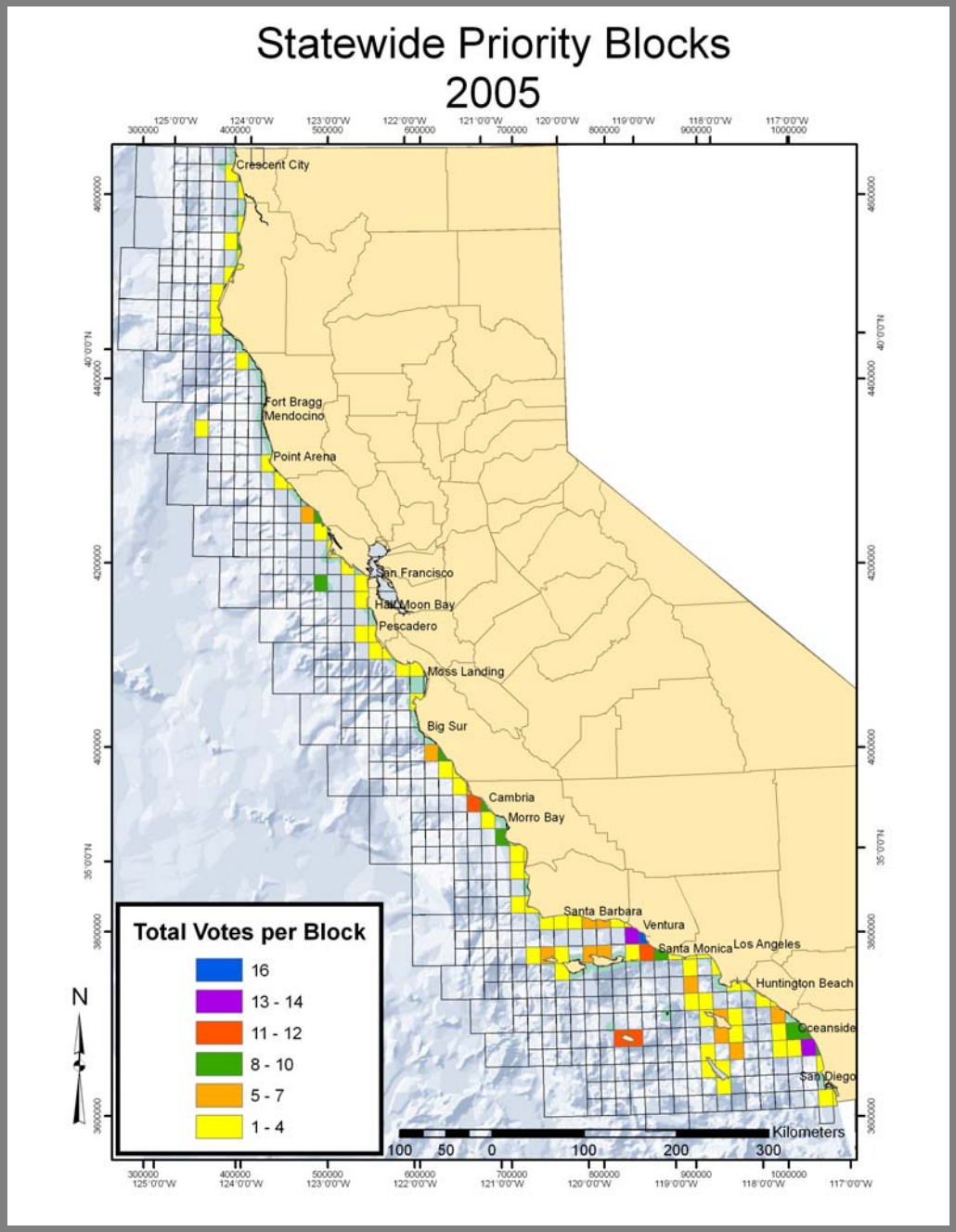

December, 2005
Statewide Marine Mapping Planning Workshop

56 participants
38 institutions

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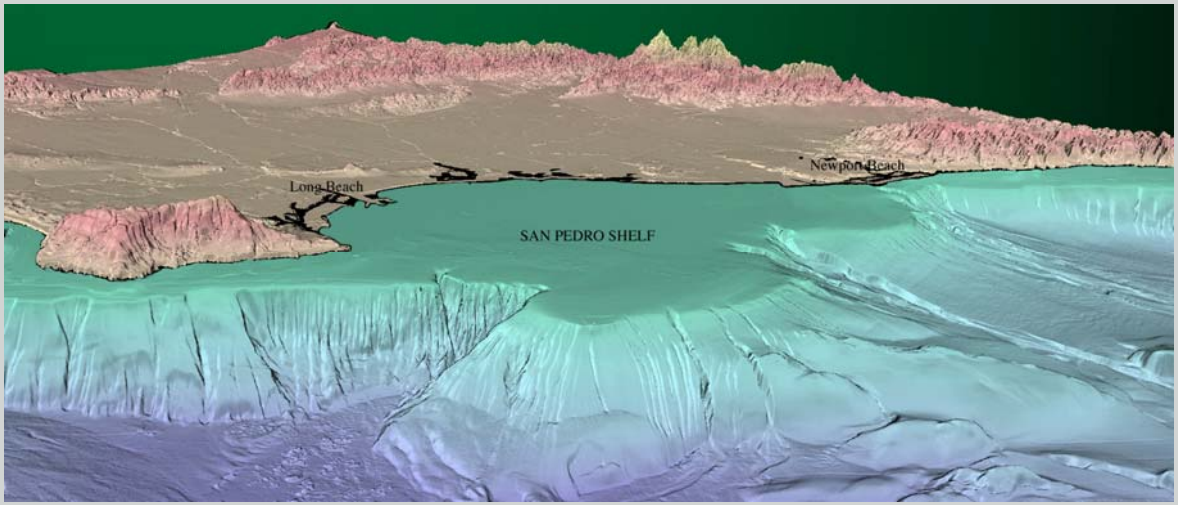
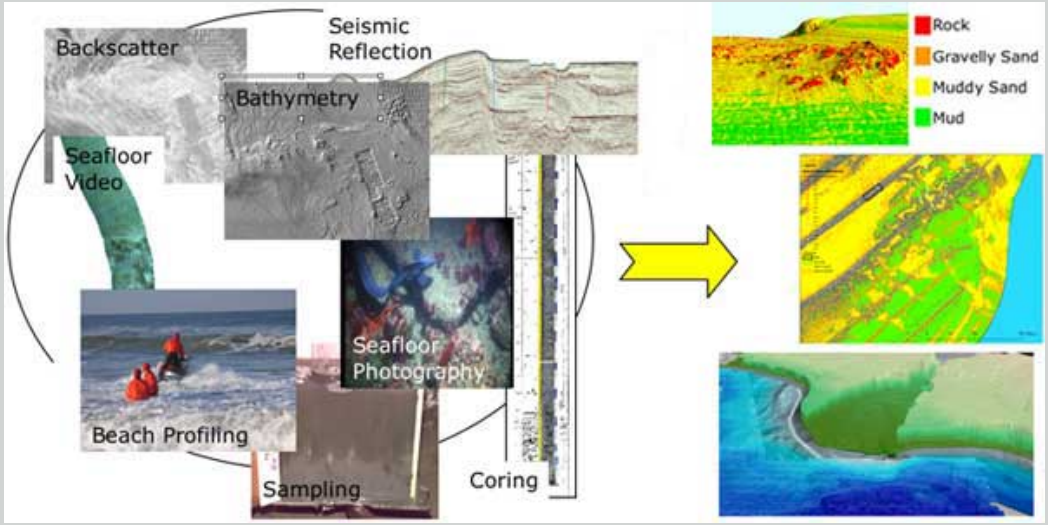
Coastal Map Development Workshop

To design a GIS map product for coastal zone management





May 2-3, 2007
Menlo Park, CA

60 participants
25 institutions

California State Waters Mapping Program

<u>Comprehensive Map Folio - Demonstration Product Line</u>

- High resolution bathymetry (color, 1:24K)
- High resolution bathymetry (grayscale, 1:24K)
- Backscatter (grayscale, 1:24K)
- Bathymetry-backscatter combo (1:24K)
- Perspective views
- Groundtruthing map and views
- Seafloor character map (1:24K)
- Habitat map (1:24K)
- Subbottom trackline map (1:50K) and seismic profiles
- Structure (local and regional), isopach, and depth maps (1:50K)
- Geologic map (1:24K)

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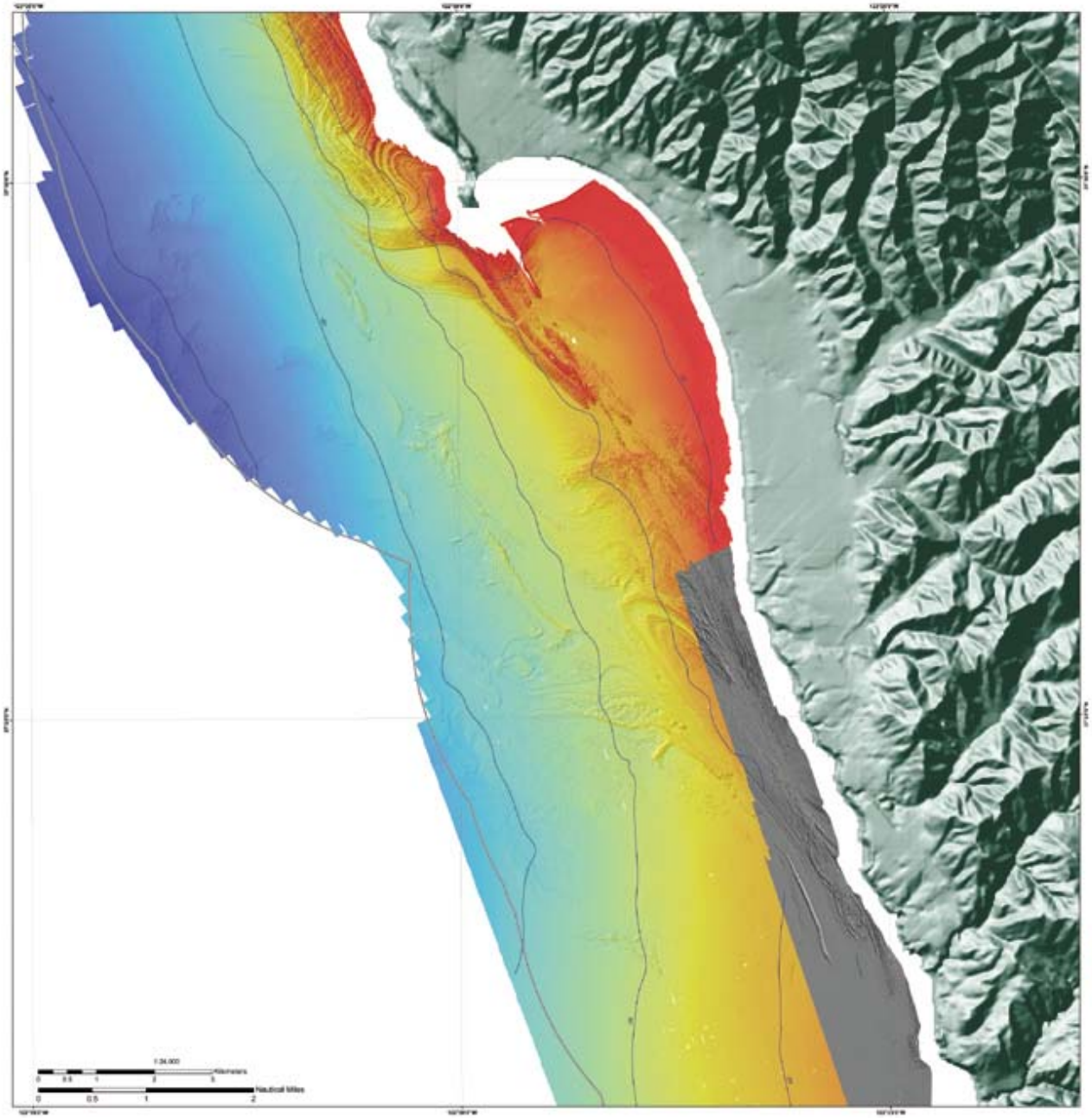

Central California Mapping Project

Half Moon Bay Sheet

DRAFT

October, 2001

Map Information

Datum - WGS 1984
Projection - UTM Zone 10

3-mile limit

10 m depth contours (generalized)

Depth (2m Digital Elevation Model)

Minimum: 2 meters

Maximum: 55 meters

Seafloor surface model colored by depth

Fine-scale seafloor geomorphology is revealed in shaded relief and colored by depth in this digital elevation model (DEM) created from multibeam sonar bathymetry data gridded at 2 m horizontal resolution.

NOTE: Areas of the seafloor for which depth grids and backscatter images are available are shown with color-coded depth values. For the area with a grey-scale hillshaded image, only geotiffs are available.

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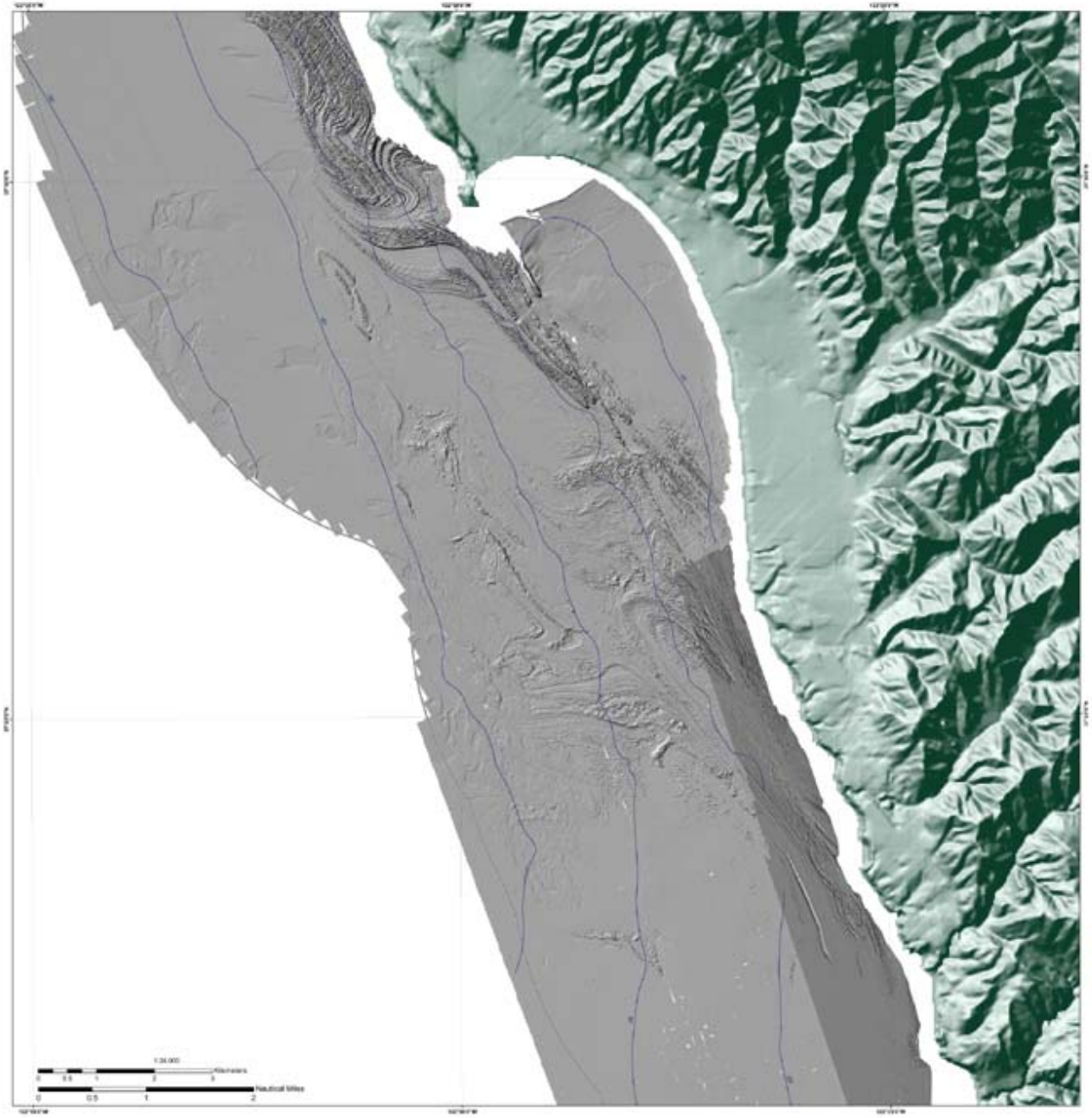

Central California Mapping Project

Half Moon Bay Sheet

DRAFT

October, 2001

Map Information

Datum - WGS 1984
Projection - UTM Zone 10

3-mile limit

10 m depth contours (generalized)

Seafloor surface model in gray scale shaded relief

Fine-scale seafloor geomorphology is revealed in this gray scale shaded relief digital elevation model (DEM) created from multibeam sonar bathymetry data gridded at 2 m horizontal resolution. Here gray scale alone is used to take advantage of the human eye's ability to discern finer detail in black and white versus color imagery. The angle of artificial illumination is from the northwest at an elevation of 45 degrees.

NOTE: Areas of the seafloor for which completed depth grids and backscatter images are available are shown in lighter gray scale. For the narrow darker gray area in the lower right of the data coverage, only preliminary imagery is available at this time.

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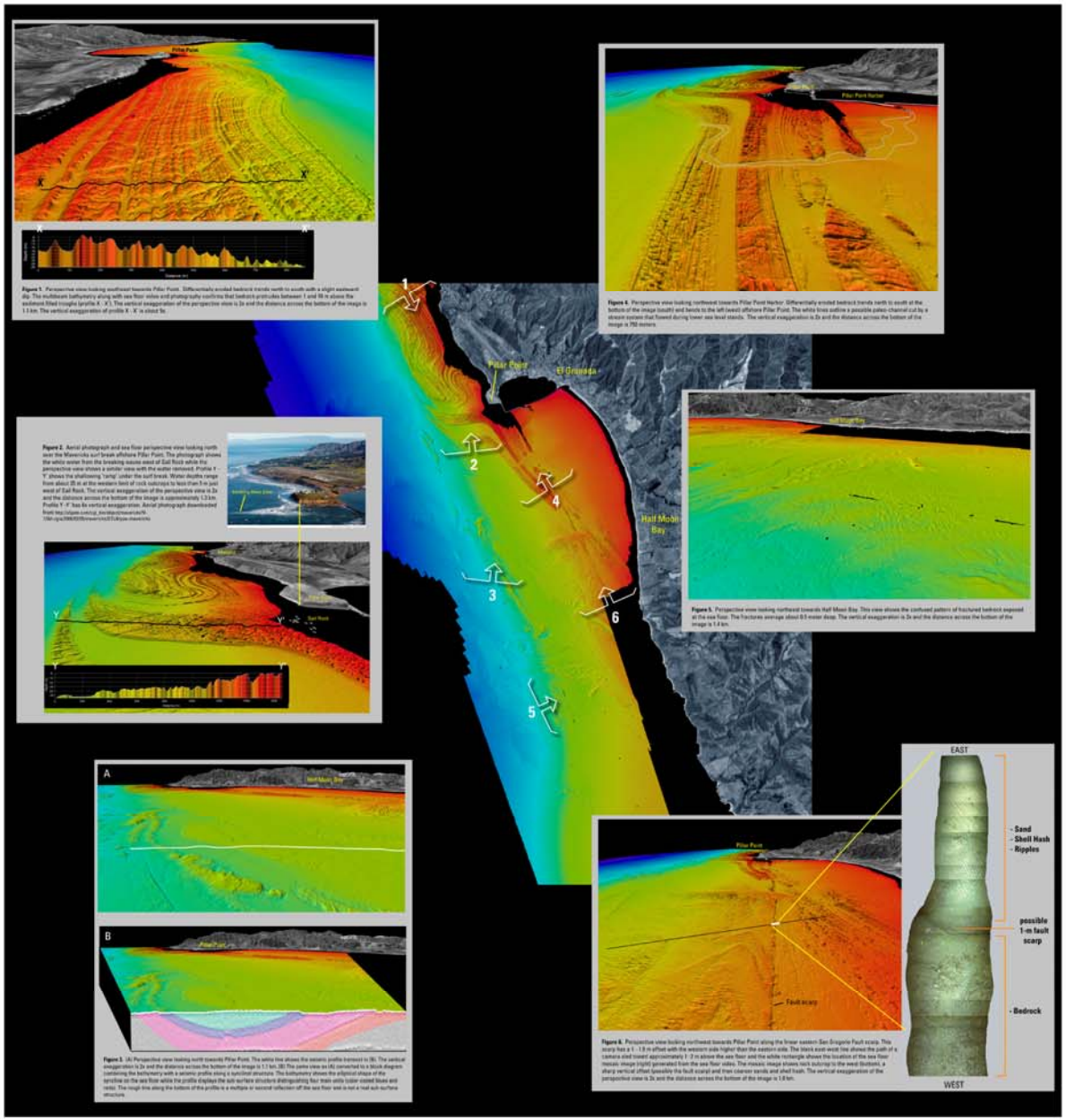


Central California Mapping Project

Half Moon Bay Sheet

DRAFT

October, 2007

Map Information

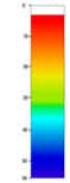
Datum - WGS 1984
Projection - UTM Zone 10

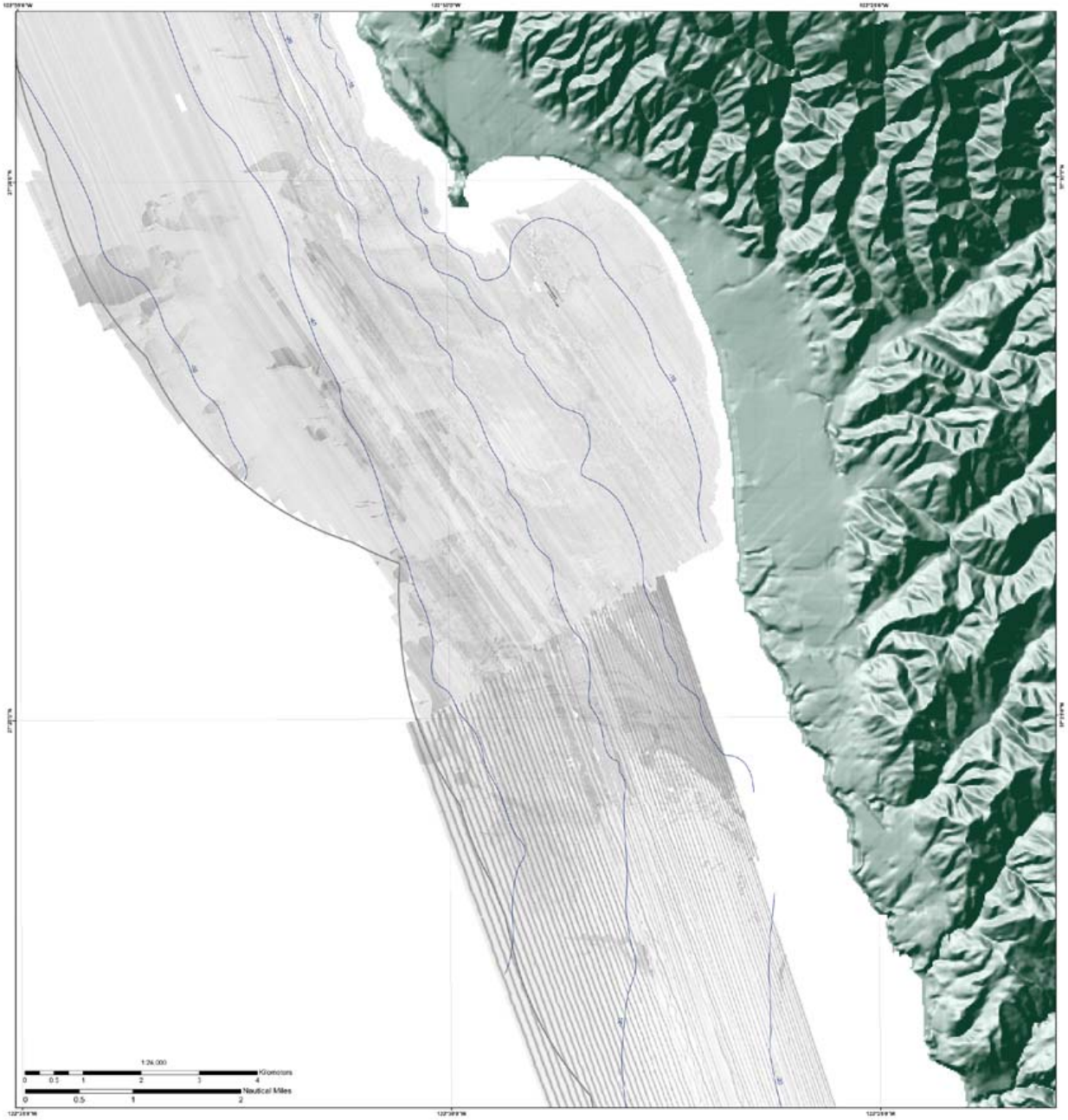
Map Sheet 5: Selected Perspective Views of Multibeam Bathymetry, Half Moon Bay, California Sheet

Bathymetry: Shaded relief image color-coded for depth from reds (shallow) to dark blues (deeper). The illumination azimuth is 300 degrees with an angle of 45 degrees from horizontal.

Land: Imagery generated by draping 10-m digital orthophoto-quadrangles over 10-m digital elevation models (data from U.S. Geological Survey

Water Depth (m)





Central California Mapping Project

Half Moon Bay Sheet

DRAFT

October, 2003

Map Information

Datum - WGS 1984
Projection - UTM Zone 10

3-mile limit

10 m depth contours (generalized)

Acoustic Backscatter Intensity - 50 cm resolution

High : 255

Low : 0

Acoustic backscatter (also known as sidescan sonar) mosaics provide an indication of seafloor texture and sediment type as represented by the intensity of sonar echo return strength. Harder and rougher bottom types typically return stronger sonar echos (darker pixels) while softer bottom types return weaker echos (lighter pixels). Acoustic shadows (areas shielded from insonification and thus having no echo return) are depicted as white.

NOTE: The parallel light/dark stripping running north and south in the lower half of the acoustic backscatter mosaic is an artifact that will be removed from this draft product during subsequent data processing.

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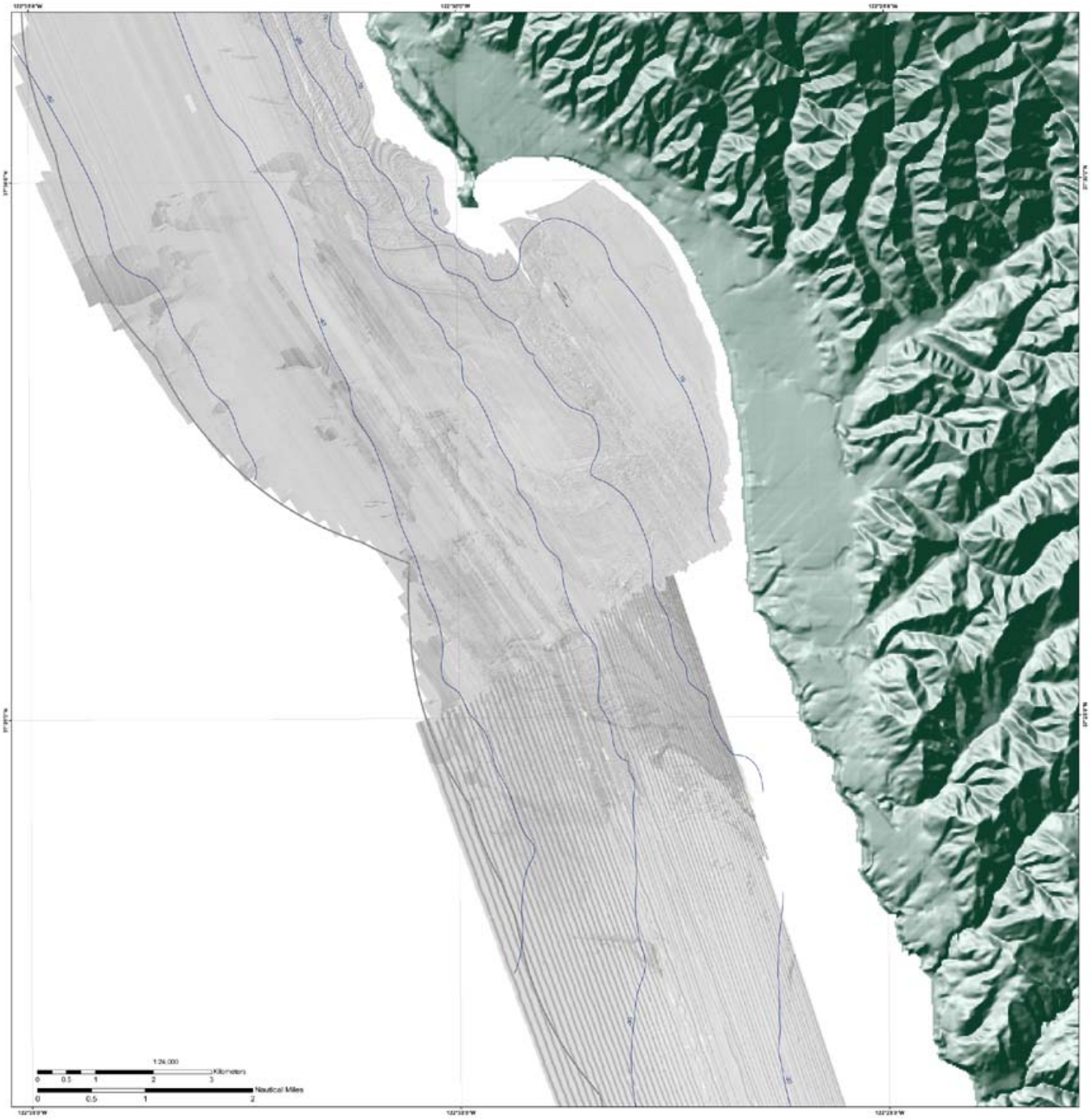

Central California Mapping Project

Half Moon Bay Sheet

DRAFT

October, 2003

Map Information

Datum - WGS 1984
Projection - UTM Zone 10

3-mile limit

10 m depth contours (generalized)

Acoustic Backscatter Intensity - 50 cm resolution

High : 255

Low : 0

Acoustic backscatter over shaded relief bathymetry

Acoustic backscatter (also known as sidescan sonar) mosaics provide an indication of seafloor texture and sediment type as represented by the intensity of sonar echo return strength. Harder and rougher bottom types typically return stronger sonar echos (darker pixels) while softer bottom types return weaker echos (lighter pixels). Acoustic shadows (areas shielded from insonification and thus having no echo return) are depicted as white. Here the 50 cm resolution acoustic backscatter data have been draped over the 2m bathymetric data depicted in hill shade to give a composit rendering of seafloor texture and geomorphology.

NOTE: The parallel light/dark stripping running north and south in the lower half of the acoustic backscatter mosaic is an artifact that will be removed from this draft product during subsequent data processing.

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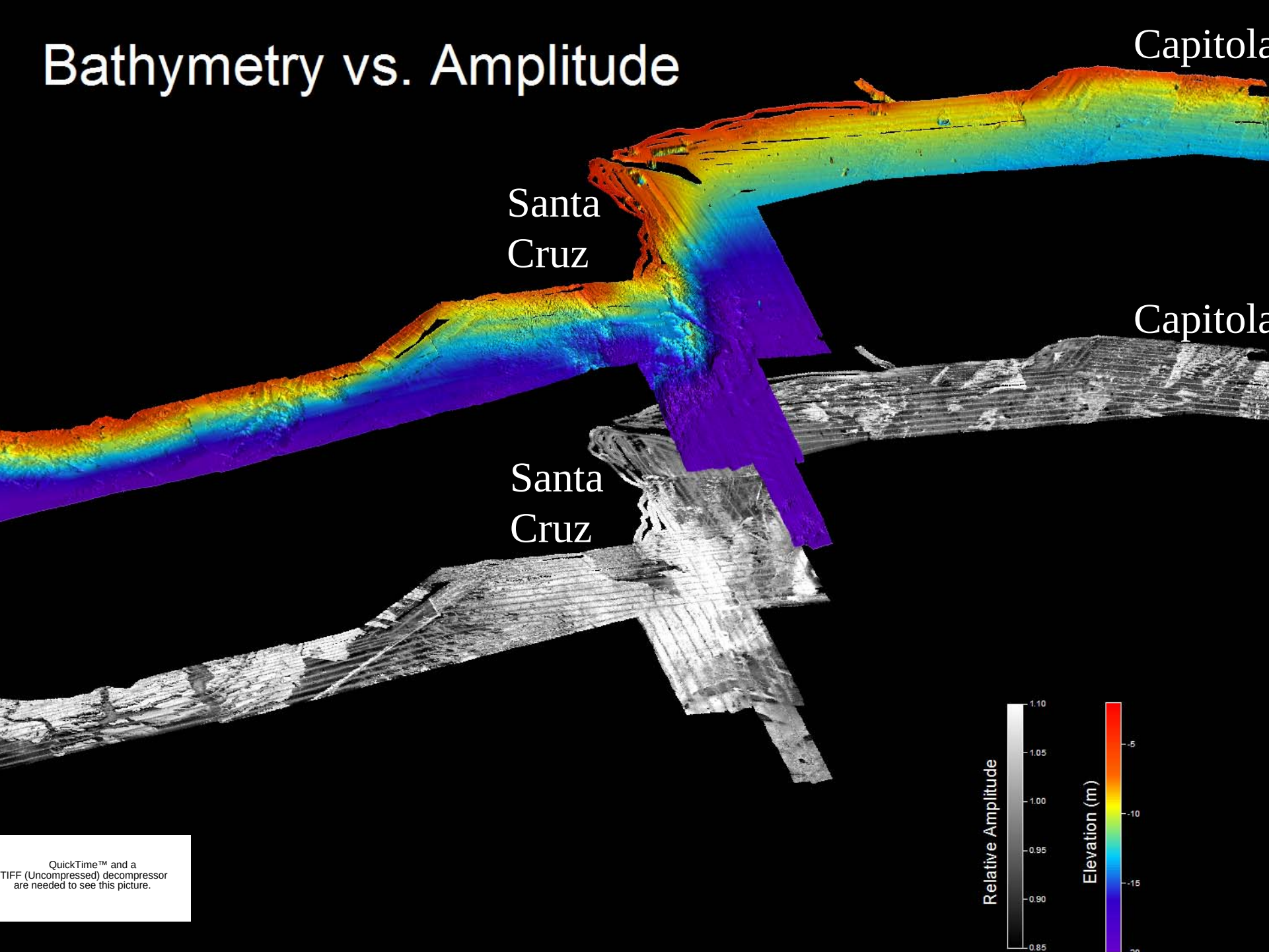
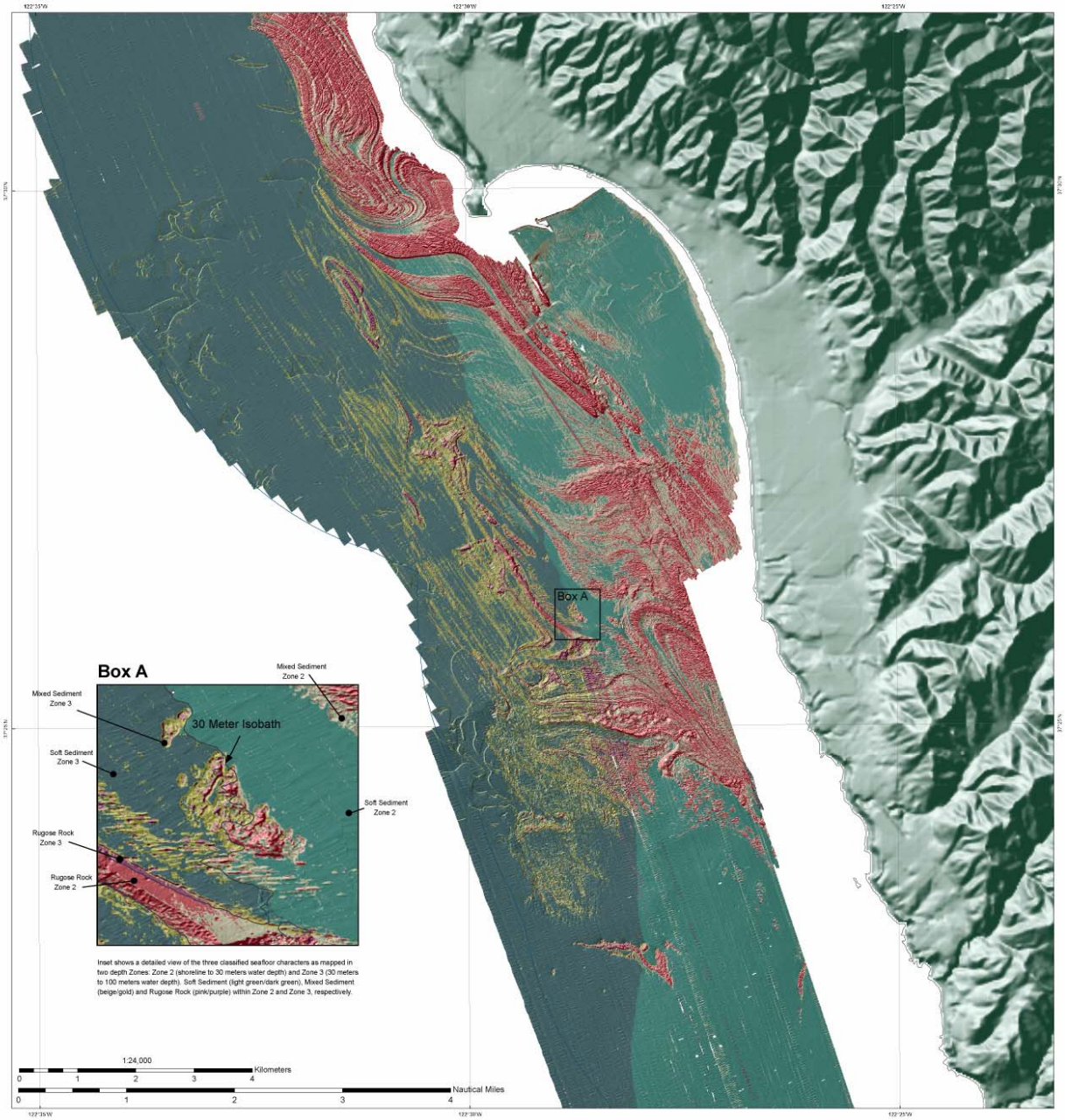
Bathymetry vs. Amplitude



QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.



Central California Mapping Project

Half Moon Bay Sheet

DRAFT

October, 2007

Map Information

N
W E
S

Datum - WGS 1984
Projection - UTM Zone 10

3-mile limit

Seafloor Character Map

Zone 2 - shoreline to 30 meters water depth	Zone 3 - 30 meters to 100 meters water depth
Soft Sediment	Soft Sediment
Mixed Sand, Gravel and Rock	Mixed Sand, Gravel and Rock
Rugose Rock	Rugose Rock

This seafloor character map was produced using video-supervised maximum likelihood classification of the bathymetry and backscatter (intensity of return) signals from sonar systems. A subsetting of the video data collected for the purpose of supervising the classification is shown on Poster Sheet #6. Derivative roughness (rugosity), intensity variability (homogeneity and entropy), and backscatter intensity were used as variables in the classification. The substrate classes have been divided into the California Marine Life Protection Act depth zones mapped in this area: zone 2 (intertidal to 30 meters) and 3 (30 to 100 meters). The interpretation is draped over shaded relief bathymetry shown in Poster Sheet #2.

Soft sediment, thick deposits composed of sand and mud, comprises 71% of the region (104 sq km) - 32 square kilometers in depth zone 2 and 74 sq km in zone 3. Mixed sand, gravel and rock, where sediment typically forms a thin veneer over bedrock, comprises 16% of the area mapped (23 sq km) - 12 sq km in Zone 2 and 10 sq km in zone 3. Rugose (complex, rough rock) comprises the final 13% (20 sq km) of the region - 16 sq km in zone 2 and 4 sq km in zone 3.

	Total		Zone 2		Zone 3	
	percent	sq km	percent	sq km	percent	sq km
Soft sediment	71	104	70	32	71	74
Mixed sand, gravel and rock	16	23	26	12	19	10
Rugose	13	20	4	16	10	4

NOTE: Regions lacking one of the component datasets (bathymetry or backscatter) could not be classified. These regions are shown in either white, for regions which were not classified due to lack of bathymetry data, or gray for regions which were not classified due to lack of backscatter data.

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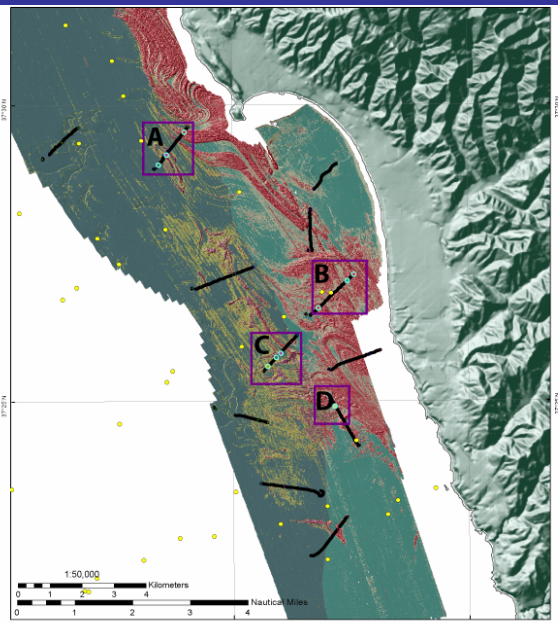
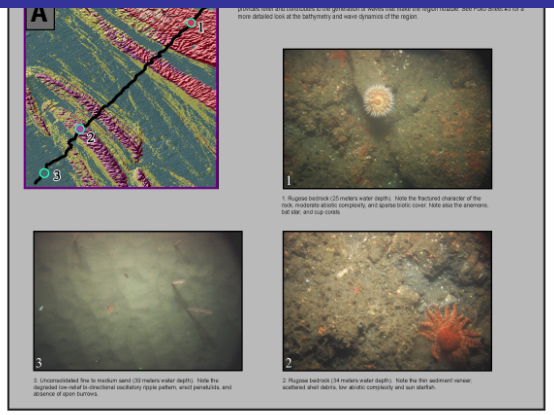


Seafloor Character map (from Folio Sheet #7) showing the location of camera tracklines (black lines) used to refine and groundtruth the classification, detailed subregions (A through D), and usSEABED sediment sample locations (yellow circles).

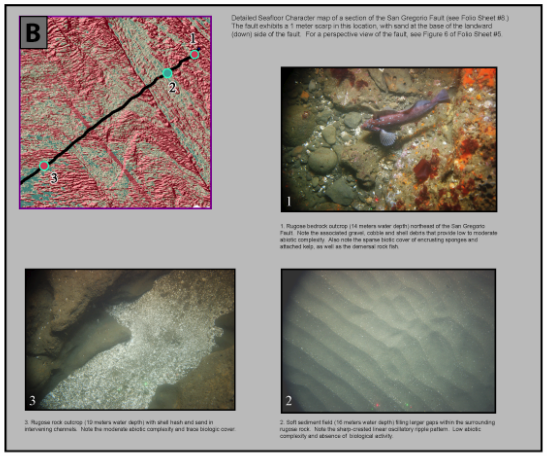


Detailed Seafloor Character map of a section of the San Gregorio Fault (see Folio Sheet #6.) The fault exhibits a 1 meter scarp in this location, with sand at the base of the landward (down) side of the fault. For a perspective view of the fault, see Figure 6 of Folio Sheet #5.

1. Rugose bedrock (25 meters water depth). Note the fractured character of the rock, moderate abiotic complexity, and sparse biotic cover. Note also the anemone, bat star, and cup corals

3. Unconsolidated fine to medium sand (30 meters water depth). Note the degraded low-relief bi-directional oscillatory ripple pattern, erect penaltulida, and absence of open burrows.

2. Rugose bedrock (34 meters water depth). Note the thin sediment veneer, scattered shell debris, low abiotic complexity and sun starfish.

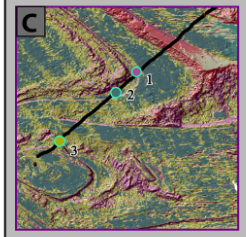


Detailed Seafloor Character map of a section of the San Gregorio Fault (see Folio Sheet #6.) The fault exhibits a 1 meter scarp in this location, with sand at the base of the landward (down) side of the fault. For a perspective view of the fault, see Figure 6 of Folio Sheet #5.

1. Rugose bedrock outcrop (14 meters water depth) northwest of the San Gregorio Fault. Note the associated gravel, cobble and shell debris that provide low to moderate abiotic complexity. Also note the sparse biotic cover of encrusting sponges and attached kelp, as well as the demersal rock fish.

3. Rugose rock outcrop (19 meters water depth) with shell hash and sand in intervening channels. Note the moderate abiotic complexity and trace biologic cover.

2. Soft sediment field (16 meters water depth) filling larger gaps within the surrounding rugose rock. Note the sharp-crested linear oscillatory ripple pattern. Low abiotic complexity and absence of biological activity.

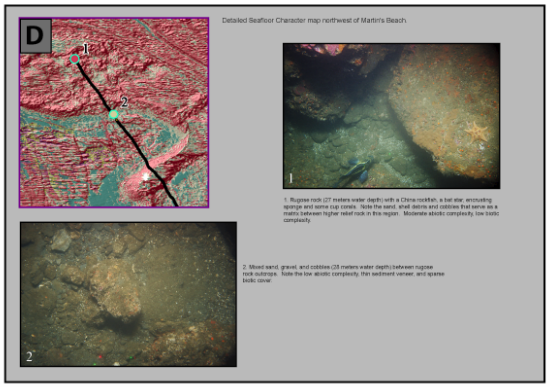


Seafloor Character map detailing a complex region of folded rugose rock with intervening mixed coarse and fine-grained sediment.

1. Rugose rock outcrop (32 meter water depth). Note the moderate abiotic complexity and moderate biologic cover provided by encrusting organisms (cup corals, encrusting sponges and strawberry anemones). Biologic complexity is low.

3. Mixed cobble and sand (36 meters water depth). Note a bat star, encrusting sponges and red brittle star arms reaching out from among the cobbles. Low to moderate abiotic complexity, low biotic complexity.

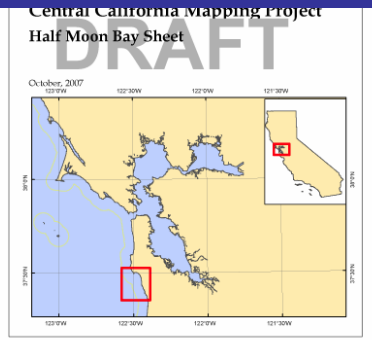
2. Soft sediment (36 meters water depth) near the nose of folded rugose rock. Note the degraded oscillatory ripples with scattered shell debris that provide low abiotic complexity. Note also the sparse biologic component (tube worms, flat fish).



Detailed Seafloor Character map northwest of Martin's Beach.

1. Rugose rock (27 meters water depth) with a China rockfish, a bat star, encrusting sponge and some cup corals. Note the sand, shell debris and cobbles that serve as a matrix between higher relief rock in this region. Moderate abiotic complexity, low biotic complexity.

2. Mixed sand, gravel, and cobbles (28 meters water depth) between rugose rock outcrops. Note the low abiotic complexity, thin sediment veneer, and sparse biotic cover.



Map Information

Datum - WGS 1984
Projection - UTM Zone 10

Groundtruthing data locations for Seafloor Character Map

- usSEABED Sample Locations

Seafloor Character Map

Zone 2 - shoreline to 30 meters water depth	Zone 3 - 30 meters to 100 meters water depth
Soft Sediment	Soft Sediment
Mixed Sand, Gravel and Rock	Mixed Sand, Gravel and Rock
Rugose Rock	Rugose Rock

During late September, 2007, the science team towed a USGS designed camera sled behind the NOAA ship R/V Fulmar to collect 20 trackline subsamples of continuous seafloor digital video and over than 1500 high-resolution still photographs in an effort to both refine and confirm (groundtruth) the Seafloor Character map (folio Sheet #7) of the study area. Camera tracklines shown as black lines on the panel to the upper left were used over representative areas of (1) rugose bedrock, (2) mixed (generally coarse-grained) sediment, and (3) soft (uncontoldated fine-grained) sediment. Real-time observations of geologic and biologic attributes were recorded approximately every minute using programmable keypads. Still photographs representative of each of the three classification categories are shown in the four subregions identified in the panels to the left.

Sediment sentinel data derived from samples in the usSEABED database (locations are shown as yellow dots on the upper left panel) will be used to further refine the classified image.

Explanation:
Rugosity: Variability of seafloor roughness based on spatial analysis involving a numerical comparison of depth values in the 2-m pixel multibeam bathymetric data. Rugose rock refers to massive bedrock exposures that exhibit large variations in adjacent pixel values, and when examined visually, demonstrates high abiotic complexity.

Complexity: In the context of marine fisheries management, benthic habitat complexity can be divided into abiotic and biotic components. The term refers to the visual classification of local vertical relief and structure that provides potential refuge for both juvenile and adult species.

Mixed sediment: Includes coarse sand, gravel, cobbles, and regions with rock exposures smaller than 2 meters (1 pixel), confirmed by observation and sample-derived characterization of sediment texture.

Soft sediment: Includes medium to very-fine sands and muds (silt and clay size particles), confirmed by visually and sample-derived characterization of sediment texture.

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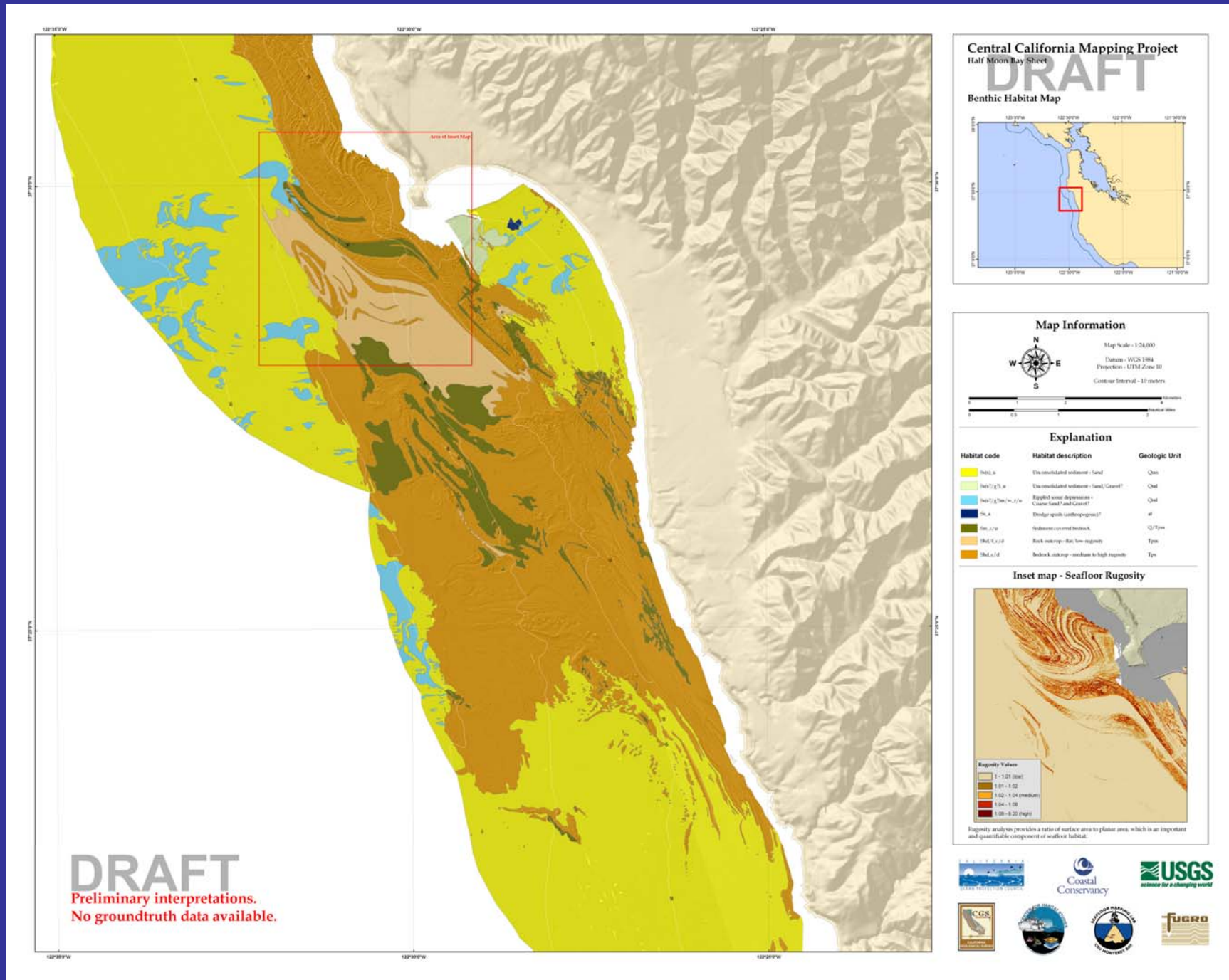

Central California Mapping Project
Half Moon Bay Sheet
DRAFT
Benthic Habitat Map
Map Information
N
W
E
S
Map Scale - 1:24,000
Datum - WGS 1984
Projection - UTM Zone 10
Contour Interval - 10 meters
Explanation
Habitat code
Habitat description
Geologic Unit
Inset map - Seafloor Rugosity
Rugosity Values
1 - 1.01 (low)
1.01 - 1.02
1.02 - 1.04 (medium)
1.04 - 1.08
1.08 - 8.20 (high)
Rugosity analysis provides a ratio of surface area to planar area, which is an important and quantifiable component of seafloor habitat.
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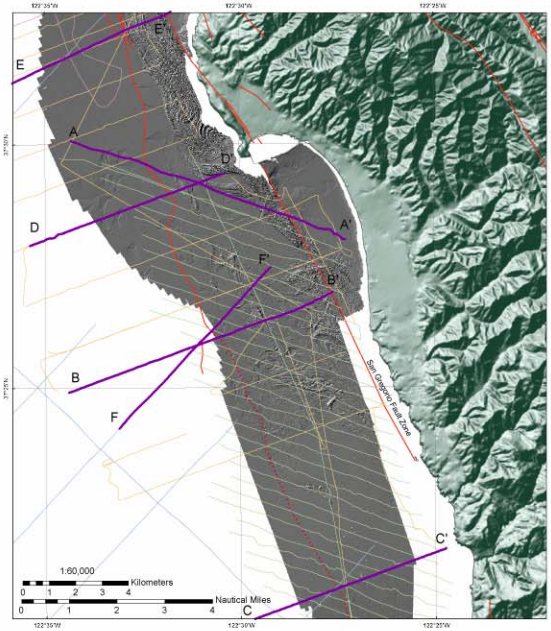
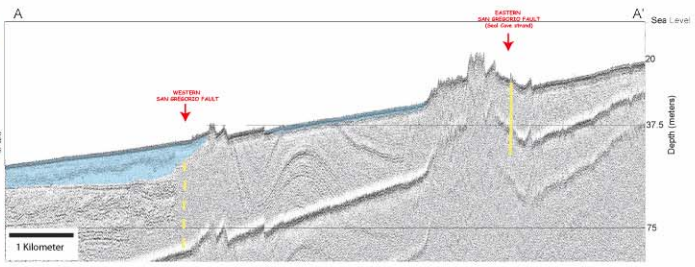
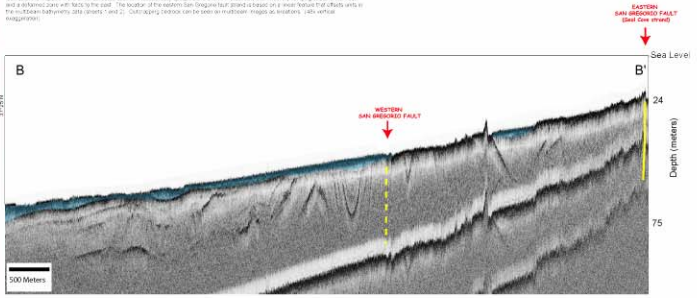
Preliminary interpretations.
No groundtruth data available.



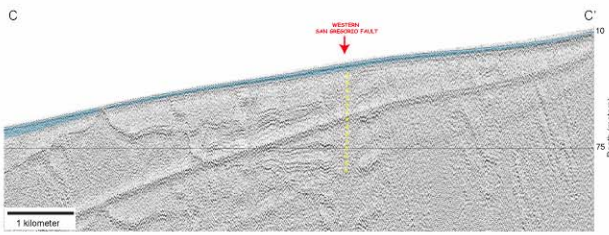
Trackines of seismic reflection profiles used to generate derivative maps on Fossil Sheet #13. The trackilines are overlaid on a map of grey-scale bathymetry (Fossil Sheet #1). Bold (red) lines A-A', B-B', etc. (upper) are the locations of seismic reflection profiles shown on this sheet.



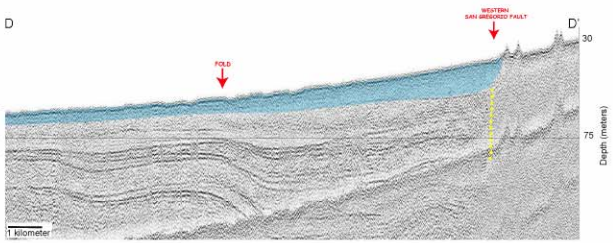
j197mb 114 (A - A') - Very high-resolution geopulse profile in Half Moon Bay across San Gregorio fault zone. Here the western San Gregorio fault strand is imaged in the uncompacted sediment (acoustically opaque zone shown in blue) between relatively flat-lying strata to the west and a deformed zone with folds to the east. The location of the eastern San Gregorio fault strand is based on a linear feature that offsets units in the multibeam bathymetry data (sheets 1 and 2). Outcropping bedrock can be seen on multibeam images as lineations. (48x vertical exaggeration).



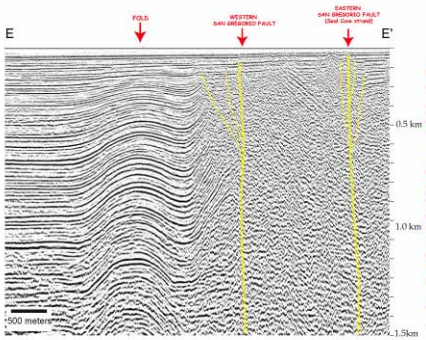
f207nc HMS0 (B - B') - Very high-resolution chirp profile in Half Moon Bay. Plunging anticlines and synclines are associated with western strand of the San Gregorio Fault. The eastern strand of the San Gregorio Fault is located on the eastern end of the profile and clearly evident in the multibeam bathymetry maps. Blue shading shows the uncompacted sediment layer (acoustically transparent) above bedrock (12x vertical exaggeration).



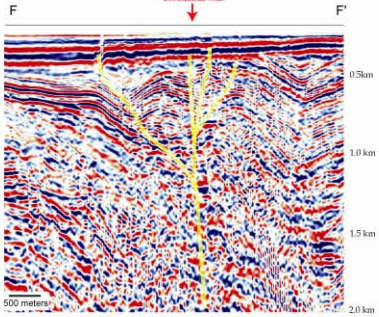
f207nc HMS0 (C - C') - Very high-resolution minisparker profile depicts gently-sloping shelf morphology offshore Half Moon Bay (see trackline map). Bedrock beneath a very thin uncompacted sediment layer (shaded blue) is complexly folded and faulted. (20x vertical exaggeration).



f207nc HMS0 (D - D') - Minisparker profile depicts the characteristic flat shelf morphology for the offshore Half Moon Bay area (see the trackline map). Bedrock, here thought to be Tertiary-age Purisima Formation, crops out close to shore then dips seaward beneath the uncompacted sediment layer (shaded blue). Bedrock consists mostly of high-angle folds that are parallel or sub-parallel to the seafloor. The uncompacted sediment layer is thin, lens shaped, and pinches out against the bedrock at its landward extent. (60x vertical exaggeration).



f205SP 129 (E - E') - Migrated and depth-converted high-resolution multichannel seismic reflection (MCS) profile 129 showing the San Gregorio Fault Zone off Point Montara (after Brown et al., 2002). Both the western and eastern San Gregorio Faults are multi-stranded positive flower structures. On this profile the Eastern (aka Gregorio) Fault is imaged along strike of the East Cove fault, which trends offshore at the Fitzgerald Marine Reserve. This fault strand is also imaged as a prominent lineation in the multibeam bathymetry (Fossil Sheets #1, 2). The fault imaged west of the San Gregorio fault zone shows increase in amplitude with depth. It is cloaked by near surface sediment and may not longer be active. (10x vertical exaggeration).



WOF-054 (F - F') - Deep penetration industry profile WOF-054 from USGS National Archive of Marine Seismic Surveys (http://walrus.wr.usgs.gov/NAMSS/index.html). This profile crosses the western San Gregorio fault zone, which is imaged as a complex positive flower structure. A tertiary sedimentary basin with over 2.5 km of sediment is imaged east of the fault zone. (2.5x vertical exaggeration).

Central California Mapping Project

Half Moon Bay Sheet

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October, 2007

Map Information

Datum - WGS 1984
Projection - UTM Zone 10

Trackline Map and Selected Seismic Reflection Profiles Showing Subbottom Data

Trackline Cruise IDs

- w1476sf - Industry Multi-Channel Sparker, 1976
- j197mb - USGS Geopulse, 1997
- f207nc - USGS Chirp and Minisparker, 2007
- g2sf95 - USGS High resolution Multi-Channel Sparker, 1995
- A - A' Location of Displayed Seismic Profile

faults

- major strand - surface
- major strand - inferred

Industry Multichannel Seismic-Reflection (MCS) 5-40Hz:
Source: high-volume airgun array
Receiver: 24 to 120 channel hydrophone streamer (~2km long)
High energy, deep penetration (25 km)

USGS high-resolution MCS 30-300Hz:
Source: single 40 cubic inch GI gun
Receiver: 24 channel hydrophone streamer (200m long)
Medium energy, 1-3km penetration

USGS very high resolution seismic reflection 300Hz-2.6kHz:
Minisparker
Source: 150-300 joule electric spark
Receiver: single channel streamer (10m long)
Geopulse
Source: "boomer" plate
Receiver: single-channel (internally processed)
Chirp
Source: high-frequency pinger (focused)
Receiver: single-channel (internally processed)

Coastal Conservancy

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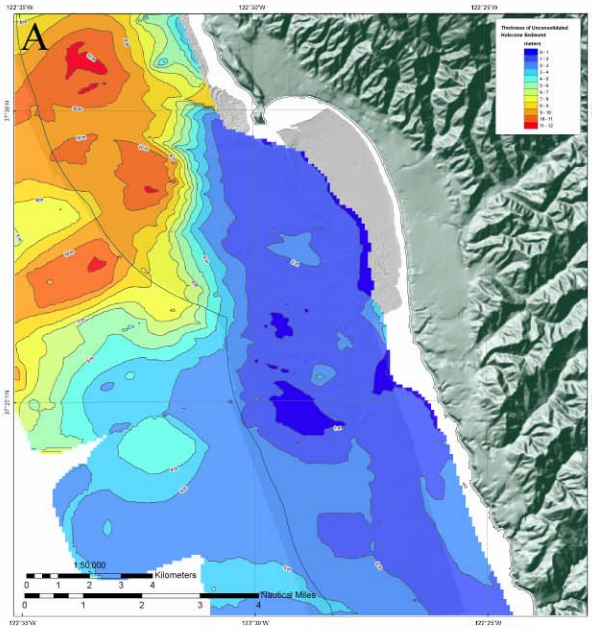
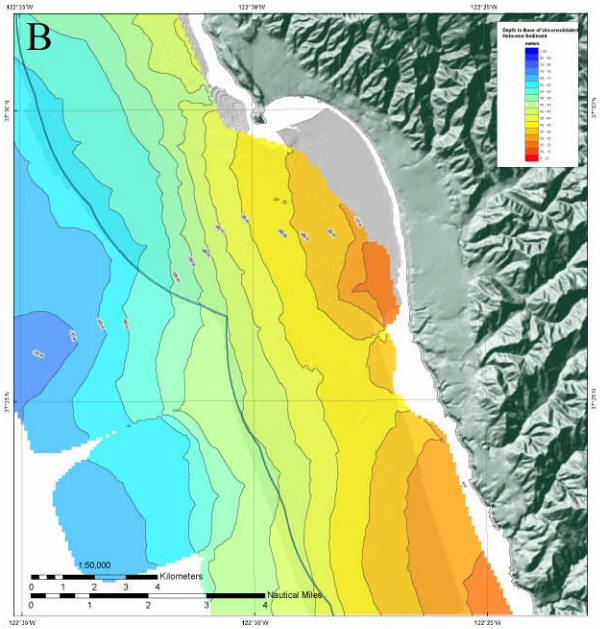
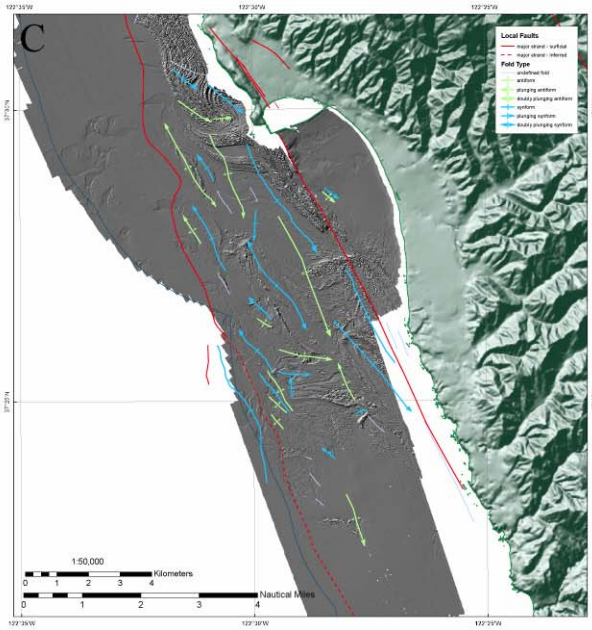
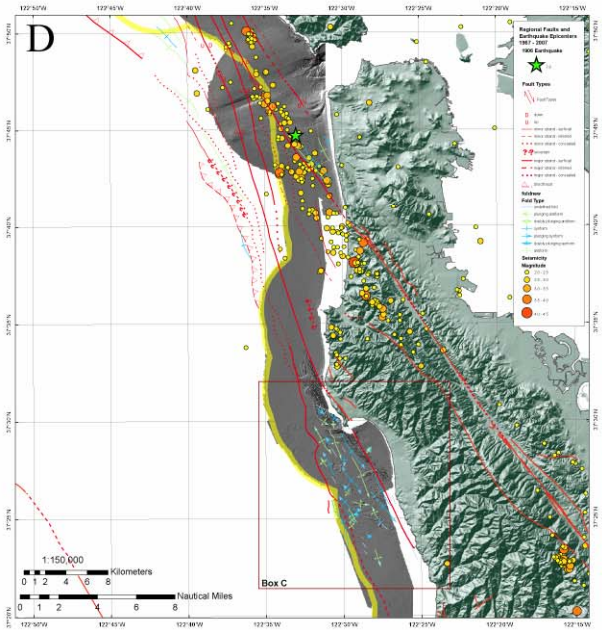
CGS CALIFORNIA GEOLOGICAL SURVEY









Central California Mapping Project

Half Moon Bay Sheet

DRAFT

October, 2007

Map Information

Datum - WGS 1984
Projection - UTM Zone 10

3-mile limit

Recent Sediment Accumulation and Faulting, Half Moon Bay, California

A *Isopach Map*

Isopach Map, depicting the thickness of unconsolidated sediment of primarily Holocene age beneath the seafloor. The isopachs are based on interpretation of high-resolution seismic reflection profiles (examples and thicknesses shown on back side of this). Unconsolidated sediment is typically imaged on these profiles as an acoustically transparent layer (ATL) that either overlies bedrock or older, more consolidated sediment deposited before or during the last ice age when sea level was significantly lower than at present. Where the thickness is zero or less than one meter, bedrock crops out on the sea floor or is covered by a very thin veneer of sediment.

B *Depth to Base of Unconsolidated Sediment*

Map showing the depth to the base of the unconsolidated sediment layer, determined from seismic reflection profiles, by adding the water depth to the thickness of the unconsolidated sediment layer (ATL). (See adjacent map). "See level is datum"

C *Quaternary Offshore Faults and Folds*

Map showing structures (faults and folds) interpreted to be active in the last ~2 million years (the Quaternary). The structurally complex area is located within the western part of the broad San Andreas fault zone. Flow (2) of much the San Gregorio fault (Sheet 1B) is a major strand. Mapping is based primarily on interpretation of high-resolution seismic reflection profiles (sub-bottom penetration 50-100 m). In addition, high-resolution multichannel seismic reflection (MCS) profiles (sub-bottom penetration 1-2 km) and industry MCS profiles (sub-bottom penetration 2-4 km) were analyzed to support fault interpretations where available. High-resolution multibeam bathymetry data (high-resolution multibeam bathymetry data of the shelf) and MCS were also used in determining fault and fold locations.

D *Regional Map of Quaternary Offshore Structures (Faults and Folds) and Earthquakes*

Map based primarily on the interpretation of high-resolution seismic reflection profiles (sub-bottom penetration 50-100 m). High-resolution multibeam bathymetry data. Faults mapped on land are from Rogers, W. A. (compiler), 2005, Digital Datamaker of Quaternary and Younger Faults from the Fault Activity Map of California, version 2.0: California Geological Survey. Earthquake epicenters are from the Northern California Earthquake Data Center (NCEDC) catalog maintained by the USGS and UC Berkeley Seismological Laboratory, all events of magnitude 2.0 and greater for the time period 1967 through August 2007 are depicted.

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Central California Mapping Project

Half Moon Bay Sheet

DRAFT

Geologic Map

Map Information

Map Scale - 1:24,000

Datum - WGS 1984

Projection - UTM Zone 10

Explanation

Offshore Geologic Units

- af — Artificial fill (Historic)
- Qms — Quaternary marine deposited unconsolidated sediment (primarily sand)
- Qmd — Quaternary marine lag deposits (sands & gravels) & sediment waves
- QTp — Quaternary sediment covered Tertiary (Pliocene) sedimentary rocks of the Purisima Formation
- Tp — Purisima Formation (Pliocene & upper Miocene)
- Tpbc — Tunitas Sandstone Member (Pliocene) of Purisima Formation
- Tpl — Lobitos Mudstone Member (Pliocene) of Purisima Formation
- Tpsg — San Gregorio Member (Pliocene) of Purisima Formation
- Tpp — Pomponio Mudstone Member (Pliocene) of Purisima Formation

Structure

- Fault
- Fault - approximate
- Anticline
- Syncline

Onshore Geologic Units

- af — Artificial fill (Historic)
- Qhb — Beach deposits (Holocene)
- Qyf — Inner alluvial fan deposits (Holocene)
- Qyfo — Outer alluvial fan deposits (Holocene)
- Qcl — Colluvium (Holocene)
- QTs — Sand dune & beach deposits (Holocene)
- Qof — Coarse-grained older alluvial fan & stream terrace deposits (Pleistocene)
- Qmt — Marine terrace deposits (Pleistocene)
- Tp — Purisima Formation (Pliocene & upper Miocene)
- Tpbc — Tunitas Sandstone Member (Pliocene) of Purisima Formation
- Tpl — Lobitos Mudstone Member (Pliocene) of Purisima Formation
- Tpsg — San Gregorio Member (Pliocene) of Purisima Formation
- Tm — Monterey Formation (middle Miocene)
- Tts — Lompico Sandstone (middle Miocene)
- Tmb — Mindego Basalt and related volcanic rocks (Miocene and/or Oligocene)
- Tvq — Vaqueros Sandstone (lower Miocene & Oligocene)
- Kgr — Granite rocks of Montara Mountain (Cretaceous)
- KJf — Franciscan Complex, undivided (Cretaceous and Jurassic)

Note: Terrestrial geology from E.E. Brabb, R.W. Graymer, and D.L. Jones, 1998, Geology of the onshore part of San Mateo County, California: Derived from the digital database Open File-98-137.

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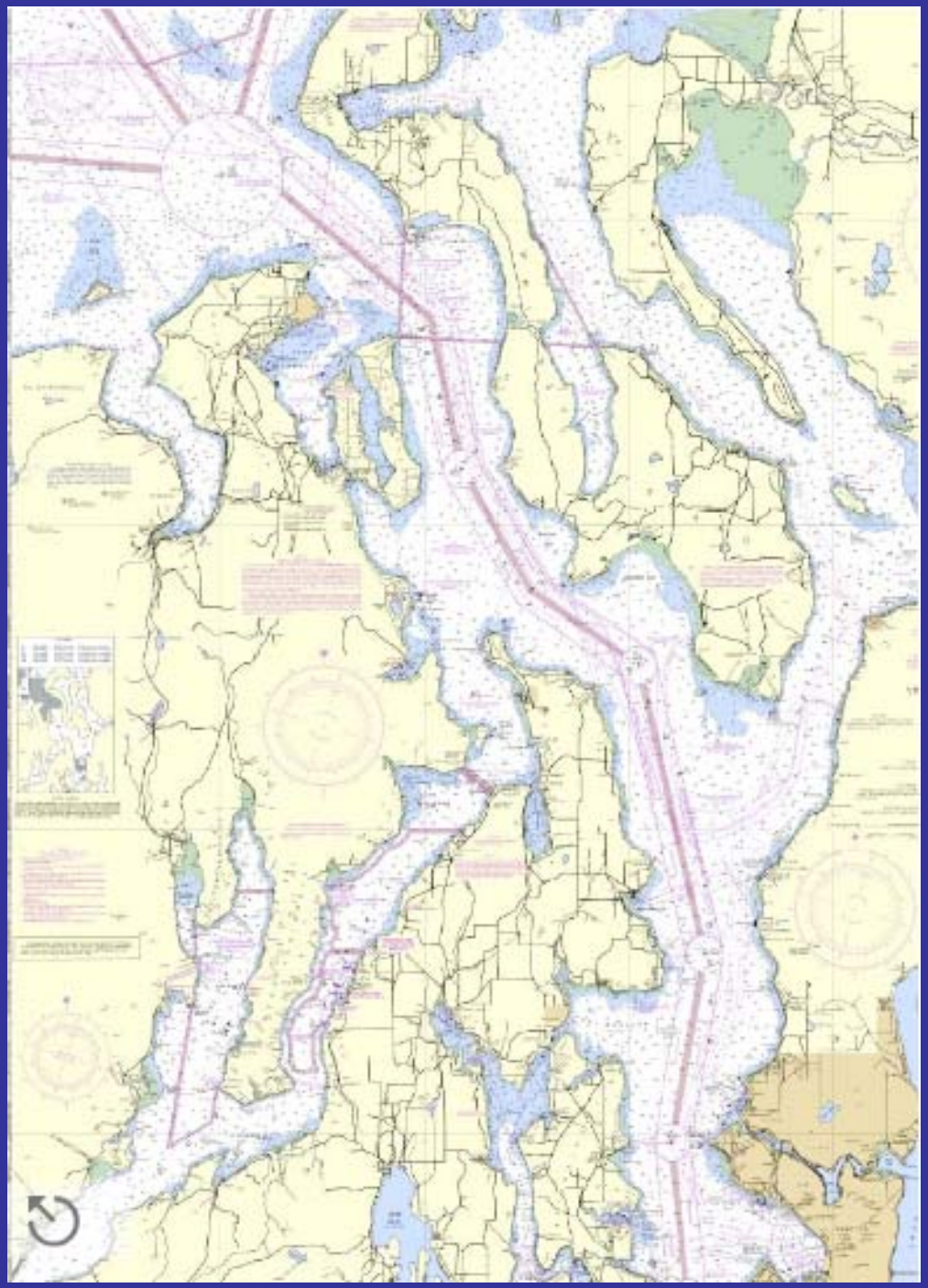
Sea Floor Maps - Why do we care?

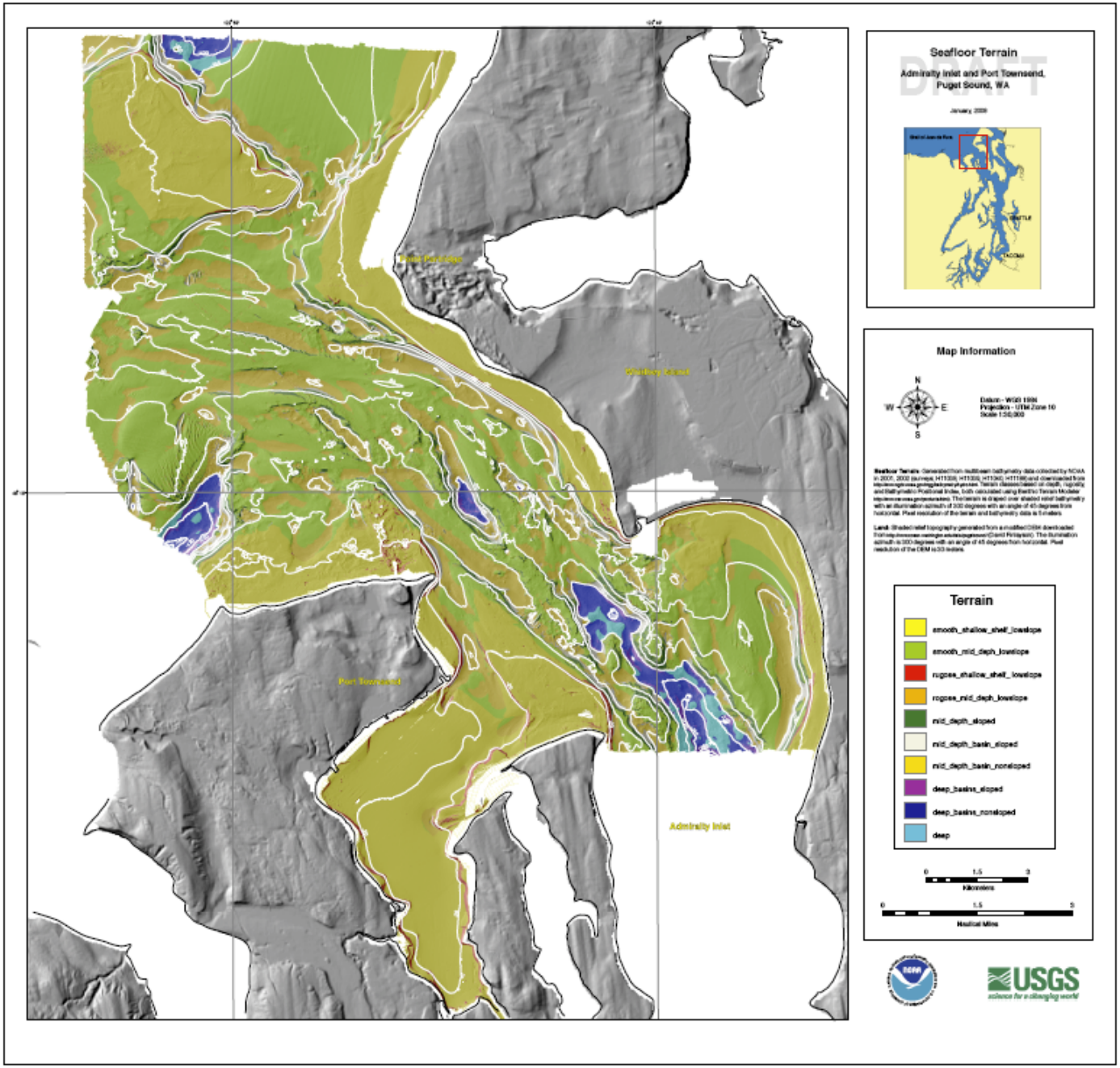
1. Safe navigation and commerce
2. Characterization of benthic habitats
3. Fisheries management, especially marine protected areas
4. Baselines for monitoring change (e.g., sea level impacts)
5. Sediment and contaminant budgets and transport, coastal processes
6. Regional sediment management, coastal erosion
7. Site evaluation - nearshore/offshore infrastructure
8. Earthquake and tsunami sources - hazard assessment
9. High-resolution for circulation and sediment transport modeling (e.g., inundation from storm surge or tsunamis)
10. Understanding geologic history and change



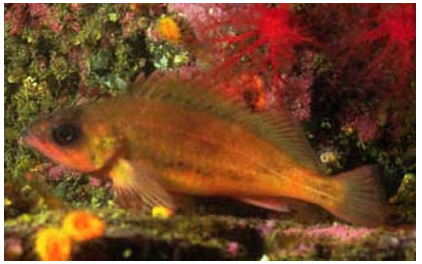
NOAA Office of Coast Survey Navigation Charts

Safe navigation and commerce

SF Bay - Cosco Busan

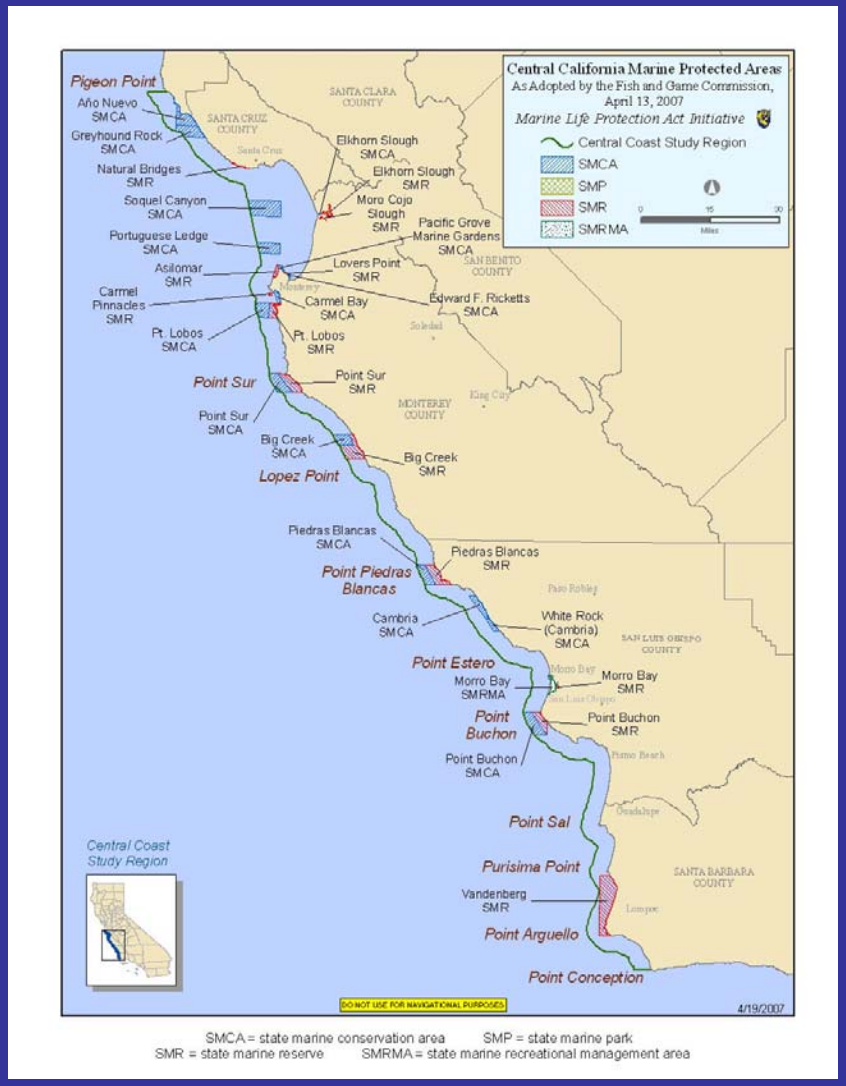


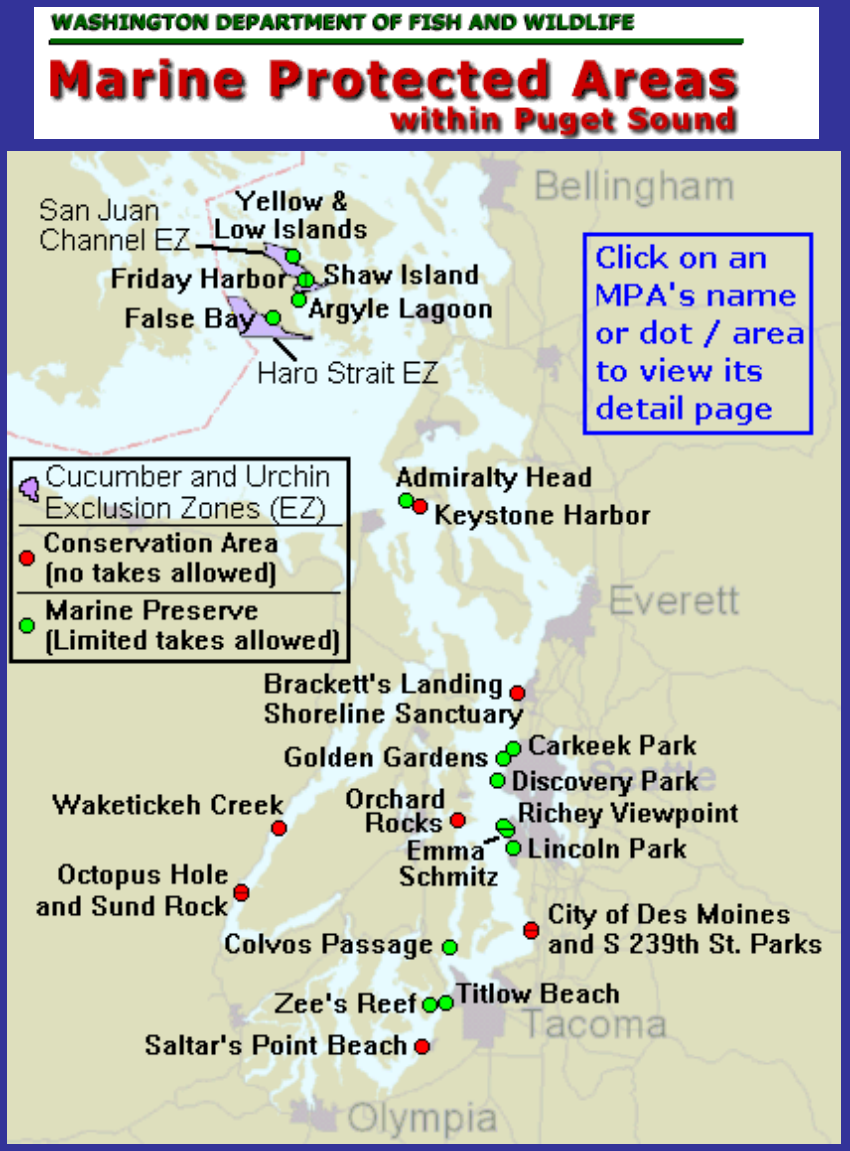
Benthic Habitat characterization

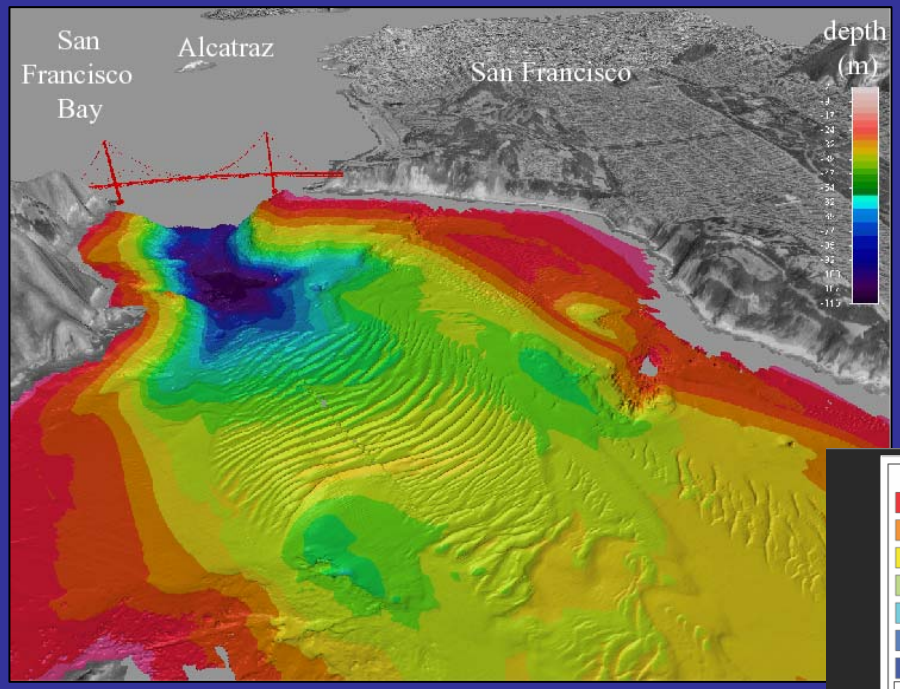


Designation and management of marine protected areas

Central CA marine protected areas







Monitoring change - Natural and human-induced

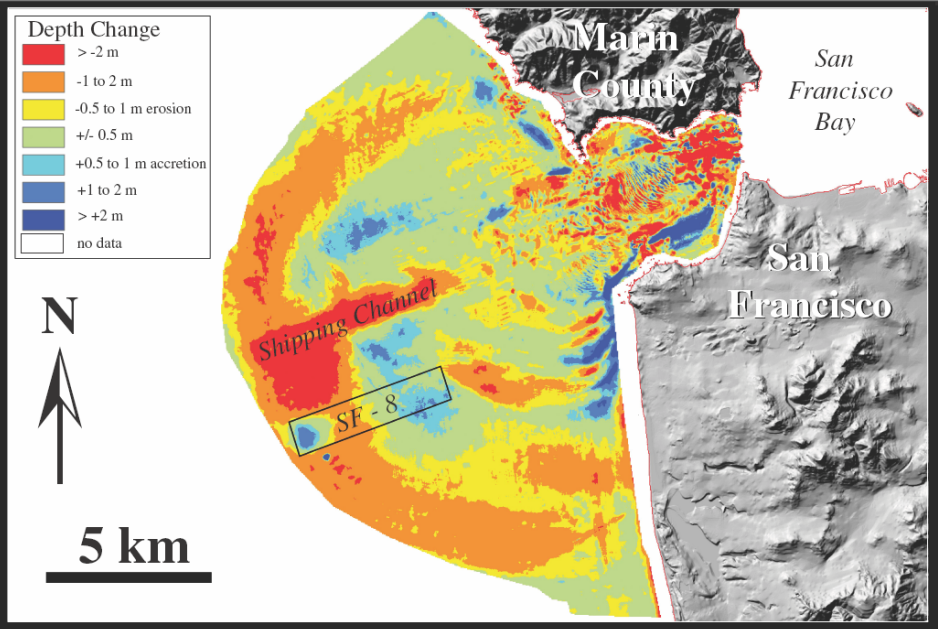
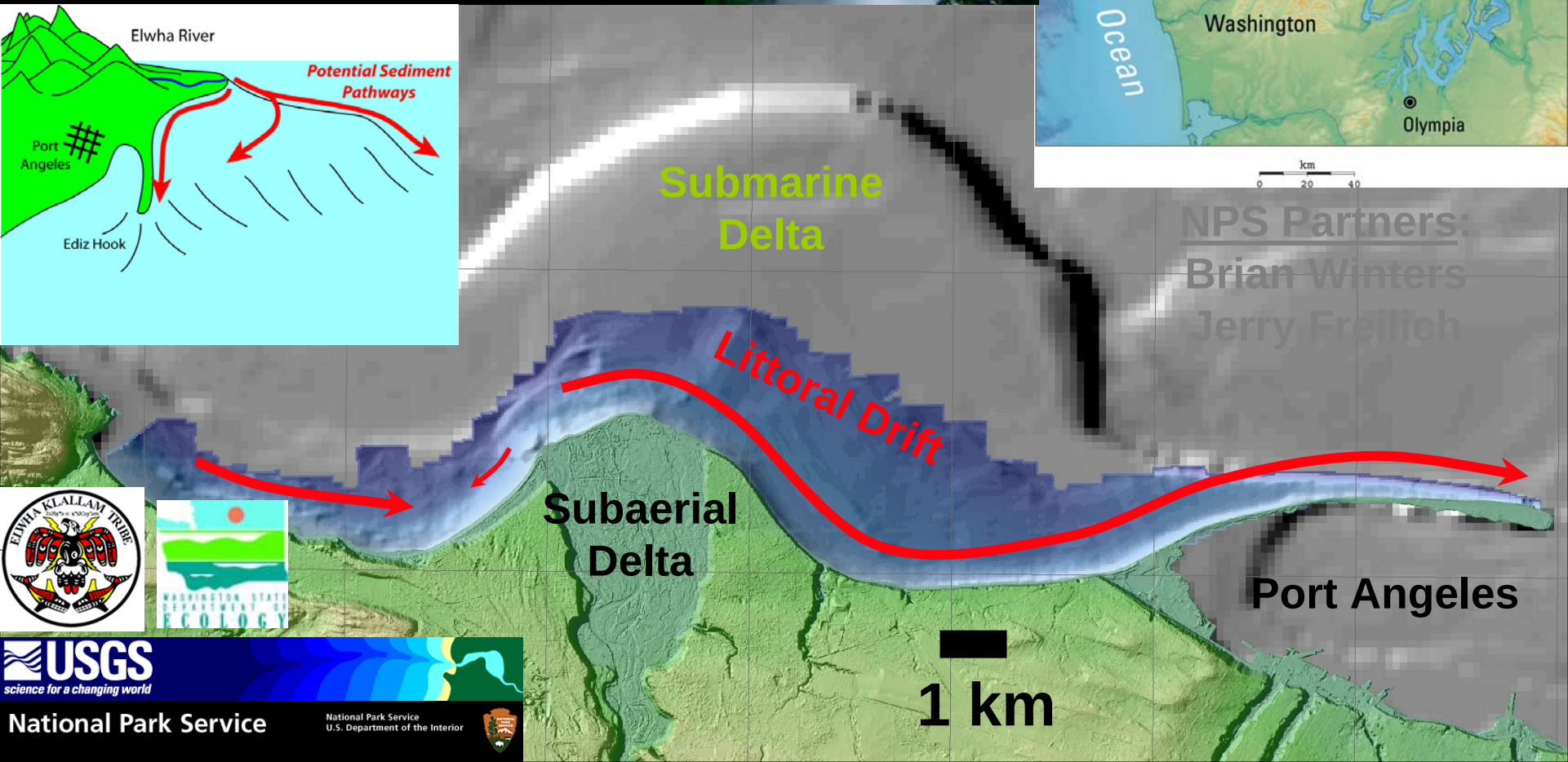


Figure 6. Difference map between the 1956 NOAA NOS survey and the multibeam survey completed in 2005.

San Francisco Bight Coastal Processes Study

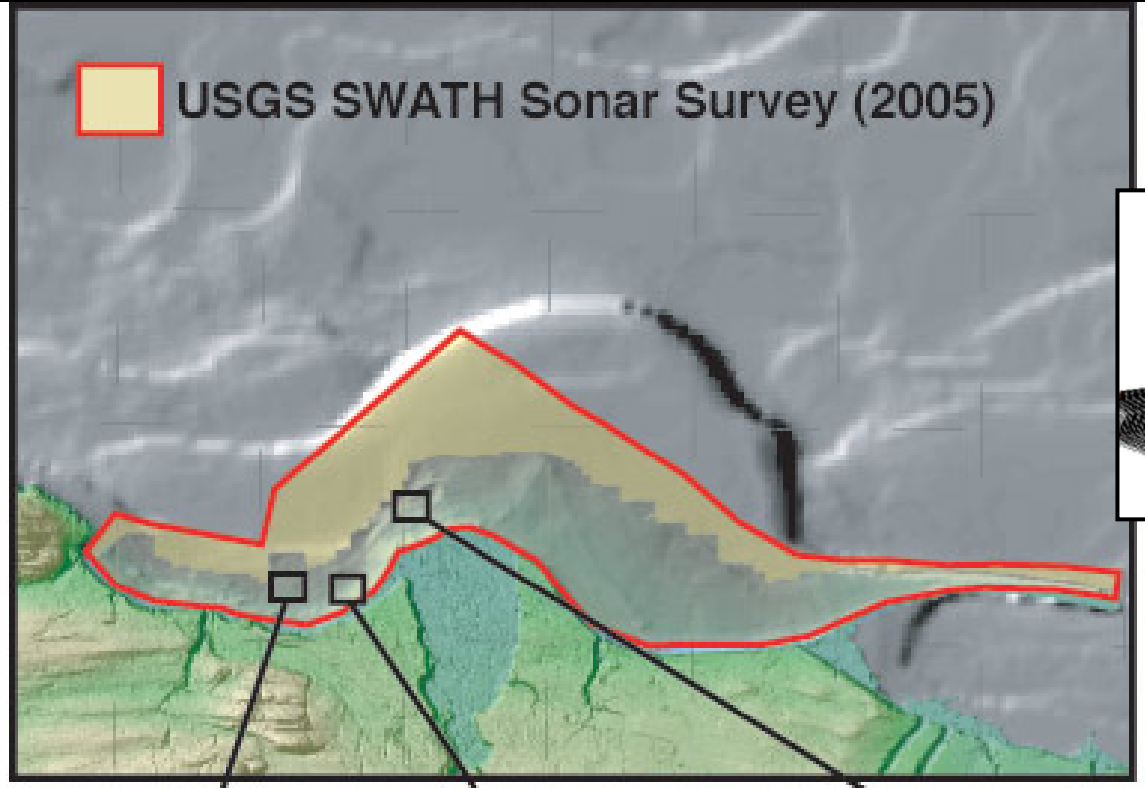
Elwha River Restoration Project

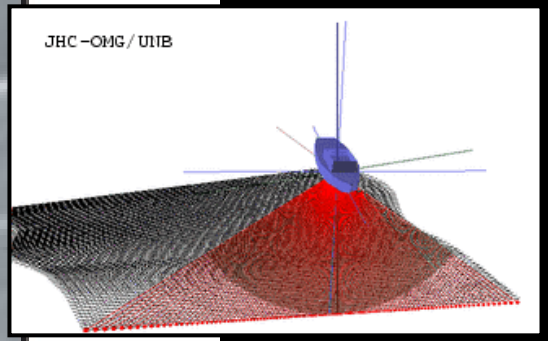
Dam Removal as Nearshore Restoration



NPS Partners:
Brian Winters
Jerry Freilich

National Park Service
U.S. Department of the Interior





Dominated by Coarse Sediment

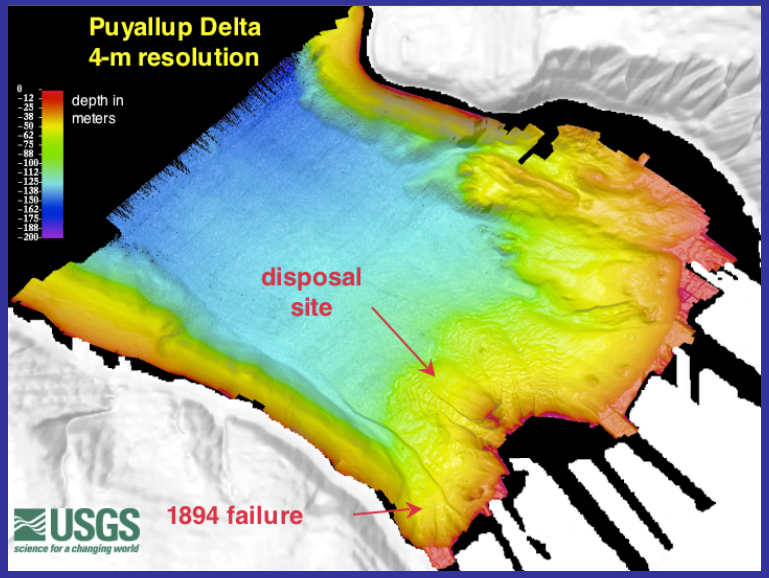
Boulders with Sand & Gravel

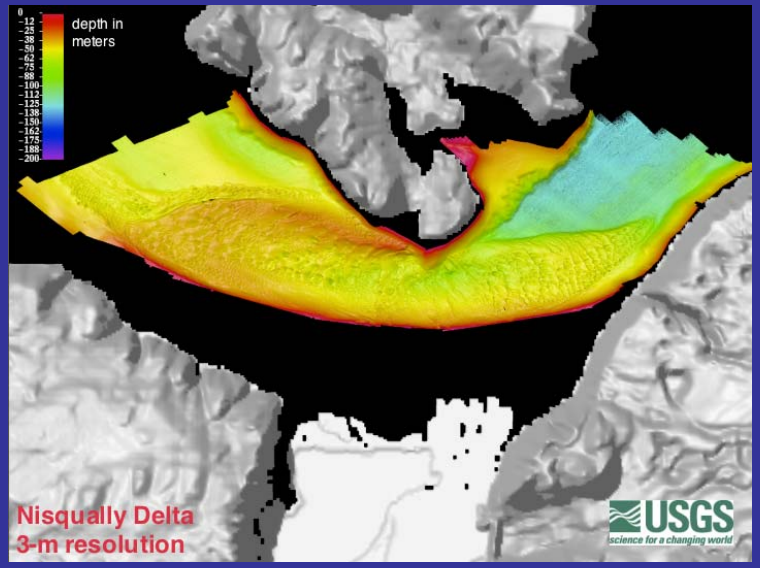
Bedrock Reef

Mixed Sand & Gravel

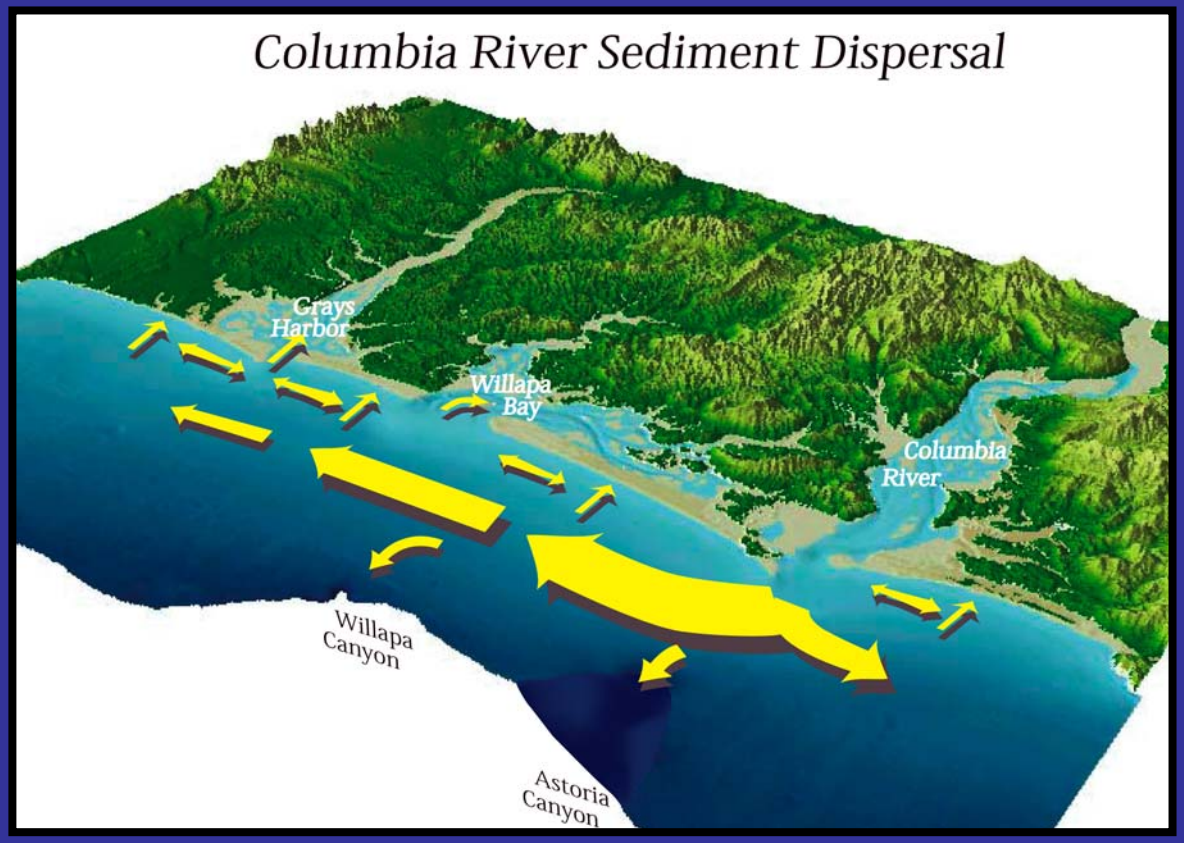
Coastal processes

Framework for understanding sediment and contaminant transport



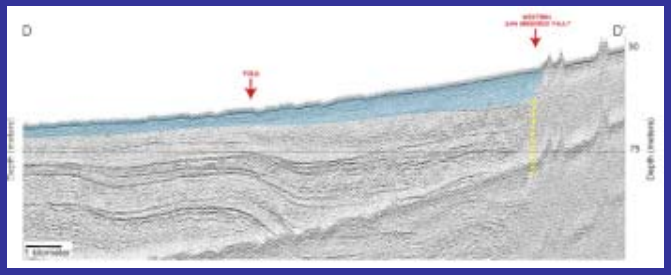


Regional sediment management



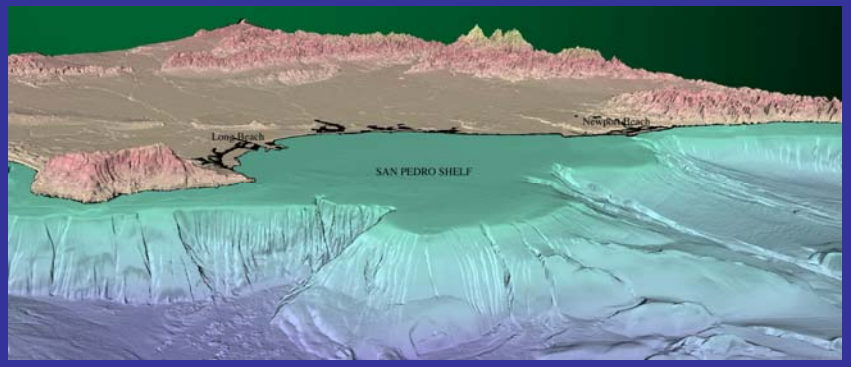
Sediment supply and transport

Coastal erosion

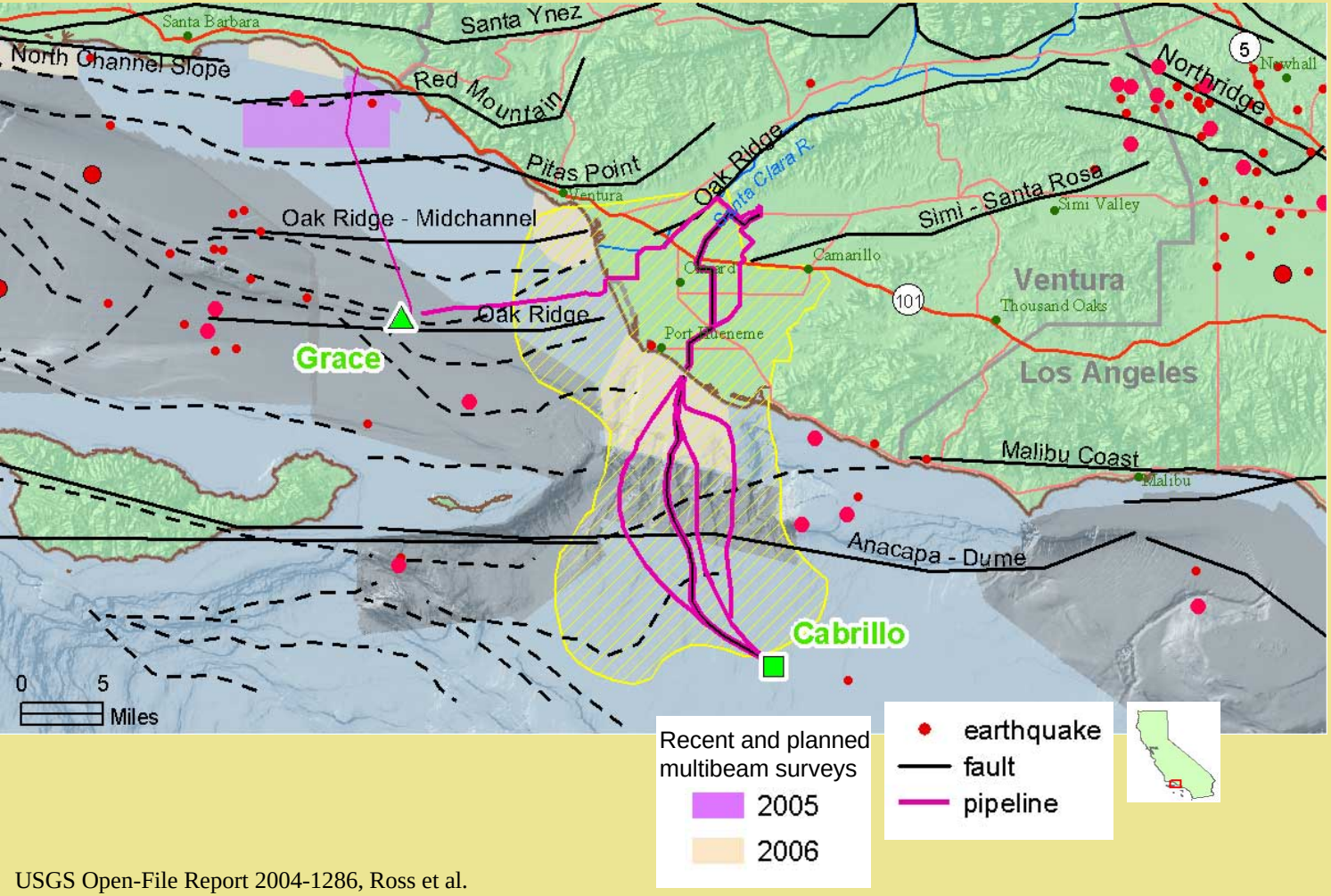


Offshore sand

Offshore development - unconventional energy, oil/LMG facilities, aquaculture, sewage outfalls, cables, pipelines, and more



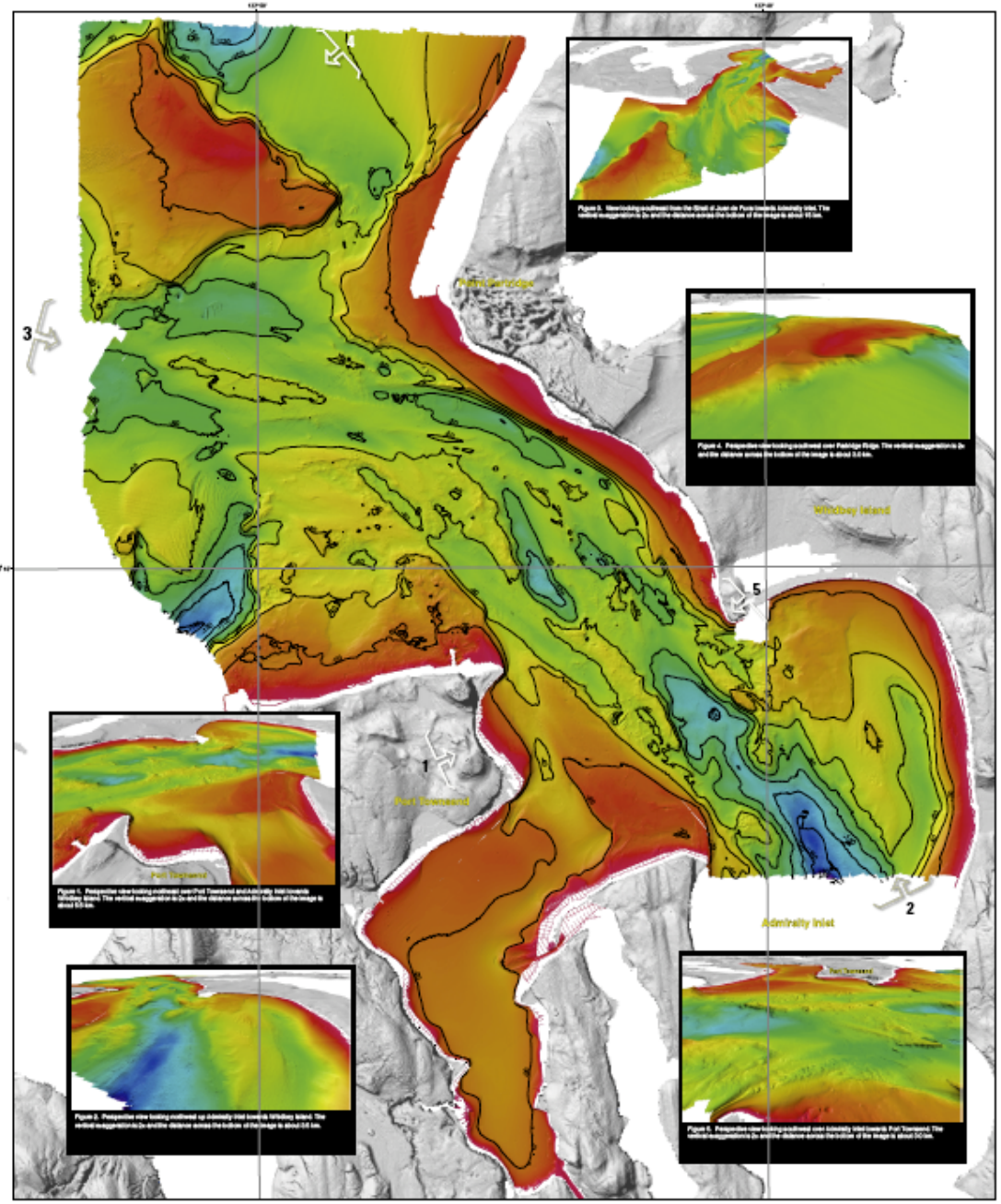
To aid in the consideration of offshore LNG facilities, the USGS prepared a report summarizing potential geologic and seismic hazards affecting coastal Ventura County.

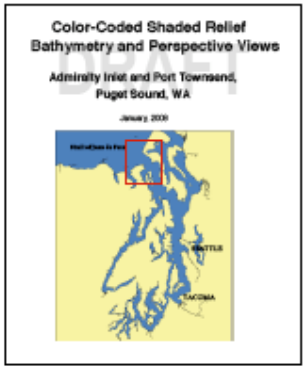


Hazards Considered:

- Earthquake history
- Ground rupture along faults
- Seismic shaking
- Ground failure and liquefaction
- Submarine landslides
- Turbidity currents and debris flows
- Tsunamis from earthquakes and landslides

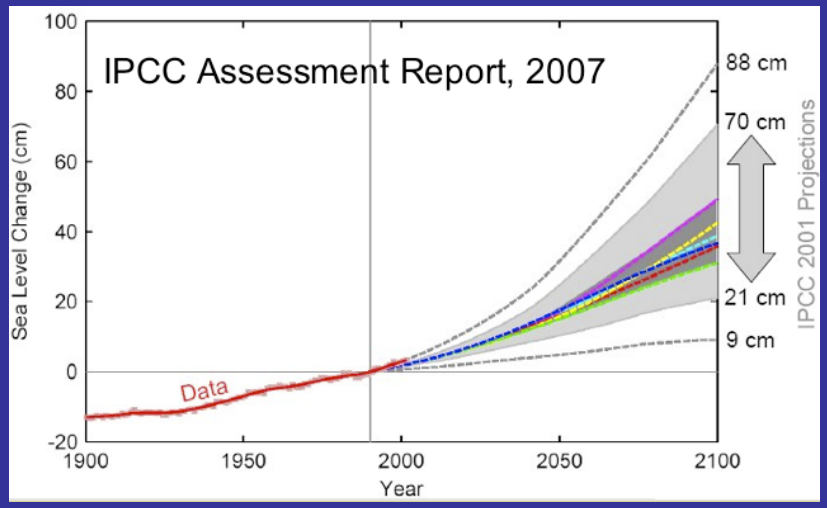
USGS Open-File Report 2004-1286, Ross et al.

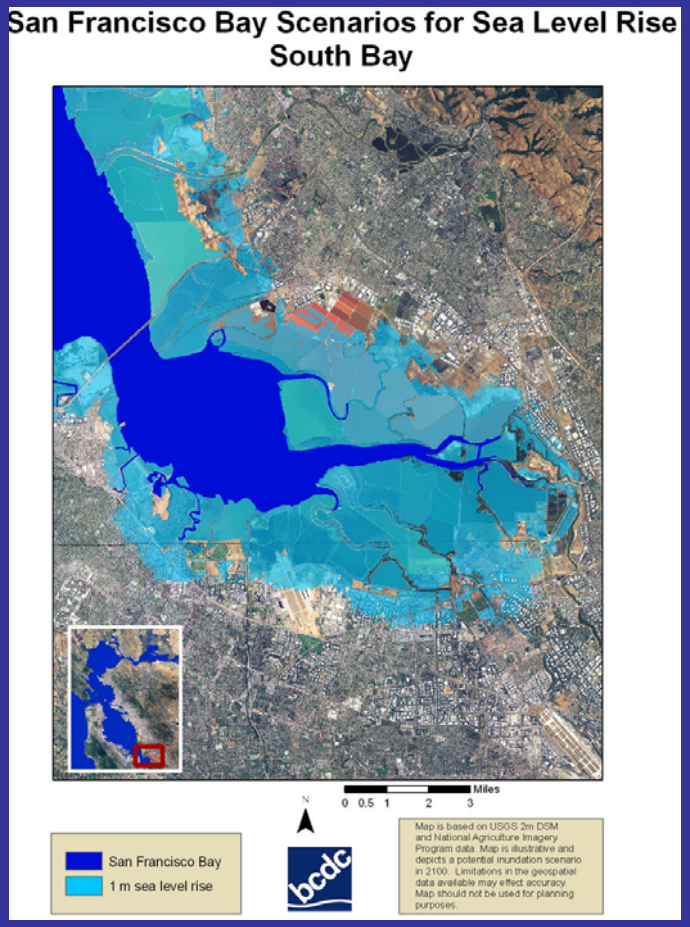




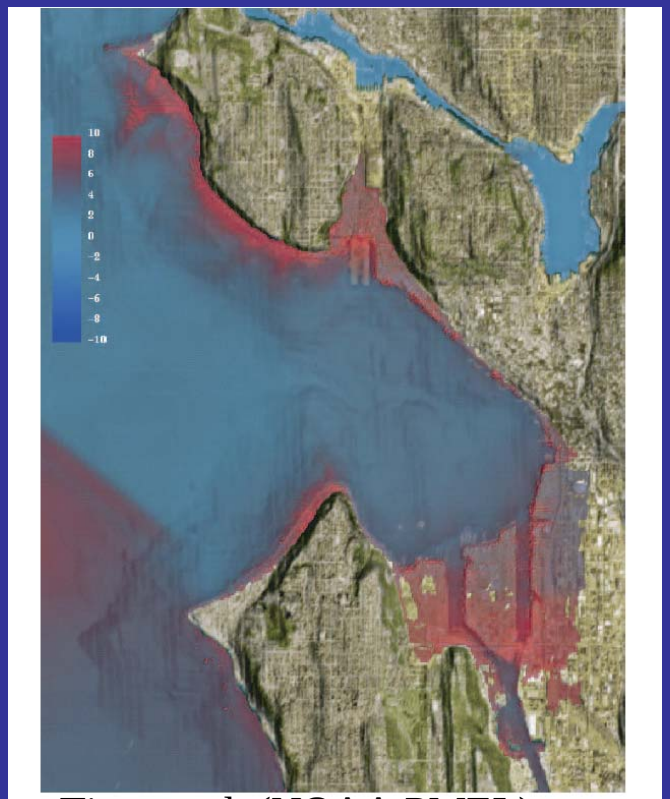
Earthquake and tsunami sources - Hazard Assessment

Inundation modeling and hazard assessment - coastal storms. “wetland squeeze,” and other sea-level rise impacts



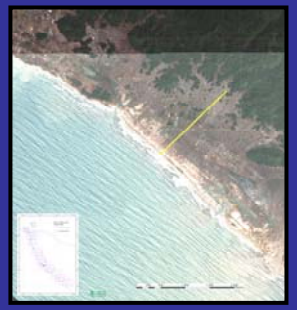


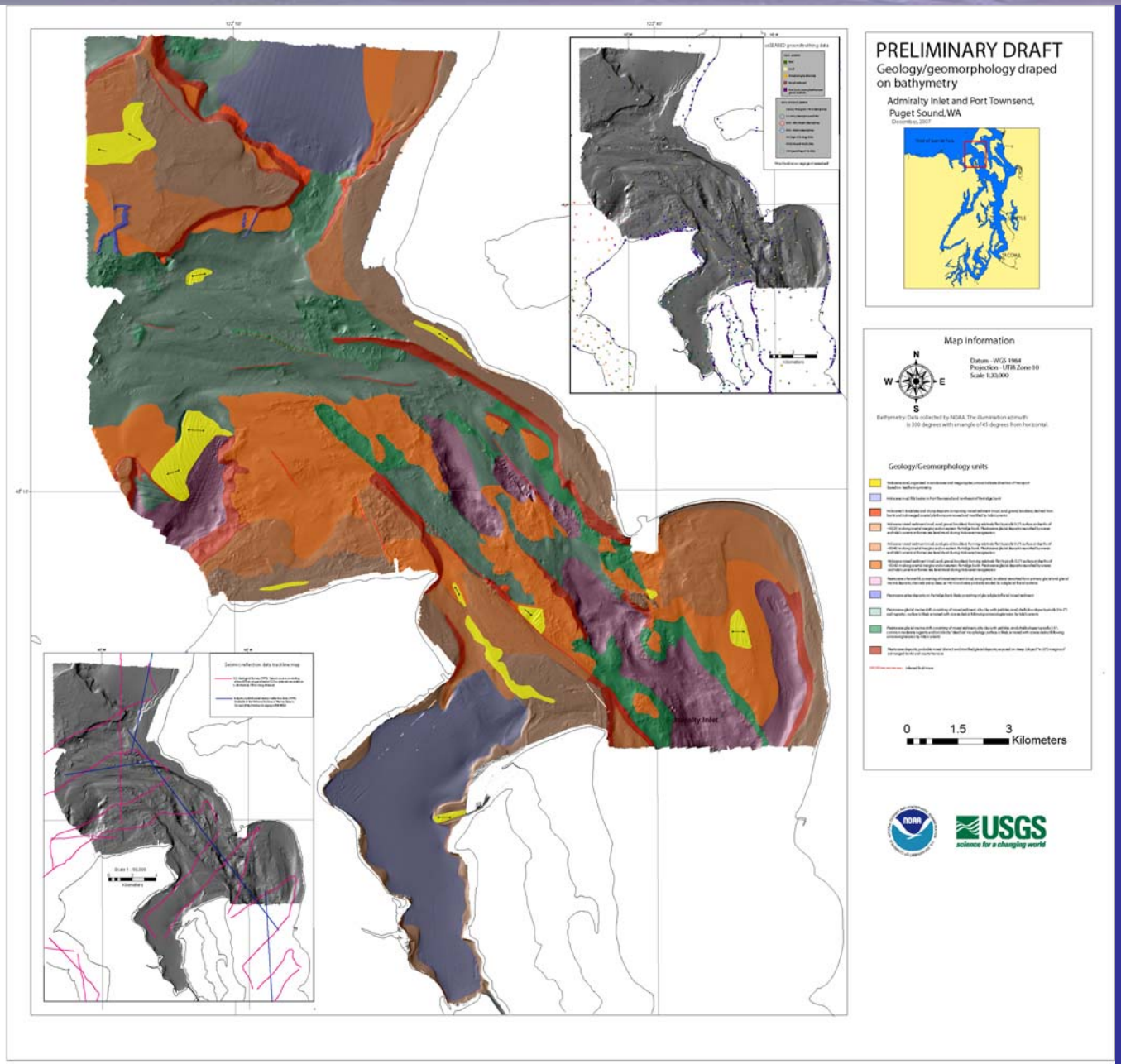
Tsunami inundation modeling and coastal change



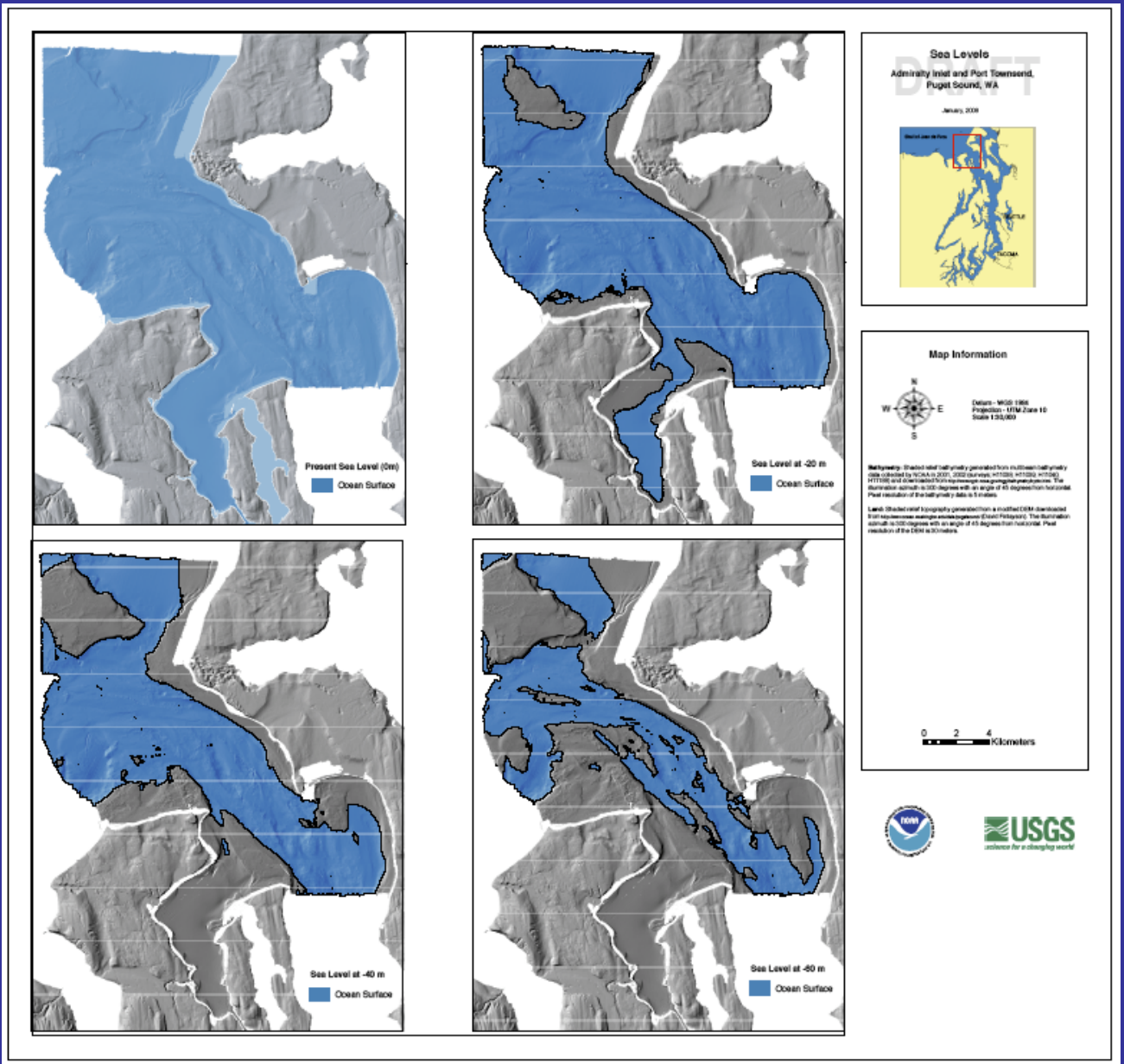
Titov et al. (NOAA PMEL)

Figure 4: Distribution of the maximum computed wave heights in Elliott Bay and runup at Seattle coastlines (in meters above MHW).





Understanding geologic history and change



Understanding geologic history and change

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