International Science in the National Interest at the U.S. Geological Survey

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Committee on Opportunities and Challenges for
International Science at the U.S. Geological Survey

Board on Earth Sciences and Resources

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Cover: The cover shows several examples of global scientific research conducted by the USGS and a complementary domestic science issue that the global research helps to inform. Design by Anne Rogers.

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Preface

The U.S. Geological Survey (USGS) was established in 1879 to provide geological, topographic, and hydrological information that would allow for appropriate management of natural resources to benefit the public. Originally much of the Survey's work consisted of mapping and data collection relating to water, energy, and mineral resources, with a focus on the national domain. However, early in its history, the USGS was also involved in international activities. For instance, in the 1890s, the USGS was involved in the planning and design of the Panama Canal.

More recently, the USGS has focused its activities on applications in seven national mission areas, all of which rely on expertise and information in the Earth sciences, including geology, geography, geophysics, geochemistry, hydrology, environmental science, climate science, soil science, and a variety of other fields. All seven mission areas are in fact interrelated, which emphasizes the fundamental importance of viewing the Earth as a system. In the 21st century we are seeing great changes in this system due to environmental impacts of political and economic globalization. Because international and U.S. interests are linked, the Survey's role in global Earth science is likely not only to continue but also to increase. Importantly, USGS international science activities directly benefit the Survey's domestic mission, and are increasingly relevant to U.S. national interests.

At a time of profound global change and following its recent reorganization, the USGS requested that the National Research Council (NRC) establish a committee on "Opportunities and Challenges for International Science at the U.S. Geological Survey." The eight-person committee assembled by the NRC consisted of a diverse group that was united by their common ties to the Earth sciences, and by their understanding of the essential role that the USGS plays as a key science organization within the federal government. As part of fulfilling the NRC statement of task, our committee placed special emphasis on identifying ways to improve the effectiveness of USGS international activities and in providing insights for strategically guiding such activities during the next 5 to 10 years.

Our committee convened two public information-gathering sessions at the National Academies Keck Center in Washington, D.C., and held a closed meeting at the Academies' Arnold and Mabel Beckman Center in Irvine, California. We also participated in multiple conference phone calls. The two public meetings allowed the committee to gain perspectives and information from two groups critical to the study: the USGS scientists and managers responsible for developing and executing domestic and international science projects for the Survey; and the Survey's most consistent external partners who request the Survey's expertise and provide support for it to conduct international projects.

The current desire for fiscal restraint in the federal government makes this a critical period for all federal agencies, including the USGS, with regard to the value of their activities for the nation. This report showcases the demonstrated and future benefits of USGS international activities to the USGS domestic mission and the U.S. national interest. The report also underscores the value of fresh approaches to complex issues in Earth science—especially highlighting the advantages of viewing Earth science problems in the context of Earth systems, appropriate for interdisciplinary examination.

The committee is deeply indebted to many USGS personnel who have gone out of their way to provide us with detailed responses to a diverse range of questions and issues. We also gratefully acknowledge various presentations made to the committee by personnel from the USGS, Department of State, U.S. Agency for International Development, the Department of Defense, and the World Bank. Immense credit also goes to the NRC staff who assisted us in preparing the report. These include Elizabeth Eide, Jason Ortego, Chanda Ijames, and Peggy Tsai. We particularly thank Elizabeth Eide, the designated study director for our committee, for her insights, professionalism, and attention to detail and for ensuring that the committee stayed "on task."

Finally, I would like to thank all of the members of the committee. It has been a privilege and an honor to interact with such a diverse group of multitalented individuals. I have learned a lot.

Ian L. Pepper
Chair

Acknowledgments

In addition to its own expertise, the committee relied on input from numerous external professionals and members of the public with extensive experience in various aspects of Earth science research and specifically international research conducted by the U.S. Geological Survey (USGS). These contributors provided presentations, data, references, figures, images, and perspectives which assisted the committee in understanding the scope of the issue and the impact of international science research on the nation's domestic and international missions. This information was very important for the committee to be able to develop this report.

We gratefully acknowledge these individuals, who include USGS staff and interested parties external to the USGS, and note their thorough and helpful responses to our inquiries throughout the study's course and their interest in enhancing the capacity of the USGS to conduct international work. In particular, the committee would like to thank the following people: David Applegate, Michael Blanpied, Sally Brady, Patricia Bright, Herb Buxton, Richard Calnan, George Coakley, Ivan DeLoatch, Jim Devine, Jeff Doebrich, John Eichelberger, Jody Eimers, Johnny Fredericia, Bruce Jones, John Kelmelis, Pat Leahy, Bill Leith, John Pallister, Jean Parcher, Brenda Pierce, Andrew Reynolds, Verne Schneider, Emily Scott, Ione Taylor, June Thormodsgard, Ivette Torres, Ingrid Verstraeten, Gotthard Walser, Annica Wayman, Jean Weaver, and Greg Withee.

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's (NRC) Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative

process. We wish to thank the following individuals for their participation in the review of this report:

Eric Calais, Purdue University, West Lafayette, Indiana
James Franklin, Consulting geologist, Nepean, Ontario, Canada
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Timberley Roane, University of Colorado, Denver
Donald Siegel, Syracuse University, New York
Allison Steiner, University of Michigan, Ann Arbor

Although the reviewers listed above provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations nor did they see the final draft of the report before its release. The review of this report was overseen by Debra Knopman, RAND Corporation. Appointed by the NRC, she was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

Contents

SUMMARY 1

1 INTRODUCTION 13
Rationale for Current Study, 14
Structure of the USGS Office of International Programs, 19
Scope and Structure of the Report, 20
Concluding Remarks, 21
References, 22

2 HISTORY AND CONTEXT OF USGS INTERNATIONAL ACTIVITIES 23
Authorization and Mission of the USGS, 23
Past International Work, 26
Present International Activities, 27
Concluding Remarks, 35
References, 36

3 ONGOING INTERNATIONAL SCIENCE ACTIVITIES AT THE USGS 39
Climate and Land-Use Change, 40
Core Science Systems, 46
Ecosystems, 48
Energy and Minerals, 55
Environmental Health, 60
Natural Hazards, 65
Water, 75
Successful Integration of Expertise from Multiple USGS Mission Areas:
The Afghanistan Project, 78

Concluding Remarks, 81
References, 81

4 STRATEGIC INTERNATIONAL SCIENCE OPPORTUNITIES FOR THE USGS 85
Toward an Overarching Approach in International Science, 86
International Science Opportunities, 87
Concluding Remarks, 105
References, 106

5 IMPEDIMENTS TO MORE EFFECTIVE USGS PARTICIPATION IN INTERNATIONAL SCIENCE ACTIVITIES 107
Factors Hindering Progress, 107
Concluding Remarks, 112
References, 112

6 FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS 113
Reference, 117

APPENDIXES

A USGS and DOI Mission and Authorization Language 121
B Committee and Staff Biographical Sketches 123
C USGS Historical International Engagement: Background Paper 129
D Meeting Agendas, Presentations, and Other Information Provided to the Committee 153
E Bibliography of Selected Peer-Reviewed Publications from USGS International Work 157

Summary

The geological, geophysical, environmental, climatic, and hydrological components of Earth science research are fundamentally global in their physical scope, impacts, and interactions. Because of the global reach of Earth science, the U.S. government frequently draws upon the scientific expertise of the U.S. Geological Survey (USGS), the principal science agency of the Department of the Interior (DOI), for data, information, advice, and technical assistance relating to Earth science—nationally and internationally—in support of U.S. interests. In addition, the emerging era of science diplomacy, which uses science and scientific cooperation to promote international understanding and prosperity, has also brought an increasing number of requests for USGS engagement on international Earth science issues.

In conjunction with the recent reorganization of the USGS, and motivated by the continuing demand for Survey expertise on a variety of urgent international Earth science problems, the USGS requested that the National Research Council (NRC) establish a study committee on Opportunities and Challenges for International Science at the USGS. The committee was tasked to examine the Survey's past and present international activities that support the USGS national mission, to identify international research areas for the coming 5 to 10 years that have high potential to benefit both USGS strategic science directions and national priorities for the U.S. government, and to identify impediments to more effective USGS participation in international science activities.

This report responds to that charge by describing the core activities of the Survey's seven science mission areas and the ways in which corresponding international activities benefit the USGS mission and U.S. national interests. The committee also identifies opportunities for new and continued international activities for the USGS to consider as part of its mission to serve the U.S. government and the nation. Based on the committee's findings and conclusions, the report's five recommendations outline a series of steps for the USGS to support and strengthen its international activities and to overcome impediments to more effective USGS participation in international science opportunities.

USGS INTERNATIONAL SCIENCE IN THE FABRIC OF THE U.S. GOVERNMENT

The DOI strategic plan for 2011-2016 indicates science as a key component of the DOI mission and identifies the USGS as the Department's primary science organization. The DOI strategic plan outlines the following goals for the USGS:

- ensure the quality and relevance of science products to partners and customers;
- provide science for sustainable resource use, protection, and adaptive management;
- provide scientific data to protect and inform communities; and
- develop a comprehensive science framework for understanding the Earth.

The mission of the USGS is to provide geological, topographic, biological, and hydrological information that contributes to the wise management of natural resources and that promotes public health, safety, and well being. In 2010-2011, the Survey restructured under the following seven mission areas: Climate and Land-Use Change; Core Science Systems; Ecosystems; Energy and Minerals; Environmental Health; Natural Hazards; and Water. These science mission areas align with the goals of the DOI strategic plan and the overall USGS mission. In the international arena, the USGS Office of International Programs (OIP) is responsible for representing all USGS mission areas and reports directly to the Director of the USGS. The authority of the Secretary of the Interior to have the USGS address international tasks, when in the national interest, was formalized in legislation in 1962.

The White House Office of Science and Technology Policy (OSTP), the White House National Science and Technology Council (NSTC), and the Department of State (DOS) have all cited specific international priorities for science that explicitly call upon USGS expertise and information (1) to address scientific and technological issues associated with a changing climate, constraints on energy resources, and environmental degradation; and (2) to establish national goals for U.S. science and technology investments that ensure economic prosperity, public health, environmental quality, and security. Similarly, the DOS/U.S. Agency for International Development (USAID) Strategic Plan lists the USGS as an essential partner in fulfilling U.S. foreign policy objectives in strategic priority areas such as energy security and the environment. USAID and organizations such as the World Bank have engaged USGS expertise in predictions of pending drought, assessments of water quality, and responses to natural disasters. The Department of Defense (DOD) has also called upon the USGS to help address U.S. government needs. In addition, the USGS works in partnership with other federal agencies such as the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), the Department of Energy (DOE), and the Centers for Disease Control and Prevention (CDC) on international activities of complementary interest. The USGS

also works with international governments and organizations: at the time of writing this report, the Survey is currently entered into 256 international agreements with 75 countries and 12 international organizations.

USGS international work is supported financially through two means: (1) federal appropriations that may be used for international Earth science projects, provided the projects support U.S. policy or benefit the Survey's domestic mission and the American public; and (2) reimbursable funds from other U.S. agency partners, international organizations, and foreign governments.

CURRENT INTERNATIONAL SCIENCE AT THE USGS

The Survey's primary international activities, as they relate to its domestic mission and broader national interests, are summarized below with reference to each of the seven mission areas. All of these international activities help to support U.S. diplomacy and capacity building, as well as other federal agencies in their missions and responsibilities.

Climate and Land-Use Change

The DOI Strategic Plan recognizes the need to engage internationally in climate and other mission areas as a core mission responsibility, and identifies key activities and strategies related to sustainable resource management. The USGS priorities for climate and land-use change include improving the understanding of

- past global changes;
- the global carbon cycle;
- land-use and land-cover change;
- droughts, floods, and water availability;
- coastal response to sea-level rise, climatic hazards, and human development; and
- biological responses to global change.

In addition to the Survey's international projects to support these six priorities, the USGS management of the Landsat system is an important asset that enables monitoring and data collection to support an enormous range of decisions about the environment, climate, natural resources, and natural hazards.

Core Science Systems

All Survey activities have a strong spatial component and require a comprehensive mapping capability and infrastructure, which fall under the USGS Core Science Systems

function. Maps are of fundamental value as the basis for theories, measurements, and analysis and are useful for assisting those who engage in land-use planning, natural hazard assessment, resource development, and environmental planning. This function is carried out through the Biological Informatics Program, National Geospatial Program, National Cooperative Geologic Mapping Program, National Geological and Geophysical Data Preservation Program, USGS Libraries, and Core Science Informatics.

Ecosystems

The Ecosystems mission activities include examining the state of the nation's terrestrial, freshwater, coastal, and marine ecosystems; studying the causes and impacts of ecological change; and the monitoring and development of methods for the protection and management of biological components and processes of ecosystems. International science activities in this mission area focus on wildlife disease research, invasive species studies and border monitoring, conservation programs, and research on river deltas and Arctic ecosystems.

Energy and Minerals

The objective of the Energy and Minerals mission area is to identify and understand the occurrence, size and extent, and genesis of energy and mineral resources. Data and information from this research are directed toward informing decisions about domestic land management and use, management of supplies of energy and mineral resources, international trade, national security, and economic development. Information about global and domestic resource distribution and overall availability also informs decisions about risks associated with import dependence on energy and mineral resources and about possible actions to mitigate supply risk. Among the mission area's ongoing international activities are the World Petroleum Assessment; gas hydrate research; geothermal energy; global mineral resource assessments; and global mineral commodity summaries and life-cycle analysis.

Environmental Health

Environmental Health research at the USGS encompasses the study of relationships among the quality of the physical environment, the health of the living environment and human health, and provides information on such issues as the effects of water, air, and soil contaminants on environmental health. This work directly supports monitoring of the spread of disease and invasive species and corresponding efforts to mitigate impacts on environmental health. International activities have included study of the transmission and prevention of a vector-borne pathogen commonly found in parts of Africa and the use of satellite telemetry to track waterfowl movement in support of avian influenza surveillance programs.

Natural Hazards

Activities in the Natural Hazards mission area involve the continuous collection of accurate and timely information from Earth observation networks, assessment of areas of risk from natural hazards, and research to improve hazard predictions. Related international activities, with global implications or scope fall under one of six programs:

- Earthquake Hazards
- Volcano Hazards
- Landslide Hazards
- Global Seismographic Network
- Geomagnetism
- Coastal and Marine Geology

In this mission area, international projects—including, among others, global hazard monitoring and notification (earthquakes, volcanoes, geomagnetic disturbances), rapid response to foreign hazard crises, and collaborative science—enable USGS scientists to stay at the forefront of the state of knowledge and best practices in monitoring, modeling, and mitigating natural hazards.

Water

The mission of this science area is to quantify, forecast, and secure freshwater for the nation. The USGS has a number of international research activities that contribute to understanding of large river systems, flooding, and groundwater availability and contamination, and to technology development and aquifer assessments. This work increases USGS capacity to fulfill its domestic responsibilities in determining freshwater availability, identifying water sources, and forecasting outcomes for water availability to inform land-use practices and decisions about the development of mineral and energy resources.

STRATEGIC INTERNATIONAL SCIENCE OPPORTUNITIES FOR THE USGS

A systems approach to scientific surveys of global Earth processes addresses a particular problem or issue as a part of a "system." This kind of approach is an effective way to examine the complex spectrum of interconnected, interdisciplinary challenges that affect the Earth, the environment, and the human population. The USGS is already promoting a systems approach in developing many of its science activities, enabling the Survey to exploit the breadth and depth of its existing expertise and capacities to monitor, analyze, and provide

a better understanding of a range of Earth processes. The USGS mission areas are cross-cutting, problem-based, and interdisciplinary and can effectively support a systems approach to the study of Earth science issues.

The committee has identified a series of international science opportunities for the USGS to consider pursuing, either on its own or in cooperation with U.S. agency partners and/or other domestic and foreign collaborators (Box S.1). These opportunities readily

BOX S.1
USGS Opportunities in International Science

Opportunities that Complement Existing International Science Activities

1. **Global natural hazards planning and response**. Strategic opportunities lie chiefly in increasing the level of USGS involvement in three areas:
   a. *The Global Earthquake Model (GEM) international partnership*
   b. *The Volcano Disaster Assistance Program (VDAP) in concert with other global volcano-hazard initiatives*
   c *Global earthquake monitoring and rapid notification activities*
2. **Energy and mineral resource assessments**. Six areas emerged as particularly compelling for the USGS to pursue, building upon the Survey's current, successful international activities through
   a. *Continuing to define and plan new oil and gas resource assessment projects in international onshore and offshore areas*
   b. *Continuing research in global gas hydrate occurrences*
   c. *Continuing research on location and development of global geothermal resources*
   d. *Quantifying the supply and demand for, and foreign dependence on, important minerals, with targeted application of mineral life-cycle analysis*
   e. Conducting *research on the global location, geological origins, age, size, production, and consumption of conflict minerals*
   f. *Capacity building: providing scientific assistance to nations to enable them to identify and develop mineral resources in ways that are sound for human and environmental health and economic development*
3. **Water sustainability research in desert regions and tropical areas.** Many areas of the world, including the United States, have regions where the hydrologic cycle operates at extremes, with either very low or very high precipitation. Continued research can aid in understanding the extent and effects of cyclic changes that have resulted from climate and land-use change and to determine how to manage water resources.

New Opportunities

1. **Use of climate and land-cover science for decisions on climate adaptation and natural resource management.** Adaptation to climate change and effective natural resource

lend themselves to a systems approach, engagement among multiple mission areas, and partnership with other federal agencies. Furthermore, the opportunities meet the following criteria: (1) they demonstrate clear means both to leverage and benefit the scientific strengths and directions of the USGS and to complement ongoing, domestic activities; and (2) they indicate strong potential for project results to increase the Survey's ability to meet needs of the U.S. government and the American public.

management are thoroughly intertwined. Climate and land-use change research contribute to informed decisions in both realms, particularly when viewing landscapes as systems.

2. **Understanding the influence of climate change on ecosystems, populations, and disease emergence.** As climate changes, the distribution and abundance of plants, animals, and insects will shift in response. Such changes could directly impact biological resources in the United States and play a role in disease ecology and emergence.
3. **Clarification and development of invasive species work using trade patterns, refugee situations, and changing climate and environment**. As global trade and travel continue to increase, research on the influx of invasive species can inform decisions about mitigating the impacts of such species on the United States.
4. **Quantitative health-based risk assessment using hazard identification, exposure assessment, dose-response assessment, and risk characterization**. When focused on a particular ecosystem, ecological risk assessment can help identify vulnerable resources and the adverse effects of human activities and pollutants on the ecosystem.
5. **Ecological and quantitative human health risk assessment analysis based on contaminant exposure levels**. Especially in regions from which food products are shipped to the United States, such assessments could support the evaluation of health risks to U.S. citizens and inform decisions about regulations.
6. **Research in water contamination and supply**. Strategic opportunities include new levels of USGS involvement in three areas:
   a. *Reduction of water contamination risk from natural and anthropogenic causes*
   b. *Water supply management*
   c. *Modeling and management of fossil aquifers in vulnerable environment*
7. **Water and ecological science in cold regions sensitive to climate change**. Warming in areas of permafrost may have impacts on the climate. Mitigating these impacts requires research on the interactions and feedbacks of water, ecosystems, and climate.
8. **Comprehensive enhancement of, and accessibility to, essential topographic and geologic map information**. **Two specific endeavors would support achievement of these aims:**
   a. *Improved and accelerated global coordination and enhancement of topographic mapping*
   b. *Rapid acceleration of the reconciliation and accessibility of geologic mapping*

IMPEDIMENTS TO INTERNATIONAL RESEARCH AT THE USGS

The committee identified the following obstacles to more effective Survey participation in international science activities: (1) lack of an overall plan for USGS international science, exemplified in various ways including fragmentary documentation on the USGS website of its international activities; (2) domestic mission pressures in the DOI and the USGS; (3) uneven disposition among the Survey's mission areas to undertake international work; (4) an institutional culture not yet predisposed to implement international and cross-disciplinary activities across the entire Survey and a suitable reward system for participating in such activities; (5) a need for greater Survey coordination with international partners; and (6) availability of resources.

FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

The USGS plays an essential role in the systematic mapping, monitoring, and study of the Earth to fulfill national needs for information on diverse Earth systems. Although the committee noted caution on the part of the USGS in fully promoting its numerous and broad-ranging accomplishments in the international arena, the USGS can be justifiably proud of its widely recognized and successful international activities in global Earth science. The committee sees compelling arguments for the USGS to play a dynamic role in international science.

The committee's first recommendation, directed to the USGS leadership and with the clear acknowledgment and support of international work already under way, concerns the benefits of a more proactive approach to international science. The development of a strategic implementation plan for international science at the USGS is also fundamentally important, and the committee outlines some basic elements that could be part of such a plan.

RECOMMENDATION: As a necessary first step to strengthen and enhance USGS international science activities, USGS leadership, in collaboration with the Secretary of the Interior, should fully embrace and unequivocally commit to international science as a fundamental part of the USGS aim "to help our Nation and the world" (Gundersen et al., 2011, p. 3) and should be open and clear about this work—internally and externally.

The committee found that USGS scientists are conducting excellent work in international science. Current activities include the mitigation of humanitarian crises through technical assistance in natural disaster response and in local capacity building, the advancement of science through interdisciplinary and international collaborations, natural resource assessments, and the promotion of national interests through science diplomacy and techni-

cal aid. The continuum of global problems and issues requiring urgent attention makes this a critical time for greater USGS involvement in international science.

RECOMMENDATION: The USGS should play an expanded, proactive role in international Earth science, consistent with, and building upon, its current strengths and science directions. In developing this expanded role, the USGS should assess how it can serve as a collaborative international leader in strategically addressing a range of urgent worldwide problems that affect U.S. interests. These include, but are not limited to natural-resource shortfalls, escalating human and economic losses from natural disasters, a degraded biosphere, biodiversity loss, the increasing threat of pandemics, and accelerating global environmental change.

As part of this broader international role, and recognizing that these endeavors maximize the effective use of government resources, the USGS can consider forging stronger links with a variety of international and domestic partners. Other nations' geological surveys and international organizations (e.g., OneGeology) are potential partners. Domestically, in addition to collaborations within the Department of the Interior, the USGS already has strong relationships on international projects with DOS, USAID, DOD, and the World Bank as well as with other federal agencies such as NASA, NOAA, and the CDC. These reliable partnerships could be further strengthened and serve as a springboard for broader scientific engagement in all of the Survey's mission areas.

New international science opportunities can support the USGS national mission. Most of these opportunities require examining Earth processes as an interconnected system, thus requiring a systems approach. Integrated efforts across USGS mission areas in international science can strengthen the Survey's scientific capabilities, increase knowledge and understanding of Earth processes, and support informed and effective decision making.

RECOMMENDATION: The Survey leadership should continue advancing the integration and coordination of activities across the seven USGS mission areas, and consider pursuit of and engagement in international science opportunities such as those outlined in this report to motivate further scientific integration within the USGS.

The committee noted that international work seems to be managed very differently in different mission areas and identified marked contrasts in the support, reward structures, and planning for such efforts. Although some differences among mission areas are to be expected, identification of current best practices for successful development and execution of global scientific projects is warranted. Encouraging collaboration among the mission areas

in developing international scientific opportunities could also enable the Survey to better prepare for official project requests from external partners and could enhance readiness to explore new international scientific opportunities. The absence of a more proactive approach to international science activities at the USGS probably weakens the overall success of the Survey in conducting such efforts.

RECOMMENDATION: A Survey-wide plan for international work should be developed to enable the USGS to fully embrace international activities. Such a strategy could be developed through the integrated efforts of the Director of the USGS, the leaders of the seven mission areas, and the Office of International Programs. The overall goal of the plan should allow the USGS to provide a dynamic, proactive response to the challenges of global geoscience problems. The plan could include guidelines or mechanisms to

- **foster activities and collaborations that anticipate and address impending global crises;**
- **identify and prioritize key international opportunities that support domestic and global science goals and address U.S. government priorities, including opportunities for international collaboration with other federal science agencies;**
- **formulate a consistent approach to international activities across all USGS science areas, with internal and extramural mechanisms to provide feedback on and evaluate the success of international projects;**
- **enhance coordination between USGS and other foreign Earth-science agencies;**
- **explore opportunities to collaborate internationally with academic institutions based in the United States and overseas;**
- **promote the development of a new organizational culture that encourages and rewards international research activities and publication of research in peer-reviewed journals; and**
- **fast-track the execution of international agreements.**

The reciprocal benefits to the nation of USGS global activities are not fully appreciated and do not generally make their way into public perception. From the committee's experience, information about USGS international activities is not readily available to the public in a conveniently organized, useful, and informative way. Although the committee became well informed about the Survey's many successful international science activities from a variety of extramural and Survey sources, the value of these activities would not be evident to the general public.

RECOMMENDATION: To increase public awareness of the value to the nation of USGS international scientific activities, the USGS should promote more effective communication and outreach about nonsensitive international work. Such communication can convey the importance, benefits, and rationale of the Survey's international science activities to the public, other stakeholders, and potential international and domestic partners. An interesting, user-friendly website focusing on global Earth science and featuring brief descriptions of the Survey's current and recent international activities and collaborations, with reference to more detailed information elsewhere on the USGS website, would help promote greater public appreciation and understanding of these activities.

REFERENCE

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CHAPTER ONE

Introduction

The U.S. Geological Survey (USGS) was established in 1879 with national responsibilities in the areas of land classification, geology, and mineral resources. Since its inception, the USGS has responded to national needs in these and other areas that span the Earth sciences, including hydrology, geophysics, geochemistry, biology, climate, and environmental health.[1] Information acquired from Earth science research, mapping, and monitoring plays an essential role in issues of public importance, such as water quality and public health, the provision of energy, mineral, and water resources, risk reduction from natural hazards, and conservation of natural habitats.

Though grounded in its domestic mission as part of the Department of the Interior (DOI) (see Chapter 2 and Appendix A), the USGS has throughout its 133-year history received a range of requests from Congress and federal agencies as well as state, local, and tribal governments, other federal agencies, the academic community, nongovernmental organizations, and the private sector (Devine, 2011). Many federal requests have been directives to respond to government priorities in Earth science–related projects internationally (NRC, 2001). The role of the Secretary of the Interior to have the USGS address these international tasks, when in the national interest, was formalized in legislation in 1962 (Chapter 2; Appendix A). In addition to supporting the work of the partnering organizations, results from these international activities have supported activities within USGS domestic areas of responsibility.

Today, USGS employees are engaged in over a thousand international trips per year to conduct work according to the requirements of 256 international agreements[2] entered into by the USGS in accordance with Department of State (DOS) guidelines (Withee, 2011). In

[1]According to USGS, "environmental health" refers to the relationships among the quality of the physical environment, the health of the living environment, and human health. See health.usgs.gov/.

[2]Number of agreements as of June 14, 2011; information provided by Jody L. Eimers, USGS, personal communication.

BOX 1.1
Statement of Task of the NRC Committee on Opportunities and Challenges for International Science at the U.S. Geological Survey

This study will describe how international collaborations and interactions support and enhance USGS strategic science directions and/or U.S. government national and international objectives. The study will also assess the benefits, opportunities, and obligations associated with USGS involvement in international science. In particular, the committee will

- in collaboration with the USGS, provide a summary of past and present USGS international scientific interactions and collaborations. The committee will identify where these activities are most effective in supporting the USGS mission or U.S. government needs.
- identify areas where USGS involvement in international activities would, over the next 5-10 years, have high potential to benefit USGS strategic science directions or U.S. government international priorities.
- identify impediments to more effective USGS participation in international science activities.

The committee will not make any recommendations related to government organization, legal authorities, funding, or other policy choices to address such impediments.

conjunction with the recent reorganization of the USGS,[3] as well as the continuing demand for Survey expertise on a variety of urgent international earth science issues, the USGS requested that the National Research Council (NRC) establish a study committee (Appendix B) on Opportunities and Challenges for International Science at the U.S. Geological Survey (USGS) (see Box 1.1 for the committee's statement of task). The committee was tasked specifically to examine past and present international activities that support the USGS national mission, to identify priority international research areas for the coming 5 to 10 years, and to identify challenges to the USGS participation in international science activities. To address the study charge, the NRC assembled an eight-person committee with diverse backgrounds that allowed for a comprehensive examination of present and potential future USGS international activities (Appendix C). A more detailed description of the rationale for the current study follows.

RATIONALE FOR CURRENT STUDY

Scientific Issues as Global Issues

The geography of the United States and its territories covers a significant portion of the globe, and many of the issues that are critical to U.S. national interests are inextricably

[3]See www.usgs.gov/start_with_science/science_strategy.asp (accessed January 26, 2012).

linked to global issues. Geological, environmental, climatic, territorial, and socioeconomic challenges are not bounded by geopolitical boundaries, and the scientific questions in these areas are of both global and national concern. Consequently, the U.S. government frequently draws upon the scientific expertise of the USGS—and other federal science agencies such as the National Oceanic and Atmospheric Administration, the National Aeronautics and Space Administration, and the Foreign Agricultural Service—to address Earth science issues in other parts of the globe in support of U.S. national interests.

Global science concerns such as invasive species, earthquakes, volcanic eruptions, emerging diseases, ecosystem changes, threats to biodiversity, and management of natural resources are areas in which the USGS provides scientific expertise to assist and inform other branches of the government. In the emerging era of science diplomacy, which uses science and scientific cooperation to promote international understanding and prosperity, the Survey has made specific contributions through its international activities (see Box 1.2; NRC, 2001).

The White House Office of Science and Technology Policy (OSTP), the White House National Science and Technology Council (NSTC), and the DOS have cited specific international priorities for science that explicitly call for USGS expertise and information. OSTP indicates the importance of addressing the science and technology issues of a changing climate, constraints on energy resources, and environmental degradation from a global perspective.[4] OSTP also suggests that national economic and defense security are improved through the strength of the nation's research and adequate support for high-quality science, some of which can be realized by increasing research collaboration with other countries.[5] The NSTC's objectives include establishing national goals for U.S. science and technology investments and ensuring that these investments contribute to economic prosperity, public health, environmental quality, and national security.[6] Several NSTC reports and documents (e.g., NSTC, 2010; 2008; 2007) have significant international components relating to these national goals, with crucial roles for USGS expertise.

The DOS, in its congressional budget request for FY 2012, includes $1.59 billion for 43 international organizations of which the United States is currently a member (DOS, 2011). The funds will enable the DOS and other federal agencies to "send delegations to represent the U.S. in governing bodies and otherwise take advantage of opportunities to promote U.S. goals and objectives at these organizations" (DOS, 2011: 543). The USGS is listed as a partner agency and provider of scientific expertise for 10 of those international organizations. In addition, the USGS is an important partner in the International Joint Commission, which was established by the Boundary Waters Treaty of 1909 to provide advice and conduct studies of transboundary river systems (DOS, 2011).

[4]See www.whitehouse.gov/administration/eop/ostp/divisions/energyenvironment.
[5]See www.whitehouse.gov/administration/eop/ostp/sciencediplomacy.
[6]See www.whitehouse.gov/administration/eop/ostp/about.

BOX 1.2
Example of International Activity Supported by USGS

In 1991, scientists from the USGS and the Philippine Institute of Volcanology and Seismology (PHIVOLCS) were able to forecast the climactic eruption of Mount Pinatubo, Philippines, which became the largest volcanic eruption in the 20th century to affect a heavily populated area. The most powerful phase of this eruption occurred on the morning of June 15 and lasted more than 10 hours, creating a gigantic cloud of volcanic ash that rose as high as 22 miles, extended more than 300 miles, and filled surrounding valleys with deposits of ash as much as 600 feet thick.

A series of small steam-blast explosions in early April 1991 was the first indication that Mt. Pinatubo was becoming a threat. Scientists from PHIVOLCS began onsite monitoring and declared a 6-mile-radius danger zone around the volcano. They were soon joined by USGS scientists from the Volcano Disaster Assistance Program, a collaborative effort with the Office of Foreign Disaster Assistance of the U.S. Agency for International Development (USAID). The USGS scientists brought specially designed, portable instruments, which the joint Philippine-American team used to detect earthquakes and swelling on the mountain. The team also mapped volcanic deposits in order to understand the volcano's eruptive history. When the data from these efforts indicated that a huge eruption of the volcano was imminent, the joint team issued urgent warnings and provided advice to the Philippine government and local U.S. military commanders. These timely forecasts enabled civil and military authorities to arrange the evacuation of people, aircraft, and other equipment to safe areas before Mt. Pinatubo exploded on June 15.

The benefits of USGS cooperation with PHIVOLCS to monitor Mt. Pinatubo were immense. Forecasts and evacuations saved an estimated 5,000 lives, and perhaps as many as 20,000. Evacuees included more than 15,000 American military personnel and their dependents stationed at the nearby Clark Air Base (see Figure). The property savings—estimated at more than $250 million—were many times the total costs of the forecasting and evacuations. In addition, the U.S. Volcano Hazards Program has been able to utilize the knowledge and experience gained by USGS scientists during the crisis to better protect people's lives and property around the globe from future volcanic eruptions.

Realignment of USGS Mission Areas

Pragmatic reasons for the current assessment of the scientific directions for future USGS international activities relate, in part, to major organizational changes at USGS, implemented in 2010-2011 and based upon the science strategy developed in 2007 (see Box 1.3). The reorganization resulted in a new strategy that moved the USGS from a discipline-focused agency to one focused on the application of integrated Earth science in support of critical mission areas.

An additional motivation for the current assessment is the DOI Strategic Plan for 2011–2016 (see Box 1.4), which cites science as a key component of the DOI mission and

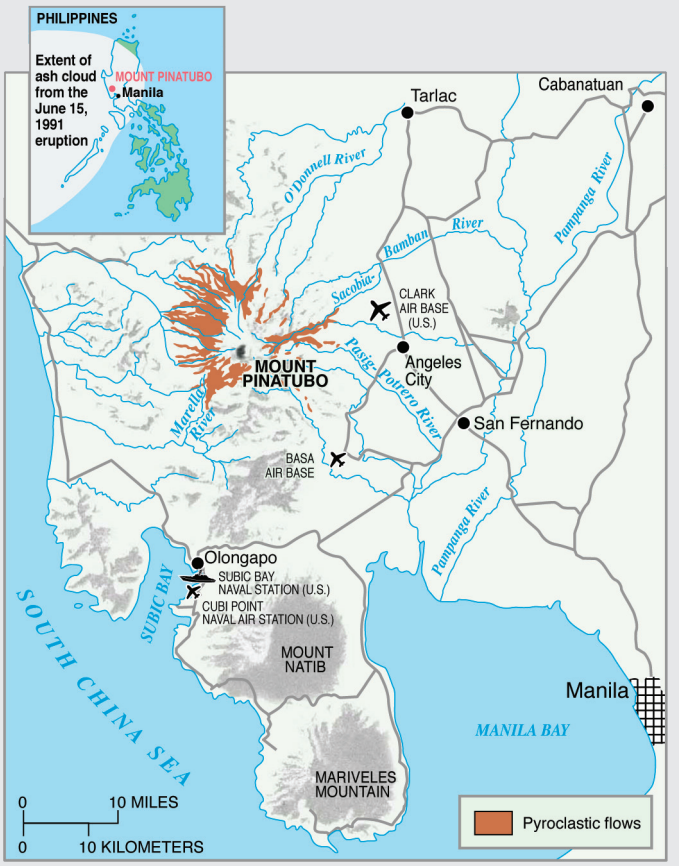


FIGURE Before the eruption more than 1 million people lived within 30 miles of the volcano, including more than 15,000 American military personnel and their dependents. SOURCE: Newhall et al. (1997).

an essential, cross-cutting element that assists bureaus in land and resource management and regulation. The Strategic Plan also identifies the USGS as DOI's primary science organization, with sister bureaus conducting mission-specific research to support their programs, and outlines the following goals for the USGS:

- ensure the quality and relevance of science products to partners and customers;
- provide science for sustainable resource use, protection, and adaptive management;
- provide scientific data to protect and inform communities; and
- develop a comprehensive science framework for understanding the Earth.

BOX 1.3
USGS Science Strategy 2007-2017

As part of an ongoing effort to respond to evolving national and global priorities, the USGS (2007) report—Facing Tomorrow's Challenges: U.S. Geological Survey Science in the Decade 2007-2017—examined the Survey's major science goals and proposed a new science strategy with six science directions:

- Understanding Ecosystems and Predicting Ecosystem Change: Ensuring the nation's Economic and Environmental Future
- Climate Variability and Change: Clarifying the Record and Assessing Consequences
- Energy and Minerals for America's Future: Providing a Scientific Foundation for Resource Security, Environmental Health, Economic Vitality, and Land Management
- A National Hazards, Risk, and Resilience Assessment Program: Ensuring the Long-Term Health and Wealth of the Nation
- The Role of Environment and Wildlife in Human Health: A System that Identifies Environmental Risk to Public Health in America
- A Water Census of the United States: Quantifying, Forecasting, and Securing Freshwater for America's Future

In addition, the 2007-2017 Science Strategy recognized the essential role in all USGS science goals of expanded information technology and other crucial emerging technologies to allow for the seamless sharing of data and information—a field now known as core science systems.

SOURCE: USGS (2007)

To fulfill these goals, and in keeping with the science directions proposed in 2007 (see Box 1.3), the USGS during 2010 and 2011 has restructured its budgeting and reporting under seven mission areas (see Figure 1.1):

- Climate and Land-Use Change
- Core Science Systems
- Ecosystems
- Energy and Minerals
- Environmental Health
- Natural Hazards
- Water

The mission areas correspond to the science directions described in the 2007 document, with two exceptions: first, the mission area on Core Science Systems was not an original science direction but was elevated to a main science direction during the organizational

BOX 1.4
Department of the Interior Strategic Plan, 2011-2016

The U.S. Department of the Interior Strategic Plan for 2011–2016 provides a blueprint for guiding and prioritizing its investments and resource allocations. The strategic goals are categorized in five missions areas: (1) provide natural and cultural resource protection and experiences; (2) sustainably manage energy, water, and natural resources; (3) advance government-to-government relationships with Indian Nations and honor commitments to insular areas; (4) provide a scientific foundation for decision making; and (5) build a 21st century DOI. The role of the USGS corresponds to the fourth mission for carrying out the Department's strategic vision.

The Strategic Plan also indicates that "International Engagement and Leadership" is one of the DOI's key principles and tenets and states that the Department

> participates in the United States' efforts to address climate change; protect biodiversity; sustainably manage energy, water, and natural resources; empower indigenous communities; protect cultural heritage; and ensure sound science as the basis for decision making. The resources for which Interior is responsible cross jurisdictional boundaries and Interior is a key player in the international community confronting the exploitation of natural resources, trade in wildlife, spread of invasive species, and in a multiplicity of scientific issues. The Department is committed to maintaining its relevance and will engage in international efforts as a core mission responsibility, consistent with its unique expertise and mandate.

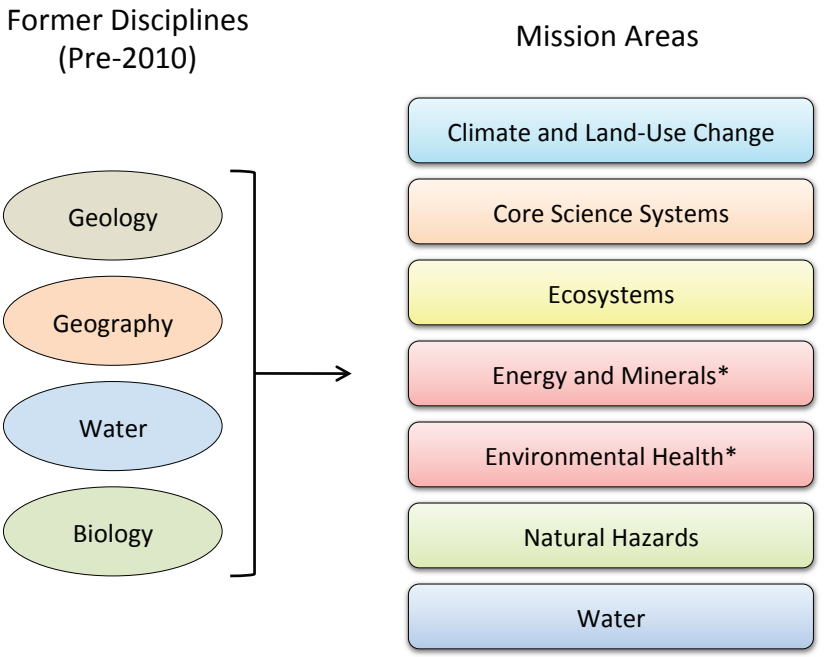
SOURCE: DOI (2011).

changes in 2010; second, the Role of Environment and Wildlife in Human Health scientific direction (see Box 1.3) is now simply called "Environmental Health." The strategic science directions remain the focal areas for the seven national mission areas, and the international activities that impact these missions are the subject of this study. Hereafter the committee uses the term "mission area" when referring to one or more of the Survey's seven areas of science priority.

STRUCTURE OF THE USGS OFFICE OF INTERNATIONAL PROGRAMS

The USGS Office of International Programs (OIP) is responsible for representing all USGS scientific disciplines in the international arena. Formerly the Office of International Geology, the OIP became a bureau-level office in 1995 under the Associate Director for Geology; with the implementation of the new USGS strategy in 2010, it was administratively placed under the Director of the USGS.

The Office has specialists who represent USGS interests and activities in five regions around the world: Europe and the former Soviet Union; Africa and the Middle East;



*The mission areas Environmental Health and Energy and Minerals are cross-serviced by (i.e., receive shared support from) the same USGS Leadership and Management Team, although they are distinct mission areas with their own science strategies.

FIGURE 1.1 Reorganization of USGS from a discipline-focused agency to one involved in the application of integrated science in support of critical mission areas. SOURCE: USGS; see also www.usgs.gov/start_with_science/.

Asia and the Pacific; Latin America and the Caribbean; and Canada, the Arctic, and the Antarctic. These five specialists represent the USGS in discussions about potential international projects with organizations such as USAID, DOS, Department of Defense, and the World Bank.

In addition to the OIP, the Survey's Bureau Support Unit provides logistical support for USGS international travelers (e.g., by obtaining passports and visas). Detailed information about the functions of the OIP and the development of international projects is provided in Chapter 2.

SCOPE AND STRUCTURE OF THE REPORT

To address the three specific points identified in the committee's statement of task as well as the more general points related to international collaborations and interactions that support and enhance USGS strategic science directions and U.S. government national and

international objectives (Box 1.1), the remainder of this report is organized into five chapters. Chapter 2 provides an overview of the context and history of the USGS as a basis for understanding past and present drivers, priorities, and arrangements for its international activities. Chapter 3 addresses a key component of the committee's statement of task, which states that the study will—in collaboration with the USGS—provide a summary of past and present USGS international scientific interactions and collaborations. The chapter additionally identifies where these activities have supported the overall USGS mission and/or U.S. government needs.

Considerable input for Chapters 2 and 3 was derived from a document drafted by the USGS in response to a request from the committee to help inform this report (Appendix C). Although these two chapters present background and historical information without the views and analysis of the authoring committee, the committee recognizes the importance of evaluating which projects may return the greatest benefits to the Survey in the international arena. Indeed, the statement of task asked the committee to "identify where these activities are most effective in supporting the USGS mission or U.S. government needs." However, a complete listing of all international activities historically and currently undertaken by the Survey was not available to the committee. Nor were other international project data available that would have enabled the committee to examine study effectiveness in a systematic and objective manner. Thus, rather than providing a priority ranking of those international activities that are most effective in supporting the USGS mission or U.S. government needs, Chapter 3 presents selected examples of international activities that demonstrate the breadth and depth of the USGS international engagement.[7]

Chapter 4, "Strategic International Science Opportunities for the USGS," describes potential new international endeavors that the committee deems particularly compelling for the USGS to consider undertaking. This chapter addresses another component of the statement of task, which is to identify areas in which USGS involvement in international activities would, over the next 5 to 10 years, have high potential to benefit USGS strategic science directions or U.S. government international priorities. Chapter 5 addresses the final component of the statement of task: to identify impediments to more effective USGS participation in international science activities. Chapter 6 summarizes the committee's major findings and recommendations.

CONCLUDING REMARKS

Early in the 21st century, we are seeing rapid and accelerating global changes in the environment that directly affect humans. As populations increase globally and worldwide

[7]Note that the committee interpreted "international" activities to include those where participating USGS scientists may or may not conduct physical fieldwork in a foreign country; for example, the committee includes in its descriptions some projects that involve collection and analysis of remotely sensed data.

exchange of information becomes more instantaneous, U.S. political, economic, and environmental interests are increasingly linked with those of the rest of the world. Multiple approaches are required to solve scientific problems domestically and abroad, and the USGS is in a position to address pertinent government priorities by working in coordination with other federal agencies and organizations and by applying scientific expertise to address pressing issues with an international dimension. Examination of the compelling international scientific opportunities that the USGS might pursue in the Earth sciences is thus timely and appropriate.

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CHAPTER TWO

History and Context of USGS International Activities

AUTHORIZATION AND MISSION OF THE USGS

The Department of the Interior (DOI) is the nation's principal conservation agency, with a mission to protect U.S. natural resources, offer recreation opportunities, conduct scientific research, conserve and protect fish and wildlife, and honor the nation's trust responsibilities to American Indians, Alaskan natives, and island communities. The DOI manages about one-fifth of the land in the United States as well as hundreds of dams and reservoirs.[1]

Issues relating to Earth and environmental science fall within the purview of a wide range of U.S. government agencies that address issues of land use and management, energy and mineral resources, environment and climate, and public health. Geological survey agencies at federal and state levels conduct mapping, monitoring, and research in Earth and environmental science to inform near- and long-term decision-making and government policies. The U.S. Geological Survey (USGS) resides in the DOI and is "the nation's largest water, earth, and biological science and civilian mapping agency [that] collects, monitors, analyzes, and provides scientific understanding about natural resource conditions, issues, and problems" (USGS, 2011a). Other federal government agencies with mandates to conduct scientific research on issues relating to Earth and environmental science are the National Aeronautics and Space Administration (NASA; an independent agency), the National Oceanic and Atmospheric Administration (NOAA) in the Department of Commerce, the Agricultural Research Service (ARS) and Foreign Agricultural Service (FAS) in the Department of Agriculture, the Department of Energy (DOE), and the National Science Foundation (NSF), among others.

[1] See www.doi.gov/facts.html (accessed January 26, 2012).

Legislative Authorization of the USGS

The USGS has a long history of providing the DOI and the nation with a scientific foundation for decision making—it has been involved in land surveys and federal exploration expeditions since it was formally established in 1879 (Rabbitt, 1989). The USGS Organic Act of March 3, 1879 (20 Stat. 394; 43 U.S.C. 31) formally charged the USGS with responsibility for "the classification of the public lands and examination of the geological structure, mineral resources, and products of the national domain." The Act of September 5, 1962 (76 Stat. 427; 43 U.S.C. 31 (b)) authorized the Secretary of the Interior to formally carry out international activities (see Box 2.1). USGS activities have since been expanded by Congress to include mapping, strategic mineral assessments, and marine surveys. In 1996, Congress transferred to the USGS the biological research functions of the former

BOX 2.1
Authorizing Language for USGS International Activity

The U.S. Geological Survey was established by the Organic Act of March 3, 1879 (20 Stat. 394; 43 U.S.C. 31), which provided for

> establishment of office; appointment and duties; examination of geological structure, mineral resources, and products of national domain; prohibitions in respect to lands and surveys. The Director of the United States Geological Survey, which office is established, under the Interior Department, shall be appointed by the President by and with the advice and consent of the Senate. This officer shall have the direction of the United States Geological Survey, and the classification of the public lands and examination of the geological structure, mineral resources, and products of the national domain.

The Act of September 5, 1962 (76 Stat. 427; 43 U.S.C. 31(b)), expanded this authorization to include

> examination of geological structure, mineral resources, and products outside national domain. The authority of the Secretary of the Interior, exercised through the United States Geological Survey of the Department of the Interior, to examine the geological structure, mineral resources, and products of the national domain, is expanded to authorize such examinations outside the national domain where determined by the Secretary to be in the national interest.

On October 1, 1990, 43 U.S.C. 51 stipulated that funds received from any state, territory, country, international organization, or political subdivision thereof, for topographic, geologic, or water resources mapping or investigations involving cooperation with such an entity shall be considered as intragovernmental funds.

SOURCE: uscode.house.gov (accessed January 26, 2012).

National Biological Service and the minerals information activities formerly conducted by the Bureau of Mines.

Federal Partnerships in International Earth Science

The mission of the USGS is to provide geological, topographic, biological, and hydrological information that contributes to the wise management of natural resources and that promotes public health, safety, and well being.[2] This information consists of maps, databases, descriptions, and analyses of water, energy, and mineral resources, land surface, underlying geologic structure, and dynamic processes of the Earth. The USGS mission is broad and thus requires expertise in multiple areas to assess climate and land-use change, manage ecosystems, assess energy and mineral resources, monitor and mitigate natural hazards, monitor and manage water resources, and provide topographic, geological, geochemical, and geophysical maps. In addition to the other DOI bureaus with which the USGS collaborates, other federal science agencies with Earth science-oriented missions and expertise (e.g., NASA, NOAA, ARS) work with the USGS in areas such as climate change, soil mapping, invasive species, natural hazards, ecological forecasting, public health, energy, and water management (see e.g., NRC, 2007). The USGS collaborates with these agencies on a variety of projects, both domestically and internationally (some of these collaborations are presented in Chapter 3).

International work conducted by NASA, NOAA, and ARS, similar to that of the USGS, may be performed at the request of outside agencies and international bodies. However, these agencies also have explicit mission statements or authorizing language to conduct international research.[3] NSF, as another example, provides direct support to the scientific community for international scientific research; USGS scientists may apply to NSF for support of the direct costs of a research project, but the Survey has to provide the salary support for its own scientists in a project.[4] The DOE participates in international science endeavors as well, and may ally with other federal science agencies such as the USGS for support on international components of its domestically based projects (e.g., NRC, 2010). The committee did not examine all of the potential federal partnerships for international work in which the USGS could ally itself; further detail regarding the mechanics of these kinds of interagency partnerships for international work is outside the scope of this report. Nonetheless, the committee considers well-organized partnerships among federal agencies

[2]Figure 1.1 in Chapter 1 shows the science areas under which such information is categorized. Also see www.usgs.gov/usgs-manual/120/120-1.html.

[3]See, for example, www.whitehouse.gov/sites/default/files/national_space_policy_6-28-10.pdf for NASA; www.ppi.noaa.gov/wp-content/uploads/NOAA_NGSP.pdf for NOAA; U.S. Code Title 7, Chapter 64, §3291 and www.ars.usda.gov/research/docs.htm?docid=1428 for ARS.

[4]NSF and USGS signed a memorandum of understanding in 2007 to facilitate development of research activities between the two organizations. See www.usgs.gov/mou/nsf_mou.pdf (accessed January 26, 2012).

to be important and provides specific encouragement for exploring these opportunities later in the report.

PAST INTERNATIONAL WORK

Since the first years of its existence as a federal agency, the USGS has conducted international projects in various countries worldwide (see Appendix C). The prompts for international work performed by the USGS over the years have been varied and include the need for information related to specific disasters; technological developments that have allowed the Survey to monitor natural hazards before they develop into disasters; geopolitical or military interests of the U.S. government during and outside active engagement in foreign wars; and trade, economic, health, and/or environmental issues. Projects in the earliest decades typically included geological and hydrogeological studies. Historically the USGS has also been a primary, independent provider of global petroleum and mineral resource assessments (see USGS, 2011b; Klett et al., 2007; and USGS, 2003a, 2003b, 2000).[5] Studies requested by organizations such as the U.S. Agency for International Development (USAID) and the World Bank have included prediction of impending drought situations, water quality assessments, and responses to natural disasters such as volcanic eruptions, earthquakes, and hurricanes (see Funk, 2009; Friedel et al., 2008; Crone, 2007; Bucknam et al., 2001; Newhall et al., 1997). New efforts to examine the influence of geological and biological factors within the Survey's mandate on environmental and human health have also been initiated. For example, in 2007 USGS mapped migration patterns and timing of vectors that transmitted avian influenza (USGS, 2007). In addition to these activities, the USGS has established several Centers of Excellence within the United States that have been asked to participate in various international projects in polar regions, wetlands areas, and seismically active zones worldwide (e.g., the Antarctic Resource Center,[6] the National Wetlands Research Center,[7] and the National Earthquake Information Center[8]). The Antarctic Resource Center has hosted international explorers and researchers for decades and has used materials from Antarctic Treaty nations to build a comprehensive collection of Antarctic aerial photography, maps, satellite imagery, and technical reports.

While carrying out its domestic mission, the USGS has also been called upon to further U.S. foreign policy through Department of State (DOS) and Department of Defense (DOD) funded projects. For example, USGS scientists served a role in the design of the

[5]"The USGS Mineral Commodity Summaries," published on an annual basis, is the earliest government publication to provide estimates covering nonfuel mineral industry data. Available at minerals.usgs.gov/minerals/pubs/mcs/ (accessed January 26, 2012).

[6]See usarc.usgs.gov/ (accessed January 26, 2012).

[7]See www.nwrc.usgs.gov/ (accessed January 26, 2012).

[8]See earthquake.usgs.gov/regional/neic/ (accessed January 26, 2012).

Panama Canal in the 1890s; supervised topographic and geological mapping in the West Indies in the 1920s and 1930s; and supported military operations through strategic mineral assessment, military topographic mapping, and provision of water resources during World War II (Rabbitt, 1989). During World War II, some international USGS projects were oriented toward national security issues, a trend that has continued to the present day with the Survey currently working in support of the DOD in Afghanistan and Iraq. The USGS has deployed staff to Afghanistan and Iraq to conduct studies on energy, mineral, and water resources, hazard assessments, and capacity building (see also Chapter 3). The Director of the DOD Task Force for Business and Stability Operations in Afghanistan, Paul Brinkley, noted the following:

> And as a part of that work, we began a partnership with the U.S. Geological Survey and, as a by-product of that partnership, became familiar with and then became actively involved with a(n) effort to understand the potential of the mineral wealth of Afghanistan and the challenges, which are many, to the Afghans in developing that resource in a socially and environmentally responsible way, but that would lead to economic sovereignty for the people of Afghanistan…[9]

Appendix C provides additional descriptions of USGS international activities from post-World War II through the mid-1990s, and Box 2.2 provides some examples of recent, major international efforts requiring USGS involvement.

In summary, past work by USGS on the international scene has been consistent with the role of a geological survey agency in maintaining systematic information needed for government to optimally function. Whereas domestic surveys tend to be broader and more long-term in perspective, international USGS activity has had a much greater tendency to be a quickly mobilized response to rapidly evolving and pressing government priorities, in which information was needed, or there was a need to assert a presence.

PRESENT INTERNATIONAL ACTIVITIES

Organizational Structure of the USGS for International Activities

At present, USGS activities are organized on both a topical and a regional basis. Seven mission areas are each administered by an associate director in (1) Climate and Land-Use Change, (2) Core Science Systems, (3) Ecosystems, (4) Energy and Minerals, (5) Environmental Health, (6) Natural Hazards, and (7) Water. Two additional associate directors are responsible for administration and enterprise information, as well as for human capital. Concurrently, activities are coordinated on a regional basis, with eight regional executives

[9]Transcript from the U.S. Department of Defense, available at www.defense.gov/transcripts/transcript.aspx?transcriptid=4643 (accessed October 28, 2011).

BOX 2.2
Examples of Major USGS International Programs: 1990-present

Delta Research and Global Observation Network: assesses the impact of climate change and human activities on the Mekong basin's ecology and food security. This is a part of the Lower Mekong Initiative conducted through the Department of State, for which USGS is a partner with relevant subject matter expertise.

Famine Early Warning Systems Network (FEWS NET): provides timely alerts on emerging food security issues (e.g., impending droughts and floods) in locations such as sub-Saharan Africa, Afghanistan, Central America, and Haiti. The USGS is a FEWS NET partner and provides geospatial data, satellite images, and technical support to aid FEWS NET's monitoring needs.

Global Mineral Resource Assessment Project: assesses global supply, demand, and availability of critical minerals. This assessment is being conducted in cooperation with other national and international geological and mineral resource institutions, with USGS serving to coordinate the global assessment.

National Earthquake Information Center: provides worldwide, near-uniform monitoring of significant earthquakes. The USGS is a partner and provides maintenance and operation, data collection, and quality control for two thirds of the U.S.-funded Global Seismograph Network.

Prompt Assessment of Global Earthquakes for Response (PAGER) system: provides rapid estimates of likely fatality and economic losses following significant earthquakes anywhere in the world. The USGS is the agency responsible for this system and for coordinating PAGER efforts with international and external collaborators.

World Petroleum Assessment: estimates total petroleum resources available worldwide and identifies new target areas for exploration. The USGS is the principal agency responsible for producing the report estimates, which have significant economic, security, and natural resource policy implications.

Wildlife Disease Information Node: provides rapid access to local and global information on wildlife disease outbreaks. The USGS aggregates information from authoritative media sources to produce an interactive Global Wildlife Disease News Map that is useful for understanding the spread of wildlife disease and its connection with human and animal health.

SOURCES: FEWS NET, 2011; NRC, 2006; USGS, 2003a,b; USGS, 2011b,c,d,e.

for the Northeast, Southeast, Midwest, South Central states, Rocky Mountains, Southwest, Northwest, and Alaska.

The Office of the Director is supported by, among others, a director for an office of science quality and integrity, a chief of an office of equal opportunity, and a senior advisor for science applications. The Director of the USGS Office of International Programs (OIP) coordinates the Survey's international activities and reports to the Survey's Senior Advisor for Science Applications (see also Chapter 1).

The OIP focuses on obtaining high-quality, timely, scientific data that are international

in scope and relevant to the USGS science strategy themes.[10] The OIP facilitates the international work of the USGS through support of activities that

- enable USGS scientists to contribute to efforts to address global scientific, natural resource, and environmental issues;
- improve the effectiveness of the United States to carry out its fundamental domestic missions;
- further U.S. foreign policy and national security interests; and
- promote the competitiveness of the U.S. private sector in the global economy.

Box 2.3 specifies OIP approaches to support these activities.

Funding and Development of USGS International Activities

USGS international work receives financial support through (1) federal appropriations that may be used for international Earth science projects, provided the projects support U.S. policy or have scientific analogues in the United States, thereby benefiting the American public; and (2) other U.S. agency partners, international organizations, and foreign governments using "reimbursable" funds.[11]

The OIP indicates that from 2006 to 2010, the USGS directed $15 million per year of federally appropriated funding toward international energy assessments, mineral assessments, and invasive species monitoring and research.[12] The USGS has also used federal appropriations to fund international activities related to natural hazards, such as global earthquake monitoring. Some of these activities take place as a result of direct congressional mandates, and others are conducted on the initiative of the USGS to support the fulfillment of its domestic mission and U.S. government needs. Total reimbursable funding for USGS international activities from 2006 to 2010 ranged from less than $10 million per year to $20 million per year.[13] The amount and sources of this funding vary annually, making continuity difficult to predict. Most of the reimbursable funding has been provided by USAID, the DOS, the Department of Defense (DOD), international organizations such as the World Bank and United Nations, and foreign governments (see Figure 2.1).

The committee gathered information from four of the USGS' largest international project sponsors—DOS, USAID, DOD, and the World Bank—at one of its two public meetings (see Appendix D). The information shared at that meeting provided background

[10]See international.usgs.gov/index.htm (accessed January 26, 2012).

[11]Reimbursable funds refer to those provided by the federal agency organization (e.g., the Department of Defense) requesting an activity to take place. Reimbursable funds may cover direct and indirect costs.

[12]Jody L. Eimers, USGS, personal communication, March 18, 2011.

[13]Jody L. Eimers, USGS, personal communication, March 18, 2011.

BOX 2.3
USGS Office of International Programs Support for International Activities

Contributing to efforts to address global scientific, resource, and environmental issues by

- developing global reference datasets for scientists investigating regional and global environmental trends;
- conducting studies of historic climatic and ecological changes in the geologic record to help understand the likely consequences of future climate change in ecosystems at different latitudes;
- representing the United States in organizations such as the International Hydrologic Program of the United Nations Educational, Scientific, and Cultural Organization.

Improving the effectiveness of the USGS to carry out its domestic missions by

- obtaining information needed by domestic programs;
- supporting cooperation in managing migratory and invasive species as well as transborder ecosystems;
- participating in international scientific professional societies by adding to the knowledge and skills base of USGS scientists.

Advancing U.S. foreign policy and national security interests by

- providing information and technical assistance in responding to natural disasters in foreign countries;
- providing technical assistance in the assessment of water, energy, and mineral resources;
- supporting development of information standards;
- facilitating collaboration among resource and information managers;
- conducting studies to manage invasive species;
- providing technical assistance to international organizations in managing biological information;
- conducting global assessments of energy and mineral resources.

Supporting the competitiveness of the U.S. private sector in the global economy by

- encouraging the use of U.S. equipment and software;
- building regional and global databases of energy and mineral resources;
- encouraging the release of data by foreign governments;
- facilitating contacts between U.S. companies and foreign counterparts;
- developing and disseminating technical and scientific information standards.

SOURCE: international.usgs.gov/mission.htm (accessed January 26, 2012).

for the text that follows. Box 2.4 presents input from these four partners on important strengths of the USGS in its conduct of international work, potential measures of success for various USGS international projects, and some keys to improving the facilitation of future international projects with the USGS.

USAID is the U.S. government's primary foreign assistance agency. International programs based on science and technology are critical components of U.S. foreign policy

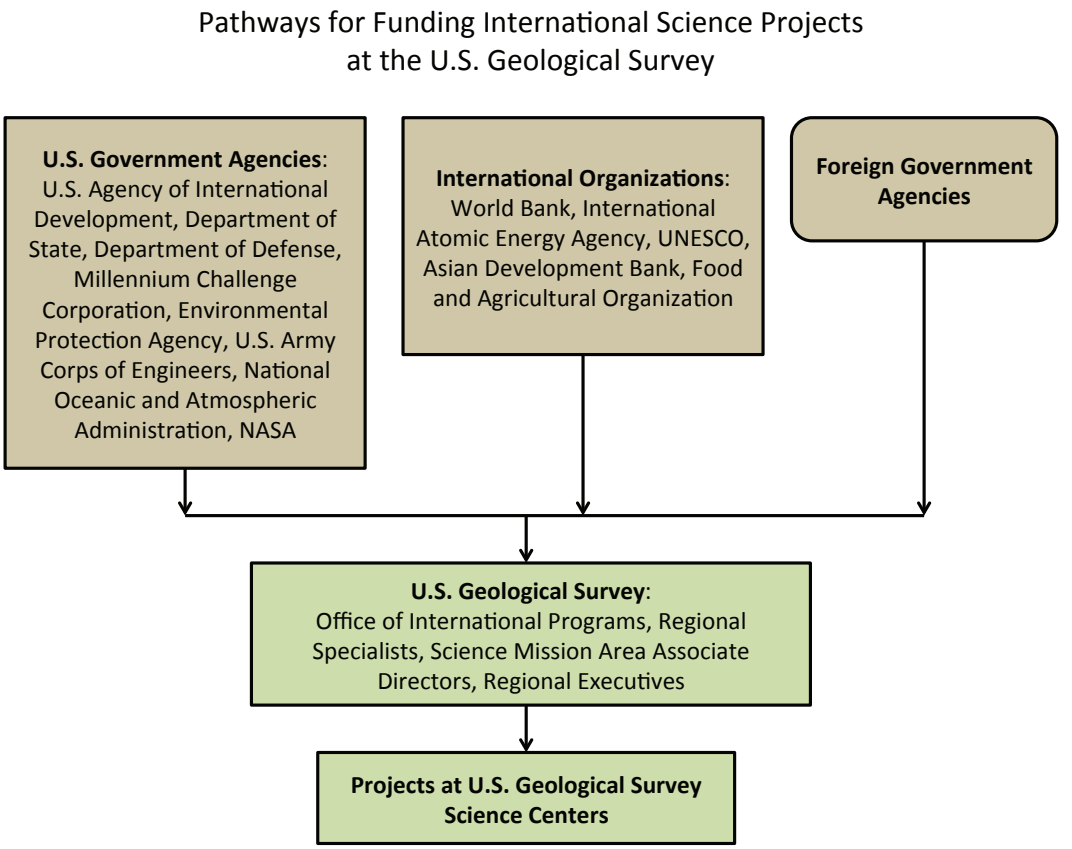

FIGURE 2.1 Flowchart showing sources of reimbursable funding (U.S. government agencies, international organizations, and foreign government agencies) for USGS international science projects. Note that the lists of agencies and organizations are not exhaustive.

(NRC, 2006), and the DOS and USAID carry out such scientific work through a variety of financial mechanisms, including contracts, cooperative agreements, grants, strategic objective agreements, and collaborative agreements. To develop high-level projects, the USGS creates international memoranda of understanding or agreements with a foreign ministry or agency following the DOS C-175 process.[14] Negotiating and approving a memorandum of understanding or agreement usually takes six months or more. Where appropriate, the USGS maximizes efficiency by writing the memorandum to be multidisciplinary, in

[14]DOS describes this process at www.state.gov/s/l/treaty/c175/index.htm (accessed January 26, 2012).

BOX 2.4
Perspectives from USGS Partners in International Science

Value of USGS International Collaboration

Discussion with representatives of four of the USGS' primary international partners—the Department of State (DOS), U.S. Agency for International Development (USAID), Department of Defense (DOD), and World Bank—underscored the importance of USGS contributions to work on a variety of global Earth science issues. The representatives pointed to natural hazards, food security, climate, natural resource availability (minerals, energy, and water), public and environmental health, and burgeoning populations in cities and along coasts as critical in the near to long term and as areas in which the USGS can provide unique scientific input. In addition to the specific scientific expertise the Survey provides to international studies, these partners cited capacity building as a critical component of much of the USGS international work. The four agencies also emphasized the value they place on the longevity of their relationships with the Survey, the fact that the USGS is an established, worldwide leader in many Earth science disciplines, and the Survey's reputation as a reliable partner that generates high-quality products.

Measures of Success

Outcomes or measures of success for international projects are important for the USGS, for the sponsoring or partnering agency, and for the nation receiving the project results. Although the committee was not made aware by the USGS or its sponsoring agencies of any single, established, formal process to collect quantitative evidence of the success of international projects, the major sponsoring partners described various quantitative and qualitative measures of success for USGS international projects. The qualitative measures include (1) the ability to demonstrate the role of natural resources in the development and stability of other foreign nations; (2) the transfer of scientific knowledge to a foreign country and of the basic tenets for scientific best practices; (3) the transfer of knowledge of the benefits of good resource management as part of a national strategy; and (4) the establishment of trust and knowledge to enable the transfer of basic research information from the USGS to practical application by the private sector and local government authorities in a foreign country.

As examples of quantitative outcomes, the four partners cited statistics such as the number of water wells established, the decrease in the number of deaths due to hazard early warning systems such as the

which case all or most science mission areas can take advantage of having a memorandum in place.

The DOS/USAID Strategic Plan lists the USGS as an essential partner in fulfilling U.S. foreign policy objectives in strategic priority areas, such as energy security and the environment (DOS, 2007). Likewise, the USGS OIP stresses the importance of partnerships in fulfilling the USGS science strategy—in particular, partnerships with the DOS, USAID, and the National Science Foundation (NSF). These international activities are authorized by legislation and by international agreements compatible with government-wide guide-

Volcano Disaster Assistance Program, and the number of new mines or new investors for mineral or energy resource development that are attracted to an international area studied by the USGS. Two specific cases involving USGS mineral resource work in Madagascar and Mauritania with the World Bank were mentioned as having yielded quantitative measures of success: the two nations showed increases in both mining output and investment of mining companies in new mines as a direct result of USGS work.

Key Considerations for Future International Work

The four sponsoring agencies identified the following critical points for the future, continued success and effectiveness of the USGS in international science projects:

- The USGS can afford to be more strategic and proactive, rather than reactionary, in its approach to and planning for participation in global science projects.
- USGS is perceived to lack empowerment or authorization to propose its own international work in a broad suite of areas where it has demonstrated expertise; partners expressed appreciation for the occasions when the USGS initiates international project ideas.
- The USGS can benefit from enhancing its collaboration with academic institutions within the United States and abroad in conducting international work.
- Streamlining the process for collaboration for interagency agreements and those with international organizations and foreign governments could add flexibility to project opportunities and increase project effectiveness. For example, although interagency agreements are simpler than exchanges with international organizations or foreign governments, agency-wide agreements for interagency work are not common but were suggested as a potential aid in promoting project development and continuity, as well as long-term planning. Project contracts with international organizations and foreign governments are difficult to execute because of legal restrictions on USGS authority to act as a part of the U.S. government; direct contracts are rare in these partnerships but may offer added efficiency.

SOURCES: Personal communications, April 18, 2011, with Andrew Reynolds, Department of State; Annica Wayman, U.S. Agency for International Development; Emily Scott, Department of Defense; and Gotthard Walser, World Bank

lines, expressed by DOS Circular 175.[15] These projects typically involve several partners and funding streams can also be from several sources, including both reimbursable and appropriated funds. The USGS Natural Hazards mission area, for example, uses a combination of congressionally appropriated funds and reimbursable funds for international work.

[15]The Department of State indicates that the Circular 175 and its successors provide regulations and a process designed to ensure that treaties and other international agreements entered into by the United States are carried out within constitutional and other legal limitations, with consideration for the agreement's foreign policy implications, and with appropriate involvement by the State Department.

The congressionally appropriated budget includes funding for the Global Seismographic Network (GSN), a joint program between the USGS, NSF, and Incorporated Research Institutions for Seismology (IRIS); the USGS is responsible for maintenance and operation, data collection, and quality control for two thirds of the GSN's globally distributed seismic stations. The USGS also receives federal appropriations under the National Earthquake Hazards Reduction Program to fund operation of the National Earthquake Information Center (NEIC) (USGS, 2011f). Through the NEIC, the USGS is responsible for the exchange of information on earthquake research and earthquake preparedness between the United States and other nations.

Sources of reimbursable funding for interactional activities in the Natural Hazards mission area include the USAID Office of Foreign Disaster Assistance (OFDA), which supports the Volcano Disaster Assistance Program and the Earthquake Disaster Assistance Team (EDAT). EDAT operations are also supported partially through federal appropriations.[16] Through EDAT, USGS scientists travel internationally to help in earthquake response in underdeveloped countries, not only providing technical assistance but also gaining "lessons learned" and advancing earthquake science. One such deployment followed the 2010 earthquake in Haiti, where USGS scientists established temporary networks of seismic stations for site-response analysis and aftershock detection, performed seismic hazard assessment for rebuilding, investigated fault ruptures and landslides, and trained others to perform earthquake monitoring and analysis.

The DOD and the World Bank are two other key international partners for the USGS in the international arena. Similar to DOS/USAID, the DOD makes requests to the Survey through an interagency mechanism to enlist the Survey's expertise in various types of projects (see Box 2.4, also Box 3.11). Reimbursable funds are provided to the USGS to conduct the work through interagency agreements. The most recent projects with DOD have been conducted in Iraq and Afghanistan and have included assessments of economic stability programs—for example: What would development of minerals mean for the country? What is the status of fresh groundwater and water wells in these nations? Details of the Afghanistan project are provided in Box 3.11.

Among nonfederal collaborations, the USGS has worked with the World Bank on various international technical assistance projects in South America, Africa, and Asia since the early 1990s. In contrast to federal partners, the World Bank has, in general, not contracted directly with the USGS but has used mechanisms such as parallel funding contributions (with funding for USGS work provided through USAID) or subcontracts (the USGS subcontracts the World Bank work to individuals or companies outside the federal government). These mechanisms have been used largely because the USGS is not permitted to enter into open competition for international projects. Such competitions or open requests

[16] Jody L. Eimers, USGS, personal communication, March 18, 2011.

for proposals are common project development mechanisms for technical assistance projects at the World Bank. A direct contract was recently established between the USGS and the World Bank for the first time for a project that entails regional geologic mapping in Mauritania and includes expert input from the British Geological Survey and the French Bureau de Recherches Géologiques et Minières (French Geological Survey). The successful establishment of this direct contract between the USGS and World Bank may serve as a model for the World Bank to streamline and enhance future engagement with the USGS (see also Box 2.4).[17]

The USGS has entered into international agreements that guide its foreign work and which are now the principal influence on most if not all near-term future activity. It currently participates in 256 agreements[18] with 75 countries and 12 international organizations.[19] Several of the high-profile projects are discussed in Chapter 3. A major but indispensible element of all international activity is travel, which constitutes a significant portion of the expense. The OIP has indicated that 2,100 USGS employees have been issued government passports, and over a thousand international trips are arranged for USGS staff annually.

International Partners

The OIP works with agencies representing more than 40 foreign governments and international organizations such as the United Nations (UN) and the International Standards Organization. USGS work in some cases is also supported by international organizations such as the World Bank (see previous section), the Inter-American Development Bank, and the private sector. Box 2.5 presents examples of UN organizations and regional consortia of multinational geological survey agencies with which the USGS is engaged.

CONCLUDING REMARKS

International work is woven into the USGS fabric and has been for many years. As authorized by a 1962 amendment to the Organic Act, the USGS examines the "geological structure, mineral resources, and products" both within and outside the national domain in support of U.S. national interests and for the benefit of the American people. In addition to pursuing projects in support of its domestic mission, the USGS conducts international work in response to a range of requests from Congress, federal and state agencies, and organizations around the world. Funding for these efforts comes from a variety of sources—federal

[17]Gotthard Walser, World Bank, personal communication, April 18, 2011.

[18]"Agreements" refer to programmatic agreements, exchanges of letter, technical assistance agreements, memoranda of understanding, memoranda of cooperation, letters of agreement, arrangements, contracts, statements of intent, and protocols.

[19]Jody L. Eimers, USGS, personal communication, June 14, 2011.

BOX 2.5
Examples of USGS Involvement with United Nations and Other Geological Survey Consortia

United Nations Activities
Intergovernmental Oceanographic Commission (IOC)
International Hydrological Programme (IHP)
International Geological Correlation Program (IGCP)
International Center for Integrated Water Resources Management
United Nations Educational, Scientific and Cultural Organization (UNESCO)
United Nations Environment Programme (UNEP)

The USGS has also been active in carrying out cooperative training and studies with several other UN organizations

International Networks and Activities
Geospatial Data Infrastructure (GSDI)
Global Biological Information Facility (GBIF)
International Union of Geological Sciences (IUGS)
Inter-American Biodiversity Information Network (IABIN)
Global Invasive Species Information Network (GISIN)
World Meteorological Organization
Group on Earth Observation (GEO)
Committee on Earth Observation Satellites (CEOS)
Global Earth Observation System of Systems (GEOSS)

appropriations (both directly to the USGS and through other federal agencies), foreign countries, international institutions, and other organizations—and the projects vary considerably in terms of scope, duration, goals, and outcomes. Chapter 3 summarizes recently concluded and ongoing USGS international interactions and collaborations, and identifies how these activities have supported the overall USGS mission and/or U.S. government needs.

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CHAPTER THREE

Ongoing International Scientific Activities at the USGS

The U.S. Geological Survey (USGS) is charged by the Department of the Interior (DOI) to respond to evolving national priorities with sound, unbiased scientific advice (DOI, 2011). In approaching its charge, the USGS science strategy recognizes that "the earth behaves as a system in which oceans, atmosphere and land, and the living and non-living parts therein, are all connected" (Steffen et al., 2004) and the USGS therefore uses a systems approach in a number of its studies. Such an approach is comprehensive in scope and enables the USGS to use the breadth and depth of its strengths, expertise, and capacities to monitor, analyze, and provide better understanding of a range of Earth processes through time.

In support of the systems approach to studying the Earth, the USGS organization comprises seven mission areas that are explicitly cross-cutting, problem-based, and interdisciplinary: (1) Climate and Land-Use Change, (2) Core Science Systems, (3) Ecosystems, (4) Energy and Minerals, (5) Environmental Health, (6) Natural Hazards, and (7) Water (USGS, 2007b; 2011a). These science areas are not isolated disciplines but rather broad domains that interact with one another. This chapter describes the seven mission areas, their core activities and international activities, and the specific benefits and relevance of international activities in these areas for both the USGS mission and U.S. national interests.

Although the mission of the USGS focuses on national resources, international approaches are necessary in at least three situations: (1) when a major resource or ecosystem spans an international boundary, (2) when threats or changes to a resource originate outside U.S. borders, and (3) when information relevant to management or conservation is available only through international collaboration or research.

Some USGS mission areas document a longer history of engagement in international activities due to the existence of their core science domains as part of the USGS structure since the Survey's inception. For example, international research in areas such as natural hazards, energy and minerals, and water has a long tradition at the Survey, and each of these

areas has a strong basis in mapping. Other areas (e.g., ecosystems, environmental health, and climate science and land-use change) are comparatively younger in terms of concentrated scientific pursuit at the Survey and thus have shorter records of international engagement. These differences are reflected in the historical record of international projects provided to the committee by the USGS (see Appendix C).

The committee interpreted its assignment to include an overview of all USGS mission areas regardless of their historical precedents in international research, and did not consider its charge to include a detailed evaluation of current (or past) international activities. Rather, the committee considered possibilities for new international science opportunities across the entire Survey organization (see Chapter 4) based on a selection of ongoing activities that the committee found to represent the breadth and depth of USGS expertise and experience as outlined in this chapter.

The information in this chapter is based on (1) presentations made to the committee by USGS scientists in each of the mission areas; (2) a document about the Survey's historical engagement in international activities, prepared by the USGS for the committee's use (see Appendix C); (3) discussions with Survey scientists; (4) information provided by project sponsors and partners (see Chapter 2); and (5) information that the committee gathered from publications and online resources (e.g., Box 3.1 and elsewhere in the chapter). This chapter does not provide an exhaustive description of all current international projects at the USGS but provides context for the strategic international opportunities identified in Chapter 4. A selected bibliography of peer-reviewed scientific publications written by USGS scientists is compiled in Appendix E for the reader's interest.

CLIMATE AND LAND-USE CHANGE

Climate system research examines the Earth's surface, ecosystems, and hydrosphere, and inherently requires a global perspective. Climate anomalies and patterns develop over scales that transcend political borders, and changing land-use patterns have global causes, feedbacks, and impacts. Thus for climate research, international activities require the capacity to anticipate the impacts of climate on the Earth and its inhabitants, and to suggest strategies for adaptation to and mitigation of ongoing climate change (e.g., NRC, 2010; 2011a).

Mission Area and Core Activities

The current DOI strategic plan charges the USGS with "conduct[ing] reliable scientific research in ecosystems, climate and land use change…to inform effective decision making and planning" and with "lead[ing] the effort on climate change science research for the Department" (DOI, 2011). The plan recognizes the need to engage internationally in this

BOX 3.1
The USGS Web Presence for International Science

The committee had the advantage of becoming well informed about the Survey's international science activities from a variety of sources both within and external to the USGS. These sources included published literature, personal communication with and presentations from individuals familiar with USGS international work, and information from various parts of the USGS website.

Examination of the USGS website revealed no central listing or description of all of the Survey's ongoing international projects. Some international information was found through a search on the USGS website for the word "international" or using the "International Activities" link near the bottom of the "About USGS" page. These options lead the viewer to the page for the Office of International Programs (OIP), which has informative descriptions of the OIP and how the USGS conducts its international activities, but no information on the many and diverse international projects themselves.

On the web pages for the individual mission areas, descriptions or mention of international science activities is inconsistent. Some mission areas, such as Energy and Minerals, describe their international activities seamlessly, together with their domestic activities on the mission area's main page. For other mission areas, international work that the committee knows to be taking place is difficult to find on the mission area's web pages or elsewhere on the Survey website.

In the same vein, information about publications—whether official USGS reports, fact sheets or other publications, or articles in peer-reviewed journals—that have resulted from international activities are not collected in a central location or organized within the individual mission area pages. With assistance from the USGS library staff, the committee was able to generate a bibliography of peer-reviewed journal articles by USGS scientists and collaborators on international work; a selection from that bibliography of nearly 300 journal articles is provided in Appendix E.

The lack of consistency with respect to a web presence for international science on the USGS web site is significant because the value of this Survey work— identified and described in this chapter by the committee through access to many well-informed sources—would not be evident to someone in the general public attempting to understand more about USGS international science. The websites of the Geological Surveys of Denmark and Greenland, the British Geological Survey, and of the Bureau de Recherches Géologiques et Minières (www.geus.dk/; www.bgs.ac.uk/; www.brgm.fr/) are examples of other national geological surveys with direct links on the organizations' main web pages to centralized, informative descriptions (and maps) of their international work.

and other mission areas as a core mission responsibility, and identifies key activities and strategies related to sustainable resource management (DOI, 2011).

The USGS has clarified its priorities for climate and land-use change in a recent document entitled *USGS Global Change Science Strategy: A Framework for Understanding and Responding to Climate and Land-Use Change* (Burkett et al., 2011; hereafter referred to as the GCSS report). The GCSS report describes the science necessary to "broadly inform global change policy," identifies core competencies in global change science, and outlines key research questions and strategic goals. The six major research goals are to improve un-

derstanding of (1) rates, causes, and impacts of past global changes; (2) the global carbon cycle; (3) land-use and land-cover change rates, causes, and consequences; (4) droughts, floods, and water availability under changing land use and climate; (5) coastal response to sea-level rise, climatic hazards, and human development; and (6) biological responses to global change. The first two goals are explicitly global, whereas the latter four require a global scope to derive a full understanding of the problems.

Complementing the science priorities outlined in the GCSS is USGS participation in a variety of national and international climate research initiatives. The USGS is one of 13 partnering agencies in the national U.S. Global Change Research Program[1] (USGCRP), and USGS scientists have contributed to Intergovernmental Panel on Climate Change[2] (IPCC) assessments both as authors of influential papers and as participants in writing and reviewing these reports. USGS scientists have also participated in international dialogues—in meetings, workshops, and visits—that advance worldwide understanding of climate data and information.

Current International Activities

The USGS has developed a portfolio of international activities that effectively leverage its capabilities in the science of climate and land-use change, particularly in Earth surface observations and studies of climate-ecosystem-land cover interactions. The Survey's climate work includes the cycling of carbon, nitrogen, and water; the effects of climate change on hydrology and ecosystems; the integration of climate and land-cover change; and proxy-based studies of past changes and interactions of climate, landscapes, and ecosystems. The structure of the Survey's climate activities promotes integration and synergies with other mission areas (e.g., Water and Ecosystems). At the same time, the focal areas draw on the Survey's scientific strengths and capacities in ways that help distinguish the USGS climate science program from that of other federal agencies.

The GCSS report updates these focal areas that take advantage of USGS core strengths and provides linkages to other Survey-wide science directions, all of which include an international dimension. An important asset to the USGS and international science is the management of the Landsat system and the related Earth Resources Observation and Science (EROS) Center. Landsat's comprehensive, global view of the Earth's surface over time provides rich opportunities for basic and applied science related to climate variability and change. The extensive land surface observations acquired by Landsat over the past decades are a highly valuable resource to the scientific community worldwide, particularly as these images are freely available to researchers. Landsat-based observations are a key

[1]See www.globalchange.gov/.
[2]See www.ipcc.ch/.

resource for melding climate and other USGS priorities, and support a strong role for the USGS in international collaboration and coordination efforts (see next section on Core Science Systems).

A further fundamental strength of the USGS lies in the in situ datasets that have resulted from its long history of monitoring and observing and that are highly useful for environmental change research. These datasets include observations of hydrological, cryospheric, ecological, and other environmental variables that provide a sound basis for analyzing climate and land-use change impacts. The scope of many such studies extends far beyond U.S. borders. Box 3.2 presents examples of climate- and land-use change-related international projects in which the USGS plays a crucial role.

Value to USGS Domestic Mission

The science of climate and land-use change encompasses observations of natural phenomena across space and time; the synthesis and integration of datasets at multiple scales; assessment and modeling of fundamental processes and systems; development of near-term projections; and support for environmental decisions. Domestically, the USGS provides scientific input to understand climate and land-use change through collaborations with governments at local, state, tribal, and national levels, and with academic, nongovernmental, and private sector organizations. The knowledge, experience, data, and examples that are gained through international collaborations and studies enhance the capacity of USGS scientists to provide useful information in support of U.S. domestic needs.

Climate projections and reconstructions are also important in assessing how future climate could impact resource management and environmental decisions. Such work has led to or nourished international partnerships, which can bring into focus changes occurring outside U.S. borders that could prove to be instructive for evaluating the effects of a future changing climate (e.g., the impact of climate change on sensitive ecosystems, such as coral reefs or Arctic ecosystems). Theoretical advances that enable better analysis of complex environmental systems are another area in which USGS science benefits from collaboration with international research programs.

Relevance to U.S. National Interests

The USGS addresses national interests in several ways through its international activities in climate and land-use change science. The priorities set forth in the GCSS report (Burkett et al., 2011) align closely with many research elements of the USGCRP: climate variability and change; global water cycle; ecosystems**;** land-use and land-cover change; and the global carbon cycle. Through its management of the Landsat activities, the Survey is a key resource for USGCRP's cross-cutting element of "Observing and Monitoring the

BOX 3.2
Examples of USGS International Activities in Climate and Land-Use Change

Earth observation networks yield observations of land cover and land-use change for quantifying and attributing fluxes of carbon from terrestrial systems. These networks monitor biodiversity, desertification, ecosystem performance, and mangroves in regions vulnerable to tsunami. USGS is an active member of the Committee on Earth Observation Satellites (CEOS), and is involved in the Forest Carbon Tracking project led by the Group on Earth Observations (GEO), which supports national carbon estimation and reporting systems worldwide.

Satellite-based monitoring of drought and flood enables better understanding, management, and prediction of these climate hazards. The Famine Early Warning System Network (FEWS NET) focuses on agriculture-related climate deviations and projects food insecurity in Central Asia, Central America, the Caribbean, and Africa.

Polar region research provides baseline data needed to assess glacier and ice sheet mass balance. Such data are critical for understanding the processes of sea-level change and local hydrologic and ecosystem impacts (see Figure).

Antarctic ice core research at the National Ice Core Lab curates information from international coring programs in Antarctica, Greenland, and at U.S. sites. Ice cores provide critical climate records across thousands of years.

Paleoclimate studies focus on global sea levels and analyze changes over the distant past. USGS scientists use global climate models to examine climate change research questions from the deep past (3.3 to 3.0 million years ago) and provide insight into the near future.

Coastal marine work links relevant global ocean processes, such as sea-level rise and ocean acidification, to climate change. The work conducted by USGS scientists provides critical coastal information for forecasting future conditions.

SOURCES: CEOS (2011); GEO (2011), Robinson and Dowsett (2010), USGS (2005, 2007a, 2009a,b, 2010a).

Climate System" and is in a position to address key elements of environmental change, such as security and humanitarian risks posed by environmental degradation. Remote observations provide data, images, and observations that are essential in global research on fundamental global change processes and trends, ecosystem mapping, carbon cycle studies, and pan-Arctic assessments. Through Earth imaging, for example, the USGS contributes to the Famine Early Warning System Network[3] (FEWS NET) that provides information enabling rapid response to food crises in Africa and other regions. Other key partners in FEWS NET are the U.S. Agency for International Development (USAID), the United Nations,

[3]See www.fews.net/Pages/default.aspx.

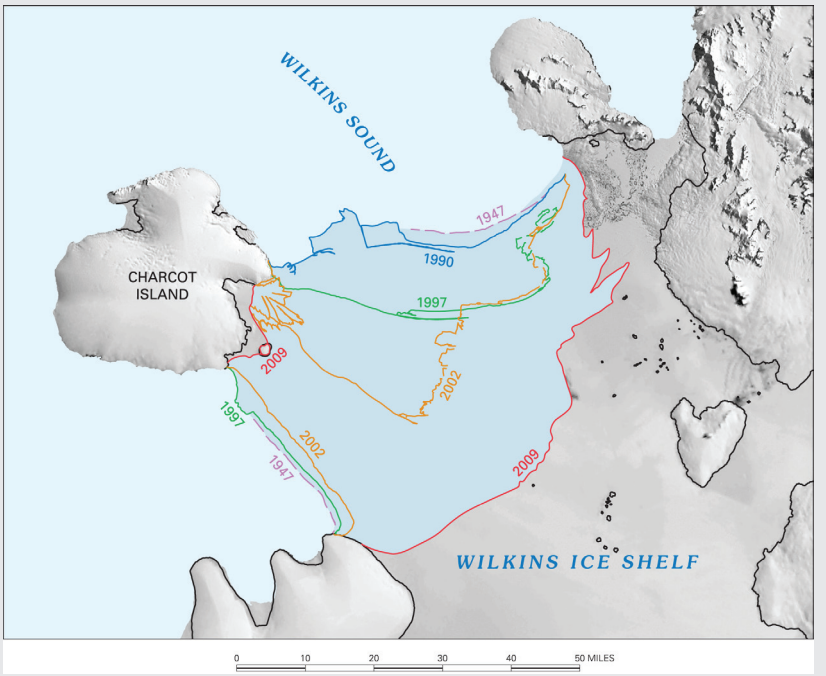


FIGURE USGS scientists studying coastal and glacier change along the Antarctic coastline have documented significant ice-sheet retreat in part of the southern Antarctic Peninsula between 1947 and 2009. Maps such as this one are presented in the USGS report *Coastal-Change and Glaciological Map of the Palmer Land Area, Antarctica: 1947—2009* (map I—2600—C). SOURCE: USGS (gallery.usgs.gov/photos/02_18_2010_hLc5FSq11Y_02_18_2010_0).

the U.S. Department of Agriculture, the National Aeronautics and Space Administration (NASA), and the National Oceanic and Atmospheric Agency (NOAA).

In another example, management of Landsat enables the Survey to play an important role in developing international protocols and conventions for coordinating Earth observations (e.g., through the Committee on Earth Observation Satellites). Furthermore, Landsat activity integrates across nearly all USGS science strategy areas, and strongly supports national-interest activities such as disaster response, biodiversity monitoring, and hydrological analyses on a worldwide basis (see also next section on Core Science Systems).

Individually and collectively, USGS scientists bring expertise and approaches to work in climate and land-use change that strengthen the national climate science enterprise and contribute to the global advancement of climate and land-use science.

CORE SCIENCE SYSTEMS

Mission Area and Core Activities

The USGS conducts surveys in geology, hydrology, geography, and biology to support work of user communities in USGS mission areas. Such work has a strong spatial component and requires a comprehensive mapping capability and infrastructure that is in the purview of the Core Science Systems function, which is carried out through the Biological Informatics Program, National Geospatial Program, National Cooperative Geologic Mapping Program, National Geological and Geophysical Data Preservation Program, USGS Libraries, and Core Science Informatics (see Box 3.3).

Current International Activities

In the USGS Biological Informatics Program, the Integrated Taxonomic Information System (ITIS) is building a database of species names and their hierarchical classification, for which coordination with both national and international biodiversity programs is essential. Similarly, the National Biological Information Infrastructure (NBII) Geospatial Interoperability Framework (GIF) strategy is based on International Standards Organization (ISO) standards and Open Geospatial Consortium (OGC) specifications (see next paragraph), to ensure reciprocal mobility of data at the international level. Other major USGS international initiatives are the World Data Center for Biodiversity and Ecology, the Global Biodiversity Information Facility (GBIF), and the Inter-American Biodiversity Information Network (IABIN).

Within the National Geospatial Program, the Global Earth Observation System of Systems (GEOSS) and the Group on Earth Observations (GEO) are important international coordination mechanisms. In addition, through the Federal Geographic Data Committee (FGDC), the USGS is engaged in the OGC, an international consortium of over 400 companies, government agencies, and universities that participate in a consensus process to develop publicly available interface standards designed to spatially enable Web, wireless services, and location-based services. These standards enable technology developers to make complex spatial information and services accessible and useful with a broad range of applications.

As previously mentioned, Landsat is another example of a comprehensive global program coordinated by the USGS. Landsat represents the world's longest continuously acquired collection of space-based moderate-resolution land remote sensing data. It provides a valuable resource for users worldwide who work in agriculture, geology, forestry, regional planning, education, mapping, and global change research.[4]

[4]Landsat satellites were initially designed, built, launched and operated by NASA throughout the 1970s; operational control and management of the satellites was transferred to NOAA in 1981. USGS assumed operational management of Landsat in 1999. Further information on the history of Landsat is available in NRC (2011b).

BOX 3.3
Programs in Core Science Systems at the USGS

Biological Informatics Program examines issues at the intersection of biological and information science. The program works with partners to maintain the informatics framework needed for the understanding and management of U.S. biological resources. Major program components include state, regional, and national conservation assessments of native vertebrate species and natural land-cover types; taxonomic, biological, and vegetation information and characterization; and the USGS Science Center Informatics Programs.

National Geospatial Program makes and maintains topographic mapping to produce The National Map. The program works cooperatively to share the costs of acquiring and maintaining geospatial data. It also encompasses the Federal Geographic Data Committee, which promotes consistent data and metadata standards, system interoperability, and cross-government best business practices for geospatial resources, policies, standards, and technology as part of the National Spatial Data Infrastructure.

National Cooperative Geologic Mapping Program produces geologic mapping to enhance understanding of earth materials, processes, and history across areas including energy, mineral, and water resources, and natural hazards. The program coordinates and supports the production of most geologic maps in the United States through cost-shared federal-state-university partnerships.

National Geological and Geophysical Data Preservation Program is responsible for archiving geologic, geophysical, geochemical, and engineering data, maps, well logs, and samples. The program provides and maintains a national catalogue of archived materials and provides technical and financial assistance to state geological surveys.

USGS Libraries support comprehensive access to USGS literature, data, and information and serve both internal and external users. There are four branch libraries and there is support for 22 Center Libraries. The collection features 1.5 million volumes of data spanning over 400 years, and 500,000 maps over the globe. The Digital Library Plan encompasses digitization of all USGS-published literature within 5 years, migration of services online, and curation of digital content for long-term accessibility.

Core Science Informatics coordinates and develops data integration services, capacity, and framework for Bureau science programs. It supports identification and development of best practices and standards to ensure efficiencies and innovation. It also works with USGS science programs, partners, and industry to improve methods for accessing, integrating, visualizing, and delivering USGS information.

The National Cooperative Geologic Mapping Program (NCGMP) provides accurate geologic maps and three-dimensional framework models that support efforts to mitigate natural hazards. The Program works to integrate geologic mapping with progress in geologic research worldwide, including using classifications, symbols, and terminology compatible with usage throughout the international business and research communities, and ensuring that maps are usable by a broad range of clients. For decades, these requirements have been achieved through close coordination with the International Commission on Stratigraphy (ICS), the International Geological Correlation Programme (IGCP), and the Commission for the Geological Map of the World (CGMW). In recent years, OneGeology,

an international initiative of the world's geological surveys dedicated to making geologic map data for the Earth widely accessible, has been of escalating importance.

Value to USGS Domestic Mission

Core Science Systems addresses mapping, monitoring, and regional geology directly in support of all other science activities at the USGS. Well described as "ground truth," geologic maps constitute the worldwide test of the theories, measurements, and analyses of all other mission areas of the USGS. Geologic maps are indispensable for understanding the deep Earth, energy and mineral resources, Earth surface processes, and groundwater availability and quality. Such cartographic data inform and support DOI land management decisions, hazard mitigation, resource identification and evaluation, ecological and climatic monitoring and modeling, and understanding of onshore-offshore sediment processes.

Relevance to U.S. National Interests

Mapping and related monitoring activities help to sustain and improve the quality of life and economic vitality of the nation by providing the basis for decisions about natural hazard mitigation, land-use planning and management, natural resource development and conservation, and ecosystem and environmental issues. In addition, oversight of global, space-based, moderate-resolution land remote sensing data, Landsat, and other geographically referenced datasets enables users in federal, state, and local governments to conduct tailored research with layered, georeferenced data in many different areas of the United States and the world. This access facilitates project reconnaissance, planning, and data collection on the ground; research in areas that are otherwise difficult or impractical to access for ground-based field studies; and continuous monitoring of regions with the potential to collate different kinds of data for the same location to understand changes in Earth processes over time.

ECOSYSTEMS

Mission Area and Core Activities

USGS expertise allows the Survey to advance the understanding of U.S. terrestrial, freshwater, coastal, and marine ecosystems and predict ecosystem change. The USGS mission on Ecosystems involves activities such as reporting on the state of the nation's ecosystems; studying the causes and impacts of ecological change; and monitoring and providing methods for the protection and management of biological components and processes of ecosystems. Issues such as the distribution, condition, and conservation of organisms and

predictions of biodiversity change—in conjunction with climate and land-cover change—also fall under the purview of this science direction (DOI, 2011).

Core activities focus on ecological and environmental change in the nation's ecosystems and on the implications for resource managers and the public. The USGS organizes its ecosystem science work into major programs on Invasive Species, Fisheries Resources, Terrestrial Resources, and Terrestrial Freshwater and Marine Environments. Although many of the programs and activities in this science area are conducted at USGS science centers and field stations, understanding the full range of stresses and vulnerabilities and the potential ecosystem responses is enhanced by investigations conducted outside U.S. borders. Such studies yield information about how similar systems respond to change (e.g., Figure 3.1) and provide understanding of corresponding international perspectives on resources and management strategies. Many USGS scientists and collaborators have developed considerable expertise and experience in this area as a result of their international research and collaborations.

Current International Activities

USGS international work provides key information on global drivers of ecosystems in U.S. territory. Ecosystem and biological science activities with international components

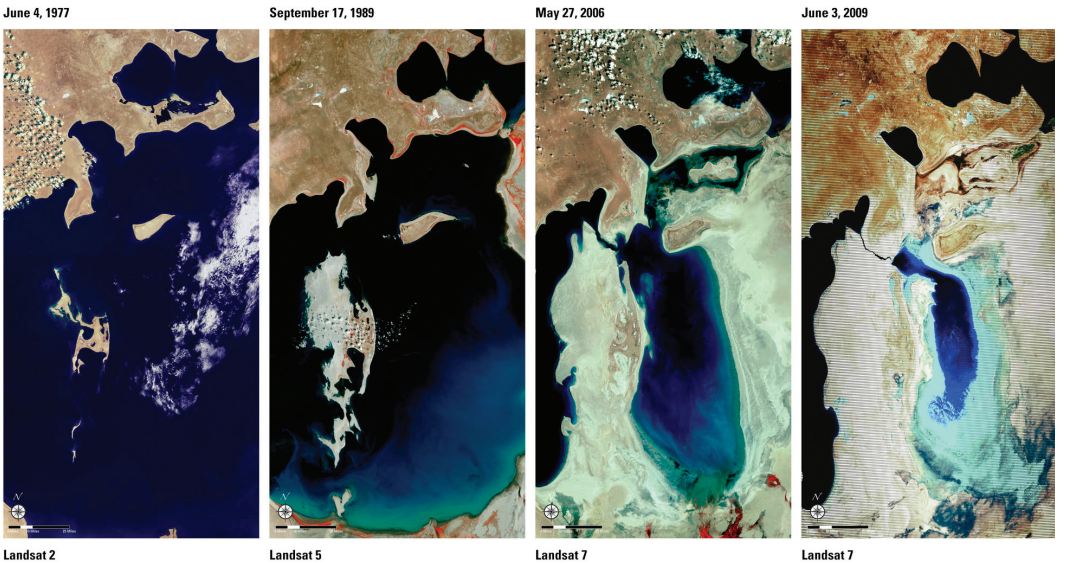


FIGURE 3.1 "The Vanishing Aral Sea." Located in Kazakhstan and Uzbekistan, the Aral Sea was previously one of the largest inland bodies of water. USGS Landsat images capture its diminishing capacity over the span of 30 years due to water usage upstream for crop irrigation. The shrinkage has changed the ecological balance of the area and contributed to habitat loss, increased numbers of sandstorms, and noticeable changes in climate conditions for the region. SOURCE: USGS (landsat.usgs.gov/about_LU_Vol_3_Issue_4.php).

conducted by the USGS range from wildlife disease research to invasive species studies and conservation programs. For instance, to better understand the threats of invasive species into the United States, the USGS Invasive Species Program strategically seeks to "initiate/expand research efforts and cooperation with source countries for introduction of new invasive species into the United States (e.g., China, Russia, and Ponto-Caspian region of Russia, South Africa, Australia/New Zealand, Canada/Mexico)" (USGS, 2004). Further examples of USGS activities involving an international approach are described in Box 3.4.

Value to USGS Domestic Mission

USGS ecosystems activities support the larger DOI mission to "provide a scientific foundation for decision making" by identifying and predicting ecosystem change and by

BOX 3.4
Examples of USGS Ecosystem Activities with International Dimensions

Global Wildlife Disease News Map. Carried out under the auspices of the National Wildlife Health Center through the National Biological Information Infrastructure program, the Global Wildlife Disease News Map presents a visual display of data illustrating the locations of reported wildlife disease outbreaks worldwide. It is the only global surveillance system for monitoring wildlife diseases in the world. Users can see wildlife disease headlines, both locally and globally, and study how such diseases (e.g., West Nile virus) can impact livestock and human health (see Figure).

National Invasive Species Management Plan. USGS scientists play a leading role in implementing a plan to provide a scientific basis for preventing, detecting, and managing invasive species, which can pose a serious threat to U.S. interests. For example, USGS scientists are studying how to better manage the population of nonnative Asian carp, whose population numbers have been increasing exponentially and posing a threat to native fish populations.

North American Breeding Bird Survey. The North American Bird Breeding Survey (BBS) generates data critical for conservation and regulatory purposes (e.g., setting hunting limits for game birds and waterfowl). It is a cooperative effort between the USGS and the Canadian Wildlife Service, and USGS scientists use BBS data to provide information management for the bird banding program.

Partners in Flight. The USGS partners with other federal agencies and with state, local, nongovernmental, and private groups to advance science-based conservation and management of bird species throughout the Americas. Initially focused on neotropical migrants, the program has expanded its goals to include conservation of all birds that require terrestrial habitats.

Great Lakes Fisheries. USGS scientists study this high-priority ecosystem for domestic purposes (especially the high-value fisheries in the lakes) where international considerations are essential. The Great

providing an understanding of connections between the natural environment and wildlife and human health (DOI, 2008). Most USGS capabilities in ecosystem science originated in the transfer of research staff and responsibilities from other DOI agencies in the creation and then reorganization of the U.S. Biological Survey, and thus there are intrinsic linkages and partnerships between USGS and federal resource management agencies (e.g., Fish and Wildlife Service, National Park Service).

Transboundary examples of USGS work include major research efforts in the Great Lakes region, where the Upper Midwest Environmental Sciences Center partners with several Canadian governmental agencies on fisheries and on river science, restoration, and management efforts. In addition, USGS capabilities in monitoring and spatial technologies have made the agency a core participant in North American collaborations to understand migratory birds, especially waterfowl. For example, USGS scientists have worked with

Lakes Science Center is the only organization in the United States and Canada that has a research vessel with deepwater capability on each of the Great Lakes, enabling comparative offshore field studies on fish population dynamics and related habitat research topics.

FIGURE Screenshot of the USGS Global Wildlife Disease News map. SOURCE: USGS (wildlifedisease.nbii.gov/wdinNewsDigestMap.jsp).

Canadian and South American colleagues to develop technologies for tracking migratory birds (e.g., Farmer et al., 2004).

As globalization affects the speed and distance with which disease and invasive species cross the planet, vital U.S. resources may be vulnerable. The USGS has unique capabilities in geospatial technologies and information management that are key elements in efforts to track and project emerging threats to biological resources from outside the nation's boundaries. The USGS National Wildlife Health Center is the primary source of support for the Wildlife Data Integration Network and the Global Wildlife Disease News Map, which shows the emergence and movement of disease outbreaks in wildlife species outside the United States. USGS mapping and data-sharing capacity are essential for forecasting diseases that could affect U.S. wildlife resources and for real-time tracking of wildlife pathogens that may be zoonotic (e.g., avian influenza, West Nile virus) and affect human health. For example, international collaboration has allowed geneticists at the Western Fisheries Research Center to lead efforts to describe and better understand serious threats to commercial fisheries in the Great Lakes posed by viral hemorrhagic septicemia virus (USGS, 2010b).

Similarly, species that cross international borders during natural or human-influenced migration can affect local human populations, indigenous plant and animal species, and ecosystems. USGS has built on its expertise in detection, monitoring, and mapping to develop major programs aimed at understanding and mitigating the threats of invasive species. Unique data-sharing capabilities, such as the Global Invasive Species Information Network and the Pacific Basin node, were established through the NBII to track and share information on highly invasive species and their associated threats among U.S. territories and other Pacific island nations. These core capacities in mapping and monitoring have built a foundation for forecasting the arrival and spread of invasive species from outside the nation's boundaries. For example, the USGS Southeast Ecological Science Center has been involved in mapping and understanding the impacts of the exotic lionfish (*Pterois* spp., see Figure 3.2) through the Caribbean, whose explosive spread is severely impacting native fish populations and coral reefs (USGS, 2011b).

International work related to the nation's ecosystems is necessary to improve understanding of certain threats by studying them in their place of origin. While the scientific literature and other data-sharing approaches provide adequate background to assess threats, such information is not always available. For example, many plant species that have proven to be invasive in North America are not weedy or aggressive constituents in their home ranges and thus have not attracted much attention from researchers there. New work is thus essential to identify natural enemies for biocontrol.

Relevance to U.S. National Interests

Ecosystem function and health are increasingly being understood as having national security implications. The DOS has identified soil conservation, sustainable development

FIGURE 3.2 Adult lionfish (*Pterois* spp.). The lionfish is an invasive species whose population has rapidly spread throughout the Atlantic Ocean, Caribbean, and the Gulf of Mexico. SOURCE: USGS, photo by James Morris, Jr.

of watersheds, and other environmental issues as critical to short- to medium-term security and foreign relations (Reynolds, 2011). Accordingly, the USGS has been involved in relevant ecosystem projects such as

- *Southwest Border monitoring*. The USGS partners with the Department of Homeland Security (DHS) to quantify the impacts of fencing, barriers, lighting, and other border security infrastructure on natural and cultural resources along a 700-mile-long section of the U.S.-Mexico border.
- *Information management support*. From genomics and biological diversity to geospatial and remote system data, USGS has been a leader in developing advanced information management capabilities that facilitate data sharing, international collaboration, and effective problem-solving. Among its contributions are the Global Biological Information Facility, Global Invasive Species Information Network, NBII, and International Taxonomic Information System (see also Core Science Systems section, above).
- *Delta Research and Global Observation Network (DRAGON)*. The USGS studies major coastal delta systems similar to the Mississippi River Delta by drawing

on scientific studies of massive river systems in Asia, Africa, Europe, and South America (Figure 3.3). DOS's lower Mekong River activities are built on DRAGON collaborations, which in turn draw on the expertise of the USGS National Wetlands Research Center (Farris, 2010). The modeling and management tools being developed as a result of this work can strengthen domestic capabilities in the Mississippi Basin, and the associated international collaborations have considerable value for foreign relations (Reynolds, 2011).

- *Arctic sea ice ecosystem and species conservation work.* Modeling sea ice and the relationship of key species populations (e.g., polar bears and walruses) for conserva-

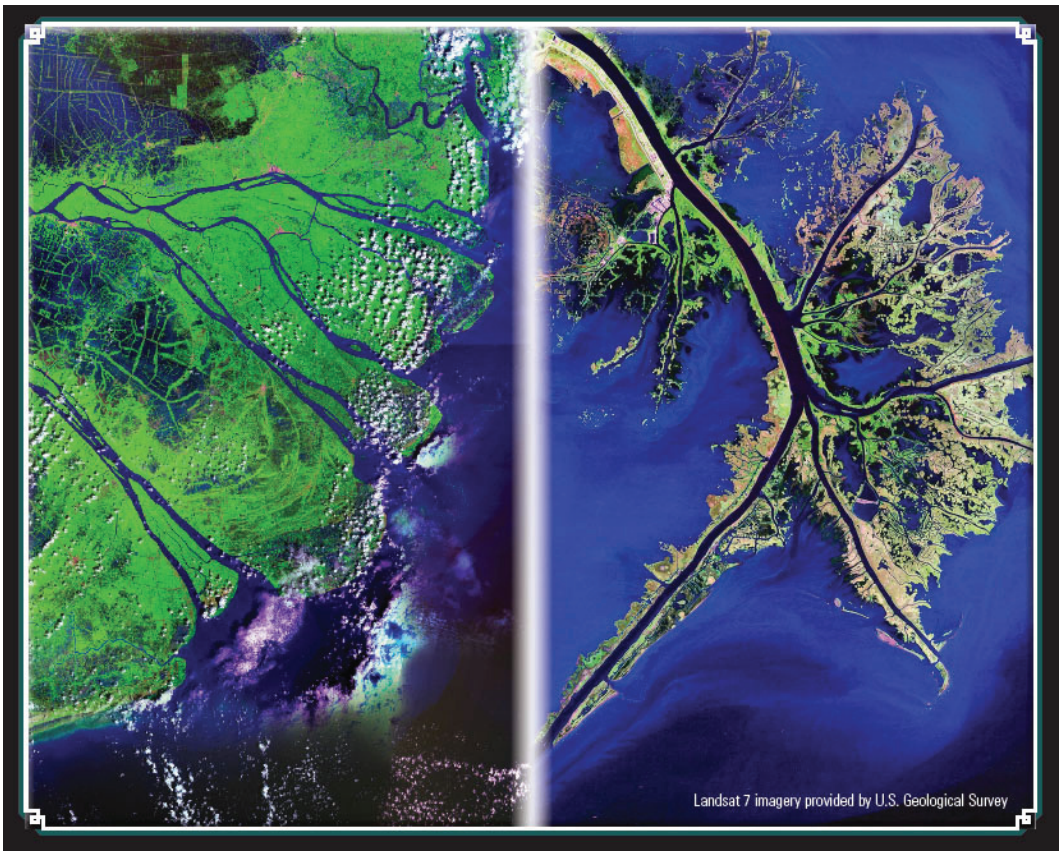


FIGURE 3.3 Research on major river delta systems around the globe have allowed USGS scientists to improve understanding of the U.S. Mississippi Delta (right) and the Mekong Delta (left) in southeast Asia. The USGS Delta Research and Global Observation Network (DRAGON) partnership, operating through the U.S. government's Lower Mekong Initiative, draws on USGS expertise to assist countries in the Mekong Delta area in assessing the actual and potential impacts of human activities and climate change on the ecology and food security of the Mekong River basin. SOURCE: USGS (deltas.usgs.gov/).

tion and management in the Arctic region has been a high-priority USGS effort for several years. Changing sea ice patterns and ecosystem function in the Arctic have major implications for access to both biological (fisheries) and abiotic (mineral, oil, and gas) resources in the region (see section on Climate and Land-Use Change). For instance, access to new resources is tied to ongoing diplomatic and commercial negotiations among the Arctic nations, including Russia, Canada, and several northern European countries. USGS wildlife and ecosystem scientists have been key participants in multinational studies of marine mammal and fisheries resources in the Arctic, and USGS scientists are collaborating to provide research and monitoring for multinational polar bear management efforts (e.g., Stirling et al., 2011).

- *Environmental status of boundary rivers.* The USGS Columbia Environmental Research Center conducts a program on Biomonitoring of Environmental Status and Trends in the Large Rivers Monitoring Network. USGS scientists collect data on biological and contaminant condition of resources in the Colorado, Rio Grande, and Yukon river basins that are important to U.S. relationships with Canada and Mexico.

ENERGY AND MINERALS

Mission Area and Core Activities

The USGS conducts strategic research to identify and understand the occurrence, size and extent, and genesis of energy and mineral resources. Data and information acquired with this research inform national decisions about domestic land management and use, management of energy supplies and mineral resources, international trade, national security, and environmental quality. The USGS identified four strategic areas to focus its efforts in energy and minerals for the 2007-2017 period: (1) natural resource security for the future,[5] (2) environmental health, [6] (3) economic vitality of the nation, and (4) management of DOI and other lands. The core activities within energy and mineral resources are described separately below (Brady and Doebrich, 2011).

Core Domestic Energy Resource Activities

The main activities in energy resource research at the USGS include oil and gas; coal; other energy (such as gas hydrates, geothermal energy, wind energy, uranium, and oil shale);

[5]See www.usgs.gov/start_with_science/docs/energy_minerals.ppt (accessed July 11, 2011).
[6]See www.usgs.gov/resources_envirohealth (accessed July 11, 2011).

and geologic carbon sequestration (Box 3.5). Core activities related to oil and gas include (1) national assessments of undiscovered oil and gas resources in areas such as the Gulf Coast and Cook Inlet, Alaska; (2) identification of unconventional oil and gas projects;

BOX 3.5
Geologic Carbon Sequestration

The Energy Resources Program has been a primary contributor to the USGS Carbon Sequestration Program by developing a method to estimate the CO_2 storage potential of different geologic formations in the United States (Brennan et al., 2010). This method is used by the USGS to assess storage resources on a large scale (the scale of geologic basins). The USGS is also conducting research to refine current and future CO_2 storage potential. Some of this work has been undertaken in response to the Energy Independence and Security Act of 2007.[a] The Carbon Sequestration Program spans multiple mission areas at the Survey (see Figure), including Climate and Land-Use Change, where the program is administered, and Environmental Health, which contributes research about the potential environmental impacts of carbon sequestration.

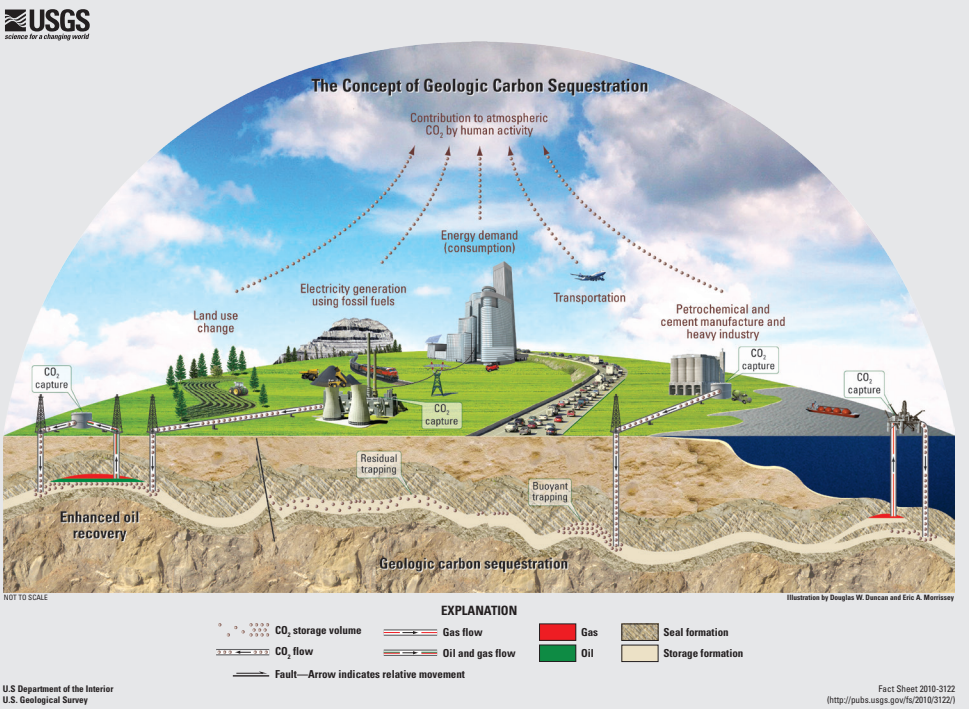


FIGURE Illustration depicting the concept of geologic carbon sequestration. SOURCE: USGS; Duncan and Morrissey (2011).

[a] Public Law 110-140 (available at www.gpo.gov/fdsys/pkg/PLAW-110publ140/content-detail.html

(3) monitoring of reserve field growth—or the potential for oil and gas fields to increase total proved reserves over time; and (4) research in energy economics.

Coal research entails resource assessments, analysis of coal quality, research on coalbed natural gas, and studies of the impact of coal on human health. Gas hydrate and geothermal research are two examples of work within "other" energy sources at the USGS. These activities include cross-agency, interdisciplinary research and development projects for gas hydrates on the Alaska North Slope and offshore Gulf of Mexico (NRC, 2010) and projects to support exploration for geothermal resources and potential energy development, especially in the western United States.[7] The USGS collaborates extensively with other DOI bureaus as well as with the Department of Energy (DOE), National Science Foundation, Environmental Protection Agency (EPA), and Department of Defence (DOD) on these topics.

Core Domestic Mineral Resource Activities

The Mineral Resources Program supports research for two primary functions: (1) research and assessment and (2) data collection, analysis, and dissemination (USGS, 2011c). Quantitative assessments are conducted to determine the potential for undiscovered mineral deposits. Such work involves updating national mineral resource assessments, assessing techniques for evaluating concealed mineral deposits, developing an understanding of mineral systems, developing data and information for minerals on federal lands, evaluating risk and uncertainty in mineral resource assessments, investigating minerals and materials used by industry, and conducting mineral life cycle analysis (including materials flow and supply chain studies). These studies also include data collection, modelling, and development of methods to determine the potential environmental impacts on federal lands of mineral exploration and production. The collection, analysis, and dissemination of mineral commodity information (see discussion of international activities in next section) have been the subject of enormous interest in the last decade, and particularly in the last several years as interest in important minerals such as the rare earths has increased dramatically (e.g., NRC, 2008).

Current International Activities—Energy and Minerals

The USGS World Petroleum Assessment 2000 is an impartial, science-based resource on global petroleum information and data. The USGS is updating these assessments and has also begun to conduct newer, more detailed assessments for the Circum-Arctic, basins in Ukraine, Russia, and Belarus, coastal West Africa and north-central Africa, and South America (Figure 3.4).[8]

[7]See also energy.usgs.gov/Coal.aspx; energy.usgs.gov/OtherEnergy/Geothermal.aspx.
[8]See energy.usgs.gov/OilGas/AssessmentsData/WorldPetroleumAssessment.aspx.

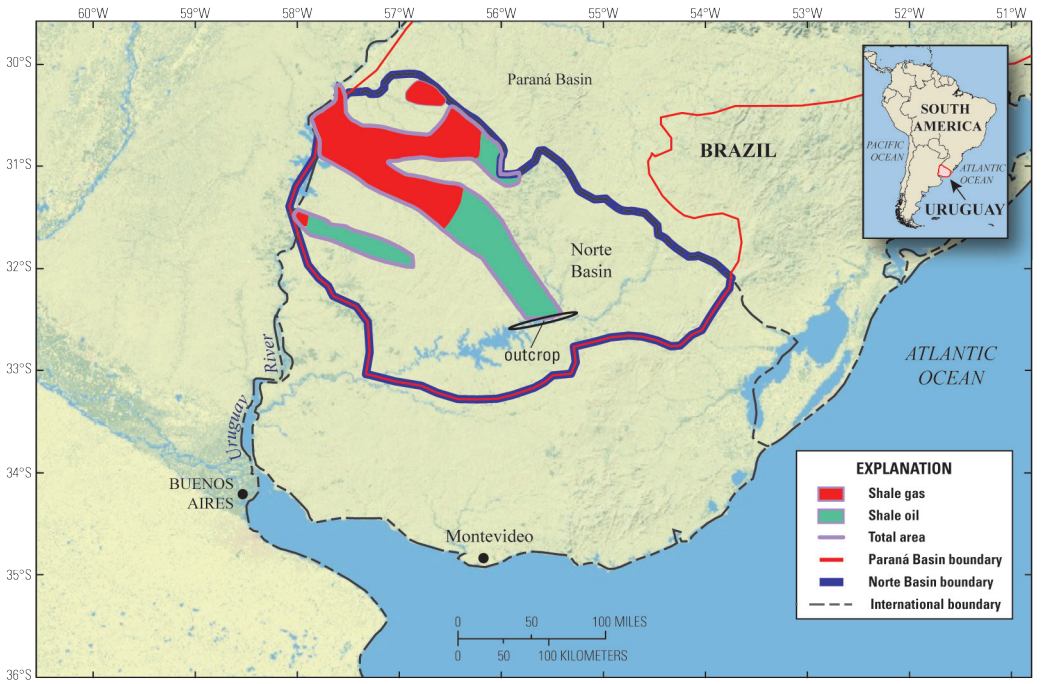


FIGURE 3.4 The Norte Basin in Uruguay and the areas of the Devonian Cordobés Formation Shale Gas Assessment Unit (red) and Devonian Cordobés Formation Shale Oil Assessment Unit (green). SOURCE: Schenk et al. (2011).

Estimates of high concentrations of gas hydrates on the world's continental shelves have encouraged international interest in gas hydrate as a potential energy source. The USGS has been engaged in gas hydrate research for several decades and been a key collaborating partner in such research with Japan, South Korea, India, Canada, and several other countries, generally working together with the Department of Energy (e.g., NRC, 2010). In the area of geothermal energy, USGS scientists have engaged in planning experiments at geothermal fields in Soultz-sous-Forêt (France), Iceland, and Tyrniauz (Russia), and have participated in several projects in Japan.

The quantitative Global Mineral Resource Assessment Project addresses the needs of the federal government, industry, and research community for global minerals information to aid in decision making. Regional reports provide assessment of nonfuel mineral deposits in Latin America, Canada, Asia and the Pacific, Europe and northern Central Asia, and Africa and the Middle East (e.g., Schulz and Briskey, 2005). Analyses are also available for specific types of resources, such as minerals containing rare earth elements (e.g., Long et al., 2010; USGS, 2011c) and porphyry copper in South America (Cunningham et al., 2008) and Mexico (Hammarstrom et al., 2010).

The annual *Mineral Commodity Summaries* (USGS, 2011c) and *Minerals Yearbook*[9] compiles information on the worldwide supply, demand, and flow of minerals and materials, with analysis of mineral production, consumption, and resource information for 180 countries. The USGS also provides mineral life cycle analysis (including global materials flow and supply chain) of different minerals. One such study was requested by the Organization for Economic Cooperation and Development on global flow of aluminium, and another was recently released on the effects of the March 2011 earthquake and tsunami on mines and mineral processing in Japan (Menzie et al., 2010, 2011).

An example of a cross-cutting international research activity among Mineral Resources, the Toxic Substances Hydrology Program (in the Environmental Health science area), and the Water science area (see subsequent sections) is the examination of mercury sources and global mercury cycling. This activity is described in detail in the next section on Environmental Health.

Value to USGS Domestic Mission

An important function of the USGS Energy and Mineral Resources mission area is the quantification of current energy and mineral resources production, consumption, imports and exports. USGS expertise and information on these topics directly support numerous energy and mineral resource activities across the federal government, and the Survey often collaborates with other DOI agencies (e.g., Bureau of Land Management, Bureau of Ocean Energy Management, Fish and Wildlife Service, Bureau of Indian Affairs) and with the DOE, DOD, DOC, EPA, and U.S. Forest Service. Each of these collaborating agencies has specific responsibilities and roles in terms of regulation, permitting, leasing, land management, oversight, and environmental protection. In partnership with these other federal agencies and the private sector, the USGS fulfils a key domestic mission as a purveyor of reliable and unbiased energy and mineral data and information to the federal enterprise, industry, and the American public.

Relevance to U.S. National Interests

The ongoing and recently completed projects and activities in this mission area have complementary domestic and international benefits, as is evident from the strong U.S. and foreign interest in the global distribution of energy and mineral resources. Imports of these resources have the potential to affect U.S. economic development and national security, thus information on global and domestic resource distribution and availability can inform decisions about risks associated with import dependence and possible actions to mitigate supply risk. Understanding the life cycle of energy and mineral resources and of practices

[9]See also minerals.usgs.gov/minerals/pubs/myb.html.

FIGURE 3.5 The interrelationship of the quality of the physical environment, the health of the living environment, and human health as it relates to environmental health science. SOURCE: USGS (www.usgs.gov/start_with_science/docs/enviro_overview.pdf).

to make resource use more efficient and less harmful of the environment is also important for the country.

From a geopolitical perspective, the USGS also plays a key role in assessing the availability and potential role of energy and minerals in other countries, as part of the effort to support investment, development, and political stability in these countries while potentially increasing supply to the world market (see Section 3.8 for a detailed description of an Afghanistan project). Some international energy and mineral projects include collaboration with developed nations to enhance the scientific exchange of ideas and information, develop national and global databases, and bolster the quality of scientific energy and mineral resource development in the participating countries (including the United States).

ENVIRONMENTAL HEALTH

Mission Area and Core Activities

The USGS defines environment health as "The multi-disciplinary study of relationships among the quality of the physical environment, the health of the living environment, and human health" (Figure 3.5).[10] The link between environmental health and human

[10]See www.usgs.gov/start_with_science/docs/enviro_overview.pdf.

BOX 3.6
Environmental Impacts on Human Health

Human health is determined by intrinsic characteristics and influenced by external exposures through air, water, food, or contact. It is also dependent on the health of the surrounding environment and wildlife. Environmental contaminants and increasing evidence of zoonotic and vector-borne diseases are of concern around the world. Current scientific information is important to understand and address chemical and pathogenic contaminants in water, air, dust, and soil, and in food that may threaten public health. According to the Institute of Medicine's Roundtable on Environmental Health Sciences, Research, and Medicine, "In its broadest sense, the environment is one of the major determinants of human health and well-being . . . Underlying the need for enhanced education of health professionals is the need for more research. . . that will further elucidate the linkages that exist between the environment and human health" (IOM, 2004).

Many adverse exposures stem from anthropogenic disturbances of the natural environment, others from natural sources near or at the Earth's surface. Research on Earth sciences–including geology, geophysics, geochemistry, geomorphology, soil science, mineralogy, hydrology, mapping, remote sensing, and other subdisciplines–yields critical information about natural Earth materials and processes to enhance understanding of such adverse exposures.

SOURCE: IOM, 2004; NRC, 2007; USGS, 2008.

health is well established, but the relationship between environmental health and Earth processes has not been examined as extensively, although such information is necessary for protecting public and environmental health and supporting U.S. national interests. The impact of Earth minerals and processes on human health was recognized in the 2007 National Research Council report *Earth Minerals and Health: Research Priorities for Earth Science and Public Health* (NRC, 2007). A recent USGS report also acknowledged the nexus between environmental health and human health (USGS, 2008; see Box 3.6).

The USGS has undertaken a systems approach to examine the impacts of Earth processes on environmental health, with the following goals outlined for activities in this area:[11]

- Anticipate, detect, and assess emerging threats from contaminants and diseases that affect aquatic and terrestrial organisms and humans.
- Characterize both the environmental factors that control exposure to natural and anthropogenic contaminants and their effects on aquatic and terrestrial organisms and humans.
- Elucidate the ecological and environmental factors that influence the occurrence

[11]See www.usgs.gov/start_with_science/docs/enviro_overview.pdf.

and evolution of infectious diseases that affect aquatic and terrestrial organisms and humans.
- Determine interactions among contaminants, pathogens, environmental changes, and other stressors that together affect the health of aquatic and terrestrial organisms and humans.
- Enhance methods to anticipate and rapidly assess the environmental impacts of natural or anthropogenic disasters on the health of aquatic and terrestrial organisms and humans.
- Synthesize and communicate integrated environmental health science information to decision makers and the public.

Determining routes of exposure through which human health can be adversely impacted might be a helpful way to identify work in other USGS mission areas that has direct links to environmental and human health (see Table 3.1). Quantitative microbial risk assessments require exposure and dose response data to characterize risk, yet such data may not be readily available for risks that are not prevalent in the United States. By studying cases outside the United States, USGS scientists can glean valuable information to examine linkages between environmental contaminants and human health. For example, in Bangladesh, historical contamination of surface waters with waterborne pathogens necessitated the drilling of tube wells to reach pristine groundwater, which inadvertently resulted in the largest mass poisoning of arsenic-contaminated water ever recorded. The USGS has since been involved in decade-long studies in Bangladesh to develop new analytical methods for arsenic detection and for understanding processes that affect arsenic mobilization. All of these efforts are directly applicable to arsenic issues in the United States and illustrate how the route of exposure (in this case, consumption of potable water) can result in devastating adverse human health effects.

Current International Activities

USGS domestic and international activities related to environmental health address public health impacts of arsenic groundwater contamination, wildlife diseases (particularly zoonotic diseases, which are transmissible between animals and humans), natural hazards, and water, air, and soil quality (see Box 3.7). For example, the Global Wildlife Disease News map (see Box 3.4) provides an invaluable service by tracking the emergence of diseases such as avian influenza in migratory birds and West Nile virus in wild birds, and serves as an "early warning system" for emerging wildlife pathogens. The USGS National Wildlife Health Center is also involved in disease surveillance of birds, sea turtles, fish, amphibians, and coral reefs, and in detecting invasive pathogens and emerging diseases in wildlife (USGS, 2011d). These and many other Environmental Health activities involve expertise from several USGS mission areas.

TABLE 3.1 Routes of Exposure That Result in Adverse Human Health Effects: Links to Research in Other USGS Mission Areas

Exposure Route	Explanation of Risk	Example of Specific Activity	USGS Mission Area(s)	Adverse Health Effect
Inhalation	The human respiratory system consists of organisms and tissues in the upper body which allow us to breathe ambient air, extract oxygen, and respire carbon dioxide back into the atmosphere. Inhalation of hazardous materials in ambient air can cause adverse health effects and disease. Such hazardous materials can be found in gas, liquid, or solid matter.	Volcanic eruption in Laki Iceland	Natural Hazards	Death from volcanic gas inhalation (SO_2, HCl and HF) (Stone, 2004)
Ingestion: water	Water is essential to life and good health, but unfortunately safe, healthy potable water is in limited global supplies. In addition, interactions between potable water and anthropogenic or natural contaminants can compromise potable water quality.	Tube well drilling in Bangladesh	(1) Water (2) Energy and Minerals	Mass poisoning via arsenic (Chowdhury et al., 2000)
Ingestion: food	Food is essential to life and good health, and it is also susceptible to contamination by anthropogenic or natural contaminants.	Mine and smelting in Toyama Province, Japan	Energy and Minerals	Cadmium contamination of rice (Alloway, 2005)
Infection	A variety of viral, bacterial, and protozoan pathogens can infect humans and cause disease. In addition, helminth infections from organisms such as *Ascaris* infect billions of people worldwide (Fleming et al., 2006). Exposure to such pathogens can be due to multiple and diverse factors.	Global warming induced El Niño events in South America	Climate and Land-Use Change	Enhanced incidence of cholera (Gil et al., 2004)
		Reforestation in northeastern United States	Ecosystems	Enhanced incidence of Lyme Disease (NRC, 2007)

BOX 3.7
Examples of USGS Projects in Environmental Health

Arsenic groundwater contamination. USGS involvement in studies of groundwater contamination in Bangladesh has yielded information that is directly applicable for arsenic groundwater contamination issues in the United States. Specifically, results from examining the microbiological, biochemical, and hydrogeologic processes that control the mobilization of arsenic from geologic materials critically enhance understanding and thus support efforts to mitigate the impacts of such contamination. Over the past decade, USGS has participated in multiple international evaluations of arsenic contamination and used new methods of analyses (Breit et al., 2006, 2007).

Avian influenza. The USGS has been active in efforts to sample and test high-priority migratory bird species for highly pathogenic avian influenza. The National Wildlife Health Center performs laboratory testing of birds known to migrate between Asia and North America and investigates wild bird mortality events throughout the United States (USGS, 2007c).

Natural hazards. The USGS has been critically involved in international activities and partnerships that use predictive monitoring for disaster prevention and mitigation, as well in providing assistance after earthquakes, tsunamis, or volcanic eruptions. Such participation benefits national USGS studies in support of efforts to reduce the impacts of natural hazards on public health (Ewert et al., 2005).

Water, air, and soil quality. The USGS engages in interdisciplinary research on the relationship between human health and environmental quality on both sides of the U.S.-Mexico border, evaluating water, air, and soil quality (including the effects of heavy metals and pesticides) (Papoulias et al., 2006).

Value to USGS Domestic Mission

USGS information on the effects of water, air, and soil contaminants on environmental health supports work and collaboration with other DOI agencies (e.g., Fish and Wildlife Service, Bureau of Reclamation, Bureau of Land Management, Bureau of Indian Affairs), as well as other federal agencies such as the Environmental Protection Agency, Department of Homeland Security (DHS), DOD, and the Centers for Disease Control and Prevention (CDC). For example, research on natural hazards and their effects on human health is relevant to emergency managers and incident specialists in the Federal Emergency Management Agency (FEMA) and DOD, as is work related to climate and land-use change for the CDC (e.g., climate change influencing the incidence of thermotolerant organisms such as *Legionella pneumophila* and *Naegleria fowleri*). Research studies related to energy and minerals in the area of bioremediation are of interest to the National Institute of Environmental Health Sciences. International data collection in the areas of exposure and dose response can be extremely beneficial to domestic risk characterization and assessments.

Relevance to U.S. National Interests

Environmental health can impact public health; therefore, several USGS international activities in this area are of national interest, as illustrated by the following examples:

- A USGS scientist joined a team at the Pasteur Institute in Tunis, Tunisia, to study the transmission and prevention of zoonotic cutaneous leishmaniasis, a pathogen commonly found in parts of Africa that is transmitted by sand fly and carried by rodents.
- USGS wildlife experts use satellite telemetry in support of avian influenza surveillance programs, tracking the waterfowl movement across Hong Kong and India in order to understand migratory pathways and interactions between wild and domestic birds.
- A USGS scientist who studied the source of mercury in the ocean helped demonstrate that mercury from the atmosphere settles in the ocean and can end up in fish that are harvested for human consumption (Krabbenhoft, 2009). Health managers use this knowledge to minimize human exposure to mercury through marine fish consumption.
- USGS researchers explore links between coal aquifers and the kidney disease Balkan Endemic Nephropathy (BEN), which is suspected of decreasing viability and inducing cell death in human kidney cell lines. The research helps U.S. scientists to understand links between kidney disease and coal aquifers that supply drinking water in the United States.

NATURAL HAZARDS

Escalating losses from natural disasters have become a societal problem worldwide—all too evident from the recent impacts of major earthquakes, tsunamis, floods, volcanic eruptions, hurricanes, and landslides. A chronicle of such major disasters[12] indicates their alarming frequency. To address these events, the USGS Natural Hazards mission area encompasses six program elements: Earthquake Hazards, Volcano Hazards, Landslide Hazards, Global Seismographic Network, Geomagnetism, and Coastal and Marine Geology (USGS, 2007d).

Mission Area and Core Activities

The strategic science direction for the USGS Natural Hazards mission area (USGS, 2007b) calls for continuous collection of accurate and timely information from Earth

[12]International Charter: Space and Major Disasters (see www.disasterscharter.org/web/charter/activations).

observation networks, natural hazards risk assessments, and research to improve hazard predictions. This mission area also coordinates and supports the broader work of the USGS—including floods, hurricanes and severe storms, tsunamis,[13] and wildfires—and it coordinates USGS response activities following disasters (Eichelberger, 2011). These activities fall under Goal 4, Increase the Resilience of Communities to Geologic and Environmental Hazards, articulated in USGS Circular 1369 on Implementing the USGS Science Strategy, which "emphasizes the need for providing real-time, integrated national monitoring and warning systems, conducting research to better understand risk, and planning effective communications products and partnerships to build resilient communities across the globe" (Gundersen et al., 2011, p. 2). Key information sources for the activities of the six program elements described below include the DOI (USGS, 2011a), Eichelberger (2011), and the USGS Natural Hazards website.[14]

Earthquakes and Volcanoes

The USGS has the lead federal responsibility to monitor and provide notification of earthquakes in the United States and worldwide, and the USGS Earthquake Hazards Program is a central part of the National Earthquake Hazards Reduction Program (see NEHRP, 2011), a joint effort of the USGS with the National Science Foundation (NSF), DHS (FEMA), and the National Institute of Standards and Technology. Seismic monitoring for the nation is achieved through the Advanced National Seismic System (ANSS), a real-time earthquake information system operated by the USGS together with state and university partners. As an integral part of ANSS, the USGS operates the National Earthquake Information Center (NEIC), located in Golden, Colorado, and staffed on a 24/7 basis to provide rapid and accurate information on earthquakes worldwide.

Critical data for continuous worldwide earthquake monitoring and rapid reporting by the USGS come from the Global Seismographic Network (GSN), a permanent digital network of more than 150 globally distributed seismic stations, operated as part of a joint USGS-NSF program. GSN stations provide near-real-time data to tsunami warning centers operated by NOAA, and 97 percent of GSN stations transmit real-time data continuously to the NEIC (DOI, 2011).

The Volcano Hazards Program (VHP) monitors active and potentially active volcanoes, assesses their hazards, responds to volcanic crises, and conducts research on volcanic phenomena. In 2005, the VHP completed a systematic assessment of volcanic threat and

[13]The National Tsunami Hazard Mitigation Program of 1995 designates the National Oceanic and Atmospheric Administration (NOAA) as the lead federal agency for addressing tsunami hazards affecting the U.S.—in partnership with the USGS, the Federal Emergency Management Agency (FEMA), the National Science Foundation (NSF), and the 28 U.S. Coastal States, Territories, and Commonwealths.

[14]See www.usgs.gov/natural_hazards/.

monitoring capabilities for all 169 of the nation's active volcanoes and developed a framework for a National Volcano Early Warning System (NVEWS), with state-of-the-art volcano monitoring and 24/7 alerts (Ewert et al., 2005). Implementation of NVEWS is now the central goal of the VHP (DOI, 2011).

Landslides, Geomagnetism, and Marine Geology

USGS scientists working in the Landslide Hazards Program (LHP) assess landslide hazards, investigate landslides, monitor landslides in critical areas, provide technical assistance to respond to landslide emergencies, and engage in outreach activities. Relevant data and timely information are provided by the USGS National Landslide Information Center and in advisories issued in conjunction with the National Weather Service. The LHP has a unique, large-scale experimental facility for the study of mass flows used by scientists from around the world (Eichelberger, 2011).

The Geomagnetism Program focuses on real-time and long-term monitoring of the Earth's magnetic field. Its main activities include the operation of a network of 14 ground-based geomagnetic observatories in the United States and its territories; data management, processing and dissemination; and research to better understand geomagnetic processes and help mitigate adverse effects of magnetic storms on technological infrastructure in space and on the ground. The program is an integral part of the U.S. government's National Space Weather Program, whose observations, warnings, and forecasts are important for national security and the U.S. economy (see Love et al., 2008).

The Coastal and Marine Geology Program (CMGP) involves capabilities and activities in marine geology, geophysics, geochemistry, and oceanography—all aimed at providing information and research on both naturally occurring and human-induced changes in the coastal and marine environment. CMGP data, research, and assessments support efforts to deal with critical problems such as earthquake-generated tsunamis, hurricanes, and flooding (USGS, 2011e).

Current International Activities

The following review presents a representative, but not exhaustive, description of current international activities in the Natural Hazards mission area. Using Eichelberger (2011) as a starting point, it adds information from the USGS OIP (Withee, 2011), the DOI (2011), the USGS Natural Hazards website,[15] and other sources suggested by USGS research scientists during informal conversations.

[15]See www.usgs.gov/natural_hazards/.

Rapid Response to Foreign Hazard Crises (and Local Capacity Building)

U.S. government emergency assistance to other countries is facilitated and coordinated by the USAID Office of U.S. Foreign Disaster Assistance (OFDA). With support from and in partnership with OFDA, the USGS provides technical assistance overseas, when requested, in response to disasters caused chiefly by earthquakes, volcanoes, landslides, and tsunamis (Box 3.8). Two prominent USGS/OFDA programs for rapid response are the Volcano Disaster Assistance Program (VDAP), which has the only rapid-response volcano crisis team in the world, and the Earthquake Disaster Assistance Team (EDAT), modeled after VDAP. In developing countries, local capacity building is a key part of the process, generally continuing after the immediate crisis passes.

Recent EDAT activities include deployments to Mozambique and Malawi in 2008 and 2009, Indonesia in 2009, and Chile and Haiti in 2010 (Blanpied, 2010; Eichelberger, 2011; Mooney, 2011). VDAP deployments are credited with saving tens of thousands of lives, including recent VDAP activities in Huila, Colombia, and Chaiten, Chile, both in 2008, and in Merapi, Indonesia, in 2010 and 2011 (Eichelberger, 2011). During the 2010 Eyjafjallajökull volcanic eruption, USGS scientists provided advice to Iceland on radar imagery, held lead positions on a task force of the International Civil Aviation Organization dealing with ash/aviation issues, and worked with European colleagues and NOAA on improved ash cloud forecasting (Eichelberger, 2011).

The Landslide Hazards Program has worked through USAID/OFDA in responding to many foreign hazard crises—in Haiti, the Dominican Republic, China, Pakistan, and in Central American countries affected by Hurricane Mitch in 1998 (Eichelberger, 2011). The USGS also plays an important role in responding to foreign hazard crises as the leading U.S. link to the International Charter on Space and Major Disasters (Stryker and Jones, 2010).

Global Hazard Monitoring and Notification

Earthquakes. Perhaps foremost in USGS global hazard monitoring and notification—and typifying the involvement of the USGS in international science—is operation of the NEIC. Recognized as "the *de facto* international authority on earthquake notification for both U.S. and international stakeholders" (SESAC, 2007, p. 4), the NEIC is a primary partner of NOAA's Tsunami Program and is closely linked to NOAA's Pacific Tsunami Warning Center in Hawaii and West Coast/Alaska Tsunami Warning Center in Alaska.

The NEIC was significantly upgraded in FY 2005 and FY 2006 through a presidential tsunami warning initiative following the catastrophic South Asian tsunami of 2004. Upgrades included the implementation of 24/7 staffing, new software for faster identification and analysis of earthquakes worldwide, modern network security measures, and new

BOX 3.8
Rapid Response to Natural Hazard Crises Abroad and Local Capacity-Building

Under the auspices of the U.S. Agency for International Development's (USAID) Office of Foreign Disaster Assistance (OFDA), USGS scientists routinely provide technical assistance and disaster responses associated with earthquakes, volcanoes, landslides, and tsunamis in foreign countries. This involvement directly supports U.S. diplomacy and provides humanitarian benefits. In response to a request for assistance from a foreign government, USAID/OFDA and the USGS agree on scope and budget, USGS staff members are drawn as responders, and local experts work in collaboration with U.S. responders. Local capacity building, which is typically a part of emergency responses in developing countries, provides the benefit of reduced long-term need for U.S. disaster aid.

The Volcano Disaster Assistance Program (VDAP) has the only rapid-response volcano crisis team in the world, and was established after the disastrous eruption of Nevada del Ruiz volcano in Colombia that killed more than 23,000 people in 1985. In 1991, prior to a large eruption of Mount Pinatubo volcano in the Philippines, VDAP and Philippine scientists issued timely warnings that resulted in the safe evacuation of more than 75,000 people and saved of hundreds of millions of dollars by moving U.S. military aircraft and hardware at Clark Air Force Base out of harm's way (see also Box 1.2). VDAP scientists have since responded to volcano crises in Central and South America, the Caribbean, Africa, Asia, and the South Pacific.

The Earthquake Disaster Assistance Team (EDAT) is modeled after VDAP and was established in 2008. EDAT has been engaged in earthquake responses in Haiti, East Africa, and Indonesia (see Figure). The involvement of USGS scientists in natural hazard crises abroad has demonstrably resulted in scientific advances and lessons learned that are directly applicable in the United States.

FIGURE Technical assistance in U.S. government response to natural hazard crises abroad. *Left*: USGS/VDAP scientist discussing with Indonesian colleagues the impacts of pyroclastic flows on villages shortly after the eruption of Mt. Merapi volcano (Indonesia) in late 2010. *Right*: USGS/EDAT scientist and Haitian colleagues installing a digital seismograph in a school in Port au Prince following the magnitude 7.0 earthquake in Haiti on January 12, 2010. SOURCES: *Left*, courtesy of Tom Uhlman, Associated Press; *Right*, Sue Hough, USGS.

automated earthquake information products (NEHRP, 2007, p. 35). Rapid earthquake notifications are now delivered by e-mail and text message to over 175,000 users (DOI, 2011). In addition to these features, one of the NEIC's critical services is its automated PAGER system (for Prompt Assessment of Global Earthquakes for Response), developed with OFDA support (Box 3.9).

Volcanoes. Natural drivers for VHP international collaborations in volcano monitoring and notification (besides VDAP activities) are the geography of active U.S. volcanoes throughout a large part of the Pacific Basin (Ewert et al., 2005) and the potential impact of

BOX 3.9
USGS PAGER (Prompt Assessment of Global Earthquakes for Response)

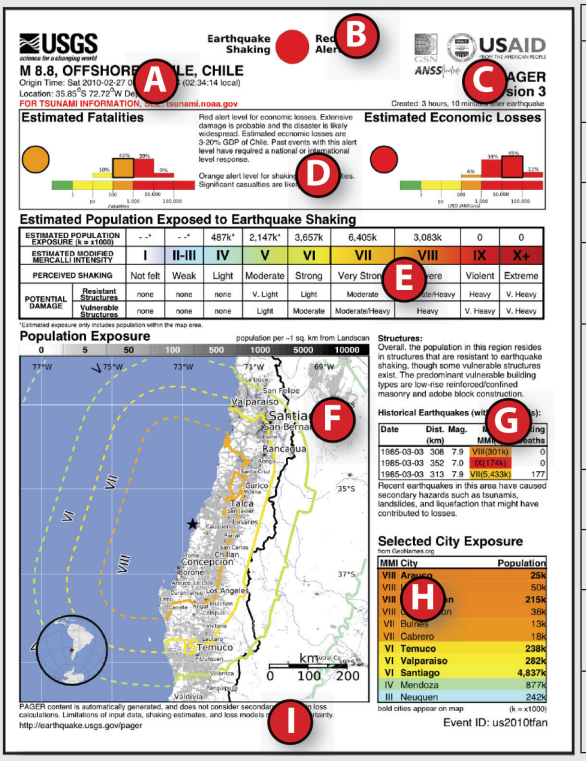
PAGER,[a] developed by USGS scientists at the Survey's National Earthquake Information Center (NEIC) in Golden, Colorado, is an automated alert system that produces information on earthquake ground shaking and loss estimates for rapid situational awareness. PAGER results, including a printable one-page report (see example below for the M 8.8 Chile earthquake in February 2010), are generally available within 30 minutes following significant earthquakes anywhere in the world—informing emergency responders, government and aid agencies, and the media (see Figure). PAGER is an example of a USGS international science activity that serves both U.S. Government international priorities and the Survey's domestic mission in natural hazard monitoring and notification.

FIGURE Damage to structures in downtown Concepcion, Chile, due to the February 27, 2010, magnitude 8.8 earthquake. For significant earthquakes, PAGER information helps guide emergency responders to areas that likely require priority attention (see image and table opposite). SOURCE: Walter Mooney, USGS.

[a]PAGER development and maintenance are supported by the U.S. Geological Survey under the Advanced National Seismic System, with additional funding from the Global Earthquake Model project and a grant from the U.S. Agency for International Development/Office of Foreign Disaster Assistance.

volcanic ash clouds on civil aviation, maritime activities, and meteorology. Relevant VHP international activities described by Eichelberger (2011) are (1) Pacific-wide coordination with volcano and seismic observatories, aviation authorities, and meteorological agencies in Russia, Japan, and Canada; (2) assistance to Russian scientists in establishing volcanic eruption response teams for Sakhalin Island and the Kamchatka Peninsula; and (3) work with international organizations to establish ash protocols, procedures, training, and research.

Geomagnetism. Distribution of the USGS Geomagnetism Program's 14 observatories extends to the Caribbean, Alaska, and the western Pacific Basin. The program's work is closely



LEGEND	
A	Summary of the basic earthquake parameters, including time, magnitude, location, and depth
B	Earthquake Impact Scale—summary alert level
C	Version of PAGER alert and time alert was created
D	Earthquake Impact Scale—alert levels for estimated fatalities (left) and estimated economic losses (right)
E	Table showing population exposed to different Modified Mercalli Intensity (MMI) levels of ground shaking and possible damage at different intensity scales for resistant and vulnerable structures
F	Map of MMI contours of estimated ground shaking
G	Region-specific structure and earthquake commentary
H	Table of MMI estimates for selected cities affected by the earthquake and their populations
I	Footer, including link to USGS PAGER Web page and event identification number

FIGURE One-page PAGER report on the February 2010 Chile earthquake. The table on the right describes the different, lettered sections of the one-page document which includes earthquake parameters, impact (fatalities and economic losses), population exposure, cities affected, and information on ground shaking.

coordinated with that of other foreign national programs through INTERMAGNET (the International Real-time Magnetic Observatory Network) and the International Association of Geomagnetism and Aeronomy (Love et al., 2008).

Global Hazard Analysis, Modeling, and Mitigation

Global Earthquake Model (GEM). Since 2006, USGS scientists have been involved in creating a vision and implementing a global partnership for using state-of-the-art models and tools for assessing earthquake risk worldwide to improve risk resilience and mitigation practices. The GEM[16] is a global, nonprofit, public-private partnership of more than 50 companies, institutions, and organizations from 26 countries, with a Secretariat based in Pavia, Italy. Benefits to the USGS include (1) a "seat at the table" when setting global standards for seismic hazard analysis and risk assessment, (2) the opportunity to use worldwide datasets and collaborate with international scientists in developing state-of-the-art models and tools, and (3) financial support for the participation of four USGS scientists and two USGS postdoctoral fellows.[17]

Mitigating Volcano Hazards. In the arena of international volcano hazard mitigation, USGS/VHP collaborations include (1) formation of a tri-national consortium with Japan and Russia to promote natural hazards science relating to Japan-Kamchatka-Alaska subduction processes; (2) participation in the Smithsonian's Global Volcanism Program, which seeks a better understanding of volcanoes from documentation of their eruptions during the past 10,000 years; and (3) co-convening an international forum with Italy to bring together world observatories to establish "Volcano Observatory Best Practices" (Eichelberger, 2011).

Cooperative Earthquake Research Programs with Japan and China

Two prominent USGS international activities involve EHP programs and scientists in cooperative earthquake research and development with Japan (Ellsworth, 2011) and China (Mooney, 2011). These highly successful endeavors, carried out under government-to-government agreements dating back decades, involve joint panels, meetings, and workshops; collaborative research on earthquake science and disaster mitigation; exchange of researchers and seismic technologies; and access by U.S. scientists to valuable seismological datasets that otherwise might be unavailable. The USGS also assists with the bilateral operation of 10 seismic observatories in China.

[16]See www.globalquakemodel.org/summary.

[17]M. Blanpied, USGS, Personal communication, March 18, 2011.

Value to USGS Domestic Mission

Natural hazard monitoring and the underlying science have become global. There are additional compelling arguments for the value of international activities and collaborations on earthquake, volcano, and landslide programs to the USGS domestic mission in the Natural Hazards mission area:

- International organizations and scientists drive the globalization of natural hazard monitoring, analysis, and mitigation practices and the science that underlies them (e.g., Eichelberger, 2011). USGS participation in, and in many cases leadership of, international activities relating to natural hazards help keep the USGS at the forefront of the state of knowledge and practice for domestic applications—and ensure USGS involvement in the adoption of international standards, formats, and best practices.
- The exercise of response capabilities to hazard events outside the United States greatly enhances USGS's ability to respond effectively to similar domestic events. An example is the exercise on readiness of USGS/NEIC staff to respond to earthquakes. From 2000 to 2010, NEIC staff rapidly located and provided notification for, on average, 160 earthquakes per year of magnitude 6.0 and greater worldwide—compared to an average of 7 such earthquakes per year in the United States.[18]
- The development, testing, and refinement of monitoring technologies in responding to international hazard crises directly serve the associated USGS mission. The development of new volcano-monitoring techniques in responding to volcano crises overseas, together with the experience gained by USGS scientists, can be applied by VDAP to future volcanic eruptions in the United States.[19] In earthquake monitoring, the escalation of NEIC activities after the catastrophic South Asian Tsunami of 2004 was a critical underpinning for the Advanced National Seismic System in the United States and led to 24/7 staffing at the NEIC, new automated response capabilities, enhanced earthquake information products such as PAGER, and robust continuity of operations.
- The participation of USGS scientists in responding to foreign hazard crises and in international collaborations has demonstrably resulted in scientific advances and lessons learned that are directly applicable in the United States. Relatively large inter-event times in the occurrence of large earthquakes and volcanic eruptions in the United States make each international case study greatly valuable for U.S. science, engineering, and hazard mitigation.

[18]Based on data from the USGS Earthquake Hazards Program website (available at earthquake.usgs.gov/).
[19]See volcanoes.usgs.gov/vhp/vdap.php.

- International collaborations such as the USGS cooperative earthquake research programs with Japan and China promote the exchange of research and technologies, and give U.S. scientists access to valuable seismological data that otherwise might be unavailable.

Relevance to U.S. National Interests

The USGS National Hazards mission area is replete with international activities that are relevant and beneficial to U.S. national interests:

- Under the auspices of USAID/OFDA, USGS rapid response to foreign disasters caused by earthquakes, volcanoes, landslides, and tsunamis directly supports U.S. diplomacy and provides humanitarian benefits. USGS foreign capacity building for hazard mitigation is a typical companion activity to the USAID/OFDA emergency responses and provides the added benefit of reduced long-term need for U.S. disaster aid.
- Continuous real-time global earthquake monitoring yields critical information for rapid situational awareness. Among the recipients of rapid information from the NEIC on potentially damaging earthquakes are the U.S. Coast Guard National Command Center, White House, DOD, DHS, DOI, DOE, DOS, and Department of Transportation offices for disaster services (DOI, 2011). The immediate availability of information on significant earthquakes in Afghanistan, western Pakistan, Iran, and various theaters of U.S. military operations is of direct relevance to U.S. national interests. Data from the Global Seismograph Network also contribute to Comprehensive Test Ban Treaty monitoring.
- Partnership of the NEIC with NOAA's Tsunami Program is vital for tsunami warnings in the Caribbean, the Pacific Basin, and other areas of U.S. government responsibility, military operations, and economic interest.
- Volcano monitoring and notification by the VHP are critical for advisories about the potential impact of volcanic ash clouds on civil and military aviation, maritime activities, and global meteorology.
- As an integral part of the U.S. government's National Space Weather Program, the ground-based magnetic observatories of the USGS Geomagnetism Program provide essential data for warnings and forecasts associated with "space weather" (conditions relating to the dynamic interaction of the Earth's magnetic field with the Sun). Space weather has global implications for the performance and reliability of space-borne and ground-based technological systems—ranging from satellite systems to electric power grids—and is vitally relevant to national security and the U.S. economy (Love et al., 2008; DOI, 2011).

- The USGS cooperative earthquake research programs with Japan and China support U.S. diplomacy in government-to-government protocol agreements and partnerships.
- USGS CMGP activities include membership in the U.S. Extended Continental Shelf Task Force, chaired by the DOS. The task force evaluates scientific data collected by USGS scientists to address the legally defined continental shelf that encompasses the oceanic basins in the Atlantic and Pacific (DOI, 2011).

WATER

Mission Area and Core Activities

Water plays a central role in the interactions and coupling of different components of the Earth system. The Survey addresses water in the context of local and regional hydrologic cycles that influence the way in which water can be used as a sustainable resource by providing reliable, impartial, timely information to understand the nation's water resources, including surface and groundwater systems. The quality and quantity of water in surface and groundwater is affected by human activity and natural causes and the mission of the USGS includes activities related to monitoring water quality and quantity. The primary activities of this mission area involve collection of basic water data through long-term monitoring and project-specific data gathering, data analysis, and basic research. The Survey organizes the Water program into seven areas: (1) Groundwater Resources, (2) National Water Quality Assessment, (3) National Stream Flow Information Program, (4) Hydrologic Research and Development, (5) Hydrologic Networks and Analysis, (6) Cooperative and (7) Water Program Water Resources Research Act Program.

The executive summary of the *U.S. Geological Survey Science in the Decade 2007–2017* sets forth the main direction for USGS water research under the title "A Water Census of the United States: Quantifying, Forecasting, and Securing Freshwater for America's Future":

> The USGS will develop a Water Census of the United States to inform the public and decision makers about (1) the status of its freshwater resources and how they are changing; (2) a more precise determination of water use for meeting future human, environmental, and wildlife needs; (3) how freshwater availability is related to natural storage and movement of water, as well as engineered systems, water use, and related transfers; (4) how to identify water sources, not commonly thought to be a resource, that might provide freshwater for human and environmental needs; and (5) forecasts of likely outcomes for water availability, water quality, and aquatic ecosystem health caused by changes in land use and land cover, natural and engineered infrastructure, water use, and climate. (USGS, 2007b, p. ix)

Current International Activities

Water availability is directly linked to climate change, countries' economies, and human existence. Climate change affects global precipitation patterns and groundwater and surface water systems. With increasing global economic interdependence, water has become an internationally-shared resource. Furthermore, human health is critically dependent on the quantity and quality of available water. Population growth and land-use changes associated with urbanization also affect the availability and management of water. Efforts to protect water as a resource and to ensure water sustainability present major scientific and technological challenges that require global knowledge.

The USGS, with its long history of research on all components of the hydrologic cycle, has a number of international research activities that contribute to understanding large river systems, flooding, groundwater availability and contamination, technology development, and aquifer assessments (particularly where aquifers cross one or more country borders). Some of the larger projects are (1) a sediment sampling and capacity-building project jointly performed with the Mekong River Commission, the USGS Louisiana Water Science Center (WSC), and the Office of Surface Water (part of the USAID/OFDA Asia Flood Network);[20] (2) instrumentation training in Chile with the USGS Idaho WSC;[21] (3) monitoring of Southern Africa flooding for OFDA;[22] (4) development of a groundwater model for the Egyptian Nubian Sandstone Aquifer System;[23] (5) groundwater resources research in West Africa (see e.g., Box 3.10); (6) Transboundary Aquifer Assessment Program, which includes collaboration with the Texas, New Mexico, and Arizona State Water Resource Research Institutes and neighboring Mexican states; and (7) a broad range of research on surface water, groundwater, and water quality as well as collaborative water monitoring projects with Canada.[24]

Value to USGS Domestic Mission

The Water science area engages in a broad spectrum of international activities that enhance and benefit USGS domestic programs. Opportunities to study water systems and challenges abroad increase USGS capability to fulfill domestic responsibilities such as the determination of freshwater availability; evaluation of water use; identification of water

[20] See "Asia Flood Network (AFN)," July 2006, available at pubs.usgs.gov/gip/130/pdf/GIP130.pdf; see also "The Office of U.S. Foreign Disaster Assistance," October 2006, available at www.usaid.gov/our_work/humanitarian_assistance/disaster_assistance/publications/prep_mit/mods/program_updates/asia_flood_network.pdf.

[21] See "USGS Hydroacoustics and Sediment Field Techniques Class, January 24–February 4, 2011, Coyhaique, Chile available at www.eula.cl/doc/Programa3.pdf.

[22] See www.usaid.gov/our_work/humanitarian_assistance/disaster_assistance/countries/south_africa/template/index.html.

[23] See www-naweb.iaea.org/napc/ih/IHS_projects_nubian.html.

[24] J. Eimers, USGS, personal communication, September 4, 2011.

BOX 3.10
Groundwater Resource Assessment, Cape Verde Islands, West Africa

The Cape Verde Islands off the coast of West Africa host volcanic aquifers where a lens of fresh groundwater overlies a layer of brackish water at the freshwater/saltwater boundary. Groundwater is needed by the islands for human consumption, as well as for agriculture and industry. If the amount of groundwater pumped from the volcanic aquifers increases too much, the brackish water or other contaminants can be drawn up into the freshwater zone and make the aquifer unsuitable for use. Similarly, drought or climate change can affect freshwater accessibility. The USGS conducted a study on Cape Verde to evaluate baseline groundwater conditions and provide information that could be used to help develop sustainable and clean water resources.

A study of three watersheds on three of Cape Verde's nine islands entailed data collection at varied water discharge points: wells, springs, streams, and direct submarine discharge to the ocean (see Figure). The data were used to assess groundwater budgets, travel time for rainfall through the watershed to the discharge point, depth to and vertical column of freshwater, and practical issues of potential contamination and freshwater drawdown due to pumping and the timing and potential for recharge of the freshwater aquifers.

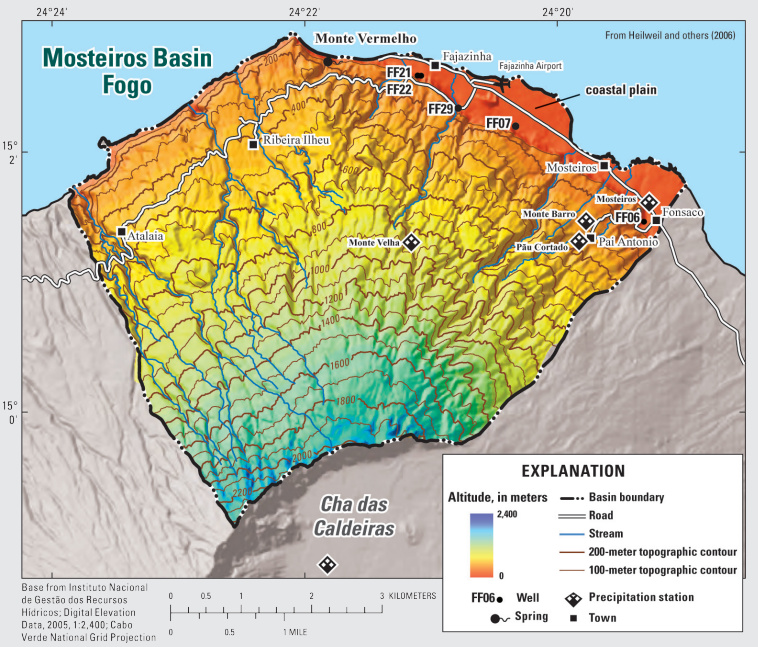


FIGURE Hydrologic map of the Mosteiros Basin, Island of Fogo, Cape Verde Islands showing the watershed area with streams, springs, wells, and precipitation stations. Information from research in this watershed was used to identify challenges to water resource managers on Cape Verde and options for monitoring to ensure sustainable water supplies.

SOURCE: Heilwel et al. (2010).

sources; and the forecasting of outcomes for water availability and relationships to ecosystems, human health, hazard mitigation, land use practices, and development of mineral and energy resources. The Survey shares this information with other federal, state, and local water resource managers responsible for surface and groundwater management and safety, land and resource management, mine reclamation, emergency preparedness, and public health.

Relevance to U.S. National Interests

Because water is tied to climate change, human health, and geopolitical peace within and among nations, any international activities associated with the management of water are relevant to the U.S. national interest. As water becomes a scarce resource, potential exists for conflicts to arise in parts of the world that may already be experiencing dry climates or drought (e.g., Middle East, East Africa). As a preeminent science leader in water science, the USGS has a major role in serving international humanitarian needs and promoting, supporting, and implementing U.S. foreign policy concerning water. The information and expertise the USGS derives from its international water projects thus contributes directly to work conducted by the DOS, USAID, and DOD in addition to international organizations such as the United Nations.

SUCCESSFUL INTEGRATON OF EXPERTISE FROM MULTIPLE USGS MISSION AREAS: THE AFGHANISTAN PROJECT

A multicomponent, interdisciplinary research project initiated by USGS scientists in Afghanistan beginning in 2005 involved research in coal, oil and gas, minerals, natural hazards, and water (see Box 3.11), and thus engaged scientists from four of the seven USGS mission areas: Core Science Systems, Energy and Minerals, Natural Hazards, and Water. The project was conducted in cooperation with Afghan scientists and research institutions to assess the potential for resources essential to Afghanistan's economic development and emphasized transfer of expertise in such areas as airborne geophysics and geospatial infrastructure development. A similar USGS project in Iraq, supported by the DOD Task Force for Business and Stability Operations,[25] involved an assessment of nonfuel mineral and water resources of the country, assistance with development of the Iraq National Spatial Data Infrastructure, and modernization of analytical laboratories.

The considerable investment of USGS staff time in such a wide-ranging endeavor over many years cannot be overestimated. In an effort to identify critical future international science opportunities for the USGS in Chapter 4, the committee considered the challenge for Survey management and staff to allocate the scientific expertise of their personnel to

[25]See iraq.cr.usgs.gov/.

BOX 3.11
USGS Projects in Afghanistan

The USGS has been active in a number of programs to assess Afghanistan's natural resources and hazards, develop its geospatial infrastructure, and build capacity and institutions essential to the effective transfer of skills. These programs are conducted by the USGS under the auspices of the USAID and the U.S. Department of Defense Task Force for Business Stabilization Operations, and in cooperation with the Afghanistan Geological Survey (AGS) and the Afghanistan Ministry of Mines and Industry (AMMI). The long-term goals of these activities are to provide data and, more broadly, to develop institutions necessary for the reconstruction and development of Afghanistan's economy, and to promote interest in investment and development. The activities conducted through this project address the following areas: coal resources, oil and gas resources, minerals, natural hazards, water, airborne geophysics, geospatial infrastructure development, and capacity building.

Coal resources: Afghanistan has moderate to potentially abundant coal resources. However, most deposits are relatively deep or currently inaccessible, and the scale of development has been limited. USGS scientists carried out comprehensive assessments of Afghanistan's coal resources beginning in 2005 in cooperation with the AMMI.

Oil and gas resources: USGS scientists collaborated with Afghan scientists to characterize Afghanistan's petroleum geology by obtaining and reviewing geochemical, geologic, seismic, tectonic, and petroleum exploration and production data. The Survey also collaborated with the AMMI to assess undiscovered oil and gas resources in northern Afghanistan.

Minerals: As part of reconstruction efforts, USAID funded a joint USGS-AGS cooperative study from 2005 to 2007 to assess nonfuel mineral resources of Afghanistan (Figure). USGS scientists worked closely with their AGS colleagues to compile information on mineral deposits, and to collect new data on potentially undiscovered deposits of non-fuel mineral resources in Afghanistan. As a result of such collaboration, a 2007 report was produced on a *Preliminary Assessment of Non-Fuel Mineral Resources of Afghanistan.*

Natural hazards: Afghanistan is located in a geologically active region with considerable seismic activity. With reconstruction efforts under way to rebuild infrastructure and develop natural resources, major construction plans and facility designs will need to consider the potential impact of natural hazards. Using data on the location, size, and frequency of previous earthquakes in Afghanistan and examining satellite data to locate potential fault lines, USGS researchers have created preliminary earthquake hazard maps.

Water: USGS scientists, in collaboration with the AGS and the Afghanistan Ministry of Energy and Water, collected hydrogeological data and developed data-collection networks in order to better understand and manage water resources.

continued

BOX 3.11 ***continued***

Airborne geophysics: USGS researchers used magnetic, gravity, radiometric, and electromagnetic technologies to gather geophysical surveys and produce high-quality datasets for selected minerals. Such data can aid the AGS in their role to assist Afghanistan in business development and investment decisions.

Geospatial infrastructure development: USGS scientists have worked with the AGS and AMMI to create an integrated GIS data framework to provide state-of-the-art maps and data. Such databases capabilities can equip AGS and AMMI with the ability to assess their natural resources and restore operations for their geosciences ministries.

Capacity building: The USGS Capacity and Institution Building Project involves the transfer of knowledge, skills, and expertise from USGS scientists to their Afghan counterparts and colleagues for assisting program development in various Earth science areas.

FIGURE Mountains south of Kabul, Afghanistan. Photo taken during fieldwork for the mineral assessment portion of the project.

SOURCE: Steve Ludington, USGS (afghanistan.cr.usgs.gov/).

domestic and international projects. In the case of the Afghanistan project, benefits to both U.S. national interests and foreign policy were clearly identified by the project sponsor.

CONCLUDING REMARKS

The Survey's portfolio of current and recently completed international science activities includes widespread projects that integrate information and data on natural resources, natural hazards, ecological systems, and environmental health with which authorities and decision makers can evaluate management or policy options. The projects range from satellite monitoring of droughts and floods in foreign countries to sampling of invasive species in their countries of origin, monitoring of volcanic activity around the globe, field mapping and sampling of foreign mineral resources, and evaluation of the interaction between water quality and human health. The results from these projects not only fulfill requests from federal agencies and other organizations that call on Survey expertise, but also benefit the Survey's domestic mission and U.S. national interests.

Although some international science projects draw on specific expertise from a single mission area—for example, the successful collaboration on earthquake research between the USGS and Japan and China—many international Earth science problems are best addressed by research that uses a systems approach. Such an approach yields more than one set of data and a broader suite of information for managers and decision makers. The Afghanistan project is one such example, as multiple datasets and analyses of a range of issues yielded a more complete foundation for addressing the country's resource potential and resource management. Such a project demonstrates the Survey's ability to draw on existing diverse expertise across its organization. Chapter 4 considers other types of international opportunities to make the most of USGS expertise and resources.

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CHAPTER FOUR

Strategic International Science Opportunities for the USGS

The USGS science strategy, *Facing Tomorrow's Challenges: U.S. Geological Survey Science in the Decade 2007-2017* (USGS, 2007), identified science directions for the Survey in addressing the increasingly severe challenges facing the nation. Seven science mission areas now guide research, mapping, monitoring, and assessment activities at the USGS for an ever-broadening range of projects domestically and internationally (see also Figure 1.1 and Chapter 3). The information and results from these projects have clearly been beneficial to the USGS and to U.S. government priorities across the breadth of Survey responsibilities.

The committee outlines below a series of international science opportunities that the USGS could pursue either on its own initiative or in cooperation with some of its U.S. agency partners and other domestic and foreign collaborators. These activities represent a reasonable extension and evolution of the activities summarized in the preceding chapter and correspond to emerging government priorities. The committee believes that the scientific merits of the projects described in this chapter are sufficiently strong to warrant USGS pursuit through annual appropriated funds, new funding initiatives, or in collaboration with external partners through reimbursable funds.

Having a portfolio of strategic international science projects, both active and in development, can be a constructive way for the USGS to position itself to anticipate and respond efficiently to external requests. Such a portfolio could also help mitigate the challenges that arise when USGS managers have to reallocate resources from existing projects to new projects in response to urgent requests from external partners.

The international science opportunities described in this chapter do not constitute an exhaustive list of possible endeavors. Some are new and would require development by USGS scientists and leadership; others are a direct result of, or would provide additional support for, successful ongoing international projects at the Survey. Most would benefit substantially from a systems approach (see Chapter 3) that would draw on expertise and

input from several USGS mission areas. All of the international scientific opportunities described meet the following criteria:

(1) they demonstrate clear means to leverage and benefit the scientific strengths and directions of the USGS and complement ongoing domestic activities; and
(2) they indicate strong potential for project results to increase the Survey's ability to meet needs of the U.S. government and the American public.

Guidance for USGS international activities that can benefit U.S. government international priorities is available from the U.S. Department of State (DOS) and U.S. Agency for International Development (USAID) in documents such as the 2010 *Quadrennial Diplomacy and Development Review* (DOS, 2010); the strategic plan for the DOS and USAID for 2007–2012 (DOS, 2007); Project Horizon of the Office of the Science and Technology Adviser to the U.S. Secretary of State (Project Horizon, 2006); and the *Final Report of the State Department in 2025 Working Group* (Advisory Committee for Transformational Diplomacy, 2008).

TOWARD AN OVERARCHING APPROACH IN INTERNATIONAL SCIENCE

A systems approach to scientific surveys of Earth processes is a viable and effective way to address the complex spectrum of interconnected, interdisciplinary problems affecting the Earth and its environment, including its burgeoning human population (see Chapter 3). For example, many scientific questions raised under the USGS Environmental Health mission area are inevitably affected by—and have feedback to—climate, ecosystems, water, energy and mineral extraction and use, and natural hazards, and they involve core science systems.

Taking this example further, a case could be considered where mineral resources are targeted for development in a given area of a country. In such an area, ensuring environmental and human health through sustainable, safe mining practices requires information about the commodities being extracted and processed; the amount and quality of water necessary to support mineral resource development and normal human and environmental activities; the ambient climate, which also can affect decisions about which extraction and processing technologies are used; and any effects of mining or mine waste on the surrounding ecosystem. Appropriate decision making about best approaches and practices in these circumstances requires access to a wide variety of data interpreted from the perspective of the entire lithosphere-hydrosphere-atmosphere-biosphere system at that potential mine site. This kind of information captured and interpreted through the lens of a systems approach is highly valuable for decision makers.

In another example of an Earth systems problem, land-use practices can affect human-induced changes to a local ecosystem and increase the risk of natural hazards. In some areas, land-use practices may contribute to the inability of the local topography to absorb seasonal rains that may themselves be increasing in intensity over historical levels. The result may be greater likelihood of debris flows and flooding, with attendant effects on local populations and ecosystems. Understanding this kind of Earth system, and developing corresponding datasets for monitoring and analysis, is relevant and necessary for effective hazard abatement.

In the committee's view, the USGS has adopted a wise course in restructuring its strategic science efforts to encourage more interdisciplinary work and its adoption of an Earth systems approach to address societal issues within its mandate. International science work is typically well suited to employing a systems approach because the scientific problems are frequently not only multidisciplinary but also multifaceted, including socio-cultural and geopolitical dimensions. Furthermore, once the decision has been made to conduct research in another country, combining different types of data collection and monitoring—for different parts of the Earth system being examined—can often maximize the return from the investment of personnel and other resources.

INTERNATIONAL SCIENCE OPPORTUNITIES

Box 4.1 lists compelling international science opportunities identified by the committee. Some of these opportunities require input and participation from scientists with expertise from several USGS science areas, in effect calling for a systems approach; others are directed to one of the seven mission areas. Where practical, other potential federal partners (outside the Department of the Interior) are also indicated, although the committee does not offer suggestions on the mechanics of interagency engagement on international projects. These opportunities and their anticipated impacts and effects are grouped into two categories: (1) those that complement or extend current international science activities at the USGS in science areas that have traditionally had active and successful international projects; and (2) those that have not yet, to the committee's knowledge, been conducted by Survey scientists but that fit well within the context of the Survey's science strategy and recent restructuring. The committee has not assigned priorities to these opportunities, considering all of them to be of high value and with the promise of excellent return to support U.S. government interests and national needs.

Importantly, "capacity building" was cited as a key component of most international projects in discussions with USGS international partners and USGS scientists. Although described explicitly in only a few of the opportunities listed below, the committee urges the USGS to explore ways to implement capacity building in its international projects to help sustain U.S. impact and influence abroad.

BOX 4.1
Future International Science Opportunities for the USGS

Opportunities that Complement Existing International Science Activities

1. **Global natural hazards planning and response.** Strategic opportunities chiefly lie in *increasing* USGS involvement in three areas:
   a. *The Global Earthquake Model (GEM) international partnership.* Such involvement would provide direct benefits in advancement of state-of-the-art earthquake science, potential progress in earthquake forecasting, and the development and refinement of methodologies and uniform standards for earthquake hazard and risk assessment.
      Target locations: Earthquake-prone locations around the world.
      Primary collaborations among USGS mission areas: Natural Hazards and Core Science Systems.
      Potential federal partners: Department of State (DOS), Federal Emergency Management Agency (FEMA), National Oceanic and Atmospheric Administration (NOAA), U.S. Agency for International Development (USAID).
   b. *The Volcano Disaster Assistance Program (VDAP) in concert with other global volcano-hazard initiatives.* Monitoring and analysis of global volcanic hazards can help reduce the potential human and economic impact of major volcanic eruptions, including the likelihood of widespread disruption of civilian aviation.
      Target locations: Volcanically active locations around the world.
      Primary collaborations among USGS mission areas: Natural Hazards and Core Science Systems.
      Potential federal partners: DOS, NOAA, National Aeronautics and Space Administration (NASA), Department of Transportation, USAID.
   c. *Global earthquake monitoring and rapid notification activities.* Prospects exist for continually improving earthquake monitoring and rapid notification, with fundamental importance to U.S. domestic and international humanitarian and economic interests. Companion opportunity: capacity building to support collaborating seismic network operators in developing nations.
      Target locations: Earthquake-prone locations around the world.
      Primary collaborations among USGS mission areas: Natural Hazards and Core Science Systems.
      Potential federal partners: Department of Defense (DOD), DOS, NOAA, NASA, USAID.
2. **Global energy and mineral resource assessments.** Six areas emerged as particularly compelling for the USGS to pursue in this category, building on the Survey's current successful international work in these areas. The activities will enhance the United States' capability to monitor and understand its use and import of energy and mineral resources relative to global and domestic supplies, and thus contribute to national security and economic growth.
   a. *New oil and gas resource assessment projects in international onshore and offshore areas.*
      Target locations: Onshore Asia, Africa, and South America; offshore continental shelves of

Africa, Asia, and the polar regions; and expansion to other countries and areas as resource interests warrant.
Primary collaborations among USGS mission areas: Energy and Minerals; Climate and Land-Use Change; Core Science Systems.
Potential federal partners: DOD, Department of Energy (DOE), NOAA, USAID

b. *Research on global gas hydrate occurrences.*
Target locations: Onshore Arctic Russia and Canada; offshore Japan, China, India, Chile.
Primary collaborations among USGS mission areas: Energy and Minerals; Climate and Land-Use Change; Ecosystems; Core Science Systems.
Potential federal partners: DOD, DOE, NOAA

c. *Research and development of global geothermal resources.*
Target locations: Iceland, Germany, Switzerland, France, Italy, Norway, Sweden, Russia, Japan, Australia, New Zealand, Mexico, the Caribbean, and Southeast Asia
Primary collaborations among USGS mission areas: Energy and Minerals; Climate and Land-Use Change; Core Science Systems.
Potential federal partners: DOD, DOE

d. *Quantification of the supply and demand for, and foreign dependence on, important minerals with targeted application of mineral life-cycle analysis.*
Target locations: Countries in which minerals originate as raw ores and are processed, manufactured, transported, and/or recycled.
Primary collaborations among USGS mission areas: Energy and Minerals and Core Science Systems.
Potential federal partners: Department of Commerce (DOC),[a] DOD, DOE, DOS, Environmental Protection Agency, USAID

e. *Research in the global location, geologic origins, age, size, production, and consumption of conflict minerals.*
Target locations: Current focus areas are in Africa. As new international conflicts arise, other nations may become target areas for this kind of research.
Primary collaborations among USGS mission areas: Energy and Minerals and Core Science Systems.
Potential federal partners: Department of Commerce (DOC), DOD, DOE, DOS, USAID

f. *Capacity building: scientific assistance to nations to identify and develop mineral resources in ways that are sound for human and environmental health and economic development.*
Target locations: Focus areas could be determined in a collaborative way with other U.S. government agencies, the United Nations, other national geological surveys, and developing nations.
Primary collaborations among USGS mission areas: Energy and Minerals; Environmental Health; Water; Ecosystems; and Core Science Systems.
Potential federal partners: DOC, DOD, DOE, DOS, USAID

continued

BOX 4.1 ***continued***

3. **Enhanced water sustainability research in desert regions and tropical areas.** Many areas of the world, including the United States, have regions where the hydrologic cycle operates at extremes—with either very low or very high precipitation. Changes to these cycles occur as a result of the effects of climate change and land use, and research is required to understand the extent of these changes, how they affect ground- and surface water supplies, and how water resources may be managed.
   Target locations: Ethiopia, Haiti, Horn of Africa, Mozambique, Pakistan, Afghanistan, Iraq, Philippines, various areas of the Middle East.
   Primary collaborations among USGS mission areas: Water; Climate and Land-Use Change; Ecosystems; Core Science Systems.
   Potential federal partners: DOD, DOS, NASA, NOAA, USAID

New Opportunities

1. **Use of climate and land-cover science for decisions on climate adaptation and natural resource management.** Adaptation to climate change and effective natural resource management are intertwined. Climate and land-use change research makes a key contribution to informing decisions in both realms, particularly when regarding landscapes as systems. International hydrologic monitoring could be a key aspect of this opportunity.
   Target locations: High-latitude areas and semi-arid or arid areas.
   Primary collaborations among USGS mission areas: Climate and Land-Use Change; Energy and Minerals; Water; Core Science Systems.
   Potential federal partners: U.S. Department of Agriculture (USDA), NOAA, NASA, National Science Foundation (NSF)
2. **Understanding the influence of climate change on ecosystems, populations, and disease emergence.** As climate changes, the distribution and abundance of plants, animals, and insects shift in response. Such changes could directly impact biological resources in the United States and play a role in disease ecology and emergence. The USGS is already involved in understanding such changes domestically through the U.S. Global Change Research Program, and the Survey's high-level capabilities in geospatial technology and information management combined with climate and ecosystem expertise would allow it to contribute significantly in understanding global ecosystem responses to climate change.
   Target locations: transboundary ecosystems, ecosystems represented currently in limited spatial extent in the United States but more widespread elsewhere and believed to represent future environmental conditions in the United States.
   Primary collaborations among USGS mission areas: Climate and Land-Use Change; Ecosystems; Environmental Health.
   Potential federal partners: USDA, DOI, CDC, NASA
3. **Clarification and development of invasive species work using trade patterns, refugee situations, and changing climate and environment for initial prioritization.** As global trade and travel continue to rise, research on the accompanying and increasing

influx of invasive species and infectious diseases can inform decisions about mitigating the impacts of invasive species and infectious diseases on the United States.
Target locations: Countries of origin of invasive species.
Primary collaborations among USGS mission areas: Ecosystems; Climate and Land-Use Change; Core Science Systems.
Potential federal partners: USDA, DOC, DOD, DOS, NSF, Centers for Disease Control and Prevention (CDC)

4. **Quantitative health-based risk assessment using hazard identification, exposure assessment, dose-response assessment, and risk characterization.** When focused on a particular ecosystem, ecological risk assessment can help identify vulnerable resources and evaluate the adverse effects of human activities and pollutants on the ecosystem.
Target locations: All regions of the world.
Primary collaborations among USGS mission areas: Environmental Health; Ecosystems; and Water.
Potential federal partners: CDC, DOS, EPA, NSF, USAID
5. **Ecological and quantitative human health risk assessment analysis based on contaminant exposure levels.** Quantitative ecological and human risks based on contaminant exposure levels, especially in regions from which food products are shipped to the United States, could help evaluate health risks to U.S. citizens and inform decisions about regulations.
Target locations: Regions from which foods and food products are shipped to the United States.
Primary collaborations among USGS mission areas: Ecosystems; Environmental Health; and Water.
Potential federal partners: CDC, DOC, DOT, DOS, NSF
6. **Research in water contamination and supply.** Strategic opportunities chiefly lie in developing new levels of involvement by the USGS in three areas:
   a. *Reduction of water contamination risk from natural and anthropogenic causes.* Research in this area would aid in understanding the fundamental geochemical and biochemical processes that contribute to groundwater contamination problems.
   Target locations: Bangladesh, Thailand, China, India, much of Africa.
   Primary collaborations among USGS mission areas: Water; Environmental Health; and Ecosystems.
   Potential federal partners: DOS, USAID
   b. *Water supply management.* Establishing scientific foundations to deal with uncertainty of discharge measurements and joint development of instrumentation for monitoring water systems. See also New Opportunity (1), above.
   Target locations: China, Europe, most of Africa.
   Primary collaborations among USGS mission areas: Water; Ecosystems; Climate and Land Use Change; and Core Science Systems.
   Potential federal partners: DOD, DOS, NSF, USAID

continued

BOX 4.1 ***continued***

c. *Modeling and managing fossil aquifers in vulnerable environments.* Fossil aquifer systems can be very extensive in area and are often a critical, non-renewable supply of water in regions that do not have extensive rainfall. In some countries experiencing a concentration of the population due to civil conflict, high local demand for water can result. Survey experience could contribute to better management of these finite water supplies for vulnerable populations.
Target locations: Sudan, Afghanistan.
Primary collaborations among USGS mission areas: Water; Ecosystems; Environmental Health; Climate and Land Use Change; and Core Science Systems.
Potential federal partners: DOD, DOS, NSF, USAID

7. **Water and ecological science in cold regions sensitive to climate change.** Warming in areas of permafrost may have impacts on the climate. Mitigation of these impacts requires research on the interactions and feedbacks of water, ecosystems, and climate.
Target locations: Antarctica, Canada, Russia.
Primary collaborations among USGS mission areas: Water; Ecosystems; Climate and Land Use Change; and Core Science Systems.
Potential federal partners: NASA, NOAA

8. **Comprehensive enhancement of, and accessibility to, essential topographic and geologic map information through the following:**
   a. *Improved and accelerated global coordination and enhancement of topographic mapping.* Mapping is required for all place-based business, for smart-phone access to all georeferenced information, and for efficiency and effectiveness in all resource, security, public health, and heritage activity.
   Target location: The world.
   Primary collaborations among USGS mission areas: Increased engagement with partners through global mechanisms such as the Open Geospatial Consortium (OGC) and the International Steering Committee for Global Mapping (ISCGM).
   Potential federal partners: NASA, NOAA, USDA
   b. *Rapid acceleration of the reconciliation and accessibility of geologic mapping.* Geologic mapping is essential as the context for all Earth science activity.
   Target location: The globe.
   Primary collaborations among USGS mission areas: Participants in the OneGeology project, particularly the International Union of Geological Sciences Commission for the Management and Application of Geoscience Information.
   Potential federal partners: USDA, NSF, NASA, NOAA

[a] The committee distinguishes here between NOAA, which is part of the DOC, and other parts of DOC that may have relevant activities specific to one or another science opportunity (e.g., the Bureau of the Census or those parts of DOC that monitor international trade). References to "DOC" are to generally relevant parts of the organization that do not include NOAA.

Opportunities that Complement or Enhance Existing International Activities

1. Global Natural Hazards Planning and Response

The strategic interest of the DOS and USAID most relevant to the USGS Natural Hazards mission—besides the general promotion of science and technology as an integral component of U.S. diplomacy—is global hazards planning and response. For the "mid- to long term (5-10-15 years and beyond)," information shared with the committee emphasized (1) the critical problem of megacities (urban agglomerations of 10 million or more) in regions vulnerable to earthquakes and other natural hazards and (2) the importance of USGS involvement in successfully reducing disaster risks and impacts (Reynolds, 2011).

To a significant extent, the USGS has already self-identified and is pursuing many international activities consistent with the priorities of the Natural Hazards mission area (described in Chapter 3). Future strategic opportunities chiefly lie in *increasing* the level of involvement in activities with a high potential to benefit both USGS and U.S. government interests. The committee highlights three such opportunities:

a. USGS involvement in the Global Earthquake Model (GEM)

USGS scientists have played a pivotal role in establishing the Global Earthquake Model[1] (GEM) international partnership. In late 2011, the United States became a formal member of the consortium as a "public participant" with representation on GEM's Governing Board. Taking advantage of this new development, greater USGS involvement in GEM could lead to a host of benefits for USGS and U.S. government interests, including the advancement of state-of-the-art earthquake science, potential progress in earthquake forecasting, the development and refinement of methodologies and uniform standards for earthquake hazard and risk assessment, and greater familiarity with data and problems in earthquake-prone regions around the world. The USGS could also consider replicating successful aspects of GEM to address other natural hazards that ideally involve international collaboration and coordination, such as volcano hazards. The GEM model may also be appropriate for other federal agencies working in the hazards area to consider—for example, NOAA might consider a GEM approach to mitigating tsunami hazards with international partners.

The Quadrennial Diplomacy and Development Review of DOS and USAID (DOS, 2010) underscored the need for the United States not only to keep up with but to stay ahead of change affecting international affairs. In the arena of global earthquake hazards, increased USGS involvement in the GEM international partnership would be an effective and proactive way to do this.

[1]See www.globalquakemodel.org/summary.

b. Enhancement of VDAP in concert with other global volcano-hazard initiatives

The USGS Volcano Disaster Assistance Program (VDAP) is heralded by USAID's Office of Foreign Disaster Assistance (OFDA) as an exemplary success story in U.S. government emergency assistance to developing countries, and the program fits squarely in the realm of global hazards planning. The geographic extent of active volcanoes around the globe and the human and economic impacts of major volcanic eruptions, including the potential for widespread disruption of civilian aviation, make a compelling argument for enhancing VDAP in concert with other global volcano-hazard initiatives (Eichelberger, 2011), such as the Smithsonian's Global Volcanism Program and international collaboration to establish Volcano Observatory Best Practices.

Implementation of the Survey's National Volcano Early Warning System (NVEWS; see Ewert et al., 2005; DOI, 2011) may also be considered integral to USGS international activity in this area. First, hazardous U.S. volcanoes affect a large area of the western United States (including Alaska) and the Pacific Basin, effectively making NVEWS international in scope. Second, aspects of NVEWS such as state-of-the-art volcano monitoring, 24/7 alerting, and the improvement of forecasting capabilities for volcanic eruptions will benefit VDAP and the other global initiatives.

c. USGS commitment to global earthquake monitoring and rapid notification

The committee has described the operation of the USGS National Earthquake Information Center (NEIC) and the development of its automated Prompt Assessment of Global Earthquakes for Response (PAGER) system as outstanding successes in USGS global hazard monitoring and notification (see Chapter 3). The fundamental importance of earthquake monitoring and rapid notification to U.S. domestic and international interests, coupled with the high visibility and prospects for improvement of such monitoring and notification activities, all argue for pursuing these activities as a high-priority, strategic international opportunity for the Survey. The committee emphasizes key points made by Eichelberger (2011): Natural hazard monitoring and the underlying science have become global, and international organizations and individual scientists are driving the globalization of monitoring, analysis, and mitigation practices.

Based on its 2007 strategic plan, the USGS is already committed to establishing robust monitoring infrastructure and implementing new and emerging technologies for network communications and the rapid, useful dispatch of hazards information (USGS, 2007, pp. 32–33). Greater USGS involvement in GEM is a natural complement. A companion opportunity for the USGS in global earthquake monitoring and rapid notification, whether as part of GEM or separately, is capacity-building to help seismic network operators in developing nations improve their network operations and learn how to use and contribute to rapid earthquake information products as part of a global endeavor. Earthquake Disaster

Assistant Team (EDAT) deployments under USAID/OFDA auspices, such as in Haiti (Box 3.8), exemplify both needs and opportunities for the USGS to expand such activities.

2. Global Energy and Mineral Resource Assessments

The USGS is uniquely qualified in the federal government to provide assessments of energy and mineral supply and demand and their uncertainty (see e.g., NRC, 2008). Because most of the importation of much of the nation's oil and nonfuel mineral supplies from overseas, scientific data, analysis, and knowledge acquired through international projects addressing energy and mineral resources are of paramount importance for the United States. The USGS has the necessary expertise to conduct this kind of work in concert with other federal agencies. The following six international opportunities stand out as particularly compelling for the Survey to undertake in that they build upon existing international and domestic projects and results. Although they rely on specific expertise within the Energy and Minerals mission area, many of these international opportunities can also benefit from collaboration with other mission areas at the USGS (see Box 4.1).

a. New oil and gas resource assessment projects in international onshore and offshore areas

As part of its continuing work with the World Energy Project, the USGS Energy Program has examined specific areas of the globe with respect to undiscovered oil and gas resources (see Chapter 3). The committee supports the continued definition and planning of new assessment projects in target areas of Asia, Africa, and on the continental shelves, where understanding of conventional and unconventional oil and gas resources could inform policy and decision makers, the science community, the private sector, and the general public. Maintaining and updating data and information for previously completed assessments is also encouraged.

b. Research on global gas hydrate occurrences

The USGS has been an active participant in international projects to study gas hydrate occurrences and the committee supports continued Survey participation in these projects in permafrost environments onshore (Canadian and Russian Arctic) and on the continental shelves (with Japan, India, Chile, and others). Enhanced understanding of gas hydrate as a potential energy resource and its effects on the environment remain important issues for the U.S. government and for industry (NRC, 2010).

c. Research and development of global geothermal resources

Geothermal energy resources are an important part of the renewable energy portfolio of the United States. Involvement in the research and development of geothermal resources overseas would enable access to valuable data to inform geothermal research

and development of new geothermal energy projects in the United States. The committee supports ongoing work by the USGS with its federal and foreign partners in Iceland, France, Russia, and Japan to plan scientific experiments related to geothermal energy and its development as an energy resource. In addition, Australia, New Zealand, Mexico, the Caribbean, Southeast Asia, Germany, England, Switzerland, Italy, and Sweden have active geothermal projects and energy production in enhanced geothermal and hydrothermal systems. Strategic collaboration with other federal agencies, industry, and foreign government agencies on geothermal experiments in some of these nations could complement USGS domestic work in areas such as heat flow and hydrologic characteristics determined from research wells, possibilities for induced seismic activity related to resource development, and assessments for power production. These kinds of data and analysis are important for industry actors and other federal agencies in promoting sound development of domestic geothermal resources.

d. Quantification of supply and demand for, and foreign dependence on, important minerals with targeted application of mineral life-cycle analysis

Most current technologies have central components that rely on a variety of minerals for operation and performance efficiency. Many of these minerals are not produced in the United States for reasons including geologic availability, social and environmental factors, land-use and land management constraints, and economics (e.g. NRC, 2008). The U.S. government and industry require reliable, independent, scientifically sound data and assessments of global mineral resources and reserves to gauge supply and demand, dependence on foreign sources, the likelihood of supply or demand disruptions or material changes, the impact on the U.S. economy and security, and the potential to explore or mine specific minerals domestically.

A "life-cycle" analysis examines a mineral or its component element(s) from its origins in an ore deposit through its extraction and processing to its incorporation in a manufactured product and eventual disposal or reuse through recycling. This kind of approach is time-consuming because there are many sources of necessary data; such analysis requires a thoroughly global approach, based on the countries in which the minerals may be mined, processed, manufactured, and transported to market, as well as interaction with other federal agencies and relevant data they may collect on imports and exports, manufacturing activities, and other information. Life-cycle analysis could include examination of nations or regions where the private mining sector is very active and considerable data are already available, and those where mineral resources exist but the knowledge and data are sparse.

e. Research on the global location, geologic origins, age, size, production, and consumption of conflict minerals

The sale and purchase of conflict minerals (e.g., in Africa) is of concern to the U.S. government and international organizations such as the United Nations. The USGS has

been engaged in supporting scientific efforts to address and curb the supply of these minerals and the committee considers these opportunities appropriate for continued and more advanced work. The USGS can be at the forefront in assisting the U.S. government in maintaining knowledge of important mineral resources through targeted examination of these minerals in their geological and political settings overseas. As part of the work in both opportunities (d) and (e), periodic review of USGS methodologies for mineral resource assessments is important as more data and better understanding of mineral resources are acquired.

f. Capacity building: scientific assistance to nations to identify and develop mineral resources

In efforts to build capacity overseas and to promote science diplomacy, the provision of assistance to developing nations to explore for, identify, and develop mineral resources can support their steps toward establishing a source of income and thus a stronger economy. The increasing international focus on resource development that is also sensitive to concerns for human and environmental health makes this research opportunity particularly relevant to several mission areas at the USGS in addition to Energy and Minerals (see Box 4.1). Because this type of information is directly used by U.S. and international agencies with responsibilities for aiding development in other countries, the countries targeted for analysis would best be determined in a collaborative way with other U.S. government agencies (e.g., DOS, USAID), the United Nations, other national geological surveys, and developing nations.

3. Enhanced Water Sustainability Research in Desert Regions and Tropical Areas

Regions across the globe experience hydrologic cycle extremes with chronic water shortages in desert areas and high precipitation in tropical regions. These cycles are changing as a result of the effects of climate change and land use. Research to understand the extent of these changes, their effects on ground- and surface water supplies, and methods to improve water resource management is important in many nations, including the United States. USGS water supply projects in Darfur and Afghanistan serve U.S. interests and other Survey activities contribute information and data to USAID contracts (e.g., Iraqi Marsh Restoration Projects). Such assistance can provide guidance to the World Bank for project scoping and to the DOD and private sector for related activities that promote U.S. interests abroad. USGS is currently involved in water related activities in Pakistan, Afghanistan, Iraq, India, Abu Dhabi and elsewhere in the Middle East, Ethiopia, and Philippines (IAEA IWAVE Project). The committee supports these as opportunities the USGS would do well to continue, potentially at an enhanced level of activity. Their pursuit would benefit both the Survey and the nation.

New Opportunities

1. Use of Climate and Land-cover Science for Decisions on Climate Adaptation and Natural Resource Management

The USGS Global Change Science Strategy (GCSS) report (Burkett et al., 2011) highlights six goals to improve understanding of

- rates, causes, and impacts of past global changes;
- the global carbon cycle;
- land-use and land-cover change rates, causes, and consequences;
- droughts, floods, and water availability under changing land use and climate;
- coastal response to sea level rise, climatic hazards, and human development; and
- biological responses to global change.

These goals align with the aims of many global change research programs domestically and worldwide, and all require international collaboration. As climate change intensifies, the need for expertise in climate adaptation and resource management will also grow internationally, and the USGS has the relevant expertise to take advantage of this opportunity. The Survey has a strong record of providing integrated scientific information for resource management and the GCSS goals also represent a call for the USGS to maintain recognized expertise in international climate science. The USGS could increase its capabilities to use climate and land-use science for decisions on natural resource management and could expand into areas overseas, particularly where both the vulnerability and the risk associated with climate change are greater than in the United States. The USGS' broad experience in hydrologic monitoring, for example, could potentially be used in a collaborative way to provide international hydrologic data that is relevant for climate analysis. The USGS National Streamflow Information Program and National Water-Quality Assessment Program (NAWQA) could serve as models for similar data that might be collected and shared internationally.

High-latitude systems might serve as "sentinels" for changes likely to impact high-elevation ecosystems in the United States, and semiarid or arid systems elsewhere in the world may be harbingers of what is to come for U.S. semiarid ecosystems. Such efforts could build on current approaches (e.g., FEWS NET, NAWQA; see also Chapter 3) and provide information to help other federal agencies determine appropriate responses to areas around the globe where environmental degradation and potential conflicts over resources could threaten political stability. This high level of experience will benefit the eight region-

ally based DOI Climate Science Centers in the United States (five of which have been awarded as of summer 2011).

2. Understanding the Influence of Climate Change on Ecosystems, Populations, and Disease Emergence

The USGS could play a crucial role in providing information that indicates the geographic distribution and seasonal variation of infectious diseases and determining whether evidence points to linkages with climate and weather. The 2001 NRC report *Under the Weather: Climate, Ecosystems, and Infectious Disease* identified numerous federal agencies including the USGS that needed to take a critical role in furthering the understanding of the relationship between climate, ecosystems, and infectious diseases. The report provided recommendations for future research and surveillance and identified the need "to foster interdisciplinary work in applying remote-sensing and GIS technologies to epidemiological investigations" (NRC, 2001, p. 7).

USGS expertise in this area would be beneficial specifically for

- using satellite-based remote sensing to provide data on ecological conditions; and
- developing GIS analytical techniques to assist in epidemiological investigations that would provide data on the distribution of pathogens and their ecological niches.

3. Clarification and Development of Invasive Species Work

The substantial commitment of the USGS to invasive species work was not detailed explicitly in the information the committee reviewed. Clear formulation of the USGS work in this area could highlight the value of international projects regarding invasive species. In particular, the USGS would benefit from prioritizing its invasive species work according to

- trade patterns
- refugee situations
- changing climatic and environmental conditions

Such a prioritization could help to indicate the most likely sources of novel introductions of invasive species. Basic biology of and management options for invasive species in the United States could also be achieved by studying them in their original overseas ranges. Initial work in this area would most naturally occur in the Ecosystems; Climate and Land-Use Change; and Core Science Systems areas.

4. Quantitative Health-Based Risk Assessment Employing Hazard Identification, Exposure Assessment, Dose-Response Assessment, and Risk Characterization

Health-based risk assessment consists of four basic steps (Box 4.2). The process can also be used to conduct ecological risk assessments. When focused on a particular ecosystem such as a watershed, the ecological risk assessment process can be used to identify vulnerable and valued resources and to evaluate the adverse effects of human activities and pollutants on plants and animals in the ecosystem.

The USGS can play a critical role in human and ecological risk assessments by providing exposure data on

- chemical and pathogenic contaminants in air, dusts, and soils;
- chemical and pathogenic contaminants in drinking water;
- human consumption of bioaccumulative contaminants;
- vector-borne and zoonotic (transmitted between animal and human) diseases; and
- contaminant exposure through recreational waters.

For example, in terms of a systems approach, global change, ecosystems, and water all impact the range and habitat of microbial infectious disease. In many areas, human activity directly affects the magnitude of exposure to environmental pathogens, as in the case of

BOX 4.2
The Risk Assessment Process

Hazard identification: Defining the hazard and nature of the harm; for example, identifying a chemical contaminant, such as lead or carbon tetrachloride, and documenting its toxic effects on humans.

Exposure assessment: Determining the concentration of a contaminating agent in the environment and estimating its rate of intake in target organisms; for example, determining the concentration of arsenic in groundwater and determining the dose an "average" person would receive.

Dose-response assessment: Quantifying the adverse effects of exposure to a hazardous agent based on the degree of exposure. This assessment is usually expressed mathematically as a plot showing the response in living organisms to increasing doses of the agent.

Risk characterization: Estimating the potential impact of a hazard based on the severity of its effects and the amount of exposure.

SOURCE: Pepper et al. (2006)

the voluntary risk associated with a decision to drink water that may or may not be fecally contaminated. In other situations, whole communities in the United States could be exposed to pathogens of international origin as in the case of the involuntary risk associated with Asian flu pandemics that occur in certain areas because of prevailing trade winds. Climate change and changes in ecosystems due to urbanization and deforestation can also impact the scope of microbial infectious disease. Table 4.1 documents recent El Niño enhanced microbial infectious disease as one example. The USGS is already involved and will likely continue to be involved in international activities focused on microbial infectious disease.

Of particular importance are data on emerging chemical contaminants such as endocrine disruptors and emerging microbial contaminants including viruses and biological hazards such as infectious prions. National laboratories (e.g., Argonne National Laboratory), other federal agencies (e.g., the Centers for Disease Control and Prevention [CDC], Environmental Protection Agency), and schools of public health are engaged in various aspects of this kind of research, which may elucidate possibilities and advantages of collaboration for the USGS on international projects in these areas (see also Chapter 3).

5. Ecological and Quantitative Human Health Risk Assessment Analysis Based on Contaminant Exposure Levels

Currently no state or federal regulations in the United States define acceptable levels of waterborne pathogens such as *E. coli* in surface waters used for irrigation of vegetables. Therefore, the extent of waterborne disease resulting from potentially contaminated irrigation water is unknown. Data on contaminant levels in surface waters in Mexico would provide exposure estimates that, coupled to dose response parameters, could provide a quantitative microbial risk assessment for these waterborne agents. In collaboration with the CDC and the World Health Organization, the USGS could conduct a survey of quantitative ecological and human risks based on contaminant exposure levels, in particular in regions from which food and food products are shipped to the United States. Two major outcomes of such a study would be (1) an evaluation of the risk to U.S. citizens of infec-

Table 4.1 El Niño Enhanced Microbial Infectious Disease Outbreaks

Country	Disease
Peru, Uganda	Cholera
Ecuador, Peru, Bangladesh, India	Malaria
Thailand, Brazil	Dengue fever
Southwestern United States	Hantavirus
Southwestern United States	West Nile virus

SOURCES: Adapted from Gagnon et al. (2002); Alajo et al. (2006); Anyamba et al. (2006).

tion from eating contaminated food, and (2) the accumulation of data that could be used to develop state and/or national regulations.

6. Research in Water Contamination and Supply

Water is central to all life and is unconstrained by international borders. The supply of clean water is a fundamental underpinning of peace, order, and civil society. The USGS maintains the most extensive groundwater monitoring network of any large landmass nation in the world. By enhancing the supply of clean drinking water through proper use and management of groundwater resources, the USGS could play a key role in U.S. foreign policy and have a positive and lasting impact internationally.

The United States faces water issues similar to those of other countries. Understanding of these issues globally could strengthen U.S. domestic capability to meet these water resource challenges. Many opportunities exist to expand the existing knowledge base of water issues by studying various environments; the committee highlights the following three areas for the Survey to consider pursuing in its water research:

a. Reduction of water contamination risk from natural and anthropogenic causes

As described in Chapter 3, arsenic occurs naturally in the groundwater in Bangladesh (see Box 3.6.) Local and foreign scientists expended considerable scientific effort to understand the fundamental geochemical and biochemical processes that contributed to this groundwater contamination problem. USGS scientists have the opportunity to access this new science knowledge and develop it in a way that could yield practical solutions for the reduction of arsenic and other types of contamination elsewhere.

b. Water supply management

As a new economic power, China has to manage its water supplies effectively to support both its large population and the industrial production necessary to sustain its economy. The USGS has opportunities to contribute in many ways to groundwater and surface water management in China. One area identified by USGS scientists involves the establishment of more accurate discharge measurements in China's wide network of streams, rivers, and surface water conveyance systems. The Survey has a long history of keeping domestic stream flow records and thus has accumulated considerable expertise in this area. Furthermore, recent European investment in the development of a number of hydrologic observatories to gather real-time data for use in scientific investigations related to water and climate creates opportunities for collaboration with USGS scientists. Close to home, the USGS can build on its extensive collaborations with Canada in areas of both surface and groundwater research and joint development of instrumentation for water system monitoring.

c. Modeling and managing fossil aquifers in vulnerable environments

With its expertise, the Survey is well positioned to seek opportunities to study a broad range of hydrology and water-resources-related issues including environmental and health problems. Its modeling expertise will help in managing the Nubian Sandstone Aquifer System (NSAS), the world's largest known fossil water aquifer system, located in the eastern end of the Sahara Desert. This aquifer, estimated to contain 150,000 km^3 of groundwater, spans a land area of over 2 million km^2 that includes Sudan, Chad, Libya and Egypt.[2] Due to ongoing civil conflict, Darfur in Sudan is experiencing concentration of population that has resulted in high local demand for water.[3] The rainfall in the region is limited to only 4 months a year and the geologic conditions limit any storage of groundwater. The USGS has the capacity to provide the expertise needed to develop and manage a sustainable water supply in vulnerable environments such as Darfur and the Bari Karb, Afghanistan; such assistance would not only alleviate a humanitarian crisis but it could also serve U.S. foreign policy goals.

7. Water and Ecological Science in Cold Regions Sensitive to Climate Change

Warming in permafrost areas may result in decreases in permafrost content with potential for large negative impacts on global climate. Possible mitigation efforts require a better understanding of these impacts and feedbacks. USGS efforts to improve such understanding could include partnering with science agencies in

- countries working in Antarctica;
- Canada; and
- Russia, where the largest cold-region area on Earth in Siberia will be affected by impending climate change.

8. Comprehensive Enhancement of and Accessibility to Topographic and Geologic Map Information

Topographic mapping is required for all place-based business, for infrastructure development, for smart-phone access to all georeferenced information, and to guide resource, security, public health, and heritage activity. In addition to enhancing topographic information for these uses, an urgent need exists to accelerate reconciliation and accessibility of the geologic mapping that is essential for all Earth science activity.

[2] See www-naweb.iaea.org/napc/ih/IHS_projects_nubian.html.
[3] See www.unicef.org/infobycountry/sudan_darfuroverview.html.

a. Improved and accelerated global coordination and enhancement of topographic mapping

A pressing need exists to improve and accelerate global coordination and enhancement of topographic mapping. Such improvements can be achieved most efficiently through increased engagement with partners via crucially important mechanisms such as the Open Geospatial Consortium (OGC) and the International Steering Committee for Global Mapping (ISCGM). The OGC is an international consortium of more than 400 companies, government agencies, and universities that participate in a consensus process to develop open standards for geospatial information (see Chapter 3). OGC standards guide the optimization of all georeferenced information for use on the Web, wireless and location-based services, and all institutional information technology systems. A fully active and influential role for the USGS in the OGC thus is essential.

b. Rapid acceleration of the reconciliation and accessibility of geologic mapping

Most geologic maps remain optimized for the printing press. Present-day applications in fields such as resources and hazards require reconciliation of adjacent maps and the ability to readily query for aspects such as lithology. Progress in this field is facilitated by the Commission for the Management and Application of Geoscience Information (CGI), a commission of the International Union of Geological Sciences. Accelerated reconciliation of these maps could be achieved through an active role of the USGS in this commission.

In association with CGI activity, an escalating role is now also being fulfilled by the OneGeology project.[4] OneGeology is developing a formal governance model that is seen as having great potential for bringing about dramatically enhanced efficiency and effectiveness in international geological mapping and related fields. OneGeology is an international initiative of the geological surveys of the world which aims to create dynamic digital geological map data for the world and make existing geological map data accessible in whatever digital format is available in each country. The project has also committed to transfer knowhow to those who need it by adopting an approach that recognizes that different nations have differing abilities to participate.

The objectives to which all geological survey agencies need to aspire, with respect to the development of interpretations, protocols, and standards needed for seamless and 3D geologic maps, were well stated in USGS Circular 1369, released in early 2011 (Gundersen et al., 2011). Similar objectives exist in the fields of geophysical surveys and geochemical mapping, as these fields along with geology are major factors in attracting and facilitating activity such as mineral exploration. These objectives can be pursued globally, in close coordination with domestic and international partners. Continued USGS leadership in development of worldwide digitally based standards for geological mapping

[4] See www.onegeology.org/

and database development is important and could be augmented by providing added assistance to developing nations in obtaining robust geological databases; these databases, as mentioned above, will underpin resource exploration and wealth creation in these countries.

CONCLUDING REMARKS

Congress has empowered the USGS to maintain an aggregate technical breadth and depth that qualifies the Survey to assume a principal role in the identification, study, and mitigation of the effects of natural and human-induced changes to the Earth. Ongoing basic and applied domestic and international research projects by the USGS, conducted closely with similarly empowered Earth science agency partners, are now beginning to approach interactive Earth systems as an integrated atmospheric-oceanic-biospheric-solid Earth continuum. Mapping and monitoring at all scales, employing a large array of observational platforms—from Earth-orbiting satellites to high-energy transmission electron microscopes—are providing a new appreciation for the complex interrelationships and feedback loops that are responsible for the local, regional, and global environmental changes now being defined. The USGS can embrace the challenge of addressing problems associated with global change, in the framework of interactive Earth systems, as a principal scientific thrust.

Science at the USGS is intrinsically global, and each of the seven mission areas is already involved in significant international activities that serve the USGS and U.S. government interests. As global population grows and anthropogenic impacts on the environment increase, the many consequences of global change are likely to shape USGS strategic science and give rise to new opportunities for Survey international activities.

The committee sees benefits to the USGS in developing and executing self-generated international projects as well as those performed in response to external requests. Maintaining a balance between these kinds of projects requires foresight and planning so that the priorities of USGS, DOI, and the nation are met. Allocation of resources, particularly of personnel, will remain a constant but manageable challenge as the USGS also responds to requests from external partners to undertake international studies. The committee considers that a more uniformly proactive approach toward international projects within and among the mission areas could enhance flexibility and preparation for evaluating and acting upon requests from external partners.

Although not exhaustive, the strategic scientific opportunities identified in this chapter target problems or questions that can be addressed with various types of data collection and analysis. These project ideas can be initiated in specific countries or geographic regions (with potential to translate to other countries or regions). All such efforts have strong potential to benefit U.S. government priorities and USGS mission areas.

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CHAPTER FIVE

Impediments to More Effective USGS Participation in International Science Activities

The influential and effective involvement of the U.S. Geological Survey (USGS) in international science activities over many years has included numerous successful projects with demonstrated benefits to U.S. government priorities and the USGS mission (see Chapter 3). Despite this established history of accomplishments in international science, USGS scientists, collectively and individually, face challenges in engaging in overseas activities and collaborations. The challenges and impediments identified in this chapter are based on information gathered through presentations made to the committee and from conversations with Survey representatives, individuals who have worked as primary collaborators and advisers on international projects with the Survey, and other professionals with direct knowledge of USGS international work (see Appendix C). Although fact finding and reporting in an assessment of this type involve some subjectivity, the challenges described here are significant, in the opinion of the committee, and thus are worthy of attention.

FACTORS HINDERING PROGRESS

Various factors pose obstacles for more effective Survey participation in international science activities. As discerned by the committee, these relate chiefly to (1) the lack of an overall plan for USGS international science; (2) domestic mission pressures within the Department of the Interior (DOI) and the USGS; (3) uneven disposition to undertake international work among the Survey's mission areas; (4) an institutional culture not yet predisposed to implement international and cross-disciplinary activities across the entire Survey or to implement a suitable reward system for participating in these international activities; (5) a need for greater Survey coordination with international partners; and (6) availability of resources. Each of these factors is discussed in subsequent sections.

Lack of an Overall Plan for USGS International Science

The diverse international activities carried out by USGS scientists described in Chapter 3 are not presently part of an agency-wide plan or vision for international science. Although the current strategic plans of the USGS and the DOI do acknowledge fundamental trends such as globalization, climate change, and the importance of understanding the Earth as a system (DOI, 2011a; USGS, 2007), the plans do not explicitly address USGS participation in international science activities. High-level endorsement in these planning documents of the importance of USGS involvement in international science activities—especially those activities serving national interests and benefitting both the USGS and DOI domestic missions—would be consistent with the level of international work already being conducted by the Survey and, in the opinion of the committee, could mitigate some of the other challenges and roadblocks described below (see also Box 3.1).

DOI and USGS Domestic Mission Pressures

Under the Organic Act of 1879, the USGS was charged with "the classification of the public lands and examination of the geologic structure, mineral resources, and products of the national domain." The Congress in 1962 expanded authorization for the USGS to pursue similar activities *outside* the national domain, although this authority was not given directly to the Survey but rather to the Secretary of the Interior, who may exercise that authority through the USGS (see Box 2.1).

The mission of the DOI significantly influences the USGS to maintain focused attention on its domestic role. For example, domestic agendas and performance measures are outlined in the DOI's new five-year strategic plan (DOI, 2011a). The key roles to be played by the Survey in this framework are emphasized in a press release accompanying the unveiling of the strategic plan (USGS, 2011a).

Although USGS international activities are allowed under the Organic Act, the guiding authority of the Secretary of the Interior suggests the need for compelling arguments to undertake such activities—whether these activities are advanced within other parts of the Executive Branch or from within the USGS. One starting point for the USGS is to demonstrate reciprocal benefits to the United States of its international science work in support of the Survey and DOI domestic missions. These benefits can be readily documented (see Chapter 3) but in general, in the committee's observations, they do not appear to have been adequately or consistently communicated over the years in the USGS or the DOI, or to the public. Some systematic and consistent basis for an evaluation of the benefits of these international projects could play a useful role as part of the Survey's documentation of these activities. To the committee's knowledge, no consistent internal or external evaluation mechanisms are currently in place at the USGS for their international work. Lacking

a more universal recognition of the benefits of USGS strategic international science to the Nation or internal and extramural mechanisms to provide feedback on and evaluate the success of international projects, the Survey's domestic mission tends to be emphasized and narrowly interpreted.

Uneven Disposition to International Work among the Survey's Mission Areas

In the committee's information gathering, we were struck by a remarkably uneven response when asking representatives from the Survey's various mission areas about international science activities. The responses ranged from ready descriptions of ongoing international activities, to ambivalence about such projects, to disinclination to undertake overseas work. In the latter case, various factors have contributed, including the perception that the USGS lacks a congressional mandate to extend activities into the international arena; this perception makes some USGS scientists and program managers reluctant to undertake these activities, particularly when setting priorities for resource allocations (see also sections below). Correspondingly, the interests and aspirations of individual Survey scientists toward international work or foreign travel to international meetings do not appear to be universally encouraged or strategically incentivized. Our observations suggest that the uneven disposition to international work among the Survey's mission areas may be the combined result of perceived constraints on international work vis-à-vis the USGS domestic mission, the relatively small number of congressional mandates clearly calling for the USGS to conduct international work, and the absence of an agency-wide plan for USGS international science. For reference, a compendium of congressional authorizations for USGS activities, both domestic and international, is available in DOI (2011b, Part T).

Institutional Culture

The Survey's institutional culture poses an assortment of challenges to encouraging more universal engagement of USGS scientists in international activities. For example, similar status and respect for international as well as domestic work in merit review for USGS scientists would be consistent with an overall acknowledgement of international science as an integral part of the USGS project portfolio. This kind of recognition could entail support for presentation of scientific results of global work at international conferences and publication in premier journals (see, for example, Appendix E). The committee's observations did not indicate that international science conducted by USGS scientists is presently given equal status to domestic project work throughout all of the science mission areas.

Interdisciplinary work—potentially aided by use of a systems approach to certain scientific investigations—can strengthen the information and analysis provided from scientific research and aligns well with the variety of international scientific opportunities and issues

that fall within the USGS mission (see Chapter 4 for a selection of some of these opportunities; also Box 3.11). In an international project, carefully planned interdisciplinary work can also maximize the value and return from invested resources (including costs for preparation, field and analytical time, staff support, travel, and other logistics associated with international campaigns). The USGS has, through its recent reorganization, attempted to enhance the interdisciplinary nature of its scientific thrusts. International science is a useful vehicle for the Survey, armed with its remarkable interdisciplinary competencies, to embrace and encourage effective collaborative research in the investigation, quantification, and amelioration of the effects of global change on the nation.

The rapid development and evolution of information technologies also poses a broad institutional challenge. To its credit, the USGS is building new capabilities in informatics as part of its restructuring. For more effective participation in international science activities, notably where vast datasets are involved, individual Survey scientists are likely to need assistance in improving technical skills in order to use those informatics capabilities more efficiently.

The new Environmental Health mission area faces a distinct challenge arising from the restructuring of the USGS. Survey activities that enhance and support the Environmental Health mission area cross with all of the other USGS mission areas. Essential to the success of this mission area—particularly in the international arena—will be the establishment of strong linkages and cooperation with the other USGS mission areas, including identification of shared priorities and complementary capabilities. Ultimately, strategic planning in the Environmental Health mission area will require a thoroughly integrated systems approach.

Need for Greater USGS Coordination with International Partners

Effective engagement in international science activities requires efficient, wisely arranged coordination with foreign partners. Bilateral arrangements on a case by case basis have great utility in many situations. Multilateral arrangements, however, can also be appropriate for projects that are directed toward a broad set of shared objectives; they can also be effective in accommodating the different capacities and strengths of partnering agencies, and potentially address a wider array of scientific questions. Some existing international coordination mechanisms offer the opportunity to engage more effectively in multilateral arrangements to conduct international science. The USGS does not, in the committee's opinion, avail itself of these international coordination mechanisms to the degree that it could.

These arrangements occur at the institution level and to some extent can be built on existing provisions maintained by USGS administrative units. Tri-national coordination in North America, for example, can influence and be influenced by regional multinational geological survey agency coordination mechanisms elsewhere, including EuroGeoSurveys, an organi-

zation of 33 European Geological Surveys,[1] the Coordinating Committee for Geoscience Programmes in East and Southeast Asia,[2] and federal models such as the Chief Government Geologists' Committee in Australia.[3] Geological survey agency delegates at the 2008 International Geological Congress in Oslo also discussed ways to further develop the organization of the International Consortium of Geological Surveys (ICOGS) (IGC, 2008). New arrangements for coordination are also emerging, such as the OneGeology project,[4] which has recently led to greatly improved collaboration among geological surveys around the world.

Availability of Resources

Because the USGS is the premier Earth science agency in the United States, Survey scientists and administrators receive numerous requests for assistance to other countries and for involvement in international cooperative activities. They face a tension between (1) their inclination, as scientists, to do more international work, and (2) their duty, as public servants, to discern the appropriate level of such commitments and the benefits both to U.S. taxpayers and the USGS domestic mission. A constant factor in considering international engagements is understaffing—even to handle domestic responsibilities. For example, in the Earthquake Hazards Program, staffing has been reduced from a high of over 400 full-time equivalents in the 1980s to fewer than 250 at the end of 2009, despite increased responsibilities for monitoring, data analysis, and providing real-time information products (SESAC, 2010). Foreign travel also poses a challenge because commonly it is expensive.

International activities, insofar as they are supported by external funding, provide a diversified source of financial support for some USGS science centers. However, the committee was informed that restrictions on sources of funding and means of funding (for example, in-kind contribution, repayment to a USGS account, payment directly to the traveler) have increased in recent years, making it more difficult to organize repayment of foreign travel costs for Survey scientists. Questions about how to assess overhead on refunds of travel costs have also been raised, with potential to impact the availability of funds originally intended for carrying out USGS scientific work. These issues may, in turn, affect the effectiveness of and terms upon which agreements are negotiated with potential project sponsors within the federal government (e.g., the U.S. Agency for International Development) or by institutions such as the World Bank. The committee also observed the challenges associated with making longer-term plans for multiyear international projects within a federal system currently structured toward annual funding appropriations.

[1]See www.eurogeosurveys.org/.
[2]See www.ccop.or.th/.
[3]See www.geoscience.gov.au/ggic.jsp.
[4]See www.onegeology.org/.

The committee acknowledges that resource limitations, both in professional staffing and funding, can impede any agency's ability to undertake new efforts, whether domestic or international. Perhaps the use of some of its available appropriated funds may offer some option for the USGS to judiciously support selected overseas work, adding to the support provided for international projects as requested by external partners and managed through reimbursable funds.

CONCLUDING REMARKS

The impediments to more effective USGS participation in international science activities are varied. Action for change presupposes a high-level commitment to the proposition that international science activities are not just accommodated and ancillary to the Survey's mission but truly a fundamental part of the Survey's aim "to help our Nation and the world" (Gundersen et al., 2011: 3). Impediments that relate to mission pressures within the DOI or to the flexibility of the USGS to undertake more international science activities, while still ably performing its domestic mission, will continue to pose significant challenges. The impediments most amenable for the USGS to overcome are those relating to an overall plan for global science activities, cooperative and otherwise, and to the Survey's present institutional culture. If USGS participation in international science activities is to be more effective in the future, then an overarching Survey-wide plan for such activities would represent a solid starting point. As with most federal agencies, increased funding may arguably be a requirement for growth—but not for significant change.

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CHAPTER SIX

Findings, Conclusions, and Recommendations

A global, integrated understanding of the Earth sciences is of fundamental importance to enhance U.S. public health and security, safeguard our natural heritage, and support economic development. For both the public and private sectors of the nation, *global* information and knowledge about Earth's natural processes are absolutely critical for any engagement in Earth science issues either at home or abroad. Chemical modification of the world's oceans and atmosphere has direct consequences for the United States, whether considering the direct effects on people, plants, animals, or water resources. The effects of severe weather events, droughts, inland and coastal flooding, crop failures, and sea-level rise all have an adverse aggregate impact on American life. The future acquisition of additional fresh water supplies, nonrenewable Earth resources, and a sufficient supply of inexpensive energy require attention to the changing global conditions on the Earth.

As the Nation's leading, integrated Earth science agency, the U.S. Geological Survey (USGS) has a significant role to play in contributing information and knowledge to address Earth science issues arising in and beyond U.S. national boundaries. The USGS contributes effectively to the amelioration of such largely adverse trends, to the benefit of the public. The committee sees international work as integral to the Survey's ability to respond to its national mandate. With this in mind, the committee has developed five recommendations based on significant findings and conclusions that outline a series of steps for the USGS to support and strengthen its international activities.

The committee's initial overarching recommendation, directed to the USGS leadership and with the clear acknowledgment and support of international work already under way, concerns the benefits of a more proactive approach toward international science. The committee sees compelling arguments for the USGS to play a dynamic role in international science. With an eye to the future, the development of a strategic implementation plan for international science at the USGS is fundamentally important, and the committee outlines some basic elements that could be part of such a plan. These include scientific opportunities

in the international arena with strong promise of high return value to the nation and the USGS together with strategies that may enable the USGS to bypass some of the potential impediments to engaging effectively in international science activities.

Global Earth science, including deep understanding of ecological systems, is critical, and becoming more so, as populations increase and access to resources becomes more challenging. The world is increasingly interconnected, and global environmental problems frequently impact the United States. The USGS plays an essential role in the systematic mapping, monitoring, and study of the Earth to fulfill wide-ranging national needs for information on diverse Earth systems. Although the committee noted caution on the part of the USGS in fully promoting its numerous and broad-ranging accomplishments in the international arena, the USGS can be justifiably proud of its widely recognized and successful international activities in global Earth science.

RECOMMENDATION: As a necessary first step to strengthen and enhance USGS international science activities, USGS leadership, in collaboration with the Secretary of the Interior, should fully embrace and unequivocally commit to international science as a fundamental part of the USGS' aim "to help our Nation and the world" (Gundersen et al., 2011, p. 3) and should be open and clear about this work—internally and externally.

The committee found that USGS scientists are conducting excellent work in international science, as described in Chapter 3 of this report. Current activities include mitigating humanitarian crises through technical assistance in natural disaster response and in local capacity building, the advancement of science through interdisciplinary and international collaborations, natural resource assessments, and the promotion of national interests through science diplomacy, technical aid, and other means. However, the continuum of global problems and issues requiring urgent attention for which the Survey has relevant expertise makes this a critical time for greater USGS involvement in international science on behalf of our national interests. The USGS is especially well positioned in terms of its multidisciplinary expertise and organizational capabilities to play either a leading or collaborative role, both in the United States and internationally, in addressing Earth science problems that will arise as conditions and processes change on our planet.

RECOMMENDATION: The USGS should play an expanded, proactive role in international Earth science, consistent with, and building upon, its present strengths and science directions. In developing this expanded role, the USGS should assess how it can serve as a collaborative international leader in strategically addressing a range of urgent worldwide problems that affect U.S. interests. These include, but are not limited to natural-resource shortfalls, escalating

human and economic losses from natural disasters, a degraded biosphere, biodiversity loss, the increasing threat of pandemics, and accelerating global environmental change.

As part of this broader international role, and in keeping with the idea that these endeavors maximize effectiveness in the use of government resources, the USGS can consider forging stronger links and collaborative efforts with a wide variety of international and domestic partners. Other nations' geological surveys and international organizations such as OneGeology are potential partners. In addition to its collaborations within the Department of the Interior, the USGS already has strong relationships on international projects with the Department of State, U.S. Agency for International Development, the Department of Defense, and the World Bank, as well as with other federal agencies such as the National Oceanic and Atmospheric Administration, the National Aeronautics and Space Administration, and the Centers for Disease Control and Prevention. These reliable partnerships could be further strengthened and serve as a springboard for broader scientific engagement among all of the Survey's mission areas. Examples of this kind of approach might include different USGS mission areas working in concert to develop and propose innovative international projects that serve the partners' needs along with best practices for implementation.

The USGS has recently identified seven mission areas, which are applied to national Earth science activities. Internationally, new science opportunities exist to support these national directions; however, most of these opportunities require examining Earth processes as an interconnected system, thus requiring a systems approach. The latter is already being fostered by the USGS in its domestic science strategies. Integrated efforts, across USGS mission areas, can strengthen the Survey's scientific capabilities, increase knowledge and understanding of Earth processes, and support informed and effective decision-making. A selected, though not exhaustive, set of international science opportunities with demonstrable potential to benefit national priorities is described in Chapter 4. Many of these offer further opportunities to evolve the institutional culture within the USGS in terms of interdisciplinary research and collaboration.

RECOMMENDATION: The Survey leadership should continue advancing the integration and coordination of activities across the seven mission areas, and consider using international science opportunities such as those outlined in Chapter 4, to motivate further scientific integration within the USGS.

From the standpoint of the structure of USGS' international activities, the committee noted that international work seems to be managed very differently in different mission areas and identified marked contrasts in the support, reward structures, and planning for

such efforts. Although some differences among USGS mission areas are to be expected and are likely healthy, identification of current best practices for successful development and execution of global scientific projects is warranted and could facilitate adoption of those practices more broadly across the different mission areas. Encouraging engagement among the mission areas in developing international, interdisciplinary scientific opportunities could allow the Survey to better prepare for official project requests from external partners and could enhance readiness to explore new international science opportunities. The absence of a more proactive approach to international science activities at the Survey probably weakens the overall success of the USGS in conducting such efforts.

RECOMMENDATION: A Survey-wide plan for international work should be developed to allow the USGS to fully embrace international activities. Such a strategy could be developed through the integrated efforts of the Director of the USGS, the leaders of the seven mission areas, and the Office of International Programs. The overall goal of the plan should allow the USGS to provide a dynamic, proactive response to the challenges of global geoscience problems. Elements of the plan could include guidelines or mechanisms that would

- **foster activities and collaborations that anticipate and address impending global crises;**
- **identify and prioritize key international opportunities that support domestic and global science goals and address U.S. government priorities, including opportunities for international collaboration with other federal science agencies;**
- **formulate a consistent approach to international activities across all USGS science areas, with internal and extramural mechanisms to provide feedback on and evaluate the success of international projects;**
- **enhance coordination between USGS and other foreign Earth-science agencies;**
- **explore opportunities to collaborate internationally with academic institutions based in the United States and overseas;**
- **promote the development of a new organizational culture that encourages and rewards international research activities and publication of research in peer-reviewed journals; and**
- **fast-track the execution of international agreements.**

As outlined in Chapter 5, the reciprocal benefits to the Nation of USGS global activities are not fully appreciated and do not generally make their way into public perception. From our own committee experience, information on USGS international activities is not

readily available to the public in a conveniently organized, useful, and informative way. The committee had the advantage of becoming well informed about the Survey's international science activities from a variety of extramural as well as Survey sources, and the resulting overview led us to be impressed by the great value of such activities and partnerships, including benefits to the USGS domestic mission and clear relevance to U.S. national interests. This same value would not be evident to someone in the general public attempting to understand more about USGS international work.

RECOMMENDATION: To increase public awareness of the value to the nation that results from USGS international scientific activities, the USGS should promote more effective communication and outreach about nonsensitive international work. Effective communication can convey the importance, benefits, and rationale of the Survey's international science activities to the public, other stakeholders, and potential international and domestic partners. An interesting, user-friendly website focusing on global Earth science and featuring brief descriptions of the Survey's current and recent international activities and collaborations, with reference to more detailed information elsewhere on the USGS website, would allow for greater public appreciation and understanding of these activities.

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Appendixes

APPENDIX A

USGS and DOI Mission and Authorization Language

U.S. GEOLOGICAL SURVEY

Creation and Authority

The Geological Survey was established by the Organic Act of March 3, 1879 (20 Stat. 394; 43 U.S.C. 31), which provided for "the classification of the public lands and examination of the geological structure, mineral resources, and products of the national domain." The Act of September 5, 1962 (76 Stat. 427; 43 U.S.C. 31(b)), expanded this authorization to include such examinations outside the national domain. Topographic mapping and chemical and physical research were recognized as an essential part of the investigations and studies authorized by the Organic Act, and specific provision was made for them by Congress in the Act of October 2, 1888 (25 Stat. 505, 526).

Following the early work on classification of land available for irrigation, provision was made in 1894 for gaging the streams and determining the water supply of the United States (28 Stat. 398). Authorizations for publication, sale, and distribution of material prepared by the Geological Survey are contained in several statutes (43 U.S.C. 41-45; 44 U.S.C. 1318, 1320).[1]

Mission

The mission of the Geological Survey is to provide geologic, topographic, and hydrologic information that contributes to the wise management of the nation's natural resources and that promotes the health, safety, and well-being of the people. This information

[1]See www.usgs.gov/usgs-manual/120/120-1.html.

consists of maps, databases, and descriptions and analyses of the water, energy, and mineral resources, land surface, underlying geologic structure, and dynamic processes of the earth.

U.S. DEPARTMENT OF THE INTERIOR

Creation and Authority

On March 3, 1849, the last day of the 30th Congress, a bill was passed to create the Department of the Interior to take charge of the nation's internal affairs. The DOI is now the nation's principal Federal conservation agency. It manages many of the nation's special natural, cultural, and historic places, conserves lands and waters, protects cultural legacies, and keeps the nation's history alive. Interior manages parks, refuges, public lands and recreation areas for public enjoyment, provides access to many of the nation's natural resources, increases scientific knowledge, and fulfills America's trust and other responsibilities to native peoples. Interior also provides hydropower to the Western States. It delivers water to over 31 million citizens through management of 479 dams and 348 reservoirs.[2]

Mission

The U.S. Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated Island Communities.

[2]See www.cr.nps.gov/history/online_books/utley-mackintosh/index.htm.

APPENDIX B

Committee and Staff Biographical Sketches

COMMITTEE BIOGRAPHIES

Ian L. Pepper (***Chair***) is an environmental microbiologist specializing in the fate and transport of contaminants in soils, potable water and municipal wastes. He is currently the Director of the National Science Foundation Water and Environmental Technology Center, Director of the Environmental Research Laboratory, and Professor and Research Scientist for the Department of Soil, Water and Environmental Science at the University of Arizona. During the past ten years, his research has focused on the fate and transport of emerging contaminants such as prions, the causal agent of Mad Cow disease, bacterial, viral and protozoan pathogens in water, and more recently, chemical endocrine disruptors such as pharmaceuticals and personal care products detected in water supplies around the globe. He is widely published in the fields of environmental microbiology and pollution science. Pepper is a fellow of the American Academy of Microbiology, the American Association for the Advancement of Science, the Soil Science Society of America, the American Society of Agronomy, and a recipient of the American Society of Agronomy 2010 Environmental Quality Research Award. National Research Council service includes membership on the Research Associateship Program Review Committee, Research Priorities for Earth Science and Public Health, Biosolids Applied to Land: Advancing Standards and Practices, and the U.S. National Committee for Soil Science. He received a Ph.D. in soil microbiology from The Ohio State University.

Walter J. Arabasz is Research Professor Emeritus of Geology and Geophysics at the University of Utah. In July 2010 he retired as director of the University of Utah Seismograph Stations after 25 years in that position. His research interests include network seismology, earthquake-hazard analysis, mining-induced seismicity, and tectonics and seismicity of the Intermountain West. He has had extensive involvement since the mid-1980s in national

and state public policymaking for U.S. network seismology and earthquake risk reduction. Since 1977, Dr. Arabasz has performed routine and ongoing professional consulting relating to earthquake hazards and risk for dams, nuclear facilities, and other critical structures and facilities. He is a member of the Seismological Society of America, American Geophysical Union, and Geological Society of America. In 2008, Arabasz was the recipient of Western States Seismic Policy Council Lifetime Achievement Award in Earthquake Risk Reduction, for extraordinary commitment, level of service, and contribution of the application of earthquake risk reduction to public policy. National Research Council service includes membership on the Committee on Seismology (1989-1994), Panel on Regional Networks (1988-1990), and Panel on Seismic Hazard Evaluation (1992-1996). He received his Ph.D. in geology and geophysics from the California Institute of Technology.

Julia E. Cole is a Professor of Geosciences within the School of Earth and Environmental Sciences at the University of Arizona. Her research centers on expanding our view of recent climate variability, using geological and biological proxies for climate along with instrumental records and climate models. Common themes include the development of geochemical records from long-lived corals and sediments, the variability and impacts of large-scale climate systems throughout the tropical oceans, and stable isotopes in the hydrologic cycle. She has written or co-written over 60 publications. National Academy of Sciences service includes membership and assessments on the Climate Research Committee, Committee on Global Change Research, Panel on Climate Variability on Decade-to-Century Time Scales, and Intergovernmental Panel on Climate Change. In 2008, Dr. Cole was awarded the Leopold Leadership Fellowship in environmental communication and policy. She received her M.S. and Ph.D. from Columbia University.

W. Gary Ernst (NAS) is Benjamin M. Page Professor of Earth Sciences, Emeritus, in the Department of Geological and Environmental Sciences at Stanford University. On the Stanford faculty since 1989 as Dean of the School of Earth Sciences (1989-1994) and Professor, he became emeritus in 2004. Prior to Stanford, Dr. Ernst spent 30 years at the University of California Los Angeles as Professor in the Department of Earth and Space Sciences and Institute of Geophysics and Planetary Physics. Author of seven books and research memoirs, editor or co-editor of 19 others, Ernst is author or co-author of more than 260 scientific papers dealing with physical chemistry of rocks and minerals; Phanerozoic interactions of lithospheric plates and orogenic belts, especially in central Asia, the Circumpacific and the western Alps; early Precambrian petrotectonic evolution; high- and ultrahigh-pressure subduction-zone metamorphism and tectonics; geobotanical studies/remote sensing; and geology and human health. A member of the National Academy of Sciences, the American Academy of Arts & Sciences, and the American Philosophical Society, Ernst was president of the Mineralogical Society of America (1980-1981) and

the Geological Society of America (1985-1986). He received the MSA Award (1969), the Geological Society of Japan Medal (1998), the Penrose Medal of the GSA (2004), the Roebling Medal of the MSA (2006), the AGI Legendary Geoscientist Award (2008), and the Distinguished Career Award of the GSA International Section (2010). He received his B.A. degree in Geology from Carleton College, M.S. in Geology from the University of Minnesota, and Ph.D. in Geochemistry from The Johns Hopkins University.

Laura F. Huenneke is Vice President for Research at Northern Arizona University (NAU). Before coming to NAU, Dr. Huenneke spent 16 years on the faculty at New Mexico State University in Las Cruces, where she became Regents' Professor and served five years as department chair in Biology. She served as Lead Investigator/Project Director for the NSF-funded Jornada Basin Long-Term Ecological Research program, a consortium of multiple universities and federal agencies focused on desert ecosystem structure and function. Her research interests pertain to the influence of biological diversity on ecosystem structure and function. In 1999 she was selected as one of the initial cohort of Aldo Leopold Leadership Fellows, a program promoting the development of communication and leadership skills among environmental scientists. She has served on several editorial boards for ecological research journals and on NSF and other review panels, and has been elected twice to the governing board of the Ecological Society of America (most recently as Vice President for Public Affairs). She is also a member of the Steering Committee for the Arizona Bioscience Roadmap, the Northern Arizona Economic Development Advisory Council, and the Board of Directors for the Northern Arizona Sustainable Economic Development Initiative. Dr. Huenneke earned her Ph.D. in Ecology and Evolutionary Biology from Cornell University.

Tissa H. Illangasekare is AMAX Distinguished Chair and Professor of Environmental Science and Engineering in the Division of Environmental Science and Engineering and Professor of Civil Engineering at the Colorado School of Mines and the Director of the University/Industry/National Laboratory collaborative Center for the Experimental Study of Subsurface Environmental Processes. Professor Illangasekare has 32 years of experience with numerical and physical modeling of saturated and unsaturated flow in soils, surface-subsurface interaction, arid-zone hydrology, arctic hydrology, tsunamis and natural disasters, integrated modeling of hydrologic systems, subsurface chemical transport and multiphase flow, CO_2 sequestration and leakage, and environmental impacts of energy development. He served on the NRC Committee on Subsurface Contamination at Department of Energy (DOE) Complex Sites: Research Needs and Opportunities, an important precursor to this activity. He is currently serving on NRC Committee on Future Options for Management in the Nation's Subsurface Remediation Effort. He is a Fellow of American Geophysical Union (AGU), Fellow of American Association for Advancement of Science (AAAS), and

a Fellow of American Society of Civil Engineers (ASCE). He is a registered Professional Engineer, registered Professional Hydrologist, Board Certified Environmental Engineer with the American Academy of Environmental Engineers, and a Diplomat of the American Academy of Water Resources Engineers. He is currently serving as editor of Water Resources Research. He was a past co-editor of Vadose Zone Journal. Dr. Illangasekare received a Ph.D. in Civil Engineering from Colorado State University, M.E. from the Asian Institute of Technology, and a B.S. from University of Ceylon, Sri Lanka. He also received an Honorary Doctorate in Science and Technology from Uppsala University, Sweden. He is the recipient of the 2012 Henry Darcy Medal from the European Geosciences Union (EGU).

Jean-Michel M. Rendu (NAE) is a Group Executive with Newmont Mining Corporation with global responsibility for mineral resource evaluation and modeling. Dr. Rendu was previously an Executive Consultant with Snowden Mining Consultants with worldwide responsibilities for project analysis and professional development. Dr. Rendu was previously an independent consultant and retired vice president for resources and mine planning at Newmont Mining Corporation. Other positions included being an associate with Golder Associates in Denver, Colorado, an adjunct professor at the Colorado School of Mines, a professor of mining engineering at the University of Wisconsin, Madison, and head of operations research with Anglovaal in Johannesburg, South Africa. Dr. Rendu's current interests are in optimizing the evaluation, development, and operation of mining projects using appropriate mathematical and managerial techniques; as well as development and implementation of systems which facilitate and speed up data collection, quality control, data analysis, and decision making. He has supplied expert advice to operations worldwide. Dr. Rendu is also interested in the education of mining professionals and has played a leading role in the development of international standards for the evaluation and public reporting of mineral resources and ore reserves. In 1997, Dr. Rendu was elected into the National Academy of Engineering for his contributions to theoretical and applied geostatistics for improved ore reserve quantification and grade control at mines throughout the world. Dr. Rendu received his Doctor of Engineering Science from Columbia University.

Harvey Thorleifson is Director of the Minnesota Geological Survey, State Geologist of Minnesota, Professor in the Department of Earth Sciences at the University of Minnesota, and President-elect of the Association of American State Geologists. Since 2003, he has been active in coordinating activities of state geological surveys and the U.S. Geological Survey and has had several organizational roles in international geological meetings and programs including the 2008 International Geological Congresses in Norway and OneGeology. While at the Geological Survey of Canada from 1986 until 2003, his early research on Lake Agassiz, the Great Lakes, Hudson Bay, and North American glacial

history evolved to work on indicator mineral methods in mineral exploration, geological and geochemical mapping, regional groundwater investigations, shoreline erosion, natural hazards, and climate change programs. Dr. Thorleifson's last two years in Canada were largely spent coordinating science and policy with respect to water-related issues in the Government of Canada system, with emphasis on groundwater. This work also involved planning coordination of the geological survey role with those of other departments and universities. Previously, he was also President of the Geological Association of Canada, and President of the Canadian Federation of Earth Sciences. He did his undergraduate studies at the University of Winnipeg, received his Masters at the University of Manitoba, and received his Ph.D. from the University of Colorado in Boulder.

STAFF BIOGRAPHIES

Elizabeth A. Eide is the director of the Board on Earth Sciences and Resources at the NRC, a position she has held since spring 2012. Prior to joining the NRC in 2005 as a senior program officer, she served as a researcher, team leader, and laboratory manager for 12 years at the Geological Survey of Norway in Trondheim. While in Norway her research included basic and applied projects related to isotope geochronology, mineralogy and petrology, and crustal processes, with emphasis on both basic and applied research projects. Her publications include 45 journal articles and book chapters, and 10 Geological Survey reports. She completed a Ph.D. in geology at Stanford University and received a B.A. in geology from Franklin and Marshall College.

Jason R. Ortego is a research associate with the Board on Earth Sciences and Resources at the National Academies. He received a B.A. in English from Louisiana State University in 2004 and an M.A. in international affairs from George Washington University in 2008. He began working for the National Academies in 2008 with the Board on Energy and Environmental Systems, and in 2009 he joined the Board on Earth Sciences and Resources.

Peggy Tsai is a program officer with the Board on Agriculture and Natural Resources at the National Research Council (NRC). Since joining the board in 2004, she has worked on various studies in topics such as agricultural biotechnology, infectious diseases, food security, and international agriculture. She served most recently as the study director for the Evaluation of a Site-Specific Risk Assessment for the Department of Homeland Security's Planned National Bio- and Agro-Defense Facility in Manhattan, Kansas (2010). She began her work with the NRC as a Christine Mirzayan Science and Technology Policy Fellow. Peggy received an M.A. in Science, Technology, and Public Policy from George Washington University, and B.S. in microbiology and molecular genetics with a double major in political science from UCLA.

Chanda Ijames is a senior program assistant with the Board on Earth Sciences and Resources at the National Academies. She received a B.S. in Psychology from the University of Maryland University College and is pursuing an M.Ed. in Instructional Technology from University of Maryland University College. She began working for the National Academies, Board on Earth Sciences and Resources in 2011.

APPENDIX C

USGS Historical International Engagement: Background Paper

The statement of task for this study calls for a background paper to be prepared in collaboration with the USGS. This background paper provides a summary of past and present USGS international scientific interactions and collaborations. It has been prepared by the USGS International Programs Office and has been reviewed by the USGS Bureau International Committee (BIC), but it is not an official document of the USGS.

THIS DOCUMENT IS IN REVIEW AND HAS NOT RECEIVED THE DIRECTOR'S APPROVAL FOR RELEASE AND IS SUBJECT TO CHANGE

PREFACE

The National Academies, through its Board on Earth Sciences and Resources, have been funded by USGS to examine: "Opportunities and Challenges for International Science at the U.S, Geological Survey (USGS)." The Statement of Work for this study calls for a background paper to be prepared in collaboration with the USGS. This background paper is a summary of past and present USGS international scientific interactions and collaborations. Its purpose is to assist the NAS study committee in its deliberations.

This background paper has been prepared by the USGS International Programs Office and has been reviewed by the USGS Bureau International Committee (BIC), but is not an official document of the USGS.

EXECUTIVE SUMMARY

The role of the USGS in the international arena has evolved over its 131-year existence. These changes have been influenced by changing national priorities, the available of funding, changing USGS expertise, and the evolution of foreign policy. However, throughout its

history, the USGS has remained unique among the world's earth science agencies in terms of its size and breadth of expertise. No other geological survey has the ecosystem and satellite missions of the USGS and few have national responsibility for both geology and hydrology.

The USGS and its partners in the Federal Government have examined the role of the USGS in the international arena before. The salient aspects of these previous studies are discussed in the pages that follow and in Annex 2. More recently, in 2010, the USGS has been reorganized to emphasize its commitment to multidisciplinary science. In so doing, the USGS established offices for six science "mission areas," including: climate; ecosystems; natural hazards; minerals, energy and health; water; and core sciences including mapping. These recent changes make this an appropriate time for the USGS to make an objective assessment of how the USGS can best serve the interests of the United States in the international arena.

This background paper is a summary of past and present USGS international scientific interactions and collaborations. It documents the early years of USGS international engagement, the rapid growth of USGS international work in the years following WW II, and the recent changes within the last decade as the USGS has increasingly emphasized multidisciplinary work and has grappled with post 9/11-related changes. The paper cites a number of different USGS international activities, not as a comprehensive discussion of USGS work, but as examples of the breadth and depth of USGS international efforts. Finally, this paper examines some of the critical issues that will influence the future of USGS international activities.

This background paper has been prepared to assist the National Academy of Sciences committee regarding the study on "Opportunities and challenges for international science at the U.S. Geological Survey," USGS looks forward to the committee deliberations and its recommendations and final report.

INTRODUCTION

At irregular intervals over the 131-year history of the U.S. Geological Survey (USGS), various efforts have been made to take stock of USGS' unique scientific and technical capabilities and to analyze the potential for an increased USGS role in international science and in the Nation's foreign affairs programs. Over the years studies have been carried out by the USGS, the U.S. Department of State, and the National Academy of Sciences (DOS and USGS 1983; NRC, 1987; NRC, 2001). The results of these studies have been fairly consistent: they recognize USGS' unique contributions and capabilities, encourage a larger international role for the USGS, and acknowledge the financial, legal and political constraints on the growth of USGS' international activities.

A new study is being undertaken by the National Academy of Sciences in the 21st century, with a new USGS Director, Dr. Marcia McNutt, a new science strategy (USGS,

2007), a recent realignment of the USGS under "mission areas" and a vastly changed geopolitical scene. Global science issues such as climate and global change, invasive species, food shortages, emerging diseases, changing ecosystems, biodiversity, energy and mineral resources, natural hazards, and water quantity and quality are all of great concern today, and are examples where USGS science is involved internationally. In addition, more than any time in recent memory, there exists at this time a heightened expectation of the potential for science diplomacy to inform foreign policy and contribute towards world peace and mutual understanding around the globe. It is increasingly important that global science issues be well understood before proceeding with foreign policy development, and the USGS is playing an increasing role in advising the Department of State about global science issues.

This paper presents a historical summary of the USGS international activities and some of the critical issues the USGS is currently confronting. This background paper is intended to serves as a starting point in discussing ways that the USGS can become more effective in addressing its priority issues in the international arena.

EARLY USGS INTERNATIONAL HISTORY FROM 1879 THROUGH WORLD WAR II

Beginning 131 years ago, the USGS established itself as a world leader in international earth science, providing training, technical assistance and institution building on both a bilateral and a multilateral basis, to countries around the world. The results of these efforts can be seen in the earth science and hazard monitoring agencies in many Lesser Developed Countries (LDC's).

The first international efforts of the USGS were quite modest and included:

- 1882, Clarence Dutton conducted volcanic studies in the Kingdom of Hawaii.
- 1884, the USGS began cooperative work on boundary waters with the Geological Survey of Canada.
- 1890, Herbert Wilson studied irrigation in India.
- 1897, Willard Hayes and Arthur Davis assisted the Canal Commission with geological and hydrogeological studies of proposed routes for what would become the Panama Canal.

Before and during World War II, USGS geologists, hydrologists and cartographers assisted in the war effort by identifying sources of water for military installations, identifying strategic mineral reserves, and compiling maps and charts of strategic international locations. In 1942, a Military Geology Unit (MGU) was started within the USGS, employing approximately 100 scientists fully funded by the U.S. Army Corps of Engineers. This unit was later transformed into the Military Geology Branch. Much of this Branch's work was

international in nature and involved the preparation of hand layered (geologic, hydrologic, lithologic and botanical) maps.

POST WW II THROUGH 1995 USGS INTERNATIONAL HISTORY

In the post WW II era, the USGS continued to expand its international engagement. However, organizationally, the USGS conducted this work from separate international offices that were administratively housed within the Geology, Mapping, and Water Divisions. Significant activities included country specific work such as the following.

Brazil The USGS began new, significant, long-term international technical assistance programs in Brazil involving 180 temporary duty assignments over 35 years.

Saudi Arabia One of the longest and most successful USGS international activities involved hydrologic and geologic work in Saudi Arabia. This program extended over 40 years, involved over 200 long-term, and more than 400 temporary, duty assignments, and resulted in the establishment of the Saudi Geological Survey (Worl, 2003).

Pakistan In the 1950's, the USGS began a technical assistance program in Pakistan that included stationing hydrogeologists in country for several years to collaborate on groundwater resource assessments. This work led to the creation of the Geologic Survey of Pakistan.

During this period the USGS continued international work through its Military Geology Branch. It made notable Cold War era contribution in the use of seismic monitoring to assist the Defense Intelligence Agency and other federal agencies to detect nuclear weapons testing around the world.

Also in the 1950s, the USGS Mapping Division began the Antarctic Research Program, which continues to this day in close cooperation with the National Science Foundation (NSF).

During the post WW II period, training became an increasing part of USGS international work. Between 1943 and 1963, more than 600 foreign geologists were trained by USGS staff, while thousands of others were trained in cartography and hydrology. Additionally, in the 1960s the USGS, in cooperation with NASA, began an Astrogeology Branch in Flagstaff, AZ. That Branch trained astronauts for lunar missions and the USGS was placed in charge of handling and testing the rock samples retrieved from the moon. Beginning in 1963, the International Water Resources Branch coordinated the training of thousands of foreign visitors, primarily through the Techniques of Hydrologic Investigations for International Participants (THIP) program.

This period also saw a dramatic rise in USGS engagement with international organi-

zations. In 1973, the USGS co-founded the Circum Pacific Council (CPC), a non-profit international organization of Earth Scientists and Engineers that continues to this day to develop and promote research and cooperation among industry, government and academia for the sustainable utilization of earth resources in the Pacific Region. The USGS also began its involvement with UNESCO's International Geological Correlation Program (IGCP), a program which has been critical in bringing USGS specialists in contact with similar specialists from around the world. In 1991, the USGS partnered with UNESCO to develop the Reduction of Earthquake Losses in the Extended Mediterranean Region (RELEMR) program. This program engages Middle East Countries by using seismology and a common interest in reducing earthquake hazards as a means to bridge political difference and promote regional cooperation.

Additionally, in 1991, the USGS partnered with the United Nations Environmental Program (UNEP), resulting in the USGS hosting the North American Node of its Global Resource Information Database (GRID) at the USGS Earth Resources Observation and Science (EROS) Center in Sioux Falls, South Dakota (see Figure C.1). This is the only UN office in the United States outside of New York and Washington (see figure showing current world offices of UNEP GRID). Today the USGS has played a major role in the popular UNEP publications—"One Planet Many People: Atlas of our Changing Planet", and "Africa Atlas of our Changing Environment". The USGS is also supporting a planned

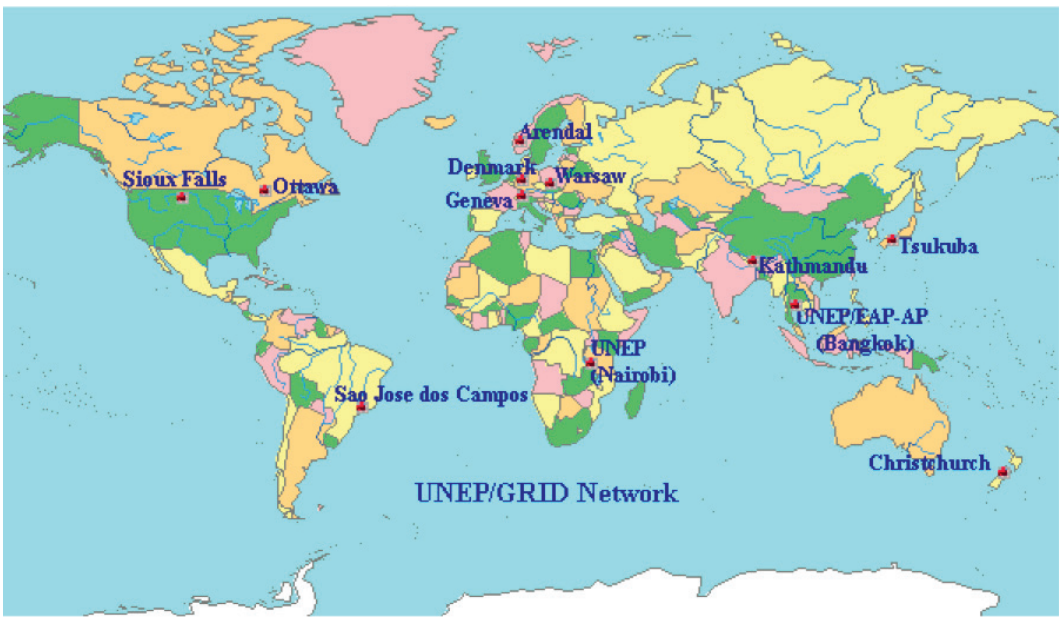

FIGURE C.1 Location of all UNEP GRID Centers. SOURCE: USGS.

UN Educational, Scientific, and Cultural Organization (UNESCO) atlas illustrating the use of remote sensing to monitor endangered World Heritage Sites.

The USGS leadership in remote sensing and land characterization took a big step forward in 1966 when it worked with the National Aeronautics and Space Administration (NASA) and other U.S. agencies to provide continuous global coverage of the land surfaces of the Earth. Since 1972, the United States has flown Landsat satellites that have ably served the economic, security, and environmental interests of the United States and its foreign partners. Recently, the 2010 U.S. National Space Policy confirmed USGS leadership role for future land imaging, and directed the USGS, NASA, OSTP, and OMB to develop plans and procedures to maintain continuity of land imaging satellite observations. Today, the USGS owns and operates the Landsat system, and provides open and free access to the entire Landsat archives, where over 4 million scenes have been downloaded and provided to some 184 countries around the world (see Figure C.2 and Figure C.3). To maintain the global archives, 14 Landsat ground stations are operated by a network of International Cooperators that are members the international Landsat Ground Station Operators Working Group managed by the USGS.

In 1985, the USGS began the Volcano Disaster Assistance Program (VDAP) in cooperation with USAID's Office of Foreign Disaster Assistance (OFDA). VDAP provides training and technical assistance for volcano monitoring agencies in Lesser Developed Countries. This program has saved thousands of lives and many millions of dollars in property. One of its most notable successes was the 1991 early warnings of the pending

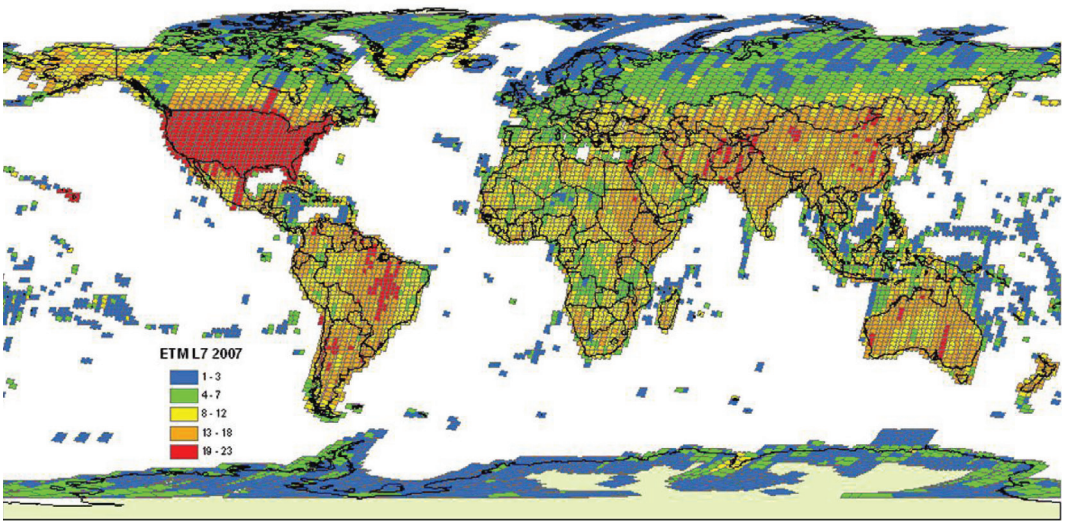

FIGURE C.2 Landsat 7 provides unique systematic coverage of the global land surface on a seasonal basis via a long-term acquisition plan (LTAP). The legend shows the number of scenes collected over each land area. SOURCE: USGS.

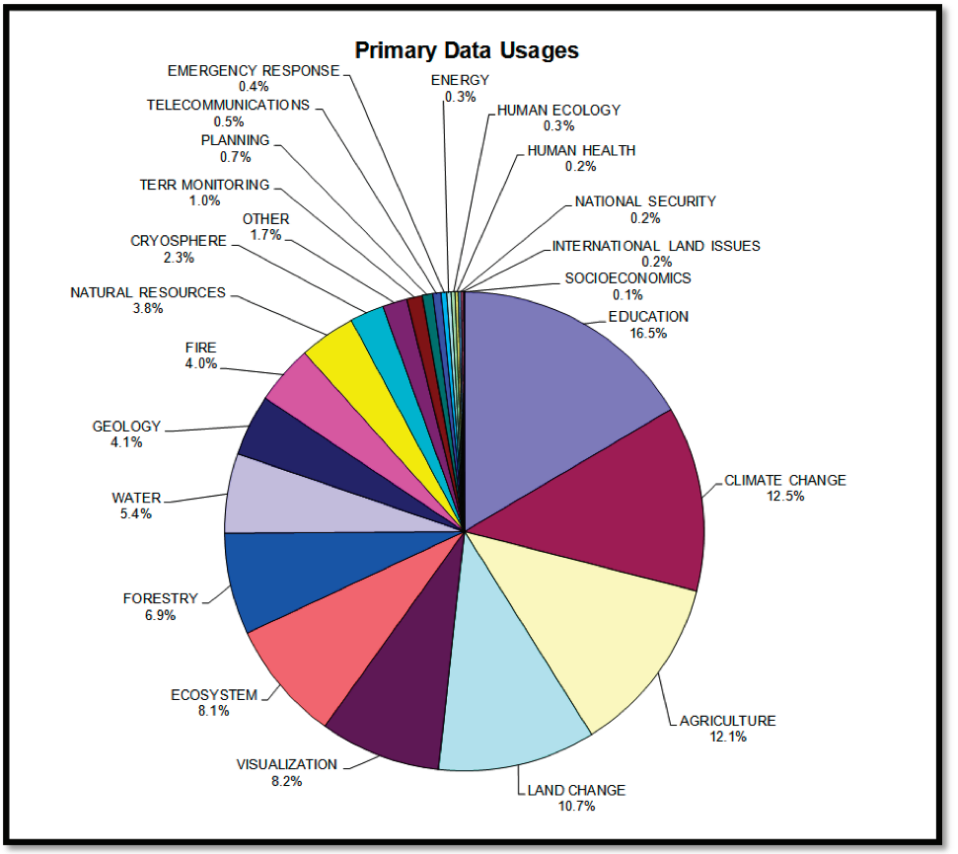

FIGURE C.3 User reported primary use of Landsat data. SOURCE: USGS.

eruption of Mt. Pinatubo, thus enabling the evacuation of Clark Air Base in the Philippines and the saving of hundreds of lives and hundreds of millions of dollars in aircraft and related equipment.

Recent (Post 1995) Developments at the USGS

In the decade of the nineties, the USGS continued to expand its international engagement. In 1995, the Office of International Geology became a Bureau-level International Programs Office, called the International Programs Office, under the Associate Director for Geology. During this same time period, the USGS established the Biological Resources Division (BRD) as a result of reorganization in the Department of the Interior. From this time forward, the USGS international dimension was concerned with the science disciplines

of geology, geography, water, and biology. The following is an accounting of a few of the notable international efforts from 1995 to date.

Traditional Engagements

Post 1995 the USGS has continued, and expanded, many of its traditional areas of international engagements. Often these are in support of, and funded by, USAID. Examples of these efforts include:

FEWS: The USGS is continuing its highly successful involvement in the more than 25 years old Famine Early Warning System (FEWS) program. This program is able to detect impending drought situations 3 month in advance of crop failures, thus providing assistance agencies time to prepare an emergency response. Originally deployed in a few countries in Africa, this very successful program is used throughout Africa and Asia and was one of the first development tools used by the U.S. in Afghanistan.

USAID/OFDA: Supported by USAID's Office of Foreign Disaster Assistance (OFDA), the USGS has responded to disasters such as the December 2002 tsunami, the recent Haiti earthquake, the eruption of Chiatin volcano in Chile, and volcanic eruptions in Kenya. Similarly, OFDA has supported USGS development of the PAGER system, a system that rapidly locates significant earthquakes, estimates their magnitude, estimates the intensity of ground shaking, estimates the amount of infrastructure and numbers of people likely to have been subjected to strong shaking, and then makes a preliminary evaluation of damage and loss of life. PAGER has been repeatedly used by first responders to prioritize their relief efforts. Finally, after the South Asian Tsunami of 2004, OFDA provided funds that allowed the USGS to install a Caribbean Tsunami Warning System to help protect the Caribbean region.

Hurricane Mitch support: In 1998, with the support of USAID, the USGS launched one of its first interdisciplinary efforts in the international arena. The successful Hurricane Mitch Project involved USGS staff from the Geography, Geology and Water Divisions, working together in four Central American nations under a USAID financed disaster recovery program. USGS was one of the many Federal agencies which joined together to from the "Hurricane Mitch Reconstruction Task Force", designed to provide aid and assistance to the affected Central American countries. Resulting efforts, including training in GIS, remote sensing application, coupled with The Treaty on Open Skies, produced photographs and imagery to reveal detailed information about natural and man- made structures for in-country decision makers.

International Wetlands Research and Observation: As part of the State Department's Lower Mekong Initiative, the USGS Delta Research and Global Observation Network

(DRAGON) partnership is using its experience with the Mississippi River and its expertise in earth science modeling to help the Mekong countries assess how climate change and human activities could impact the ecology and food security of the Mekong basin. Despite a geographic difference of twelve time zones, there are many cultural, economic and ecological similarities between the Mississippi and Mekong River Deltas. DRAGON has created an international community of practice among scientists and resource managers to share data on the great deltas and rivers of the world. The Forecast Mekong project, a component of the DRAGON partnership, will continue moving forward with building the foundation for later activities through strengthening relationships with Mekong region scientists and organizations, data sharing and joint research.

USGS Funded International Missions

As previously noted, as an agency within the Department of Interior, the USGS mostly engages in domestic work. In large measure the budgets of USGS are directed nationally. However, there are some notable exceptions where the USGS is funded out of its budget to work internationally in order to be more effective domestically. Three examples are of note.

Global Seismic Network: The USGS is an active partner in setting up and operating the Global Seismic Network (Figure C.4), a system which monitors earthquakes around the world.

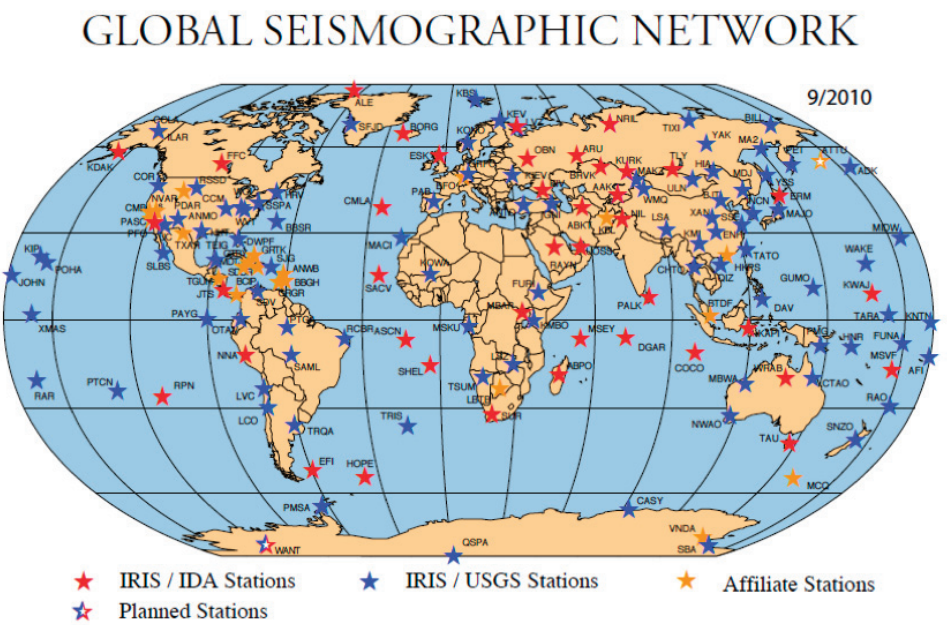

FIGURE C.4 The Global Seismic Network. SOURCE: USGS.

World Petroleum Assessment Program: Energy resources are critical to our Nation's future. The USGS World Petroleum Assessment program is an ongoing activity to estimate total petroleum resources and identify new targets for exploration.

Global Mineral Resource Assessment Project: mineral resources are also of National importance and the USGS Global Mineral Resource Assessment Project attempts to assess the global availability of selected critical minerals while the USGS minerals information team tracks the global supply and demand for virtually all minerals commodities. An example is provided as USGS (2010). As Figure C.5 shows, the U.S. is heavily reliant on imports for most minerals and such information is critical for anticipating and responding to minerals shortages. China's recent restriction on exports of rare earth elements, materials that are critical for manufacturing of many high tech products, highlights the need for this information.

Global Wildlife Disease News Map: The USGS has created the Global Wildlife Disease News Map (see Figure C.6), which displays news articles from the Wildlife Disease News Digest.[1] On it users can easily see wildlife disease headlines both locally and globally. The Map displays Wildlife Disease News Digest articles that have been posted within the last 45 days that have a geographical reference. The complete collection of articles, going back to December 2005, can be found on the online Digest.[2] With no global surveillance system in existence for the monitoring of wildlife health, this tool helps to fill the void by harvesting unstructured, disparate information about disease outbreaks and other wildlife related topics. Not only supplied for the wildlife professional, the information is directly applicable to those who study diseases of concern for livestock, domestic animals, and human health.

Invasive Species: Invasive species represent a serious threat to many vital U.S. interests, including the livelihood of commercial fishermen, the danger to threatened species and sensitive habitats, and the importation of wildlife and human disease agents. By definition, invasive species have entered the U.S. from other countries, and to understand their biology and thus mitigate the damage they cause, it is essential to work collaboratively with foreign researchers. USGS scientists study the life cycle of the non-native Asian carp to better understand how to manage this invasive species in the Missouri River. Asian carp were introduced into the United States for use in aquaculture production of food fishes, and biological control of plankton in aquaculture ponds and sewage treatment lagoons. The carp escaped confinement, however, and spread to the waters of the Mississippi River basin and other large rivers. Today, the carp live in 23 states; their population numbers

[1]See wildlifedisease.nbii.gov/wdinNewsDigestMap.jsp.
[2]See wdin.blogspot.com.

2009 U.S. NET IMPORT RELIANCE FOR SELECTED NONFUEL MINERAL MATERIALS

Commodity	Percent	Major Import Sources (2005-08)[1]
ARSENIC (trioxide)	100	China, Morocco, Belgium, Hong Kong
ASBESTOS	100	Canada
BAUXITE and ALUMINA	100	Jamaica, Brazil, Guinea, Australia
CESIUM	100	Canada
FLUORSPAR	100	China, Mexico, South Africa
GRAPHITE (natural)	100	China, Mexico, Canada, Brazil
INDIUM	100	China, Japan, Canada, Belgium
MANGANESE	100	South Africa, Gabon, China, Australia
MICA, sheet (natural)	100	China, Brazil, Belgium, India
NIOBIUM (columbium)	100	Brazil, Canada, Germany, Estonia
QUARTZ CRYSTAL (industrial)	100	China, Japan, Russia
RARE EARTHS	100	China, Japan, France, Russia
RUBIDIUM	100	Canada
STRONTIUM	100	Mexico, Germany
TANTALUM	100	Australia, China, Brazil, Japan
THALLIUM	100	Russia, Germany, Netherlands
THORIUM	100	United Kingdom, France, Canada
VANADIUM	100	Czech Republic, Rep. of Korea, Canada, Austria
YTTRIUM	100	China, Japan, France
GALLIUM	99	Germany, Canada, China, Ukraine
GEMSTONES	99	Israel, India, Belgium, South Africa
ANTIMONY	93	China, Mexico, Belgium
BISMUTH	90	Belgium, China, United Kingdom, Mexico
GERMANIUM	90	Belgium, China, Germany, Russia
PLATINUM	89	South Africa, Germany, United Kingdom, Canada
BARITE	80	China, India
TIN	80	Peru, Bolivia, China, Indonesia
RHENIUM	79	Chile, Netherlands
DIAMOND (natural industrial stone)	78	Botswana, South Africa, Namibia, India
STONE (dimension)	78	Brazil, Italy, China, Turkey
ZINC	76	Canada, Peru, Mexico, Ireland
COBALT	75	Norway, Russia, China, Canada
POTASH	73	Canada, Belarus, Germany, Russia
TITANIUM MINERAL CONCENTRATES	73	South Africa, Australia, Canada, Ukraine
TITANIUM (sponge)	67	Kazakhstan, Japan, China, Ukraine
SILVER	63	Mexico, Canada, Peru, Chile
TUNGSTEN	63	China, Germany, Canada, Bolivia
PEAT	60	Canada
PALLADIUM	47	Russia, South Africa, United Kingdom, Belgium
NITROGEN (fixed), AMMONIA	40	Trinidad and Tobago, Canada, Russia, Ukraine
CHROMIUM	39	South Africa, Kazakhstan, Russia
VERMICULITE	39	China, South Africa
GARNET (industrial)	37	India, Australia, China, Canada
DIAMOND (dust, grit and powder)	35	China, Ireland, Russia, Republic of Korea
MAGNESIUM METAL	35	Canada, Israel, Russia, China
MAGNESIUM COMPOUNDS	28	China, Austria, Canada, Australia
SILICON (ferrosilicon)	27	China, Russia, Venezuela, Canada
COPPER	24	Chile, Canada, Peru, Mexico
PERLITE	21	Greece
GYPSUM	19	Canada, Mexico, Spain
SALT	19	Canada, Chile, Mexico, Peru
ALUMINUM	18	Canada, Russia, Brazil, Venezuela
NICKEL	18	Canada, Russia, Australia, Norway
MICA, scrap and flake (natural)	11	Canada, China, India, Finland
CEMENT	8	China, Canada, Republic of Korea, Thailand
IRON and STEEL SLAG	8	Japan, Canada, Italy, France
IRON and STEEL	7	Canada, European Union, China, Mexico
SULFUR	4	Canada, Mexico, Venezuela
PUMICE	3	Greece, Turkey, Iceland, Mexico
BERYLLIUM	2	Kazakhstan, United Kingdom, Kenya, Ireland
LIME	2	Canada, Mexico
STONE (crushed)	2	Canada, Mexico, The Bahamas
PHOSPHATE ROCK	1	Morocco

[1]In descending order of import share.

FIGURE C.5 2009 U.S. net import reliance for selected nonfuel mineral materials. SOURCE: USGS.

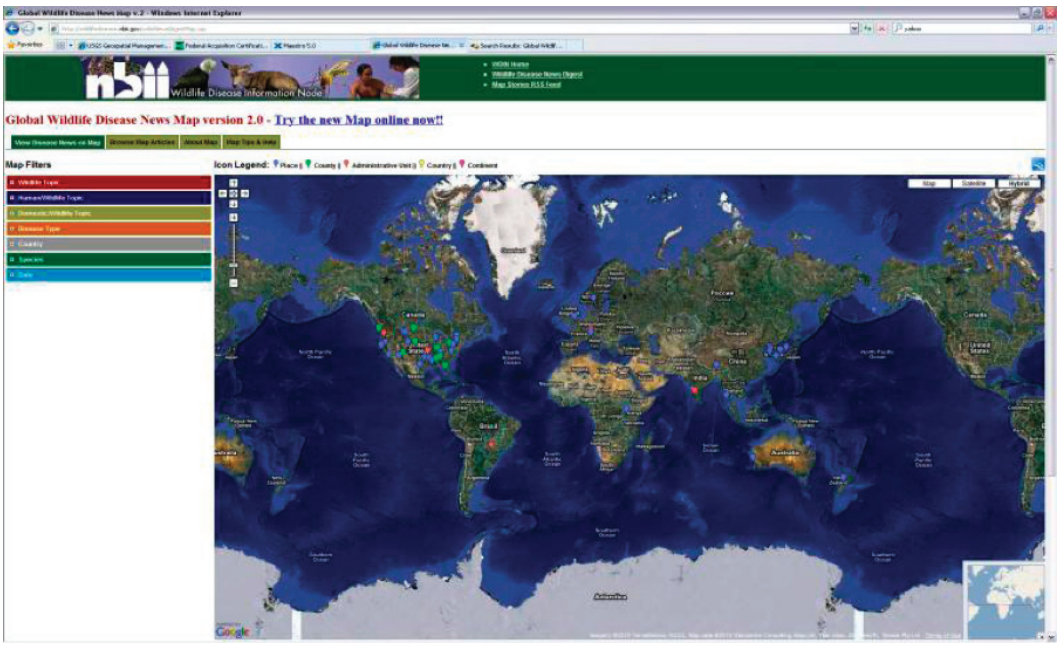

FIGURE C.6 Global Wildlife Disease News Map. SOURCE: USGS.

increasing exponentially, and they are close to entering the Great Lakes. Nutria are invasive semiaquatic rodents whose populations in the United States have become so large that their marsh habitats often cannot sustain them, or our native species. USGS has developed and continues to improve tools to assess nutria population densities, movements and life history characteristics. Such tools can lead to ecological forecasting models, enabling a proactive response to reduce their harmful impacts.

USGS Center of Excellence: The USGS has several Centers of Excellence around the U.S. that have played a role in various international efforts and could play a larger role in the future. The Antarctic Resource Center in Reston, VA has hosted international explorers and researchers for decades. It has evolved into a Polar Center and could be a great asset to climate change researchers. The National Wetlands Research Center in Lafayette, Louisiana has hosted wetlands managers from around the world. The National Earthquake Information Center (NEIC) in Golden, Colorado hosts international seismic experts on a regular basis (see Figure C.7). The National Wildlife Health Center in Madison, Wisconsin is a world-class facility that conducts research on wildlife diseases, including those that affect human health. The USGS EROS facility in Sioux Falls, South Dakota hosts the World Data Center for medium resolution satellite imagery, the UNEP GRID North American

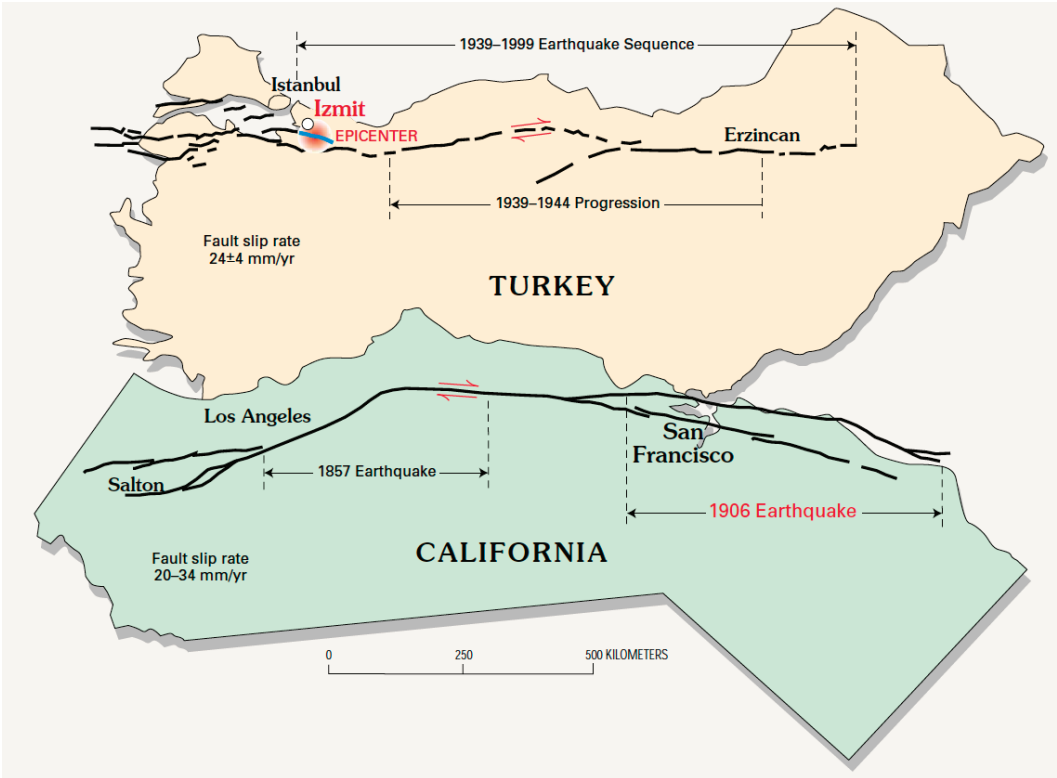

FIGURE C.7 The striking resemblance between the San Andreas and North Anatolian faults suggests that understanding one fault may help to understand the other. SOURCE: Ross S. Stein, USGS (2000a).

office, and conducts remote sensing and geographic information training for geographers from developing countries. Most of these facilities are collocated with a university.

Finally, many USGS scientists are leaders in their area of specialization. As such they are an important part of a global community of scientists and their profession demands that they engage internationally both in their research and in their communications and collaborations.

USGS Support to Department of Defense

The post 9/11 era has seen an increased emphasis on national security issues. The USGS, as have many Federal Agencies, has responded to this change. A result has been an increase in USGS partnership with both the Department of Defense and Department of State. The following are some examples of this increase:

Afghanistan: Since 2002, the USGS has had a significant program in Afghanistan, including a more than 2 year long assignment of a resident advisor at the U.S. embassy in Kabul. With funding from USAID and, more recently, DOD, the USGS has conducted interdisciplinary studies of energy, mineral, and water resources, hazard assessments, and capacity building (Peters et al., 2007). These assessments are intended to promote Afghanistan's use of its natural resources and to stimulate its sustainable economic development. One result of these efforts is the recently released evaluations of Afghanistan's mineral resource potential, work that shows that large mineral deposits are likely to be present (Figure C.8). In evaluating this work, one Deputy Undersecretary of Defense noted that, "The USGS work has fundamentally changed the discussion of how Afghanistan might economically develop."

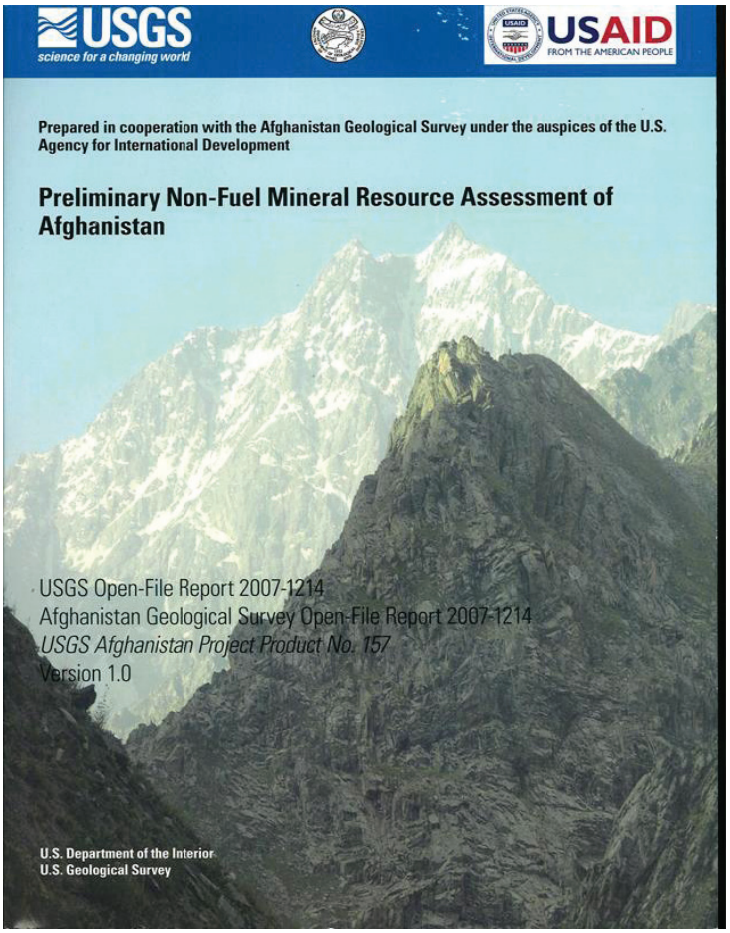

FIGURE C.8 USGS preliminary mineral resource assessment of Afghanistan. SOURCE: USGS.

Iraq: In 2009, the USGS executed an intense, year-long effort to evaluate Iraq's mineral and water resources, while also providing capacity building in the geological and hydrological sciences. One result of this training and new instrumentation is that Iraq can now directly monitor the snow fall and water resources outside of its borders and thus is in a stronger position to discuss trans-boundary water issues with its neighbors.

Additional support to DOD Commands: The USGS continues to cooperate with DOD in a number of other areas. It has a full time employee in Colorado serving as a liaison with the Northern Command (NORTHCOM). It has cooperated in a series of training exercises with the Southern Command (SOUTHCOM). As noted above it has been active in its support of the Central Command (CENTCOM) with work in Afghanistan and Iraq. Currently, the USGS is also working with the recently established African Command (AFRICOM) to detail a USGS scientist to Stuttgart, Germany to support AFRICOM's "soft power" agenda in Africa.

Department of State Support

In the post 9/11 world, the U.S. Department of State has placed renewed emphasis on science diplomacy. President Obama's Cairo speech is one example of this. Not surprisingly, the Department of State has repeatedly recognized the USGS as one of its most important partners in its science diplomacy efforts. The Department of State's Bureau of Oceans, Environment, and Science (OES) is one of the principal groups with which the USGS engages. Recently, OES identified its 5 priority topics. In order, these are:

- **Climate Change**
- Science Diplomacy
- **Global Health**
- **Water and Sanitation**
- **Environmental Protection**
- Clean, Safe, Secure Oceans and Polar Regions
- **Sustainable Natural Resource Management**

There is clearly significant overlap between these priorities and the new USGS restructuring into mission areas (see discussion of Organization Structure above; also note that OES priorities that closely match USGS mission areas are marked in bold text.)

Although "science diplomacy" is not a USGS mission, many of the USGS international scientific activities clearly support diplomatic objectives. A previously cited example is USGS leadership of the RELEMR program which uses earthquakes to bring Middle East countries together. Similarly, USGS leadership of the Middle East EXACT program used

common interests in water resources to bring Israel together with Jordan and the Palestinian Authority to discuss water resource concerns. Both efforts were funded by the Department of State as part of its Middle East Peace Process. Science diplomacy efforts are becoming increasingly important and one may reasonably expect them to become a larger part of USGS' international activities.

Embassy Science Fellows Program: The USGS is an important participant in the State Department's Embassy Science Fellows (ESF) program, which began in 2002. Participants in the program are detailed to an embassy, consulate, or cooperating host country institution for a short period of time to address a particular issue or problem. Most Embassy Science Fellows are assigned 1-3 months at post. Because the embassy only provides office space and some housing, the main cost of the program is borne by the USGS. This cost has limited USGS participation to only one to three scientists per year.

Conflict Diamonds: In response to the Department of State's support of the Kimberley Process, an effort to reduce the trade in "Conflict" diamonds, the USGS has performed a number of geologically based diamond production capacity assessments and capacity building work in Liberia, Ghana, the CAR, Mali, and Guinea.

Muslim Majority Countries: In 2009 President Obama gave a speech in Cairo which emphasized the importance of U.S. science and technology engagement with Muslim Majority countries. Subsequently, the USGS has been actively supporting the President's position with S&T engagements in Kuwait, UAE, Saudi Arabia, and Indonesia.

USGS Organizational Outreach and Support

Since 1995, USGS engagements with international organizations have significantly expanded. The USGS continued its outreach efforts by providing scientists to a wide variety of organizations, and included many opportunities to lead development of international science plans and standards.

The USGS has a long history of support for UNESCO. This support continued, even during the period when the U.S. was not a UNESCO member, and has included direct support for UNESCO's Intergovernmental Oceanographic Commission (IOC) activities and the previously mentioned USGS/UNESCO RELEMR program. Now the United States is fully engaged in UNESCO and the USGS continues to provide U.S. leadership to UNESCO International Hydrological Programme (IHP), UNESCO International Geological Correlation Program (IGCP), and the UNESCO Category II Center (the International Center for Integrated Water Resources Management) that is to be established in the United States. Finally, the U.S. Ambassador to the U.S. Mission to UNESCO has recently

requested a USGS detailee to support the U.S. science agenda at UNESCO headquarters in Paris, France.

The USGS has been active in carrying out cooperative trainings and studies with a variety of other UN organizations (UNDP, IAEA, FAO, and the World Meteorological Organization, WMO). These have provided multiple benefits as well as the ability to interact with scientists from countries that do not have diplomatic relations with the United States.

The USGS has also been a leader or cooperator with several smaller earth science organizations, including CCOP, CPC, OAS, SOPAC, PAIGH, and Eurogeosurveys (see list of acronyms in Annex 3). The USGS also has a special relationship with some of the more established bilateral and multilateral earth science organizations. Collaborative research, sharing of equipment and reciprocal visits of scientists are common with these comparable agencies, including BGR (Germany), BGS (UK), BRGM (France), GA (Australia), GSC (Canada), Environment Canada, and National Institute of Water and Atmospheric Research Limited (New Zealand).

The USGS has leadership roles in efforts to promote Geospatial Data Infrastructure (GSDI), Global Biological Information Facility (GBIF), the International Union of Geological Sciences (IUGS), the Inter-American Biodiversity Information Network (IABIN), the Global Invasive Species Information Network (GISIN), and the hydrology program at the WMO. Traditionally, at least two USGS staffers are members of the National Academy of Sciences' National Committee for Geological Sciences.

Another highly successful USGS engagement has involved the Group on Earth Observation (GEO), the Committee on Earth Observation Satellites (CEOS), and efforts to implement the Global Earth Observation System of Systems (GEOSS). USGS leadership in these efforts started in 2003 and continues to the present day. As an example, the USGS just participated in the Earth Observation Summit in Beijing in November 2010. The USGS provides critical resources for GEO, such as maintaining the global clearinghouse for remote sensing and geospatial data, and participation in the agriculture, climate, disasters, ecosystems and energy societal benefit areas. More than 80 percent of the imagery for the GEO project on Global Land-Cover Data Initiative can be obtained from USGS Landsat missions. In addition, for the past three years, the USGS has funded an employee in Geneva to serve on the GEO Secretariat.

The USGS has also played a key role in the International Charter for Space and Natural Disasters. Since 2005, this effort has involved 19 agencies that have worked to provide a unified system to acquire remote sensing imagery and to delivery those images to areas affected by natural or man-made disasters. The USGS participates in the Charter insures that it receives foreign remote sensing data in support of U.S. disaster response and recovery efforts. In turn, the USGS involvement ensures provision of U.S. land imaging data to support foreign disaster response and recovery efforts.

Future Directions and Challenges

USGS international work has a long and distinguished history. From its beginning in 1882 through the post World War II era, the USGS international work supported its domestic research priorities as well as provided support to many developing countries. During World War II, the Military geology branch played a role in supporting the Nation's security and foreign policy. In the post 9/11 world, USGS international work has increasingly emphasized issues associated with national security and support for U.S. foreign policy. At the same time, USGS international work has also increasingly emphasized multi-disciplinary science, an emphasis that reflects organizational changes within the USGS. The transfer of USGS International Programs into the Director's office in 2010 emphasizes the USGS commitment to have International Programs represent all of the USGS science capability and its six "mission" areas.

Although the USGS is part of a domestically oriented Department of the Interior (DOI), the scientific research it conducts is not limited by international, political boundaries. The USGS has long recognized the mutual benefits that ensue from interaction with scientific colleagues overseas. Such interactions contribute to a better understanding of earth and life science issues here in the United States. In addition, there are many scientific issues, such as invasive species and climate change, which can only be dealt with on an international scale. For example, significant lessons have been learned about the San Andreas Fault in California by studying the similar Anatolian Fault in Turkey. As described in 2000 by the Science Priorities Team for International Activities, "In a world that increasingly recognizes that the earth is a system, the USGS has a unique opportunity and responsibility to provide global scientific leadership" (USGS, 2000b).

The international activities of the USGS continue to evolve to meet other National needs. Often this work is in support of USAID's foreign assistance efforts, work that almost invariably incorporates training, technical assistance and institution building. Increasingly, USGS international efforts have had and will continue to have an element of support for U.S. foreign policy. The most recent example is the DOS effort to promote S&T engagement with Muslim-Majority Countries. The USGS has a more than 50-year record of successful S&T engagement with the Islamic world, work that includes cooperative projects with Afghanistan, Bangladesh, Indonesia, Pakistan, Saudi Arabia, and the United Arab Emirates. Most recently, the USGS has worked with DOD in a number of efforts to promote regional stability and economic growth.

The new USGS reorganization makes this an excellent time to review past USGS international engagements and contemplate what changes might be made to support and strategize future USGS international science. In making these evaluations, it will be critical to consider the role of international work in supporting the USGS core responsibilities as a domestically focused agency that is committed to multi-disciplinary science. It will also be

critical to consider the increasing demands that other organizations, such as the Department of State, USAID, and the Department of Defense, are making of the USGS in support of foreign development, international diplomacy, and National security. In that connection, it may be useful to balance an idealistic vision with realistic constraints posed by limited and uncertain funding and restricted legal authorities for international work (USGS, 2005). The USGS looks forward to the NAS findings and recommendations as a critical part in developing a new international strategic plan and engagement strategy.

ANNEX 1
USGS INTERNATIONAL PROGRAM OFFICE

In 1995, the Office of International Geology became a Bureau-level International Programs Office under the Associate Director for Geology. During this same time period, the USGS established the Biological Resources Division (BRD). BRD was formed at the behest of Secretary of Interior Babbitt who transferred most of the research biologists from the various Bureaus of DOI into this new USGS Division. The result of these changes was that International Programs assumed responsibility for representing all USGS scientific disciplines (geology, hydrology, cartography, and biology) in the international arena.

Further changes occurred in 2010, at which time the USGS completed an internal reorganization that moved it from a discipline focused (geology, water, mapping, biology) Agency, to one focused in the application of integrated science in support of critical "mission areas". The scientifically focused mission areas are:

1. Ecosystems
2. Climate and Land-Use Change
3. Energy and Minerals, and Environmental Health
4. Natural Hazards
5. Water
6. Core Science Systems

An additional result of this change was that International Programs was administratively placed directly under the Director of the USGS. As a Bureau-level function, International Programs is supported by contribution from all of the USGS mission areas.

Although the USGS structure has changed, International Programs Office remains charged with representing USGS interests and capabilities in the international arena. New emphasis is placed on the broader USGS interest in pursuing integrated science in support of all of its critical mission areas.

To accomplish this, International Programs Office has five regional specialists whose primary jobs are to represent USGS interest and coordinate USGS activities around the globe. The five regions covered by these specialists are:

- Europe and the Former Soviet Union
- Africa and the Middle East
- Asia and the Pacific
- Latin America and the Caribbean
- Canada, the Arctic, and the Antarctic

In practice, these specialists have extremely diverse tasks which include support of USGS scientists engaged in international work, representing USGS to organizations such as USAID, Department of State, Department of Defense, and the World Bank, and developing contacts and programs in the countries that are part of their region. A number of programs and activities developed and coordinated by these specialists are discussed in this background paper/

The second group within the International Programs Office is the Bureau Support Unit. Their primary task is to obtain passports, visas, State Department clearances, and other logistical support that is required for USGS international travelers, which amount to over 1000 per year. Additionally, this group processes and maintains the approximately 70 international bilateral agreements which the USGS has in place. Finally, the Bureau Support Unit also is shepherding approximately 30 additional international agreements through the often lengthy approval process.

In 1997, the Bureau International Committee (BIC) was established to support International Programs and to promote closer coordination between IP and the operational scientific parts of the USGS. The BIC makes contributions in two main areas. First, it provides advice used to set Bureau international policy. Second, when needed, it can help to identify the scientific units and scientists that might best respond to an international opportunity. The BIC is now transitioning to include representatives from all the USGS Mission Areas.

ANNEX 2
PREVIOUS USGS INTERNATIONAL REVIEWS

In January 1983 the State Department and the USGS completed a joint report titled "International Role of the U.S. Geological Survey". This report drew heavily on previous USGS summaries of international activities that were updated about once every decade.

In 2000, the Associate Director for Geology convened a Bureau wide meeting to discuss international science priorities for the USGS. This meeting followed on the heels of the

decision by the Director to consolidate the Bureau's international activities into a single office under the leadership of Associate Director for Geology. The results of this meeting are summarized in the report, "Science Priorities Team for International Activities" (USGS, 2000b).

In 2001, the National Academy of Science National Research Council published the results of a study "Future Roles and Opportunities for the U.S. Geological Survey". This study (NRC, 2001), made several references to the potential international role of the USGS and made several recommendations including:

> …it is appropriate for the USGS to become more active at international and global levels as well. By playing a strong role on behalf of the U.S. in promoting, facilitating, and conducting international and global studies to develop critical science information, the USGS lends support to national security as well as foreign policy… (p. 52)

> Because many science issues today are global and international in nature, the USGS in the 21st century should place high priority on the following:
>
> - Performing a more vigorous role in pursuing foreign area and global studies,
> - Providing increased technical assistance to foreign countries,
> - Becoming more active internationally. (p. 63)

> …the USGS is encouraged to play a stronger international role, on behalf of the United States, in order to accomplish its mission. The Committee believes that the importance to the United States of USGS international activities and collaboration cannot be overstated. (p. 87)

In 2007, the USGS developed its Science Strategy for the coming decade (USGS, 2007). The USGS is implementing the recommendations outlined in this Strategy by realigning its management and budget structure around the six scientific mission areas proposed in the Science Strategy. The six mission areas, which are inherently international or global, include global climate change, water resources, natural hazards, energy and minerals, ecosystems, and data integration.

ANNEX 3
LIST OF ACRONYMS AND ABBREVIATIONS

AFRICOM	Africa Command, DOD, Stuttgart, Germany
ARC	Arctic Resource Center, USGS, Reston, VA
BGR	German Geologic Survey
BGS	British Geologic Survey

BIC	USGS Bureau International Committee
BRD	Biological Resources Discipline or Division, USGS
BRGM	French Geologic Survey
CCOP	Coordinating Committee for Geoscience Programmes in East and Southeast Asia
CCP	Circum Pacific Council
CEOS	Committee on Earth Observation Satellites
CPC	Circum Pacific Council
CTWS	Caribbean Tsunami Warning System
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of Interior
DOS	Department of State
DRAGON	Delta Research and Global Observation Network
EDC/EROS	EROS Data Center/Earth Resources Observation and Science Center
ESF	Department of State's Embassy Science Fellows Program
FAO	Food & Agriculture Organization of United Nations, Rome
FEWS	Famine Early Warning System
GA	Geoscience Australia
GBIF	Global Biological Information Facility
GEO	Group on Earth Observations
GEOSS	Global Earth Observation System of Systems
GISIN	Global Invasive Species Information Network
GRID	Global Resource Information Database
GSC	Geological Survey of Canada
GSDI	Geospatial Data Infrastructure, USGS
GSN	Global Seismic Network
IABIN	Inter-American Biodiversity Information Network
IAEA	International Atomic Energy Agency, Vienna
ICA	International Cooperative Agency
IGCP	International Geological Correlation Program (UNESCO)
IHP	International Hydrologic Program (UNESCO)
IOC	Intergovernmental Oceanographic Commission

IOTWS	Indian Ocean Tsunami Warning System
IUGS	International Union of Geological Sciences
LDC	Lesser Developed Countries
MGU	Military Geology Unit, USGS
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NEIC	USGS National Earthquake Information Center
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
NSF	National Science Foundation
OAS	Organization of American States
OES	Department of State's Bureau of Oceans, Environment, and Science
OFDA	USAID's Office of Foreign Disaster Assistance
OIG	Office of International Geology
OMB	Office of Management and Budget
OSTP	Office of Science & Technology Policy, White House
PAGER	Prompt Assessment of Global Earthquakes for Response
PAIGH	Pan American Institute of Geography and History
RELEMR	Reduction of Earthquake Losses in the Extended Mediterranean Region
RGEG	USGS' Research Grade Evaluation Guide
S&T	Science and Technology
SOPAC	South Pacific Council
SPTIA	Science Priorities and Training for International Affairs
THIP	Techniques of Hydrologic Investigations for International Participants
UAE	United Arab Emirates
UNDP	United Nations Development Program
UNEP	United Nations Environmental Program
UNESCO	United Nations Educational, Scientific and Cultural Organization, Paris
USAID	U.S. Agency for International Development (aka "AID")
USGS	United States Geological Survey

USTDA	U.S. Trade and Development Agency, Dep't. Of Commerce
VDAP	USAID/USGS Volcano Disaster Assistance Program
WMO	United Nations World Meteorological Organization, Geneva

ANNEX 4
REFERENCES

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APPENDIX D

Meeting Agendas, Presentations, and Other Information Provided to the Committee

MEETING ONE

February 14-15, 2011, Washington, DC

DAY ONE

08:00-10:15	CLOSED SESSION (Committee & NRC Staff only)	
10:30-16:00	OPEN SESSION	
10:30-10:45	Welcome and introductions	*Ian Pepper, Committee Chair*
10:45-11:30	U.S. Geological Survey perspectives on international science *Jim Devine, Senior Science Advisor to the Director, U.S. Geological Survey*	
11:30-12:00	Background to study and overview of international science at the USGS *Greg Withee, Director, International Programs Office, U.S. Geological Survey*	
12:00-12:45	Lunch	
12:45-15:15	Presentations from USGS senior scientists from six science mission areas	
	12:45-13:10 Climate and Land Use Change	*June Thormodsgard*
	13:10-13:35 Core Science Systems	*Ivan DeLoatch*
	13:35-14:00 Ecosystems	*Bruce Jones*
	14:00-14:25 Energy and Minerals, and Environmental Health	*Sally Brady and Jeff Doebrich*

14:25-14:50	Natural Hazards	*John Eichelberger*
14:50-15:15	Water Resources	*Verne Schneider*

Guiding questions:
1. Summarize your area's current science mission(s) and international activities and describe you mission area's future (5-10 years) science priorities and activities.
2. Why are international activities important to your science mission area and how do you see international activities helping to support national USGS and U.S. Government roles, priorities, and needs?
3. Identify what impediments exist, if any, to more effective participation of your science mission area and the USGS in international science activities.

15:15-16:00	General discussion between USGS and committee
16:00-20:00	CLOSED SESSION (Committee & NRC Staff only)

DAY TWO

08:30-14:30	CLOSED SESSION (Committee & NRC Staff only)

MEETING TWO

April 18-19, 2011, Washington, DC

DAY ONE

08:00-09:15	CLOSED SESSION (Committee & NRC Staff only)	
09:30-12:30	OPEN SESSION	
09:30-09:45	Welcome and introductions	*Ian Pepper, Committee Chair*
09:45-12:30	Panel discussion (15-minute opening remarks followed by discussion with committee)	

Andrew Reynolds, Acting S&T Adviser to the Secretary of State, U.S. Department of State

Annica Wayman, AAAS S&T Policy Fellow, Science & Technology Office, U.S. Agency for International Development

Gotthard Walser, Lead Mining Specialist, The World Bank Group

Emily Scott, Assistant to Undersecretary of Defense, U.S. Department of Defense

12:30-13:30 Lunch

13:30-20:00 CLOSED SESSION (Committee & NRC Staff only)

Day Two

08:00-08:30 CLOSED SESSION (Committee & NRC Staff only)

08:30-09:30 OPEN SESSION - Skype discussion

John Kelmelis, Professor, School of International Affairs, Penn State University

09:30-14:00 CLOSED SESSION (Committee & NRC Staff only)

MEETING THREE

August 16-17, 2011, Irvine, CA

CLOSED SESSIONS (Committee & NRC Staff only)

APPENDIX E

Bibliography of Selected Peer-Reviewed Scientific Publications from USGS International Work

This appendix provides a selected bibliography of peer-reviewed scientific publications about international work authored or co-authored by USGS scientists. Drawn from a total international publication list of nearly 300 going back to 1980, these examples illustrate the wide range of international science work performed by the USGS over many years. Although a number of these references predate the USGS reorganization in 2010, we have, for convenience, attempted to organize the publications by mission area, although the cross-disciplinary nature of many of the publications is also evident.

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