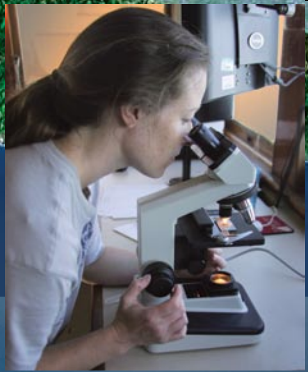
# USGS Science in Menlo Park—A Science Strategy for the U.S. Geological Survey Menlo Park Science Center, 2005-2015



Circular 1290

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

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By Thomas M. Brocher, Michael D. Carr, David L. Halsing, David A. John,
Victoria E. Langenheim, Margaret T. Mangan, Mark C. Marvin-DiPasquale,
John Y. Takekawa, and Claire R. Tiedeman

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**U.S. Department of the Interior**
Gale A. Norton, Secretary

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# Preface

In the spring of 2004, the Menlo Park Center Council (senior managers from each of the U.S. Geological Survey (USGS) organizational units in Menlo Park, California) commissioned an interdisciplinary working group to develop a collective future science strategy for the USGS Menlo Park Science Center (hereafter also referred to as "the Center"). The Council recognized that science priorities must be the primary consideration guiding critical decisions the USGS faces about the future size and nature of staff, facilities, and science support infrastructure at the Center. Each of the science units at the Center has program goals on which they base decisions about science priorities, staffing, and infrastructure needs, but no common vision existed to guide the future science of the Center as a whole. The Council believes that centerwide planning will help focus future science conducted at the Center and provide a framework for maintaining the scientific vibrancy of the Menlo Park Science Center and its leadership role in the Earth sciences.

During the remainder of 2004, the working group gathered and synthesized information. It sought to answer key questions that were developed to help guide future decisions on science and science infrastructure for the Menlo Park Science Center. These questions include:

- What should be the core scientific roles of the Center in the portfolio of USGS science centers in central California, the USGS Western Region, and the Nation?
- What key analytical and infrastructure capabilities should be maintained or developed in Menlo Park to support the roles of the Center to serve the broader USGS mission?
- What existing, enhanced, or new partnerships will be key to USGS success in fulfilling the core scientific roles of the Center?
- What opportunities and challenges are presented by the quality of life and cost of living in the San Francisco Bay Area to the Center's ability to continue to recruit and retain a world-class scientific workforce?

The working group reviewed numerous USGS planning documents and recent external reviews of USGS programs to ensure that future science directions in Menlo Park remain in the vanguard of national USGS science priorities (National Research Council, 2001, 2002; Bohlen and others, 1999; McMahon and others, 2005; U.S. Geological Survey, 1996, 1999, 2002). They sought guidance from the USGS executive leaders in the Western Region and at the national headquarters.
The working group then interviewed representative panels of junior and senior scientists in Menlo Park, Center Chiefs of all the USGS Science and Geographic Information Offices with a presence in Menlo Park and other central California locations, and USGS Program Coordinators.

Written responses to the key planning questions given above were solicited from the entire Menlo Park workforce and all Science Center Chiefs in the Western Region. Representatives of more than 20 universities, other research partners, and client agencies in the San Francisco Bay Area also commented in writing or through interviews on a series of questions about their relationship with the USGS and specifically with the Menlo Park Science Center. Finally, the working group held an all-employees open meeting in Menlo Park to discuss science goals and objectives. Earlier drafts of this document were posted on an internal USGS Internet site for comment. By the end of the process, most stakeholders in the Menlo Park Science Center had

had an opportunity to participate. The contributions of participants from the USGS, science collaborators, and clients broadly agree—they greatly value the accomplishments of USGS at the Menlo Park Science Center and support a continuing USGS commitment to sustain the Center's status as an internationally recognized science center and national resource for achieving USGS mission goals.

Membership of the science strategy working group for the Menlo Park Science Center consisted of seven mid-career research scientists stationed at Menlo Park and representing the diversity of science activities at the Center, a USGS research biologist stationed outside Menlo Park, and a member of the Menlo Park Council to serve as facilitator and management liaison. The members are:

Thomas Brocher, Geology Discipline, Earthquake Hazards Team
Michael Carr, Associate Western Regional Geologist (Chair)
David Halsing, Geography Discipline, Geographic Research and Technology Team
David John, Geology Discipline, Mineral Resources Team
Victoria Langenheim, Geology Discipline, Earth Surface Processes Team
Margaret Mangan, Geology Discipline, Volcano Hazards Team
Mark Marvin-DiPasquale, Water Resources Discipline, Branch of Regional Research
John Takekawa, Biology Discipline, Western Ecological Research Center
Claire Tiedeman, Water Resources Discipline, Branch of Regional Research

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## Executive Summary

In the spring of 2004, the U.S. Geological Survey (USGS) Menlo Park Center Council commissioned an interdisciplinary working group to develop a forward-looking science strategy for the USGS Menlo Park Science Center in California (hereafter also referred to as "the Center"). The Center has been the flagship research center for the USGS in the western United States for more than 50 years, and the Council recognizes that science priorities must be the primary consideration guiding critical decisions made about the future evolution of the Center. In developing this strategy, the working group consulted widely within the USGS and with external clients and collaborators, so that most stakeholders had an opportunity to influence the science goals and operational objectives.

The Menlo Park Science Center is the largest USGS science center in the Western Region and has the greatest breadth of scientific capabilities. The Center is strategically located to take advantage of partnerships in one of the greatest geographic concentrations of nationally and internationally recognized Earth science institutions in the world. The Center also houses the most extensive laboratory, library, and other research-support infrastructure of any USGS facility in the West. USGS scientists in Menlo Park lead in implementing many national USGS science activities, as well as in supporting science activities at other USGS science centers throughout the region and the nation. Other, smaller USGS science centers in the Western Region are designed with more limited scientific and (or) geographic scopes to their programs.

The economic, workforce, and scientific planning environment for the Menlo Park Science Center has changed rapidly over the past two decades. Staff size has decreased, and there has been a shift in emphasis from basic to applied research. Despite the high cost of living, the USGS attracts top scientists for research positions in Menlo Park, largely because of the Center's scientific reputation and setting within the vibrant research environment in the San Francisco Bay Area. Also attractive is the healthy employment market for spouses of USGS scientists in the Bay Area.

A number of recent trends in society and science are important to consider for future science at the Menlo Park Science Center. These include rapid urban population growth, especially in coastal areas; globalization of resource development; increasing demand for limited water resources; global climate change; and increasing capability to construct predictive Earth-system models.

The most promising science directions at the Menlo Park Science Center have evolved and will continue to evolve from traditional capabilities in geologic and hydrologic research, complemented by a growing capability in geographic research, and hopefully augmented by biological expertise from USGS biological resources programs. Future science in Menlo Park will build on and link existing strengths to lead research that supports USGS program priorities as they evolve to meet America's science needs throughout the region, the Nation, and the world.

This science strategy recommends that the USGS Menlo Park Science Center continues to address important national science needs by focusing on Earth-system science through four equally important and interrelated Science Goals, each with associated strategic actions. These Science Goals are to:

1. **Natural Hazards:** Conduct natural-hazard research and assessments critical to effective mitigation planning, short-term forecasting, and event response.
2. **Ecosystem Change:** Develop a predictive understanding of ecosystem change that advances ecosystem restoration and adaptive management.
3. **Natural Resources:** Advance the understanding of natural resources in a geologic, hydrologic, economic, environmental, and global context.
4. **Modeling Earth System Processes:** Increase and improve capabilities for quantitative simulation, prediction, and assessment of Earth system processes.

The strategy presents seven key Operational Objectives with specific actions to achieve the scientific goals. These Operational Objectives are to:

1. Provide a hub for technology, laboratories, and library services to support science in the Western Region.

[1]Authors are listed in alphabetical order.

2. Increase advanced computing capabilities and promote sharing of these resources.

3. Enhance the intellectual diversity, vibrancy, and capacity of the work force through improved recruitment and retention.

4. Strengthen client and collaborative relationships in the community at an institutional level.

5. Expand monitoring capability by increasing density, sensitivity, and efficiency and reducing costs of instruments and networks.

6. Encourage a breadth of scientific capabilities in Menlo Park to foster interdisciplinary science.

7. Communicate USGS science to a diverse audience.

These long-term Science Goals and Operational Objectives are intended as a vision to guide the actions of the USGS at the Menlo Park Science Center. Designing, prioritizing, and implementing actions to advance this strategy are the responsibility of local, regional, and national USGS leadership, as well as the entire USGS research and science support community in Menlo Park. Most especially, the Menlo Park Center Council must, as its most important charge, provide the leadership to continually enhance the scientific vitality of the Center in response to changes in the planning environment.

# Introduction—Context for Strategic Planning

> **Planning Framework for the U.S. Geological Survey (USGS)**
>
> **Mission—**The USGS serves the Nation by providing reliable scientific information to describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy, and mineral resources; and enhance and protect our quality of life.
>
> **Vision—**The USGS is a world leader in the natural sciences through our scientific excellence and responsiveness to society's needs.
>
> **Strategic Direction—**The USGS continually looks for ways to combine and enhance its diverse programs, capabilities, and talents and increase customer involvement to strengthen our scientific leadership and contribution to the resolution of complex issues.

The U.S. Geological Survey (USGS) established its science center in Menlo Park, California, in 1954, responding to the expanding national need and Federal support for science information following World War II. The vision for the Menlo Park Science Center (hereafter also referred to as "the Center") was to concentrate scientific expertise from dispersed sites around the western United States and develop a center where experts representing a variety of disciplines could interact to tackle complex Earth science problems of scientific and societal importance. An important consideration in choosing the Menlo Park site was to interact with nearby institutions having strong Earth science programs, notably Stanford University and the University of California at Berkeley (see section below on Working with Partners).

For more than 50 years, scientists at the Menlo Park Science Center have made key contributions to the USGS mission, to the Earth sciences, and to society through research, scientific monitoring, hazard and resource assessments, and the dissemination of relevant scientific and geospatial information (Gohn, 2004, p. 15). Scientists at the Center have led many of the scientific and program innovations that have helped the USGS meet the changing needs of the Nation. The Center supports USGS programs regionally, nationally, and, as appropriate, internationally. The Menlo Park Science Center is acknowledged worldwide for the excellence, objectivity, and impact of its science and scientists. The strategy presented herein provides long-term science goals intended to guide USGS science at the Center toward a few focused science directions in which Center scientists will sustain a leadership role as they serve the Nation into the future.

## Organizational, Economic, and Workforce Realities

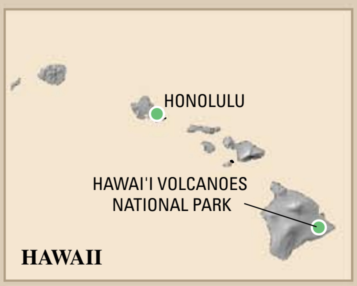
The Menlo Park Science Center is the largest USGS Science Center in the Western region and is likely to remain so for the foreseeable future. Other USGS science centers in the Western Region have been designed with more specific scientific and (or) geographic scopes to their programs. No other USGS science center in the West, existing or planned, is expected to have the breadth of scientific scope or capability currently at the Menlo Park Science Center. The Center is the USGS research hub for the Western Region and supports monitoring and science programs throughout the region. Scientists in Menlo Park conduct a wide array of both basic and applied science, usually in collaboration with scientists from outside the Center. Ongoing collaborations are with other USGS locations, other government agencies, private sector institutions, and academic partners from the local, regional, national, and international scientific communities. Menlo Park also houses the most diverse suite of research laboratories, scientific infrastructure, and library facilities within the region (appendixes 1 and 2), as well as the backbone of the USGS and Department of the Interior Internet technology and infrastructure for the Western United States.

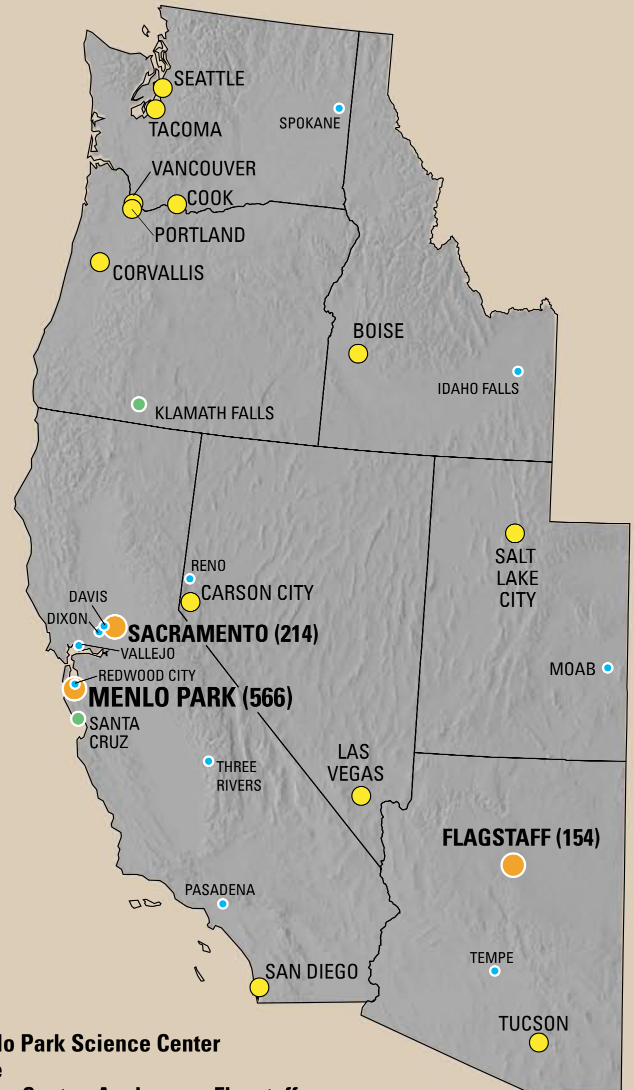
USGS science and information programs span four areas of responsibility, organizationally referred to as Disciplines—Biological Resources, Geography, Geology, and Water Resources—as well as a Geospatial Information Office. The Menlo Park Science Center was originally established as a multidisciplinary regional science center (Gohn, 2004), and it now houses science units that implement USGS programs in the Geography, Geology, and Water Resources Disciplines and

## MAJOR U.S. GEOLOGICAL SURVEY (USGS) FACILITIES IN THE WESTERN REGION

The Menlo Park Science Center is the largest of a regional network of USGS Science Centers working together to serve national science needs in the western United States.

**Employees**
- 10-24
- 25-49
- 50-99
- 100+


### USGS SCIENCE CENTERS, TEAMS, AND BRANCHES IN THE WESTERN REGION

Alaska Science Center, **Anchorage**, **Fairbanks**, **Juneau**
Astrogeology Team, **Flagstaff**
Branch of Regional Research in the Hydrologic Sciences, **Menlo Park Science Center**
Forest and Rangeland Science Center, **Corvallis**, **Seattle**, **Boise**
Geospatial Information Office, **Sacramento**, **Menlo Park Science Center**, **Anchorage**, **Flagstaff**
Pacific Island Ecological Research Center, **Honolulu**
Southwest Biological Science Center, **Flagstaff**, **Tucson**, **Moab**
Southwest Geographic Science Center, **Tucson**, **Flagstaff**
USGS Arizona Water Science Center, **Tucson**, **Flagstaff**, **Tempe**
USGS California Water Science Center, **Sacramento**, **San Diego**, **Santee**
USGS Hawaii/Guam Water Science Center, **Honolulu**
USGS Idaho Water Science Center, **Boise**, **Idaho Falls**
USGS Nevada Water Science Center, **Carson City**, **Las Vegas**
USGS Oregon Water Science Center, **Portland**
USGS Utah Water Science Center, **Salt Lake City**, **Moab**
USGS Washington Water Science Center, **Tacoma**, **Spokane**
Volcano Hazard Team, **Vancouver**, **Menlo Park Science Center**, **Hawaii Volcanoes National Park**
Western Coastal and Marine Geology Team, **Santa Cruz**, **Menlo Park Science Center**
Western Earthquake Hazards Team, **Menlo Park Science Center**, **Pasadena**, **Seattle**
Western Earth Surface Processes Team, **Menlo Park Science Center**, **Flagstaff**, **Tucson**
Western Ecological Research Center, **Sacramento**, **Davis**, **Dixon**, **San Diego**, **Three Rivers**, **Las Vegas**
Western Fisheries Research Center, **Seattle**, **Cook**, **Reno**, **Port Angeles**
Western Geographic Science Center, **Menlo Park Science Center**, **Seattle**, **Vancouver**
Western Mineral Resources Team, **Reno**, **Menlo Park Science Center**, **Tucson**, **Spokane**

the Geospatial Information Office (see appendix 1). Although USGS programs in the Biological Resources Discipline currently are not represented in Menlo Park, substantial biological research is conducted at the Center by Water Resources and Geologic programs, especially in estuary, lake, wetland, and stream environments. Such studies emphasize contaminant biology, bioavailability, and bioaccumulation of potentially hazardous naturally occurring and manmade materials. Menlo Park scientists also collaborate widely with biologists at other USGS centers and at universities nationwide.

The economic, scientific, and workforce planning environment for science in Menlo Park and the USGS as a whole has been changing rapidly over the past several decades. Appropriated funding for the USGS has been essentially constant since the middle 1970's (National Research Council, 2001), while costs have increased. As national priorities have shifted, there has been a shift in the balance between basic and applied research, and reimbursable programs have become a larger part of the USGS funding portfolio. Computer technology has revolutionized scientific approaches. The workforce has become smaller. More specific to the Menlo Park Science Center, the economic boom during the 1990's in Silicon Valley gave rise to concerns that the Center would become economically untenable for the USGS because of the rising costs, particularly real estate costs, in the San Francisco Bay Area. The workforce size at the Center reached a peak in 1979. Since then, hiring in permanent research and science support positions has been sparse, owing to budget constraints. By 2010, nearly all of the permanent staff hired in the middle to late 1970's will be eligible for voluntary retirement and the USGS will be threatened with losing much critical expertise over a relatively short time period. At the same time, this rapid evolution of the workforce will provide opportunities to move in new science directions by adding new skills, capabilities, technology, and ideas.

To examine these issues, in 1998 the Secretary of the Interior commissioned a panel to review program and facilities plans for Menlo Park. The panel drew two major conclusions: (1) in the short term, practical considerations alone require the retention of the Center at Menlo Park and (2) consideration of space and facilities costs should play a larger role in program management decisions at Menlo Park. In addition, the panel recommended that "the precious and costly resource of Menlo Park space should be allocated only for those particular programs that receive definable and demonstrable benefit from it." It further recommended that "consideration should be given to the fuller integration of the Biological Resources Discipline regional office and program elements with the strongest need and potential for collaboration with other Menlo Park programs" (U.S. Geological Survey, unpublished administrative report, 1999).

As a result of this review, the USGS developed a Long-Term Science and Facility Plan for the Western Region (U.S. Geological Survey, unpublished administrative report, 1999); dispersed USGS executive leadership from Menlo Park and distributed it across the region; committed to the gradual relocation of regional administrative support functions to Sacramento, California; and committed to the gradual relocation of the Coastal and Marine Geology Program to Santa Cruz, California, to partner with the growing ocean-science community in the Monterey Bay Area. In addition, a shift in program emphasis of USGS geographic data programs from paper cartographic products to the digitally based products of *The National Map* is resulting in fewer staff devoted to production of cartographic products in Menlo Park.

In aggregate, these changes have allowed the USGS to successfully implement the 1998 panel recommendation to the Secretary of the Interior that the USGS should complete its planned consolidation of programs and operations on the Menlo Park facility into Federally owned space. By 2008, completion of planned gradual program migrations, mainly to Sacramento and Santa Cruz, will achieve further reductions in USGS use of Menlo Park space. The only recommendation of the 1998 panel that has not been implemented is "the fuller integration of the Biological Resources Discipline … program elements with the strongest need and potential for collaboration with other Menlo Park programs." Integrating USGS Biological Resources programs into the Menlo Park Science Center thus remains an issue.

The Menlo Park Science Center is evolving from past multiple roles as a research center, cartographic production center, and administrative headquarters for the USGS Western Region to a more coherent role as the largest USGS research center in the West, serving the entire region, as well as national and international USGS programs. Miscommunication about the future plans of the Menlo Park Science Center over the past decade have led to misperceptions that persist within the local public, parts of the USGS, and the larger scientific community that the USGS is closing Menlo Park. This is not the case. Current consolidation is not intended to close Menlo Park, but to adjust Menlo Park facilities to a size that most successfully supports USGS science and the research infrastructure needed across the Western Region as a whole and that reflects budget and staffing resources (U.S. Geological Survey, unpublished administrative report, 1999).

In addition, several elements of the planning environment have changed since the 1998 panel reported to the Secretary of the Interior and the USGS completed its Long Term Science and Facility Plan (U.S. Geological Survey, unpublished administrative report, 1999). Notably, the economic downturn in Silicon Valley since 2000 has entirely altered forecasts of future commercial real estate rates in the area. In contrast to the twofold to threefold increase in rental rates projected during the peak of the economy in the late 1990's, current forecasts of future rent rates in Menlo Park compare favorably with recently negotiated leases for other USGS centers elsewhere in the Western Region. The USGS and General Services Administration currently are negotiating a new occupancy agreement for the Menlo Park facility that will mitigate concerns over rent costs through 2012. However, USGS must remain vigilant in planning to ensure that science facilities can continue to evolve to meet scientific program needs well beyond 2012.

The cost-of-living adjustment (“locality pay”) paid to Federal employees in the San Francisco Bay Area is among the highest in the nation. Therefore, the costs for Federal salaries at many USGS locations in central California, including Menlo Park, are higher than in other USGS locations. These differential costs almost certainly will remain in the future and must be weighed against enhancements to scientific productivity that are generated by the intellectual environment created by a large multidisciplinary science center and the opportunities for collaboration afforded by the diverse intellectual community of academic, Federal laboratory, and other science institutions and clients in the San Francisco Bay Area.

Hiring for permanent positions in Menlo Park has been sufficiently rare over the past decade that there are no statistically meaningful data on recruitment and retention of research staff. Discussions with recently hired Ph.D.-level research scientists during the development of this science strategy indicate that the intellectual environment and scientific vibrancy of the Menlo Park Science Center and the San Francisco Bay Area as a whole outweighed concerns about cost of living in most of their decisions to join the USGS. Affordable housing, commutes, and child day care remain acute concerns. However, the USGS has been able to recruit highly qualified scientists to the two dozen or so permanent research positions that have been offered in Menlo Park during about the past decade. The USGS remains an especially attractive employer for Earth scientists who were trained at San Francisco Bay Area universities and who wish to continue living in the local area.

The Menlo Park Science Center is a leader within the USGS in contributing to the training of the next generation of Earth scientists through student and postgraduate research internships. Local economics have not prevented the USGS from attracting strong candidates to postdoctoral research positions at the Center. During the past five years or so, the Center has led the USGS nationally in filling appointments for postdoctoral research fellows (including, but not limited to, Mendenhall Fellows in Geology and National Research Council Fellows in Water Resources programs). Postdoctoral fellows also are attracted to the Center primarily by the scientific vibrancy, especially the opportunity to work with nationally renowned scientific leaders. A few of these research fellows eventually compete successfully for permanent research positions in Menlo Park. Even more of them go on to permanent positions at other USGS facilities across the Nation. Still others take positions in academia and in other agencies, while retaining strong ties to the USGS, continuing to contribute to USGS programs, and strengthening organizational ties between the USGS and other science institutions.

## Working with Partners—Local, Regional, National, and International

Menlo Park is located at the geographic center of one of the greatest concentrations of nationally and internationally recognized Earth science institutions in the world. Local academic partners include the University of California (Berkeley, Davis, and Santa Cruz), Stanford University, and California State University (San Francisco, San Jose, East Bay, Sacramento, and Monterey Bay). Partnerships with other Federal laboratories include ones with the Lawrence Livermore and Lawrence Berkeley National Laboratories, operated by the University of California for the Department of Energy, and the Ames Research Center of the National Aeronautic and Space Administration. State science agencies such as the California Geological Survey, as well as state and local resource and emergency management agencies are additional key collaborators and clients. The USGS also cooperates with local and regional government organizations, local industry partners, and nongovernmental organizations.

These local partners help produce USGS science and contribute to focusing USGS science products on addressing decisionmaking needs. San Francisco Bay Area universities have been a dominant recruiting source for USGS researchers. A 1992 workforce summary showed that more than 20 percent of doctoral-level researchers in the USGS Geologic Division nationwide received their highest-level academic training at Stanford University or one of the three University of California campuses in the Bay Area (Berkeley, Davis, and Santa Cruz). In addition, Bay Area partners have provided USGS access to unique and costly analytical facilities, such as the synchrotron radiation laboratories at Stanford and Berkeley, the USGS/Stanford Ion Microprobe, and the Lawrence Livermore National Laboratories Center for Accelerator Mass Spectrometry.

Representatives of more than 20 institutions—universities other research partners, and client agencies in the San Francisco Bay Area—provided input to this strategy by responding to questions about their organization’s interactions and experiences with the USGS in Menlo Park. The majority of these collaborators and clients reported that their interactions with the USGS are frequent, positive, and important to essential contributions toward their organization’s missions. The majority also reported that the greatest scientific strength of the USGS Menlo Park Science Center is its diverse, large pool of talented scientists.

The USGS in Menlo Park must continue to foster these and other important partnerships. Evolving science priorities and USGS organizational structures in the Western Region are modifying the nature of local and regional USGS partnerships. Collaborations between individual USGS scientists in Menlo Park and their counterparts in other institutions remain strong. These individual collaborations continue to expand well beyond central California, involving universities and other science institutions worldwide. The USGS must constantly review and renew its institutional partnerships in the Bay Area, continually foster opportunities to collaborate, share facilities and expertise, and encourage student involvement in USGS studies.

As the research hub of the USGS Western Region, the Menlo Park Science Center must also foster and expand partnerships with and between other USGS scientists and facilities. The

## WORKING WITH LOCAL PARTNERS HELPS USGS LEARN HOW TO MEET THE SCIENCE INFORMATION NEEDS OF THE NATION

A Cooperative Research and Development Agreement (CRADA) between the U.S. Geological Survey (USGS) and Pacific Gas and Electric Company (PG&E) is helping USGS understand industry's specific needs for earthquake hazard information and how USGS information is used to protect America's lifeline utilities infrastructure.

Scott Dam, built in 1921, formed Lake Pillsbury on the Eel River and is used to regulate annual runoff. In addition to flood control, this multipurpose project provides for electricity production at PG&E's Potter Valley powerhouse, domestic water supply, and recreational needs around Lake Pillsbury.

In 2005 the USGS, in collaboration with PG&E, established a dense array of 31 campaign Global Positioning System (GPS) sites in the area to measure fault creep along the Bartlett Springs Fault. Although some data indicated that significant fault creep might be occurring on the fault, few geodetic observations were available before this deployment. In addition, an alignment array spanning the fault at the north end of Lake Pillsbury was established to measure near-surface creep. During the next five to ten years, both the GPS and alignment arrays will be used to constrain the nature of crustal deformation in the area and provide a better estimate of seismic hazard in the vicinity of Scott Dam.

*Scott Dam*

*GPS receiving station at Lake Pillsbury, Northern California.*

USGS in the Western Region is becoming more geographically dispersed. The balance of science is shifting more to short-term applied research, although the need to advance basic scientific understanding as a long-term investment for the Nation remains high. Increased application of Earth system science to problem solving requires more interdisciplinary collaboration. Finally, scientific planning involves greater input from end-user clients. Consequently, collaboration and communication among USGS centers throughout the Nation will become increasingly important to maintaining regionally relevant science in context of national program goals. In this way, the USGS national role and science impact will remain greater than the sum of the parts. As the largest and most diverse research center in the West, Menlo Park must exert greater leadership in linking USGS sciences centers in the West as a virtual regional center that can effectively share science capabilities and science support infrastructure and bring the diverse capabilities of the USGS to bear wherever they are needed.

The USGS Menlo Park Science Center is recognized internationally as a center of excellence for Earth science research. It conducts hazard research in response to earthquakes, volcanic unrest, and tsunamis worldwide. It participates in global mineral and energy resource assessments and international environmental research. Scores of scientists from around the world have visited Menlo Park to work with USGS scientists, and many USGS scientists from Menlo Park have participated in overseas scientific exchanges. As environmental, natural-hazards, and natural-resource issues become increasingly global, the USGS must appropriately engage in international science partnerships and scientist exchange programs. Scientists in Menlo Park can and should assume a greater leadership role in the international science program of the USGS as a whole.

## Scientific Opportunities—The Nation's Need for Science

Future social trends will continue to shape the scientific and program priorities of the USGS (National Research Council, 2001). Among the key trends and technical developments that will most influence science at the Menlo Park Science Center are:

- Continued growth of urban populations relative to the world population, especially in coastal areas
- Increasing exposure to natural hazards, particularly in growing urban areas
- Continued globalization, which will require the USGS to play a stronger role in international and global studies to provide critical science information as the Nation's wellbeing becomes more tied to global markets and developments
- Growing recognition that natural and human-induced changes in the global environment, particularly climate variability and change, will have substantial effects on Earth systems and resources at all geographic scales
- Increasing demand on water resources
- Increasing numbers of costly and complex environmental restoration and adaptive management efforts at ecosystem scales
- Need for water, ecosystem, mineral, and energy resource information on a global scale
- Greater emphasis in the natural science community on Earth system science approaches and willingness to explore science questions at the boundaries between traditional science disciplines
- Growth in understanding and technical capability to produce process-based, integrative, quantitative models of Earth systems
- Growing expectations and demand for information from the science community in formats useful to support making decisions at all levels of society

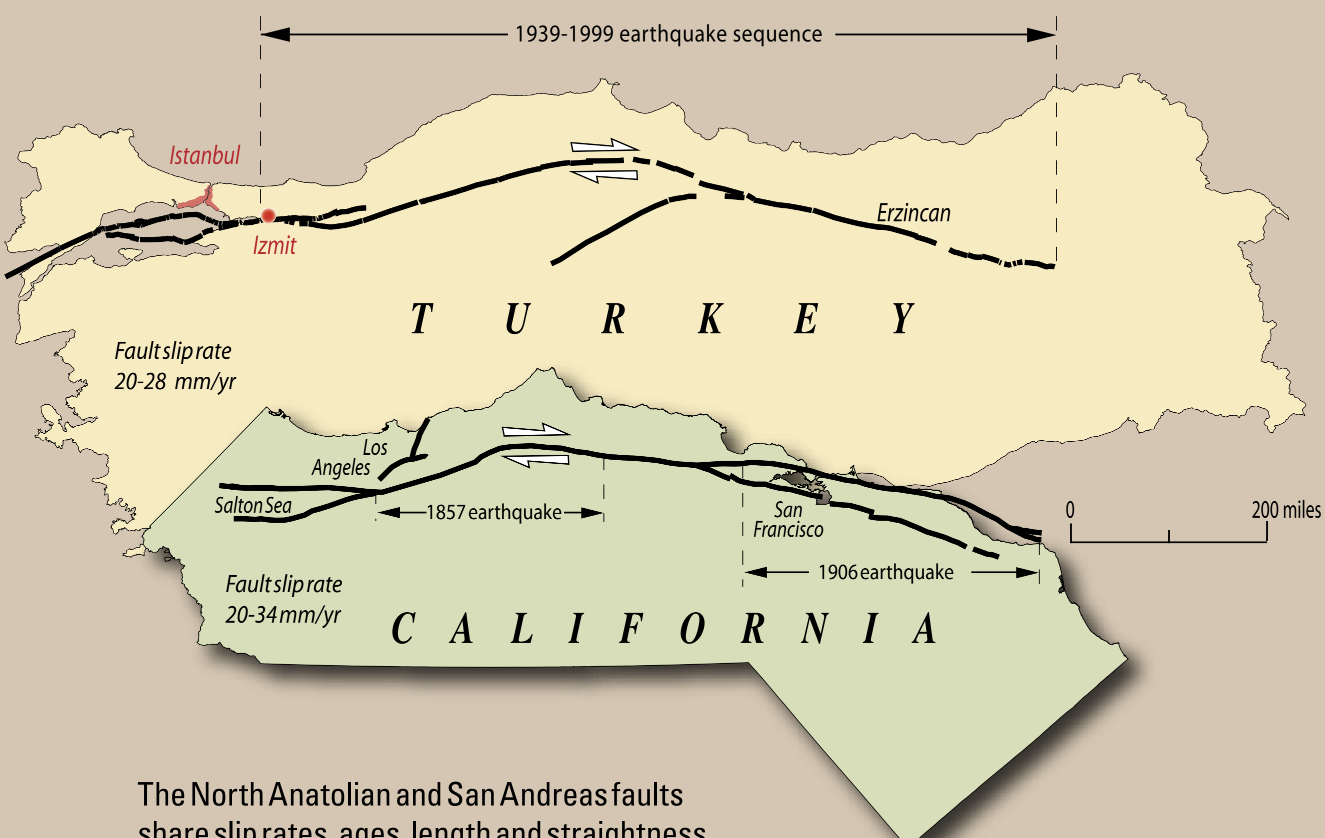
In response to these developments, the science strategy focuses the role of the Menlo Park Science Center as a center for Earth system science, addressing national needs in the topics of ecosystem change, natural hazards, and natural resources. Crossing all areas of investigation is an emphasis on quantitative modeling approaches based on understanding of Earth system processes, which aims to forecast the future behavior of Earth systems in response to natural and human-induced change. Scientists in Menlo Park already are internationally recognized for scientific contributions that address societal issues in these scientific areas.

Several priority demands for cross-disciplinary science information form a basis for shaping science goals at the Menlo Park Science Center. For example, the growth of urban areas is increasing the complexity of resource-management decisions and emergency-management planning decisions to secure against a variety of natural hazard threats. While efforts to improve assessment methodologies addressing single resources or hazards should and will continue, assessment methodologies that support decisions about prioritizing competing resource demands within a land-management area or prioritizing the commitment of hazard-mitigation resources in a community also must advance.

In addition, there is a need for science results in formats that are readily understandable by decisionmakers at all levels, from individual citizens to institutions and governmental agencies. Developing quantitative simulation, forecast, and assessment methodologies with user-friendly output are part of the challenge. This is particularly important for the USGS to fulfill its special responsibilities to supply the information needed for science-based decisions by the Department of the Interior agencies responsible for land and resource management. Plans to expand USGS research in Geography (National Research Council, 2002; McMahon and others, 2005) provide

## LESSONS FROM AROUND THE WORLD HELP U.S. GEOLOGICAL SURVEY (USGS) SCIENTISTS UNDERSTAND NATURAL HAZARDS AT HOME

Immediately following the magnitude (Mw) 7.4 Kocaeli, Turkey, earthquake of August 17, 1999, scientists from the Menlo Park Science Center were invited to participate in the postearthquake investigations. In addition to assisting Turkish colleagues, the USGS scientists had an opportunity to learn lessons for reducing the risk of earthquakes in the United States. The striking similarities between the Northern Anatolian Fault in Turkey and the San Andreas Fault in California suggest that new understanding of the fault mechanics of one system may be applied directly to the other (U.S. Geological Survey, 2000). Photograph shows USGS scientists at Dilovasi, Turkey, installing a component of a portable seismograph network to monitor earthquake aftershocks.




The North Anatolian and San Andreas faults share slip rates, ages, length and straightness

Illustration by: Serkan Bozkurt

an opportunity to consider the human dimension in all of its science goals, exploring the interactions between natural systems and social systems in a geographic context.

The Menlo Park Science Center's program emphases are built around traditional capabilities in geologic and hydrologic research, complemented by a growing capability in geography research (see appendix 1), and will ideally be augmented by appropriate USGS biological expertise. Addition of biological expertise in terrestrial and aquatic ecology and ecological modeling would enhance the ability of the USGS in Menlo Park to build on existing capabilities in surficial geology, hydrology, and landscape characterization to address a broader range of ecosystem science questions. The Menlo Park Science Center also must continue to engage in basic research necessary as a basis for providing the science leadership to advance the state of science and technology employed in USGS applied research throughout the Center, the region, and the Nation.

In addition to its role as a national Earth systems research center, the Menlo Park Science Center will continue to take the lead in scientific monitoring, assessments, and information activities appropriate to its location. For example, the Center will continue to partner with collaborators and clients to maintain the Northern California Seismic Network, contribute to earthquake hazard assessments, monitor change in the San Francisco Bay ecosystem, and implement activities for The National Map in Bay Area counties.

The science strategy presented herein represents a synthesis of discussions with USGS scientists at the Menlo Park Science Center, USGS national leadership, and USGS collaborators and clients in the San Francisco Bay Area. These discussions are distilled into a set of science goals and operational objectives that are intended to articulate the common science vision of the Menlo Park science community and broadly guide the direction of USGS science at the Menlo Park Science Center into the next decade. The remainder of this document is devoted to articulating these "Science Goals" and "Operational Objectives," and recommending some "Next Steps" to implement this science strategy. No priority is implied by the order in which the goals and objectives are presented.

# Science Goals of the Menlo Park Science Center

## Science Goal 1: Conduct natural-hazard research and assessments critical to effective mitigation planning, short-term forecasting, and event response

The Menlo Park Science Center is recognized for its leadership role in providing the Nation with reliable, timely Earth science information for the purposes of identifying and mitigating a wide array of natural hazards. It is especially well known for seminal contributions to the science of earthquake and volcano hazards, but also contributes substantively to understanding hazards related to toxic contamination, tsunamis, landslides, hydrothermal disturbances, flooding, sediment and salt-water incursions, forest fires, and insect-born pathogens. Although many natural hazards are unpreventable, their impact can be reduced through a combined approach of research, monitoring, and assessment that effectively answers the crucial questions—where? when? how big? how often? The human catastrophe and economic impact to the Nation associated with Hurricanes Katrina and Rita, as well as the tragic impacts of recent tsunamis in coastal nations around the Indian Ocean, underscore the societal value in understanding, anticipating, and mitigating natural hazards.

Hazards research at the Center owes its long record of success to the diverse scientific workforce, technological expertise, and state-of-the-art laboratories located at the Center and in nearby institutions. The regional partner and customer base for the hazards work conducted by USGS scientists at the Center is broad, including important, long-standing relationships with the state geological surveys and county water districts in California, Nevada, and Oregon; the CALFED Bay-Delta Program; the California Governor's Office of Emergency Services; Pacific Gas & Electric Company; Earth science departments at Stanford University, University of California Berkeley, University of Nevada; and other Federal agencies such as the Department of Energy, National Aeronautic and Space Administration Ames Research Center, Bureau of Reclamation, Army Corps of Engineers, U.S. Forest Service, Federal Emergency Management Agency, and the National Park Service. New academic and interagency partnerships will emerge in the coming decade through the Center's prominent role in EarthScope (www.earthscope.org), an initiative led by the National Science Foundation and designed to advance basic research in the solid Earth sciences through the deployment of hundreds of new seismic, geodetic, and other monitoring stations across North America.

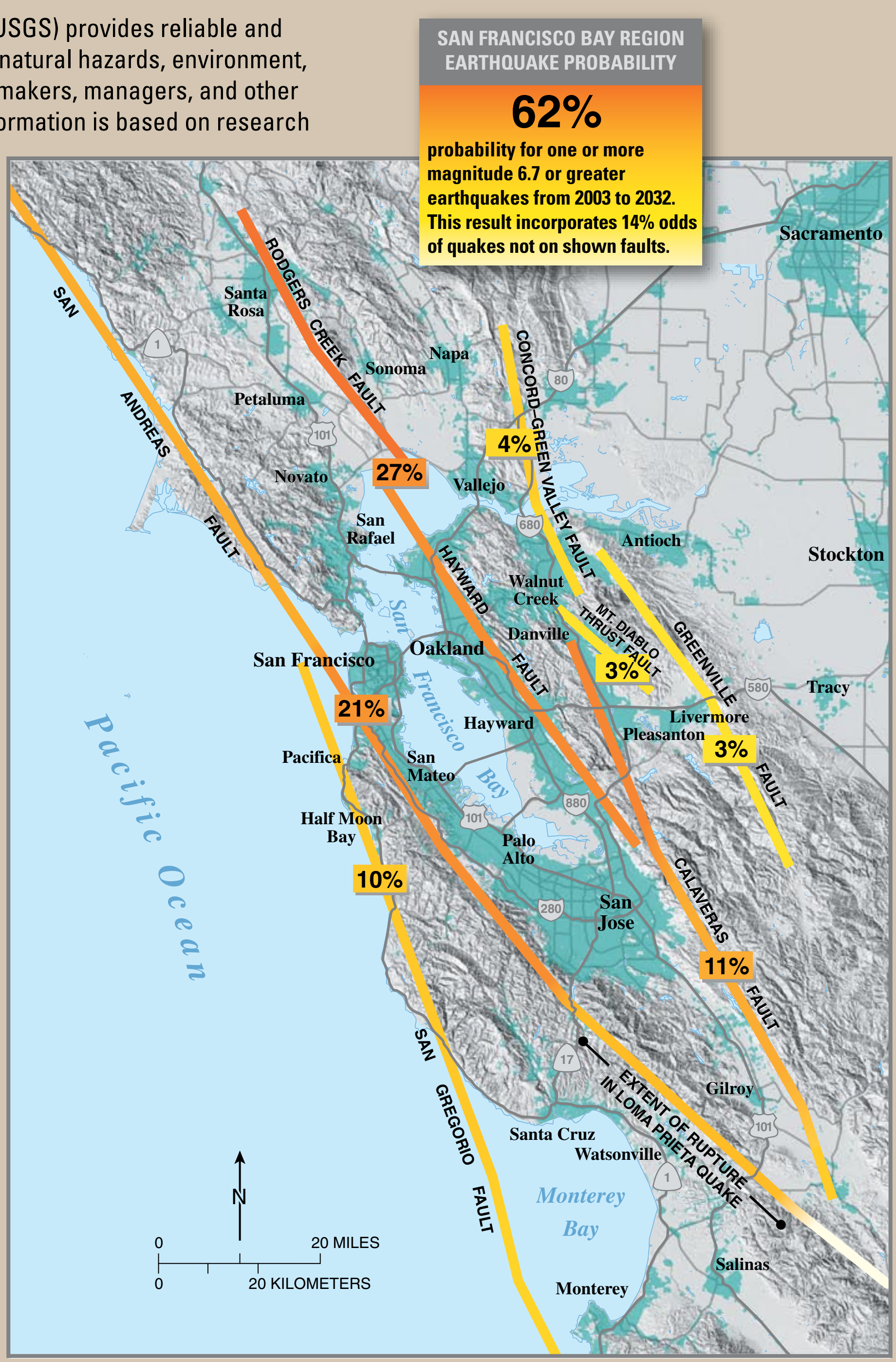
Future hazard research and assessment activities at the Menlo Park Science Center will be guided by the following four strategic actions:

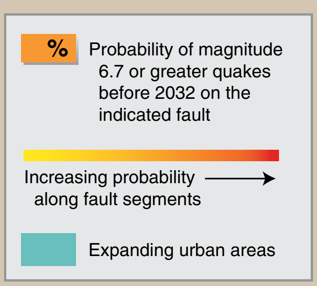
### 1a. Monitor potentially hazardous areas and develop the scientific framework necessary to understand and model the signals of change

Effective long- and short-term monitoring of dynamic and potentially hazardous Earth systems relies on collecting and integrating diverse geophysical, geological, geochemical, hydrologic, and biologic data. Collectively, hazard research at the Menlo Park Science Center has an impressive record of innovative Earth monitoring and network design. For example, Menlo Park is headquarters for the Northern California Seismic Network, which records more than 15,000 earthquakes occurring in central and northern California each year, as well as for the National Strong Motion Program, which maintains 900

## CAREFUL RESEARCH IS THE BASIS FOR PROVIDING SOUND SCIENCE RESULTS FOR DECISIONMAKERS

The U.S. Geological Survey (USGS) provides reliable and useful scientific information on natural hazards, environment, and natural resources to policymakers, managers, and other stakeholders. This scientific information is based on research results that generally are described in peer-reviewed journal articles and USGS books and maps targeting the scientific community and represent new knowledge obtained using controlled studies or detailed analyses. The peer-review process provides a mechanism to achieve a consensus in the scientific community on the accuracy of the results. The broad knowledge that is used in providing sound, impartial scientific advice to the Nation's decisionmakers typically is distilled from many research studies conducted over decades. For example, the report Earthquake Probabilities for the San Francisco Bay Area (Working Group On California Earthquake Probabilities, 2003) has about 220 citations covering more than 20 years of work, much of which was conducted at the USGS Menlo Park Science Center. Careful research is the source of new knowledge that enables the USGS to continue to play a leading role in providing sound, impartial, and useful information for the Nation.

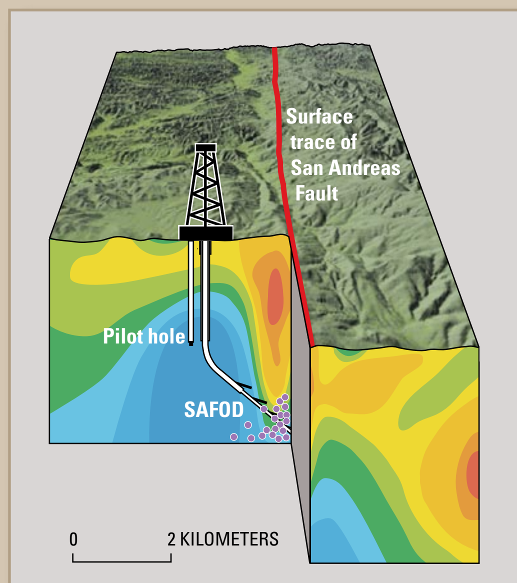



*Is a powerful earthquake likely to strike in the next 30 years? Using newly collected data and evolving theories of earthquake occurrence, scientists from USGS Menlo Park and other institutions in the region have concluded that there is a 62% probability of at least one magnitude 6.7 or greater quake, capable of causing widespread damage, striking somewhere in the San Francisco Bay region before 2032. (From Michael and others, 2003.)*

## SAN ANDREAS FAULT OBSERVATORY DEPTH (SAFOD): DIRECT OBSERVATION OF PHYSICAL, CHEMICAL, AND HYDROLOGIC PROCESSES THAT CONTROL EARTHQUAKES

The goal of the 3.2-km-deep The SAFOD borehole, 3.2 km deep, is a partnership between the U.S. Geological Survey and the National Science Foundation under the EarthScope program (see www.earthscope.org). Its goal is to penetrate and sample the San Andreas Fault Zone in a region that produces repeated and characteristic magnitude 6 earthquakes. Drilling of the SAFOD hole started west of the San Andreas Fault. The hole then angles through the entire fault zone using advanced directional-drilling technology. Fault-zone rocks and fluids are being retrieved for laboratory measurements. Other measurements will be made directly within the active fault zone. Direct sampling of the fluids and geological units in the fault zone and surrounding country rock, in-place stress measurements, in-place seismic monitoring, and many other borehole studies performed in the fault zone will provide direct tests of current earthquake models. SAFOD will yield information on the composition and mechanical properties of rocks in the fault zone, the nature of stresses responsible for earthquakes, the role of fluids in controlling faulting and earthquake recurrence, and the physics of earthquake initiation and rupture. This project will also, for the first time, allow scientists to monitor and record earthquakes up close, marking a major advance in the pursuit of a rigorous scientific basis for assessing earthquake hazards and predicting earthquakes.




accelerographs in 32 states and the Caribbean. Menlo Park's Yellowstone and Long Valley Volcano Observatories coordinate geologic and hydrologic monitoring of potentially active volcanic centers in Yellowstone National Park, the California Cascades, and the Eastern Sierra Nevada. The landslide group in Menlo Park maintains the capability to deploy a real-time network of geotechnical instruments to Northern California sites subject to ground failure. A future challenge is to maximize monitoring capabilities through coordination with EarthScope instrument deployments and judicious use of new technology in electronic miniaturization, synoptic remote sensing, satellite communications, and extreme-environment instrumentation.

The scientific framework for interpreting dynamic signals in the context of fundamental Earth processes and potential hazards will be advanced through studies providing (1) realistic, surficial and three-dimensional Earth models; (2) information on the timing, duration, and cyclicity of past hazardous events; (3) characterization of the chemical, physical, and dynamic properties of Earth materials; (4) knowledge of the physiochemical processes acting at the interfaces between geosphere, hydrosphere, and biosphere; and (5) quantitative understanding of large-scale earth processes that trigger cascading hazardous events (for example, an earthquake triggering a landslide that in turn triggers a tsunami). Laboratory infrastructure, field studies, and computational facilities are all critical to advances on these fronts. Linking hydrologic and geologic processes is a particular strength of the hazards research conducted at the Menlo Park Science Center. For example, ongoing studies of the role of fluids in subduction zones are teaching us how rapidly subduction zone thrust faults are dewatered and as a result become increasingly seismogenic (Saffer and Bekins, 2002).

### 1b. Spearhead the development of multiple-hazard assessment methodologies that draw on quantitative predictive modeling and decision-support science

The burgeoning growth of population centers and infrastructure in the Western United States calls for the creation of a new generation of probabilistic assessment products that address multiple and interrelated hazards. Public and private institutions that make hazard policy decisions are faced with a variety of environmental, geological, and hydrological concerns. In order to balance economic constraints with a plethora of potential natural hazards, decisionmakers must have a coherent framework for prioritizing mitigation, preparedness, and

## USGS NATURAL HAZARDS INITIATIVE

The Menlo Park Science Center is particularly well positioned to respond to the USGS Natural Hazards Initiative, which is focused on rapid-onset natural disasters such as earthquakes, tsunamis, volcanoes, landslides, debris flows, floods, and fires. The Center has a long history of pioneering highly visible, high-impact products that have helped to mitigate losses from these types of rapid-onset natural disasters, of conducting the basic research necessary to develop these products, and of educating the public about the risks posed by such natural hazards. Tools already in wide use at the Center can be used for assessing a number of these hazards. For example, high-resolution topographic (LIDAR) mapping and InSAR imagery are useful for a wide variety of natural hazard assessment, including fires, flooding, landslides, volcanoes, and earthquakes. Finally, scientists in Menlo Park are among the leaders in advancing decision support science in the USGS and can provide leadership in interfacing new scientific understanding developed in Menlo Park with public policy and decisionmaking tools.

response efforts. Probabilistic, regionally based assessments of all known hazards used in tandem with traditional deterministic assessments provide this framework. New products will take advantage of the Menlo Park Science Center's growing expertise in Geographic Information Systems (GIS) and GIS-based scenario simulation and decision-support science. For example, researchers at the Center have developed the Land Use Portfolio Model to integrate natural-hazard and socioeconomic information and to help communities evaluate alternative natural-hazard mitigation policies (Bernknopf and others, 2001, in press). The Land Use Portfolio Model is a statistical, modeling, mapping, and risk communication methodology that can assist government agencies and communities in understanding and reducing their vulnerability to natural hazards (also see Science Goal 4). Understanding the human impact and improving the resiliency of communities to hazards are a key focus for future hazards assessment research and for USGS partnerships with the emergency planning community. The Menlo Park Science Center is already a leader in many types of natural hazard assessment, such as earthquakes and volcanoes. Making progress in developing multi-hazard assessment methods will require other parts of the USGS to supply expertise on other natural hazards, such as floods and wildfire.

### 1c. Provide short-term hazard forecasting and real-time event response

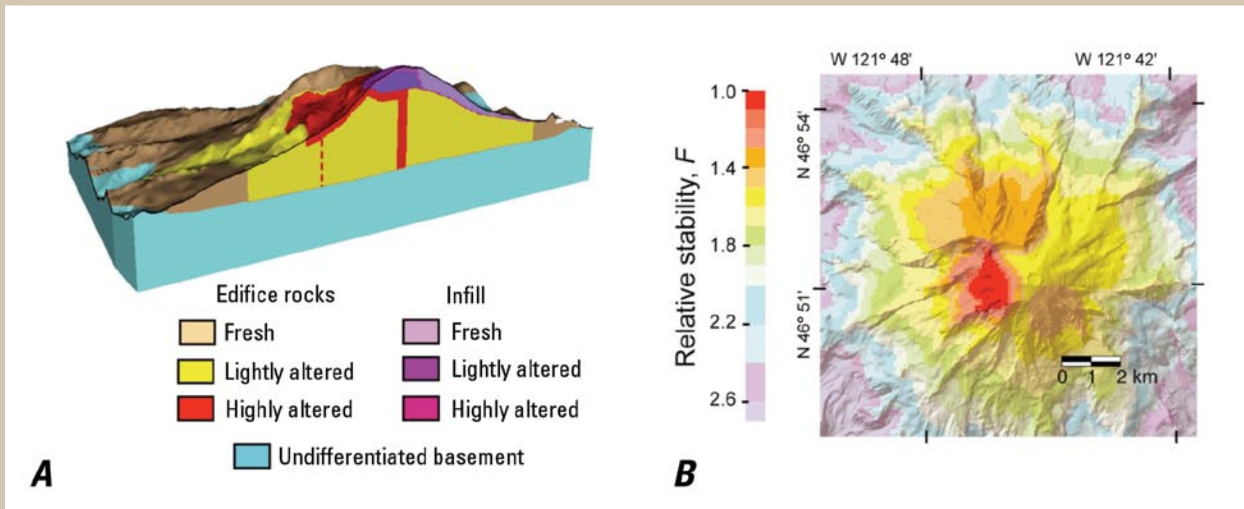
An imperative aspect of this science goal is to provide realistic deterministic forecasts of specific hazardous events in a relevant timeframe. Indeed, effective short-term forecasting is probably the most tangible measure of success. A future challenge for the Menlo Park Science Center is to hone the science of dynamic forecasting, which involves real-time analysis of events as they unfold. Dynamic forecasting requires expeditious throughput of real-time data to quantitative simulation models and high-speed computation of realistic simulations. For example, Menlo Park scientists have devised techniques for simulating volcanic eruptions using molten rock created in specially fabricated high-temperature furnaces and pressure vessels. The simulations provide input to numerical models that can be used to predict eruption intensity for a given set of conditions (Mangan and others, 2004). Likewise, seismic waveform modeling using broadband data collected during field experiments at active volcanoes show how long-period seismic signals can be used to track magma ascent, map out volcanic conduits, and identify eruption triggers at restless volcanoes (Chouet and others, 2003; Chouet and others, 2005). The development of site-specific predictive simulations (Science Goal 4) is pivotal to the success of dynamic forecasting and will allow vulnerable areas and failure points to be identified during an event, providing authorities the real-time information needed to target and prioritize mitigation and rescue efforts. For example, Center scientists are working with the National Oceanic and Atmospheric Administration to develop a database of faults that could potentially generate tsunamis in the Pacific, Caribbean, and Atlantic Oceans. This fault database will be used to configure the optimal deployment of tsunami buoys (DART stations) and for real-time, dynamic warnings at regional tsunami warning centers any time an earthquake with tsunami-generating potential is detected by the Global Seismic Network.

### 1d. Coordinate landslide-hazard mitigation research in the Western Region

Although landslides are a national hazard, the San Francisco Bay Area, southern California, and the Puget Sound lowland are some of the main urban regions in the United States with significant landslide hazards, a problem that is becoming acute as land for building becomes sparser and development encroaches on steeper hillsides. The Menlo Park Science Center has a diverse cadre of landslide experts, positioning the Center to be a key contributor in implementing the recommendations of the National Landslide Hazards Mitigation Strategy—A Framework for Loss Reduction (Spiker and Gori, 2003) in the Bay Area and elsewhere in the Western Region. As for other types of hazards, predictive landslide hazard mitigation can be addressed in a three-pronged approach: (1) field studies that test the predictions of current and future models for landslide processes and triggering mechanisms, (2) studies of the physical properties of materials involved in slides, and (3) computer modeling and predictions of the various types of landslides. Rapid response to actual landslides is necessary to obtain the observations needed to test prevailing models. Required expertise in the Western Region includes GIS hazard mapping of landslides, hill-slope hydrology, instrumentation/real-time monitoring of active landslides, quantitative geomor-

## SIMULATION OF LANDSLIDE TRIGGERING MECHANISMS IMPROVES ASSESSMENT OF LANDSLIDE HAZARDS

Scientists from the Menlo Park Science Center simulate coupled three-dimensional (3-D) ground-water flow, heat flow, effective stresses, and slope instability to understand where and when different types of landslides are likely to occur. This 3-D approach has been used successfully to assess potential massive edifice collapse at several volcanoes, including Mount St. Helens and Mount Rainier in Washington and Casita Volcano in Nicaragua, and to assess coastal bluff stability in Seattle, Washington, and along the Big Sur Coast of California. *A*, 3-D perspective of Mount Rainier showing distribution of weak, hydrothermally altered rocks from detailed geologic mapping and high-resolution geophysics. *B*, Predicted relative slope stability on Mount Rainier using 3-D modeling of 29 million potential failure surfaces within a digital elevation model. Parts of the volcano's west flank have the lowest stability, consistent with the Holocene debris-flow history. (From Reid and others, 2001.)




phology of hillside development, and the geochronology of landslides and landslide deposits to establish recurrence rates needed for probabilistic hazard mapping. Currently, landslide research at the Center is conducted in numerous programs, organizational units, and field studies. This strategic action challenges landslide researchers at the Menlo Park Science Center to achieve their collective potential in landslide hazard science by assuming a leadership role and partnering with others regionally and nationally to implement a better coordinated and integrated landslide science agenda.

## Science Goal 2: Develop a predictive understanding of ecosystem change that advances ecosystem restoration and adaptive management

For more than 30 years, USGS scientists in Menlo Park have led research and monitoring to understand the San Francisco Bay ecosystem and have partnered with others in marine, aquatic, and terrestrial ecosystem studies ranging from the sea-floor habitats of Glacier Bay National Park and the continental shelf off California to the arid landscapes of the Mojave Desert. This Science Goal builds on the diverse expertise at the Menlo Park Science Center, particularly in the physical aspects of ecosystem science. One of the strengths of the Center is the ability to conduct long-term investigations across a diverse range of physical and biological sciences. In addition, the Center contains a breadth of technological resources, infrastructure, and specialized laboratory support for ecosystems research.

Many of the pressing environmental issues facing the Nation are manifest at ecosystem scales. These include deteriorating ecosystem health and habitat loss resulting from urbanization, agriculture, and pollution; engineered modifications of the hydrologic system; invasive species; and the effects of climate change. A firm understanding of the physical and biological interactions within and among ecosystems—encompassing ecosystem function, processes, current status and trends, and past changes—is required to make informed land-use decisions and anticipate ecosystem changes. In addition, there is a need to develop process-based models that can forecast short- and long-term ecosystem change as an aid to resource managers in developing proactive restoration and adaptive management[1] programs.

This Science Goal challenges scientists in Menlo Park to build on past experience and take an even stronger leadership role in developing a comprehensive set of future USGS research priorities that address ecosystem processes and predictive change. These research priorities should focus on emerging science questions relevant to ecosystem restoration and strategic adaptive management issues important to Department of the Interior agencies and other resource managers throughout the region and Nation. Integral to expanding success in this arena is partnering with others in the USGS, academic, and resource-management communities, particularly in many of the biological aspects of ecosystem science. Forging stronger links with scientists supported by USGS biological resources programs is especially important. These USGS biologists also have extensive experience in ecosystem studies, especially vertebrate ecology that complements the invertebrate ecology expertise at the Menlo Park Science Center. Important as well is capitalizing on the proximity of the Center to interdisciplinary academic programs such as the Stanford Institute for the Environment.

The scientific community has yet to develop systematically a guiding scientific framework necessary to undertake ecosystem restoration activities. This Science Goal challenges the Menlo Park Science Center, and the USGS in general, to assert greater leadership in developing such a systematic framework of basic scientific principals for ecosystem restoration and adaptive management. Future ecosystems research and assessment activities will be guided by the following four strategic actions:

## 2a. Conduct Studies of Ecosystem Change and of the Causes and Effects of such Change

In developing a scientific framework for guiding ecosystem restoration and adaptive management activities, it is critical that there be a fundamental understanding of how and why ecosystem changes occur, whether by natural or human induced forces. Establishing the relation between ecosystem processes and the forcing functions that result in functional ecosystem responses requires a dedication to ongoing studies of the cause-and-effect dynamics of ecosystem change.

[1] "Adaptive management" (Holling, 1978; Walters, 1986) is an approach to resource management that treats resource management policies as experiments. It is a formal, systematic, and rigorous approach to learning from the outcomes of management actions, accommodating change, and improving management. It involves synthesizing existing knowledge, exploring alternative actions, and making explicit forecasts about their outcomes. Management actions and monitoring programs are carefully designed to generate reliable feedback and clarify the reasons underlying outcomes. Actions and objectives are then adjusted on the basis of this feedback and improved understanding.

## 2b. Expand Capabilities for Real-Time and Spatially Robust Data Collection

Ecosystem change happens over multiple temporal (minutes to decades) and spatial (centimeters to kilometers) scales, and our ability to predict change is dependent upon our ability to evaluate ecosystems at these multiple scales. Study of ecosystem dynamics is by nature resource intensive, and current techniques for on-site environmental data collection by USGS staff are not practical in many instances where and when intensive ongoing data collection is needed. Consequently, the use and development of technology for collecting real-time data at appropriate spatial/temporal intervals will provide an invaluable and necessary tool to achieve the goal of developing our capacity to predict ecosystem change.

A key to realizing this Science Goal will be enhancing the agency's ability to collect and process temporal data in real time and ecosystem data over very large spatial scales and diverse habitats. This will require an increased investment in the use of technology, such as in-place monitoring, neural networks, telemetry, auto-sampling devices and satellite imaging. Such an emphasis is consistent with the emerging remote-sensing goals of the new USGS geography research strategy (McMahon and others, 2005) and can be accomplished with established remote-sensing partners, such as the USGS EROS Data Center and the National Aeronautics and Space Administration. Developing other monitoring technology will require new partnerships with academic and industry groups such as the Center for Information Technology Research in the Interest of Society (CITRIS), a cooperative venture of several local University of California campuses and industry partners.

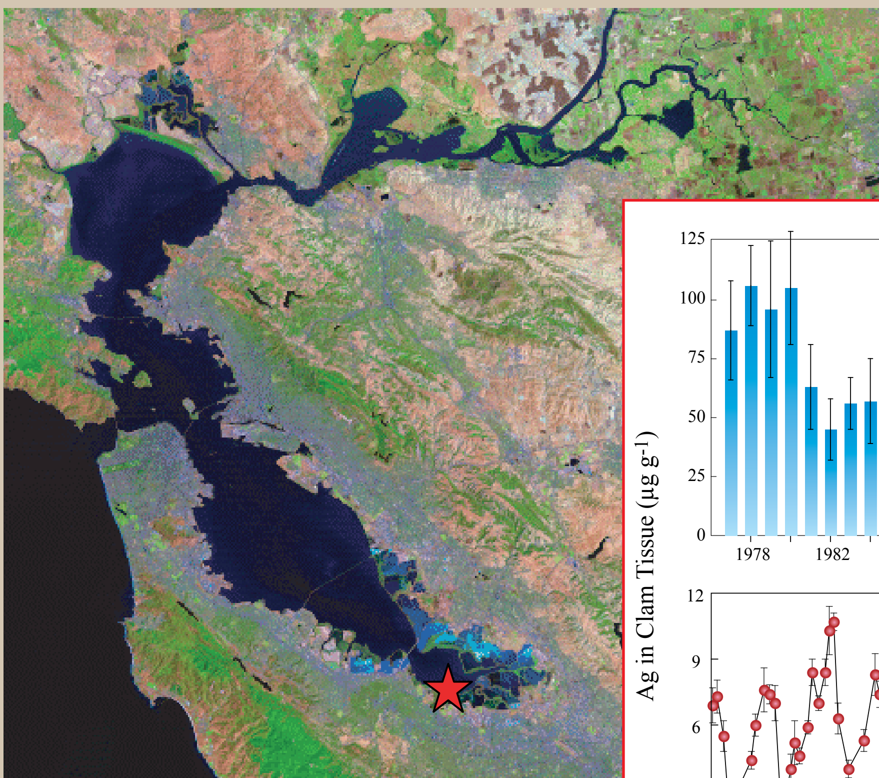
## 2c. Advance Ecosystem Modeling and Computing Capabilities

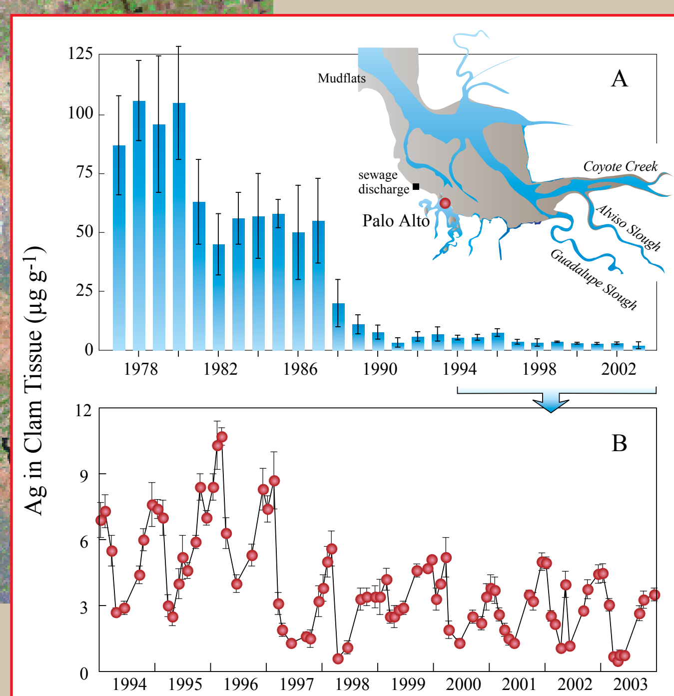
Ultimate success in the ability to forecast ecosystem change is linked to the degree of understanding, and the ability to model, the underlying physical, biological and (geo)chemical processes at the appropriate temporal and ecosystem scales. The development of various types of models (such as conceptual, deterministic, probabilistic) is increasingly important in achieving this Science Goal. For example, studies underway at the Menlo Park Science Center are teaching us about the role of surface materials in making moisture available for plants in desert ecosystems (Bedford and others, 2004). Properties that can be extrapolated through the desert by geologic mapping are studied by evaluating the response of typical deposits and soils to infiltration tests and measuring natural infiltration events. The map distribution of surface materials describes a large part of the variability of the plant communities in the desert. These maps become valuable as predictive models to understand present vegetation conditions and identify locations where plant communities depart from expected conditions in order to determine if past disturbances have caused these departures.

## SAN FRANCISCO BAY ECOSYSTEM SCIENCE

The San Francisco Bay ecosystem is the largest estuary on the west coast of the United States. It covers approximately 1,600 square miles (4,150 km2) and drains an area of 60,000 square miles (155,000 km2), or more than 40 percent of California's landscape. The associated rivers, delta, and estuary provide a rich and diverse habitat for countless plant and animal species, many unique to this ecosystem. The land surrounding San Francisco Bay and its upper watershed is also home to millions of people, who over the past 150 years have severely impacted the natural system. Human-caused changes to the ecosystem include the loss of more than 90 percent of original wetland habitat; reduced freshwater flows due to water diversion projects to supply the Central Valley agricultural region and southern California; introduction of pollutants including toxic metals, nutrients, pesticides, industrial waste, and sediment; and the introduction of many non-native plants and animal species. In recent decades there has been a concerted effort on the part of regulating and management agencies, academics, scientists, and the public at large, to reduce degradation and improve the health of the ecosystem.

For more than fifty years, U.S. Geological Survey (USGS) scientists at the Menlo Park Science Center have used the San Francisco Bay ecosystem as a natural laboratory in which to conduct nationally relevant ecosystem-science investigations. Scientists at the Center have also supplied critical information regarding the Bay to the public and to local, state, and Federal agencies responsible for managing the Bay and the lands around it. Many of the restoration actions being pursued today would not be possible were it not for the wealth of scientific information collected and provided by USGS scientists to the larger community of stakeholders. This information includes basic hydrologic data, sediment and contaminant loading, biological resource assessments and food web characterization, aquatic and benthic geochemistry, and process studies involving contaminants. Of particular importance are the long-term data sets collected by the USGS, which assist scientists and managers in assessing long-term trends in system response to changing conditions, such as contaminant loading. An example of this long-term monitoring is shown below.






*Annual trends of silver (Ag) in the bivalve* Macoma balthica *from a consistently sampled site (red star) in South San Francisco Bay demonstrate the value of long-term continuous environmental monitoring.* A, *Annual average trend of declining Ag tissue concentrations between 1977 and 2003. The decline in silver is unambiguous until 1990.* B, *After 1990, silver concentration in clam tissue fluctuates seasonally, with some additional decline in recent years. (From Hornberger and others, 2000; inset graphic by Jeanne DiLeo.)*

In addition to developing these traditional model types, it is important to advance user-friendly decision tools designed specifically for adaptive management. Currently, "adaptive management" is a concept frequently discussed, but rarely used in practice by resource managers, who are often unclear on how much and what scientific information is appropriate in the decisionmaking process. Developing better user-friendly decisionmaking tools will help to inform the adaptive management process. As models become larger and more complex, it will be important to ensure that both the human and computational resources are available to achieve this strategic action.

### 2d. Include the Human Dimension in Ecosystem Studies

An important focus area of this Science Goal is improving our understanding of the impact and connections between human social and cultural practices, economics, and natural systems. This strategic action recognizes that humans are part of the ecosystem, and that human activities must be considered in ecosystem studies. For example, when studying the resource, land-use, and non-economic values of ecosystems (both healthy and deteriorated), it is important to include the impact of ecosystem changes on human society. Conversely, when conducting studies to examine patterns of land and resource use, it is important also to assess the impact of these patterns on ecosystem processes. These types of studies should involve economists and social scientists and can be linked to efforts being developed as part of an expanded USGS geography research program (McMahon and others, 2005) and the current bureau emphasis on understanding the societal impact of science. Scientists in Menlo Park were among the first to develop this sort of geographic research focus within the USGS, collaborating with partners at Stanford and other universities.

## Science Goal 3: Advance the understanding of natural resources in a geologic, hydrologic, economic, environmental, and global context

Natural resources are a foundation of the economic security of the United States. Water resources for domestic, agricultural, and industrial use, as well as for production of hydroelectric power, are critical to life and economic growth. The Nation is among the world's leading producers and consumers of energy and mineral resources. The supply and use of these resources, competing uses for Federal lands, and the environmental consequences of resource development are issues that the United States constantly faces, especially in the mineral-rich, water-poor Western States. On a larger scale, the future national and global availability of these natural resources will continue to be an issue that affects the economic growth and security of the Nation. The Department of the Interior provides water for 31 million people and for one-fifth of the irrigation needs of western farmers, manages one-fifth of the Nation's lands, and manages lands and offshore areas that supply about 30 percent of domestic energy production. Consequently, the Department has a unique interest in science for resource management. Making informed decisions about natural-resource issues requires current and accurate information about the origin, distribution, and quality of water, energy, and mineral resources. Information about economic factors that influence resource development and the resulting environmental consequences also is needed.

The Menlo Park Science Center is well suited to address these scientific challenges. USGS scientists in Menlo Park have a long tradition of developing innovative techniques for quantitative assessments of energy and mineral resources, and they are among the leaders in applying these assessments to decision-support analysis. For example, Menlo Park scientists led in the development of the quantitative assessment methods that are used by the USGS and established many of the fundamental guidelines now followed internationally by governments, industry, and academia to assess mineral resources (Cox and Singer, 1986; Singer, 1993, 1995). USGS scientists in Menlo Park also are leaders in developing theoretical, laboratory, field, and modeling methods for assessing the quantity and quality of water resources. For example, Menlo Park scientists were among the leaders in establishing the conceptual design of the National Water Quality Assessment Program (Rubin and others, unpublished memorandum report, 1985) and are leaders in developing models and methods to study contaminant and groundwater transport (Essaid and Bekins, 1997, Stonestrom and Constantz, 2003). Scientists throughout the USGS use these developments in assessing local, regional, and national water supplies. USGS scientists in Menlo Park are leading the USGS in the development of three-dimensional geologic maps and the use of these maps to model ground water flow, geochemical anomalies, and other earth processes and characteristics (see Strategic Action 3c).

Many of the extensive and diverse analytical capabilities at the Menlo Park Science Center (appendix 2) provide critical information for developing and applying these resource-assessment methods. Through partnerships with local universities, the Center has access to additional unique analytical tools to examine natural resource systems in new ways. Precise and accurate characterization of elements and compounds (for example, mercury speciation in geologic materials) can now address questions about how these systems interact, from the molecular scale to global-scale interactions within the geosphere, hydrosphere, and biosphere.

Future natural-resource research, assessment, and management activities at the Menlo Park Science Center will be guided by the following three strategic actions:

## 3a. Develop innovative techniques for conducting quantitative assessments of water, energy, and mineral resources

A fundamental mission of the USGS is to provide information on water, energy, and mineral resources in a format useful to policy makers. For all types of resources, information is needed about their quantity and quality, and for mineral resources about their composition. For mineral and energy resources, two types of information are needed: (1) estimates of resources, reserves, or composition of known deposits and (2) estimates of resources in undiscovered deposits. When multiple resources are involved, there is a need to provide information at a landscape scale that will allow land managers to make better decisions regarding the impacts of resource development relative to other competing land uses. Consequently, there is a clear need to develop new methodologies, tools, and models for obtaining these types of information and for conducting quantitative assessments. Quantitative methods and models are required to make resource assessments explicit and reproducible, to allow uncertainty to be presented, to specify risks inherent in the assessments, and to allow comparison of alternative methods. Objective quantitative assessments need to be presented in a format usable in decision support systems so that the consequences of alternative courses of action with respect to resources can be examined.

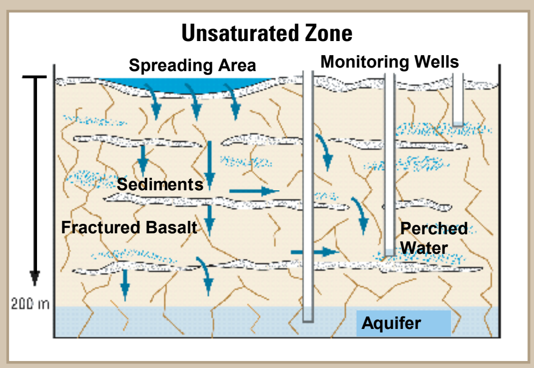
To address these needs, USGS scientists in Menlo Park will build on past research in developing assessment methods to improve tools for quantitatively assessing water, energy, and mineral resources. Fundamental to this strategy are developing quantitative models (Science Goal 4), devising new techniques for use in quantitative assessments, such as artificial intelligence using neural networks, developing methodology required to assess multiple resources at the landscape scale, and devising methods for estimating uncertainty and risk inherent in all resource assessments. For example, Menlo Park scientists are using petroleum systems models to recreate quantitatively the geologic history of sedimentary basins and describe the extent and timing of petroleum generation, as well as its migration and accumulation, in three dimensions over the fourth dimension of geologic time (Peters and others, in press). This tool is also used routinely by the oil and gas industry, but mainly to explore local-scale portions of petroleum basins making up their individual lease blocks. The USGS is beginning to apply this tool to energy assessments on a basinwide scale, because it can improve understanding of how, when, and where petroleum accumulates.

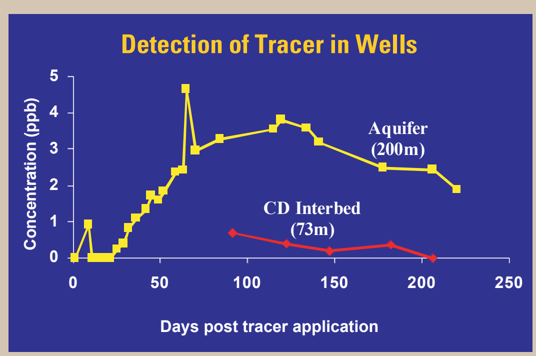
## 3b. Conduct process-oriented field, laboratory, and theoretical studies of mineral, energy, and hydrologic cycles

Understanding the mineral, energy, and hydrologic cycles is critical to identifying economic, environmental, and human health issues related to the use of mineral, energy, and water resources. For example, the life cycle of minerals includes

### UNSATURATED-ZONE STUDIES HELP TO UNDERSTAND GROUND-WATER RECHARGE AND TRANSPORT

The unsaturated zone lies between the land surface and the top of the saturated ground-water flow system. Unsaturated-zone processes, such as infiltration of precipitation and surface water and its subsequent drainage and redistribution, play key roles in determining the quality and quantity of ground-water resources. These processes can be especially important in the western United States, where unsaturated zones reach thicknesses of hundreds of meters. The unsaturated zone of the Snake River Plain in Idaho, illustrated above, is deep and geologically complex (from Nimmo and others, 2002). Water within it was expected to travel very slowly through the relatively dry rock fractures and dense beds consisting of fine-textured sediments; however, an investigation by U. S. Geological Survey Menlo Park scientists demonstrated surprisingly rapid and long-ranging flow. A benign artificial tracer applied in an ephemeral surface-water spreading area was detected within nine days in the aquifer at a point 200 m deep and 200 m laterally from the application point. In a sedimentary bed 73 m deep and 1.3 km away, the tracer already was detectible when sampling began at that location 90 days after application. The finding of such rapid and far-reaching flow has prompted important modifications to predictive models being used to evaluate contamination hazards and plan remediation strategies at this site



initial formation of a mineral deposit, deformation and degradation resulting from metamorphism and surface weathering, mineral extraction through mining, modification of mine waste by biogeochemical and hydrogeochemical processes, and mine site restoration following mineral extraction. This cycle results in the economic concentration of rare elements but can also produce widespread dispersion of potentially harmful elements into the environment.

Studies of energy and hydrologic cycles are important for similar reasons. Understanding and recognizing the environments and processes that lead to petroleum generation, migration, and entrapment are necessary for predicting where these resources lie. Understanding the properties of gas hydrates and the processes that form them are first steps in their potential exploitation as new sources of energy. Understanding the interaction between the components of the hydrologic cycle is important to predicting the effects of changes in the quantity and quality of a particular component. These effects might be manifested as changes to other parts of the hydrologic cycle, as well as to the broader environment, including the biologic and geologic realms. For example, reduced ground-water recharge from precipitation can cause decreased ground-water discharge to streams, which in turn can affect the aquatic ecology of the stream.

USGS scientists at the Menlo Park Science Center will advance techniques for assessing the hydrologic, mineral, and, energy cycles by combining field-based studies of these systems with laboratory and theoretical studies to better understand the processes that affect formation, distribution, and quality of water, mineral, and energy resources. These studies will increase understanding of the origin of these resources; improve process-based, quantitative models of their occurrence and distribution; improve resource assessments; and quantify the effects of changes in their quantity and quality on the environment, where changes may impact biota and human health.

### 3c. Focus interdisciplinary research on developing three- and four-dimensional maps to improve understanding of key processes that control the distribution and quality of energy, mineral, and water resources

Understanding the three-dimensional and four-dimensional distribution of water, energy, and mineral resources can be improved by interweaving geologic, hydrologic, and biologic data. Integrated geophysical, geochemical, and geological studies can produce a three-dimensional geologic map that identifies and characterizes subsurface features, such as faults, folds, basin geometry, hydrothermal systems, and igneous intrusions. These three-dimensional geologic maps are extremely valuable for providing important physical constraints on models of subsurface processes, such as ground-water flow and chemical transport, geothermal reservoir behavior, and petroleum migration and entrapment. They provide a framework upon which boundary conditions for these types of models can be superposed. Thus, constructing these maps can help produce more accurate model predictions of the behavior of ground-water, geothermal, and petroleum resources. Theoretical reconstruction of these three-dimensional geologic maps back through time also can provide four-dimensional models for the genesis of mineral and energy resources.

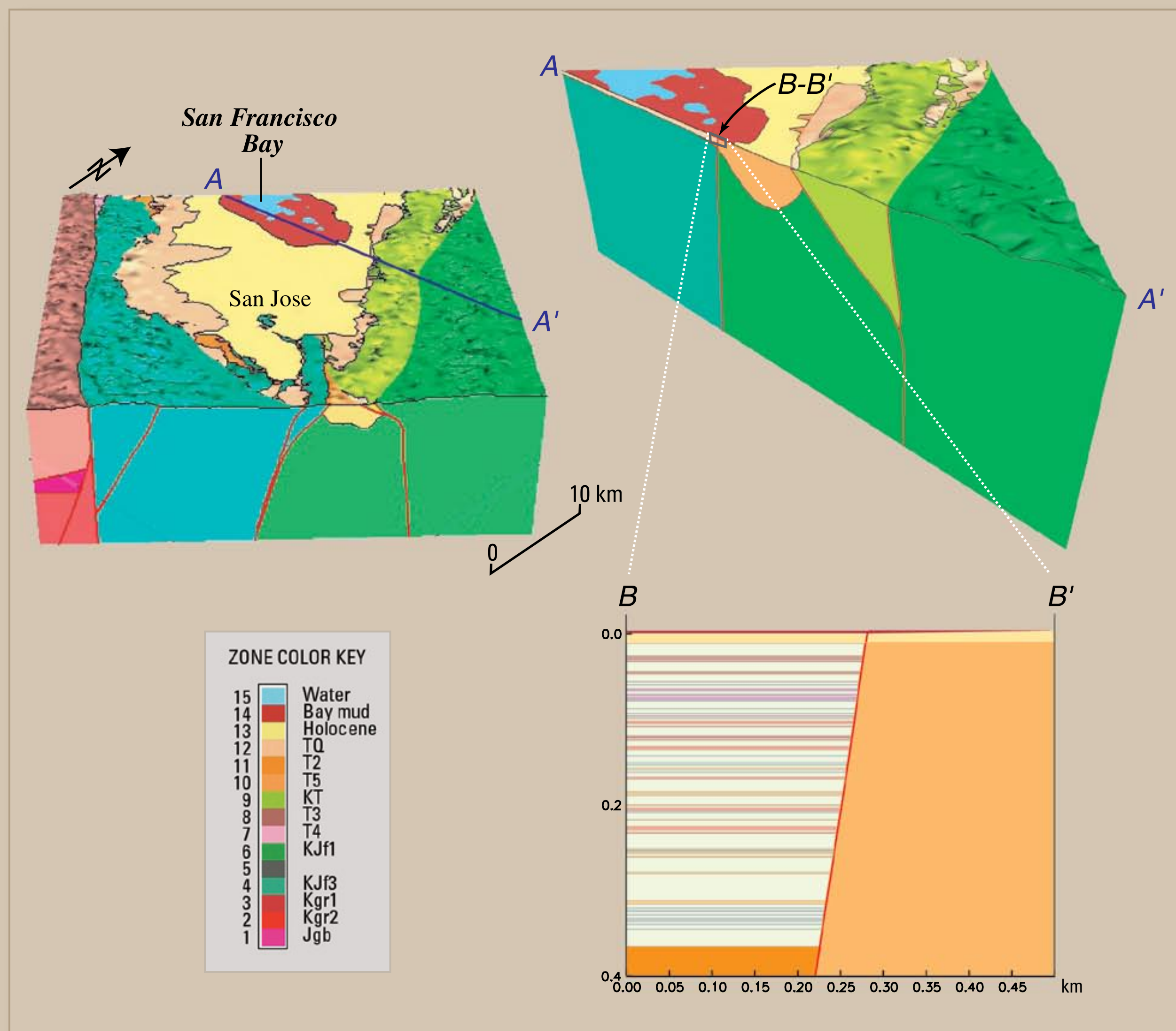
Scientists at the Menlo Park Science Center will advance techniques for creating and displaying three- and four-dimensional geologic, geophysical, and geochemical maps. These maps will be used in assessments to model ground-water flow and resources, petroleum systems, mineral and geothermal resources, and in geoenvironmental assessments. Such maps also can provide a framework for understanding natural hazards (Science Goal 1) and for forecast modeling (Science Goal 4).

## Science Goal 4: Increase and improve capabilities for quantitative simulation, prediction, and assessment of Earth system processes

Probabilistic and process-oriented models that quantitatively simulate, predict, and assess Earth system processes are essential for addressing complex scientific issues of regional to global extent. Advances in a wide range of Earth science fields can be gained from both the development and application of these types of models. For example, incorporating relevant geologic, hydrologic, biologic, and chemical mechanisms in process models can facilitate understanding and hypothesis testing of the particular mechanisms that control Earth system processes. Similarly, incorporating a wide range of constraints and observations in probabilistic models can facilitate understanding the most important factors affecting environmental, hazard, and resource assessments. Multidisciplinary, integrated system science calls for a new generation of models that can operate on a variety of spatial scales, from molecular to global, and timescales, from milliseconds to millions of years. The new generation of models must provide seamless computational boundaries between diverse system components. Application of models to field systems provides insight into processes occurring in the system and integrates the diverse data that characterize systems, enabling identification of knowledge gaps and resolution of contradictory or conflicting information. These models also are powerful tools for focusing and prioritizing future research.

Earth systems models can be used in conjunction with decision-support tools to address nationally important societal issues related to natural hazards (see Science Goal 1), ecosystems (see Science Goal 2), and natural resources (see Science Goal 3). For example, process models can be developed to predict strong ground motion resulting from an earthquake, and probabilistic models can be developed

## THREE-DIMENSIONAL GEOLOGIC MAP OF SILICON VALLEY, CALIFORNIA, PROVIDES THE GEOLOGIC FRAMEWORK FOR GROUND-WATER STUDIES





*A-A'* is a slice through the model, which extends to a depth of 14 km (see Jachens and others, 2005). *B-B'* is a slice of the depth range of hydrologic interest, illustrating the scale independence of the model. Finer resolution geology in the upper 200-400 m is based on sequence stratigraphy calibrated by cores and geophysical logs (see Wentworth and Tinsley, 2005). Three-dimensional geologic maps are providing new insights in a variety of natural resource and natural hazards applications.

to assess the likelihood of earthquake damage to structures. Quantitative simulations, predictions, and assessments can also facilitate the delivery of scientific results and analyses to a wide audience. Model inputs and outputs can be displayed as maps, images, or other visual representations that are readily understood by the public and by decisionmakers working in applied science, natural resource management, emergency response, and other related fields.

At the Menlo Park Science Center, there is a wide range of modeling expertise, particularly related to earthquake, volcano, landslide, tsunami, and erosion hazards and to water, mineral, and energy resources (see sidebar). This Science Goal calls for building on and linking these existing strengths to (1) increase and improve the modeling capabilities, (2) increase the relevance of the modeling to societal issues, and (3) enhance the interaction and collaboration among scientists from different disciplines within and outside of the USGS. By expanding its modeling expertise and shifting toward a more multilayered system approach, the Menlo Park Science Center will enhance the Nation's ability to address important societal problems on a national and global scale.

This Science Goal also underlies and unifies Science Goals 1 to 3. Although some aspects of this goal are included in the strategic actions for Science Goals 1 to 3, Science Goal 4 is presented as a separate goal because actions for increasing these capabilities are common to the modeling endeavors conducted for ecosystems, hazards, and resources, and because Earth system modeling in general is a challenging research topic unto itself, independent of the application. Furthermore, there is great potential for improved exchange of ideas, approaches, and methods among Menlo Park scientists conducting modeling related to the first three goals. Science Goal 4 calls for this increased communication to benefit advances in modeling and to enhance the role of modeling in unifying research related to ecosystems, hazards, and resources at the Menlo Park Science Center.

Future Earth system modeling activities at the Menlo Park Science Center will be guided by the following four strategic actions:

## 4a. Produce improved models that represent important mechanisms and relations controlling Earth systems

Development of sound and relevant process and probabilistic Earth systems models requires understanding the important geologic, hydrologic, biologic, and chemical mechanisms and relations that occur in simulated systems and including them in model software and its applications. In even the best understood Earth science fields, there are areas in which further theoretical, laboratory, and field studies are required for improved understanding of these mechanisms and relations. Furthermore, Earth system models may benefit from new paradigms for representing model complexity, such as cellular automata, self-organized criticality, genetic algorithms, and neural networks. This action calls upon Menlo Park scientists to conduct research for advancing the understanding of fundamental mechanisms that occur in simulated Earth systems, will improve modeling software by incorporating these processes and relations, and will address the significant modeling challenges that can arise from these improvements, such as coupled equations, nonlinearities, and increased computational requirements. In developing and applying process and probabilistic models that are increasingly multidisciplinary, it is important to collaborate with colleagues who have complementary expertise, within the USGS at Menlo Park, at other USGS locations, and at other institutions. This collaboration will facilitate increased model accuracy, completeness, and usefulness.

## 4b. Advance methods for cost-effective selection, collection, interpretation, and assimilation of the data most critical to characterizing the simulated systems and enhance the use of data across projects and disciplines

To address scientific and societal problems, models that simulate, predict, and assess Earth system processes must realistically represent the characteristics of the system. This characterization can require substantial geologic, geophysical, hydrologic, chemical, biologic, and (or) socioeconomic data. The cost of collection and analysis of these types of data, particularly for subsurface investigations, can be very high. This action emphasizes the need to develop innovative strategies for obtaining the most important information for characterizing the systems being simulated and for interpreting and interpolating the data to maximize their value. It also is important to develop and advance strategies to effectively assimilate large and multiple data sets so they can be incorporated into models, made available for other research activities, and augmented as new data are obtained. For example, data sharing can be facilitated by populating databases that can be accessed by other scientists and modelers through a Web site (for example, the USGS San Francisco Bay Web site, http://sfbay.wr.usgs.gov/).

## 4c. Advance methods for characterizing and incorporating uncertainty in model inputs and processes, quantifying model output uncertainty, and valuing and achieving uncertainty reductions

Predictive models are more realistic and useful when they account for uncertainty in the data used for their development and calibration and also in the processes controlling the simulated system. It is critical that process and probabilistic modeling activities in Menlo Park progress toward incorporating and quantifying as many forms of uncer-

## SIMULATION, PREDICTIVE, AND PROBABILISTIC MODELING AT THE MENLO PARK SCIENCE CENTER

USGS Menlo Park scientists use models to address a broad range of issues related to hazards, ecosystems, and resources. Selected examples of these modeling endeavors are listed here.

### Modeling for Hazards Assessment

- GIS modeling of shallow landslide initiation
- Sediment transport during landscape processes
- Volcano eruptive probabilities
- Volcano processes
- Tsunami size and timing
- Strong ground motion in 3-D geologic/velocity models
- Earthquake rupture
- Physical and statistical models of earthquake recurrence
- Crustal stress evolution and tectonic deformation
- Seismic-wave propagation
- Coupled fluid flow, heat flow, and subsurface deformation
- Fluid pressures in subduction zones
- Coupled ground-water flow and slope stability

### Modeling of Ecosystem Processes

- Nutrient transport in streams
- Surface-water hydrodynamics and biological processes

### Modeling to Assess Resource Quality and Quantity

- Saturated and unsaturated ground-water flow
- Subsurface transport and reaction of chemicals
- Contaminant transport in small stream systems
- Statistical modeling for mineral resource assessment
- Process-based petroleum system modeling
- Probabilistic assessment of oil and gas resources
- Inversion of seismic data in geothermal areas

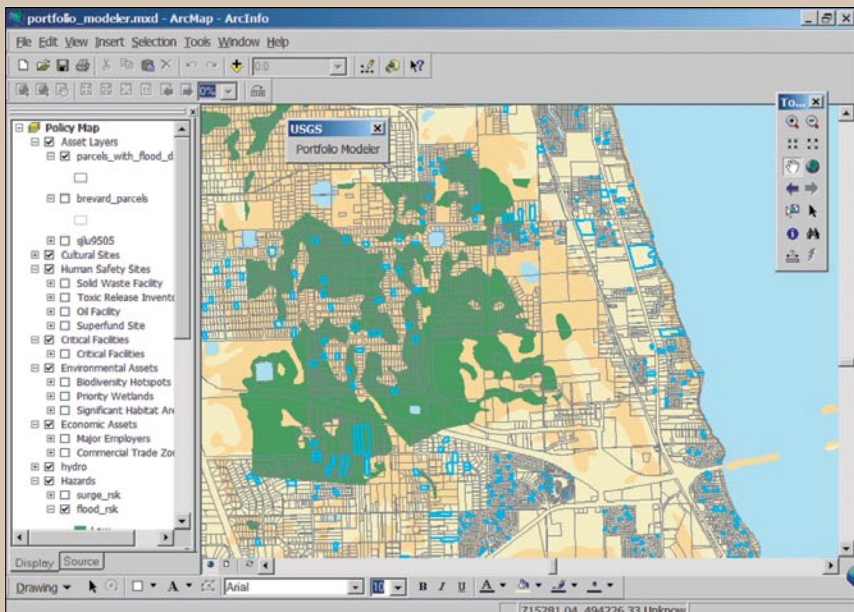
### Modeling to Address Multiple Issues

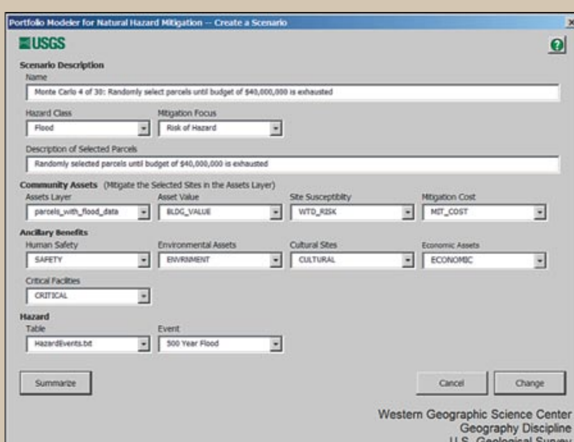
- Simulation of wave action, hydrodynamics, sediment transport, and morphology for hazards assessment and ecosystem management
- Simulation of gravity and magnetic data to characterize geologic hazards and resources
- Probabilistic risk analyses for decisionmaking about environmental and hazards issues

## THE LAND USE PORTFOLIO MODEL FOR NATURAL HAZARDS RISK ASSESSMENT

U.S. Geological Survey researchers in Menlo Park have developed the Land Use Portfolio Model to integrate natural-hazard and socioeconomic information and to help communities evaluate alternative natural-hazard mitigation policies. The Land Use Portfolio Model is an innovative statistical, modeling, mapping, and risk-communication methodology that can assist Federal, state, and local agencies and communities in understanding and reducing their vulnerability to natural hazards. The model builds upon financial-portfolio theory, a method for evaluating alternative investment decisions on the basis of the estimated distribution of risk and return on different investment possibilities. It is implemented in decision-support software based on geographic information system (GIS) technology and designed to facilitate user interaction with the data and analysis of the cost-effectiveness of potential predisaster mitigation strategies. Using the Land Use Portfolio Model, stakeholders can select a set of locations in which to invest a hazard-mitigation budget and evaluate metrics such as expected community wealth retained. Stakeholders can also use the model to compare outcomes of different potential policy decisions.

For the development and initial application of the model, geographers and earthquake-hazard researchers from the Menlo Park Science Center collaborated on an investigation of hazards from earthquake-triggered lateral-spread ground failure in Watsonville, California, to develop risk maps. Frequent interaction with Watsonville city managers was also important in gathering data and understanding the community resources. Current efforts are focused on expanding the Land Use Portfolio Model to have the capability of evaluating simultaneous decisions about multiple natural hazards.




*Application of the GIS-based Land Use Portfolio Model Decision Support System, showing a map of Brevard County, Florida, and a data input window. Parcels selected for mitigation have blue borders; green polygons represent areas susceptible to flooding.*

tainty as possible, such as those related to the conceptual model and to simulation model input. Equally important are advancements in methods for translating this uncertainty to the model responses and predictions and for identifying the model aspects that contribute most to prediction uncertainty. These efforts can lead to strategies for determining data collection and other scientific activities most beneficial for reducing model uncertainty. It also is important to quantify the benefits and costs of uncertainty reductions, which can help prioritize activities to reduce uncertainty. For improving decisionmaking under uncertainty, advances can be made in incorporating model and prediction uncertainty in decision support tools, such as by linking predictive models with optimization procedures, land-use plans, and socioeconomic valuations. Including uncertainty in these manners enables more realistic model results to be used for decisionmaking.

### 4d. Develop effective methods of interpreting and presenting models and their results for delivery to collaborators, partners, and other end users

Whereas the first three strategic actions under this Science Goal seek to improve the quality and expand the use of process and probabilistic models, this action calls for ensuring the effective delivery of these models to users, including communities, resource managers, and Federal, state, and local agencies. To achieve maximum impact and influence, it is important to ensure that these models address society's needs, are accessible and available to all potential users, and can be adapted for use in different locations and situations. This action is distinctly different from outreach or education, in that it recognizes that interpreting and delivering models and their results is an important scientific activity in itself. This action relies on closer connection with and greater awareness of the needs of collaborators, partners, and end users. Effective delivery of models and their results will help demonstrate the importance and relevance of USGS science, will enhance its visibility and utility, and will broaden its influence.

# Operational Objectives

Meeting challenges to achieve important science goals requires an operational commitment to an outstanding workforce, strong partnerships, state-of-the-art scientific infrastructure, and effective mechanisms to communicate science information to those who ultimately use it to make decisions. Presented below are seven key operational objectives, each with a set of specific actions, necessary to achieve the Science Goals of the Menlo Park Science Center. Whereas a few of these objectives are relevant only to the Center, most address issues that are relevant to the successful attainment of scientific goals across the USGS.

## Objective 1: Provide a hub for technology, laboratories, and library services to support science in the Western Region

The state-of-the-art research laboratories, information-technology facilities, and library services located on the Menlo Park USGS campus are vital to conducting and coordinating high-impact, interdisciplinary science. To ensure that these unique facilities are available to all Western Region projects, the Menlo Park Science Center should act to:

- Coordinate the sharing of research laboratories across disciplines and facilitate access for USGS and non-USGS scientists located offcampus (see appendix 2).
- Develop strategies to enhance library services necessary to support science in the region, such as expansion of on-line products and services (including access to references relevant to biological sciences).
- Pool technical expertise and inventory to meet routine Geographic Information System (GIS), systems support, and equipment fabrication needs.
- Develop and operate an innovative Information Technology (IT) center that fosters effective communication and data sharing across disciplines and regions.

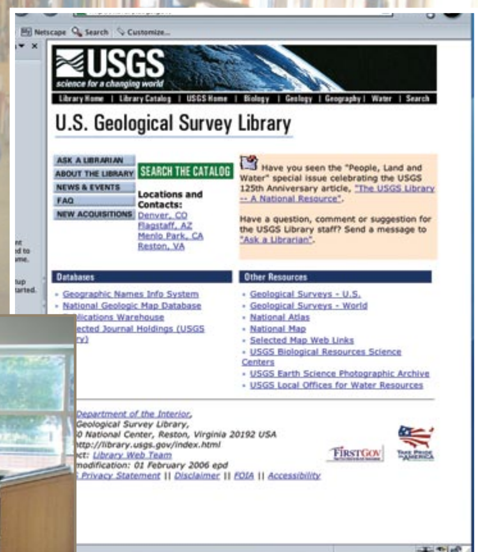
## Objective 2: Increase advanced computing capabilities and promote sharing of these resources at the Menlo Park Science Center

Computers and computer networks are an integral component of Earth science research, from data collection, processing, and analysis to complex Earth systems modeling. To facilitate cutting edge Earth science research, Menlo Park scientists must have access to advanced computing capabilities, including computers with multiple fast processors and very large storage and memory capacities, as well as fast networks to enable rapid transfer of digital information. In addition, while the bulk of computing capabilities will continue to reside with individual scientists and groups, increased emphasis should be placed on sharing advanced computing resources as needed throughout the Menlo Park Science Center. Doing so will help effectively and efficiently make these capabilities available to a wide range of scientists. To achieve these objectives, the Menlo Park Science Center should:

- Promote acquisition of advanced computational capabilities (for example, Beowulf clusters).
- Encourage scientists to publicize their intentions for purchasing advanced computers and related hardware and software, so that other scientists can potentially participate in and add value to the purchase and subsequently share use of the facilities.

## THE USGS LIBRARY SYSTEM—A NATIONAL RESOURCE FOR THE NATURAL SCIENCES

The U.S. Geological Survey (USGS) library system has been and will remain an integral resource for USGS science. However, both the dispersal of USGS facilities and new innovations in technology are altering the ways the library provides services and manages collections. Changing use patterns and changing technology are challenging the library system to balance between providing walk-in service to users at regional centers and providing virtual online library services to dispersed USGS scientists and other users. The library also is being challenged to assess what hard-copy materials must be preserved as unique reference collections and what materials are more efficiently and effectively managed and served online as digital references. The USGS library will continue to evolve to serve the changing needs of the natural sciences community.





- Develop and maintain a list of advanced computer facilities available as a shared resource for computationally intensive modeling and other tasks.
- Increase the use of Center-wide licenses for expensive Earth science specialty software; develop and maintain a list of active licenses.
- Promote shared computer storage facilities for archiving of storage-intensive datasets, models, and other digital information.

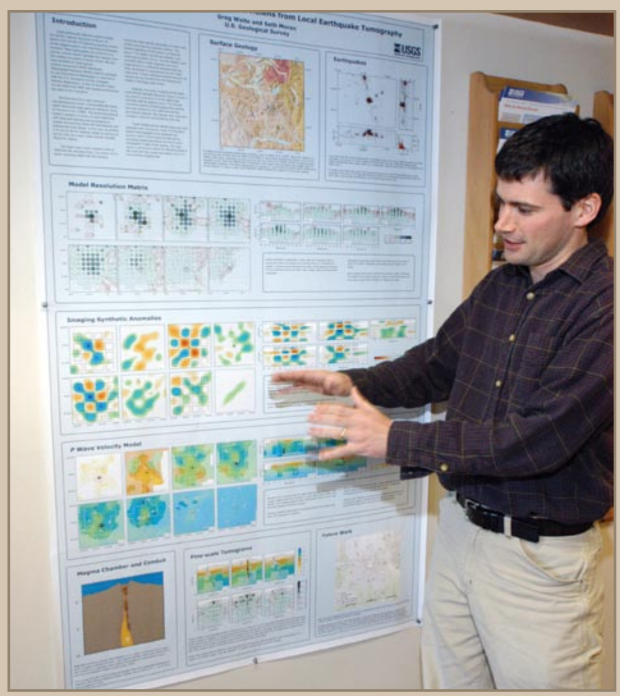
## Objective 3: Enhance the intellectual diversity, vibrancy, and capacity of the workforce through improved recruitment and retention

The USGS Menlo Park Science Center must assess the skills of its workforce, develop plans to retain key capabilities, and set priorities to acquire the new capabilities needed to achieve its Science Goals. This should be done in a timely manner to stop the loss of institutional knowledge as senior scientists complete their careers. Newly hired scientists should possess the types of capabilities and expertise necessary to pursue scientific excellence in topics that contribute toward the Science Goals. These goals will require intellectually diverse scientists who are highly flexible, computationally proficient, and skilled in interdisciplinary collaboration. To meet the objective of a highly skilled workforce capable of meeting the Science Goals, the Menlo Park Center should:

- Recruit actively for the next generation of USGS scientists with the Center's Science Goals in mind.
- Create a balance of research and science-support staff that is appropriate to the Science Goals.
- Investigate structural changes to the workforce that would maximize scientific leadership and workforce flexibility (for example, greater use of faculty appointments in senior science advisory roles and term appointments at the postdoctoral level).
- Pursue the hiring of technical specialists needed to meet the Science Goals, including computer programmers, technicians, and information technology support.
- Address employee quality-of-life issues by promoting childcare, housing, commuter incentives, recruitment incentives, and other applicable programs.
- Promote sabbatical and exchange programs in Menlo Park for scientists from universities, Federal and state agencies, and other USGS research centers and for Menlo Park scientists to collaborate at other institutions and USGS centers.

### ANNUAL POSTDOCTORAL INTERN SCIENCE SYMPOSIUM

The U.S. Geological Survey investment in postdoctoral interns helps train the next generation of Earth scientists. The Menlo Park Science Center annually sponsors a science symposium to introduce postdoctoral interns to the Center community and celebrate their evolving scientific contributions.



- Revitalize student internship and fellowship programs and increase the opportunities for students to gain valuable scientific experience with the USGS.

- Increase opportunities for participation in scientific and technical training in Menlo Park

## Objective 4: Strengthen collaborative relationships in the community at an institutional level

The Menlo Park Science Center is a leader in collaborative Earth science research. Most collaborative research is conducted at the individual scientist level and through both formal and informal relationships between individual organizational units at the Center and other governmental agencies, academic institutions, and private organizations in the San Francisco Bay Area. Formal relationships at the Center level could enhance collaborative research by facilitating the exchange of resources between the USGS and other institutions and the sharing of facilities and specialized equipment. Improved communication at the institutional level can help widely disseminate USGS research and promote potential opportunities for collaboration. This objective seeks to strengthen ongoing collaborative research and facilitate opportunities for additional collaboration between the USGS and its partners (see appendix 1). To meet this objective, the Center should:

- Formalize memoranda of understanding and cooperative agreements with local institutions to help streamline exchange of ideas, people, and resources.

- Promote the exchange of ideas through seminars with the regional science community, including other USGS facilities, and by encouraging teaching by Center scientists at local universities.

- Encourage Menlo Park scientists to develop more joint projects and science initiatives with the local science community and to consider development of formal joint centers of excellence between the Menlo Park Science Center and local institutions.

- Improve the involvement of students and other local scientists in USGS projects by encouraging student appointments and considering joint appointments with local institutions.

- Develop and distribute a database of USGS facilities, expertise, and contacts in Menlo Park and encourage the sharing of facilities and equipment with the local science community.


**THE MENLO SURVEY DAYCARE CENTER (GEOKIDS)**

**The Menlo Survey Daycare Center (GeoKids) is an accredited, nationally recognized, nonprofit parent cooperative providing high-quality child care for children aged 3 months through prekindergarten. Located on the Menlo Park campus of the U.S. Geological Survey, this early childhood development center has been an attractive feature to many Survey employees with young children.**

## SCIENCE INTERNS OF TODAY WILL BE THE SCIENTIFIC LEADERS OF TOMORROW

The Menlo Park Science Center has been an incubator of scientific leaders in part because of its close proximity to and association with numerous San Francisco Bay Area universities with vibrant Earth science programs. Many postdoctoral fellows, students and postgraduate interns who have their early professional experiences at the Center go on to successful Earth science careers in the U.S. Geological Survey, academia, and industry. The varied roles of interns in Center-based research projects, as illustrated in the photographs below, reflect the diversity of Earth science research at the Center.









## Objective 5: Expand monitoring capability by increasing density, sensitivity, and efficiency and reducing costs of instruments and networks

A wide variety of fundamental scientific questions and long-term monitoring efforts conducted by the USGS in Menlo Park and elsewhere will be better addressed by improving the spatial density, sensitivity, and temporal sampling rates of USGS monitoring networks. Such networks include those monitoring the hydrology, geochemistry, and biosphere of the San Francisco Bay-Delta ecosystems; earthquakes and ground deformation in northern California; and volcanic unrest at Long Valley, Yellowstone, and northern California volcanoes. To achieve this objective, the Menlo Park Science Center should:

- Take advantage of Menlo Park's proximity to high-technology research centers in Silicon Valley for possible Cooperative Research and Development Agreements with industry and universities, particularly in developing less expensive alternatives to current monitoring methods.
- Improve capacity for real-time and near-real-time data dissemination.
- Coordinate satellite-based monitoring with ground-based monitoring networks.
- Capitalize on increasing bandwidth and other technological advances in communication systems.
- Continue development of field instruments that can be deployed in extreme conditions.

## Objective 6: Encourage a breadth of scientific capabilities in Menlo Park to foster interdisciplinary science

In the past 50 years, scientific research has greatly increased in complexity, largely driven by rapid advances in digital technology. Society is reaching a level of information overload, where more science information is collected and handled than can be readily processed. Scientists not only are relied upon to provide detailed data for supporting specific management actions, but also to develop complex process models that help provide fundamental understanding of how systems work and the ability to predict problems before they happen. Although valuable single-focus studies are still conducted, many programs are now following highly productive interdisciplinary approaches, resulting in new efforts to link interactions among scientific specialties. To foster and conduct these interdisciplinary efforts, the Menlo Park Science Center should:

- Play a leadership role in promoting and coordinating interdisciplinary science throughout the Western Region.
- Encourage hiring in new scientific specialties (for example, social and decision science, predictive modeling, advanced computing) that are important additions to interdisciplinary studies.
- Strengthen biological science in Menlo Park and throughout in the Western Region by further collaboration between USGS science centers, science exchanges, temporary details, and establishing a few key biological research positions in Menlo Park to help integrate the goals of USGS Biological Resources Programs in ecosystem science and modeling.
- Expand studies to understand the interaction between natural systems and human development in the growing urban populations center of the West.

## Objective 7: Communicate USGS Science to a diverse audience

In addition to conducting world-class Earth science research, it is equally important that USGS scientists communicate their research results in a clear, timely, and effective manner to a large and varied group of stakeholders. The multiple recipients of USGS information include research partners, other USGS units and governmental agencies, decisionmakers, and the general public. Just as our audience is diverse, so are their information needs and the scope and depth of their scientific literacy. It is thus important that USGS information be communicated and disseminated in manners responsive to the needs of these multiple audiences. This objective can be achieved in a number of ways:

- Communicate and disseminate USGS information at an appropriate level of scientific detail for particular target audiences (for example, other scientists, decisionmakers, news media, general public).
- Foster the recognized role of the Menlo Park Science Center as a regional communications focal point for USGS media relations.
- Improve Web-based information and advance methods for real-time communication and dissemination of data using the Internet.

Develop user-friendly computer models and decision tools as USGS products for use by government agencies and other decisionmakers, including model output and data products compatible as input to decision tools developed by clients.

Raise public awareness of natural-science issues through participation in K-12 and university education programs, USGS open-house events, and public lectures (including national access to Menlo Park Science Center public lectures using internet technology).

- Staff the Menlo Park Science Center with one or more specialists having news media and congressional com-

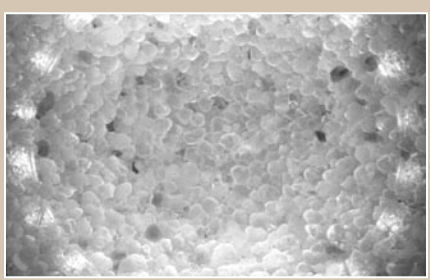
## THE CALIFORNIA GEOLOGICAL SURVEY AND U.S. GEOLOGICAL SURVEY ARE PARTNERS IN THE MENLO PARK SCIENCE CENTER

In October 2005, the California Geological Survey established an office at the U.S. Geological Survey (USGS) Menlo Park Science Center. The California Geological Survey conducts over-the-counter sales of both State of California and USGS scientific information products at the Center. In addition, several California Geological Survey scientists involved in geologic mapping and natural-hazard assessment programs are stationed at the Center. The California Geological Survey and USGS have enjoyed a long-standing and productive partnership for many decades. Both agencies believe that sharing facilities at the Center will lead to even closer collaboration and more joint science ventures.


## THE UNDERWATER MICROSCOPE

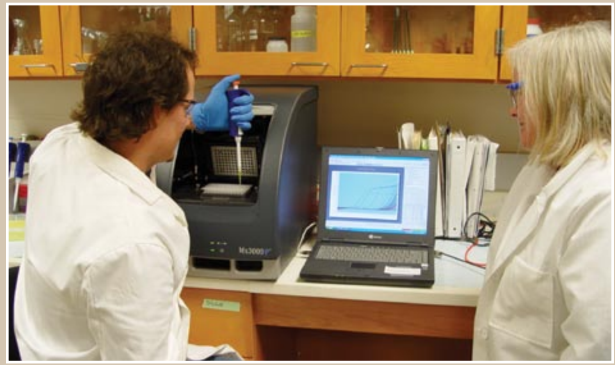
The U.S. Geological Survey recently was granted a patent for an underwater microscope developed by scientists from Menlo Park and Santa Cruz (see Chezar and others, 2001). The system collects and analyzes electronic images of sediment deposits in riverbed, lakebed, or seabed environments. Scientists now can collect hundreds of electronic samples and analyze them for grain size in a matter of hours to days. This process typically takes months using traditional sampling and grain-size analyses. The underwater microscope not only saves time and money but also spares scientists from sampling activities that can be dangerous in areas of strong currents or extreme marine conditions. The technology has been licensed and is being commercially produced.

*U. S. Geological Survey raft deploying underwater microscope system in the Colorado River.*



*Sample image of sand grains on the bed of the Colorado River. Image was taken in highly turbid water and is approximately 1 cm across. The ring of light spots near the outside of the image is a reflection from LED (light-emitting diode) lights built into the video camera assembly.*

## ENVIRONMENTAL BIOMARKER STUDIES REVEAL HOW MICROBIOLOGICAL COMMUNITIES INFLUENCE GEOCHEMICAL PROCESSES WITHIN AQUATIC AND TERRESTRIAL ENVIRONMENTS



Geomicrobiologists study the influence of microorganisms on geochemical processes such as the formation or destruction of minerals and the release or transformation of toxic metals in the environment. U.S. Geological Survey scientists at the Menlo Park Science Center were at the forefront of geomicrobiology before that term was even coined. For example, several new species of bacteria that transform toxic metals such as selenium and arsenic were first discovered at the Center. Studies of single microorganisms remain an important component of environmental research at the Center, but a new generation of Earth scientists with new skills and technology are now developing environmental biomarker techniques at the Center that will allow the study of the interaction of specific groups of microbes or whole microbial communities with their environment. Environmental biomarkers are molecules present in sediments and waters that can be used to identify microorganisms or to monitor specific microbial processes of interest. Advanced technology for measuring these biomarkers has recently been acquired at the Center and is being used to determine the extent of microbial influence on key geochemical processes such as the oxidation/reduction of carbon, nitrogen, and sulfur, the degradation of subsurface hydrocarbon spills, and the transformation of potentially toxic elements such as mercury, selenium, and arsenic.

## THE U.S. GEOLOGICAL SURVEY MENLO PARK SCIENCE CENTER IS A PREFERRED NEWS SOURCE FOR EARTH SCIENCE TOPICS

The Menlo Park Science Center is a preferred news source when natural disasters, such as earthquakes, volcanic eruptions, landslides, and tsunamis occur within the United States or abroad. Reporters are attracted to Menlo Park because they know that there will be an opportunity to interview a wide variety of scientists who are directly involved in natural-hazard research and monitoring. Scientists from Menlo Park also are sought out for interviews and as expert advisors for documentaries on a spectrum of Earth science topics.

munications expertise to maintain the Center's position as a preferred science news source and to help scientists reach these priority communications audiences.

## Next Steps

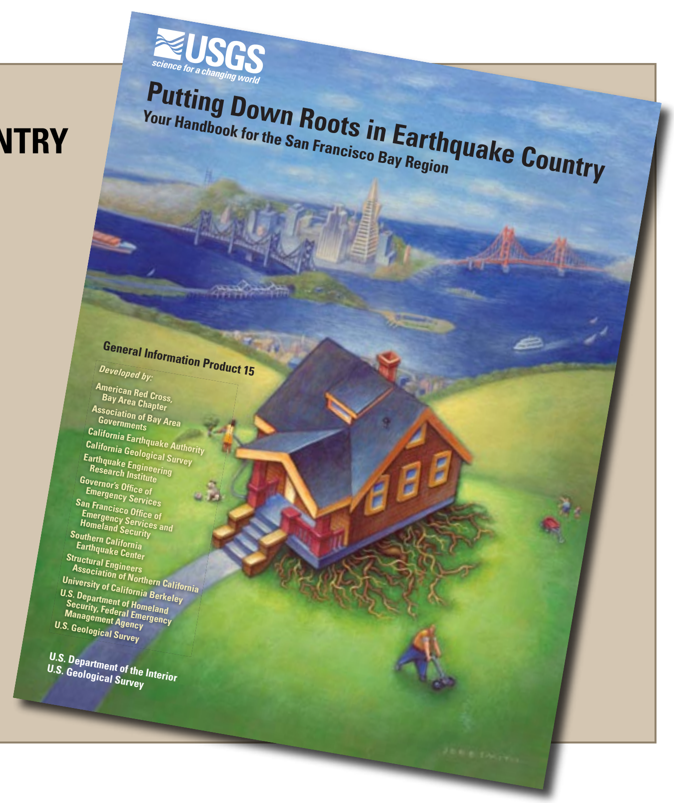
This strategy provides long-term Science Goals and Operational Objectives intended to inspire and guide, rather than direct, the actions of the USGS at the Menlo Park Science Center and, as appropriate, other USGS centers in the Western Region and across the Nation. The principal responsibility for leading the Menlo Park Science Center toward these Science Goals lies with the Menlo Park Council. Designing, prioritizing, and implementing the actions necessary to achieve these goals and objectives, however, is an ongoing process that is the responsibility of the entire USGS research and science support community in Menlo Park. Each and every member of the USGS in Menlo Park must contribute to movement toward the common goals and objectives of the Center through their individual and team efforts, as well as by vigorously participating in collective planning activities as requested. An integral part of successfully achieving USGS Science Goals at the Menlo Park Science Center is collaboration with colleagues throughout the USGS, especially with national and regional program leadership.

Some specific actions that the Menlo Park Council should consider for implementing this strategy are:

- Commissioning working groups to develop specific science plans for each of the Science Goals. Such working groups should, in addition to Menlo Park scientists, involve appropriate USGS scientists throughout the region and Nation, as well as non-USGS cooperators and clients. Planning activities should include appropriate involvement of USGS program coordinators to ensure that regional priorities are effectively considered in national program planning. The Menlo Park Council should consider sponsoring workshops that exert science leadership for the USGS in these science issues. Planning should focus on the collective Science Goals of the center and should complement and enhance, rather than duplicate or compete with, planning for specific projects, organizational units, and programs.
- Establishing committees as appropriate to address details of Operational Objectives. The Council should prioritize actions under these objectives and charter committees according to those priorities and the resources available for their implementation.
- Developing a communications plan for the Menlo Park science strategy to reach not only USGS employees in Menlo Park, but also the USGS regionally and nationally, as well as appropriate audiences outside the USGS.
- Developing an annual plan for the Center that outlines implementation plans, specifies resources available to advance the science strategy during the upcoming fiscal year, and documents accomplishments of the previous fiscal years.
- Presenting an annual "State of the Center" address at the Menlo Park Science Center (video streamed to other locations) that presents the annual plan to the workforce and allows for discussion.

### PUTTING DOWN ROOTS IN EARTHQUAKE COUNTRY

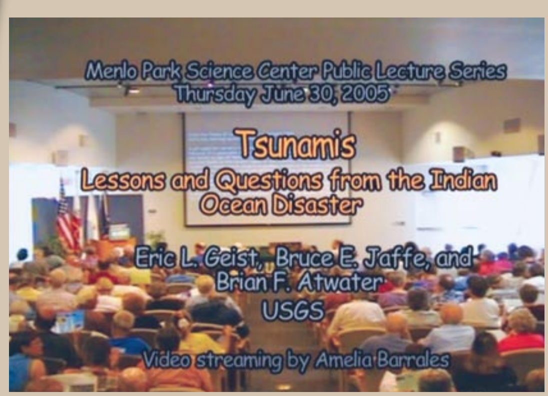
The U.S. Geological Survey in Menlo Park worked with a host of local cooperators to create an earthquake handbook for residents of the San Francisco Bay Region (U.S. Geological Survey, 2005). This timely publication describes the likely impacts of future earthquakes in the Bay Area and gives the seven important steps that people should follow to prepare for, survive, and recover from future earthquakes. More than 750,000 copies have been distributed to the public as inserts in local newspapers, through large home-improvement chain stores, and directly by the U.S. Geological Survey.



## USING THE INTERNET TO COMMUNICATE WITH THE SCIENCE COMMUNITY AND THE PUBLIC

The Menlo Park Science Center is the only facility within the U.S. Geological Survey (USGS) where presentations can be videostreamed to other locations using the Internet. Seminars, training, and other presentations are routinely broadcast in real time over the Internet and are preserved for later viewing in an Internet archive (see for example, http://online.wr.usgs.gov/calendar/ for public lectures and http://volcanoes.usgs.gov/seminar.html talks for Volcano Hazard Team technical seminars).


*In a videostream presentation on August 16, 2005, Acting Director Patrick Leahy addressed a live audience in Menlo Park and, simultaneously using videostream technology, all USGS facilities around the nation. Employees from other USGS facilities participated in a question and answer session by telephone that was linked to the broadcast.*


*On June 30, 2005, a team of USGS scientists presented a public lecture on tsunamis to a live audience at the Menlo Park Science Center. These monthly evening public lectures are simultaneously broadcast over the Internet using videostream technology.*

Integration of Biological Resources programs into science activities of the Menlo Park Science Center is a special issue requiring additional attention of the Menlo Park Council and Western Region leadership as a whole. Greater integration of biological capabilities into the Center is critical especially to Science Goal 2 of this strategy; however, specifics of how to implement such integration requires further planning and more direct involvement of Biological Resources Discipline leadership. Among the key questions that must be addressed are: does participation require colocation?; what would be the mix of colocation and other means of collaboration?; and how should Biological Resources program participation be organized within USGS? How Biological Resources program regionally and nationally could benefit from potential scientific partnerships with San Francisco Bay Area institutions, from the laboratory and other science infrastructure at the Menlo Park Science Center, and from the cadre of invertebrate biologists, microbiologists, and biogeochemists already stationed in Menlo Park also must be explored. Budget and staffing realities dictate that development of a Biological Resources presence at the Menlo Park Science Center would be limited and its implementation phased over time. However, planning for this presence should be considered for immediate attention by Western Region managers.

Commissioning of this report was a first step on the part of the Menlo Park Council to chart a collective vision of the science future of the USGS Menlo Park Science Center into the twenty-first century. To achieve this vision, the Council must consider, as its most important charge, exerting leadership in enhancing the scientific vitality of the Center. This leadership must be made visible both within and external to the USGS.

Opportunities abound to strengthen the Nation's ability to minimize loss of life and property from natural disasters, manage natural resources, and enhance and protect our quality of life on the basis of sound science. The need to advance the natural sciences to meet the challenges that face the Nation has never been greater. The scientific contributions of the Menlo Park Science Center will remain as, if not more, critical to the Nation over the coming 50 years as they have been since the center was established 50 years ago.

## Acknowledgments

The USGS is grateful to all of those who contributed their time and thoughtful ideas to the development of this science strategy. The working group thanks the more than 100 members of the USGS, clients, and cooperators who contributed to the development of this strategy through participating in panels, responding to questionnaires, and providing written comments on various drafts of the document. We also thank those members of USGS in Menlo Park who participated in the open Center meeting to discuss the strategy and who shared their ideas with working group members in numerous individual conversations.

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# Appendixes 1–2

# Appendix 1. Science and Science Support Units in Menlo Park

## Core Science Units

**Earthquake Hazards Team**—Conducts studies of earthquake processes in support of USGS earthquake hazard assessments and monitoring; operates the seismic monitoring network for Northern California in collaboration with the University of California Berkeley. Plans are to remain one of the core science programs at the Menlo Park Science Center.

**Volcano Hazards Team**—Conducts studies of volcanic processes in support of USGS volcano hazard assessments and monitoring; operates volcano monitoring observatories for Long Valley and Yellowstone. Plans are to remain one of the core science programs at the Menlo Park Science Center.

**Branch of Regional Research in the Hydrologic Sciences**—Conducts long-term research in ground- and surface-water chemistry; ground- and surface-water hydrology; aquatic contaminants cycling, transport and toxicity; geomorphology; sediment transport; microbiology; and ecology. Plans are to remain one of the core science programs at the Menlo Park Science Center.

**Mineral Resources Team**—Conducts regional and global mineral resource assessments and research to improve quantitative resource assessment methods; conducts studies of geologic processes related to the evolution of mineral deposits and their environmental impacts. Plans are to retain a small group of researchers specializing in mineral resource information, processes, geochemical hazards, and assessment methodology at the Menlo Park Science Center.

**Earth Surface Processes Team**—Conducts geologic mapping, crustal characterization, process studies, and assessments to characterize and understand the landscape and solid earth as a framework for addressing issues of regional and national interest in natural hazards, energy, mineral and water resources, and environmental science. Plans are to remain one of the core science programs at the Menlo Park Science Center.

**Geographic Research and Technology Team**—Conducts studies to map changes on the land surface throughout the Western Region and explain their significance, to integrate natural science with social science, and to provide tools and measures to decisionmakers at many levels that will improve their use of scientific information. Plans are to build a larger geography research group at the Menlo Park Science Center.

**Coastal and Marine Geology Team**—Conducts geologic-hazard, resource, and environmental studies and assessments that provide science needed to inform public decisions concerning America's coastal and marine regions. Plans are to migrate most of Coastal and Marine Geology Team to Santa Cruz, California, by 2009 and develop there the nucleus of an interdisciplinary USGS coastal and marine science center that can partner with more than 25 institutions in the growing Monterey Bay Area ocean science community. The USGS center in Santa Cruz will retain strong collaboration with the Menlo Park Science Center, and some activities, particularly those related to hazards from offshore earthquakes, are likely to remain in Menlo Park.

## Core Science Support

**Research Laboratories and Field Capabilities**—The Menlo Park Science Center currently supports a broad range of laboratory and field-based hydrologic, geophysical, geochemical, geotechnical, and computational tools to characterize Earth system components, understand Earth system processes, and model complex Earth systems (see appendix 2). Plans are to advance these laboratory and field capabilities, investing in and developing state-of-the-art tools that support evolving research at the Center and in the Western Region as a whole.

**Geospatial Information Office** provides the following four key elements of services central to the USGS Western Region Scientific community:

- **National Geospatial Technical Operations Center**—Provides geospatial technical expertise and partnership services to the scientific community; regional, state and local government; business liaisons and partnership offices in support of *The National Map* and National Geospatial Program Office.
- **Natural Science Network**—The Western Region Library and Earth Science Information Center are being realigned to create the Natural Science Network, a nationally linked network of USGS data, information, and knowledge strategically located in Menlo Park.
  - **Western Region Library**—Western Region hub for the USGS Library, which is the largest collection of Earth science literature in the world. Provides an invaluable information resource to USGS scientists, academics, other governmental agencies, and the general public, both locally and nationally. Plans are to remain a core science support function within the Menlo Park Science Center and to expand paperless (on-line) journal collections and electronic information acquisition systems.
  - **Earth Science Information Center (ESIC)**—Provides outreach support through information dissemination about the use of USGS data to both internal and external customers Sales of USGS products and publications at the Menlo Park Science Center, formerly provided by the ESIC, are now provided through cooperative agreement by the California Geological Survey.

- **Information Technology Services—**Provides telephone, video conferencing, remote access, and both local and wide-area network services. Menlo Park is the Western Region hub of the national network for Department of the Interior, serving the needs of all Interior bureaus with bandwidth access to five Optical Carrier levels, including three OC-3 connections that each has the capability of processing information at a rate of 155.52 megabits per second with redundant methodology.

- **Menlo Park Publishing Service Center—**Provides a full range of publications support services, including planning, editing, graphics, layout, Web preparation, and archiving for print, Web, CD, and other formats of information dissemination. Part of the newly reorganized USGS Enterprise Publishing Network, this is the largest group of USGS publishing professionals in the Western Region. Plans are to remain a core science support unit within the Menlo Park Science Center.

- **Office of Regional Support—**Provides region-wide financial, procurement, human resource, and facilities management support for the USGS. Plans are to migrate most of the Office of Regional Support to the campus of California State University Sacramento by 2009 to reduce operating costs and facilitate recruitment of support personnel.

# Appendix 2. Menlo Park Science Center—Key Research Laboratory and Portable (Field) Capabilities

**Magma Dynamics Laboratory**
(Building 2, contact Tom Sisson)

Partially or completely molten magma samples are created at controlled high temperatures and pressures (as high as 1,400°C and 3 GPa) using specially fabricated furnaces and pressure vessels. Depending on the study, the samples may be held at fixed conditions, or can be decompressed or cooled at precisely controlled rates. They are then rapidly quenched to preserve magmatic compositions and assemblages of minerals, melt (glass), and gases or gas bubbles. Experiments are designed to simulate the creation, storage, ascent, and degassing of magma in order to develop a quantitative understanding of the physical and chemical processes leading to hazardous volcanic behavior. The facility also produces a wide range of high-quality interlaboratory glass and mineral standards.

**Gas Chromatography and Stable Isotopes Laboratory**
(Building 15, contact Jake Lowenstern)

The gas chromatography and stable isotopes laboratory is optimized for chemical and isotopic analysis of volcanic and geothermal fluids (gas and liquid phases).

**Infrared Spectroscopy Laboratory**
(Building 15, contact Jake Lowenstern)

The infrared spectroscopy laboratory is designed to measure the amount and speciation of water and carbon species dissolved in naturally and experimentally produced silicate glass and rock-forming crystals. The data are used in magmatic degassing studies and to determine the molecular structure of silicate melts and solid crystals.

**High Precision Argon Geochronology Laboratory**
(Building 9G, contacts Andy Calvert and Bob Fleck)

Geochronology laboratories in Menlo Park provide absolute age control for a wide variety of USGS projects. The laboratories are world renowned for high-quality results on difficult samples and for careful work to develop new techniques and interlaboratory standards. Geochronologists use high-precision $^{40}Ar/^{39}Ar$, conventional K/Ar, and Rb/Sr techniques to date rocks ranging in age from 10,000 years to billions of years old. Recent results have placed precise and reliable time constraints on tectonic events, volcanic systems, and ore deposits. In recent years, the emphasis has been on dating young (10,000 to 200,000 years) volcanic deposits from active centers to understand rates of volcanic growth and geochemical evolution and to constrain volcanic hazards. The laboratory has recently purchased a new multi-collector noble-gas mass spectrometer and is developing a custom argon extraction line to date younger rocks with higher precision.

**Paleomagnetic Laboratory** (Building 16, contacts Duane Champion and Jonathan Hagstrum)

The paleomagnetic laboratory houses a superconducting magnetometer that is used to determine the magnetostratigraphy of rock and sediment sequences and to quantify paleosecular variations of the geomagnetic field for correlation and dating purposes.

**Mineralogy and Petrology Laboratory**
(Building 15, contact Judy Fierstein)

The mineralogy and petrology laboratory is a shared facility for preparation and identification of mineralogical and petrologic samples. It houses automated X-ray powder diffractometer, heavy-liquid and magnetic mineral separation equipment, fine grinding and sieving equipment, wafering saw, petrographic and binocular microscopes, and fume hoods for caustic chemical treatments.

**Rock Preparation Laboratory**
(Building 4, contact Judy Fierstein)

The rock preparation laboratory is a shared facility for rock cutting, grinding, and sieving of bulk samples. It includes a separate rock/core layout room.

**Machine Shop** (Building 4, contact Ben Hankins)

The machine shop is a shared facility for machining and repair of equipment. It includes lath, drill press, vertical mill, band saw, and standard hand tools, chemicals, and lab accessories.

**Carbon Cycling Laboratory**
(Building 15, contact Jennifer Harden)

The carbon cycling laboratory analyzes soil gases, solids, and liquids for elemental carbon, sulfur, nitrogen, and methane. It supports climate-change research; in particular, results are used to track global warming through monitoring of carbon reservoirs in soils and vegetation.

**Soil Properties Laboratory**
(Building 4, contact Tom Holzer)

The soil properties laboratory contains equipment to measure density, grain size, and simple geotechnical properties of soils.

**Gas Hydrates Laboratory**
(Building 4, contact Steve Kirby)

The gas hydrates laboratory is designed to measure physical properties of low-temperature gas hydrates with cryogenic scanning electron microscopy and conduct hydrate synthesis under high pressure/low temperature conditions. It also supports studies to analyze properties of planetary ices.

**Single Contact Pressure Solution Laboratory**
(Building 4, contact Steve Hickman)

This laboratory contains equipment to measures the rates of cementation, neck growth, and pressure solution for a single crystal contact in high-temperature/high-pressure aqueous solutions.

**Rock Friction Laboratory** (Building 4, contact David Lockner)

This laboratory is designed to measure frictional properties of faults, including rupture nucleation and propagation and time/rate/state/normal stress dependence of shear strength.

**Stress and Heat Flow Mobile Laboratory**
(Building 9E, contacts Steve Hickman and Colin Williams)

This mobile laboratory provides field support and rock physical property measurements for borehole investigations of stress, heat flow, and fluid transport along active faults and in geothermal areas. Activities run out of this mobile lab include operation and maintenance of two geophysical wire-line logging trucks for making measurements of stress, heat flow, permeability, and fracture geometry in deep boreholes.

**Rock Deformation Laboratory**
(Building 10, contact Dave Lockner)

The rock deformation laboratory measures physical, mechanical, frictional, and hydraulic properties of rocks and fault-gouge materials at high pressures and temperatures appropriate for conditions found in seismogenic faults.

**Cone Penetration Testing Mobile Laboratory**
(mobile lab, contact Tom Holzer)

This truck-mounted facility measures penetration resistance and shear wave velocity of unconsolidated sediment to characterize shaking and liquefaction potential in earthquakes as well as to map the shallow stratigraphy.

**Portable Seismic Array**
(Building 3A, contacts Russell Sell and Joe Fletcher)

The USGS maintains an array of REFTEK portable seismic instruments for staging of passive field studies, such as earthquake aftershock studies.

**Drill Rig Mobile Laboratory** (mobile lab, contact Tom Holzer)

This truck-mounted hollow stem auger is used for collecting subsurface samples to depths of 50 feet.

**Earthworm Computer Laboratory**
(Building 11, contact Will Kohler)

This facility is for the development, maintenance, and operation of the software and hardware used in the real-time detection and location of earthquakes throughout northern and central California.

**Earthquake Hazards Computing Facility**
(Building 3, contacts G. Allen, L. Baker, and S. Silvermen)

This is a facility with conditioned air and power for Earthquake Hazards Team servers (Web, program, and data), cluster computing system, and Storage Area Network device.

**Northern California Seismic Network (NCSM) Electronics Laboratory** (Building 11, contact Gray Jensen)

The NCSM electronics laboratory provides for the development, repair, and maintenance of the seismometers, radios, voltage control oscillators (VCO's), and related hardware used in each of the more than 500 seismic stations located between southernmost Oregon and central California.

**Borehole Strain and Magnetometer Laboratory**
(Building 3A, contact M. Johnston)

This facility provides for development and maintenance of downhole strain meters and magnetometers used in both permanent and temporary installations.

**Geostationary Operational Environmental Satellites (GOES) Laboratory** (Building 3A, contact C. Dietel)

This facility provides for maintenance, testing, and repair of GOES seismic recorders, which are used in both permanent and temporary seismic arrays, both in this country and internationally.

**Potential Field Geophysics Facility**
(Building 2, contact T. Hildebrand)

This facility is a deployment hub for gravity and magnetic field measurements. It also serves as a computing facility for 3-D modeling and visualization.

**Environmental Geochemistry & Geomicrobiology Laboratory**
(Building 15, contact A. Foster)

Microbial ecology of environmental samples is studied by culture-independent methods such as in-situ microscopic fluorescent hybridization and ex-situ analyses of prokaryotic (bacterial and archea) and eukaryotic (fungal, to date) ribosomal DNA via polymerase chain reaction, restriction fragment length polytypism, cloning, and sequencing. The lab is at the forefront of the development of high-throughput techniques for large-scale microbial ecology studies via denaturing high-performance liquid chromatography. The second major activity of the lab is in the nondestructive, in-situ determination of trace metal/metalloid speciation in complex matrices (for example, soils, mine wastes, aquifer sediments, plants, biota) using synchrotron-based X-ray absorption spectroscopic techniques. The lab also maintains field instruments and supplies for collection of environmental samples from historic mining sites.

**Electron Beam Instruments**
(Building 11, contact Robert Oscarson)

A scanning electron microscope (SEM) and electron microprobe (electron probe microanalyzer, EPMA) provide submicrometer imaging and micrometer-scale quantitative chemical analyses of natural and synthetic solid materials. The LEO 982 field-emission SEM is equipped with secondary electron, backscattered electron, and cathodoluminescence detectors for imaging objects such as microfossils and rock microtextures. The fully automated JEOL 8900 EPMA has 5 wavelength-dispersive x-ray spectrometers and is used for quantitative analysis of minerals, volcanic glass, products of high-temperature experiments simulating rocks, and biological materials. Both instruments also are capable of energy-dispersive x-ray analysis (EDS) for rapid chemical characterization and identification of substances.

**Ion Microprobe**
(housed at Stanford University, contact Charles Bacon)

In partnership with the Stanford University School of Earth Sciences, the USGS operates a large-format Sensitive High-Resolution Ion MicroProbe (SHRIMP) that provides a unique capability for the Western Region and the Bureau (http://shrimprg.stanford.edu). Ion microprobe analysis (secondary ion mass spectrometry, SIMS) is used for precise determination of isotope ratios and trace element concentrations in solid materials with high spatial resolution. The SHRIMP RG (Reverse Geometry) typically extracts atoms for analysis in its doubly focusing mass spectrometer from a volume 30 micrometers in diameter and a few micrometers deep. USGS scientists from all regions use the SHRIMP RG, most in geology, some in hydrology, and a few in biology. Recent research topics include U–Pb and U–Th (U series) geochronology; trace element concentrations in minerals, volcanic glass, and biogenic carbonates; and Sr isotope ratios in biogenic and hydrothermal calcium carbonate.

**Paleontology Laboratory**
(Building 4, contacts Bonnie Murchy and Chuck Powell)

This laboratory provides for microfossil and macrofossil preparation and analysis for geologic framework, paleoclimate, and paleoenvironmental investigations.

**Tephrochronology Laboratory**
(Building 15, contact Andrei Sarna-Wojcicki)

This facility is a tephra (volcanic ash) preparation, characterization, and data archive lab for dating and correlating Quaternary and late Neogene deposits in the Western United States. Applications are to fault movements, volcanic sources and recurrence intervals, regional climate studies, and geologic mapping.

**Isotope Tracers/Mass Spectrometer Laboratory**
(Building 15, contacts Carol Kendall and Steve Silva)

This laboratory contains four stable-isotope mass spectrometers capable of analyzing C, N, O, H, S, Cl, and Br isotopes in a wide variety of natural materials, including waters, organic matter, gases, and minerals. It also has peripheral equipment for automated preparation of samples for stable-isotopic analysis, including gas chromatographs, combustion and pyrolysis elemental analyzers, purge and trap, head-space gas analyzer, $CO_2$-water and $H_2O$-water equilibration devices, carbonate autoanalyzer, automated manifold for sealed tubes, and total inorganic/organic carbon instruments. In addition, there are four liquid scintillation counters for tritium and 35S, 3H extraction systems (distillation and electrolysis).

**Phytoplankton Dynamics Laboratory**
(Building 15, contact Tara Schraga)

The phytoplankton dynamics laboratory is a facility to determine the chemical and biological aspects of water quality related to phytoplankton dynamics using a CHN analyzer to measure particulate organic carbon, fluorometer, oxygen analyzer, gas chromatograph (for $CO_2$), and microscopes.

**Solute Transport Laboratory**
(Building 15, contact Jim Kuwabara)

This facility measures water-quality parameters including dissolved organic compounds in high-ionic-strength solutions. In addition, the lab contains an atomic absorption spectrophotometer with a hydride generator for As and Se, a hanging mercury-drop electrode for sulfide measurement in high-ionic-strength solutions and a Winkler titrator for small (7 mL) samples.

**Metals in Aquatic Environments Laboratory** (Building 15, contacts Dan Cain, Jim Carter, and Jan Thompson)

This laboratory provides for the identifying and quantifying of freshwater and estuarine invertebrates using specialized microscopic and macroscopic techniques and measurement of trace metals in bed sediments as well as in aquatic organisms using ICP-OES (inductively coupled plasma optical emission spectroscopy). In addition, the lab contains the necessary equipment needed to analyze for trace metals including specialized hoods, a freeze drier, a bench-top centrifuge, and a muffle furnace.

**Metal Partitioning Laboratory**
(Building 15, contact Chris Fuller)

This laboratory provides analysis of soils and water for metals using ICP-OES (inductively coupled plasma optical emission spectroscopy). In addition, the lab contains an ultracentrifuge, a liquid scintillation counter, a gamma ray spectrometer, a KPA (kinetic phosphorescence analyzer) for low concentrations of uranium, a flow-injection analysis unit for routine colorimetric analysis (currently used for Br, but it can also be used for phosphate, silicate, nitrate, and nitrite), a glove box for anoxic work, and a $CO_2$ analyzer.

**Microbial Biogeochemistry Laboratory** (Building 15, contacts Larry Miller and Mark Marvin-DiPasquale)

This laboratory contains equipment used to determine biogeochemical transformations including gas chromatographs (with detectors including flame, thermal conductivity, photoionization, and mass spectrometer—to quantify volatile organic compounds), ion chromatographs (for organic and inorganic anions and nonmetallic cations), HPLCs (high-performance liquid chromatography; for semivolatiles), microscopes, and equipment to work with cultures under anaerobic conditions (Hungate system, glove boxes).

**Fluvial Transport Processes Laboratory**
(Building 15, contact Ron Avanzino)

This laboratory has equipment for analysis of water for dissolved constituents, including ion chromatograph (for anions) and gas chromatograph (for gases such as $CH_4$, $N_2O$, acetylene). In addition, this lab has a low-level nutrient analyzer (nitrogen and phosphorus).

**Geochemical Processes Laboratory**
(Building 15, contact Larry Schemel)

This laboratory provides analysis of aqueous samples using physical and chemical techniques for water-quality parameters. Equipment includes a salinometer to measure salinity, ion chromatograph to measure anions, atomic absorption spectrophotometer for major metals, and a double beam ultraviolet spectrophotometer.

**Molecular Biology Common Use Laboratory**
(Building 15, contact Ean Warren)

The molecular biology common use lab serves science projects intent on expanding research capabilities to include analysis of biomolecules in environmental samples. The lab contains instruments capable of amplifying DNA and RNA to detectable levels using the polymerase chain reaction (PCR). The resulting products can be analyzed using restriction fragment length polymorphisms (RFLP) and DNA separation techniques including gel electrophoresis and denaturing gradient gel electrophoresis (DGGE). Further manipulations can be achieved through cloning DNA PCR products.

**ICP Common Use Laboratory** (Building 15, contact Tom Bullen)

This laboratory consists of an ICP-MS (inductively coupled plasma mass spectrometer), whose function is to measure concentrations of elements by measuring specific isotopes, and a thermal ionization mass spectrophotometer to measure elemental isotopes.

**Geochemical Reactions Laboratory**
(Building 15, contact Jori Schulz)

This laboratory provides analysis of mineral surfaces and water using an ultraviolet spectrophotometer, an autotitrator for alkalinity and pH, a gas chromatograph, a chamber for suboxic conditions, a BET (Brunauer-Emmett-Teller) analyzer for specific surface area, a petrographic microscope to look at rock thin sections, a Franz magnetic separator to isolate different mineral fractions, a muffle furnace, and a bench-top centrifuge.

**Soils Laboratory** (Building 15, contact Kim Perkins)

The soils laboratory provides determination of physical characteristics of soils using a particle size distribution analyzer, centrifuges to measure water flow through soils, and a SPOC (submersible pressure outflow cell) to measure water (not electrical) conductivity.

**Environmental-Organic-Inorganic Geochemistry Complex**
(Building 15, contact Robert Rosenbauer)

This laboratory contains a wide array of analytical capabilities, including the following: high sensitivity gas chromatograph/mass spectrometer (GC/MS) for determining low levels of environmental contaminants and biomarkers in sediments and oils; an older gas chromatograph/mass spectrometer for routine determinations of biomarkers; a variety of gas chromatographs for determining hydrocarbons and permanent gases in water, sediment, and environmental samples; microwave extraction system for the simultaneous extraction of organics from multiple sediment samples; Zymark solvent evaporation system that allows simultaneous nitrogen blowdown of multiple samples; experimental capability to react rocks and fluids, in both fixed and flexible inert cells, over a wide range of geologic conditions and monitor these reactions with time; alpha spectrometers for dating various geologic materials using the U-decay scheme; atomic absorption spectrometer for the determination of dissolved components in fluids; and hydrogen, air, and nitrogen generators for the GC/MS and evaporators to eliminate the need for these as bottled gasses. Purchase is anticipated of a CHNS analyzer for the determination of total carbon, hydrogen, nitrogen, and sulfur in environmental samples.

**Micropaleontology Laboratory**
(Building 15, contact Mary McGann)

This laboratory provides for the subsampling, processing, and data archiving of sediment cores and grabs obtained by the Coastal and Marine Geology program in order to gain information on the paleoecology and biogeography of sedimentary deposits for mapping historic and paleoenvironments, for reconstructing past climates, for determining sedimentation rates, and for dating sediments using detailed biostratigraphy and accelerator mass spectrometry (AMS) C-14 chronostratigraphy. Laboratory processing techniques include vital staining for live studies, wet sieving, settling, and nontoxic floatation (sodium polytungstate). In addition, the lab has the capability to study ostracods, nannofossils, radiolarians, pollen, and diatoms.

**Sediment Laboratory** (Building 15, contact Michael Torresan)

The sediment laboratory includes a specialized, lead-lined room for X-ray imaging of long (1.5 m) core section, a darkroom for processing X-ray radiographs of marine sediment, facilities to split, describe, photograph, and subsample sediment cores, and facilities for coarse-fraction sediment analysis using USGS-built rapid sediment analyzers (RSA's). Also available is equipment for analysis of fine-fraction sediment texture, carbon/carbonate content, heavy mineral separation, insoluble residues, and preparation of samples for use in other laboratories (for example, marine mineralogy). Results are useful in defining sedimentary environments, biohabitats, and establishing sediment transport models. Specific items of equipment include: Coulometrics coulometer (carbon/carbonate analysis), state-of-the-art digital Faxitron/MFI X-ray imaging system for 8-cm-diameter cores up to 1.5 m in length, three 2-m-long settling tubes for sand-fraction textural analysis, and a SediGraph (for fine-grained, silt-clay sediment size analysis).

**Particle Size Analysis Laboratory**
(Building 15, contact Michael Torresan)

Three laboratories house analytical equipment used to conduct particle-size analysis based on both sieve and sedimentation analysis. The systems used in these laboratories range from classical techniques employing sieves and pipettes to modern techniques using automated systems that employ sedimentation analysis as it applies to particles settling in columns of water or to light or X-ray attenuation through a dispersed sediment suspension. A separate room is dedicated to determining the size distribution of mud. Another room houses settling tubes for the analysis of sand-size particles. The Sediment Laboratory (previously described) houses sieves and a rotap machine used to analyze gravel- and sand-size distributions. Sediment analysis requires that samples be pretreated and disaggregated to remove flocculating agents, cements, organic matter, and soluble materials in order to obtain an accurate measurement of the grain-size distribution. Sample preparation is conducted in the Sediment Laboratory.

**Sediment Dynamic Laboratory** (Building 15, contact Homa Lee)

This laboratory specializes in the instrumented study of sediment transport. Functions include calibration tests and experiments on optical sensors used in bottom tripods or moored instrument arrays, experiments on the fall velocities of particles, internal wave and turbulence experiments using flume tanks, and specialized particle analyses. Results are useful for sediment transport studies (for example, pollutant dispersal studies). Specialized equipment includes a Coulter counter for specialized fine-fraction particle analysis and a calibration tank for sensors used in field measurements of suspended sediments.

**Geotechnical Laboratory** (Building 15, contact Robert Kayen)

This laboratory specializes in geotechnical studies of marine, estuarine, lacustrine, and terrestrial sediment. Capabilities include fully automated computer-controlled testing of consolidation, permeability, and shear-strength properties, as well as nondestructive analysis of whole-core sediment sections using a whole-core logging system. Results are extremely useful in submarine and earthquake failure analysis. The facility includes state-of-the-art computer-controlled geotechnical testing equipment and GEOTEK multi-sensor logging system (MSL), which nondestructively provides data on P-wave velocity, bulk density, and magnetic susceptibility in 1-cm increments.

**Sea-floor Mapping Laboratory**
(Building 15, contact Peter Dartnell)

This laboratory can process, display, and generate maps from high-resolution multibeam data. It also has the capability to archive data on CD-ROM. The laboratory uses University of New Brunswick's Ocean Mapping Group software to process multibeam data and Interactive Visual Systems software to interactively fly through color and (or) black-and-white georeferenced sea-floor images (sidescan and (or) bathymetry). This software can create oblique views, combine backscatter and bathymetry into a single image, and quantitatively analyze the images. In addition, georeferenced data of different resolution can be combined into a single or multiple images, and multiband satellite data, USGS DEMs, or Seasat altimetry can be combined with our own multibeam data for overviews of any area of interest. Procedures developed in-house can generate hard-copy color and (or) black-and-white maps of the sea floor. All datasets are routinely made available as on-line reports.

**Infrared Mineral Analyzer** (portable, contact David John)

This facility is a portable spectrometer capable of determining the mineralogy of rocks containing hydrous phases (clays, micas, amphiboles), carbonate minerals, and ammonium-bearing minerals in the field.

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