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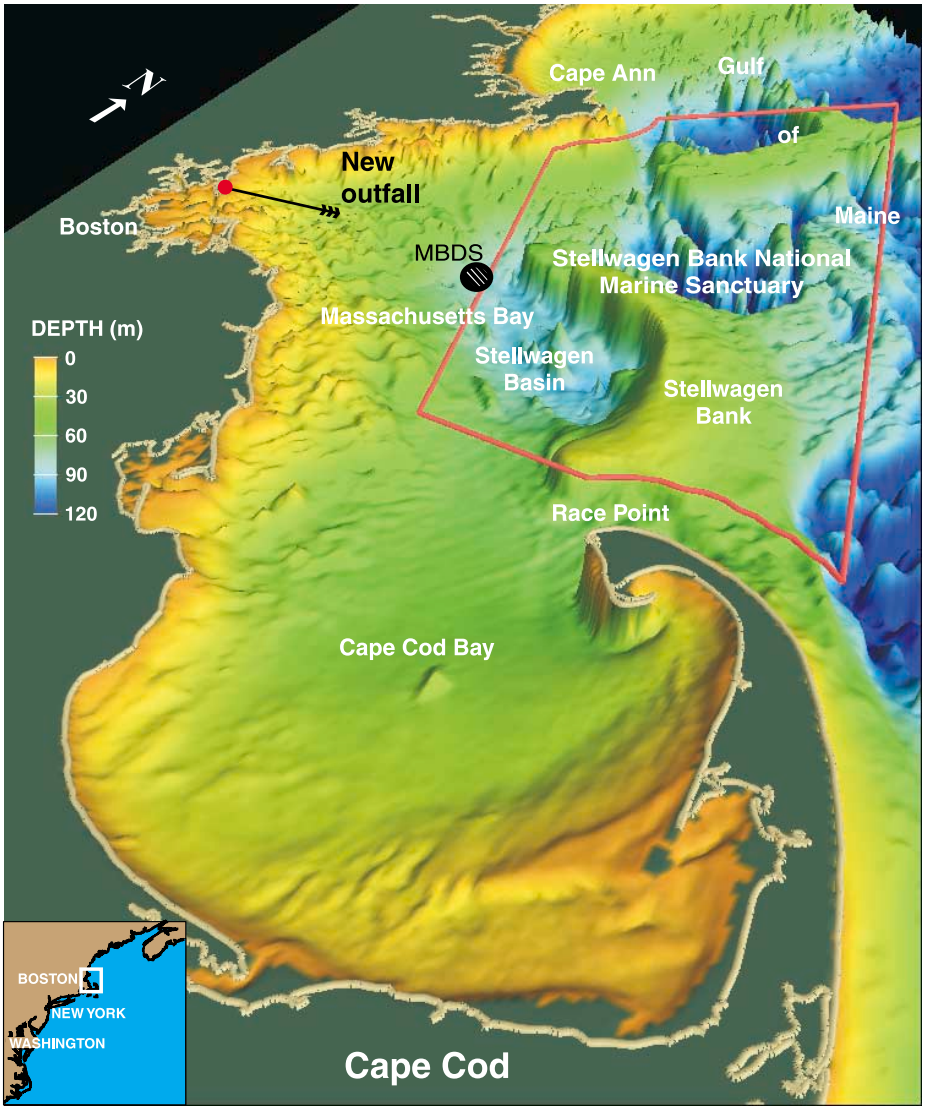
U.S. Geological Survey
Coastal and Marine Geology Research—
Recent Highlights and Achievements

U.S. GEOLOGICAL SURVEY CIRCULAR 1199



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

Cover: Perspective map of Massachusetts Bay and Cape Cod Bay showing the complex underwater topography. From U.S. Geological Survey Fact Sheet FS–172–97. The discharge of treated sewage effluent from the Boston metropolitan area is being relocated from Boston Harbor to a new site 15 kilometers offshore in Massachusetts Bay. Detailed geologic maps and circulation modeling provided by the USGS were used in selecting the new outfall location; see p. 7.

U.S. Department of the Interior
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U.S. Geological Survey Coastal and Marine Geology Research—Recent Highlights and Achievements

By S. Jeffress Williams, Peter Barnes, and Ellen J. Prager

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PREFACE

To ensure that the U.S. Geological Survey (USGS) is prepared to meet society's need for scientific information, the USGS has developed a scientific strategy to address the complex earth science issues that the Nation and the world are likely to face in the next decade. As part of that strategy, the USGS Coastal and Marine Geology Program has large-scale national and regional research projects that focus specifically on environmental quality, geologic hazards, natural resources, and information transfer. These themes parallel and complement the goals of the USGS science strategy.

This Circular highlights recent scientific findings, products, and activities of the USGS Coastal and Marine Geology Program. Research results as highlighted here play a vital role in the USGS endeavor to understand human interactions with the natural environment and to determine how the fundamental geologic processes controlling the Earth work. The scientific knowledge acquired through USGS research, assessment, and monitoring is critically needed by planners, government agencies, and the public. Effective communication of the results of this research will enable the USGS Coastal and Marine Geology Program to play an integral part in assisting the Nation in responding to the pressing earth science challenges of the 21st century.

The list on the next page hints at the variety of recent activities described in this Circular.

S. Jeffress Williams, Coordinator
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Peter Barnes, former Associate Coordinator
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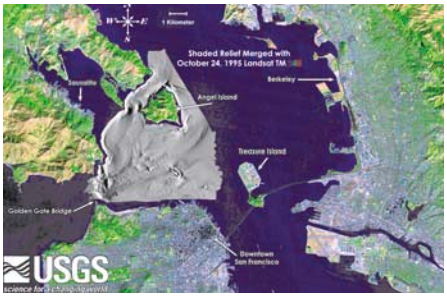
Damage from the tsunami that hit Papua New Guinea on July 17, 1998. Computer modeling by the USGS may help predict future tsunamis. See p. 18.

The SWASH (Surveying Wide Area of Shorelines) system, developed by the USGS for accurate measurements of shoreline position using recent advances in the Global Positioning System (GPS). See p. 15.



Multibeam map of the underwater topography of west-central San Francisco Bay merged with a Landsat image. The map was prepared by the USGS and its partners to help understand sea-floor processes and find safe disposal sites for dredge materials. See p. 10.

Scientists from the U.S. Geological Survey's Coastal and Marine Geology Program–

- studied El Niño-induced storm erosion and landslides along California's coast. The USGS is providing information that will help prevent loss of land and property during future El Niño events.

- went to Papua New Guinea in the wake of one of the most devastating tsunamis ever **(top figure)** to learn how and why the tsunami occurred so that, in the future, coastal communities worldwide can be warned of and better prepared for tsunamis.

- developed a low-cost, easily deployed, and highly accurate research system, called SWASH **(middle figure)**, to measure and monitor beach erosion and long-term change and to rapidly assess storm impacts on the shoreline.

- completed scientific mapping of the sea floor, sediments, and biologic habitat in areas such as Massachusetts Bay, Stellwagen Bank Marine Sanctuary, Monterey Bay Marine Sanctuary, Long Island Sound, and San Francisco Bay **(bottom figure)**. These maps enable local, State, and Federal managers to make informed decisions about waste disposal, marine reserves, resource use and conservation, navigation hazards, and dredging operations.

- led the scientific field in the study of coral reefs in Hawaii and the Florida Keys, gas hydrates, and ground-water flow and developed a multi-agency hurricane response team to study storm impacts in coastal environments.

Access to general information about the USGS can be obtained through the World Wide Web at http://www.usgs.gov. More detailed information on projects, data, maps, and other products by the Coastal and Marine Geology Program is referenced throughout this Circular or can be found at http://marine.usgs.gov.

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CONVERSION FACTORS

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch
meter (m)	3.281	foot
kilometer (km)	0.6214	mile
nautical mile	1.852	kilometer
	Area	
hectare (ha)	2.471	acre
square kilometer (km^2)	0.3861	square mile

INTRODUCTION

U.S. Geological Survey
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COASTAL AND MARINE ISSUES

The U.S. Geological Survey is the Nation's premier earth science agency, responsible for providing credible, objective, and significant scientific information to improve and protect the quality of life on Earth and contribute to a future of wise economic development, sustainable resource use, and environmental preservation. Within the Coastal and Marine Geology Program, the USGS focuses its efforts on issues the Nation faces in coastal and marine environments, including the Great Lakes.

Today, more than half of all Americans live within an hour's drive of the coast; by the year 2010, this is expected to increase to an astounding 75 percent. In addition, one out of every six jobs in America is related to or associated with the marine environment. As human populations increase, particularly within the coastal zone (fig. 1), so do their impact, resource needs, and vulnerability to natural hazards.

Pollution within coastal bays, particularly in areas of urban development, has already threatened human health, damaged fragile environments, hurt the fishing industry, and curtailed recreational activities. Wetlands, coral reefs, and mangroves play a vital role in the coastal ecosystem, but they are vulnerable habitats. Louisiana is losing as much as 75 square kilometers of its wetlands each year due to both natural and human-induced change. Coral reefs, which some consider the "canary of the seas," are showing signs of global decline and may signal an overall trend towards ocean degradation.

Figure 1. Dense populations and development along barrier islands like the Florida Gulf Coast area shown here are vulnerable to hazards from coastal erosion, storms, and sea-level rise. USGS photograph.

Although demand is steadily increasing, supplies of drinking water, sand for construction and beach replenishment, and energy resources are all in decline. Denser populations along the shore leave more communities vulnerable to hazards from coastal erosion, catastrophic storms, landslides, and tsunamis. In Hawaii, nearly 30 km of Oahu's beaches have been lost due to erosion over the last century. In 1997 and 1998, El Niño-related storms and major hurricanes, such as Georges and Mitch, caused enormous loss of life and billions of dollars in damage within the coastal zone.

PROGRAM RESEARCH

This Circular contains highlights of USGS Coastal and Marine Geology Program research organized under the following themes of national importance:

- Environmental quality and preservation
- Natural hazards and public safety
- Natural resources
- Information and technology

A final section summarizes future research needs.

COOPERATORS, PARTNERS, AND CLIENTS

The USGS is committed to providing other Federal and State agencies, industry, the public, and the scientific community with the most relevant, credible, and objective scientific information possible. To best utilize the expertise and technology available today, the USGS works with other government agencies, industry, academia, and organizations to form cooperative partnerships in earth science research and technology development. The highlights include the names of many cooperators.

FACILITIES AND RESEARCH AREAS

The 250 scientists and support staff of the USGS Coastal and Marine Geology Program work at three regional centers: Menlo Park, Calif.; St. Petersburg, Fla., and Woods Hole, Mass. Facilities are co-located with other Federal and academic institutions to facilitate cooperation and to share expertise and resources. Figure 2 shows the

locations of the three centers and areas where most program research is carried out.

Although the program's primary focus is on coastal, estuary, and continental shelf regions, studies encompass the Great Lakes and offshore deep-ocean areas within the U.S. Exclusive Economic Zone (EEZ). The EEZ was created on March 10, 1983, when President Reagan declared an expansion of the United States' sovereign rights to all natural resources within a zone extending to 200 nautical miles beyond the shoreline. The proclamation provided a mandate for exploration and resource utilization. The program has also done research in some international areas, which provide opportunities to understand fundamental marine and coastal geology.

INFORMATION SOURCES

Access to general information about the USGS can be obtained through the World Wide Web at http://www.usgs.gov. More detailed information on projects, data, maps, and other products by the Coastal and Marine Geology Program is referenced throughout this Circular or can be found at http://marine.usgs.gov.

For additional information about projects and products described in this Circular, contact one of the people listed below.

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Figure 2. Locations of the headquarters in Reston, VA, and the three centers for the USGS Coastal and Marine Geology Program and areas where most program research is carried out.

PROGRAM HIGHLIGHTS

Environmental Quality and Preservation Theme

The goal of research under the theme of environmental quality and preservation is to aid in the preservation of coastal and marine habitat, enable long-term sustainable resource use while maintaining environmental quality, and anticipate possible environmental impacts of climate change. The USGS Coastal and Marine Geology Program is providing critical information about the sea floor, sediments, ocean currents, habitat distribution, contamination, sea-level rise, and geologic history in areas including urban estuaries, fragile environments, such as wetlands and coral reefs, and marine reserves and other important biologic habitats.

URBAN ESTUARIES

Coastal bays within highly developed and populated regions provide invaluable resources but face mounting environmental pressures. Coastal managers, policymakers, and commercial and recreational users need information about the sea floor, sediments, ocean currents and waves, and circulation in urban estuaries to address problems associated with dredging, waste disposal, resource assessment, rising sea level, navigation hazards, and the preservation of important biologic habitats. Results of recent and ongoing Coastal and Marine Geology Program research in urban estuaries demonstrate the practical applicability and societal need for earth science information.

MASSACHUSETTS BAY

The discharge of treated sewage effluent from the Boston metropolitan area is being relocated from Boston Harbor to a new site 15 km offshore in Massachusetts Bay (fig. 3). Detailed geologic maps and circulation modeling provided by the USGS were used in selecting the new outfall location.

On the basis of USGS mapping of sediment type, two regions close to the new disposal site were identified as areas sensitive to change and potential contamination. Two long-term stations were established in these areas to monitor environmental change. Figure 3 shows the complex underwater topography of the region and the new outfall location.

USGS scientists simulated circulation in Boston Harbor and Massachusetts Bay based on wind, river runoff, offshore discharges, surface temperature, tides, and sea-level fluctuations. Model results suggest that with the relocation of the sewage outfall, effluent concentrations in

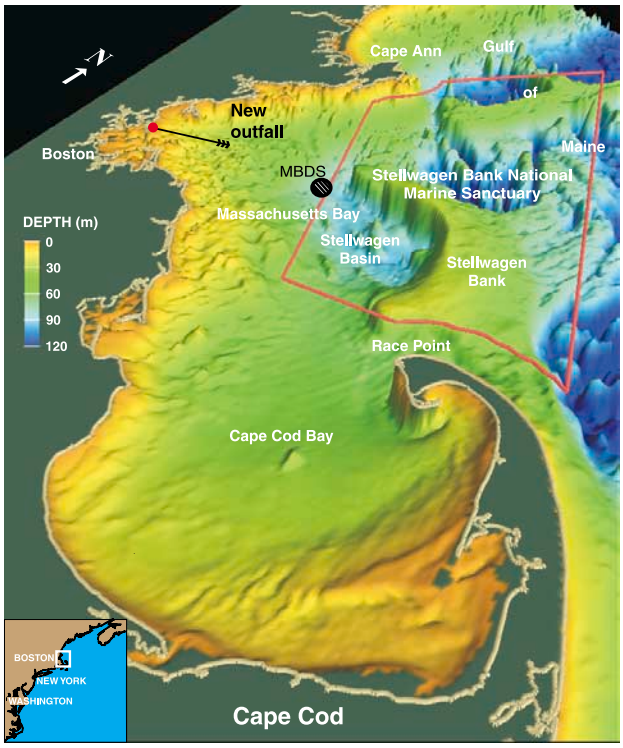

Figure 3. Perspective map of Massachusetts Bay and Cape Cod Bay showing the complex underwater topography and the new outfall location east of the Deer Island treatment plant (red dot). From Butman and others (1998). MBDS, Massachusetts Bay disposal site, which receives material dredged from the harbors of Boston and nearby cities.

Boston Harbor will be greatly reduced without significantly increasing concentrations in Massachusetts Bay. Figure 4 shows a model comparison of winter near-surface effluent concentrations at the existing and new outfall sites.

USGS collaborators and clients in the Massachusetts Bay Study include the U.S. EPA, the National Oceanic and Atmospheric Administration (NOAA), the Massachusetts Environmental Trust, the Massachusetts Water Resources Authority, the U.S. Coast Guard, and Woods Hole Oceanographic Institution. A CD-ROM (compact disc, read-only memory) containing the Massachusetts Bay seafloor map is available as USGS Digital Data Series DDS–3 (Bothner and others, 1992).

NEW YORK–NEW JERSEY REGION

The USGS and its partners have mapped (1) the sea floor along the southern shore of Long Island and off New

York City by using sidescan sonar and (2) the undersea Hudson Shelf valley and adjacent shelf off New Jersey by using multibeam surveys. These remotely sensed data were combined with high-resolution seismic-reflection profiles, sediment samples, and visual observations to characterize the sea floor, to study sediment transport, to define biological habitats, and to locate areas affected by human activities. Partners include the U.S. Army Corps of Engineers, Texas A&M University, the State University of New York at Stony Brook, the University of New Brunswick, the Canadian Hydrographic Service, Wesleyan University (Connecticut), and Coastal Carolina University.

LONG ISLAND SOUND

The USGS, in cooperation with the Connecticut Department of Environmental Protection and the U.S. EPA, has mapped the distribution of bottom sediments in Long Island Sound (fig. 5). This information provides managers insight into the long-term fate of contaminants that are associated with fine-grained materials, areas of erosion versus deposition, potential sites for disposal of dredge spoil, and regional sand and gravel resources.

Additional studies within the region are being conducted in collaboration with the U.S. Army Corps of Engineers, the Canadian Hydrographic Service, and

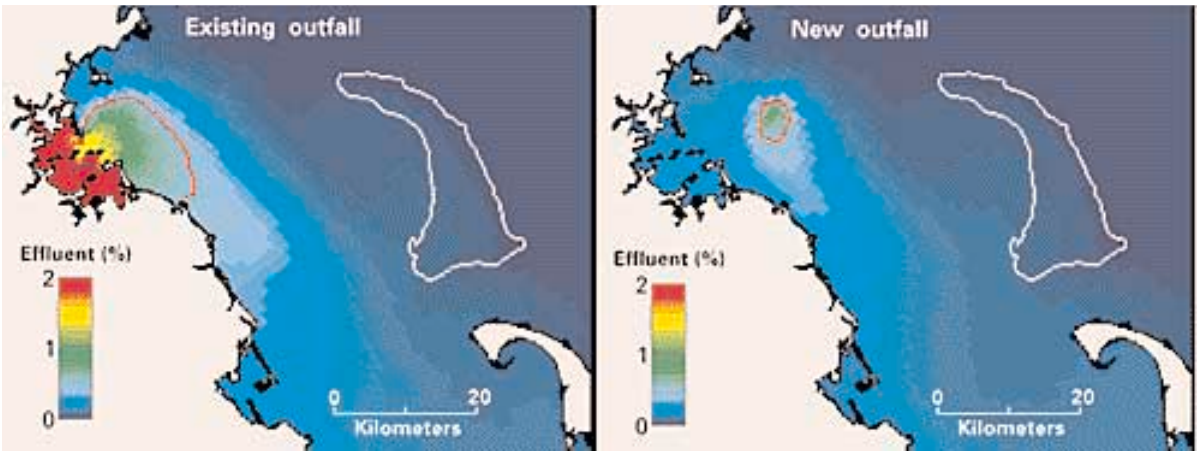

Figure 4. Model comparison of winter near-surface effluent concentrations at the existing and new sewage outfall sites in Massachusetts Bay. From Signell (1998). The red line indicates a concentration of 0.5 percent (200-fold dilution of effluent), which is approximately the level at which nutrient levels released in the effluent are comparable to background variability. With the existing outfall locations, high effluent concentrations are found within Boston Harbor and along the coastline immediately south. With the new outfall location, high concentrations are found only within a few kilometers of the outfall, concentrations are dramatically lower in Boston Harbor, and concentrations in most of Massachusetts Bay (including the region near Stellwagen Bank) are not significantly changed from their existing low levels. The white outline indicates the location of Stellwagen Bank.

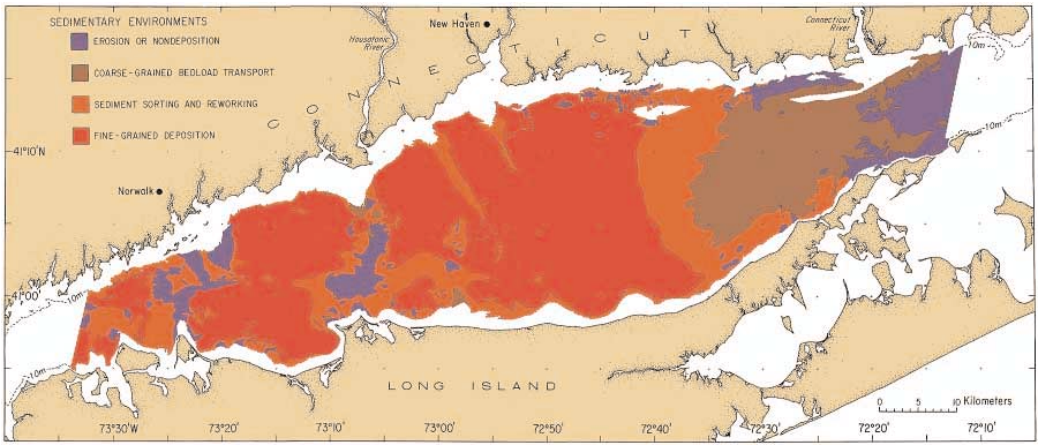

Figure 5. Reconnaissance map showing the distribution of sedimentary environments across the Long Island Sound estuary. Sedimentary environments have been inferred from sonograph patterns, sediment samples, video-camera observations, and modeled current and wave data. The 10-meter depth contour delineates the shoreward limit of the study area along the Connecticut and Long Island coasts. From Knebel (1998).

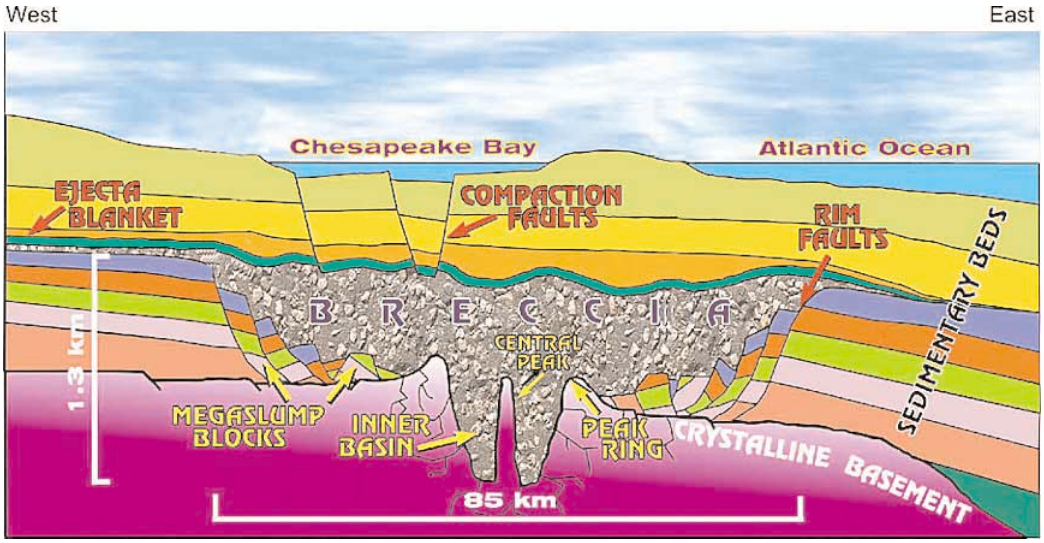

Figure 6. Cross section showing main features of the Chesapeake Bay impact crater. From Poag (1998).

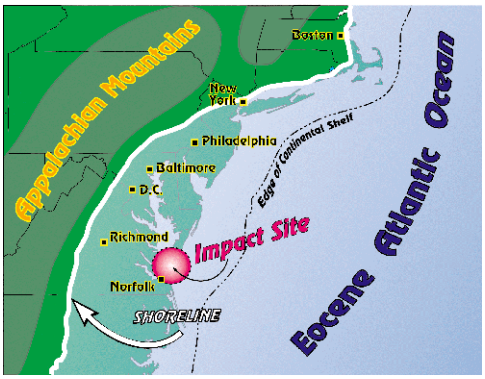

Figure 7. Location of Chesapeake Bay bolide impact relative to modern cities and the ancient shoreline when the bolide hit. From Poag (1998).

several universities to examine the geologic controls on shoreline erosion, to identify areas of recent and past dredge spoil disposal, and to assess sediment transport patterns.

CHESAPEAKE BAY

The USGS is working with Federal, State, and academic partners to understand the complex geologic and sea-level history within the Chesapeake Bay. Results so far have proven surprising and have important implications for coastal zone management and resource use in the region.

SEA-LEVEL CHANGES

The USGS role in sea-level research is national in scope and ranges from remote sensing and geologic mapping of wetlands to studies of coastal erosion and evidence of older shorelines in the geologic record. Both short- and long-term environmental records are taken into account. One goal is to be able to determine the rate of sea-level change on century to millennium time scales in order to compare consistency and agreement (or lack thereof) with the decadal and annual records of the tide gages.

In the Chesapeake Bay, the USGS is conducting research to reconstruct the detailed pattern of relative sea-level change during the last 6,000 to 8,000 years. Few modern data are available from which to establish baselines to compare with the ongoing rate of sea-level rise. Current research efforts focus on the central region of the Chesapeake Bay. For example, coring studies of marshes and tributary creeks in the Patuxent River basin are providing sedimentary and biological records of rising sea level.

Scientists at the USGS are also developing a detailed record of relative sea-level rise within the Chesapeake Bay area to assist local, State, and regional managers in assessing the potential for flooding and coastal erosion.

IMPACT CRATER

A massive impact crater has been identified beneath the southern part of Chesapeake Bay about 200 km southeast of Washington D.C. (figs. 6, 7). Evidence of the crater comes from two main sources of data on the rock and sediment structure: (1) seismic-reflection profiles collected by Texaco, Inc., the USGS, and the National Geographic Society and (2) sediment cores drilled by the USGS and the Virginia State Water Control Board. The impact crater was created by a comet or asteroid (bolide), some 3 to 5 km across, that struck the Earth approximately 35 million years ago.

Study of the giant crater beneath Chesapeake Bay indicates that breccia within the crater compacted more under subsequent sediment layers than did partially

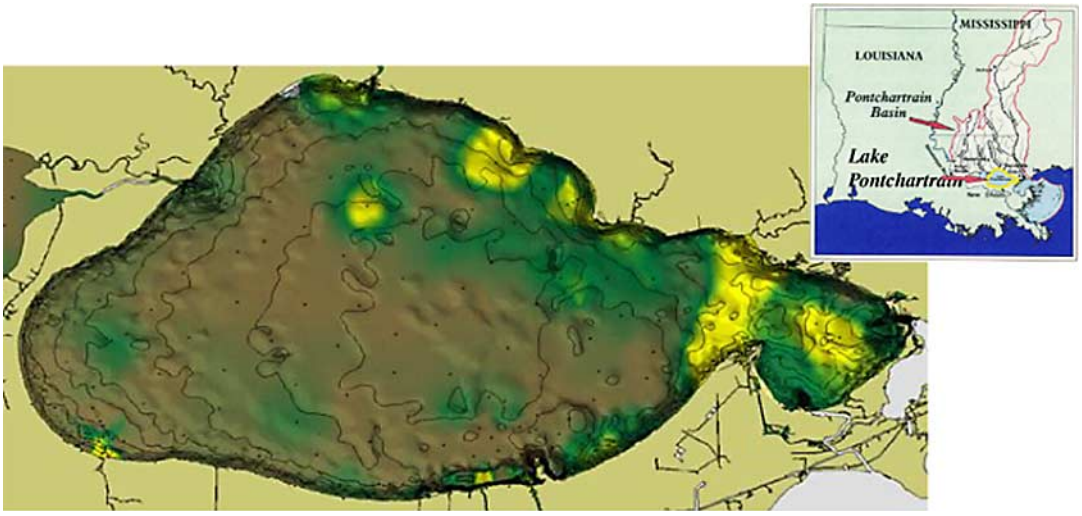

Figure 8. Grain-size distribution in the bottom sediments of Lake Pontchartrain. Color reflects percent sand, with lighter colors indicating a higher sand content. From Manheim (1999).

consolidated deposits surrounding the crater. Crater-related ground subsidence created faults beneath the bay floor, and it may have increased the rate of relative sea-level rise in the region. Furthermore, the crater may have diverted river flow, and it greatly modified all ground-water aquifers in the area. Data suggest that extraordinarily salty water is trapped beneath freshwater resources; thus, care should be taken not to inadvertently drill into lower layers and contaminate the overlying aquifer. The crater investigation also indicates that ground-water use on the Delmarva Peninsula must be especially conservative. More information on this project can be obtained from the Woods Hole Center (p. 4) or the web site at http://woodshole.er.usgs.gov/epubs/bolide/.

LAKE PONTCHARTRAIN

USGS scientists are studying sediment and ground-water contamination, transport processes, and coastal erosion in Louisiana's largest estuary, Lake Pontchartrain. The map of grain-size distribution shown in figure 8 is an example of the results that are being incorporated into an atlas for the area. Studies show that metals tend to accumulate in fine-grained sediments. Research is also being conducted to examine the effects of major discharges, to model lake circulation, to assess the chemical nature and history of the lake bed, and to determine the stability of the local shoreline and associated wetlands. The USGS is working extensively with local partners, including Louisiana's Departments of Natural Resources and Fisheries and Wildlife, the University of New Orleans, Tulane University, the U.S. EPA, the U.S. Army Corps of Engineers, and the Lake Pontchartrain Basin Foundation. This project has received extensive media coverage and is providing critical information to coastal zone managers, policymakers, commercial interests, recreational users, and local communities in Louisiana.

SOUTHERN CALIFORNIA

Recent surveys by the USGS have shown that in Santa Monica Bay, west of Los Angeles, contamination of over 95 percent of the bay has reached levels that will affect biological processes. In collaboration with the city of Los Angeles and the Southern California Coastal Water Research Project, the USGS is conducting research to determine the severity of present contamination levels in the sediments and changes that have occurred over time. Analysis of sediment samples representing the last 100 years suggests that contamination levels were worse in the past and that, overall, conditions are improving. Continued monitoring is planned, and a study of the processes controlling sediment transport in the bay is underway.

SAN FRANCISCO BAY

San Francisco Bay is the largest estuary on the U.S. West Coast and is the site of an extensive USGS program. Scientists are working with numerous partners to provide maps of the sea floor and sediments, to model sediment transport pathways and circulation, to assess historical change and geologic structure, and to monitor nearby wetlands. Figure 9 combines a map of underwater topography in San Francisco Bay with a satellite image; the map is being used to assess hazards to navigation and to locate sites for the safe disposal of dredge materials. Using state-of-the-art instrumentation and communications equipment, the USGS and its partners provide the local community,

researchers, and managers access to real-time information on water levels, currents, salinity, and winds within the bay.

The USGS has recently released a set of maps and interpretations to regional officials and the public for assessing the potential for landslides and debris flows in the area under future El Niño climate conditions. The maps are available on the web at http://wrgis.wr.usgs.gov/open-file/of97-745/.

HAWAII

In the early 1990's, the USGS began working with the U.S. Army Corps of Engineers and the U.S. EPA to study dredge spoil disposal in Mamala Bay off Oahu, Hawaii. Previous sites of dredge material dumping have been identified, and results suggest that currents are probably shifting sea-floor sediments and dredge spoil. Further work is being conducted to assess the impact of dredged materials on local habitats and to determine if dredged materials are being moved toward coral reef areas. More information is available on the web at http://walrus.wr.usgs.gov/mamalabay/.

FRAGILE ENVIRONMENTS

Many areas of the U.S coastline and island territories in the Caribbean and Pacific are lined with highly productive, yet fragile salt marshes, cypress swamps, mangroves, and coral reefs. These coastal environments harbor diverse and abundant wildlife, are critical nursery grounds for numerous commercial fish and shellfish species, provide protection from storms, and supply coastal communities with economic resources. Unfortunately, wetlands and coral reefs are highly vulnerable to the impacts of human activities and natural change. To help preserve these critical environments, the USGS is working to improve our scientific understanding of how natural processes and human influences shape and modify wetlands and coral reef environments.

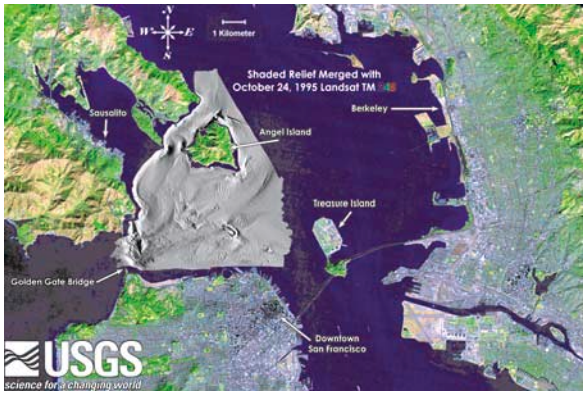

Figure 9. Multibeam map showing underwater topography of west-central San Francisco Bay combined with a Landsat image. From http://terraweb.wr.usgs.gov/TRS/projects/SFBaySonar/main30.html.

WETLANDS

LOUISIANA

Louisiana's 3 million hectares of wetlands are being lost at alarming rates, some 7,500 hectares (75 square kilometers) per year. Along with its Federal, State, and university partners, the USGS has found that a complex combination of natural and human factors contributes to the demise of Louisiana's wetlands. Sea-level rise, storms, sediment starvation, and land subsidence are the main agents of natural wetland loss.

Louisiana's fragile wetlands have been damaged, directly and indirectly, by canals dredged over the past 100 years for navigation and energy exploration (fig. 10). Seasonal flooding that once brought much-needed sediments into the wetlands of the Mississippi River and Atchafalaya River Deltas (fig. 11) and other areas has

Figure 10. Air photograph of canals dredged in Louisiana's wetlands for navigation and energy development; these canals have accelerated wetland loss over the past 50 years. USGS photograph taken in about 1985.

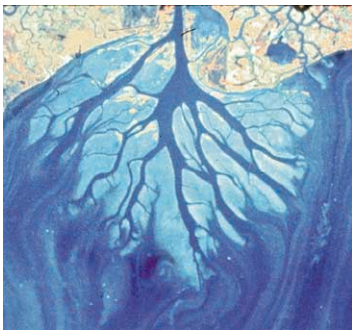

Figure 11. Image of the Atchafalaya River Delta of Louisiana showing accretion and wetland development that have occurred since floods in the early 1970's.

Figure 12. Black-band disease on a brain coral on a reef at Rum Cay in the eastern Bahamas in 1990. This and other types of band diseases can destroy a 200-year-old head in a single summer. From Lidz (1997).

been greatly reduced by levee construction, dams, and rerouted discharges. Canals also allow saltwater from the Gulf of Mexico to flow into once brackish or freshwater wetlands, killing the vegetation. Wetland drainage for development and agricultural purposes is another contributor to wetland loss.

The USGS is working with its Federal and State partners to develop cost-effective methods to mitigate wetland loss and restore the coast. Data on sea-level rise, subsidence, sediment transport, storms, and ocean currents are being used to model future diversions or alterations of the Mississippi River and to assist in other possible solutions, including sediment renourishment (a means to introduce sediment into the wetlands) and the restoration of coastal barrier islands.

FLORIDA

In Florida, USGS scientists are using satellite images to map and understand wetland change. The use of satellite imagery allows scientists and local officials to examine large regions and identify specific problem areas. Scientists can then closely monitor the geologic and physical processes that may be causing wetland loss in problem areas.

CALIFORNIA

Loss of wetlands is also a major problem on the U.S. West Coast. USGS scientists, working in cooperation with Federal and State agencies, have initiated a long-term study and monitoring of the wetlands within the San Francisco Bay area. Of particular interest in this region is the need for sites suitable for the disposal of dredge material. Researchers studied the Sonoma Baylands as a demonstration site; the results suggest that dredge spoil from the Petaluma River contributes only trace levels of contaminants to the wetlands. In a sample taken outside the demonstration dump site, researchers measured significant levels of the pesticide DDT and hydrocarbons; however, they suspect that a nearby agricultural pump and drain are the sources of contamination.

CORAL REEFS

The USGS, in cooperation with the University of South Florida, recently published new maps of the reef and sediment distribution and thickness for a major portion of Florida's coral reef tract (Lidz and others, 1997). Throughout the reef tract, corals are generally perceived as declining and may be vulnerable to diseases like that shown in figure 12. These maps are providing scientists, policymakers, and local community leaders with important information for coral reef management and understanding.

Results of another USGS project in South Florida suggest that the amount of coral fragments in the sand surrounding Florida's reefs can be used as a measure of reef vitality and possibly of regional coral health. Scientists studying sewage disposal and ground-water movement beneath the Florida Keys found that offshore reefs are probably not affected by sewage-contaminated ground water; however, nearshore environments are threatened by polluted discharges.

In nearby Florida Bay, studies of sediment cores and the geochemistry of mollusk shells indicate that major changes in salinity and productivity have occurred during the past two centuries. USGS research suggests that past efforts to drain the Everglades and reduced freshwater inflow are related to these changes in the bay. These measurements are providing engineers and managers with crucial information as they attempt a multi-billion-dollar effort to restore the Everglades and Florida Bay ecosystem.

In Puerto Rico, USGS scientists are studying the recovery of reefs following hurricane damage. Sheltered reefs were found to be little affected, while exposed reefs recovered from one storm only to be damaged by two more hurricanes. Monitoring in Puerto Rico continues in an attempt to better understand the long-term impacts of hurricanes on coral reefs.

In Hawaii, USGS scientists are examining how reefs alter incoming waves and influence sediment transport and beach erosion. In 1998, the USGS held a coral reef workshop in Hawaii and brought together eminent scientists from around the world to discuss the most crucial issues in coral reef research today.

CRITICAL HABITATS AND NATIONAL MARINE SANCTUARIES

The USGS recognizes the importance of preserving special coastal and marine areas that are of critical biologi-

cal significance and offer unique economic and recreational values (fig. 13). Therefore, a USGS priority is to provide information to managers, policymakers, and the public about National Marine Sanctuaries and other essential habitats. The following projects represent the beginning of an ongoing effort to help preserve our Nation's critical coastal and marine environments.

MONTEREY BAY, CALIFORNIA

In Monterey Bay National Marine Sanctuary, California, the USGS and its Federal, State, and local partners are mapping the sea-floor topography and the distribution of sediments and biologic habitats. Researchers study how sediments are eroded, deposited, and transported through the sanctuary; this information will help managers to protect habitats in the marine sanctuary.

FLORIDA KEYS AND OCULINA BANK OFF FLORIDA

Numerous USGS projects are underway in the Florida Keys National Marine Sanctuary and nearby Florida Bay (see previous section on "Fragile Environments"). Plans are also being made to map coral reefs in the Keys and assess their growth, health, and prospects for future survival. In conjunction with NOAA's National Marine Fisheries Service (NMFS), the USGS has surveyed a deepwater coral reef habitat off Florida's east coast. Recognized as an area of special significance by the South Atlantic Fishery Management Council, Oculina Bank has been mapped, and areas of former and current coral growth have been identified (Scanlon and others, 1999). USGS scientists are studying coral transplants within the area as a means to restore damaged reef habitats.

GEORGES BANK OFF MASSACHUSETTS

A joint project by the USGS and the NMFS is documenting the interaction between physical/geological factors and fishery abundance and distribution on Georges Bank off Massachusetts. USGS maps show that historic fish-spawning grounds on the eastern portion of the bank are located on the gravel sea floor where the strongest tidal currents occur between sand ridges (Valentine and Lough, 1991; Lough and others, 1992; Valentine and others, 1992, 1993). Data suggest that the physical disturbance of the sea floor by tides, storms, and commercial fishing activities alters benthic habitats. Figure 14 shows natural and disturbed benthic habitats on Georges Bank.

STELLWAGEN BANK OFF MASSACHUSETTS

The USGS is producing a series of maps that includes a general overview, the bottom topography, and sediment

Figure 13. Sandy barrier islands provide a buffer for waves and flooding and important habitats for marine life. USGS photograph.

Figure 14. Benthic habitats on Georges Bank: above, a natural, undisturbed habitat; below, a region disturbed by fishing activities. USGS photographs.

and biologic habitat distribution in the Stellwagen Bank National Marine Sanctuary off Massachusetts (fig. 15). These maps and data are a basis for policymakers, managers, and other scientists to understand this complex ecosystem and wisely manage its economic and natural assets. This project is being done in collaboration with NOAA, the U.S. EPA, the Canadian Hydrographic Service, and the University of New Brunswick (Valentine and others, 2000).

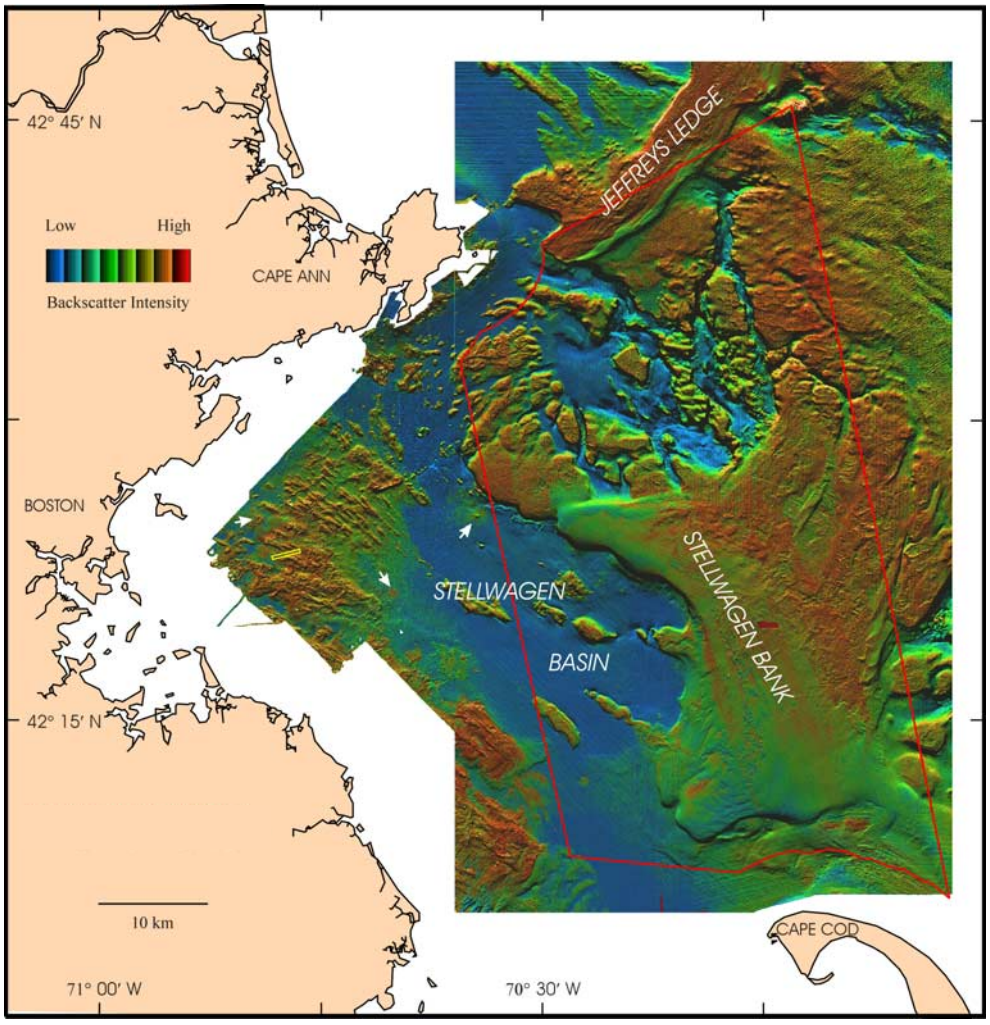

Figure 15. Geomorphology of Stellwagen Bank National Marine Sanctuary (red polygon) mapped by a multibeam echo sounder on four cruises, 1994 to 1996. From Valentine and Butman (1998) and Valentine and others (2000). The geomorphology is shown on a map with backscatter intensity draped over the topography and with shadows added as if the sun were shining. Red indicates high-backscatter material including coarse sand, gravel, and rock; green indicates sand; blue indicates mud. Within each backscatter color interval, the intensity varies from dark to light depending on the sun illumination. Present and past disposal sites (white arrows) are characterized by high-backscatter material and are especially distinct when the background material is fine-grained sediment, such as in Stellwagen Basin. The easternmost arrow points to the presently active Massachusetts Bay disposal site, which receives dredged material. The yellow rectangle in the western part of the map is the location of the new outfall that will discharge treated sewage effluent from the Boston metropolitan area into Massachusetts Bay.

Natural Hazards and Public Safety Theme

Studies on the natural hazards and public safety theme help scientists to understand the origin and extent of natural hazards in the coastal zone and to characterize their effects. Natural hazards within coastal and marine environments pose significant threats to human lives and property and the environment. A priority of the USGS Coastal and Marine Geology Program is to provide relevant short-term, predictive earth science information to help prevent loss of life, property, and land due to coastal erosion, hurricanes, El Niño, landslides, tsunamis, and earthquakes.

COASTAL EROSION

Coastal erosion is a serious national problem with immediate and long-term economic and social consequences. Developed areas are threatened with billions of dollars in property damage as a result of storm impacts and long-term erosion. In addition, wildlife refuges, critical habitats, and recreational areas are threatened by coastal land loss. The USGS is working to provide crucial information on the geologic and oceanographic processes controlling coastal erosion to local, State and Federal agencies responsible for coastal zone management.

SWASH: SURVEYING WIDE AREA OF SHORELINES

The USGS has developed the SWASH system (fig. 16) for rapid, low-cost, highly accurate measurements of shoreline position using recent advances in the Global Positioning System (GPS). Tests have shown that the new system can inexpensively survey more than 65 km of shoreline within a single low-tide period. SWASH is also being used to obtain real-time information on shoreline change during storms. The SWASH system has recently been used in North Carolina to identify erosional "hotspots" along a section of the Outer Banks.

Figure 16. SWASH vehicle surveying a North Carolina beach. USGS photograph.

SOUTHWEST WASHINGTON

Along the southwest coast of Washington, erosion has become a serious problem and is costing the State of Washington and the Federal Government millions of dollars in continued efforts to prevent land loss (fig. 17). Although there is much speculation as to the causes of coastal erosion in southwest Washington, until now there was virtually no relevant scientific or technical information available. In a long-term, interagency effort, the USGS is working with its partners to study sediment dynamics in the region and provide information that will help reduce the costs and problems associated with coastal erosion. Cooperators include the Washington Department of Ecology, the U.S. Army Corps of Engineers, the U.S. EPA, and Portland State University.

Results suggest that long-term erosion on some of the beaches within the region has been caused by a sudden 1- to 2-meter drop in land elevation along the coast due to large earthquakes that occur approximately every 500 years. Although many beaches have accreted seaward at

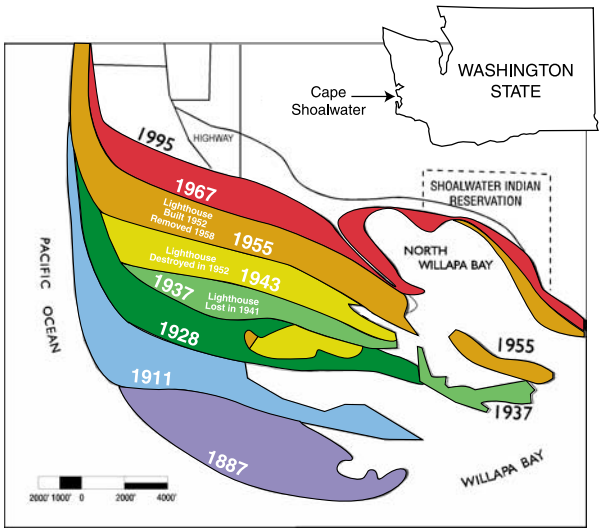

Figure 17. Historical erosion at Cape Shoalwater, Washington, from 1887 to 1995.

rates of about 0.5 meter per year over the last 4,000 years, many are now eroding rapidly. The rock jetties at the Columbia River mouth have altered patterns of beach accretion and possibly erosion for tens of kilometers to the north and south. Discharge of beach sands from the Columbia River may have been significantly reduced over the last century due to the series of dams upstream. As research continues, more data will be forthcoming and will provide local managers with much needed information. Visit the web site at http://coastal.er.usgs.gov/projects98/7242-33780.html for more information.

LOUISIANA BARRIER ISLANDS

The USGS, in cooperation with Louisiana State University, has documented the long-term historical record of land loss along Louisiana's coast as part of the USGS Louisiana Barrier Island Erosion Study. Data from the project were used to make figure 18, which shows dramatic change along the Louisiana barrier island coast from 1853 to 1998. Results from this project led to a new understanding of the factors responsible for coastal erosion in the area and are critical to the effort to stem erosion and restore coastal barriers and wetlands.

SOUTH CAROLINA

Severe erosion is also occurring along much of the rapidly developing South Carolina coast. The USGS, in cooperation with the South Carolina Sea Grant Consortium and the South Carolina Office of Ocean and Coastal Resource Management, is conducting research to examine the causes of coastal erosion. In operation since 1994, this project is producing important information and products for coastal zone managers. Based on high-resolution, digital sidescan-sonar imagery and sediment collections, a map of the sea floor and sediments is being produced for the regions of Folly Beach and Morris Island. Historical and recent data have been archived to create an accurate assessment of shoreline change over time, and three time periods are being mapped for the area from Charleston Harbor to Bull's Bay. Measurements of tides, oceanographic processes, and geologic information are presently underway; results will help South Carolina's regional managers decide how to best manage their coast.

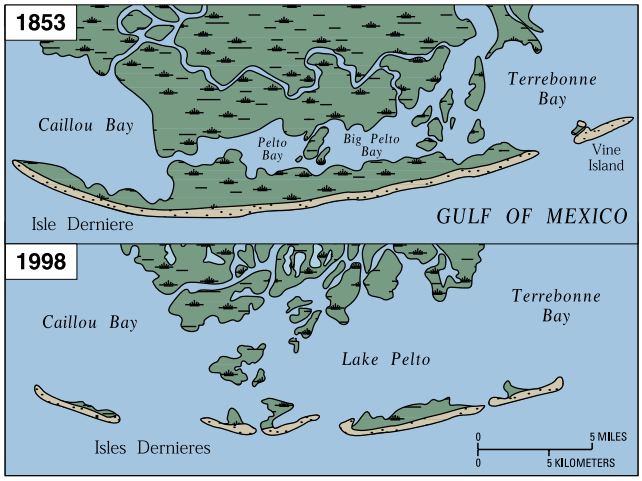

Figure 18. Dramatic changes in the Isles Dernieres barrier islands along the Louisiana coast from 1853 to 1998. The erosion of these barriers is largely a natural result of delta plain evolution. Updated from McBride and others (1991).

HAWAII

Over the last century, nearly 30 km (25 percent) of Oahu's beaches have been lost or narrowed due to coastal erosion. Research shows that beach loss occurs where seawalls and other shoreline structures refocus wave energy and prevent sand accretion. The USGS is working with the University of Hawaii and NOAA to study Hawaii's beach loss, to identify potential sources of sand for renourishment, and to help address Hawaii's coastal erosion problems.

HURRICANES

Hurricanes are tropical storms that have a sustained wind speed greater than 120 kilometers per hour. Each year, hurricanes cause billions of dollars in property loss and threaten the safety of those living in the Southeastern United States. The USGS, in collaboration with the National Aeronautics and Space Administration (NASA), NOAA, universities, and State agencies, has developed a strategy to respond to catastrophic storms. The goal is to improve our understanding of storm impacts within the coastal zone so that we can better predict the effects of future events and provide the information needed to manage shoreline development.

Pre- and post-storm data are now available from Hurricane Fran in 1996 (fig. 19) and Georges in 1998. The USGS and its cooperators continue to use state-of-the-art methods to collect data along the U.S. coastline as a prestorm baseline, and the storm response team will rapidly deploy after major storm events in the future to measure impacts such as erosion, overwash, and storm surge. For more information or photographs, visit the web site at http://coastal.er.usgs.gov/hurricanes.

In addition to studying hurricane effects on the continental United States, the USGS is also working to help assess and reduce the impacts of major storms on the islands of the Pacific.

EL NIÑO

El Niño is the periodic warming of equatorial waters in the western Pacific Ocean that can affect the weather patterns over large areas of the Earth. During late January and early February of 1998, the California coast was hit by a series of powerful El Niño winter storms. At least 27 counties were declared National Disaster Areas, with hundreds of millions of dollars in property losses. Large waves, high tides and sea level, and extensive rain produced severe coastal erosion. The pre- and post-storm photographs in figure 20 were taken along the California coast in early 1998 and show severe erosion. In another area, the beach was enlarged (fig. 21).

The USGS and its partners have initiated several projects to assess and monitor coastal erosion due to El Niño and to investigate climate change and its links to geologic processes. Results so far show that up to 4 meters of land was lost from several beaches in Monterey and that most of the property damage was due to landslides.

Maps showing landslide potential for the California coast under El Niño climate conditions have been pro-

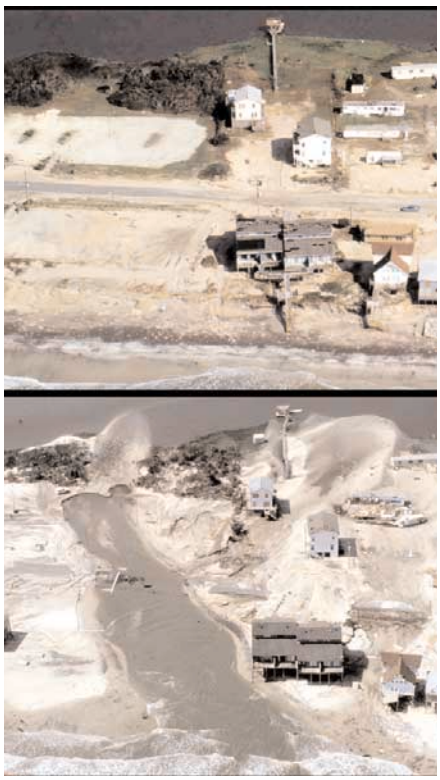

Figure 19. Topsail Island, a developed barrier island off North Carolina: above, the area on July 17, 1996, post-Hurricane Bertha/pre-Hurricane Fran; below, the area on September 7, 1996, post-Hurricane Fran, showing the dramatic effects of storm surge overwash. USGS photographs.

Figure 20. The California coast in early 1998 before and after a series of El Niño winter storms: above, the coast on January 20th before the storms; below, the coast on February 5th after the storms, showing severe beach erosion. Photographs by Bruce Richmond, USGS.

Figure 21. The mouth of Tomales Bay at Point Reyes National Seashore, California, before (above, October 1997) and after (below, April 1998) El Niño storms greatly enlarged the beach. USGS photographs.

duced and can be obtained from the web site at http://landslides.cr.usgs.gov/html_files/landslides/usgsnoaa/index.html. The USGS, NASA, and NOAA have combined efforts by using aerial photography and laser mapping technology to assess coastal erosion and landslides during El Niño winter storms.

TSUNAMIS

On July 17, 1998, a magnitude 7.0 offshore earthquake generated a series of catastrophic tsunamis (ocean waves) that devastated several villages on the northern coast of Papua New Guinea (PNG). Eyewitnesses reported waves 7–10 meters high at the coast. Confirmed deaths were in the thousands, and several villages were totally destroyed (fig. 22). USGS scientists joined an international team that traveled to PNG to study and learn about the tsunami event; the team's goal is to save lives in future tsunamis.

The USGS produced a qualitative computer simulation (fig. 23) to help visualize the July 1998 tsunami event and is preparing a more quantitative version. Coastal and marine researchers are trying to estimate how often such events happen by examining the sediments of the region for evidence of previous events of a similar nature. Scientists found a layer of sediments some 120 centimeters below the surface that is indicative of a previous tsunami and are now trying to determine the approximate time of the event.

In an effort to learn more about tsunamis and to make coastal communities aware of potential tsunami hazards, USGS scientists are investigating the past occurrences of tsunamis in the Caribbean and in the Pacific Northwest.

LANDSLIDES

In February 1995, a 500-meter section of a popular beach at Michigan's Sleeping Bear Dunes National Lakeshore suddenly slid into the waters of northeastern Lake Michigan. The National Park Service immediately requested that the USGS help to assess the hazard for future landslides at the lakefront site. USGS research indicates that landslides at Sleeping Bear Point are related to the release of water trapped within the dune sand, typically during unseasonably warm weather in winter months. Results are helping managers to identify times when landslide hazards are high and when public access to the beach should be restricted. Information will also be used to educate and warn the general public of impending landslide hazards. A summary of the USGS research is available on the web at http://wrgis.wr.usgs.gov/fact-sheet/fs020-98.

The USGS studies many types of landslides. For more information, see the web site at http://landslides.usgs.gov/html_files/nlicsun.shtml.

EARTHQUAKES

The USGS Coastal and Marine Geology Program works in concert with the USGS Earthquake Hazards Reduction Program to study earthquake hazards both on land and offshore. For more information, see the web site at http://geohazards.cr.usgs.gov/earthquake.html. An example of research on earthquakes in the Pacific Northwest is described below.

The Pacific Northwest is the site of the Cascadia Subduction Zone, where the Juan de Fuca plate is diving beneath the North American plate. Scientists at the USGS are surveying the region and modeling fault stresses and strain to better understand and predict earthquakes in the region. So far, the study indicates that long-term uplift along coastal Washington and Oregon is typical of deformation that occurs between major earthquakes along a subduction zone. Results will be used to update regional fault maps within the coastal zone and provide new information on the potential magnitude and recurrence rate of earthquakes in the region; recent studies show that seismic risks for the Pacific Northwest coast are greater than previously thought. This project will help regional administrators and planners to identify areas with significant earthquake risk and to better define the hazards posed.

Figure 22. Damage caused by the tsunamis that hit Papua New Guinea on July 17, 1998. Photograph by Guy Gelfenbaum, USGS.

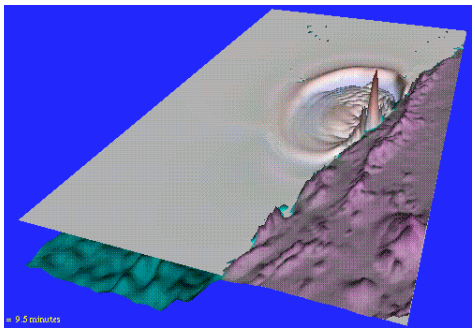

Figure 23. One frame of a USGS computer simulation of the tsunamis that hit Papua New Guinea on July 17, 1998. The complete simulation is available from the web site at http://walrus.wr.usgs.gov/tsunami/PNGhome.html.

Natural Resources Theme

Research efforts under the natural resources theme focus on understanding the Nation's fresh-water, mineral, and energy resources in a global, geologic, economic, and environmental context. Studies are conducted to evaluate resource potential and to assess possible hazards and impacts on the environment associated with resource use. The USGS Coastal and Marine Geology Program is providing critical information on gas hydrates, ground water, and sand and gravel resources.

ENERGY

METHANE GAS HYDRATES

Although gas hydrates offer a new and untapped source of energy, they also pose a significant hazard to offshore operation and may play an important role in climate change. Gas hydrates are a solid crystalline form of water, like ice, except that they contain additional gas, typically methane. Gas hydrates are widely stored in ocean-floor sediments. Extraction of methane gas from hydrates could provide a very large energy and petroleum resource. Increased temperature or decreased pressure can cause gas hydrates to dissociate and result in sea-floor instability and undersea landslides; evidence of past blowouts is indicated by seismic-reflection profiles (fig. 24). Consequently, hydrates pose a serious safety threat to offshore drilling operations. If methane in hydrates is released, it may play a significant role in global climate change.

The USGS is leading the study of gas hydrates, mapping their occurrence, studying their geologic and chemical properties, and assessing their effects on sea-floor stability. Mapping by the USGS has revealed large accumulations of methane hydrates off the coasts of North and South Carolina.

GULF OF MEXICO

The Texas-Louisiana continental slope is one of the few remaining frontiers for hydrocarbon exploration within our Nation's Exclusive Economic Zone. Detailed mapping of the sea floor and identification of potential hazards to drilling and platform stability are essential to the oil industry. USGS scientists are working with researchers from the University of Texas, Texas A&M University, and others to develop a detailed understanding of the tectonic and sedimentary conditions controlling underwater landslides in the area. Mapping so far has identified areas of mass wasting and faulting, and seismic profiles show regions influenced by underlying accumulations of salt and possible gas hydrates.

GROUND WATER

Fresh ground water, one of our Nation's most important resources, is vulnerable to contamination from saltwater intrusion at the coast, disposal of sewage wastes, and agricultural runoff. The USGS Coastal and Marine Geology Program is working with regional partners to study aquifer geology, to identify sources and processes of contamination, and to help preserve our freshwater supplies.

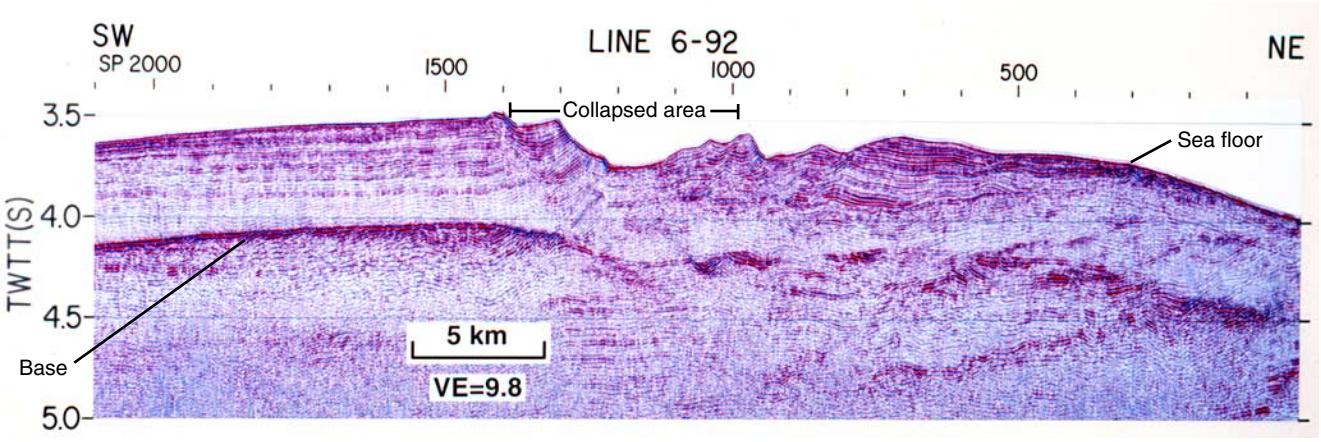

Figure 24. Seismic profile of the sea floor off South Carolina showing a large collapse area at the crest of the Blake Ridge; the collapse was probably caused by a blowout releasing considerable methane from gas hydrates. From Taylor and others (1999). TWTT(S), two-way travel time in seconds; VE, vertical exaggeration; SP, shot point; Base, the base of the gas hydrate layer, which extends to the sea floor.

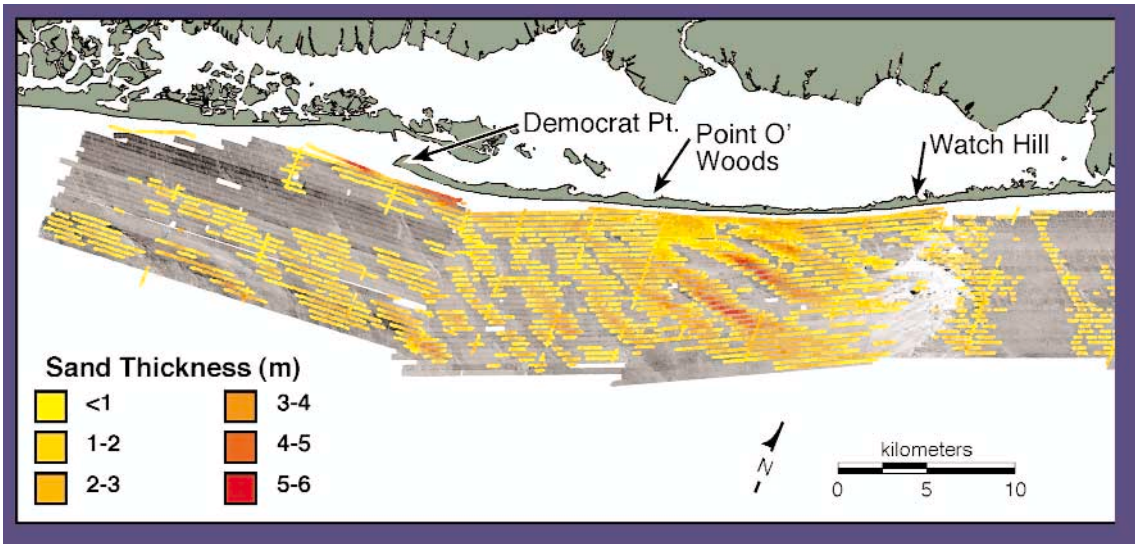

Figure 25. Offshore sand resources south of Long Island that may be used for beach replenishment. From Bill Schwab, USGS, unpublished data.

In the Florida Keys, concern over the fate of sewage waste injected into underlying, porous limestone prompted the USGS to mount a significant effort to study and monitor ground-water flow and potential contamination. More than 84 monitoring wells have been drilled, and research has revealed several important properties of ground-water movement in the Keys. Tides and sea-level variations drive ground-water flow primarily perpendicular to the islands and to the east. Studies also suggest that because seaward movement of potentially contaminated ground water is limited, the reef tract may not be substantially threatened; however, nearshore environments can be affected. This important study led to the modification of State regulations regarding the installation of sewage disposal wells in the Florida Keys.

MARINE SAND AND GRAVEL

Sand and gravel resources are essential to all coastal communities, providing materials to construct roads and buildings and to renourish beaches. Successful coastal zone management requires knowledge of sediment sources, sinks, and transport pathways. The USGS is helping to identify offshore sources of sand and gravel that have potential for use as fill material.

SOUTHERN LONG ISLAND

Coastal erosion and the need for sand resources along the south shore of Long Island, New York, have received great attention from engineers, scientists, and politicians during the last 40 years. The USGS and the U.S. Army Corps of Engineers are investigating the processes responsible for erosion and are determining the availability of sand resources for beach nourishment in the region (fig. 25). Along Fire Island National Seashore, results are showing a solid link between offshore geology and shoreline erosion. It appears that the underlying regional geology is the principal control on long-term patterns of beach erosion.

FLORIDA

A 5-year geologic study of Florida's west-central coast has provided important information for regional managers concerned about beach erosion and sources of sand for renourishment. Results indicate that most beach-quality sand is concentrated off tidal inlets and in long, linear ridges. Research suggests that although coarse carbonate sand is being produced in the modern environment, there are few or no modern sources of beach-quality quartz sediment in the region. USGS scientists, in cooperation with the University of South Florida, are measuring and modeling oceanographic processes in the area to better understand sediment transport pathways and coastal erosion and to find sources of clean sand suitable for renourishing eroded beaches.

Information and Technology Theme

The overall goals of research under the information and technology theme are to provide a national source of technology and information to better the Nation's understanding of coastal and marine environments. Major efforts of the USGS Coastal and Marine Geology Program are underway to systematically map the Nation's coastal and nearshore sea floor and sediments and to provide a comprehensive geologic data base easily accessed by the public.

SEA-FLOOR MAPPING

For years, managers, policymakers, and those conducting research in coastal and marine environments faced a vexing problem—an almost complete lack of accurate sea-floor base maps. The USGS and its partners are using high-resolution, multibeam systems and advanced data-processing techniques to systematically map the sea floor and sediments of the U.S. continental shelf and, in particular, areas of critical economic or biologic importance.

GLORIA IMAGERY OF THE U.S. EXCLUSIVE ECONOMIC ZONE

On March 10, 1983, President Reagan declared an expansion of the United States' sovereign rights to all natural resources within a zone extending to 200 nautical miles beyond the shoreline. The proclaimed Exclusive Economic Zone (EEZ) provided a mandate for exploration and resource utilization. However, although the general bathymetry was known, few, if any maps or detailed information on sea-floor topography, benthic habitats, or sediment distribution existed.

From 1984 to 1991, the USGS and its partners mapped the EEZ by using a long-range sidescan-sonar system called GLORIA. The system was specifically designed to document the morphology and texture of features in the deep ocean (water depths greater than 200 meters). Advanced computer software was then developed by the USGS to enhance the GLORIA imagery.

A CD-ROM containing the GLORIA imagery of the EEZ is now available from the USGS (Groome and others, 1997); a sample image is shown in figure 26. Information and data can also be obtained at http://walrus.wr.usgs.gov/docs/gloria/.

OTHER SEA-FLOOR MAPPING

The USGS is mapping the sea floor, sediments, and biologic habitats in areas not mapped by GLORIA (some of which have already been mentioned) and is testing new technology. Tools include multibeam-sonar systems, which provide high-quality bathymetry and quantitative backscatter data used to make shaded-relief maps and perspective views (fig. 27). Many partners are working with the USGS on sea-floor mapping; these include the University of New Brunswick, the U.S. Army Corps of Engineers, the U.S. EPA, NOAA, and the University of Hawaii. Table 1 has a list of regions for which sea-floor maps are available.

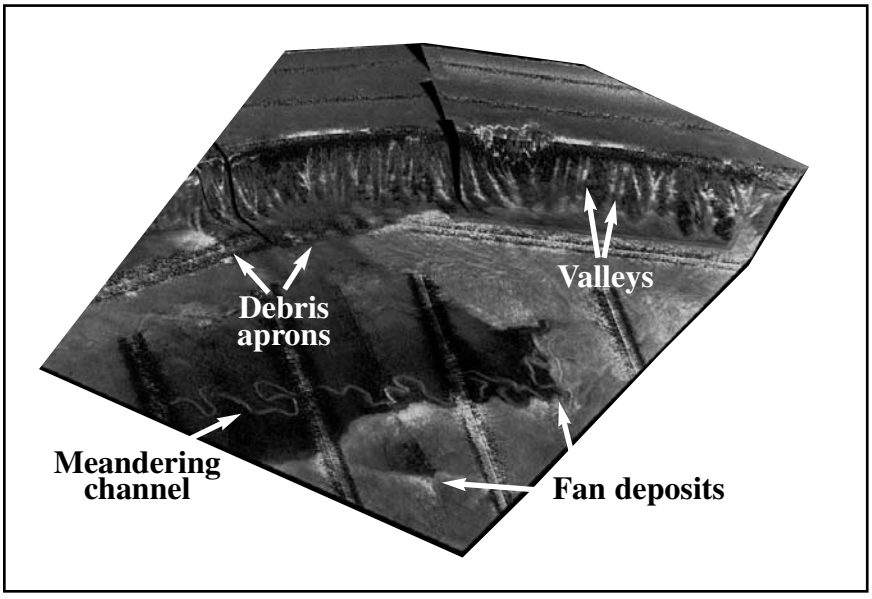

Figure 26. Perspective view of the sea floor off western Florida based on GLORIA sidescan-sonar imagery from the USGS and bathymetry from NOAA. The image shows the Florida Escarpment cut by gullies and valleys, a meandering channel formed at water depths of more than 3,000 meters, and mass-wasting fan deposits that bury the channel and that originated in the Mississippi Canyon 500 kilometers to the northwest. From Groome and others (1997).

AIRBORNE LASER MAPPING (LIDAR)

Airborne laser mapping (LIDAR) systems provide an unprecedented potential for cost-effective, precise, and rapid mapping of coastal topography and nearshore bathymetry. The USGS and its collaborators are testing and comparing several LIDAR systems (fig. 28) to determine their utility in applications such as bottom characterization, pre- and post-storm assessments, and shoreline monitoring. Partners in this effort include the U.S. Army Corps of Engineers, NASA, NOAA, Oregon State University, Scripps Institution of Oceanography, North Carolina State University, and the Naval Research Laboratory.

COMPUTER MODELING

USGS scientists and their partners develop and use state-of-the-art computer simulations to study geologic and oceanographic phenomena and to provide managers and policymakers with the best scientific information possible. Recent projects using computer simulations include modeling of circulation in Massachusetts Bay, in Lake

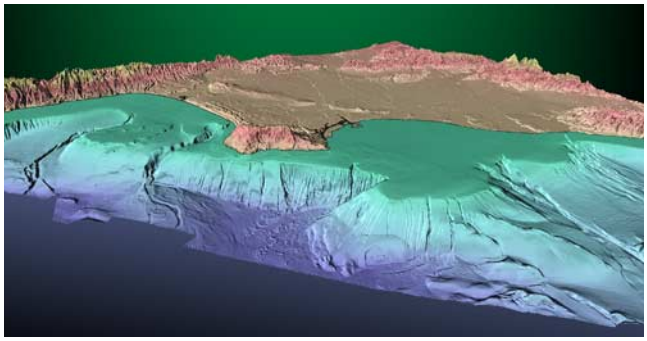

Figure 27. Perspective view looking northeast from the Pacific Ocean toward Los Angeles and Palos Verdes, California. The view was constructed from multibeam mapping data collected in 1996, 1998, and 1999 by the USGS and its partners; see the web site at http://walrus.wr.usgs.gov/pacmaps/la_pers2.html. The greater Los Angeles area is home to more than 10 million people, who put pressure on the adjacent offshore continental shelf and margin with activities such as ocean disposal for dredged spoils, explosive disposal, waste-water outfall, and commercial fishing. The data collected in 1996–99 have been used to compile the first highly accurate maps of the continental shelf and slope to serve as a base for multidisciplinary research on the coastal environment.

Table 1. Sea-floor images by the USGS Coastal and Marine Geology Program and cooperators.

Region mapped	Page where discussed in this Circular	Web site or reference
Western United States		
Pacific sea floor (Hawaiian Islands, San Diego, Los Angeles)	p. 22	http://walrus.wr.usgs.gov/pacmaps/; Dartnell and Gardner (1999)
San Francisco Bay	p. 10	http://terraweb.wr.usgs.gov/TRS/projects/SFBaySonar/; http://sfbay.wr.usgs.gov/access/mapping/multibeam/; Dartnell and Gardner (1999)
Monterey Bay National Marine Sanctuary	p. 13	http://terraweb.wr.usgs.gov/TRS/projects/MontereySonar/
Lake Tahoe	——	http://blt.wr.usgs.gov/tahoe/openfile.html; Gardner and others (2000)
Gulf of Mexico and Southeastern United States		
Gulf of Mexico	p. 21	http://coastal.er.usgs.gov/east_gulf/
Lake Pontchartrain	p. 10	http://coastal.er.usgs.gov/pontchartrain/imagery/
Florida Keys	p. 13	Lidz and others (1997)
West Florida	p. 20	Briere and others (2000)
Oculina Bank off east-central Florida	p. 13	Scanlon and others (1999)
Northeastern United States		
New York, New Jersey Bight	p. 7	Schwab and others (1997)
Long Island Sound	p. 8	Poppe and others (1997, 1998a,b); Twichell and others (1997, 1998); Knebel and others (1999)
Stellwagen Bank National Marine Sanctuary	p. 13	Valentine and others (2000)
Massachusetts Bay and Boston Harbor	p. 7, 24	Bothner and others (1992); Butman and Lindsay (2000)

Pontchartrain, and off the West Coast of Florida and recreating the devastating tsunami that hit Papua New Guinea in 1998. Figure 29 depicts the tidal flushing of Boston Harbor based on computer simulations.

REMOTE SENSING OF THE COASTAL OCEAN

Satellite imagery is providing a new frontier for oceanographic research and coastal and marine management. Advances in remote-sensing techniques now allow for large-scale, synoptic overviews of water temperature and turbidity on a near-real-time basis. The USGS and its partners are producing and making available on the World Wide Web daily data on sea-surface temperature and water turbidity for South Florida as shown in figure 30 (http://coastal.er.usgs.gov/flbay/), and the eastern Gulf of Mexico (http://coastal.er.usgs.gov/east_ gulf/). Data are available for the East Coast from New York south, the Gulf Coast and Lake Pontchartrain, the West Coast from Monterey north, and San Francisco Bay. Current work is focused on making data more accessible, including development of georeference standards and the integration of new ocean color data as they become available.

DEVELOPING AND TESTING NEW TECHNOLOGIES

A wide array of instruments is needed to characterize coastal and marine regions. The USGS Coastal and Marine Geology Program tests commercially available systems and develops new instruments for its special needs. Two custom-built systems are described next.

OCEAN BOTTOM SEISMOMETER (OBS)

The Ocean Bottom Seismometer (OBS) is a self-contained, low-cost system developed by the USGS to acquire seismic data on the sea floor (fig. 31); it is easily deployed and retrieved. The OBS is designed to fall freely to the sea floor and to record shock wave information from earthquakes or geophysical instruments. Twelve OBS's are currently in operation and have been used to study a wide range of important geologic features throughout the world, including gas hydrates, sea-floor sediments, and the underlying structure of the Earth's crust. More information is available from the web site at http://obs.er.usgs.gov/index_text.html.

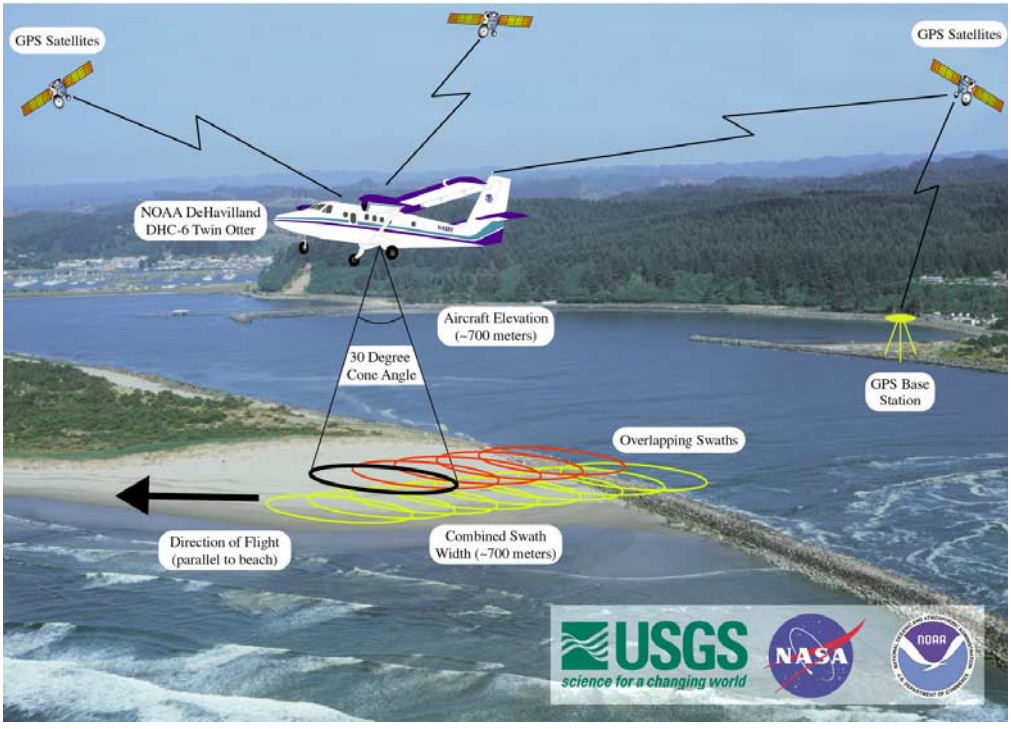

Figure 28. Elliptical scan pattern of NASA's airborne laser mapper (LIDAR) system operated from a NOAA Twin Otter aircraft. New LIDAR mapping technology is leading to high-resolution information about the Nation's coasts. For example, data collected by the USGS and its partners before and after storms document the extent of beach erosion.

GAS HYDRATE AND SEDIMENT TEST LABORATORY INSTRUMENT (GHASTLI)

Scientists at the USGS have created a unique, custom-built computer-controlled laboratory system, GHASTLI, to study the in situ properties of gas hydrates and hydrate-related processes (fig. 32). GHASTLI provides the first link between theoretical and field studies of gas hydrates and will serve as a tool to improve gas hydrate recognition and assessment.

INFORMATION PRODUCTS

The USGS Coastal and Marine Geology Program is committed to providing the most relevant, credible, and objective scientific information possible. The results of program studies are easily accessible to Federal and State governments, the public, industry, and the scientific community. The web sites mentioned in this Circular describe a wide range of information in both digital and hard-copy formats.

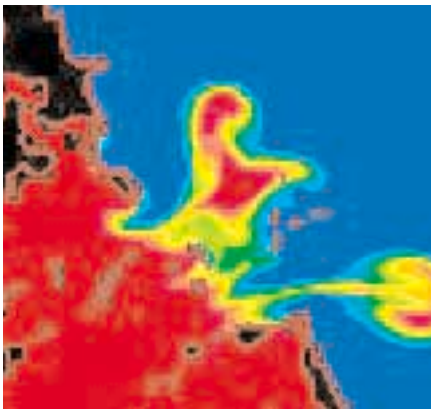

Figure 29. One frame of a computer simulation of tidal flushing of Boston Harbor. Water in Boston Harbor is shown in red; other colors represent it mixing with the blue Massachusetts Bay water. Computer models like this one are aiding environmental restoration.

Figure 31. Ocean Bottom Seismometer (OBS), which was developed by the USGS to acquire seismic data on the sea floor. USGS photograph.

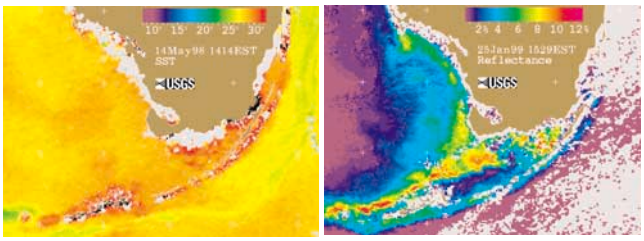

Figure 30. Satellite images of Florida Bay showing sea-surface temperature in degrees Celsius (left) and reflectance in percent (right). Reflectance values at the red end of the bar scale indicate high turbidity.

Figure 32. Part of the GHASTLI system built by the USGS to study gas hydrates. USGS photograph.

Future Research

The U.S. Geological Survey and its Coastal and Marine Geology Program are committed to serving the Nation's needs in earth science monitoring, research, and assessment. Future efforts will continue to provide fundamental geologic information while responding to new areas of interest or concern as they arise. Although topics of study will typically be either national or regional in extent, when warranted, more localized demonstration projects will be conducted. Geologic hazards, resources, climate change impacts, ecosystem function, human health, and ground-water issues will continue to be the focus of future efforts of the Coastal and Marine Geology Program. Future directives for the program include the topics discussed below.

CORAL REEFS

Coral reefs are critical habitats for the United States and for many developing nations in the tropics. They provide vast resources through their biodiversity, protection against destructive wave forces, supply of sand for nearby beaches, appeal to tourists, and importance to recreational and commercial fishing. Changes in sea level, water quality, global warming, adjacent land usage and drainage, coastal construction, overfishing, ship groundings, and the proliferation of diseases are all factors placing coral reefs at risk. The USGS has begun projects of coral reef research and thematic mapping coordinated with other Department of the Interior agencies (National Park Service, Fish and Wildlife Service) and NOAA.

The USGS efforts will focus on providing a better understanding of the factors that influence coral reef growth, regional diversity, distribution, and productivity. By mapping coral reef locations and ground-checking diversity and health, the USGS will help to develop a clear understanding of how waves, the underlying sea-floor morphology, sedimentation, water clarity, and water quality influence reef growth. State and Federal managers in coral reef regions, such as Hawaii, Florida, the U.S. Territories, and other island nations, will be able to use this information to better balance the protection of reefs with the activities of growing coastal populations.

MAPPING OF SEA-FLOOR HABITATS

Recently, the USGS Coastal and Marine Geology Program, in cooperation with NOAA, held a workshop to review research needs regarding benthic marine habitats, specifically in areas where a poor understanding exists of relations between fundamental geologic processes and biologic habitats, resources, and health. Over 50 marine scientists and managers participated in the workshop. Three themes of national importance were discussed: habitat characterization, natural and human-induced effects on habitats, and coral reefs. In addition, several specific regions were identified as areas of concern. These include the Northeast and Great Lakes, Southeast and Gulf of Mexico, West Coast, Alaska, and Hawaii, and low-latitude coral reef environments.

Workshop results suggest that research is needed in benthic habitats where fishing pressures are increasing while fisheries are declining, and where habitat degradation is occurring due to manageable activities such as poor fishing practices, pollution, and coastal development. If recent legislation to preserve biologic habitats is to succeed, knowledge about benthic habitats, human influences, and ecosystem functioning is essential.

Participants developed a comprehensive list of research requirements. For all of the areas discussed, it was clear that accurate, accessible maps of the sea floor and its geologic and biologic composition are critically needed. As a result of the workshop, the USGS Coastal and Marine Geology Program, along with its partners, has made the mapping and study of benthic habitats, particularly in areas of national and regional concern, one of its highest priorities for the future.

UNDERSTANDING COASTAL AND INNER SHELF SYSTEMS

Geologic framework and processes are critically important in determining erosion, accretion, and sediment budgets for coastal and nearshore regions. This area of research will be a major focus for the Coastal and Marine Geology Program over the next decade.

STORM IMPACTS IN THE COASTAL ZONE

The USGS will continue its efforts to better predict storm impacts on coastal landforms. A hurricane response team is now in place and will continue to provide critical information about preventing property damage and loss of life and land along the shore. The Coastal and Marine Geology Program will also continue to develop technology such as SWASH to better monitor and assess coastal land loss and change.

RELATIVE SEA-LEVEL RISE

Sea-level rise due to global climate change and land subsidence is of great national and worldwide concern. The USGS Coastal and Marine Geology Program will continue to study natural and human-induced sea-level change and help to predict the environmental impacts of climate change.

METHANE GAS HYDRATES

Gas hydrates are a new and developing frontier in terms of energy resources, offshore hazards, and climate change. The USGS is taking a leadership role in the study of gas hydrates and hydrate-related processes.

GEOLOGIC CONTROLS ON GROUND-WATER RESOURCES

Freshwater is one of the Nation's most valuable resources. Study of ground-water resources and the geologic controls on their supply, flow, and potential contamination will continue to be a priority for the Coastal and Marine Geology Program.

DEEPWATER GULF OF MEXICO

The deepwater region of the Gulf of Mexico may be the last unexploited source of petroleum resources in or near the continental United States. The USGS is committed to continue its work to assess offshore hazards and to determine the geologic structure and history of the region.

REGIONAL STUDIES

Future research efforts are planned for the coastal and marine environments in regions of specific interest, two of which are North Carolina and the southeast region. The Coastal and Marine Geology Program is working to develop a strategy for projects that meet regional science needs.

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