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Coastal and Marine Hazards and Resources Program

Coastal and Marine Hazards and Resources Program Decadal Science Strategy 2020–2030



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

Cover. A U.S. Geological Survey diver finishes installing ocean chemistry monitoring equipment on Sombrero Reef, Florida Keys. Photograph by Ilsa Kuffner, U.S. Geological Survey.

Coastal and Marine Hazards and Resources Program Decadal Science Strategy 2020–2030

Compiled by Carolyn Ruppel and Patricia (Soupy) A. Dalyander

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Preface

"The Coastal and Marine Hazards and Resources Decadal Science Strategy" was originally made available to the public in a geonarrative format in 2020, which was deprecated in February 2026. This circular is an effort to preserve the content from the original document that was compiled by Carolyn Ruppel (U.S. Geological Survey emerita) and Patricia (Soupy) A. Dalyander (former U.S. Geological Survey employee).

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
mile, nautical (nmi)	1.852	kilometer (km)

Abbreviations

CMHRP	Coastal and Marine Hazards and Resources Program
IT	information technology
USGS	U.S. Geological Survey

Coastal and Marine Hazards and Resources Program Decadal Science Strategy 2020–2030

Compiled by Carolyn Ruppel and Patricia (Soupy) A. Dalyander

Overview

The decadal science strategy of the Coastal and Marine Hazards and Resources Program (CMHRP) of the U.S. Geological Survey (USGS) for 2020 to 2030 describes the CMHRP's vision and mission and the strategic framework needed to support key program goals: Conduct research and develop science-based tools that lead to safer, more productive coastal communities and improved stewardship of natural resources.

Our Vision

A Nation prepared for coastal and ocean changes.—More than 120 million people—about 40 percent of the U.S. population—live in a county bordering an ocean or one of the Great Lakes. As coastal populations continue to increase, more people, infrastructure, and ecosystems will be threatened by storms, sea level rise, and tsunamis (Climate Central, 2024; National Centers for Environmental Information, 2025). Growing worldwide demand for natural resources will increase our dependence on the products and services provided by coastal and marine environments.

The CMHRP of the USGS envisions a Nation that uses scientific knowledge to prepare for, mitigate, and respond to short- and long-term environmental threats to coastal regions and to sustainably manage coastal and marine resources. Management decisions that are guided by an understanding of persistent coastal and marine processes and extreme events (for example, storms, oil spills, submarine earthquakes, and tsunamis) can minimize negative human, ecological, and financial consequences.

Mission

The mission of the CMHRP is to conduct research and develop science-based tools that lead to safer, more productive coastal communities and improved stewardship of natural resources. As part of a nonregulatory science agency, the CMHRP is responsible for leading research and developing science-based products focused on reducing the potential damage to communities from natural and human-caused disasters and on improving natural resource management. The CMHRP is also responsible for communicating the results of that research to other governmental agencies and the public.

The CMHRP supports regulatory agencies by providing scientific data and expertise for use in developing policy and evaluating plans. The program provides scientific data and models that are used by stakeholders to assess the potential outcomes of management decisions. The program complements the work of public agencies and private entities that make or implement decisions associated with mitigating risks from natural hazards and with managing natural resources.

By conducting research that advances scientific support for hazard mitigation and improves stewardship of our natural resources, the CMHRP contributes to our Nation's long-term prosperity.

CMHRP Goals

The CMHRP's goal is to achieve the following across the spectrum of coastal and marine settings:

- Provide scientifically based, timely, and credible information that enables effective preparation for and response to natural hazards.
- Conduct research and develop science-based tools that inform sustainable use and management of natural resources.
- Serve diverse stakeholders, including Federal, Tribal, State, and local regulatory and management authorities; the public; and the scientific community.
- Measure and forecast short- and long-term changes of coastal and oceanic environments.
- Identify and fill scientific knowledge gaps to empower predictions of the response of coastal and ocean environments to natural processes and human activities.

The program focuses its research and products on filling gaps that impede sound decision making in resource management and coastal threat mitigation in the short and long term. The CMHRP pivots quickly when necessary to address emerging national priorities, while also providing sustained leadership in collecting the data and developing the tools necessary to inform stakeholders and policymakers on persistent national issues. The CMHRP also emphasizes collaboration within and outside of the USGS to identify and address national needs in coastal and marine environments. This cooperation gives the program access to external perspectives and capabilities, while also maximizing the return on Federal investment through leveraging of resources.

Explore

Additional details about CMHRP science are available at https://www.usgs.gov/natural-hazards/coastal-marine-hazards-and-resources.

Strategic Framework

In order to provide scientific information and products that can be used to reduce risks from natural hazards and to increase national prosperity, the CMHRP of the USGS will use four overarching approaches to develop and apply program resources:

- Build on the USGS's and CMHRP's foundation of scientific integrity, expertise, and collaboration with partners.
- Invest in capabilities required to achieve the CMHRP's mission.
- Address priority information needs and management challenges across diverse environments.
- Integrate knowledge for comprehensive, long-term support to the Nation.

These components constitute a strategic framework (fig. 1) that enables the program to provide the scientific information and products required for achieving its mission to conduct research and develop science-based tools that lead to safer, more productive coastal communities and to improved stewardship of natural resources. At the most fundamental level, the framework relies on program resources such as a skilled and flexible workforce to develop essential capabilities that address the Nation's needs and challenges. The CMHRP applies these capabilities across varied coastal and marine environments, then builds on the expertise and knowledge gained to develop science-based products of increasing scope, scale, and complexity. This framework permits the CMHRP to address shifting management priorities and diverse stakeholder requirements and to develop robust methods for gathering a variety of data in complex physical environments.

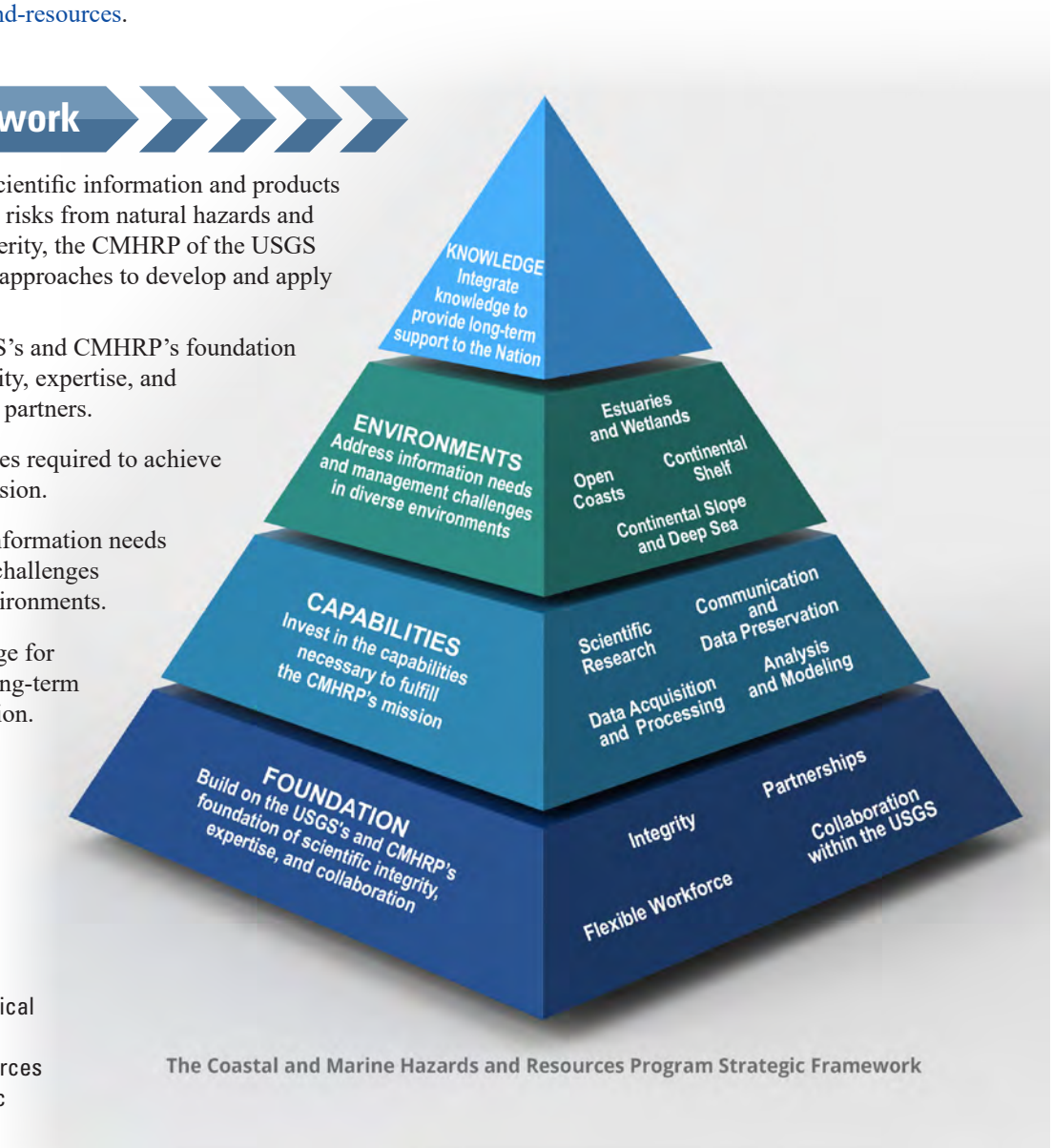


Figure 1. The U.S. Geological Survey (USGS) Coastal and Marine Hazards and Resources Program (CMHRP) strategic framework diagram.

Foundation

The first component of the CMHRP's strategic framework is to build on the USGS's and the CMHRP's foundation of scientific integrity, expertise, and collaboration with partners.

Scientific Integrity

The CMHRP will maintain its reputation as a trusted and reliable science leader by upholding the highest standards of scientific integrity. This trust is vital if stakeholders and partners are to rely on the CMHRP's information and products.

The CMHRP is a leading entity for research on coastal and marine environments and has earned a reputation as a provider of impartial and high-quality scientific research, data, and decision-support products. The quality of CMHRP work is grounded in adherence to the highest standards for scientific integrity, as articulated by the USGS and the U.S. Department of the Interior (https://www.usgs.gov/office-of-science-quality-and-integrity/scientific-integrity). Furthermore, standards for internally and externally published products are underpinned by rigorous peer review. This reputation for excellence enables effective collaboration with external partners and ensures confidence in products that are provided to policymakers, resource managers, and the public.

Scientific Integrity: Strategy

Ensure that CMHRP research and products are impartial, robust, and scientifically defensible, as is consistent with USGS and U.S. Department of the Interior policy.

Scientific Integrity: Representative Action

- Adhere strictly to scientific integrity principles, including laboratory oversight and appropriate peer review of products.
- Support and encourage publication of CMHRP research in scientific, peer-reviewed outlets and presentation of CMHRP research at scientific and technical conferences.
- Ensure that CMHRP capabilities (instrumentation, facilities, processing methods, and data archiving and dissemination) are up to date and provide for high-quality data and interpretation.

Skilled and Flexible Workforce

The CMHRP will maintain the research, technical, management, and support staff it needs to advance its capabilities and enhance its scientific credibility. The CMHRP's workforce will continue to be committed to applying its skills to evolving challenges in a broad range of environments and problems.

Creative, skilled, and enthusiastic personnel are integral to reaching program goals. The CMHRP staff formulate and conduct research to address scientific and societal priorities, collect data for use internally and by partners, and ensure valuable information is communicated to potential users. Each of the CMHRP-supported science centers on the Atlantic coast (Woods Hole, Massachusetts; https://www.usgs.gov/centers/whcmsc), Pacific coast (Santa Cruz, California; https://www.usgs.gov/centers/pcmsc), and Gulf coast (St. Petersburg, Florida; https://www.usgs.gov/centers/spcmsc) cultivates a workforce that supports the center's regional focus and scientific emphasis, and the centers also coordinate on shared solutions to program-wide needs (for example, information technology [IT] and acquisition of deepwater seismic data).

Skilled Workforce: Strategy

Develop and maintain a diverse and skilled workforce with the expertise and flexible skill sets necessary to respond to evolving national needs.

Skilled Workforce: Representative Actions

- Balance expertise across the following roles:
  - Scientific: Researchers with varied areas of expertise who can identify key gaps in understanding of processes based on societal or scientific need; interpret data and test hypotheses; translate that knowledge into appropriate field survey strategies, analytical techniques, and models; and communicate the results
  - Technical: Diverse staff with a wide range of expertise who are able to design, customize, maintain, operate, and deploy instrumentation; collect high-quality scientific measurements; identify promising new technologies; run models, analyze the output, and interpret results; develop new approaches to processing and managing data; and carry out specialized tasks
  - Information technology: Professionals to implement hardware and software solutions to enable scientific progress and meet Federal system requirements
  - Outreach: Personnel dedicated to expanding the impact of CMHRP's products and engaging the public and other stakeholders
  - Administrative: Staff to efficiently manage hiring, procurement, and other business activities
  - Management: Inspirational leaders to attract, retain, and support their staff; effectively coordinate across science centers and with external stakeholders; and successfully oversee the CMHRP's mission

- Conduct strategic hiring at the three CMHRP-supported science centers to maximize center and program research capability and minimize redundant skill sets.
- Encourage hiring by using programs that identify talented underrepresented groups in the earth sciences.
- Develop workforce plans that anticipate future CMHRP and science center needs in filling current and expected vacancies.
- Recruit and retain creative and adaptable scientific and technical personnel who have the flexibility to anticipate and align CMHRP focus with current and emerging national priorities.
  - Capitalize on USGS programs to engage students and recent graduates while working with the Bureau to expand and improve these opportunities (USGS "Students and Recent Graduates" web page: https://www.usgs.gov/human-capital/students-and-recent-graduates; USGS Mendenhall Research Fellowship Program: https://www.usgs.gov/centers/mendenhall-research-fellowship-program).
  - Foster relationships with undergraduate and graduate institutions through mechanisms such as internships and cooperative agreements.
- Cultivate a welcoming and rewarding workplace to attract and retain a diverse workforce, consistent with USGS objectives.
  - Recognize and reward extraordinary performance.
  - Encourage and provide opportunities for career advancement.
  - Reward outreach and collaboration with external partners.
- Encourage mentoring to share institutional knowledge as well as foster a system-wide mentoring culture.
- Enable all staff to take advantage of training or other opportunities to maintain and increase their skill sets to meet CMHRP needs.
- Participate in training programs to promote visionary leadership in support of scientific excellence, a diverse workplace, and employee satisfaction and enthusiasm.

Collaboration Within the USGS

The CMHRP will continue to coordinate across all USGS mission areas to leverage expertise, respond to diverse issues and needs, and provide maximum benefit to the Nation. In addition, collaboration among the three CMHRP-supported science centers on the Atlantic, Pacific, and Gulf coasts will allow the program to be efficient as a national program while responding nimbly to regional needs.

The CMHRP is administratively housed within the Natural Hazards Mission Area and works extensively to quantify threats such as coastal erosion and tsunamis. As one of the few USGS programs working in coastal and marine environments, the CMHRP also coordinates with other mission areas to address the full range of challenges in these settings (https://www.usgs.gov/science/mission-areas). For example, program staff collaborate with USGS researchers outside of the CMHRP to link physical processes with ecosystem response and to evaluate the connection between marine and terrestrial processes.

CMHRP-supported facilities are primarily at three science centers along the Atlantic, Gulf, and Pacific coasts, and program management is at USGS Headquarters in Reston, Virginia. This geographic distribution enables the CMHRP to interact closely with regional partners such as academic institutions, which fosters student mentoring opportunities and exchange of scientific ideas. Similarly, each science center works with regional, State, and local partners and develops unique expertise to be more responsive to needs that vary across the Nation. The CMHRP coordinates across all three science centers to share resources to make the program more efficient nationwide.

Coordination Within the USGS: Strategy

Coordinate across the CMHRP-supported science centers and the rest of the USGS to respond to broad-scale, nationally important challenges in coastal and marine settings.

Coordination Within the USGS: Representative Actions

- Develop methods of communicating information—such as new and evolving program priorities, project initiatives, external funding, and collaborative opportunities—across science centers so that personnel are aware of and can engage in activities suited to their expertise.
- Share personnel, equipment, and fiscal resources when appropriate to increase efficiency, make use of unique expertise, and (or) reduce cost.
- Foster strong interpersonal relationships to encourage collaboration across science centers and the USGS by enabling in-person and web-based meetings of staff such as the following:
  - Workshops focused on specific areas of common interest (for example, data management and research planning)
  - Training opportunities and classes at individual science centers and open to all program and (or) USGS personnel

- Develop an exchange program between science centers within and outside of the CMHRP for all staff to increase awareness of capabilities.
- Fund CMHRP projects that include staff from multiple science centers and (or) collaboration with other programs to make better use of distributed resources and expertise.
- Participate in and encourage regional and Bureau-level opportunities for collaborating with personnel outside of the CMHRP.

External Partnerships

The CMHRP will maintain collaboration with Federal, State, Tribal, and local agencies, nongovernmental organizations, and the academic community. As it leverages external resources, capabilities, and knowledge, the program will apply its unique expertise to ensure responsiveness to stakeholder's needs, increased efficiency in pursuit of the CMHRP mission and those of its partners, and broad benefit to the Nation.

One mechanism through which the CMHRP ensures that its products support the Nation is partnerships with Federal, State, and local agencies; nonprofit organizations; and other entities. The CMHRP provides guidance to management agencies, including identifying and filling scientific knowledge gaps that obstruct decision making. Land or resource managers in turn may assist the CMHRP with identifying program priorities. Collaborating agencies may also provide resources and expertise that can be combined with CMHRP capabilities and investments. In the short term, collaboration allows the CMHRP to meet the specific needs of management agencies. In the long term, this engagement focuses the CMHRP on research with high societal relevance and broad applicability. By working with partners, the scope and benefits of CMHRP activities are increased, and the Nation receives more return on its investment in the program.

External Partnerships: Strategy

Coordinate with external collaborators to identify and respond to broad-scale, nationally important challenges in coastal and marine settings.

External Partnerships: Representative Actions

- Engage with land managers, engineers, and local and State governments to facilitate the use of CMHRP information in practical decision making.
- Collaborate with researchers in academic institutions, in industry, and at other agencies to develop science-based tools and products that address relevant coastal and marine issues.
- Enable and encourage CMHRP staff to participate in and lead professional and scientific societies, interagency collaborative working groups and panels, and review committees.
- Identify and prioritize research and development efforts and site-specific data collection that can meet the needs of multiple stakeholders, as well as advance the CMHRP's mission.
  - Facilitate the temporary exchange of personnel between agencies through interagency personnel agreements to increase the program's awareness of outside entities' needs and capabilities, and vice versa.
  - Increase use of memoranda of understanding and other mechanisms for working with other agencies.
  - Create opportunities for external researchers to temporarily work at CMHRP-supported science centers.

Capabilities

The second component of the CMHRP's strategic framework is to invest in capabilities required to achieve the mission of the CMHRP.

Scientific Research

CMHRP researchers will continue to identify and fill key gaps in the understanding of coastal and marine environments and processes in order to enable more robust hazard mitigation and resource management.

As a nonregulatory Federal program, the CMHRP researches coastal and marine landscapes at local, regional, and national scales in environments ranging from estuaries and wetlands to the deep ocean. The results of CMHRP research have produced reliable predictive models and formal assessments, have guided the acquisition of new data to improve understanding of coastal and marine processes, and have informed management decisions related to coastal and marine resources and hazards. CMHRP research efforts drive new developments in data acquisition and processing, while also identifying previously unknown national needs that could be addressed by the USGS, other Federal agencies, and academic partners. CMHRP research products meet high standards of integrity, are seen as authoritative, and have scientific and societal impact as measured by direct and indirect value to resource managers, emergency planners and responders, and other stakeholders.

Scientific Research: Needs, Challenges, and Strategies

The CMHRP's research objectives include improving fundamental understanding of coastal and marine landscapes and processes, as well as providing the relevant data, technology, and scientific guidance to bolster management decisions. The breadth of these objectives can lead to challenges in maintaining the CMHRP's research efforts. In some cases, partners, especially other State and Federal agencies, partially or fully fund tools, data acquisition, and products that lead to better management of resources or mitigation of the risks of hazards. In the face of evolving societal needs, research gaps newly identified by the USGS must sometimes be funded by the agency itself, placing these emerging priorities in competition with ongoing research for limited internal resources.

The CMHRP must respond to the needs of stakeholders who rely on its existing data, products, and expertise while simultaneously supporting cutting-edge research that leads to new avenues for advancing the program's mission. The research conducted by the CMHRP increasingly depends on complex, and sometimes expensive, data collection platforms or equipment, data analysis and modeling strategies, and new approaches to information dissemination. Maintaining the flexibility and breadth to carry out multidisciplinary research to address the Nation's evolving needs in coastal and marine science requires bolstering core capabilities, maintaining the capacity to respond rapidly in the face of catastrophic events, and facilitating long-term commitments to disciplines in which the CMHRP fills a unique leadership niche.

The CMHRP uses the following strategies to maintain the scientific research capacity needed to complete its mission:

Scientific Research: Strategy I

Maintain a research portfolio that is broad enough to address current and emerging research topics within the CMHRP's mission.

Scientific Research: Representative Actions I

- Invest in filling fundamental research gaps that are identified by the USGS or external partners as impediments to effective hazard mitigation and natural resource management.
- Encourage academic partnerships (for example, cooperative agreements and joint proposals with USGS in-kind support) when USGS and academic expertise are complementary.
- Identify and seek support for new areas of research that meet previously unrecognized national needs and that are within the program's mission.
- Bolster support for long-term research on topics for which the CMHRP provides much of the Nation's expertise.

Scientific Research: Strategy II

Focus scientific research through external partnerships and increase productivity by using data acquisition, analysis and modeling, and dissemination resources provided by collaborators.

Scientific Research: Representative Actions II

- Engage in science partnership opportunities that meet the Nation's priority scientific needs while also advancing the CMHRP's mission and long-term objectives.
- Implement cost- and resource-sharing activities through collaborative and other appropriate agreements.
- Actively disseminate data, analyses, and assessments using web-enabled tools and portals hosted by other organizations to highlight the CMHRP's scientific and technological accomplishment.

Data Acquisition and Processing

The CMHRP-supported science centers will maintain the capacity to collect and process many types of data and samples that are needed to fulfill the full breadth—local to regional to national scale—and multidisciplinary nature of the program's mission. This combination of short- and long-term data collection, some of which is uniquely provided to the Nation by the CMHRP, will be used simultaneously to satisfy immediate research and application requirements and to build the foundation for sustained research and extended impact.

Field Data Collection

Advancing the CMHRP's mission requires collection and processing of geological, geophysical, oceanographic, chemical, and biological data from estuaries to deep-sea environments. To support these activities, the CMHRP maintains core capabilities that include field instruments, equipment, and personnel to image, measure, or monitor natural systems and processes and to directly sample rocks, sediments, water, or gases. In some cases, the CMHRP may develop new instrumentation to meet the needs of the program and (or) collaborators. In other instances, the CMHRP will work with partners to improve or design new approaches that better address research or product goals. The overriding goal of the CMHRP is to maintain a flexible suite of core capabilities and expertise that fosters high-quality research and successful partnerships.

The program conducts marine and coastal research from a range of platforms. Small vessels maintained by CMHRP-supported science centers or by State or Federal partners collect data in coastal regions. Research programs studying the inner continental shelf contract with larger, privately owned or Federal fleet ships. Deepwater research requires larger,

more expensive ships and is carried out through contracts with Federal fleet ships or by sharing ship use with collaborators. To most efficiently use resources, the CMHRP collaborates with other agencies and conducts research that serves multiple purposes whenever possible.

Land, Sea-Floor, and Subsurface Surveying

CMHRP-supported science centers maintain a variety of instruments for mapping sea-floor characteristics that reveal processes shaping the shoreline and seabed. The program's capabilities also include expertise in processing raw data (collected by the CMHRP or others) to produce maps and interpretive products that meet a variety of national needs. Such data and associated products include maps of sea-floor features on the inner and outer continental shelf (for example, single beam and swath bathymetry), topography of the coast and bathymetry of shallow adjacent areas and rivers (for example, light detection and ranging [lidar] and drone imagery), properties of the sea floor that can be used to infer characteristics such as sediment texture and lithology (for example, side-scan sonar), and subsurface maps of sediment layers or other deposits (for example, seismic-reflection profiling systems and ground-penetrating radar).

Sample Collection

Physical samples collected from the environment can be analyzed to determine the physical, geological, and chemical characteristics of a location of interest. These samples can also be used to confirm the accuracy and interpretation of data acquired through remote sensing, such as acoustic mapping of the texture of the sea floor (https://www.usgs.gov/programs/cmhrp/science/usseabed). Examples of CMHRP sample collection capabilities include shallow and deepwater techniques for taking a "core" (a sample that preserves surface and subsurface sediment layers) and conducting a "grab" from the sea floor.

Imagery

Video and still images (https://cmgds.marine.usgs.gov/idsviewer) can be used to rapidly and intuitively document the state of the environment, and multiple images taken over time can be used to track environmental change. Like physical samples, images can also be used for assessing the accuracy of other types of data. The CMHRP collects and archives image data for many research purposes, including sea-floor pictures that reveal sediment types, images that document the state and health of ecosystems such as coral reefs, and repeated photographs of the coast to document its evolution.

Oceanographic Data

Oceanographic data can be analyzed to understand the processes that govern coastal change and sediment transport in estuarine, coastal, and marine environments. Data collected (https://stellwagen.er.usgs.gov/) include current velocities, wave properties, salinity, and suspended sediment concentration. Example of instruments used to collect these data include acoustic Doppler current profilers for measuring waves and currents, pressure gauges for measuring water depth, autonomous and towed instrumentation for characterizing ocean chemistry, and optical backscatter remote-sensing instruments for estimating the concentration of sediment in the water column.

Deployment Platforms

CMHRP-supported science centers maintain vessels such as small boats and personal watercraft that can be used locally and regionally to operate or deploy instrumentation in shallow water. Also maintained in-house are structures for mounting sensors and cameras during deployment, including custom landers and tow frames (https://www.usgs.gov/centers/whcmsc/science/coastal-model-applications-and-field-measurements-advances-instrumentation?qt-science_center_objects=0#qt-science_center_objects). The program also maintains the capabilities needed to operate its instrumentation from partner or contracted vessels, such as Federal fleet vessels used for some deep-sea work.

Laboratory Capabilities

CMHRP researchers use specialized laboratory facilities to analyze (1) solids and fluids collected in the seawater column and beneath the sea floor, in estuarine and ocean waters, and in coastal zone groundwater; (2) gases collected over wetlands, in open water, or from sediments; and (3) microbiological samples from the marine environment. In addition to meeting the program's needs, the CMHRP's laboratory infrastructure for sediment, water, and gas analyses also supports other Federal and State agencies and research institutions by analyzing samples acquired by collaborators. In some cases, external entities fund the CMHRP to provide analyses not available elsewhere.

Sediment Laboratories

These CMHRP laboratories conduct analyses needed to characterize the physical properties and structure of marine and coastal sediments and rocks, acquiring information about their composition, texture, carbon and shell content, and age. Such data are used to interpret sea-floor images, infer depositional environments and fluid migration patterns, estimate ages of submarine landslides, and estimate methane production rates. Geotechnical measurements to constrain sediment strength support assessments of submarine slope failures and the impact of gas hydrates on sea-floor properties. Specialized equipment measures mechanical and hydraulic properties of hydrate-bearing sediments maintained at their original pressure conditions.

Organic and Inorganic Geochemistry Laboratories

In addition to routine analyses of key chemical species and nutrients, these laboratories include specialized instrumentation developed by the CMHRP in collaboration with partners. Stable isotope and radioisotope analyses are used to infer the age and origin of coastal groundwater, rock, and sediment samples and to study the role of microbes in the biogeochemical cycling of carbon, sulfur, and nitrogen. CMHRP scientists also conduct biomarker studies of hydrocarbon samples from oil seep and gas hydrate settings and use X-ray diffraction to characterize minerals.

Gas Analysis Laboratories

The CMHRP analyzes the concentration and composition of gases in water samples, in atmospheric samples collected from wetlands or just above the ocean's surface, and in the byproducts of methane hydrate breakdown. The CMHRP has specialized instrumentation to discern gas sources on the basis of rapid measurement of gas isotopic characteristics and to work with gases under pressure in gas hydrate laboratories.

Data Acquisition and Processing: Needs, Challenges, and Strategies

To fulfill its mission of increasing the resilience, adaptability, and prosperity of our Nation's coastal communities and improving stewardship of natural resources, the CMHRP requires access to high-quality datasets about processes and locations of interest. If datasets are outdated, have gaps in space or time, or otherwise do not meet high standards for quality, large uncertainties may be introduced into the analysis and products. The program balances maintaining capabilities in-house, where quality and timeliness can be directly overseen, and relying on partners or contracted services, which may be more cost effective or technologically advanced in some cases.

The CMHRP uses the following strategies to maintain the data acquisition and processing capacity needed to complete its mission:

Data Acquisition and Processing: Strategy I

Balance in-house and external data acquisition capabilities on the basis of the priorities of the CMHRP's mission, the requirements of the program and its partners, the urgency of the necessary response, and the degree to which the technology is widely available.

Data Acquisition and Processing: Representative Actions I

- Share instrumentation across CMHRP-supported science centers and the USGS.
- Regularly evaluate capacity and appropriateness of in-house technology.
- Develop science center- and program-level investment strategies for instrument maintenance and replacement schedules based on data-quality requirements, scientific need, and technological advancement.

Data Acquisition and Processing: Strategy II

Access innovative new technologies through a combination of internal development and external collaborations.

Data Acquisition and Processing: Representative Actions II

- Investigate the use of instruments that are inexpensive and rapidly deployable (for example, uncrewed aircraft systems, also referred to as unmanned aircraft systems [https://www.usgs.gov/programs/national-land-imaging-program/science/national-uncrewed-systems-office]) while following regulations and National Environmental Policy Act requirements (https://www.epa.gov/nepa).
- Evaluate the potential for novel remote-sensing technology and techniques to provide low-cost ways of acquiring data (for example, using structure-from-motion approaches).
- Maintain in-house capability (people and infrastructure) to operate and customize equipment.
- Buy, lease, and partner for use of new equipment, where cost effective.
- Engage in policy discussions on issues that may affect and (or) limit data collection technology (for example, regulation of uncrewed aircraft systems).
- Explore pilot programs for expensive new technologies before investing in them.

Analysis and Modeling

The program will continue to synthesize understanding of oceanographic and geologic processes, along with their linkages to ecological and societal consequences, into conceptual and predictive models. These models will be used to predict how landscapes and ecosystems will evolve and respond to different scenarios (for example, management actions taken to reduce coastal hazards).

The CMHRP plays a vital role in analyzing data to predict how ecosystems, coastal landscapes, and geologic structures will evolve. This analysis includes synthesizing the current understanding of oceanographic and geologic processes and investigating their ecological and societal impacts. Model development and application are integral parts of this research. CMHRP personnel develop conceptual models that describe

how a natural system works (for example, the response of coastlines to hurricanes [https://coastal.er.usgs.gov/hurricanes/assessments/background.php]), statistical models that capture relationships and trends (for example, shoreline evolution [https://www.usgs.gov/centers/whcmsc/science/digital-shoreline-analysis-system]), and deterministic models of coastal processes that make detailed forecasts (for example, the Coupled Ocean-Atmosphere-Wave-Sediment Transport model [http://woodshole.er.usgs.gov/project-pages/cccp/public/COAWST.htm]). External partners and stakeholders use the information provided by the CMHRP's data analysis and models to prepare for natural and human-induced hazards (for example, earthquakes, submarine landslides, major storms, and oil spills), to plan ecosystem restoration projects, and to inform resource management.

Analysis and Modeling: Needs, Challenges and Strategies

As scientific and societal needs and standards for analytical and predictive capabilities continue to evolve, the CMHRP needs to maintain state-of-the-art expertise and equipment. A particular need is access to high performance computing, which is required to conduct advanced analysis and predictive modeling in a timely fashion. At the same time, standards and requirements for using information technology (IT) are becoming more challenging in response to data-sharing requirements and security threats, in some cases slowing access to remote IT resources.

The CMHRP uses the following strategies to maintain the analysis and modeling capacity needed to fulfill its mission:

Analysis and Modeling: Strategy I

Invest in CMHRP, USGS-wide, partner agency, and commercial computing solutions that maintain the flexibility needed for research and development while also meeting Federal standards for IT.

Analysis and Modeling: Representative Actions I

- Foresee administrative impediments to productivity (for example, internet speeds that are prohibitively slow for accessing remote, cost-effective computing solutions) and proactively develop solutions that are both secure and efficient.
- Share solutions to IT problems and critical IT personnel across science centers.
- Consider cost-saving solutions offered by internal and external partners, such as centralized USGS high-performance computing options.
- Develop effective approaches for storage and distribution of numerical model output.

Analysis and Modeling: Strategy II

Continually evaluate current standards in modeling and analysis techniques to ensure that the program uses scientifically accepted methods and incorporates the latest knowledge into developing new products needed to achieve its objectives.

Analysis and Modeling: Representative Actions II

- Enable collaboration with partners in other agencies and the academic community on model evaluation and development.
- Support development and maintenance of in-house models and tools when needed for efficiency or to advance the program's objectives.
- Encourage participation in scientific and technical conferences that enable CMHRP staff to keep abreast of developments and advancements in their field.

Preserving Data and Communicating Information

The CMHRP will continue to preserve its data, scientific findings, model predictions, and other products and provide this information for use by stakeholders to maximize the continuing return on investments in the program.

Historical and long-term datasets are vital to understanding the natural environment. Substantial investment over multiple years is necessary to generate these data. For this reason, the CMHRP preserves the data it collects. Preserving data saves time and money and makes the information available for reuse by the CMHRP, other researchers and agencies, and the public. The CMHRP archives digital data and develops robust and consistent metadata (information that describes the data, such as where, when, and how they were collected) so that future users can find and use existing data sources for their own needs. The CMHRP's data also include physical items, such as geological, chemical, and biological samples; paper records; and archived media (for example, DVDs and photographs). CMHRP staff catalog these samples, preserve them in appropriate facilities (for example, a refrigerated core repository [https://www.usgs.gov/centers/whcmsc/labs/samples-repository] and a subzero freezer for biological samples), and digitize paper records for easier access, preservation, and long-term use.

The CMHRP shares its data, analysis results, and model predictions to meet national needs for credible information to plan for and react to natural hazards, environmental change, and evolving resource management issues. Digital data acquired and preserved by the CMHRP are made available in accordance with the USGS Public Access Plan (https://www.usgs.gov/about/organization/science-support/science-quality-and-integrity/public-access-results; U.S. Geological Survey, 2023) and USGS Fundamental Science Practices (https://www.usgs.gov/office-of-science-quality-and-integrity/fundamental-science-practices;

Fundamental Science Practices Advisory Committee, 2011; Fundamental Science Practices Advisory Council, 2023). CMHRP data products include integrated databases (for example, the USGS Oceanographic Time-Series Database [https://stellwagen.er.usgs.gov/] and the National Archive of Marine Seismic Surveys [NAMSS; https://walrus.wr.usgs.gov/namss/]). The CMHRP also releases data and information through portals (for example, https://cmgds.marine.usgs.gov/) designed to facilitate use by partner agencies, community leaders, decision makers, and the public. For example, the CMHRP provides data, analysis, and interpretation online in near-real time during natural disasters, such as hurricanes (https://marine.usgs.gov/coastalchangehazardsportal/). The CMHRP also collaborates with media specialists to use crowd sourcing and citizen science (https://coastal.er.usgs.gov/icoast/index.php) in data acquisition, while also assessing the uncertainty and accuracy of these data acquisition methods to ensure that the program maintains its high standards for supplying credible information.

Data and Communications: Needs, Challenges, and Strategies

The CMHRP collects large quantities of digital data that must be stored, catalogued, and backed up in case of primary storage failure. These data are in a wide variety of formats that constantly change as new instrumentation or processing techniques are developed. IT security requirements continue to evolve, and demands for digital storage capacity increase considerably each year. In addition to digital data, the CMHRP possesses, maintains, and continues to acquire a variety of samples, including cores, rocks, handwritten paper log sheets, slides, digital photographs, videos, microfilm reels, and DVDs, many of which must be preserved in an environment that controls the temperature and humidity. The CMHRP is responsible for making these myriad resources discoverable, available, and accessible so that potential partners and end users benefit from them now and in the future.

One long-term goal of the USGS and the CMHRP is to develop integrated scientific products that draw from multiple data sources and span multiple applications. These products would deliver comprehensive and easily digestible earth science information to the Nation. The data that support these efforts, such as bathymetric elevation and model outputs, require a large digital storage capacity. The size of these datasets inhibits efficient access by users over web-based platforms and can also exceed prescribed limits on USGS data release mechanisms. Potential users of CMHRP information have a diverse set of needs based on the scale of their interests (local, State, or Federal) and their particular challenges and priorities for reducing the risks of hazards and sustainably managing resources. The program is strategically addressing these challenges to provide comprehensive, reliable, and timely access to information in user-ready formats.

The CMHRP uses the following strategies to maintain the capacity it needs for preserving data and communicating information:

Data and Communications: Strategy I

Consider the potential future uses of physical sample materials when deciding which to preserve, the storage methods to adopt, and the archiving schemes to implement.

Data and Communications: Representative Actions I

- Design space and facilities at the science center level to account for archiving needs.
- Implement data cataloging strategies that are as consistent as possible across science centers and over time.
- Develop procedures and timelines for disposal of samples that have a finite lifespan.
- Make sample holdings discoverable online and available for loan to other science agencies and researchers.

Data and Communications: Strategy II

Identify, use, and develop archiving systems that are practical for managing large volumes of historical data, newly acquired digital data, and model output.

Data and Communications: Representative Actions II

- Dedicate trained, professional staff to data management activities to improve efficiency and reduce burden on other personnel.
- Review documentation, apply consistent standards, and maintain authoritative metadata for data, including collections submitted to the USGS Science Data Catalog and Data.gov.
- Work with the USGS and the larger scientific data community to improve standards for data preservation and distribution and develop tools and procedures for implementing the new standards.
- Coordinate data management efforts with partners to ensure implementation of best practices.
- Foster consistency among science centers in data backup procedures and implementation.
- Evaluate cloud or other centralized storage solutions.
- Centralize and standardize data archiving procedures so data preservation and accessibility are a consistent part of the research process and are not project or scientist dependent.
- Digitize data (such as film or paper logs) for more widespread access.

Data and Communications: Strategy III

Pursue cost-effective internal and external solutions for making quality-controlled CMHRP data and products broadly and easily accessible to users as soon as possible after the data and products are generated.

Data and Communications: Representative Actions III

- Develop and expand user-friendly dissemination tools, such as on-demand access to digital data or USGS data product types specifically designed for quicker review and publication.
- Implement peer-review mechanisms for rapid-response scientific products, such as those generated after a natural disaster.
- Continue to advance and use standard web services and standards-based tools that facilitate access to CMHRP data, particularly larger datasets.
- Stay abreast of and engaged in open-source technologies (software code that is developed and maintained through public contributions).
- Use data management tools provided by the USGS Core Science Systems Mission Area, the USGS Office of the Associate Chief Information Officer—Information Technology (IT) and Information Management (IM), and other programs and offices.
- Take advantage of emerging technologies and standards to improve distribution, discoverability, and accessibility of CMHRP data and products.

Environments

The third component of the CMHRP's strategic framework is to address priority information needs and management challenges across diverse environments.

Estuaries and Wetlands

Estuaries and wetlands contribute to the economic and environmental health of the Nation. They provide habitat for commercially valuable and endangered species, and many are the sites of key infrastructure like ports and harbors. The CMHRP will continue to quantify the geologic and ecosystem structures and processes driving the evolution of estuarine and wetland ecosystems under various scenarios of climate and human influence. The program uses this knowledge to provide tools to assist resource managers in restoring and protecting these ecosystems and their benefits.

Estuaries are partially enclosed bodies of water along the coast where freshwater from rivers and streams mixes with saltwater from the ocean. Some estuaries are subterranean, existing within coastal aquifers (https://www.usgs.gov/natural-hazards/coastal-marine-hazards-and-resources/science/coastal-aquifers). Wetlands are freshwater, brackish, or saltwater environments that are permanently or intermittently flooded with shallow water and that are predominantly covered by plants adapted to living in saturated soils. Wetlands are found adjacent to estuaries, along open coasts, and in low-lying inland settings. Estuaries and wetlands share certain characteristics that distinguish them from open coastal areas, including the diversity and productivity of their ecosystems and the relative importance of biological and chemical processes in their physical evolution. However, estuaries and wetlands are inextricably linked to open coasts as important transition zones from freshwater- to saltwater-dominated environments.

The importance of estuaries and wetlands to the Nation's prosperity.—Estuaries and wetlands provide economic, ecological, and cultural resources and benefits to people. Many large estuaries (for example, Chesapeake Bay, Puget Sound, and San Francisco Bay [https://www.usgs.gov/natural-hazards/coastal-marine-hazards-and-resources/science/ecosystem-restoration-san-francisco-bay]) serve as protected harbors, supporting national and international commerce and hosting energy and defense infrastructure. Estuaries and wetlands serve as refuges for migratory birds and as nurseries for a diverse range of species, including commercially and recreationally harvested fish and shellfish. Healthy coastal wetlands protect inland areas from flooding and erosion and act as filters to detoxify contaminated water and to trap land-based pollutants. Estuaries similarly intersect flow from upstream watersheds, trapping sediment and contaminants before they reach the open ocean. Estuaries and wetlands are also repositories for organic-rich sediments and decaying plant material and are therefore important for processing and storing carbon.

The CMHRP's role in improving natural hazard protection and resource management in estuaries and wetlands.—The extensive expertise and techniques that the CMHRP has developed and applied for supporting hazard mitigation along open coasts can be used to address similar national needs in estuaries and wetlands. Physical, geological, chemical, and biological processes in estuaries and wetlands are complex, interconnected, and constantly changing. CMHRP researchers' diverse range of experience allows effective consideration of the wide range of processes and interactions relevant to the physical and geological evolution of estuaries and wetlands and to the management of wetland and estuarine resources.

Needs, Challenges, and Strategies for Estuaries and Wetlands

Natural and anthropogenic pressures driven or exacerbated by climate change, sea level rise, extreme storms, and upstream and coastal zone developments affect ecosystems, physical conditions, and water quality in estuaries

and wetlands. National, regional, and local resource managers require scientific information on the evolution of estuaries and wetlands and readily accessible planning tools, such as maps of shoreline vulnerability and inundation. Such information and tools guide decisions about threat mitigation, ecosystem restoration and management, and coastal planning. Considerable knowledge gaps exist about the complex interactions of biological, chemical, geological, and physical processes that shape estuaries and wetlands, and better data are necessary to produce more robust models and predictions about the response of these settings to changing conditions.

The CMHRP uses the following strategies to meet high-priority needs and challenges related to estuaries and wetlands:

Estuaries and Wetlands: Strategy I

Provide baseline knowledge about physical and biogeochemical processes in estuaries and wetlands over multiple temporal and spatial scales to help understand how these ecosystems will change in the future.

Estuaries and Wetlands: Representative Actions I

- Determine how key characteristics of estuaries and wetlands (for example, sediment deposition rate, and land and habitat loss) change in response to winter storms, hurricanes, fair-weather conditions, anthropogenic effects, climate change and sea level rise.
- Measure and analyze past and present changes in elevation, sediment accumulation, and erosion to forecast impacts from changes in sea level.
- Identify the physical factors that are most important in controlling the evolution of individual estuaries and wetlands to inform habitat restoration.
- Collect new observational data to evaluate and test models of turbidity and sediment movement and accumulation in estuaries and wetlands.
- Investigate the role of estuarine and wetland processes in carbon cycling and storage.
- Investigate the role of coastal groundwater as a source for nutrient enrichment, nutrient cycling, and effects on estuarine habitats.
- Understand the effects of alterations to water and sediment flow, including dams and diversion channels, on natural estuarine processes and ecosystems.
- Establish long-term monitoring sites to acquire the data needed to refine models and vulnerability assessments.

Estuaries and Wetlands: Strategy II

Create and distribute planning-support tools that assess estuary and wetland vulnerability to impacts from coastal hazards, natural disturbances, and human activities.

Estuaries and Wetlands: Representative Actions II

- Synthesize existing information and historical data on estuary and wetland response to climate change, sea level rise, storms, and land use to identify which characteristics are best used to assess change.
- Develop assessments (evaluations of the current state or vulnerability of environmental features identified as important for management applications) that can be used to quantify and forecast shoreline change, erosion, and deposition on regional scales.
- Refine assessments of vulnerability to include the influence of adjacent environments identified as critical to the evolution of a coastal wetland or estuary.
- Link regional wetland and estuary assessments to related processes such as eutrophication (excessive nutrients leading to algal blooms) and net coastal carbon cycling and sequestration (removal of carbon dioxide from the atmosphere).
- Transform historical assessments into vulnerability indices that can be used to predict the response of estuaries and wetlands to storms in near-real time.

Estuaries and Wetlands: Strategy III

Create models that forecast the effects of coastal hazards, climate change, human perturbations, and restoration activities on estuaries and wetlands.

Estuaries and Wetlands: Representative Actions III

- Create preliminary models that link geophysical, biogeochemical, and ecological processes as a foundation for more advanced techniques.
- Use knowledge of past and present estuary and wetland conditions to improve models that predict the physical, chemical, and biological response of these systems to storms, sea level rise, and other drivers.
- Create and test forecasts of critical processes, including storm inundation, sea level rise, carbon storage and release, and exchange of nutrients and greenhouse gases.
- Integrate models of different physical (for example, carbon, sediment, and greenhouse gases) and ecological (for example, habitat distribution and evolution) components of wetlands and estuaries.

- Develop an approach for linking wetland and estuary response to changes in adjacent coastal environments, such as tidal rivers, barrier islands, and offshore processes.
- Build the capacity to assess the condition and predict the evolution of wetlands and estuaries around the Nation by extending the applicability of existing site-specific models.

Open Coasts

Much of the U.S. population lives near the open coast, and the Nation depends on infrastructure and commerce that are concentrated in this region. The highly dynamic nature of this region frequently necessitates management action to reduce risk to coastal residents and (or) natural resources or to repair damage that has already occurred. The CMHRP will continue to study the current state and evolution of coastal landscapes and their responses to natural and human-driven processes in order to develop forecasting tools for mitigating dangers to communities or for more effectively managing coastal resources.

Coasts are the transition between land and sea, including sandy beaches and dunes, coastal cliffs, and rocky coastlines. In addition to mainland coasts, the Nation has extensive coastlines around islands (https://www.usgs.gov/natural-hazards/coastal-marine-hazards-and-resources/science/islands) and on the shores of the Great Lakes. The coastal system extends offshore and is connected via water and sediment flows to the shallow ocean (for example, the surf zone and the continental shelf). Coastal environments include coral reefs in some tropical locations (https://www.usgs.gov/natural-hazards/coastal-marine-hazards-and-resources/science/coral-reefs). Estuaries and wetlands are also part of the broader coastal system and are connected with the open coast by the exchange of water and sediment through tidal, storm, and riverine processes.

The importance of open coasts to the Nation's prosperity.—About 40 percent of the U.S. population lives near the coast (including the coastlines of the Great Lakes), and critical infrastructure, such as roadways, buildings, ports, and bridges, is concentrated in these areas (National Oceanic and Atmospheric Administration, 2020). Trillions of dollars have been invested to build this infrastructure, which supports billions of dollars in annual wages for workers in industries like maritime shipping, marine resource extraction, and fishing. Losses from natural hazard events affect the owners and users of coastal property, as well as the insurance industry and Federal, State, and local governments. Fishing, recreational boating, and beach tourism are sectors worth billions of dollars and are the economic foundation of many coastal communities. Sites of cultural value, such as the historic locations of Native American villages, are often found along the coast. Natural features, including dunes, bluffs, and cliffs, are important for providing protection from storm surge and other events that can threaten people, infrastructure, and resources. The coastal zone also serves as critical habitat for a variety of plants and animals, such as sea turtles that nest on sandy beaches and ecologically and economically important fish species. In tropical locations, management of the coastal zone is critical for maintaining healthy coral reefs that protect the coast and generate billions of dollars of revenue to the Nation.

The CMHRP's role in improving natural hazard protection and resource management on open coasts.—The CMHRP is the leading Federal research program for characterizing the current state and evolution of coastal systems and their vulnerability to natural and human-induced hazards. The CMHRP is also the only Federal science agency program tasked with observing and predicting coastal change, such as the erosion of coastal cliffs and loss of protective features such as sand dunes, and for forecasting other effects of storms and sea level rise. As part of its mission, the CMHRP has developed an array of tools, including forecasting models and mapping capabilities across the land-sea interface. The CMHRP applies these tools to support the understanding and mitigation of coastal hazards and the management of coastal resources at local, regional, and national scales. In doing so, the program has built deep expertise, an extensive collection of relevant historical datasets, and considerable institutional knowledge about coastal zone processes.

Needs, Challenges, and Strategies for Open Coasts

One of the most pressing national priorities that the CMHRP addresses for open coasts is preparation for, response to, and recovery from coastal hazard events. Communities in low-lying areas are affected by extreme precipitation, sea level rise, tsunamis, storm surge, and disturbance to freshwater resources. Threats include both natural hazards that may be exacerbated by climate change (for example, sea level rise, hurricanes, and winter storms) and unintentional negative effects from human activities (for example, oil spills, coastal development, redistribution of sand due to construction of jetties and groins, and excavation of ship channels). These same drivers affect economically and ecologically valuable coastal features and habitats, including protective beaches, dunes, sea cliffs, and coral reefs.

The Nation makes a substantial investment each year in managing its coasts to ensure the protection of coastal populations, economies, infrastructure, natural resources, and sensitive ecosystems. Effective management depends on the ability to understand and forecast coastal processes and the threats from associated hazards. Adequate protection requires understanding the risk that individual and co-occurring coastal hazards pose to human and natural assets. Lives and money are saved by improving preparation for immediate threats, such as storms, landslides, and tsunamis, and by understanding when and where these hazards occur and their likely effects. By coupling this awareness with improved understanding

of the long-term evolution of coastal landscapes, decisions regarding infrastructure planning and natural resource management will be more effective and economical.

Although decades of research have advanced understanding coastal landscapes, the ability to predict when and how natural processes and hazards will change coastal environments must be improved to meet the needs of the Nation's coastal zone managers. The level of uncertainty associated with predictions of coastal hazards is still unacceptably high given the percentage of the U.S. population that lives along the coasts and the value of the Nation's infrastructure and resources that are at risk. Knowledge gaps exist that prevent effective linking between the physical response of coastlines during extreme events and the underlying geology and weather-related processes that shape these changes. Filling these gaps would improve predictions of how landscape evolution will affect communities, infrastructure, and natural resources. New scientific data and analyses are required to bridge these gaps and meet the needs of those who live on the coast or rely on coastal resources.

The CMHRP uses the following strategies to meet high-priority needs and challenges related to open coasts:

Open Coasts: Strategy I

Improve understanding of coastal zone physical processes.

Open Coasts: Representative Actions I

- Link offshore geologic processes and structure to historical coastal change through conceptual and predictive models and use the resulting understanding to improve predictions of the vulnerability and evolution of coastal systems.
- Investigate the interactions and effects of hazard processes, such as storm surge and large waves during tropical and extratropical storms.
- Develop a better understanding of the connections between global-scale changes and regional and local variability.
- Create and improve models that can predict the recovery of coastal systems after storms, supported by data collected at appropriate temporal and spatial scales.
- Refine models for predicting the decadal evolution of coastal systems by increasing understanding of processes that occur slowly (for example, beach accretion, coral reef accretion, vegetation growth, and sand transport by wind).

Open Coasts: Strategy II

Increase accuracy in predicting the evolution and vulnerability of coastal systems.

Open Coasts: Representative Actions II

- Reduce uncertainty in predictions of coastal vulnerability by acquiring new field data to update models when existing data are out of date or have insufficient accuracy to support evolving requirements.
- Enhance the skill of forecasting sediment transport processes in diverse open-coast settings across the Nation's coasts, from permafrost settings to tropical coral reefs.

Open Coasts: Strategy III

Increase the impact of the CMHRP's research capabilities by broadening the scope of problems addressed in coastal environments.

Open Coasts: Representative Actions III

- Adapt existing expertise and tools developed for sandy shorelines to predictive modeling and vulnerability forecasting for other systems, such as rocky shorelines, permafrost bluffs, and coral reef-lined coasts.
- Include interactions between changing oceanographic conditions and resulting landform change in hazard response, recovery, and long-term change models.
- Link coastal landscape change to economic impacts and ecosystem evolution to evaluate the sustainability and vulnerability of infrastructure and resources in the coastal zone.

Open Coasts: Strategy IV

Increase the impact of the CMHRP's existing coastal hazard mitigation support products by improving access and communication.

Open Coasts: Representative Actions IV

- Provide web-based access to coastal system information and products to planners working to protect resources, identify risk, and help prevent economic losses along the Nation's coastlines.
- Interact with users of the CMHRP's tools and data to more effectively address stakeholders' decision and planning needs.
- Facilitate better incorporation of CMHRP tools into decision-support systems that are used by management agency partners tasked with designing and implementing restoration projects.
- Work with the U.S. Integrated Ocean Observing System (https://ioos.noaa.gov/) to improve interoperability and access to all governmental, academic, and commercial data in the coastal zone.

Continental Shelf

Stretching from the coasts to the deep sea, the continental shelf encompasses many of the Nation's critical resources, including fishing grounds, sand and gravel supplies, and energy assets. The CMHRP will continue to collect and interpret geologic and physical data about the shallow ocean in order to characterize its resources and habitats and to quantify the processes that shape the shallow ocean, drive coastal evolution, and generate hazards.

The continental shelf is the broad, gently sloping region that extends underwater from the shoreline to the shelf break. Adjoining the open coast, the inner continental shelf has a structure and geologic history that contribute to coastal change. At the continental shelf's outer edge, the sea floor dips steeply and transitions into the continental slope and deep sea.

The importance of the continental shelf to the Nation's prosperity.—The State and Federal waters that make up the continental shelf are largely unexplored, and the characteristics and distribution of marine resources in this region are poorly understood. This vast, submerged territory includes many of the Nation's important social, economic, and environmental assets, such as fishing grounds, natural gas and oil reserves, sand and gravel resources, and cultural resources (for example, shipwrecks and early Native American habitation sites). The shelf also includes a variety of sea-floor habitats that are important for fish, shellfish, and marine mammal species. Reliance on shelf areas is increasing as the Nation's needs evolve and more focus is placed on offshore resource development, including wind and tidal power, hydrocarbon exploration, and sand for beach and barrier island restoration. The continental shelf is also important because of its physical connection to the coast and the human populations that live there. Because of its proximity to the coast, continental shelf waters are widely used for activities such as commercial and sport fishing, which sustain some coastal economies. Sediment exchange between the inner shelf and the coast affects the patterns and rates of coastal erosion and the sustainability of beaches.

The CMHRP's role in improving natural hazard protection and resource management on the continental shelf.—Decades of experience in geology, geophysics, oceanography, and predictive modeling have made the CMHRP a world leader in characterizing natural resources, processes, and hazards along the continental shelf. Managers and scientists often lack information on sediment abundance, geohazards on the sea floor or in shallow sediments (for example, scour and natural gas), frequency of past tectonic events (for example, movement on earthquake faults), sea level histories, substrate heterogeneity, and other regionally variable characteristics that affect the Nation's use of this region. As a Federal science program, the CMHRP plays a fundamental role in filling these information gaps and in developing research approaches and technologies that provide valuable insight into continental shelf evolution and vulnerability. The CMHRP efficiently and effectively addresses a variety of national needs by coordinating studies and research cruises that provide information and data for multiple uses.

Needs, Challenges, and Strategies for the Continental Shelf

As the Nation's population grows, demands for information about mineral and energy resources on the continental shelf and about the regional effects of offshore development (for example, traditional and renewable energy infrastructure) continue to increase, and more people and infrastructure will be at risk from coastal hazards. Uses of the continental shelf overlap in potentially conflicting ways. For example, sensitive fisheries and associated habitats could be disrupted through activities that disturb the sea floor. Clear, objective, and reliable scientific information is needed to make informed and coordinated decisions in managing these diverse activities.

Infrastructure on the continental shelf can be threatened when the sea floor becomes unstable, either through catastrophic events like submarine landslides or through gradual erosion of the sea floor by storms or other processes. The Nation needs quantitative information on the processes that link the continental shelf to the coast to reduce the risks of coastal hazards and guide ecosystem restoration. Examples of the specific types of information that managers and scientists require in order to reduce the risks of natural hazards, manage continental shelf resources, and understand the processes in this environment include the frequency and locations of modern and historic geohazards, the history of sea level changes, and the spatial variability of sea-floor characteristics (such as sediment texture) that affect the Nation's use of the shelf.

The CMHRP uses the following strategies to meet high-priority needs and challenges related to the continental shelf:

Continental Shelf: Strategy I

Resolve physical and geological processes of continental shelf evolution at storm-event and longer timescales, including linkages to the coast.

Continental Shelf: Representative Actions I

- Collect new observational data to evaluate and test models of sediment movement and sea-floor change.
- Analyze the distribution and transport patterns of inner shelf sediments on decadal, centennial, and millennial timeframes.
- Develop, verify, and apply models that can predict the movement of sediment between the inner continental shelf and the coast.
- Use information on shelf sediment distribution and dynamics and linkages to the coast to improve predictive models of coastal vulnerability.

Continental Shelf: Strategy II

Identify the distribution and characteristics of potential continental shelf resources and hazards and the spatial variation of sea-floor characteristics (sediment type, bathymetric features, and sediment movement patterns).

Continental Shelf: Representative Actions II

- Establish regional-scale geologic mapping efforts that are coordinated (when possible and beneficial) with studies of sea-floor processes.
- Conduct modeling studies to create local-, regional-, and national-scale estimates of sea-floor processes and hazards, such as sediment mobility and transport (for example, https://cmgds.marine.usgs.gov/data/whcmsc/data-release/doi-P999PY84/).
- Create interactive, readily accessible maps that can be used by regulatory agencies, managers, and research partners for natural and cultural resource identification, benthic habitat delineation, siting for offshore development, hazard mitigation, and marine spatial planning.
- Develop numerical models of ocean circulation to allow testing of potential management actions, such as disposal of dredge spoils and siting of ocean outfalls.

Continental Shelf: Strategy III

Increase understanding of past changes in climate and sea level and the associated response of coastal and marine environments as a basis for predicting the future effects of climate variability.

Continental Shelf: Representative Actions III

- Acquire and analyze sediment and coral cores to establish a climate history record.
- Constrain the history of sea level changes and glaciation along the inner continental shelves.
- Reconstruct the histories of coastal and submerged lands to determine how natural systems evolved from the past to the present.
- Identify and model the broad suite of controls on present and past sea level rise to better forecast future rates of change.

Continental Shelf: Strategy IV

Understand the current conditions and factors that affect the health of marine ecosystems on the continental shelf, as well as on the continental slope and in the deep sea.

Continental Shelf: Representative Actions IV

- Conduct multidisciplinary studies focused on important geologic processes, including calcification, sedimentation, and erosion.
- Provide assessments of marine ecosystem resources and their vulnerability to evaluate the consequences of changing conditions.
- Collect long-term datasets that can be used to test the validity of predictive models of ecosystem health.
- Document baseline conditions of ecosystem and geologic processes in anticipation of chronic (for example, ocean warming and acidification) or catastrophic (for example, oil spill) change.

Continental Slope and Deep Sea

Coastal communities and continental shelf infrastructure can be damaged by earthquakes, submarine landslides, and tsunamis that originate on the continental slope and in the deep sea. Geological and oceanographic processes in the deep sea have also concentrated minerals important for industry and technology and deposits such as gas hydrates. The CMHRP will continue to study the deep ocean to understand the geological and physical processes that cause marine hazard events, to characterize mineral and energy resources, and to investigate deep-sea ecosystems. This scientific information can be used to prepare coastal communities for marine geohazard events and to better manage offshore resources.

The deepwater ocean zone extends from the outer edge of the continental shelf (at a water depth, in most locations, between 100 and 200 meters or 330 and 590 feet), across the steep continental slope, and to the ocean's abyssal plains, where water depths can reach more than 8,000 meters or 26,000 feet (Britannica Editors, 2006, 2024, 2025). Much of the U.S. continental slope is cut by canyons that host deep-sea coral ecosystems and other habitats important for fish and marine mammal species (https://www.usgs.gov/programs/coastal-and-marine-hazards-and-resources-program/science/deep-sea-corals). Multiple marine geohazards originate on the continental slope or in the deep ocean, including submarine earthquakes and landslides, volcanic eruptions, and tsunamis. These areas also host unique natural resources (https://www.usgs.gov/centers/pcmsc/science/global-seabed-mineral-resources) as well as energy and mineral deposits (https://www.usgs.gov/programs/cmhrp/science/gas-hydrate-resources). The continental slope and deep sea pose particular challenges for research because of their remote nature and great water depths.

The importance of the continental slope and deep sea to the Nation's prosperity.—Coastal communities and continental shelf infrastructure can be damaged by earthquakes, submarine landslides, and tsunamis that originate on the continental slope

and in the deep sea. These extreme events can occur suddenly, making it imperative to prepare for and mitigate the risk to communities and to the Nation's resources. In addition, rare earth minerals and unconventional resources, such as gas hydrates, most commonly occur in certain deep-sea regions.

The CMHRP's role in improving natural hazard protection and resource management in the deep sea.—The primary focus of the CMHRP's mission for deepwater settings is marine geohazards. These sudden, extreme geologic events (for example, earthquakes and submarine landslides) affect coastlines, coastal populations, seabed infrastructure, natural resources, and (or) human health on local, regional, and global scales. The CMHRP also characterizes the geological structure and mineral resources of the Nation over areas including the Exclusive Economic Zone (the area within 200 nautical miles or 230 statute miles of the coast), as mandated by the Outer Continental Shelf Lands Act (43 U.S.C. 1331(a)(1)), and maps beyond the Exclusive Economic Zone to support U.S. sovereign rights to the sea floor and subsea floor under customary international law (Outer Continental Shelf Lands Act, 43 U.S.C. 1331(a)(1); affirmed in the Submerged Lands Act, 43 U.S.C. 1301–1315; reinforced by Presidential Proclamation No. 2667 [Truman, 1945]; defined under article 76 of UNCLOS [United Nations, 1982]; and codified in Federal regulation at 33 CFR §2.30). In addition, the CMHRP provides the Nation's expertise on the geologic evolution of the U.S. continental slope and deep ocean and the physical characteristics of deep-sea ecosystems.

The CMHRP's achievements have been made possible in part by new technologies and methods developed within the program. Conducting rigorous investigations in remote, deep-ocean settings is difficult, and the CMHRP has the expertise and access to capabilities required to be successful in these environments. As part of a Federal science agency, the CMHRP maintains the breadth of knowledge and experience and provides the continuity of resources to complete long-term and large-scale studies, as well as quick-response efforts, to fill critical gaps in understanding natural hazards and offshore resources to serve the interests of the Nation.

Needs, Challenges, and Strategies for the Deep Sea and Continental Slope

A primary focus of the CMHRP's deep-sea research is providing science to inform the Nation in preparing for marine geohazards, many of which are complex and interrelated. For example, strong ground motions that accompany submarine earthquakes may trigger sea-floor landslides, which, in turn, can cause tsunami and related coastal hazards. To reduce the risk to populations and infrastructure, a better understanding of the relation between geologic processes and geohazards is required. In many areas, the occurrences of resources such as sea-floor minerals and gas hydrates remain poorly known, and few deep-sea locations have been surveyed to determine where gas hydrates may be breaking down and causing methane to leak from the sea floor. In addition, little is known about the effects of multiple natural and human-induced stressors (for example, changes in water quality or extraction of marine minerals) on the health and sustainability of continental shelf, slope, and deep-sea ecosystems. The deep sea is remote and inhospitable to humans, leading to the need for specialized tools and rendering access expensive and sometimes challenging, particularly in remote or ice-covered areas.

The CMHRP uses the following strategies to meet high-priority needs and challenges related to the continental slope and deep sea:

Deep-Sea and Continental Slope: Strategy I

Identify and characterize marine geohazards by using a variety of methods.

Deep-Sea and Continental Slope: Representative Actions I

- Access and develop new technologies that allow researchers to conduct remote investigations far beneath the ocean's surface and sea floor.
- Conduct regional-scale geophysical mapping programs coupled with site-specific studies to address regional and local hazards.
- Continue to advance cutting-edge seismological, geophysical, and geological techniques needed to assess how and why tsunamis occur.

Deep-Sea and Continental Slope: Strategy II

Continue developing national coastal and marine hazard predictive tools to assess where marine geohazards occur and identify associated vulnerable areas.

Deep-Sea and Continental Slope: Representative Actions II

- Apply a multi-hazard approach (in other words, one that simultaneously considers the causes and interactions of more than one threat) to developing comprehensive risk and vulnerability assessments.
- Constrain the timing, location, and magnitude of potential hazards by advancing understanding of the associated processes and geologic structures.
- Continue to develop and apply modeling techniques (such as the Probabilistic Seismic/Tsunami Hazard Analysis) that evaluate the threat from marine geohazards at specific locations.

Deep-Sea and Continental Slope: Strategy III

Investigate the interaction between gas hydrates and environmental change and determine the potential of gas hydrates as an energy resource.

Deep-Sea and Continental Slope: Representative Actions III

- Develop new tools, techniques, and experiments for analyzing hydrate-bearing sediments to improve reservoir models.
- Use geophysical data to identify hydrate-rich sediments and to estimate the amount of trapped methane gas, particularly in locations where gas hydrates are breaking down because of environmental change.
- Measure methane flux from the ocean in gas hydrate provinces and analyze the contribution of gas hydrate breakdown to the atmospheric methane budget.
- Identify and map areas of the continental slope where gas hydrates and associated free gas may affect submarine slope failures.

Deep-Sea and Continental Slope: Strategy IV

Characterize and assess the origin, distribution, composition, and environmental setting of sea-floor minerals.

Deep-Sea and Continental Slope: Representative Actions IV

- Consolidate and upgrade the USGS sea-floor minerals database.
- Map sea-floor mineral deposits and advise the Nation on the distribution and accessibility of economically important marine minerals.
- Identify and analyze the potential of new marine mineral resources.
- Investigate the environmental effects of mining in the deep ocean and on continental margins.

Knowledge

The fourth component of the CMHRP's strategic framework is to integrate knowledge for comprehensive, long-term support to the Nation.

The CMHRP uses its expertise to synthesize knowledge into a more complete understanding of coastal and marine processes; their connections across environments; and their interactions with society, natural resources, and ecosystems. The program will develop increasingly integrated and innovative tools for distributing that information to users. The CMHRP will also continue to develop new science-based tools and more effectively deliver its products so that decision makers and stakeholders can anticipate future issues and confidently assess the consequences of management and regulatory decisions.

The CMHRP aspires to create robust, science-based products that can improve management of coastal and marine resources and mitigate threats to coastal communities on nationwide scales. The CMHRP will achieve this objective through collaborative, interdisciplinary research and by integrating knowledge gained from focused studies into a comprehensive understanding of how coastal and marine environments evolve. The program can then use its resources and capabilities to make the information widely available to local, State, and Federal management agencies and other stakeholders in readily accessible formats that meet users' needs.

As a Federal science program, the CMHRP is responsible for developing science-based tools to improve the socioeconomic and ecological health of the Nation as well as the management of natural resources. For this reason, the CMHRP plays an important role as a bridge between the research community and decision makers. The program also serves as a long-term provider of information and products that integrate knowledge across scientific disciplines and link coastal and marine changes to their effects on society.

Integrate Knowledge: Needs, Challenges, and Strategies

Improving our ability to predict change in coastal and marine environments requires integrating knowledge across a range of scientific disciplines as well as an understanding of the degree to which humankind has affected the natural processes in these regions. Interdisciplinary collaboration on coastal and marine issues may be impeded across agencies and the academic community because of differences in research focus and funding mechanisms. Stakeholders may find it difficult to find and use the information they need because of the large volume of data, the different sources for those data, and the number of different products available. Users also vary in their technical capability for accessing or interpreting data and may lack prior knowledge of the program's resources. Bridging the gap between researchers and decision makers to facilitate use of scientific information for addressing real-world problems can be challenging because of inherent differences in how those communities address uncertainty and the timescale of projects. Finite resources necessitate innovative and collaborative solutions to address these challenges.

The CMHRP uses the following strategies to integrate knowledge for comprehensive, long-term support to the Nation.

Knowledge: Strategy I

Integrate and expand the knowledge gained in focused studies to increase understanding of the interactions between natural and anthropogenic processes across a range of environments.

Knowledge: Representative Actions I

- Capitalize on data collected as part of focused efforts to expand understanding and create predictive models for environmental processes.
- Encourage internal communication and teamwork between research groups and across CMHRP-supported science centers to facilitate greater understanding and use of program-wide expertise.
- Develop and pursue mechanisms for collaboration across USGS mission areas.
- Research the connections between environments (such as the continental shelf and open coasts) to create a more comprehensive understanding of coastal and marine processes and ecosystems.
- Ensure access to multidisciplinary expertise by cultivating partnerships and workforce planning.
- Encourage communication and collaboration with researchers and management organizations that can link environmental processes to socioeconomic effects.

Knowledge: Strategy II

Document and communicate scientific understanding of natural processes and physical environments through a variety of methods.

Knowledge: Representative Actions II

- Partner with Federal science agencies and scientific associations to host meetings that establish the state of scientific understanding and are focused on designing research strategies to address outstanding questions.
- Use scientific journals to publish peer-reviewed articles that synthesize and critically review the current state of knowledge on a given topic in coastal and marine research.
- Publish USGS information products that express the state of scientific understanding of critically important natural processes.
- Maintain dynamic, standards-based online maps that present the state of scientific knowledge of the Nation's coastal and marine environments.

Knowledge: Strategy III

Maintain integrated knowledge banks and databases that enable widespread internal and external access and facilitate the use of information for myriad purposes.

Knowledge: Representative Actions III

- Implement technological innovations that improve discovery, accessibility, and connections among CMHRP scientific reports, data, and other research products.
- Continue to enable integration with products from other USGS programs and scientific organizations to catalyze new ways to combine data across multiple disciplines (for example, Science Application for Risk Reduction [https://www.usgs.gov/natural-hazards/science-application-risk-reduction]).
- Engage with partners to develop and implement content and format standards to enable automated discovery and integration of scientific information.

Knowledge: Strategy IV

Create national-scale and portable products that serve the needs of governmental and private-sector managers for actionable information about natural resources and hazards.

Knowledge: Representative Actions IV

- Engage with stakeholders in designing, developing, and testing tools that enhance science-based decision making.
- Work with other Federal agencies to ensure that CMHRP data can be combined with data from other sources across a wide range of disciplines, including the social sciences.
- Implement content management standards and techniques that allow rapid deployment of customized CMHRP content in online tools that are responsive to the requirements of particular stakeholders.
- Use effective communication modes that range from technical data interoperability to interactive websites, story maps, and multimedia.
- Develop and support issue-specific communication forums to foster interaction among CMHRP scientific and information experts and the governmental and private-sector managers who use CMHRP scientific information.

Knowledge: Strategy V

Facilitate integration of scientific knowledge and science-based tools into management.

Knowledge: Representative Actions V

- Pursue and leverage opportunities to work directly with partners to use or develop tools that meet specific management objectives.
- Prioritize the development of products that can address recurring or widespread societal needs.
- Use internal resources to expand tools and products initially created through partner-supported efforts.
- Maintain and enhance CMHRP capabilities that best align with national needs for science-based decision support.

Knowledge: Strategy VI

Strengthen public awareness of the value and products provided by the USGS and the CMHRP.

Knowledge: Representative Actions VI

- Develop and maintain a communications plan that reflects the program's priorities and public interest in the program's products.
- Guide staff on activities and product development in support of outreach to partners, communities, stakeholders, media, and the public at the center and Bureau level.
- Develop consistent processes, such as use of the USGS Visual Identity System (https://www.usgs.gov/information-policies-and-instructions/usgs-visual-identity-system), for identifying the USGS and CMHRP contribution to products in the public domain, particularly for interagency products.
- Improve the CMHRP's web presence and establish a review process to ensure that all content is well maintained and current.
- Increase awareness of CMHRP products through collaboration with the USGS Office of Communications and Publishing, media outlets, and nongovernmental organizations.
- Train and encourage staff to engage in public exchange forums such as GitHub to enhance understanding and usage of CMHRP products.
- Build and maintain a social media presence and track analytics to improve the impact of social media products.
- Cultivate the mindset that public outreach is vital to our organization through recruitment and training of staff and linking of activities to the CMHRP's communication priorities.

Supporting the CMHRP Vision

This strategic framework provides the CMHRP with guidance for evaluating the benefits and tradeoffs associated with decisions that prioritize activities and investments and that affect the program's ability to complete its mission. For example, cultivating partnerships with other agencies that operate deep-sea research vessels may be the most efficient way for the CMHRP to acquire the data it needs to inform coastal communities of threats from deep-sea hazards, such as submarine earthquakes and associated tsunamis. Similarly, program decisions on the prioritization of immediate, regionally important efforts must consider the potential contributions of those efforts to more comprehensive support of the Nation at large. By framing decisions in the context of their effect on the quality and scope of support that the CMHRP can provide in the short and long term, the program will continue to support its vision of a Nation that prospers by being prepared for the challenges of changing coasts and oceans.

Partnerships

The CMHRP partners with Federal, regional, State, and local agencies; Tribal governments; universities and research institutions; and stakeholder groups to deliver the best science to the Nation.

Federal Partnerships

The wide range of CMHRP interactions with Federal partners is provided through a few examples in table 1.

Other Partnerships

The CMHRP also interacts with a host of other partners, a few of which are listed in table 2 as examples.

Table 1. Examples of Federal partnerships with the Coastal and Marine Hazards and Resources Program across research environments.

[DOI, U.S. Department of the Interior; NPS, National Park Service; FWS, U.S. Fish and Wildlife Service; BOEM, Bureau of Ocean Energy Management; BLM, Bureau of Land Management; OIA, Office of Insular Affairs; Reclamation, Bureau of Reclamation; USGS, U.S. Geological Survey; CMHRP, Coastal and Marine Hazards and Resources Program; NOAA, National Oceanic and Atmospheric Administration; NWS, National Weather Service; DoD, U.S. Department of Defense; USACE, U.S. Army Corps of Engineers; ONR, Office of Naval Research; NRL, U.S. Naval Research Laboratory; NSF, U.S. National Science Foundation; NOAA, National Oceanic and Atmospheric Administration]

Federal partner	Examples of interactions
Department of the Interior (DOI): National Park Service (NPS), U.S. Fish and Wildlife Service (FWS), Bureau of Ocean Energy Management (BOEM), Bureau of Land Management (BLM), Office of Insular Affairs (OIA), and Bureau of Reclamation (Reclamation)	**Estuaries and wetlands:** Partner with NPS, Reclamation, and FWS to assess coastal watershed, estuarine, and wetland restoration projects. **Open coasts:** Partner with USFWS and NPS to obtain updated observations and to assess current and future coastal vulnerability. Provide data and interpretations to NPS, OIA, FWS, and DOI headquarters to improve management and restoration of coral reef habitat. **Continental shelf:** Provide geologic knowledge for studies of gravel and sand resources and marine archaeological sites to BOEM, FWS, and others. Collaborate with NPS on onshore-offshore geologic studies. **Continental slope and deep sea:** Partner with BOEM, FWS, and others to characterize deep-sea corals and assess potential restoration plans. Collaborate with BOEM and BLM on gas hydrate assessments and resource-based drilling and site characterization. **Information preservation and communication, and enhancing capabilities:** Provide public access to BOEM's legacy industry seismic data on the USGS CMHRP National Archive of Marine Seismic Surveys portal, and collaborate on measuring the acoustic signatures of marine sound sources.
Department of Commerce: National Oceanic and Atmospheric Administration (NOAA), including National Weather Service (NWS)	**Estuaries and wetlands:** Collaborate on assessments of restoration through dam removal and estuarine research. **Open coasts:** Use NOAA's mooring data to supplement the CMHRP's data to better constrain the CMHRP's numerical models. Collaborate with NOAA's NWS to provide real-time predictions of coastal erosion. Provide basic and applied research on the geologic, oceanographic, geochemical, and ecologic processes that affect the health and sustainability of coral reefs that NOAA, in turn, uses to explain trends in their monitoring data. **Continental shelf:** Merge NOAA bathymetric data and extract backscatter to produce new regional-scale information. **Continental slope and deep sea:** Provide geologic data to inform NOAA's tsunami models; partner on the U.S. Extended Continental Shelf Project and Ocean Exploration projects.
Department of State	**Continental shelf, continental slope, and deep sea**: Collaborate on the U.S. Extended Continental Shelf Project and on assessing the distribution and value of sea-floor minerals.
Department of Defense (DoD): U.S. Army Corps of Engineers (USACE), Department of Defense Environmental Research Program, Office of Naval Research (ONR), U.S. Naval Research Laboratory (NRL)	**Estuaries and wetlands:** Collaborate on shoreline change studies. **Open coasts:** Provide basic and applied research to better manage dredge disposal operations and forecast wave-driven flooding of DoD coastal facilities. Collaborate with USACE on evaluating the evolution and benefit of coastal restoration projects. Provide applied research for DoD to reduce the impact of their engineering efforts on coral reef ecosystems. **Continental shelf**: Provide ONR and NRL information on the geologic framework of the shelf in support of acoustic experiments.
Department of Homeland Security: U.S. Coast Guard	**Open coasts:** Interact on deployment and protection of oceanographic/atmospheric observational equipment. **Continental shelf, continental slope, and deep sea**: Use Coast Guard-operated icebreaker for the U.S. Extended Continental Shelf and Gas Hydrates Projects in the Arctic.
Department of Energy	**Continental shelf, continental slope, and deep sea**: Collaborate on identifying and implementing national priorities through USGS gas hydrates research in the CMHRP and in the Geology, Energy, and Minerals Mission Area (formerly the Energy and Minerals Mission Area).
National Science Foundation (NSF)	**All environments:** Collaborate with academics funded through NSF and use research vessels owned by NSF. Partner in the NSF-sponsored U.S. Ocean Bottom Instrument Center (https://obsic.whoi.edu/).
National Aeronautics and Space Administration (NASA)	**Coral reefs:** Collaborate on joint field studies to validate NASA airborne imagery of coral reefs.

Table 2. Examples of non-Federal partnerships with the Coastal and Marine Hazards and Resources Program.

Partner	Examples of interactions
Public	**Community outreach:** Educate the public on Coastal and Marine Hazards and Resources Program activities and provide opportunities for public feedback and input at events such as the St. Petersburg Science Festival, the Woods Hole Science Stroll, and National Marine Sanctuary Day at the Monterey Bay National Marine Sanctuary.
	Schools: Give "Women in STEM" presentations to local schools to promote careers in science, technology, engineering, and mathematics fields. Volunteer in schools to present hands-on displays and give presentations on coastal and marine topics—for example, at multiple sites for the Great American Teach-In.
	Citizen science: Engage the public to learn and contribute to scientific research through, for example, the iCOAST website (https://www.usgs.gov/tools/icoast), which enables citizens to identify coastal change in aerial photographs.
Local governments	**Hallandale Beach, Florida:** Provide guidance on U.S. Geological Survey resources available for city planning through the Resilience Dialogues (https://thrivingearthexchange.org/project/resilience-dialogues/).
	West Maui, Hawaii: Provide scientific guidance for the design of a State-managed marine protected area.
State governments	**Alabama:** Monitor, model, and conduct data analysis in support of the development of a comprehensive barrier island management plan.
	California: Develop comprehensive maps of offshore bathymetry and habitats.
	Hawaii: Monitor conditions and conduct analyses to support watershed restoration to support coral reef health. Collaborate on tsunami risk assessment and mitigation.
	Massachusetts: Map and model to support marine habitat characterization; monitor and analyze sewage outfall site in Massachusetts Bay; assess statewide coastal erosion.
	Mississippi: Provide technical guidance and collect data for the Mississippi Coastal Improvements Program.
Tribal governments	**Lower Elwha Klallam Tribe:** Provide scientific guidance on the effects of the largest dam removal in U.S. history on Tribal resources through collaborative monitoring and assessments.
Nongovernmental organizations	**The Nature Conservancy:** Provide scientific guidance for marsh and coral reef restoration for coastal hazard risk reduction.
Academic community	**University of Florida:** Research the dynamics of inlets, coral reefs, and other coastal systems, including student support through cooperative agreements.
	University of California: Research the dynamics of rocky coasts, coral reefs, and other coastal systems, including student support through cooperative agreements.
International community	**Australia:** Provide scientific guidance on sediment impacts to coral reefs due to dredging.
	Republic of the Marshall Islands: Provide forecasts of island sustainability under various sea level rise scenarios.

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