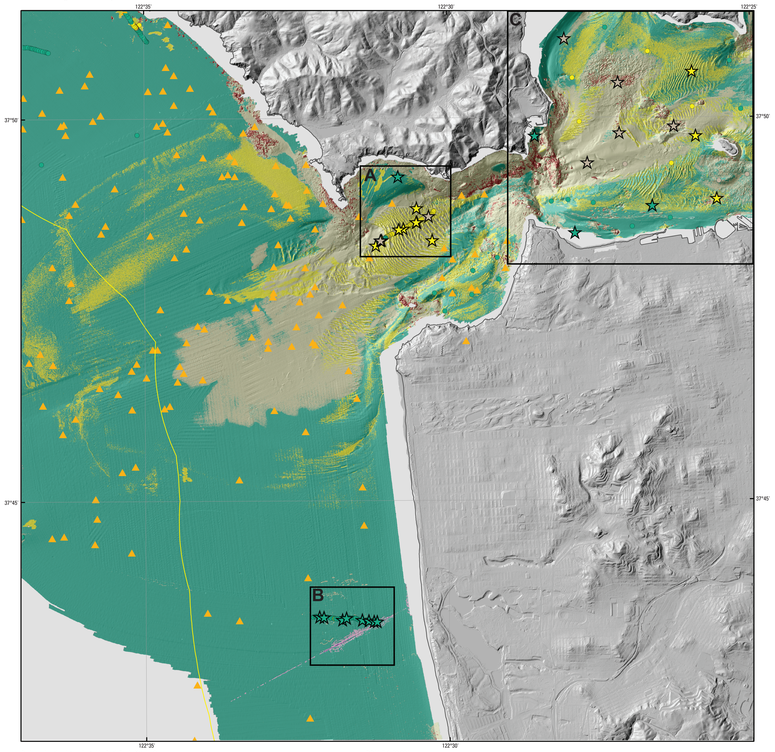
U.S. Department of the Interior
U.S. Geological Survey

Open-File Report 2015–1068
Sheet 6 of 10
Pamphlet accompanies map



Onshore elevation data collected by Earth Eye in 2010 for San Francisco State University and the U.S. Geological Survey, California's State Waters limit from NOAA Office of Coast Survey

Universal Transverse Mercator projection, Zone 10N

NOT INTENDED FOR NAVIGATIONAL USE

APPROXIMATE MEAN DECLINATION, 2015

SCALE 1:50 000

2 0 2 MILES
7000 3500 0 7000 FEET
1 0.5 0 1 KILOMETER
HEIGHT, HEIGHT
ONE MILE = 0.869 NAUTICAL MILES

MAP LOCATION

Seafloor-character map simplified from map on sheet 5, this report. Video observations recorded and digital still photographs taken in 2007-2008. Sample localities from usSEABED (Reid and others, 2006)

GIS database and digital cartography by Nadine E. Golden and Elryse L. Phillips

Manuscript approved for publication April 7, 2015

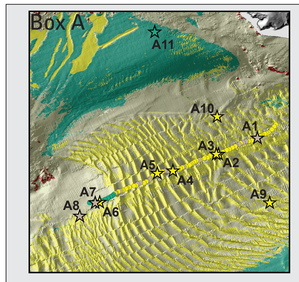


Figure 1A. Detailed view of seafloor character mapped in the Golden Gate channel of San Francisco Bay (see Box A, on map, for location), showing locations of periodic real-time video observations (dots) and digital still photographs (stars; see figs. 1B through 1H) from camera line CAM27, cruise F–3–07–NC, and locations of photographs and sediment samples collected on cruise S–8–10–SF, (stars; see figs. 1I through 1L).

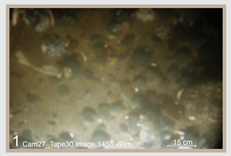


Figure 1B. Digital still photograph no. A1 (see fig. 1A for location). Mixed gravel, cobbles, and sand with scattered shell (water depth, 60 m). Abiotic complexity is moderate, biotic complexity is absent, and biocover is low. Distance between lasers (red dots are just out of view in this image but are visible in previous video frame) is 15 cm.

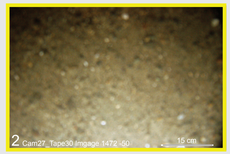


Figure 1C. Digital still photograph no. A2 (see fig. 1A for location). Unconsolidated, medium- to coarse-grained sand with gravel and shell hash (water depth, 50 m) characterize the flank and trough of a megaripple in a scour depression. Abiotic complexity is low, biotic complexity is absent, and biocover is low. Distance between lasers (red dots are just out of view in this image but are visible in previous video frame) is 15 cm.

Figure 1D. Digital still photograph no. A3 (see fig. 1A for location). Unconsolidated, medium- to coarse-grained sand with gravel and shell hash (water depth, 53 m) characterize the flank and trough of a megaripple in a scour depression. Abiotic complexity is low, biotic complexity is absent, and biocover is low. Distance between lasers (red dots) is 15 cm.

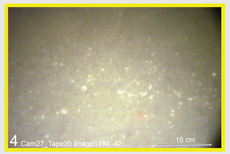


Figure 1E. Digital still photograph no. A4 (see fig. 1A for location). Unconsolidated, medium- to coarse-grained sand with gravel and shell hash (water depth, 42 m) characterize the flank and trough of a megaripple in a scour depression. Abiotic complexity is low, biotic complexity is absent, and biocover is low. Distance between lasers (red dots) is 15 cm.

Figure 1F. Digital still photograph no. A5 (see fig. 1A for location). Unconsolidated, medium- to coarse-grained sand with gravel and shell hash (water depth, 42 m) characterize the flank and trough of a megaripple in a scour depression. Abiotic complexity is low, biotic complexity is absent, and biocover is low. Distance between lasers (red dots) is 15 cm.

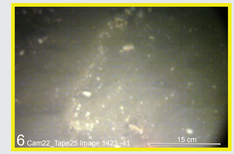


Figure 1G. Digital still photograph no. A6 (see fig. 1A for location). Sand and gravel with shell debris (water depth, 41 m) characterize the flank and trough of a megaripple in a scour depression. Abiotic complexity is low, biotic complexity is absent, and biocover is low. Distance between lasers (red dots) is 15 cm.

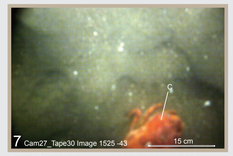


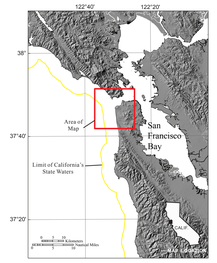
Figure 1H. Digital still photograph no. A7 (see fig. 1A for location). Mixed cobbles and boulders with scattered shell (water depth, 43 m). Abiotic complexity is moderate, biotic complexity is absent, and biocover is high. Biocover includes cancer crab (c). Distance between lasers (red dots are just out of view in this image but are visible in previous video frame) is 15 cm.

Figure 1I. Digital still photograph no. A8 (see fig. 1A for location). Sediment sample GGP03. Mixed gravel, cobbles, and sand with scattered shell (water depth, 16 m). Scale determined from size of sediment-sampling trough.

Figure 1J. Digital still photograph no. A9 (see fig. 1A for location). Sediment sample GGP11. Mixed gravel, cobbles, and sand with scattered shell (water depth, 54 m). Scale determined from size of sediment-sampling trough.

Figure 1K. Digital still photograph no. A10 (see fig. 1A for location). Sediment sample GGP10. Unconsolidated, coarse sand with gravel and shell hash (water depth, 44 m) characterize the flank and trough of a megaripple in a scour depression. Scale determined from size of sediment-sampling trough.

Figure 1L. Digital still photograph no. A11 (see fig. 1A for location). Sediment sample GGP09. Fine sand (water depth, 16 m). Scale determined from size of sediment-sampling trough.



EXPLANATION

Substrate class

- **Fine- to medium-grained smooth sediment**—Low backscatter, low rugosity; typically mud to medium-grained sand; often rippled and (or) burrowed
- **Mixed smooth sediment and rock**—Moderate to very high backscatter, low rugosity; typically coarse-grained sand, gravel, cobbles, and bedrock
- **Rock and boulder, rugose**—High backscatter, high rugosity; typically boulders and rugose bedrock
- **Medium to coarse grained sediment**—Very high backscatter, low rugosity; typically medium- to coarse-grained sediment, with varying amounts of shell hash; in scour depressions
- **Smooth, hard anthropogenic material**—High backscatter, low rugosity; related to development by humans
- **Rugged anthropogenic material**—High backscatter, high rugosity; related to development by humans

Location of real-time video observation and interpreted substrate class of seafloor

- **Fine- to medium-grained smooth sediment**—Low backscatter, low rugosity; typically mud to medium-grained sand; often rippled and (or) burrowed
- **Mixed smooth sediment and rock**—Moderate to very high backscatter, low rugosity; typically coarse-grained sand, gravel, cobbles, and bedrock
- **Rock and boulder, rugose**—High backscatter, high rugosity; typically boulders and rugose bedrock
- **Medium to coarse grained sediment**—Very high backscatter, low rugosity; typically medium- to coarse-grained sediment, with varying amounts of shell hash; in scour depressions

Location of digital still photograph and interpreted substrate class of seafloor

- **Fine- to medium-grained smooth sediment**—Low backscatter, low rugosity; typically mud to medium-grained sand; often rippled and (or) burrowed
- **Mixed smooth sediment and rock**—Moderate to very high backscatter, low rugosity; typically coarse-grained sand, gravel, cobbles, and bedrock
- **Rock and boulder, rugose**—High backscatter, high rugosity; typically boulders and rugose bedrock
- **Medium to coarse grained sediment**—Very high backscatter, low rugosity; typically medium- to coarse-grained sediment, with varying amounts of shell hash; in scour depressions

Interpreted substrate class depicted in digital still photograph—Indicated by colored frame around photograph (not shown on map; shown in figures only)

- **Fine- to medium-grained smooth sediment**—Low backscatter, low rugosity; typically mud to medium-grained sand; often rippled and (or) burrowed
- **Mixed smooth sediment and rock**—Moderate to very high backscatter, low rugosity; typically coarse-grained sand, gravel, cobbles, and bedrock
- **Rock and boulder, rugose**—High backscatter, high rugosity; typically boulders and rugose bedrock
- **Medium to coarse grained sediment**—Very high backscatter, low rugosity; typically medium- to coarse-grained sediment, with varying amounts of shell hash; in scour depressions

- **Sample localities From usSEABED (Reid and others, 2006)**
- **Area of "no data"**—Areas near shoreline not mapped owing to insufficient high-resolution seafloor mapping data; areas beyond 3-nautical-mile limit of California's State Waters were not mapped as part of California Seafloor Mapping Program
- **3-nautical-mile limit of California's State Waters**

DISCUSSION

Between 2006 and 2007, the seafloor in the Offshore of San Francisco map area in northern California was mapped by Fugro Pelagos, and California State University, Monterey Bay (CSUMB), using both multibeam echosounders and high-resolution seafloor sonar units (see sheets 1, 2, 3). These mapping missions combined to collect bathymetry and acoustic-backscatter data from about the 10-m isobath to out beyond the 3-nautical-mile limit of California's State Waters. In order to characterize the bathymetry and acoustic-backscatter data into geologically and biologically useful information, the USGS ground-truth-surveyed the data by towing a camera sled (fig. 4) over specific locations throughout the map area.

During the ground-truth-survey cruise, the camera sled was towed 1 to 2 m above the seafloor, at speeds of between 1 and 2 nautical miles/hour. The sled housed two standard-definition (640×480 pixel resolution) video cameras (one forward looking, the other downward looking), a high-definition (1,080×1,920 pixel resolution) video camera, and an 8-megapixel digital still camera, which captured a digital still photograph once every 30 seconds. The video was relayed in real time to the research vessel, where USGS and National Oceanic and Atmospheric Administration (NOAA) scientists recorded both the geologic and biologic character of the seafloor once every minute, using program-mable keypads. The location and directions of the camera-sled tracklines were chosen in order to visually inspect areas thought to represent the full range of bottom hardness and rugosity in the map area.

In the context of marine-fisheries management, benthic-habitat complexity can be divided into abiotic (geologic) and biotic (biologic) components. Benthic-habitat complexity refers to the visual classification of local abiotic and biotic vertical relief and structure that may provide potential refuge for both juvenile and adult forms of various species. Only abiotic attributes (primary- and secondary-substrate composition) were used in the production of the seafloor-character map on sheet 5. Classifications of primary and secondary substrate are based on the Wentworth (1922) scale of sediment grain-size categories, and the sand, cobble, and boulder sizes are classified as in Went-worth (1922). However, the difficulty in distinguishing the finest divisions in the Went-worth (1922) scale during video observations made it necessary to aggregate some grain-size classes: the granule and pebble sizes have been grouped together into a class called "gravel," and the clay and silt sizes have been grouped into a class called "mud." In addition, hard bottom and clasts larger than boulder size are classified as "rock." Primary and secondary substrate, by definition, constitute greater than 50 and 20 percent of the seafloor during an observation, respectively.

This sheet contains a smaller, simplified (depth-zone symbology has been removed) version of the seafloor-character map (sheet 5), on which the camera-sled tracklines used to ground-truth-survey the sonar data are indicated by aligned colored dots, each dot representing the location of a recorded observation. Primary- and secondary-substrate compositions are shown by differently colored dots. The map also shows the locations of the detailed views of seafloor character along some of the tracklines (Boxes A through C) that are highlighted on this sheet (figs. 1A, 2A, 3A). Also shown are locations of samples (triangles) from usSEABED (Reid and others, 2006) that were used to supplement the ground-truth surveys.

The seafloor-character map shows that the San Francisco offshore region is dom-inated by primarily sandy sediment (for example, figs 2B through 2I) that is characterized by sharp-crested oscillatory ripple patterns (typical wavelengths of 5 to 15 cm). The sandy shelf region is typified by low abiotic complexity, low biotic complexity, and low percentage of biocover.

Some rocky outcrops and areas of moderate to poorly sorted coarse sand and gravel are located along the north half of the map area and throughout the Golden Gate. These mobile sedimentary features are found at all water depths and are both adjacent to rocky areas and distant from rocky areas. Moderate to poorly sorted coarse sand and gravel located in these areas typically form shallow depressions relative to the adjacent sandy sea floor. Many of these depressions are characterized by large ripples and megaripples composed of coarse sand, fine gravel, and scattered shell (see, for example, figs. 2C through 2G, 1D, 1F, and 1G). These features provide low abiotic complexity, low biotic complexity, and are characterized by low percent biocover.

Each detailed view (figs. 1A, 2A, 3A) shows the locations of camera-sled tracklines (aligned colored dots), as well as of the photographs (colored stars) taken along the tracklines. These photographs, which are representative of the seafloor, are displayed with a description of the observed seafloor characteristics recorded by USGS and NOAA scientists (figs. 1B through 1L, 2B through 2I, 3B through 3L). Only primary and secondary substrates are reported, although individual photographs may show more substrate types. Organisms, when present, are labeled on the photographs.

Ground-truth surveys in the Offshore of San Francisco map area include approxi-mately 6 trackline kilometers of video, 214 still photographs, and 27 sediment samples, in addition to 118 seafloor observations of abiotic and biotic attributes. A visual estimate of slope was also recorded.

GLOSSARY

Rugosity—A GIS-derived characterization of seafloor roughness, calculated as the ratio of the three-dimensional surface area of seafloor to the two-dimensional planar-base area, for each cell in the bathymetry grid.

Backscatter intensity—The amplitude of the reflected sonar signal (see sheet 3) used to infer the hardness of the bottom, determined after sonar-data processing has removed (as much as possible) the effects of water depth, angle of reflection, and bottom rough-ness.

Biocomplexity—The assessment of the presence or absence of biological structures that have the potential of providing shelter for fauna, determined by estimating the scale, the amount, and the morphology of biological relief (as described by Tissot and others, 2006).

Biocover—The visual estimate of the proportion of biogic cover by encrusting organisms: high, greater than 50%; moderate, between 50% and 10%; low, less than 10%.

REFERENCES CITED

Reid, J.A., Reid, J.M., Jenkins, C.J., Zimmerman, M., Williams, S.J., and Field, M.E., 2006, usSEABED—Pacific Coast (California, Oregon, Washington) offshore surficial-sediment data release: U.S. Geological Survey Data Series 182, available at http://pubs.usgs.gov/ds/2006/182/.

Tissot, B.N., Yoklavich, M.M., Love, M.S., York, K., and Amend, M., 2006, Benthic invertebrates that form habitat on deep banks off southern California, with special reference to deep sea coral: Fishery Bulletin, v. 104, p. 167–181.

Wentworth, C.K., 1922, A scale of grade and class terms for clastic sediments: Journal of Geology, v. 30, p. 377–392.

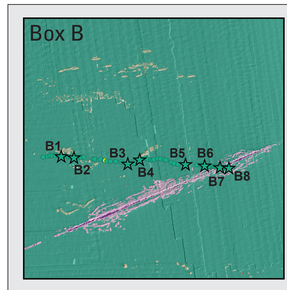


Figure 2A. Detailed view of seafloor character mapped approximately 4.5 km offshore (see Box B, on map, for location), showing the locations of periodic real-time video observations (dots) and digital still photographs (stars; see figs. 2B through 2I) from camera line CAM28, cruise F–3–07–NC.

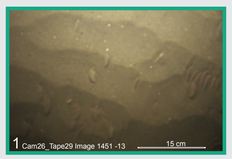


Figure 2B. Digital still photograph no. B1 (see fig. 2A for location). Fine- to medium-grained sand with sharp-crested oscillatory ripple pattern and varying amounts of scattered shells (water depth, 13 m). Abiotic complexity is low, biotic complexity is absent, and biocover is low. Distance between lasers (red dots are just out of view in this image but are visible in previous video frame) is 15 cm.

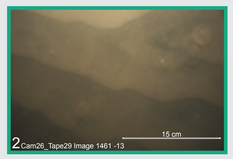


Figure 2C. Digital still photograph no. B2 (see fig. 2A for location). Fine- to medium-grained sand with sharp-crested oscillatory ripple pattern (water depth, 13 m). Abiotic complexity is low, biotic complexity is absent, and biocover is low. Visibility is poor. Distance between lasers (red dots are just out of view in this image but are visible in previous video frame) is 15 cm.

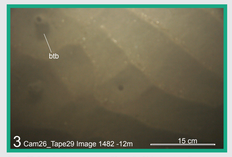


Figure 2D. Digital still photograph no. B3 (see fig. 2A for location). Fine- to medium-grained sand with sharp-crested oscillatory ripple pattern (water depth, 12 m). Biocover includes bioturbation (btb). Distance between lasers (red dots are just out of view in this image but are visible in previous video frame) is 15 cm.

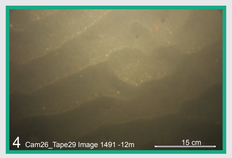


Figure 2E. Digital still photograph no. B4 (see fig. 2A for location). Fine- to medium-grained sand with sharp-crested symmetrical bifurcating ripple pattern and varying amounts of scattered shell debris (water depth, 12 m). Abiotic complexity is low, biotic complexity is absent, and biocover is low. Distance between lasers (red dots) is 15 cm.

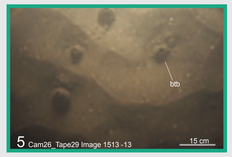


Figure 2F. Digital still photograph no. B5 (see fig. 2A for location). Fine- to medium-grained sand with sharp-crested oscillatory ripple pattern (water depth, 13 m). Biocover includes bioturbation (bt). Distance between lasers (red dots are just out of view in this image but are visible in previous video frame) is 15 cm.

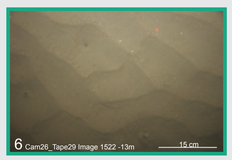


Figure 2G. Digital still photograph no. B6 (see fig. 2A for location). Fine- to medium-grained sand in a confused ripple pattern (water depth, 13 m). Abiotic complexity is low, biotic complexity is absent, and biocover is low. Visibility is moderate. Distance between lasers (red dots) is 15 cm.

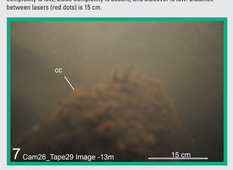


Figure 2H. Digital still photograph no. B7 (see fig. 2A for location). Pipeline surrounded by sand (water depth, 13 m). Abiotic complexity is moderate, biotic complexity is absent, and biocover is high. Biocover includes cup corals (cc). Visibility is poor. Distance between lasers (red dots are just out of view in this image but are visible in previous video frame) is 15 cm.

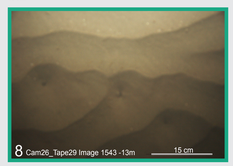


Figure 2I. Digital still photograph no. B8 (see fig. 2A for location). Fine- to medium-grained sand with sharp-crested symmetrical bifurcating ripple pattern (water depth, 13 m). Abiotic complexity is low, biotic complexity is absent, and biocover is low. Distance between lasers (red dots are just out of view in this image but are visible in previous video frame) is 15 cm.

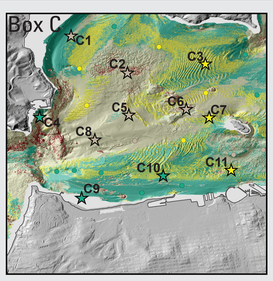


Figure 3A. Detailed view of seafloor character mapped in San Francisco Bay (see Box C, on map, for location), showing locations of photographs and sediment samples collected on cruise S–8–10–SF, (stars; figs. 3B through 3L).

Figure 3B. Digital still photograph no. C1 (see fig. 3A for location). Sediment sample CBP08. Mixed gravel, cobble, and sand with scattered shell (water depth, 24 m). Scale determined from size of sediment-sampling trough.

Figure 3C. Digital still photograph no. C2 (see fig. 3A for location). Sediment sample CBP15. Mixed gravel, cobble, and sand with scattered shell (water depth, 27 m). Scale determined from size of sediment-sampling trough.

Figure 3D. Digital still photograph no. C3 (see fig. 3A for location). Sediment sample CBP29. Unconsolidated, medium- to coarse-grained sand with cobble, gravel, and shell hash (water depth, 25 m) characterize flank and trough of megaripple in scour depression. Scale determined from size of sediment-sampling trough.

Figure 3E. Digital still photograph no. C4 (see fig. 3A for location). Sediment sample CBP02. Fine sand and silt (water depth, 44 m). Scale determined from size of sediment-sampling trough.

Figure 3F. Digital still photograph no. C5 (see fig. 3A for location). Sediment sample CBP17. Unconsolidated, medium- to coarse-grained sand with cobble, gravel, and shell hash (water depth, 23 m) characterize flank and trough of megaripple in scour depression. Scale determined from size of sediment-sampling trough.

Figure 3G. Digital still photograph no. C6 (see fig. 3A for location). Sediment sample CBP25. Mixed coarse sand, gravel, and cobbles, with scattered shells (water depth, 29 m). Scale determined from size of sediment-sampling trough.

Figure 3H. Digital still photograph no. C7 (see fig. 3A for location). Sediment sample CBP31. Unconsolidated, fine-, medium-, and coarse-grained sand with cobbles, gravel, and shell hash (water depth, 24 m) characterize flank and trough of megaripple in scour depression. Scale determined from size of sediment-sampling trough.

Figure 3I. Digital still photograph no. C8 (see fig. 3A for location). Sediment sample CBP11 Mixed gravel, cobbles, sand, and mud, with scattered shells (water depth, 45 m). Scale determined from size of sediment-sampling trough.

Figure 3J. Digital still photograph no. C9 (see fig. 3A for location). Sediment sample CBP07. Very fine-grained sand (water depth, 5 m). Scale determined from size of sediment-sampling trough.

Figure 3K. Digital still photograph no. C10 (see fig. 3A for location). Sediment sample CBP27. Fine- to medium-grained sand, gravel, and scattered shell hash (water depth, 24 m). Scale determined from size of sediment-sampling trough.

Figure 3L. Digital still photograph no. C11 (see fig. 3A for location). Sediment sample CBP33. Unconsolidated, medium- to coarse-grained sand with cobbles, gravel, and shell hash (water depth, 20 m) characterize flank and trough of megaripple in scour depression. Scale determined from size of sediment-sampling trough.

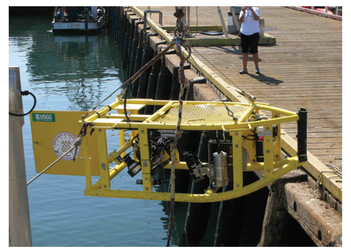


Figure 4. USGS-designed camera sled being loaded onto research vessel in preparation for ground-truth studies. Components onboard sled include four digital video camcorders, one 8-megapixel digital SLR camera, lasers for scale, and various strobe and video lights, as well as telemetry instrumentation that records depth, altitude, and compass heading.

Ground-Truth Studies, Offshore of San Francisco Map Area, California

By
Nadine E. Golden and Guy R. Cochrane

2015

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