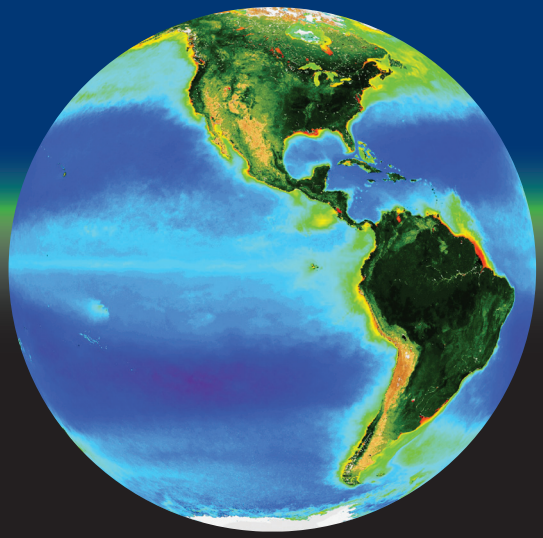
COASTAL REMOTE SENSING



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The Earth images used on the cover and on this page were provided by the SeaWiFS project, NASA Goddard Space Flight Center, and ORBIMAGE.

"In the near future, increasing numbers of state coastal programs will use remotely sensed data. Hopefully the cost will come down in response to increased competition among data providers. Improvements in Web-based map servers should make this data more accessible. Data will be delivered through Web subscription services, bringing easy access to real-time and near-real-time data."

Dave Hart
Wisconsin Sea Grant

A Coastal Resource Manager's Guide to Remote Sensing

Remote sensing is an incredible information tool that provides a big picture view of a region like no other technology can.

Despite the advantages of remote sensing, the coastal resource management community often underutilizes this technology. There are several reasons for this, including limited familiarity with and access to the data, and a shortage of in-house remote sensing expertise. But things are changing. Improvements in desktop computer software have made remote sensing more accessible and more commonly used by coastal programs.

This publication provides introductory information about remote sensing and highlights many of the ways this technology is being used to address coastal management issues. For additional information about the projects profiled in the following pages, please visit *www.csc.noaa.gov/crs/rs_info/.*

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LINKING PEOPLE, INFORMATION, AND TECHNOLOGY

REMOTE SENSING BASICS

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LINKING PEOPLE, INFORMATION, AND TECHNOLOGY

This section contains introductory remote sensing information of interest to the nation's coastal resource management programs. For more specific information, contact the Coastal Remote Sensing program of the NOAA Coastal Services Center or visit the program's Web site at *www.csc.noaa.gov/crs/.*

What are remote sensing data?

Remote sensing is the science of gathering information at a distance. The technology provides a descriptive, analytical way to identify geographic features. Examples include aerial photographs, satellite imagery, acoustic data, and radar imagery.

The use of remotely sensed data is increasing thanks to recent advancements in geographic information systems (GIS) and image processing capabilities. Information that previously was available only to large organizations is now suitable for most desktop computers and is used by all branches of government and the private and nonprofit sectors. This international, multibillion-dollar industry includes the producers, collectors, analyzers, and sellers of spatial information and the associated tools.

Why use remote sensing?

Remote sensing is unsurpassed when it comes to getting data sets for a large area in a short amount of time. Remote sensing technologies are usually the most cost-effective means of getting information for areas that are inaccessible, far away, difficult to traverse, require a broad view, or are too large to effectively manage or assess with traditional surveying methods.

What are some of the most common uses of this technology by coastal resource managers?

- Shoreline mapping and erosion analysis
- Floodplain mapping
- Land cover and land cover change mapping
- Habitat mapping
- Wetland mapping and evaluation
- Submerged aquatic vegetation mapping
- Regional planning
- Water quality monitoring
- Coastal management permitting
- Oil and toxic spill response planning
- Navigation
- Dredge disposal site monitoring
- Base maps

What are some of the more common data sets acquired with remote sensing technology?

- Digital elevation models
- Land cover and land cover change
- Vegetation type and health
- Infrastructure locations
- Sea surface temperature
- Sea surface roughness
- Ocean color and chlorophyll
- Shallow water bathymetry
- Shoreline location

How are remote sensing data obtained?

There are numerous companies in the business of acquiring and processing remotely sensed data. The federal government also collects remote sensing imagery to accomplish its mission of protecting the environment. Coastal managers use both of these avenues to acquire data. State and local organizations often work together to acquire data that they then use for a variety of purposes.

What are some of the considerations to be made before acquiring data?

Spatial resolution, which refers to the amount of detail recorded by a sensor, is an important consideration. Different remote sensing technologies provide data at varying resolutions. As the detail, or spatial resolution, increases, the area covered generally decreases. Higher resolution requirements often mean higher data costs.

Before acquiring data, consider the area's size and the amount of detail needed to meet your needs.

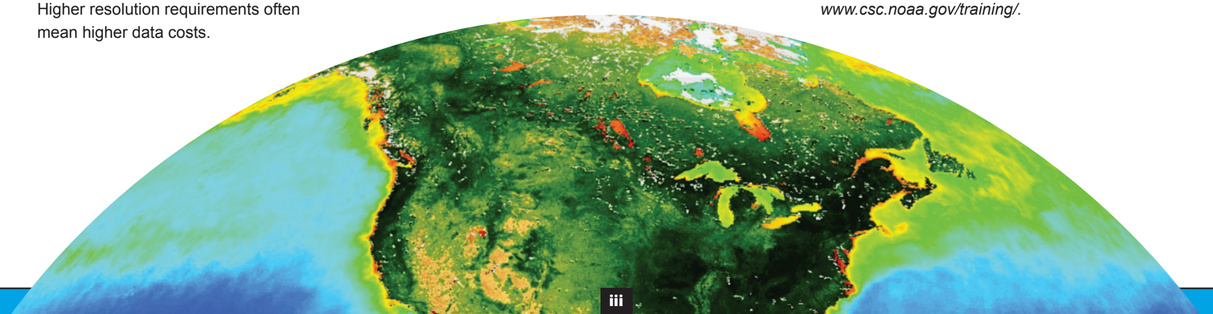
Federal, state, and local governments are a good source of free, shared, or inexpensive data, but many efforts require specific data that are purchased from the private sector. No matter what the source, users should understand where the data originated from (satellite or aircraft for instance), the final data format, possible licensing requirements or restrictions on data distribution, and associated expertise, hardware, and software needs. For airborne data, users need to know of potential weather implications that may affect a project timeline, as well as the costs associated with purchasing raw data, flying an aerial mission, using a sensor for a set amount of time, and processing data.

A key for determining the value of investing in remote sensing and spatial information technologies is a comparison of the costs and benefits relative to traditional monitoring methods.

How can I learn more?

To learn more about remote sensing data sources, visit the National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center's remote sensing Web site at *www.csc.noaa.gov/crs/.* This site contains a wealth of information, including sample applications for coastal resource managers, technical information about the different types of remote sensing technologies, and links to additional information resources.

The Center also offers an introductory remote sensing class for Center constituents. Information about this class can be found at *www.csc.noaa.gov/training/.*



Remote Sensing Today

Remote sensing use is on the rise in the coastal resource management community. This page highlights two of the reasons for this increase: better access to data, and the wide range of information that can be documented with remote sensing.

Ohio Provides Example of Innovative Data Access System

Satellite imagery has been around for over 30 years, but it is only in the recent past that the average citizen has been able to access remotely sensed data and information. This increasing access is greatly changing and expanding the way remote sensing is used.

The State of Ohio has been a leader in this effort. OhioView is a consortium of universities that focuses on making remote sensing data useable and affordable. Over the past three years, the OhioView Web site has gotten over 300,000 hits, and approximately 8,000 Landsat images have been downloaded. Thirteen states are in the process of creating services similar to OhioView, and ten more states are exploring the possibility.

"There are many vocations that benefit from remotely sensed data, including farming, forestry, urban and regional planning, and coastal resource management," says James Lein of the OhioView consortium. "Even a child in the fourth grade can use a satellite image to get a different perspective as he views his home from 500 miles in space."

OhioView can be found at *www.ohioview.org*.

One Image – Several Different Views

Remote sensing technology provides the best means of obtaining comprehensive information over large areas. The figures shown here are examples of the different types of information that can be found from a single image using remote sensing.

In addition, when comparing the same area over different time frames, trends are detected and corrective measures can be taken.

Remote sensing has been around long enough that meaningful historical records exist for many coastal areas. The availability of remote sensing information will continue to increase as a growing number of companies launch satellites that will complement government sources of imagery. Incorporating this information into the management of the coastal zone will improve the ability to protect its resources and plan for the future.

These images near Cleveland, Ohio, obtained from the Landsat Enhanced Thematic Mapper, have been processed three different ways to bring out different features in the landscape. A natural color image (left) can be created to approximate the familiar colors that the eye would see. A false color composite (center) of the same scene highlights urban areas as light blue and vegetated areas as red. A Normalized Difference Vegetation Index (NDVI) image (right) emphasizes the density and health of terrestrial vegetation. Land cover features with thick, healthy vegetation such as forests and lawns usually have high index values and appear lighter on the image. Areas with little vegetation, due to drought or development for example, appear darker.

COASTAL DEVELOPMENT

"Remote sensing is a good visual planning tool for coastal zone managers to employ in order to understand the consequence of present-day actions on the future character of their communities."

Mike De Luca
Jacques Cousteau National
Estuarine Research Reserve

Mapping Floodplains

Photo courtesy of FEMA

Photo courtesy of FEMA

In 1999, Hurricane Floyd made landfall in North Carolina. The devastation and destruction brought by this storm affected coastal communities, but dangerous flooding also occurred inland where it was completely unexpected. Fifty-two lives were lost, thousands of citizens were evacuated, and hundreds of millions of dollars worth of damage was caused to homes, businesses, and other property, many of which were uninsured or underinsured.

To be better prepared for the next hurricane, North Carolina, in partnership with the Federal Emergency Management Agency (FEMA), initiated a statewide effort to update all existing floodplain maps. Getting accurate elevation data was a critical part of this process. For this task, North Carolina has utilized remote sensing technology mounted on airplanes (Light Detection and Ranging, or LIDAR, sensors). The data are used in many ways and provide the basis for sophisticated flood forecasting models and mapping.

North Carolina and its local governments use these maps for day-to-day decisions, such as establishing zoning, permitting, flood insurance determinations, and developing safe evacuation routes. The information is also available on-line as easy-to-use, interactive maps. When the time comes to convince residents far inland that they are at high risk for flood damage, these visual predictive tools may mean the difference between life and death. ❖

ABOUT THE DATA

North Carolina became the first state to form a Cooperative Technical Partnership with FEMA, which allowed them to update this crucial information in a time- and cost-efficient manner. Elevation data from Light Detection and Ranging (LIDAR) technology are incorporated with soil type and land cover data to create flood predictions.

LIDAR data can be collected and processed relatively quickly and can be very accurate (vertical accuracy up to 20 centimeters). This represents a vast improvement over the original floodplain maps, many of which were more than 10 years old, using much less accurate approximations for elevation. The state is collecting LIDAR data in three phases. Phase I was collected in January 2001 and included approximately 53 percent of the state. Phase II data flights occurred during early 2003 and added approximately 30 percent.

To increase public awareness, the flood maps are draped over county orthophotographs, where available, or U.S. Geological Survey digital orthophoto quadrangles so that users can have a visual representation of where flooding may occur.

LIDAR data were collected by several contractors through the map coordination contractor, Dewberry and Davis.

Many private companies collect LIDAR data. These companies can be found using on-line searches or from Web sites sponsored by private companies or individuals.

Project Partners

- North Carolina Floodplain Mapping Program
- Federal Emergency Management Agency
- State Climate Office of North Carolina
- U.S. Geological Survey
- North Carolina Center for Geographic Information and Analysis
- North Carolina Department of Transportation
- North Carolina Geodetic Survey
- NOAA National Weather Service
- NOAA Coastal Services Center

NOAA Coastal Services Center

This computer-derived image shows the flooding (in blue) that occurred in Tarboro, North Carolina, as the Tar River level rose to its peak during Hurricane Floyd. An aerial photograph of the area was draped over the LIDAR-derived elevation data. Using the LIDAR-derived elevation data, a computer model was used to simulate the actual flooding that occurred.

Hurricane Forecasts

To leave or not to leave? That is the question for many coastal residents when a hurricane is brewing. When a major hurricane heads for shore, emergency preparedness staff gather to decide how, when, and where to evacuate residents who are in the path of the storm. Depending on the location, an effective evacuation requires a significant amount of lead time because representatives from all the impacted counties, the state, neighboring states, and the Red Cross must coordinate the process. For example, the Florida Keys and areas around New Orleans require up to 72 hours, and points along the South Carolina coast require up to 36 hours to clear their respective areas.

Photo courtesy of FEMA

Primary sources of information are the bulletins issued by the National Hurricane Center. Information arrives every three hours on a hurricane's position and every six hours on its intensity. Forecasters rely on information gathered from satellites and aircraft to determine the position, air temperatures, water vapor content, wind speeds, and barometric pressure of the storm system. The data are vital to mathematical models that forecast movement and changes in strength of the hurricane. The National Hurricane Center depends on the state and county managers to take the forecasts and tailor them to local needs.

Emergency managers are concerned about making the right decisions when it comes to hurricanes and public safety. When designated officials order the evacuation of a community in a dangerous area, the public responds well. However, when officials only recommend evacuation, fewer people respond. The power of up-to-date information during these quickly changing and hazardous conditions can be measured in the lives that are protected. ❖

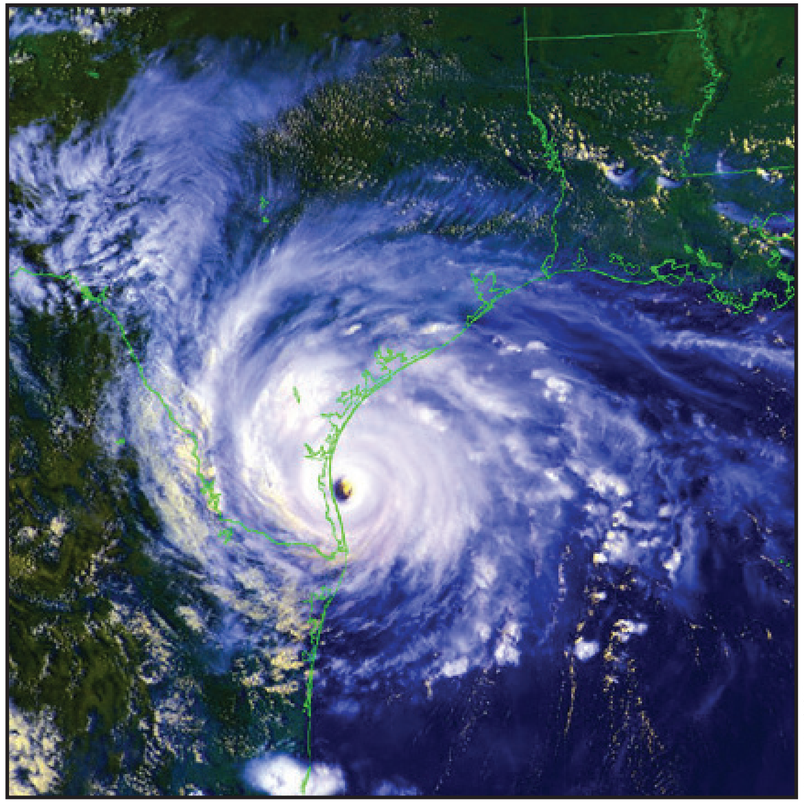


Image courtesy of NOAA

ABOUT THE DATA

The NOAA National Weather Service's National Hurricane Center uses a variety of different satellite sensors to obtain both qualitative and quantitative information on environmental conditions. A satellite that is critical for information across the large expanse of ocean where airborne sensors are impractical is the NOAA-operated Geostationary Operational Environmental Satellite (GOES). The sounder and imager sensors provide timely water vapor and temperature measurements throughout the atmosphere that are important parameters in the modeling of hurricane trajectories.

Project Participants

- NOAA National Weather Service, National Hurricane Center
- NOAA National Environmental Satellite, Data, and Information Service

The Advanced Very High Resolution Radiometer (AVHRR) multispectral sensor clearly shows the cloud formations surrounding the eye of a hurricane. Although Corpus Christi, Texas, and surrounding areas were evacuated, Hurricane Bret narrowly missed the most populated areas.

Identifying At-Risk Properties

Officials and residents on Washington's southwestern shores have enjoyed decades of shoreline stability. In many areas, beaches have experienced a net accretion rate.

It's a different story today. Numerous homes and properties that once had a wide expanse of beach are now threatened by erosion. These unstable conditions pose costly hazards to people, buildings, and infrastructure.

Washington is turning to remote sensing as the state searches for long-term solutions to its coastal erosion issues.

Many coastal states use Light Detection and Ranging (LIDAR) sensors mounted on aircraft to map shorelines, document change, and create elevation models. These sensors provide measurements that are comprehensive, quick, and accurate. The Southwest Washington Coastal Erosion Study is using this technology to explore the many factors that may be causing the beach to change and to predict these changes.

The study, which is a federal, state, and local partnership, is using LIDAR data to take an extensive look at sediment budgets, long-term shoreline stability, and the impacts of natural processes and man-made influences (enhanced runoff, dredging, coastal development, etc.) on the coast. Gaining a better understanding of the root causes of shoreline change is helping this state look past the quick fixes and concentrate on long-lasting solutions for its coastal communities. ❖

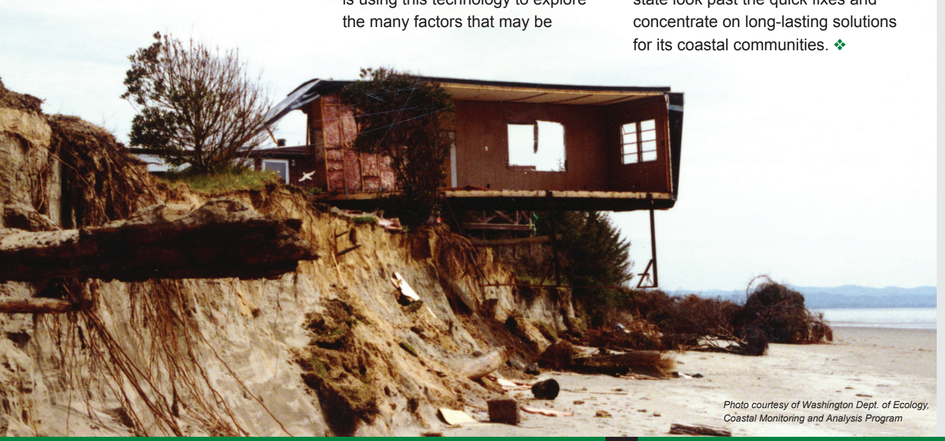
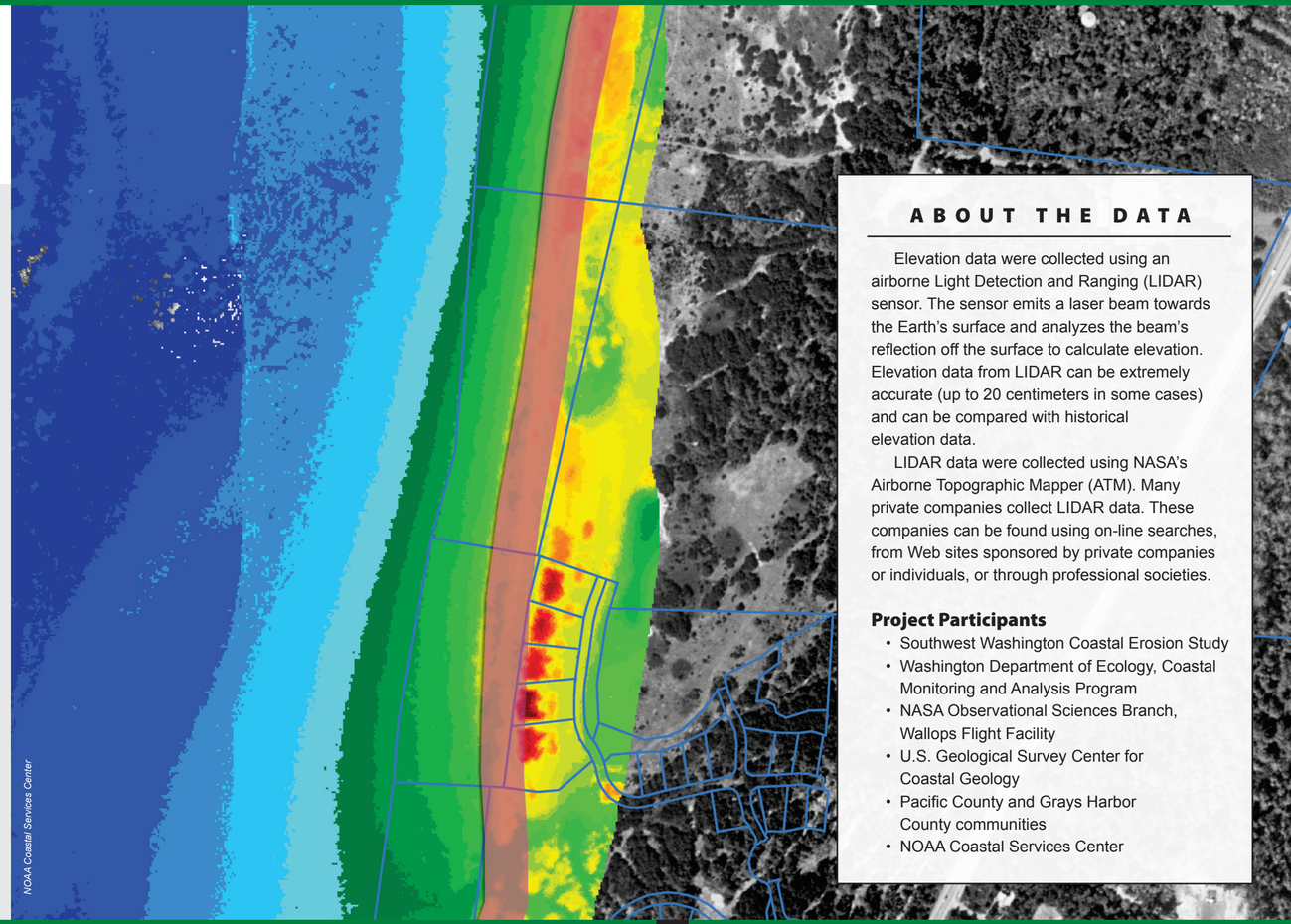


Photo courtesy of Washington Dept. of Ecology, Coastal Monitoring and Analysis Program

Since the mid-1990s, researchers have been using LIDAR data in spatial models to determine regions that have a high risk of being damaged by erosion. This model, used for South Beach, Oregon, incorporates a variety of data sets, including elevation from LIDAR, to determine areas with the highest risk of eroding (shown in light red). The LIDAR data are displayed with color gradients to indicate areas at or below sea level (blues), land (greens and yellows), and higher elevations caused by trees and buildings (dark reds). By combining this information with aerial photography and additional data, such as tax parcels (outlined in blue), managers can identify the properties that may be at risk.



NOAA Coastal Services Center

ABOUT THE DATA

Elevation data were collected using an airborne Light Detection and Ranging (LIDAR) sensor. The sensor emits a laser beam towards the Earth's surface and analyzes the beam's reflection off the surface to calculate elevation. Elevation data from LIDAR can be extremely accurate (up to 20 centimeters in some cases) and can be compared with historical elevation data.

LIDAR data were collected using NASA's Airborne Topographic Mapper (ATM). Many private companies collect LIDAR data. These companies can be found using on-line searches, from Web sites sponsored by private companies or individuals, or through professional societies.

Project Participants

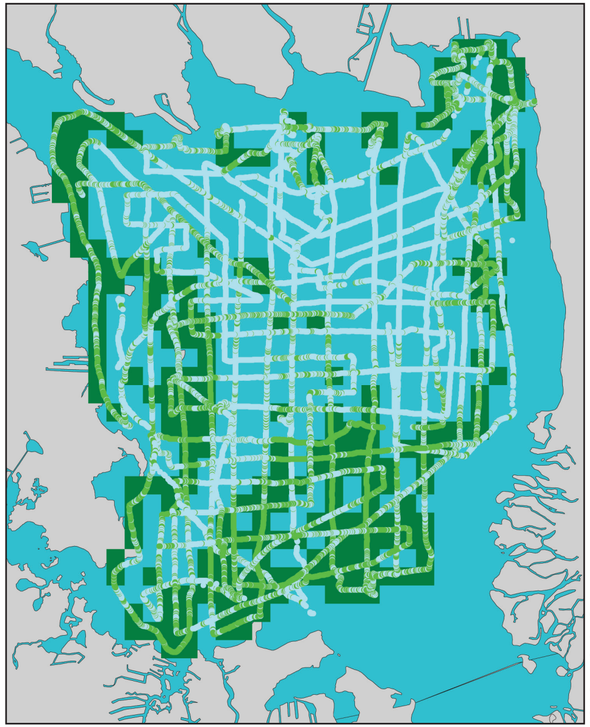
- Southwest Washington Coastal Erosion Study
- Washington Department of Ecology, Coastal Monitoring and Analysis Program
- NASA Observational Sciences Branch, Wallops Flight Facility
- U.S. Geological Survey Center for Coastal Geology
- Pacific County and Grays Harbor County communities
- NOAA Coastal Services Center

Managing Nuisance Plants

In Delaware's inland bays, development pressure and nutrient runoff are increasing every year. Fueled by nutrient loading, sea lettuce (*Ulva lactuca*) populations are growing larger and denser. Just as the tourist season and the temperatures start heating up, this plant dies and decays, emitting a noxious stench. Providing critical fish habitat in the fall, winter, and spring, sea lettuce quickly changes in the summer to an anoxic environment that no longer supports sea life.

To address this problem effectively, resource managers are trying to deal with sea lettuce while it is still alive—before it becomes a nuisance. The naturally turbid water prevents managers from seeing the sea lettuce with aerial photography, so they turned to an acoustic sensor that penetrates the cloudy water and detects where sea lettuce is growing. With this technology, managers can access comprehensive maps within days of collecting the data.

The Delaware Coastal Programs are using these maps to direct harvesters to the sea lettuce. Harvesters can target the areas with the most sea lettuce and highest potential for becoming a nuisance. Today, everyone—boaters, locals, tourists, and coastal managers—are breathing easier because of the sea lettuce maps. ❖



NOAA Coastal Services Center

What appear to be lines on this map of Rehoboth Bay, Delaware, are many acoustic data points close together. The green areas indicate where the sensor detected sea lettuce; each box represents 100 square meters that is categorized as sea lettuce habitat. The amount of detail provided by the data can be adjusted by changing the sampling pattern.

Photo courtesy of Delaware Dept. of Natural Resources and Environmental Control

ABOUT THE DATA

A single-beam acoustic sensor attached to a boat emits acoustic (sound) waves into the water and analyzes the reflection of the sound waves off the seafloor. The sensor that was used for this study measures the roughness, hardness, and depth of the seafloor. Researchers analyze these data to determine what is on the bottom.

Seafloor data were collected using the RoxAnn™ single beam acoustic sensor. There are many types of single-beam acoustic sensors, and they vary by the water depth at which they can function, how portable they are, and the type of data they record. More information about acoustic sensors can be found using on-line searches or through professional societies.

Project Participants

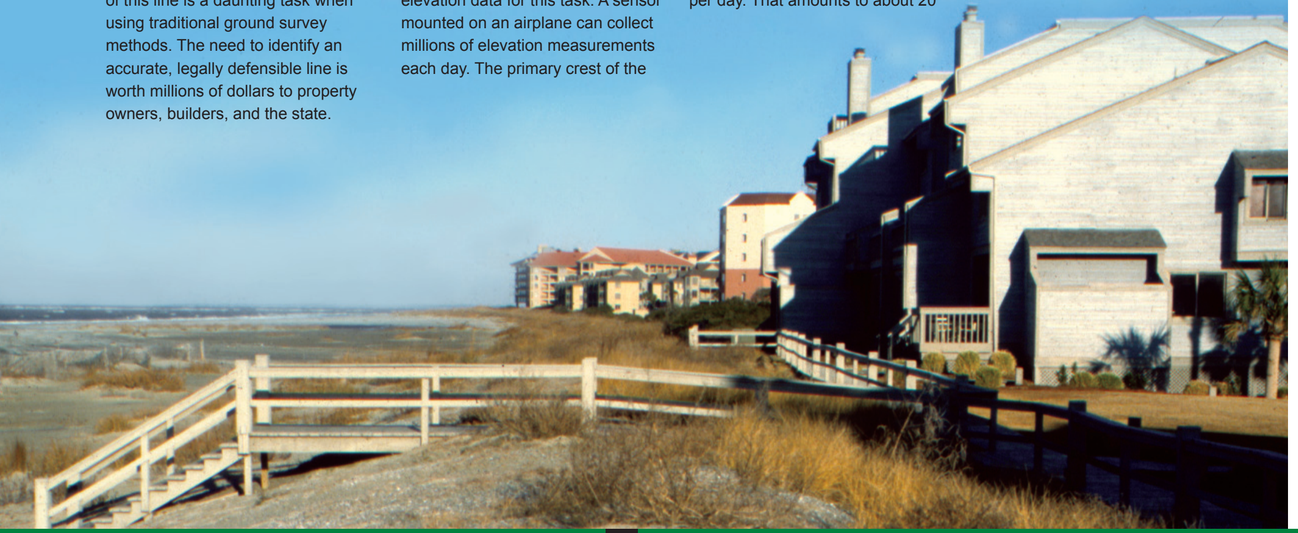
- Delaware Department of Natural Resources and Environmental Control, Delaware Coastal Programs
- NOAA Coastal Services Center

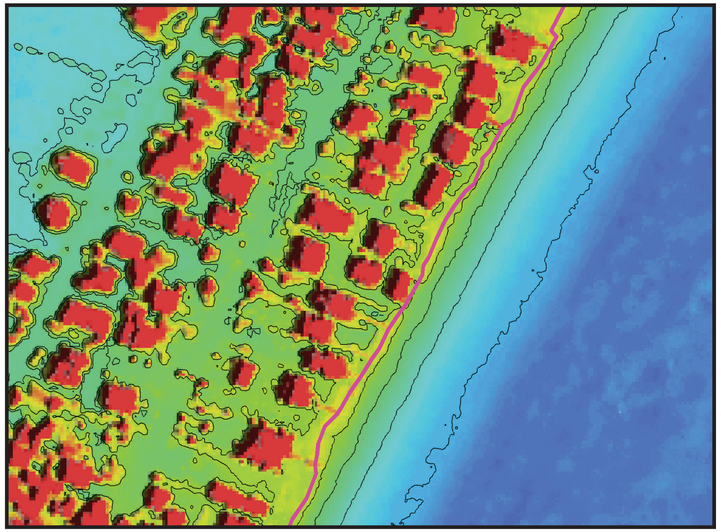
Mapping Oceanfront Setbacks

South Carolina's oceanfront setback line is 20 feet landward (at a minimum) of the primary dune crest and, by law, must be reset every 10 years. With over 200 miles of beaches, determining the location of this line is a daunting task when using traditional ground survey methods. The need to identify an accurate, legally defensible line is worth millions of dollars to property owners, builders, and the state.

The South Carolina Department of Health and Environmental Control, Office of Ocean and Coastal Resource Management (OCRM), acquired remotely sensed Light Detection and Ranging (LIDAR) elevation data for this task. A sensor mounted on an airplane can collect millions of elevation measurements each day. The primary crest of the dune is identified from the data, which is then used to delineate an accurate setback line.

A geographic information system (GIS) technician can map an average of 10 miles of beach per day. That amounts to about 20 days of work per year, compared to the 132 days required using ground surveys. With the remotely sensed data, OCRM can spend less time and manpower mapping, and more time protecting coastal resources. ❖





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LIDAR data for Pawleys Island, South Carolina, are displayed as a color grid and elevation contour lines. The grid is colored based on elevation: the blues indicate land that is at or below sea level, the greens and yellows are above sea level, and the reds are features with higher elevations, such as houses and boardwalks.

To help visualize elevation, a shading effect (hillshade) was applied. Technicians use the elevation data to designate the primary dune crest, which in this example is a pink line. The distance of the setback line from the crest varies for each area depending on the local erosion rates.

ABOUT THE DATA

Setback lines limit where someone can build on the beach. In South Carolina, these lines are 20 feet landward of the primary dune crest, or the first dune over three feet high. The elevation points collected by Light Detection and Ranging (LIDAR) can be processed into contour lines, which are then used to locate and map the primary dune crest. Deriving the dune crest from LIDAR data is faster and more accurate than the historical methods, which relied on measuring elevation from stereo pairs of aerial photographs (three-dimensional view) or by sending out a team of surveyors. In addition, LIDAR data have a high enough data density and accuracy for this type of mapping.

LIDAR data were collected using NASA's Airborne Topographic Mapper (ATM). Many private companies collect LIDAR data. These companies can be found using on-line searches, from Web sites sponsored by private companies or individuals, or through professional societies.

Project Participants

- South Carolina Department of Health and Environmental Control, Office of Ocean and Coastal Resource Management (OCRM)
- U.S. Geological Survey Center for Coastal Geology
- NASA Observational Science Branch, Wallops Flight Facility
- NOAA Coastal Services Center

HABITAT

"Remote sensing is an important way to monitor and understand the Earth's environment. The technology gives us a timely way to view our world—to see things that the eye doesn't catch."

James Lein
OhioView Consortium

Photo courtesy of National Park of American Samoa

Mapping the Coral Reefs of Hawaii and the Pacific U.S. Territories

Coral reef ecosystems are some of the most diverse, complex, and beautiful ecosystems in the marine environment. These fragile ecosystems are easily damaged by both natural and anthropogenic disturbances. Overfishing, runoff, and extreme weather events are all factors in the decline of coral reefs.

Presidential Executive Order 13089 was enacted to preserve and protect the U.S. coral reef ecosystems. A large percentage of the coral reefs addressed by this order are found in Hawaii and the U.S. territories in the Pacific Ocean; however, many areas in the Pacific are uninhabited or difficult to access. Detailed base maps of the bathymetry, location, and types of coral often do not exist.

To manage and protect the coral reefs effectively, coastal managers needed to know exactly where the corals were located. NOAA scientists chose high resolution satellite imagery to map the most remote areas. The location and size of the reefs and some information about their habitats can be documented using this satellite imagery because it is configured to detect underwater features if the water is clear.

For the first time, managers in the Northwest Hawaiian Islands have detailed base maps of their coral reefs. These maps are the first step to effectively managing these federally protected resources. Local resource managers will use these base maps to monitor coral reefs for habitat degradation, identify reefs at risk from destructive activities, and plan restoration projects. ❖

ABOUT THE DATA

In order to make large-scale maps of submerged coral reef habitats, scientists need high-resolution imagery that can detect features through water and can image the seafloor. High-resolution satellite imagery was chosen for the mapping efforts because, in clear water, some objects as small as 4 square meters can be found, and habitats can be mapped to 100 square meters. Imagery can be collected at various angles to minimize the sun's reflection off the water.

These data are multispectral, meaning that the data are captured in four spectral bands (red, blue, green, and near-infrared). Because of the multiple bands, researchers can use more than one method to map corals from the imagery. They can use the imagery for visual interpretation or they can run mathematical models on the spectral data to extract more detailed information.

Imagery was collected using the IKONOS Satellite, operated by Space Imaging.

Project Participants:

- American Samoa Coastal Management Program
- Commonwealth of the Northern Mariana Islands Coastal Resources Management Office
- Coral Reef Conservation Program
- Guam Coastal Management Program
- Hawaii Coastal Zone Management Program
- U.S. Coral Reef Task Force
- National Fish and Wildlife Federation
- NOAA National Center for Coastal Ocean Science
- Science Technology International, Inc.
- NOAA Coastal Services Center

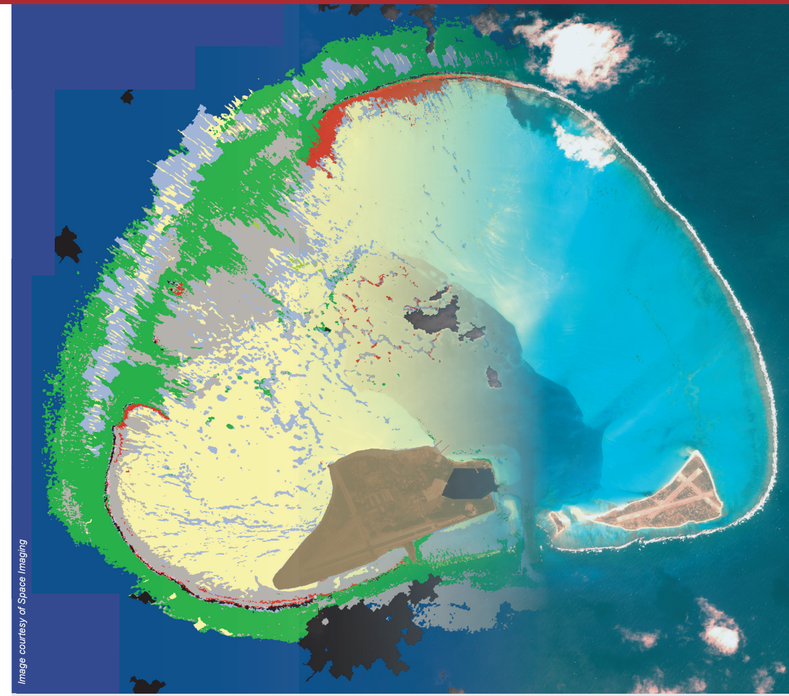


Image courtesy of Space Imaging

Because IKONOS is mounted on a satellite, it can collect data for areas that are too remote for an airplane to access, such as the Midway Islands shown here. This high-resolution imagery can be used to map features as small as four meters, such as corals and seagrass beds. The right side of this graphic is a true-color representation of the data, and the left side shows the categories of benthic data. Habitats are represented by different colors: yellow is sandy bottom, brown is land, and the remaining colors are different types of coral habitat. Areas obscured by clouds are colored black.

Monitoring the Spread of Brown Marsh

Salt marshes along the coast of Louisiana are dying at alarming rates. This phenomenon, first noticed in 2000, is commonly referred to as brown marsh. Brown marsh is true to its name; when an area is impacted, the marsh grass, *Spartina alterniflora*, turns brown, dies, and does not appear to return on its own. *Spartina alterniflora* is Louisiana's most dominant salt marsh plant type, and widespread losses will be detrimental to the various fin and shellfish, birds, and mammals that rely on marsh habitat. The losses will impact coastal communities and the economy as well.

Managers in Louisiana launched a massive effort to understand both the spatial extent and causes of brown marsh. As part of that effort, multispectral satellite imagery was used to map the regional extent of brown marsh throughout the coastal zone of Louisiana. This imagery allows managers to pinpoint where wetlands are changing and to target specific sites to monitor instead of hundreds of miles of salt marsh. The information also is being used to select restoration sites and monitor their success.

Wetland habitat is key to the survival of species that are important both ecologically and economically, and wetlands protect the land from erosion and storm events. To protect these vital wetland functions, Louisiana's coastal managers are employing satellite imagery to monitor the state's marsh grasses. ❖

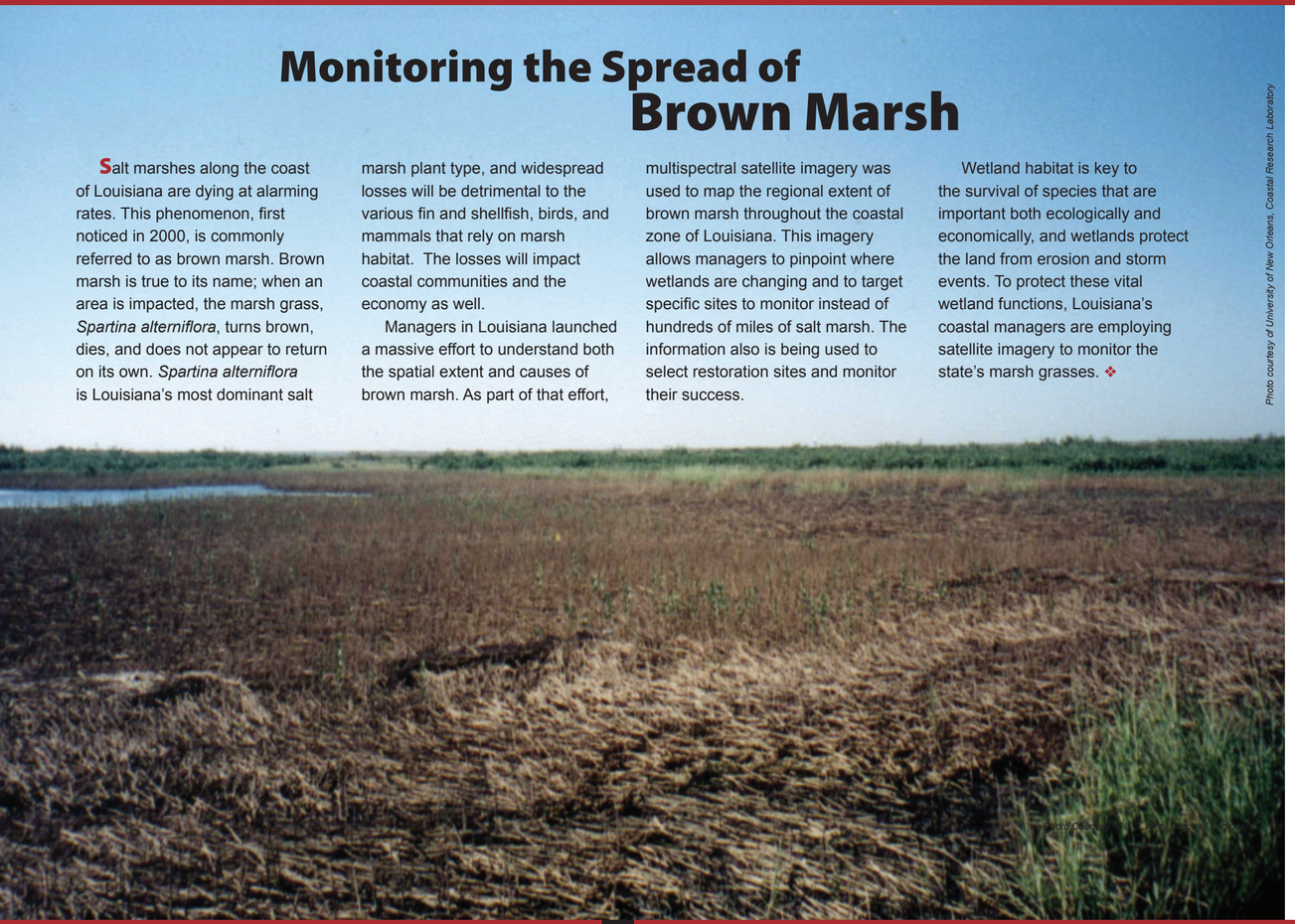


Photo courtesy of University of New Orleans, Coastal Research Laboratory

ABOUT THE DATA

Researchers used mid-resolution multispectral satellite imagery to map the regional extent of brown marsh in Louisiana's coastal areas. The imagery covers a large area (100 x 100 kilometers) and has a spatial resolution of 30 meters. The imagery used was acquired from a satellite sensor that can provide imagery of any given spot on the Earth every 16 days.

Brown marsh data were developed using Landsat Thematic Mapper (TM) data, acquired from the U.S. Geological Survey's Earth Resources Observation Systems (EROS) Data Center.

Project Participants

- University of New Orleans, Coastal Research Laboratory
- Louisiana Department of Natural Resources
- U.S. Geological Survey, National Wetlands Research Center
- NASA Stennis Space Center
- NOAA National Marine Fisheries Service
- NOAA Coastal Services Center

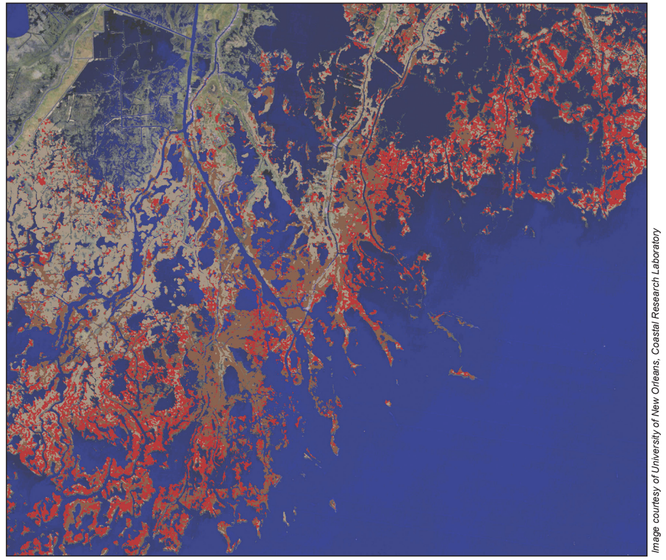


Image courtesy of University of New Orleans, Coastal Research Laboratory

This image shows areas of brown marsh in Terrebonne Bay, Louisiana. Three types of affected marshes were classified: red areas indicate the most severe impact where vegetation has died, leaving stubble or exposed soil, and the brown and tan areas indicate varying levels of stress caused by brown marsh. The classified data are displayed on a mosaiced multispectral satellite image.

Photo courtesy of NOAA Photo Library

Mapping Kelp Beds

Over the last 10 years, the herring population in Cook Inlet, Alaska, has declined dramatically, prompting managers to investigate conservation strategies. To understand the factors that might be affecting these commercially important fish, managers looked to scientists to provide information on the habitat of these species.

Herring, as well as birds, octopuses, and sea otters, depend on kelp beds for foraging and shelter. Researchers at the Kachemak Bay National Estuarine Research Reserve mapped the distribution of kelp beds in the bay in 2000, 2001, and 2002. Because local weather and tide conditions afford limited opportunities for collecting aerial photography, they needed to find a method to map large areas of Alaska's shoreline quickly and inexpensively. Using oblique aerial photography, they were able to identify kelp beds and found that the amount of kelp habitat varied annually by as much as 10 percent.

The Nature Conservancy (TNC) is using kelp bed data as a proxy for herring habitat as part of its ecoregional conservation plan for the Cook Inlet ecosystem. By designating the herring as a conservation target and identifying potential sources of stress to herring populations, such as the loss of kelp habitat, TNC can develop ways to alleviate these threats. Creating conservation plans and understanding what conditions affect the distribution of critical habitats helps managers maintain valuable resources. ❖

Image courtesy of Kachemak Bay National Estuarine Research Reserve

This oblique aerial photograph captures not only the kelp canopies (hand-digitized in red), but also the shoreline, allowing researchers to select ground control points on the land.

ABOUT THE DATA

For this study, researchers used oblique aerial photography to map kelp beds. Oblique photographs are taken at an angle, rather than vertically, and can therefore show a larger field of view. This represents a major cost savings because fewer flight lines are needed to cover the same area. Although they can be more difficult to geometrically correct, oblique photographs of the kelp beds also include the shoreline. Thus, ground control points on land can be used as reference locations, even for flight lines parallel to the shore.

Researchers chose color film, rather than color infrared film, because color film more effectively depicts the submerged canopies of the kelp beds. The photos were taken during a low spring tide between August and October, when the maximum extent of the canopy occurs. Because these conditions must also coincide with good weather and visibility, there are often only limited opportunities in a season to acquire imagery.

Oblique aerial photographs were taken by the principal investigator, Carl Schoch. Many private companies offer aerial photography services, and these companies can be found using on-line searches or through professional societies.

Project Participants

- The Nature Conservancy
- Kachemak Bay National Estuarine Research Reserve
- World Wildlife Fund
- U.S. Fish and Wildlife Service Coastal Program
- University of Alaska, Alaska Natural Heritage Program

Restoring and Preserving Wetlands and Riparian Areas

Southern California's wetlands and riparian zones are among the most diverse, productive, and densely populated habitats on the Pacific coast. These important habitats have been dramatically altered by human activities over the past 150 years, resulting in a loss of 75 percent of coastal wetlands and the threatened extinction of numerous wetland-dependent species.

The Southern California Wetlands Recovery Project (WRP), a partnership among state and federal agencies working with local government, environmental organizations, and scientists, is developing and implementing a comprehensive plan for preserving and restoring the region's wetlands. The WRP identifies wetland acquisition and restoration priorities, prepares plans for these sites, pools funds to undertake these projects, implements priority plans, and oversees post-project maintenance and monitoring.

To better prioritize acquisition and restoration projects and evaluate long-term recovery efforts, the WRP needs a regional inventory of wetland and riparian physical and biological resources. A fine-scale digital elevation model (DEM), defining the extent of the wetland and riparian zones, is a fundamental part of this inventory. Interferometric synthetic aperture radar (IfSAR) provides a means to collect high-resolution elevation data over a large area. Using this method for data collection, the regional need for consistent data can be satisfied and, at the same time, individual cities and counties have access to the wealth of information that can be provided by high-resolution DEMs.

The goal of the Southern California Wetlands Recovery Project is to accelerate the pace, extent, and effectiveness of coastal wetland restoration. With this approach, the project's efforts will result in increasing quantity and improved quality of the region's wetlands. ❖

NOAA Coastal Services Center

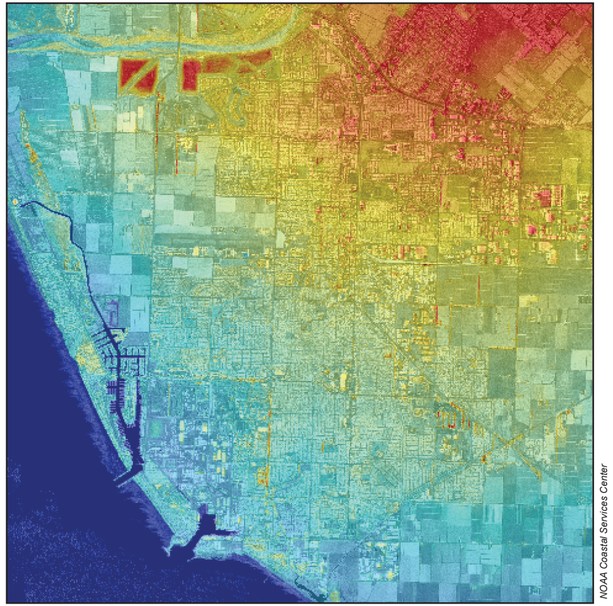
ABOUT THE DATA

Synthetic Aperture Radar (SAR) is a specialized, high-resolution form of radar that emits microwave signals that bounce off of a target and are collected and analyzed by the airborne sensor. Interferometric SAR (IfSAR) uses two SAR images of the same area taken from slightly different positions. Comparison of the images generates relative height differences that can be calibrated with known ground elevations to create three-dimensional images.

Radar can be used even when other sensors cannot because radio waves can penetrate clouds and the detectors can operate at night. IfSAR, for this project, provided elevation data with a spatial resolution of three meters and vertical accuracy of one to one-half meters. IfSAR data were collected using the GeoSAR sensor, operated by EarthData International.

Project Participants

- Southern California Wetlands Recovery Project
- Santa Barbara County
- Ventura County
- City of Los Angeles
- Orange County
- San Diego County
- NOAA Coastal Services Center



NOAA Coastal Services Center

The pattern of increasing elevation is depicted as changing colors in this IfSAR image of Oxnard, California, and surrounding areas. Low areas along the coast on the lower left side of the image are blue, and the higher inland elevations to the upper right are red. Urban features, including buildings, roads, marinas, and ports can be identified throughout the image. Patterns of agricultural development are visible as large rectangular blocks.

Photo by Joe Heath and courtesy of NOAA National Marine Sanctuary Program

Photo courtesy of Channel Islands National Marine Sanctuary

Determining Marine Protected Area Boundaries

When detailed habitat information is needed for underwater areas that occur in clear waters, aerial photography is frequently used to map the area closest to the beach (the nearshore). The primary exceptions to this rule occur when the nearshore contains deepwater areas, or where water clarity is poor due to plankton or suspended sediments. In these instances, researchers often rely on scuba divers or remotely operated observation vehicles for their data and information needs.

It's a different story for much of California. State law required the California Department of Fish and Game to establish a network of marine protected areas (MPAs) along coastal California. Habitat and seafloor data are an important component of this effort, but the deep water and the expansive area precluded the use of traditional data-gathering methods. California officials turned to remote sensing sonar (Sound Navigation and Ranging) technology to meet their needs.

Sonar is used to gather detailed data about large submerged areas. Multibeam sonar, side-scan sonar, and sub-bottom sonar are some of the instruments being used in California to collect the needed bathymetry, habitat, and sediment data. The Department of Fish and Game is using this information to help determine the best locations for marine protected areas and to create a baseline of seafloor characteristics. Special care was taken to ensure that these data were collected using a common approach and methodology so that the seafloor information could be applied to other federal, state, and local research and charting projects.

Three-dimensional seafloor maps created through this effort help people visualize the area, and therefore gain a better understanding of the seafloor and its characteristics. This improved understanding may help California's efforts to create and implement marine protected areas. ❖

ABOUT THE DATA

Multibeam, a specialized form of sonar, uses a fan-shaped transmission to sweep the seafloor below and on either side of the vessel. The sensor records the length of time that it takes for the signal to return, and produces a high-resolution bathymetric map from these data. In essence, a multibeam sonar is similar to having many single-beam depth sounders (like the "fish finders" used by many boaters and fishers) combined into a single unit, pointing not only straight down but also off to each side, yielding a swath of measurements rather than just a single one.

A side-scan sonar system is usually pulled behind a boat on an underwater unit called a towfish. The towfish transmits beams of sound energy and analyzes the signal that bounces off of the bottom. Side-scan produces "pictures" of the bottom, in which color is related to seafloor substrate composition (i.e., mud, sand, or rock) and texture, and objects that stick up from the bottom create shadows. These images can be mosaicked together to create a complete picture of the seafloor, or draped over the bathymetric map to create a three-dimensional picture of the seabed.

A sub-bottom sonar emits a single beam of lower frequency sound energy that, depending on the substrate and the frequency used, can penetrate tens or hundreds of meters into the seafloor's sediments. This type of data can provide information about the sediment layering, geology, and marine life buried in the sediments. All of these sonar systems require extensive field validation and analysis to create final maps of the seafloor.

These sonar systems are operated, and the resulting data are analyzed, by the California State University, Monterey Bay, Seafloor Mapping Lab.

Project Participants

- California State University, Monterey Bay, Seafloor Mapping Lab
- California Department of Fish and Game
- NOAA Office of Coast Survey, Pacific Hydrographic Branch
- NOAA Coastal Services Center

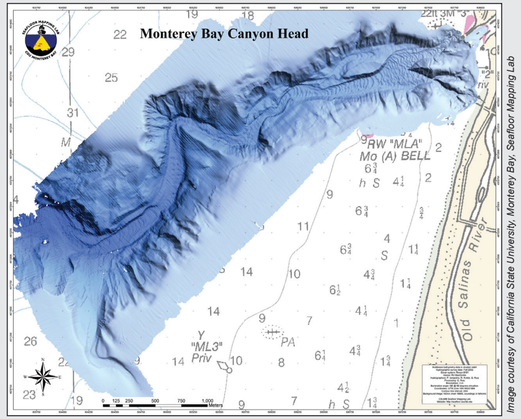


Image courtesy of California State University, Monterey Bay, Seafloor Mapping Lab

Multibeam sonar data were used to map the bathymetry and topography of the Monterey Canyon, a deepwater canyon that runs through Monterey Bay. In this image, shallow waters are lighter blue and deeper waters are darker blue.

WATER QUALITY

"We are using LIDAR to map our ocean shore and beaches from the north to the south. For the first time, we have the whole coast mapped at an accurate enough scale to provide really meaningful information to local governments so that they can use the data with some assurance that the measurements are accurate."

Bob Bailey
Oregon Ocean-Coastal
Management Program

Monitoring Stormwater Runoff

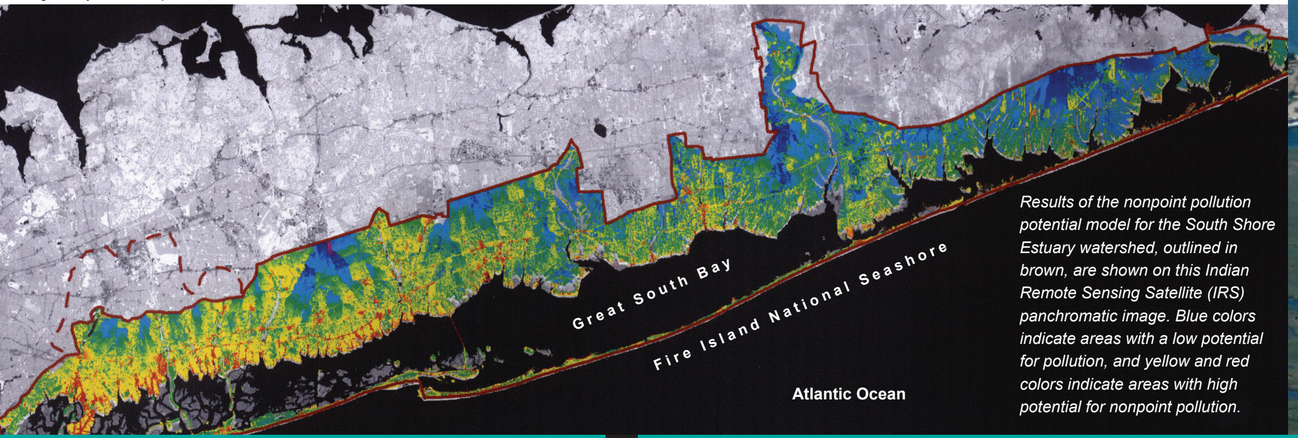
Long Island's South Shore Estuary serves as one of the region's top recreational and tourism areas, offering miles of beaches and tidal wetlands. The estuary is critical habitat for a variety of wildlife, including shellfish, finfish, migratory waterfowl, and colonial waterbirds. Designated a reserve by New York State in 1993, the area is also home to about 1.5 million people.

The high level of development in the reserve causes large volumes of stormwater to flow directly into its tributaries and bays, carrying pollutants such as bacteria, nutrients, sediment, and oil from the land. The pollutants cause closed shellfish beds, periodic beach closures, and degraded fisheries.

To better understand the scope of this nonpoint source pollution, researchers for the New York Department of State's Division of Coastal Resources developed a nonpoint pollution potential model. This model integrates remotely sensed land cover and topography data with information about the ground's ability to absorb water. The model predicts where and how stormwater can move through the reserve. This helps coastal managers determine which parts of their communities are contributing to degraded water quality.

With this information, the state program is targeting problem areas for remediation projects, such as stormwater sewer repairs, and proactively protecting areas that are doing a good job absorbing stormwater. Local officials are doing their part by implementing regulations for land and water use, using new road and highway development standards to limit runoff, and educating the public about the stormwater runoff issues. ❖

Image courtesy of New York Dept. of State, Division of Coastal Resources



Results of the nonpoint pollution potential model for the South Shore Estuary watershed, outlined in brown, are shown on this Indian Remote Sensing Satellite (IRS) panchromatic image. Blue colors indicate areas with a low potential for pollution, and yellow and red colors indicate areas with high potential for nonpoint pollution.

Photo courtesy of Geoffrey Steadman

ABOUT THE DATA

The land cover data used in the pollution potential model were developed from multispectral satellite imagery using the methods created by the NOAA Coastal Services Center. The data have a spatial resolution of 30 meters, and the methods support as many as 22 classes that describe the land cover. In this example, the researchers recategorized the developed areas to better capture the amount of impervious surface in the landscape (e.g., very industrial areas were categorized as high intensity developed; residential areas were categorized as low intensity developed).

Land cover data were developed using Landsat Thematic Mapper (TM) data, acquired from the U.S. Geological Survey's Earth Resources Observation Systems (EROS) Data Center. Land cover data can differ depending on the source of the data and the intended use. For example, land cover data can be derived from higher resolution data, such as aerial photography or multispectral satellite imagery such as IKONOS, QuickBird, or SPOT. The systems for categorized imagery may describe different types of land cover with varying amounts of detail.

Project Participants

- New York Department of State, Division of Coastal Resources
- State University of New York at Albany, Department of Geography

Monitoring Water Quality

The New Jersey Department of Environmental Protection samples over 40,000 water quality stations each year to meet its National Shellfish Sanitation Program and EPA water quality monitoring commitments. While many parameters are monitored all year, water samples for phytoplankton are collected every two weeks from May through September at standard locations using a combination of small boats and a helicopter.

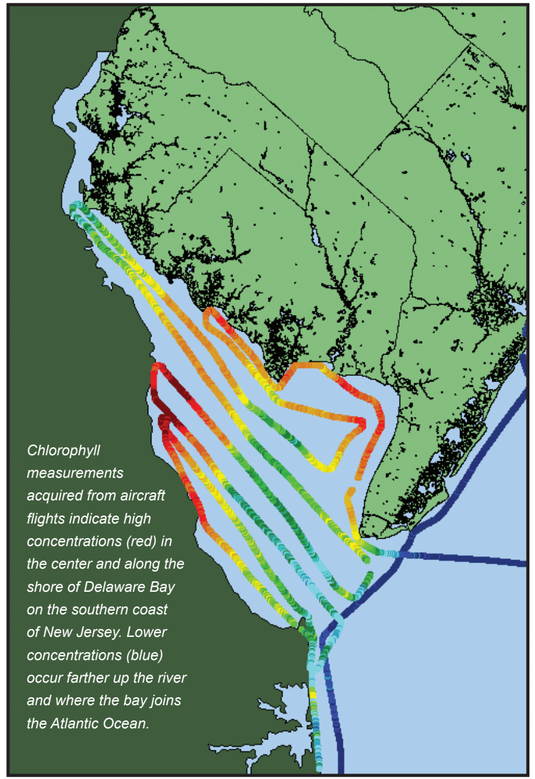
Despite the comprehensive design of the monitoring program, localized phytoplankton blooms, which could affect public health, can occur in places or at times that are not detected using fixed stations and fixed sampling.

To make its monitoring program more effective and efficient, New Jersey looked at chlorophyll data collected by satellite and airborne remote sensing systems. These systems provide information over a larger area and at more frequent intervals than could be gathered by boats.

By using airborne ocean color measurements of chlorophyll, New Jersey found that large concentrations of phytoplankton could occur in areas and during times researchers had not been sampling. Based on the remotely sensed data, the state agency has changed the time frame and expanded the location of the routine boat-monitoring program. This is increasing the agency's ability to assure the quality of New Jersey seafood. ❖

Photo courtesy of New Jersey Department of Environmental Protection, Bureau of Marine Water Monitoring

Photo courtesy of NOAA Photo Library



Chlorophyll measurements acquired from aircraft flights indicate high concentrations (red) in the center and along the shore of Delaware Bay on the southern coast of New Jersey. Lower concentrations (blue) occur farther up the river and where the bay joins the Atlantic Ocean.

NOAA Coastal Services Center

ABOUT THE DATA

This study combined several different types of airborne sensors to remotely measure chlorophyll concentrations. Multiple measurements allow the results to be compared and provide a better understanding of shallow water remote sensing.

Oceanographic Light Detection and Ranging (LIDAR) used in this project is slightly different from the terrestrial version. It has a laser that emits blue light, causing chlorophyll in the phytoplankton to fluoresce, or emit red light. The strength of the signal can be related to the amount of chlorophyll in the water. LIDAR data were collected using NASA's Airborne Oceanographic LIDAR (AOL).

A passive hyperspectral sensor that records across the visible range of the spectrum was also used for this study. Measurements in the blue and green portions of the spectrum were used to determine chlorophyll concentration. Ocean color data were collected using the Airborne Diode Array Spectrometer (ADAS) developed by NASA.

Another ocean color sensor used in the project has bands precisely matched to those of the OrbView-2/SeaWiFS satellite. Using algorithms, these measurements can be related to phytoplankton concentrations in the surface layers of the water. Ocean color data were collected using the Satlantic, Inc., SeaWiFS Aircraft Simulator (SAS) II.

A sea surface temperature sensor was used that records the infrared radiation from the water surface and converts it into a temperature measurement. Sea surface temperature was measured using a Heimann KT Infrared Radiometer.

For offshore chlorophyll measurements, the project relied on ocean color data acquired by the OrbView-2/Sea-viewing Wide Field-of-view Sensor (SeaWiFS) satellite.

Project Participants

- New Jersey Department of Environmental Protection, Bureau of Marine Water Monitoring
- NASA Observational Science Branch, Wallops Flight Facility
- NOAA CoastWatch Program
- NOAA Coastal Services Center

Monitoring Red Tides

One fall afternoon, coastal managers in Florida received a warning that a red tide might have developed off their southwestern coast. Monitoring teams were sent to investigate, and concentrations of the toxin-producing algae were confirmed.

By identifying the tide early, managers along the Gulf of Mexico were able to quickly test shellfish harvesting beds in the area for exposure to the toxin.

At certain times of the year, rapidly increasing chlorophyll is an indicator of red tide algae, and these areas can be distinguished using remotely sensed images that depict ocean color data. Identifying these areas allows for faster, more targeted sampling in this enormous body of water. Combined with circulation models, remotely sensed wind speed and direction data help managers make educated predictions as to where and how the bloom will move.

With this information, the Florida Division of Aquaculture and the Florida Marine Research Institute can reduce unnecessary closings of economically valuable shellfish beds, while effectively protecting public safety and monitoring water quality. ❖

Photo courtesy of NOAA Center for Coastal Fisheries and Habitat Research

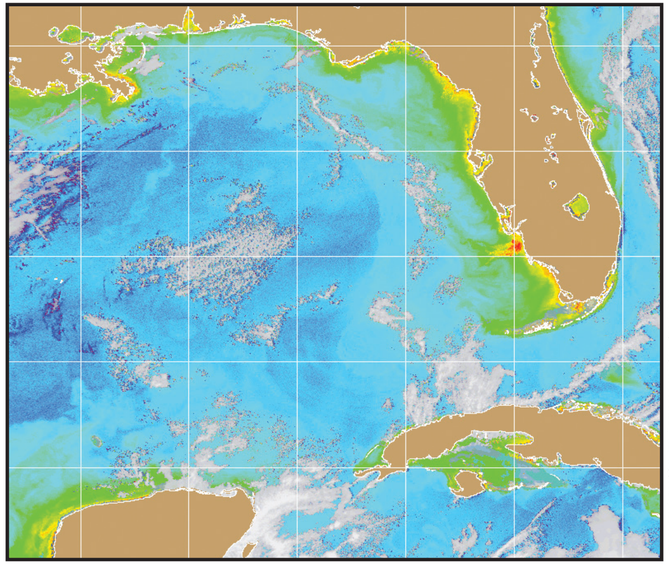


Image courtesy of OrbView-2 provided by NOAA CoastWatch

The pattern in this Orbview-2/Sea-viewing Wide Field of View Sensor (SeaWiFS) image indicates a high concentration of chlorophyll (red and orange colors) extending off the southwest coast of Florida in October 2000. During this time of year in this area, red tides are common. When the waters in this area were sampled, researchers found dead fish associated with significant concentrations of the red tide phytoplankton, Karenia brevis.

ABOUT THE DATA

NOAA researchers use measurements of chlorophyll concentrations to determine when algal blooms may be occurring. By comparing current imagery to average levels over the previous month, changes can be detected. If these changes are large, researchers can alert coastal managers to the presence of increased chlorophyll levels that may need further investigation.

Chlorophyll data were collected by the OrbView-2/Sea-viewing Wide Field-of-view Sensor (SeaWiFS), a sensor operated jointly by NASA and Orbimage.

Project Participants

- Florida Department of Agriculture and Consumer Services, Division of Aquaculture
- Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute
- Mote Marine Laboratory
- University of South Florida
- NOAA National Centers for Coastal Ocean Science
- NOAA CoastWatch
- NOAA Coastal Services Center

Mitigating Oil Spills

Transportation of oil products through the coastal waters of Texas is critical to the state and to the nation's economy. Just as critical is the ability to respond effectively to oil spills in order to protect water quality, living marine resources, and public health and enjoyment of the coast. One way managers do this is by predicting how the oil spill will move to determine where and when to place containment booms, cleanup crews, and wildlife rehabilitation teams.

The Texas Automated Buoy System (TABS), a network of nine buoys placed in strategic locations along the coastline, is designed to provide the spill response community with half-hourly current measurements during spills. The constant monitoring by these buoys allows modelers to estimate the trajectory of the oil with the most recent information.

When a barge ran aground near Galveston, spilling more than 200,000 gallons of fuel oil, Texas coordinated its current monitoring efforts with NOAA's trajectory modeling team to predict where the oil would go and minimize the impact on the lagoons, grassy dunes, and sandy beaches in its path. Using TABS, the cleanup and protection operations were placed at the predicted point of impact a full day earlier than would have been possible without this remote observing system. Since it first began operations in 1995, TABS has provided data for decision-support in more than two dozen oil spills. ❖

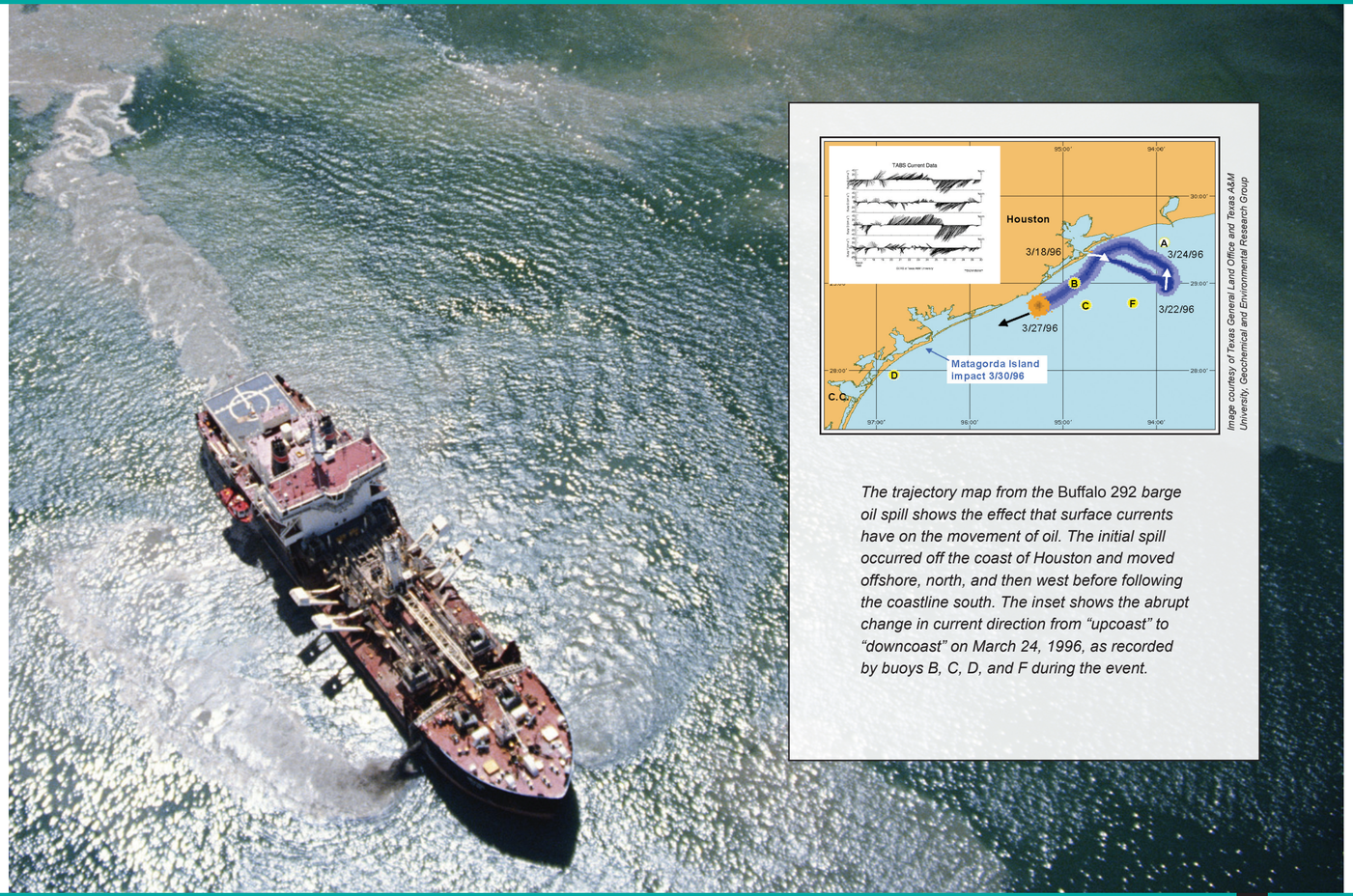


Image courtesy of Texas General Land Office and Texas A&M University, Geochemical and Environmental Research Group

The trajectory map from the Buffalo 292 *barge oil spill shows the effect that surface currents have on the movement of oil. The initial spill occurred off the coast of Houston and moved offshore, north, and then west before following the coastline south. The inset shows the abrupt change in current direction from "upcoast" to "downcoast" on March 24, 1996, as recorded by buoys B, C, D, and F during the event.*

ABOUT THE DATA

The Texas Automated Buoy System (TABS) network of nine buoys off the Texas coast transmits surface currents and water temperatures at a depth of 2 meters, as well as wind data, via satellite digital links. These data, collected every half-hour, are updated on a Web page every hour. In addition, computer simulations to forecast ocean currents two days into the future are run every night.

Project Participants

- Texas General Land Office
- Texas A&M University, Geochemical and Environmental Research Group
- Texas A&M University, Department of Oceanography
- Joint Industry Group
- Gulf of Mexico Coastal Ocean Observing System
- NOAA National Data Buoy Center
- NOAA Office of Response and Restoration

Monitoring Sewage Outfall Impacts

Photo courtesy of Massachusetts Water Resources Authority

When one of the world's largest marine sewage outfall sites was built in Massachusetts Bay, concerns about the potential for water quality degradation were high. In response, an extensive monitoring program was initiated that uses local monitoring data and remote sensing imagery to ensure the offshore waters are not significantly impacted.

The Massachusetts Water Resources Authority (MWRA) uses a boat to monitor nearly 100 indicators of water quality in the bay. While this method of sampling is effective, it can miss what is happening between sampling stations and what is happening in the time between field surveys. Satellite imagery is used to tie the sampling points together in time and space. When sampling reveals that a water quality threshold is exceeded, the MWRA promptly notifies regulators, the public, and a science advisory panel. The panel may decide that the exceedance was due to natural causes or may recommend further study or other response.

Remotely sensed ocean color imagery has allowed MWRA to view its monitoring data within a larger spatial context and determine, for example, when harmful algal blooms are regional events. Equally important, the ocean color imagery helps the coastal managers track blooms that originate elsewhere and then move towards the outfall. Thus, potential water quality issues can be dealt with sooner than traditional water testing methods would allow. ❖

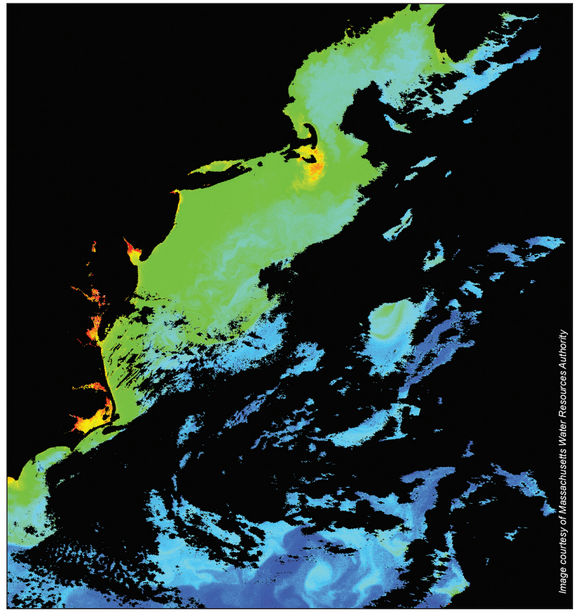


Image courtesy of Massachusetts Water Resources Authority

The chlorophyll levels from this ocean color multispectral sensor are shown in different colors to emphasize the concentration ranges. Blue represents the lower concentrations, green and yellow are intermediate, and red is high. The high chlorophyll concentrations around the Nantucket Shoals are represented by orange.

ABOUT THE DATA

In the presence of elevated nutrient levels, phytoplankton will experience rapid growth rates, therefore increasing the levels of chlorophyll in the water. In order to get early warnings of potential sewage-related problems, researchers use measurements of the intensity of light emanating from the ocean at specific wavelengths—the color of the ocean—using an ocean color multispectral satellite sensor. These data are run through a series of mathematical models (algorithms) to determine chlorophyll concentration.

Chlorophyll imagery was acquired from the OrbView-2/Sea-viewing Wide Field-of-view Sensor (SeaWiFS). Depending on the intended use, chlorophyll imagery can be obtained from either NASA Goddard Space Flight Center, OrbImage, or the NOAA CoastWatch program.

Project Participants

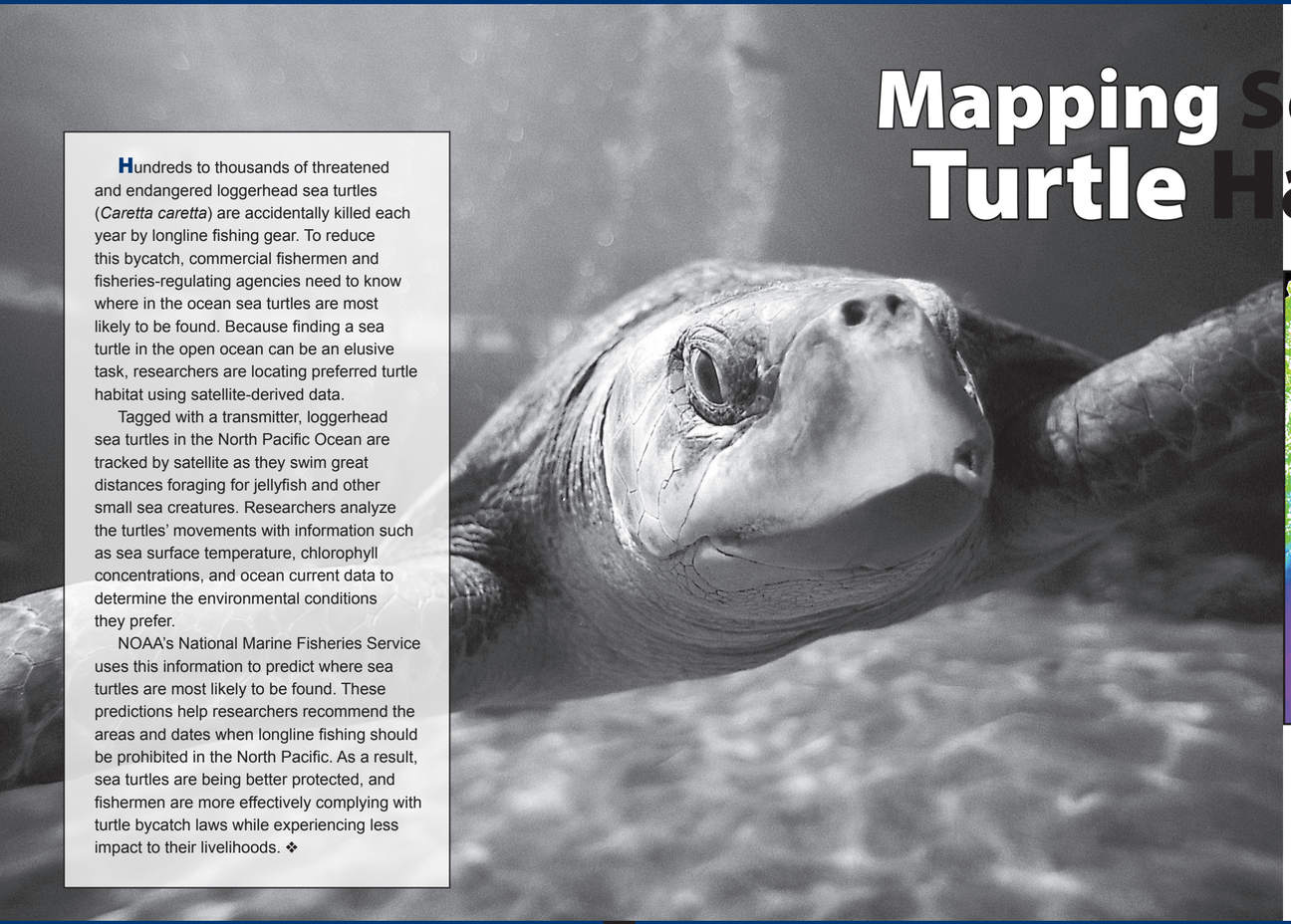
- Massachusetts Water Resources Authority
- Environmental Protection Agency, Outfall Monitoring Science Advisory Panel
- University of Maryland
- NOAA CoastWatch

LIVING RESOURCES

"Using an aerial platform is a really good way to get out fast and get a good overview. It's a great way to see the landscape, and trends and variations. Being able to get up in the air and get that bird's-eye view is really beneficial."

Ben Waltenberger
Channel Islands National Marine Sanctuary

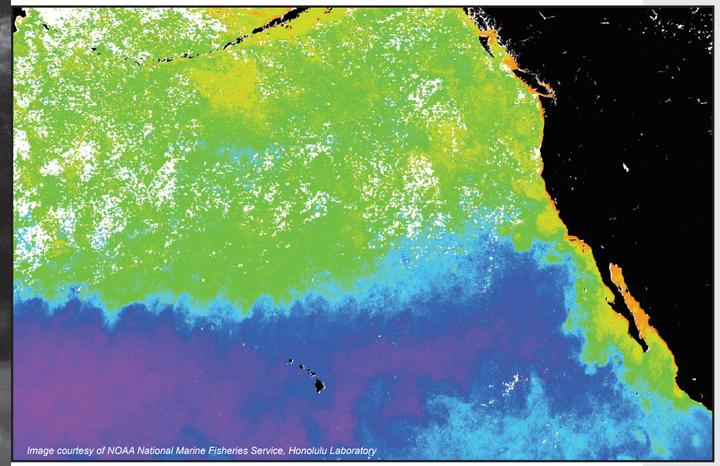
Mapping Sea Turtle Habitat



Hundreds to thousands of threatened and endangered loggerhead sea turtles (*Caretta caretta*) are accidentally killed each year by longline fishing gear. To reduce this bycatch, commercial fishermen and fisheries-regulating agencies need to know where in the ocean sea turtles are most likely to be found. Because finding a sea turtle in the open ocean can be an elusive task, researchers are locating preferred turtle habitat using satellite-derived data.

Tagged with a transmitter, loggerhead sea turtles in the North Pacific Ocean are tracked by satellite as they swim great distances foraging for jellyfish and other small sea creatures. Researchers analyze the turtles' movements with information such as sea surface temperature, chlorophyll concentrations, and ocean current data to determine the environmental conditions they prefer.

NOAA's National Marine Fisheries Service uses this information to predict where sea turtles are most likely to be found. These predictions help researchers recommend the areas and dates when longline fishing should be prohibited in the North Pacific. As a result, sea turtles are being better protected, and fishermen are more effectively complying with turtle bycatch laws while experiencing less impact to their livelihoods. ❖



Researchers use regional-scale chlorophyll images with ocean-current data to help identify the ocean fronts (convergence areas for currents) where loggerhead sea turtles are most likely to be found. In this chlorophyll image of the North Pacific Ocean from February 1998, loggerheads are most likely to be found at the interface of the areas colored blue and green, which denotes approximately 0.20 milligrams of chlorophyll per cubic meter.

ABOUT THE DATA

This research used satellite-derived sea surface temperature, chlorophyll, and ocean-current data with satellite tracking to help predict the locations of loggerhead sea turtles in the North Pacific Ocean.

Researchers used derived sea surface temperature (SST) imagery from ocean temperature multispectral instruments and chlorophyll data from the ocean color multispectral instruments. Both of these satellite-based sensors take images of large expanses of the Earth at a resolution of 1 kilometer. Users receive these data sets after they have been run through a series of mathematical models (algorithms) to determine either SST or chlorophyll. SST data were acquired from NOAA's Advanced Very High Resolution Radiometer (AVHRR). The NASA Jet Propulsion Laboratory and the NOAA CoastWatch program provide more information about using SST data. Chlorophyll data from the OrbView 2/Sea-Viewing Wide Field-of-View Sensor (SeaWiFS) were obtained from NASA Goddard Space Flight Center.

Researchers used ocean-current information derived from altimetry data collected by NASA's TOPEX/Poseidon altimetry satellite.

Loggerhead sea turtles are tracked using a satellite telemetry system. A transmitter is attached to a turtle's shell and returns data for the life of the transmitter's battery, anywhere from a few months to a year.

The transmitters used in this study are linked to the Argos Satellite Telemetry System.

Project Participants

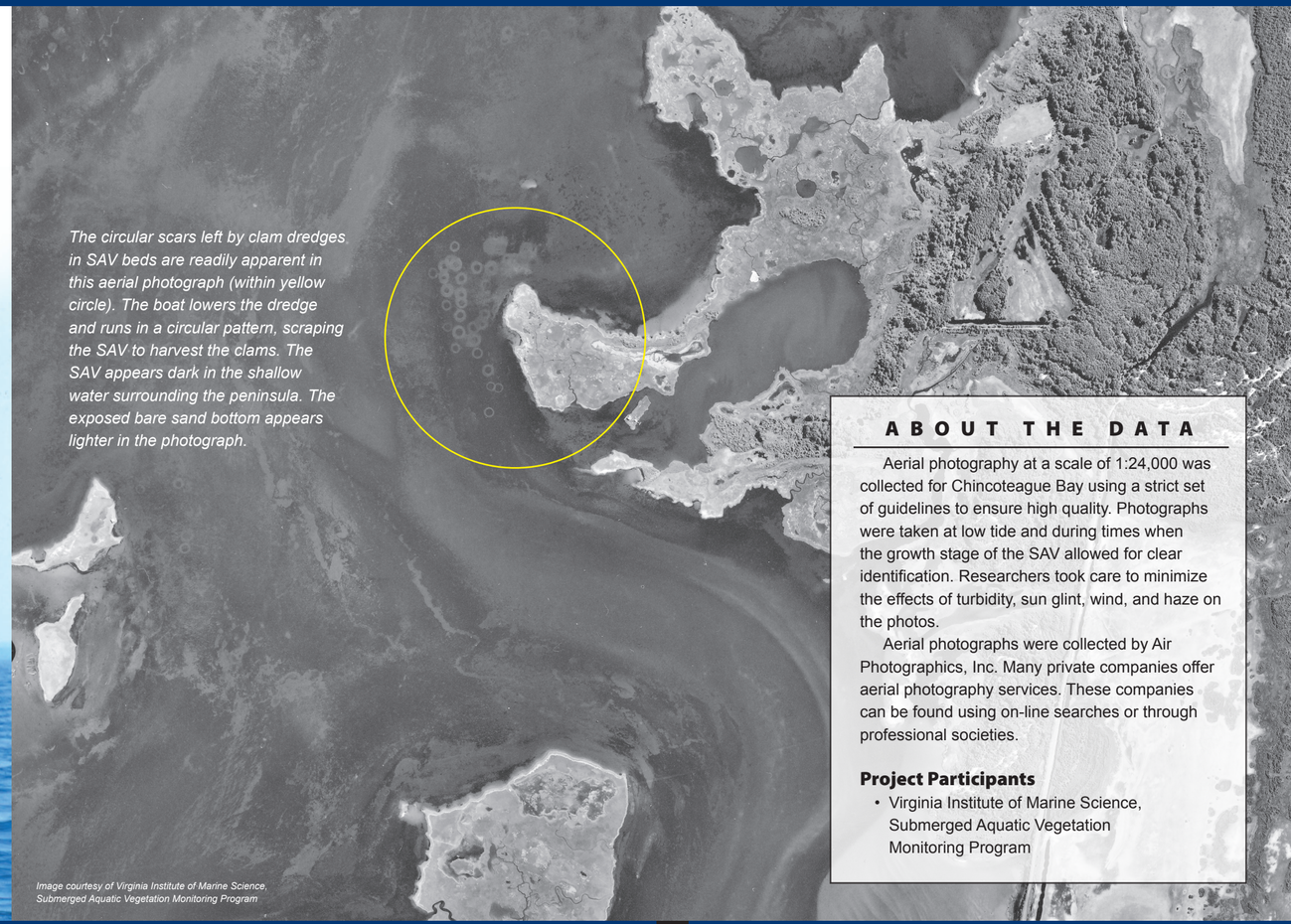
- NOAA National Marine Fisheries Service, Honolulu Laboratory
- University of Hawaii, Joint Institute for Marine and Atmospheric Research

Documenting Damage to Submerged Aquatic Vegetation

The shallow waters of Chincoteague Bay provide an ideal habitat for many types of shellfish. Clam harvesters have taken advantage of this resource and developed both an industry and a lifestyle around it. However, in the last few years, clam dredgers began to operate in submerged aquatic vegetation (SAV) beds, creating a new hazard for these federally protected plants.

Coastal resource managers depend on aerial photography for mapping and monitoring SAV because this technology can cover a large area in a relatively short time. During the 1997 mapping of Chincoteague Bay, Virginia Institute of Marine Science (VIMS) researchers noticed large rings of bare seafloor inside the SAV beds. A variety of information resources indicated that the damage was significant and that modified clam dredges were the cause, but it was the striking black-and-white aerial photographs that provided the most dramatic visual proof. The Virginia Marine Resources Commission took note and subsequently passed a regulation prohibiting the use of clam dredges in these areas.

Today, SAV maps derived from aerial photography continue to play an important role in the protection of this resource and the enforcement of this new law. Armed with this information, researchers annually monitor SAV beds to determine the effectiveness of the law and make recommendations to further protect the SAV. ❖



The circular scars left by clam dredges in SAV beds are readily apparent in this aerial photograph (within yellow circle). The boat lowers the dredge and runs in a circular pattern, scraping the SAV to harvest the clams. The SAV appears dark in the shallow water surrounding the peninsula. The exposed bare sand bottom appears lighter in the photograph.

Image courtesy of Virginia Institute of Marine Science, Submerged Aquatic Vegetation Monitoring Program

ABOUT THE DATA

Aerial photography at a scale of 1:24,000 was collected for Chincoteague Bay using a strict set of guidelines to ensure high quality. Photographs were taken at low tide and during times when the growth stage of the SAV allowed for clear identification. Researchers took care to minimize the effects of turbidity, sun glint, wind, and haze on the photos.

Aerial photographs were collected by Air Photographics, Inc. Many private companies offer aerial photography services. These companies can be found using on-line searches or through professional societies.

Project Participants

- Virginia Institute of Marine Science, Submerged Aquatic Vegetation Monitoring Program

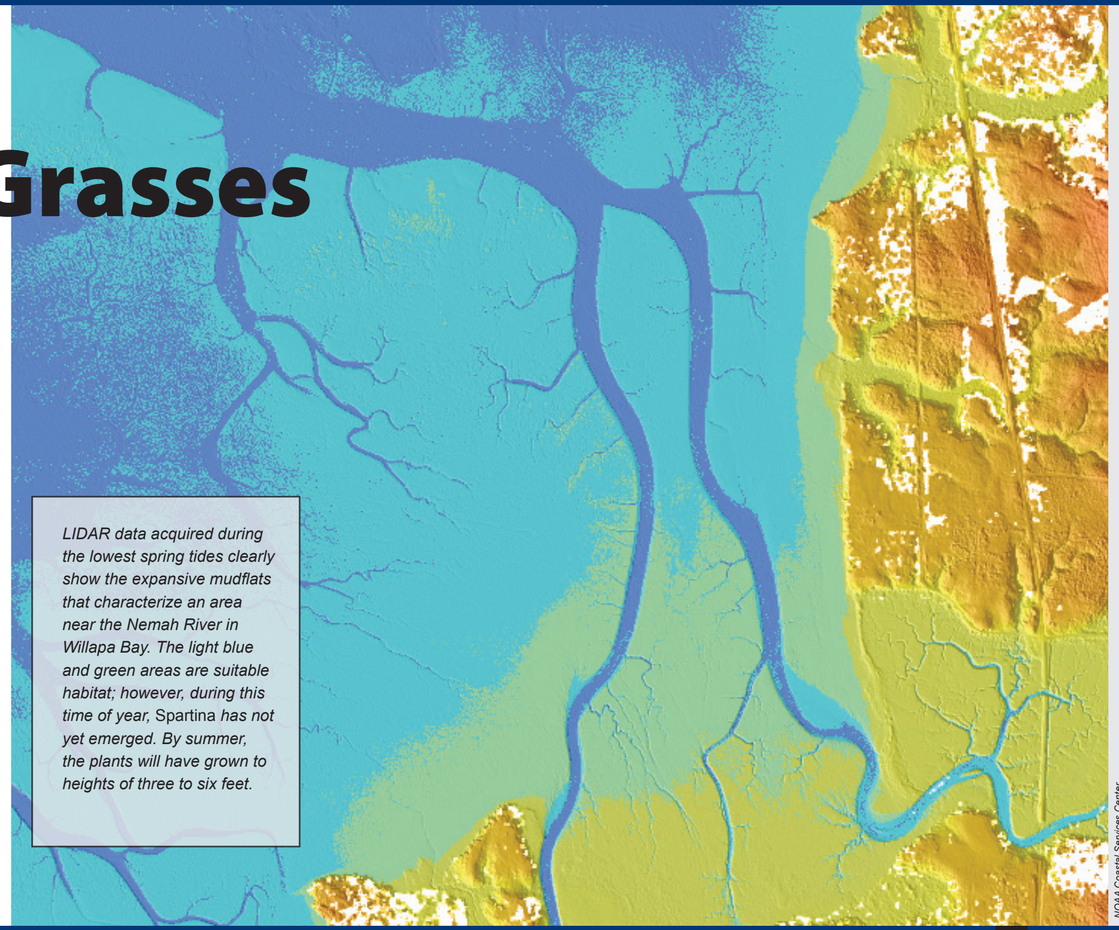
Controlling Invasive Marsh Grasses

An asset to estuaries on the East Coast of the United States, Atlantic cordgrass (*Spartina alterniflora*) is a big problem in estuaries on the West Coast. Probably introduced as early as the 19th century as seed in barrels of oysters or as packing material in ships, this plant became established in the large mudflats that are typical of West Coast estuaries.

The introduction of this species altered the elevation of the estuaries and changed the dynamics of the ecosystem. *Spartina* slows down water flow and traps sediment, lifting the elevation of the mudflats above the intertidal zone and turning them into high back marshes. As a result, the lower elevation mudflats that were once fertile feeding grounds for salmon, shellfish, migrating waterfowl, and shorebirds are disappearing rapidly.

Spartina has no competitors or enemies in this environment, so it spreads rapidly. Once an area becomes colonized with *Spartina*, it is difficult to eradicate the plants. To protect existing mudflats, researchers are using Light Detection and Ranging (LIDAR) topographic data to identify the low-lying habitat that has a high potential for *Spartina* colonization. These data are combined with mathematical models and aerial photography to determine which areas are most likely to host this invasive species. This type of information will help resource managers select and target their control efforts. ❖

Photo by Janie Civille



LIDAR data acquired during the lowest spring tides clearly show the expansive mudflats that characterize an area near the Nemah River in Willapa Bay. The light blue and green areas are suitable habitat; however, during this time of year, Spartina *has not yet emerged. By summer, the plants will have grown to heights of three to six feet.*

NOAA Coastal Services Center

ABOUT THE DATA

Elevation data were collected using an airborne Light Detection and Ranging (LIDAR) sensor. These data were used to locate potential areas of future *Spartina* colonization. The sensor emits a laser beam towards the Earth's surface and analyzes the beam's reflection off the surface to calculate elevation. Elevation data from LIDAR can be extremely accurate (up to 20 centimeters in some cases) and can be compared with historical elevation data.

LIDAR data were collected by Spencer B. Gross, Inc. Many private companies collect LIDAR data. These companies can be found using on-line searches, from Web sites sponsored by private companies or individuals, or through professional societies.

Project Partners

- University of California, Davis
- Washington Department of Natural Resources
- Washington State Department of Agriculture
- Washington State Department of Ecology
- Battelle Marine Sciences Laboratory
- National Science Foundation, Biocomplexity Program
- NOAA Coastal Services Center

NOAA Coastal Services Center

Mapping Oyster Beds

Hilton Head Island, South Carolina, is taking a holistic approach to managing what it considers the island's most important resource—Broad Creek. The creek and its watershed comprise over 50 percent of the island's uplands, and its condition today and in the future will ultimately determine the island's water quality. What makes the Broad Creek Management Plan unique is that, rather than focusing on water quality alone, officials are assessing a wide range of factors, including land use, shellfish resources, and vegetation.

Oyster resources are important to maintaining the health of Broad Creek because these mollusks help filter the water and reduce creek bank erosion. In this rapidly developing area, oyster reefs are highly susceptible to the physical impacts caused by boat wakes and dock construction. To fully protect this resource, the management plan recommended that the town update its oyster resource maps. Currently, the Town of Hilton Head Island is partnering with the South Carolina Department of Natural Resources, Marine Resources Division, and the NOAA Coastal Services Center to use digital imagery to create highly accurate oyster resource data.

Using digital imagery acquired at low tide when intertidal oysters are most exposed, researchers have been able to identify the location and extent of oyster reefs and distinguish them from the neighboring marsh grasses. By understanding where oyster reefs are located, managers can develop no-wake zones and appropriate dock siting policies to protect this valuable resource. ❖

NOAA Coastal Services Center

Oyster reefs growing along the edges of Broad Creek were mapped from near-infrared digital imagery. Because vegetation reflects near-infrared light (bright red indicates forested areas, brownish-red indicates marsh grass), researchers can distinguish the marsh grass from the oyster reef (delineated by green polygons).

ABOUT THE DATA

Digital aerial imagery was used to detect and map the locations of intertidal oyster reefs. Digital imagery, unlike analog photography, allows researchers to record geographic information during acquisition, reducing processing time for georeferencing. The digital sensor can record up to four spectral bands (red, green, blue, and near-infrared wavelengths) that can be analyzed independently of one another. Near-infrared is not something a human's eye can see; however, it is a form of reflected sunlight, and objects on the Earth reflect it in different ways. By measuring near-infrared, sensors can distinguish features such as vegetation, which reflect a high amount of near-infrared energy.

Digital aerial imagery was collected by GeoVantage Inc. More and more private companies are offering digital imaging services, and these companies can be found using on-line searches or through professional societies.

Project Participants

- Town of Hilton Head Island, South Carolina
- South Carolina Department of Natural Resources, Marine Resources Division
- NOAA Coastal Services Center

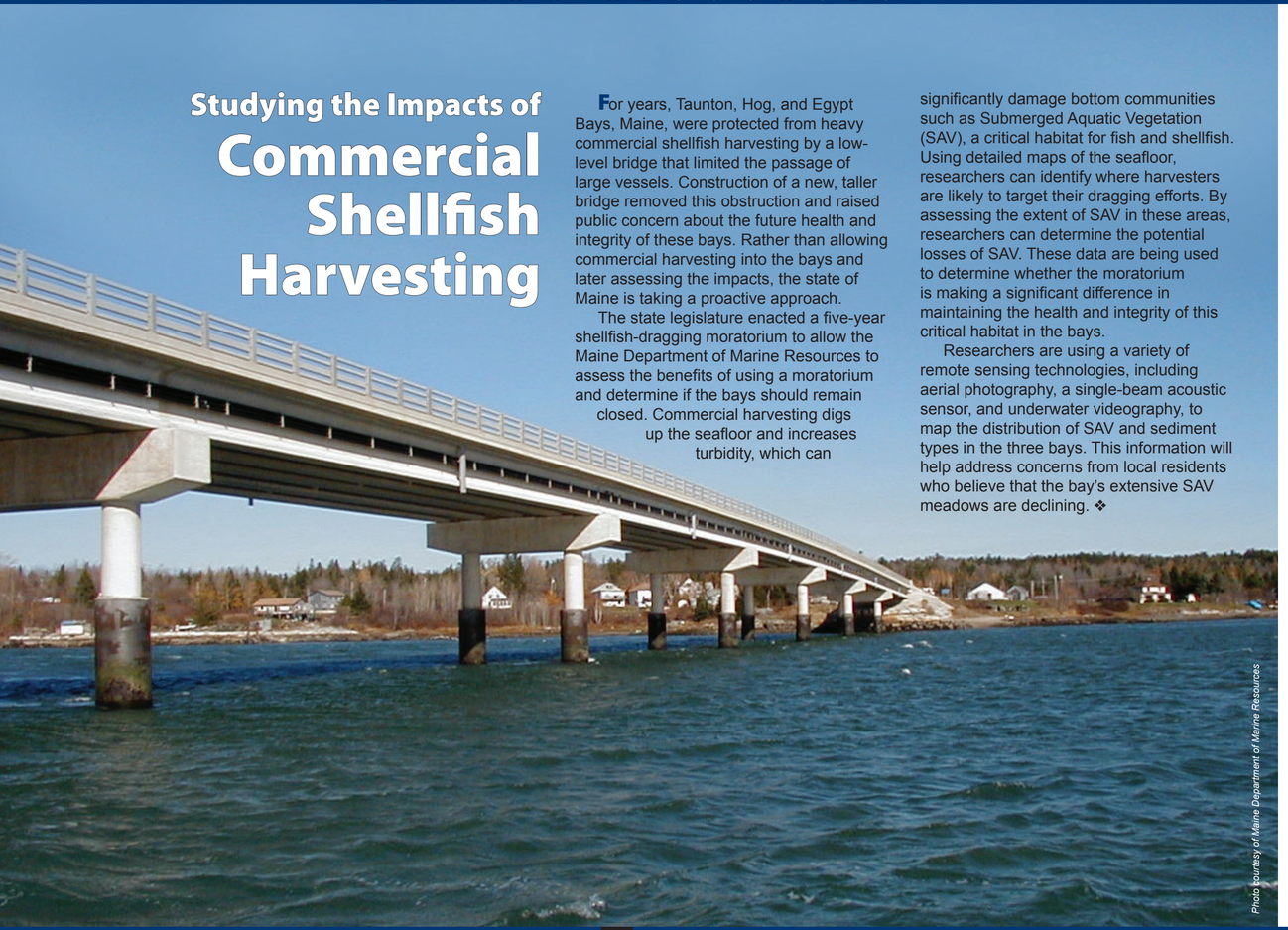


Photo courtesy of Maine Department of Marine Resources

Studying the Impacts of

Commercial Shellfish Harvesting

For years, Taunton, Hog, and Egypt Bays, Maine, were protected from heavy commercial shellfish harvesting by a low-level bridge that limited the passage of large vessels. Construction of a new, taller bridge removed this obstruction and raised public concern about the future health and integrity of these bays. Rather than allowing commercial harvesting into the bays and later assessing the impacts, the state of Maine is taking a proactive approach.

The state legislature enacted a five-year shellfish-dragging moratorium to allow the Maine Department of Marine Resources to assess the benefits of using a moratorium and determine if the bays should remain closed. Commercial harvesting digs up the seafloor and increases turbidity, which can significantly damage bottom communities such as Submerged Aquatic Vegetation (SAV), a critical habitat for fish and shellfish. Using detailed maps of the seafloor, researchers can identify where harvesters are likely to target their dragging efforts. By assessing the extent of SAV in these areas, researchers can determine the potential losses of SAV. These data are being used to determine whether the moratorium is making a significant difference in maintaining the health and integrity of this critical habitat in the bays.

Researchers are using a variety of remote sensing technologies, including aerial photography, a single-beam acoustic sensor, and underwater videography, to map the distribution of SAV and sediment types in the three bays. This information will help address concerns from local residents who believe that the bay's extensive SAV meadows are declining. ❖

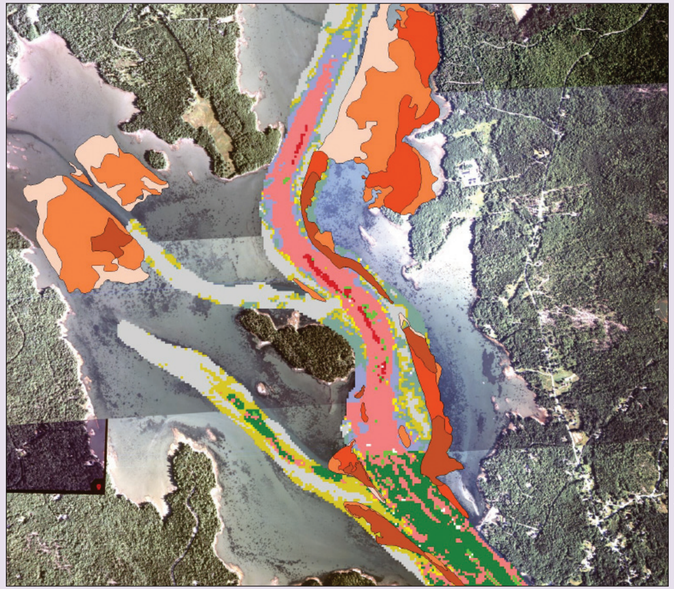


Image courtesy of Maine Department of Marine Resources

Seabed classes derived from aerial photography in the shallow waters, and acoustic data in the deeper waters of the channel, are displayed on aerial photographs. Researchers were able to map a variety of habitats, including both biologic features (kelp and eelgrass in greens) and sediment types (coarser sediments in reds, finer sediments in yellow and grey).

ABOUT THE DATA

True color aerial photography at a scale of 1:12,000 was used to map the density and distribution of eelgrass beds visible from the surface. Aerial photographs were collected by James W. Sewall Company of Old Town, Maine.

A single-beam acoustic seabed classification system was used to map submerged habitats in the channels. A single-beam acoustic sensor attached to a boat emits acoustic (sound) waves into the water and analyzes the reflection of the sound waves off the seafloor. Single-beam acoustic data were collected using the RoxAnn™ sytem.

Underwater videography was used to help delineate seagrass in deeper waters and field verify the data derived from both the aerial photos and the single-beam acoustic-sensor. Placing a live feed video camera in the water allows real-time data collection that is often comparable in quality to scuba observations, but without the added expense or time required to deploy divers.

Project Participants

- Maine Department of Marine Resources
- Maine Coastal Program
- Maine Sea Grant Program
- Frenchman Bay Fisheries

WATERWAYS

"Having remote sensing data is really important after large-scale storms, oil spills and hazardous spills, or groundings. It's the first thing you're asked: 'Do you have any imagery so we can tell the extent of the damage?'"

Henry Norris
Florida Fish and Wildlife
Conservation Commission

Creating Nautical Charts for Recreational Boaters

Florida's coastline attracts crowds of recreational boaters, and the numbers keep growing. Because today's boating community engages in diverse activities such as diving, fishing, racing, jet skiing, and kayaking, its members need nautical charts more advanced than the traditional small-craft charts of 20 years ago. To help protect both the boaters and the environment, the state needed a nautical chart that clearly conveyed information to boaters with varying needs and levels of navigation skills.

Officials went to the source to address this problem. To develop a prototype chart, agencies working with the state met with representatives from the boating community to understand their information needs. Afterwards, a diverse group of boaters was surveyed before and after using the new chart to determine changes in boating skills and knowledge, and in environmental awareness. This survey helped researchers determine whether the information was being presented effectively and whether the information was useful for changing boating practices.

The end result is a unique nautical chart that integrates aerial photography and satellite imagery, environmental data, and traditional chart information. A comprehensive amount of data is on the chart, but the easy-to-understand delivery mechanism guarantees its wide appeal and use. This combined map and educational product has proven to be very popular and is helping both Florida boaters and the coastal habitat. ❖

ABOUT THE DATA

Traditional nautical charts include information about the land and the sea. The charts are developed using a variety of remotely sensed data, such as multibeam and side-scan sonars for bathymetry and seafloor features, and aerial photography and satellite imagery to map features on land.

Aerial photographs were used for the development of both traditional NOAA nautical charts and Florida's recreational nautical charts. For traditional charts, shoreline data and land features were mapped from aerial photography. The new chart uses an image as the land "map" that was created from aerial photographs and satellite imagery. These images may help less experienced boaters find points of navigation that they are used to seeing from a photograph.

Many private companies offer aerial photography services, and these companies can be found using on-line searches or through professional societies.

The Indian Remote Sensing (IRS) satellite imagery used for this project was acquired from Space Imaging.

Project Participants

- Florida Sea Grant
- University of Florida
- University of Rhode Island
- Boaters' Action and Information League, Inc. (BAIL)
- Sarasota Bay National Estuary Program
- West Coast Inland Navigation District (WCIND)
- NOAA Office of Coast Survey
- NOAA Coastal Services Center

Image courtesy of NOAA (Prototype Chart 11425)

This type of nautical chart was created for a 150-mile stretch of the Southwest Florida coastline. Traditional chart information, such as channel markers, buoys, and water depth, is critical to safe navigation. The new chart also highlights the locations of sensitive habitats, such as corals, mangroves, and seagrass meadows, and identifies where endangered species, such as manatees and sea turtles, might congregate. The imagery, derived largely from aerial photography, provides recreational boaters with recognizable points of reference.

Stabilizing a Fluctuating Shoreline

When faced with coastal erosion, many property owners want to respond with hard stabilization structures such as jetties, groins, and seawalls to protect their property. While these are designed to reduce erosion, the structures often do no more than slow down the inevitable and in some cases can increase erosion nearby. In order to assess the impacts of current shoreline structures on Lake Michigan's shores and predict future erosion trends, researchers turned to remote sensing.

Using available data sources, primarily existing aerial photographs and digital orthophotos, researchers inventoried all of the stabilization structures in five coastal counties. Each structure was located, mapped, and classified based on field observations and videography surveys. Researchers compared historical shoreline imagery with the recent data to assess the amount of shoreline change, both loss and gain, in the selected study areas.

By knowing where erosion-control structures currently exist, and how they impact local erosion, the U.S. Army Corps of Engineers is making more educated decisions about where and when to permit stabilization structures. This type of planning and forethought allows managers to turn away from short-term fixes and look for long-term solutions to an ongoing problem of controlling erosion. ❖

Photo courtesy of U.S. Army Corps of Engineers

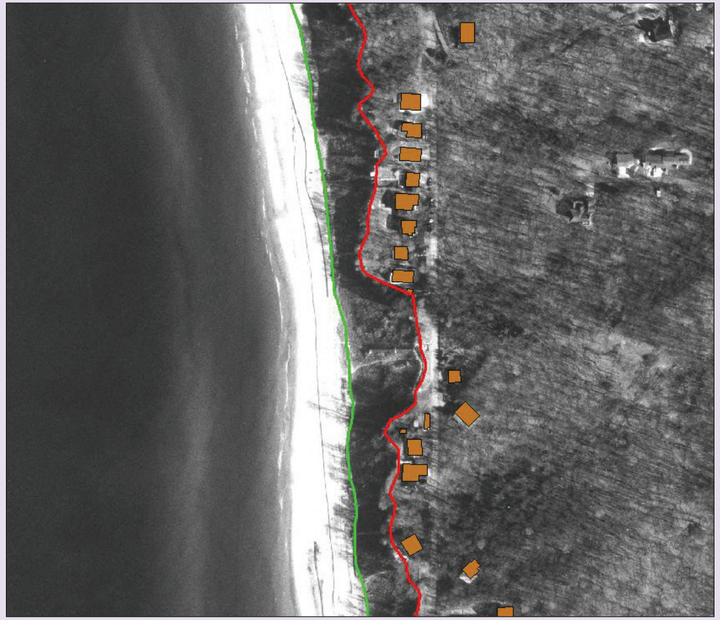


Image courtesy of U.S. Army Corps of Engineers

Using aerial photographs, like this black-and-white image of Lake Michigan's shore, researchers mapped structures such as buildings (in orange) and the tops and bottoms of the bluffs to measure erosion (red and green lines).

ABOUT THE DATA

Researchers used orthophotographs from 1999 to locate and map shoreline protection structures. Orthophotos are digitized versions of aerial photographs that have been corrected to remove distortions due to camera angle and topographic features. Orthophotographs for the Michigan study area were acquired from GRW, Inc., and the University of Wisconsin created orthophotographs for the counties in Wisconsin. Historic photographs from 1938, 1955, 1968, and 1978 were acquired from the state archives and were used to compare changes in the shoreline.

Many private companies offer aerial photography and orthophotography services, and these companies can be found using on-line searches or through professional societies. In addition, aerial photographs and digital orthophotos may be available through federal agencies such as the U.S. Geological Survey (USGS) or state data clearinghouses.

Project Participants

- U.S. Army Corps of Engineers

Protecting Cultural Resources

The treacherous waters off the coast of Alpena, Michigan, in Lake Huron were once referred to as "Shipwreck Alley" because of the hundreds of vessels lost there over two centuries. Today the historical and cultural significance of these maritime artifacts is protected as part of the Thunder Bay National Marine Sanctuary and Underwater Preserve. In order to better understand these historical resources, managers are using sonar technology and remotely operated vehicles (ROV) in exploratory missions to map the lake bottom and identify the locations and types of shipwrecks.

Side-scan sonar uses reflected sound to produce highly detailed images of the lake bottom. With these data, researchers can identify sunken vessels, suspected shipwrecks, or other artifacts such as engines, rudders, and masts. These data can be used to target sampling with an ROV if more detailed information is needed. Equipped with video and still cameras, ROVs help researchers virtually explore the shipwrecks, assess their condition, and gather enough information to identify the vessels without having to enter the cold, deep water.

At the end of the first exploration project, researchers located 11 known shipwrecks and discovered 3 new ones. The total number of vessels in Thunder Bay is still unknown, though to date over 40 wrecks have been discovered and inventoried. The shipwrecks in the sanctuary represent a great diversity of maritime history, with vessels ranging from wooden schooners of the early 1800s, to 20th-century steel-hulled freighters. ❖

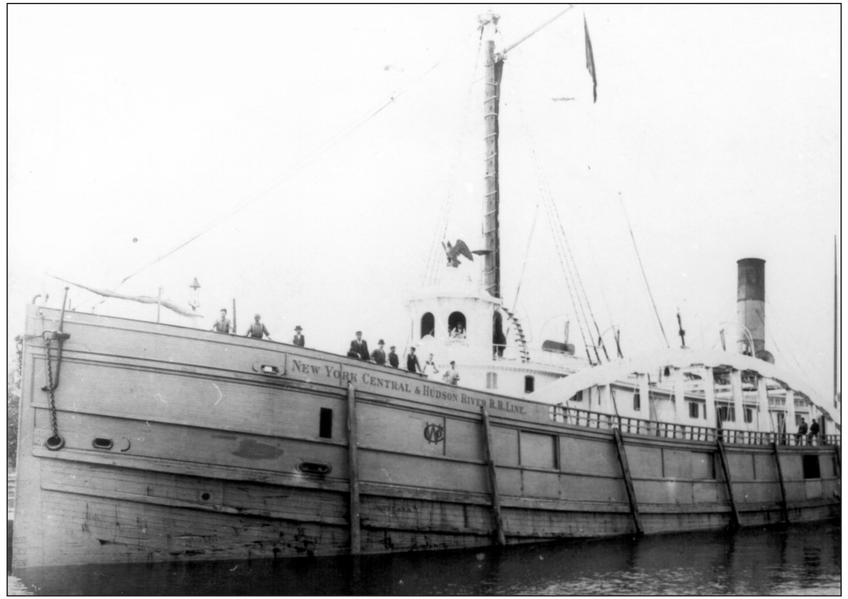


Photo courtesy of Historical Collections of the Great Lakes, Bowling Green State University

ABOUT THE DATA

The Thunder Bay exploration project utilized the Institute for Exploration's side-scan sonar system. The side-scan sonar is towed behind a boat and emits sound diagonally across the lake bottom, allowing the sensor to create detailed images of the lake bottom at great depths using only reflected sound. Researchers utilized the sensor's two sound frequencies for sampling. The lower frequency sonar was used to survey large portions of the lake bottom, while features of interest were resurveyed using the higher frequency sonar for greater detail.

The data were collected using the Institute for Exploration's side-scan sonar system known as ECHO.

Project Participants

- Thunder Bay National Marine Sanctuary and Underwater Preserve
- Institute for Exploration
- State of Michigan Department of History, Arts and Libraries
- NOAA Office of Ocean Exploration
- NOAA National Marine Sanctuary Program

Image courtesy of NOAA's Office of Ocean Exploration

In 1914, the Montana caught fire before sinking to the depths of Lake Huron. The cold waters helped preserve this wooden vessel in excellent condition. The side-scan sonar image captures the detail of this shipwreck from a view directly above the vessel.

Siting a Marine OUTFALL PIPELINE

Constructing a marine sewer outfall in a heavily urbanized environment is no simple task. Add a few sensitive habitats, and you begin to understand the dilemma managers in Puget Sound faced when selecting a site for a new wastewater treatment outfall pipeline. Managers had to consider the proximity of the outfall zone to nearby marinas, ferry terminals, and developed parkland, as well as minimize impacts to marine habitats and adjacent uplands.

Working with side-scan sonar and underwater video, researchers were able to map the seafloor of potential outfall zones, identifying marine plants, animals, and sediment types. Side-scan sonar is an acoustic sensor that detects differences in reflected sound energy based on the hardness and texture of objects, enabling scientists to map physical features and certain plants such as seagrasses. Underwater video was used to verify features detected by side-scan sonar, as well as map the location of additional plants, fish, and other marine life.

Underwater mapping tools and remotely sensed data are key in helping coastal managers in King County, Washington, select a final location for their wastewater treatment plant outfall. By selecting a site after considering all potential impacts to the environment, expensive litigation and mitigation costs can be avoided. In addition, this data set will serve as a useful baseline map for monitoring any change in the habitats that may occur in the future. ❖

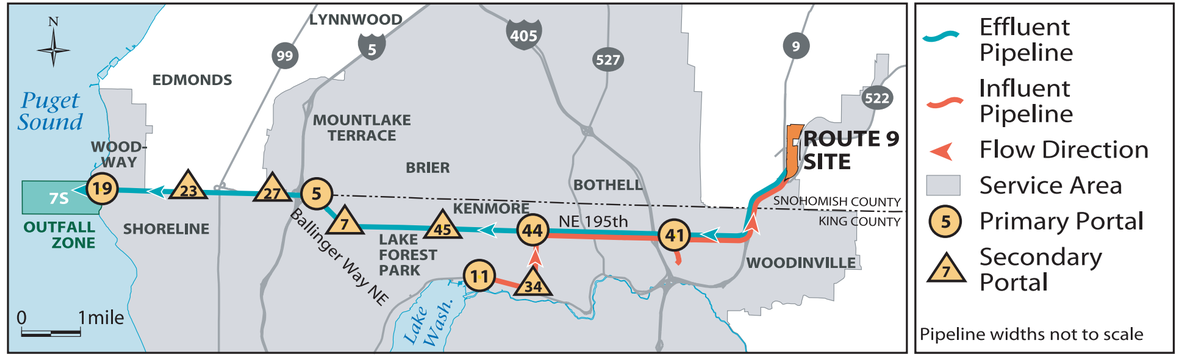


Image courtesy of King County Department of Natural Resources and Parks

The map above depicts one possible solution being considered for the outfall pipeline.

ABOUT THE DATA

Sonar (Sound Navigation and Ranging) systems use sound energy to detect and locate underwater objects. Side-scan, one type of sonar system, is usually towed behind a vessel on a subsurface unit called a towfish. The towfish transmits beams of acoustic energy (sound) out to the side and across the bottom. Sound is reflected back to the towfish and the return signal is processed to reveal the hardness of the object, creating a three-dimensional "picture" of the bottom. The side-scan sonar is linked to a differential Global Positioning System (GPS), providing highly accurate positional data.

Towed underwater video was used to verify features observed with side-scan sonar, such as sediment type, debris piles, and seagrass, and it recorded data on fish, marine invertebrates, and other marine plants. The underwater video was also coupled to the differential GPS, allowing accurate mapping and verification of underwater resources.

Side-scan data and underwater video were collected by Battelle Marine Sciences Laboratory.

Project Participants

- Battelle Marine Sciences Laboratory
- King County Brightwater Project

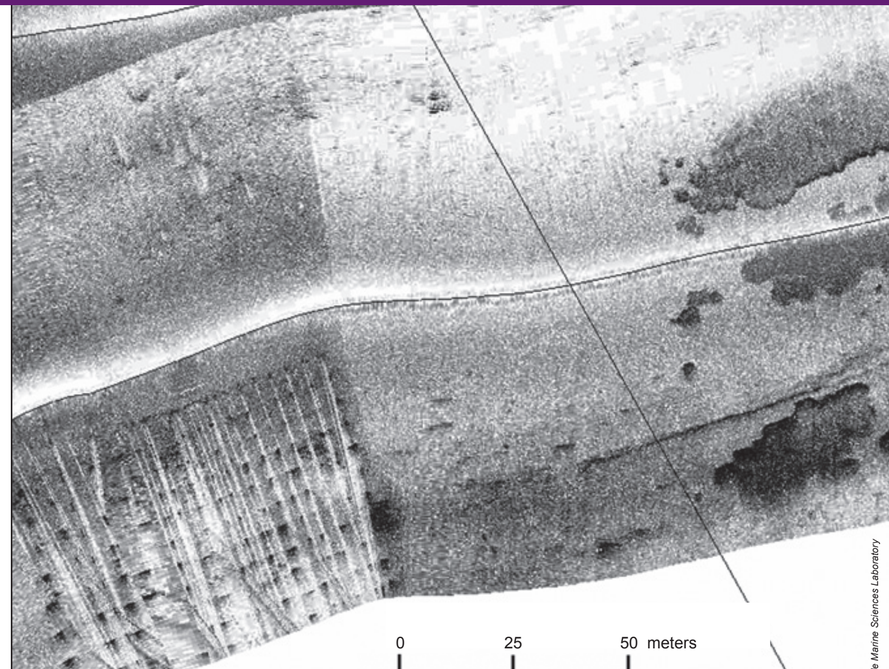


Image courtesy of Battelle Marine Sciences Laboratory

Sonar uses reflected sound energy to create an image of the seafloor. The features captured by sonar can be interpreted and mapped. This image captures the pilings of a pier (dark spots lower left) and the resulting shadows created by the pilings (light stripes within the pilings). Large patches of seagrass can be seen on the right side of the image.

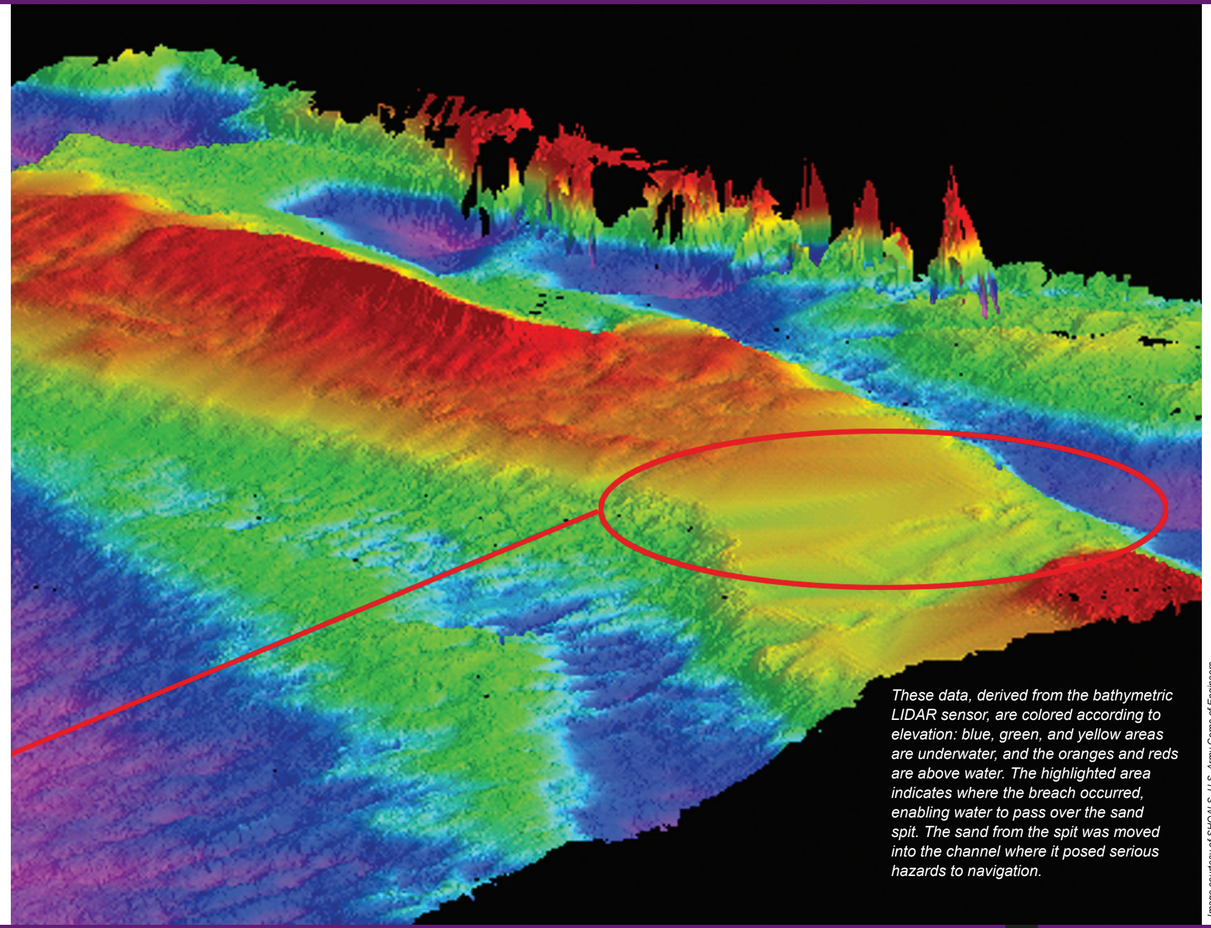
Identifying Channel Obstructions

In 1995, Hurricane Opal made landfall near East Pass, Florida. Large sandy shoals were pushed into a heavily used navigation channel, and big portions of the shoreline were reshaped. Emergency response crews needed to quickly identify and address potential navigational hazards. Remotely sensed data answered this need.

A bathymetric Light Detection and Ranging (LIDAR) sensor was used to survey the damage caused by the storm. This type of sensor is designed to penetrate water and collect bathymetric and elevation data. Completed surveys were provided to managers in less than six hours after collecting the data. Analyses included bathymetric maps of the channel, calculations of sand volume (shoaling), and the elevation of nearby land.

Using the bathymetric LIDAR data, managers determined where the channel was non-navigable and began dredging operations. They used this information to decide where the dredge material needed to be placed to effectively restore the sand point and stabilize the channel. Since Hurricane Opal, managers in Florida have continued using bathymetric LIDAR for annual surveys of East Pass and have been able to improve their understanding of the sediment movement around the inlet and through the navigation channel, thus leading to improved management practices for long-term operation of the project. ❖

Images courtesy of SHOALS, U.S. Army Corps of Engineers



These data, derived from the bathymetric LIDAR sensor, are colored according to elevation: blue, green, and yellow areas are underwater, and the oranges and reds are above water. The highlighted area indicates where the breach occurred, enabling water to pass over the sand spit. The sand from the spit was moved into the channel where it posed serious hazards to navigation.

Image courtesy of SHOALS, U.S. Army Corps of Engineers

ABOUT THE DATA

Bathymetric LIDAR (Light Detection and Ranging) senses submerged features up to 60 meters deep (depending on water clarity) by firing a laser beam from an aircraft into the water. The beam is reflected by both the water surface and the seafloor and returns to the sensor. The depth is determined by the difference in time between the water surface return and the seafloor return. Depending on water clarity, Scanning Hydrographic Operational Airborne LIDAR Survey (SHOALS) can survey up to 16 square kilometers in one hour, with a vertical accuracy of 15 centimeters and a horizontal accuracy of 3 meters. Providing rapid and accurate bathymetric surveys is an important capability, especially for time-critical events such as hurricane response.

The Joint Airborne LIDAR Bathymetry Technical Center of Expertise (JALBTCX) owns and operates the SHOALS sensor used in this study.

Project Participants

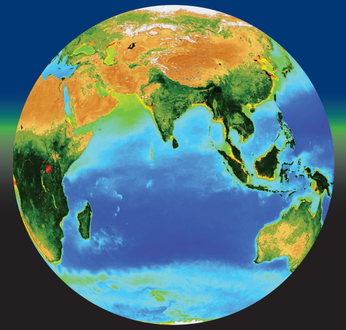
- Joint Airborne LIDAR Bathymetry Technical Center of Expertise – a partnership of the U.S. Army Corps of Engineers, the Naval Meteorology and Oceanography Command, and the Naval Oceanographic Office
- NOAA Aircraft Operations Center

NOAA Coastal Services Center

The federal government and U.S. coastal states and territories work in a voluntary partnership to ensure the health and diversity of the nation's coastline and ocean resources. Guiding the conservation and management of the coastal environment is a primary function of the U.S. Department of Commerce's National Oceanic and Atmospheric Administration (NOAA).

The NOAA Coastal Services Center, housed within the National Ocean Service, was established in 1994 to help the nation's coastal resource managers access and utilize the most up-to-date technology, information, and management strategies. Through the Center's Coastal Remote Sensing program, coastal resource managers are provided with meaningful data, information, and products derived from remote sensing technology. To learn more about the Center's remote sensing efforts, visit *www.csc.noaa.gov/crs/rs_info*.

NOAA Coastal Services Center
LINKING PEOPLE, INFORMATION, AND TECHNOLOGY



U.S. DEPARTMENT OF COMMERCE
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