OPINION

Stepping Up to the Plate

For someone coming from the outside to take a position with the federal government, one of the biggest challenges is understanding your mission and how it fits into the grand scheme of things. But coming to the U.S. Geological Survey's (USGS) Earthquake Hazards Program, the task is made quite a bit simpler because the prime directive has been clearly set by Congress. Along with its three partners in the National Earthquake Hazard Reduction Program (NEHRP), USGS shares a congressional mandate to develop "effective measures for earthquake hazards reduction", promote their adoption, and "improve the understanding of earthquakes and their effects on communities, buildings, structures, and lifelines." The USGS Earthquake Hazards Program is specifically tasked with providing earthquake monitoring and notifications, assessing seismic hazards, and conducting research needed to reduce the risk from earthquake hazards nationwide.

The USGS Earthquake Hazards Program is a program that does not, and cannot, go it alone.

In addition to close collaboration with the other NEHRP partners—the Federal Emergency Management Agency (now within the Department of Homeland Security), the National Institute of Standards and Technology, and the National Science Foundation (NSF)—fully a quarter of the program's funding supports directed research and earthquake monitoring activities by universities, state and local governments, and the private sector. This is a program that does not, and cannot, go it alone.

In seeking to understand the capabilities that the USGS Earthquake Hazards Program can bring to bear and the challenges and opportunities that it faces, a good place to start is the USGS response to the 22 December 2003 San Simeon earthquake.

Learning from San Simeon

In January of this year, the San Luis Obispo County (California) Board of Supervisors wrote a letter to USGS Director Chip Groat expressing appreciation for the Survey's assistance following the magnitude 6.5 San Simeon event, which killed two people in the town of Paso Robles and caused an estimated $300 million worth of damage in the lightly populated central coast region.

As soon as the earthquake happened, data were available in real-time from the California Integrated Seismic Network (CISN) operated in partnership by USGS, UC Berkeley, Caltech, and the California Geological Survey. Within minutes, USGS and its CISN partners produced a preliminary ShakeMap portraying the extent of potentially damaging ground shaking. The Federal Emergency Management Agency (FEMA) and California Office of Emergency Services—also a CISN partner—plugged that shaking intensity information into FEMA's *HAZUS* software to quickly generate loss estimates. The California Department of Transportation used the ShakeMap to prioritize its bridge inspections. USGS also provided real-time information and analysis on aftershock location and probability of occurrence. Pacific Gas & Electric made the decision to proceed with critical maintenance on the Diablo Canyon nuclear power plant based on the USGS aftershock analysis as well as USGS data suggesting that the San Simeon earthquake had reduced stress on faults near the facility. Working with the county geologist, USGS scientists surveyed the damage and compiled a map of observed landslides, liquefaction, road and structural damage, and other evidence of high-intensity shaking. They installed portable seismographic equipment to measure ground response to aftershocks in order to produce a detailed map of the liquefaction hazard in the nearby town of Oceano.

But the county commissioners did not write to the USGS Director just to express appreciation. They wrote to request a thorough, modern evaluation of seismic hazards in their region, something that does not currently exist. In that respect, their county is representative of much of earthquake country. Although USGS has evaluated the long-term hazard from earthquake shaking in California's central coast region as part of the National Seismic Hazard Map effort, that evaluation was based largely on information from the nearby San Andreas Fault. Many other active structures remain to be characterized. Like the far more devastating Northridge earthquake 10 years earlier, this quake struck on a blind thrust fault with no surface rupture. New technologies, such as ultrahigh-resolution topographic data from airborne laser surveys, can be applied to better assess the hazard from such structures, but the cost of such surveys is substantial.

The USGS Earthquake Hazards Program has begun to produce urban hazard assessments that incorporate local variations in geology and soil conditions. The program's five-year plan calls for expansion of this effort, because communities throughout earthquake country have made requests similar to that of the San Luis Obispo commissioners. The capability is there, but the requests far outstrip the available resources.

Likewise, the Survey's ability to produce timely ShakeMaps depends on the proximity of seismic stations providing strong-motion data in real-time. For the San Simeon quake, such stations were distant and sparse, and the preliminary ShakeMap was substantially refined after manually retrieving data from additional seismic stations that have not yet been fully connected to a central processing facility. In contrast to the dense networks that have been deployed in the Los Angeles and San Francisco Bay areas, many seismically active zones elsewhere in California and across the nation lack the necessary instruments to allow USGS to provide robust ShakeMaps and other useful products for emergency managers when they need them.

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Building the Advanced National Seismic System

And that is why the Advanced National Seismic System (ANSS) is so important. ANSS, of which CISN is a component, is intended to address that scarcity by delivering 1,000 additional regional broadband stations across the country and 6,000 strong-motion sensors—ground-based and structural— in 26 seismically active urban areas. Deploying ANSS means a great deal more than simply installing new sensors. It means building a system that seamlessly integrates the new sensors with existing networks, and it also means developing tools such as ShakeMap and delivery mechanisms to push this information to the people who need it. ANSS was established in 2000 by legislation reauthorizing NEHRP. The mandate was "to organize, modernize, standardize, and stabilize the national, regional, and urban seismic monitoring systems in the United States, including sensors, recorders, and data analysis centers, into a coordinated system that will measure and record the full range of frequencies and amplitudes exhibited by seismic waves, in order to enhance earthquake research and warning capabilities." Although the legislation authorized $36 million per year for five years, appropriations have reached only $4.4 million as of fiscal year 2004. This is the same amount requested for fiscal year 2005.

The same legislation that established ANSS also established an external advisory committee to advise the USGS Director on NEHRP matters. In its 2003 annual report, the Scientific Earthquake Studies Advisory Committee (SESAC), chaired by Lloyd Cluff of Pacific Gas & Electric, strongly recommended the need for funding at the authorized level, noting, "The ANSS data are crucial for emergency response to future earthquakes, as well as in the post-earthquake recovery period in developing safer, less vulnerable buildings, lifelines, critical facilities, and hardened military complexes, and in developing performance-based design procedures for structures and systems of all types. " Recognizing that the nation's attention has turned to vulnerability from dangers other than earthquakes, the committee also emphasized that ANSS "will play a significant role in the nation's homeland security by providing data on the integrity of structures and infrastructures, and by assessing the readiness of military bases and other critical facilities following an earthquake."

As suggested by the committee's statement, the structural instrumentation component of ANSS has the potential to deliver tremendous value in strengthening the resilience of the built environment. When members of the advisory committee presented their recommendations at a congressional briefing in February, committee member and University of Texas at Austin structural engineering professor Sharon Wood likened ANSS instruments to the "black boxes" used to reconstruct airplane crashes. Structural monitoring will provide engineers with crucial data on how buildings and critical infrastructure respond to the shaking measured by the ground-based instruments, leading to improved design standards.

The value of ANSS is reflected in many strong statements of support made by outside organizations, including the Seismological Society of America (SSA), and expressed in recent reports such as the Earthquake Engineering Research Institute's *Securing Society Against Catastrophic Earthquake Losses* and National Research Council's *Living on an Active Earth: Perspectives on Earthquake Science*, both published in 2003.

Improving NEHRP Coordination

Recognizing the fiscal constraints placed upon the USGS Earthquake Hazards Program and the broad scope of the mandate the program must meet, the SESAC report also emphasizes the need to make every effort to improve coordination with the Survey's NEHRP partners, especially the National Science Foundation (NSF). Two areas of collaboration are particularly important. The first is the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES), a distributed network of structural engineering test facilities that goes into operation in 2004. These giant shake tables, centrifuges, and tsunami wave basins represent an incredible opportunity to study seismic response. But even the largest shake table cannot reproduce the real world, and simulations are only as realistic as the input motion data they employ. Through collaboration, ANSS instruments can and should serve as an augmented field-test component to NEES, helping meet the needs of both.

Like NEES, EarthScope is a major capital investment at NSF, the first of its kind for the Earth sciences. With the first several years of funding in place, it is rapidly moving toward full deployment. Intended to provide a window into the crustal deformation of the North American continent, EarthScope includes three components, all of which can provide additional benefits through collaboration with USGS. EarthScope's Plate Boundary Observatory component will deploy hundreds of geodetic stations along the western margin of North America. In regions such as California's central coast, this network can provide loading rates for faults both known and yet to be discovered—crucial data for developing a more robust hazard assessment. The San Andreas Fault Observatory at Depth component of EarthScope takes advantage of the USGS' longstanding Parkfield experiment to provide a well constrained setting for a directionally drilled, heavily instrumented, long-term borehole observatory across the San Andreas Fault at depths where earthquakes nucleate. Finally, the USArray seismic array component of EarthScope is contracting with the USGS Albuquerque Seismological Laboratory to test and deploy instrumentation with further opportunities for shared station location and data distribution with ANSS.

The SESAC recommendations underscore the value of stepping up to the plate. By being an active partner in NEES and EarthScope, USGS will ensure that these projects not only achieve their scientific goals but also make a significant contribution to the broader societal goal of reducing losses from earthquakes. At the same time, pushing forward toward full deployment of ANSS will enable USGS to deliver valuable products such as ShakeMap to all communities with significant seismic risk. Across the country, states and localities are adopting the International Building Code, the seismic provisions of which are based on the USGS National Seismic Hazard Map. ANSS data will feed into the next generation of national and urban seismic hazard maps, further improving the precision of ground-shaking forecasts. Such information allows communities and states to prepare their citizens better for earthquakes and make their communities and critical infrastructure more resilient.

Evaluating Predictability

As if these challenges were not enough, yet another remains. Short-term earthquake prediction—the specification of a time, place, and magnitude window for a future event—retains a talismanic quality for many outside the earthquake research community. Interest in—and optimism about—short-term prediction has waxed and waned over the years. While the promise that prediction held in the 1970's has long since faded, new tools and technological advances are generating another groundswell of interest in both short- and intermediate-term prediction. As a sign of what is to come, NASA has made earthquake prediction a target for its Earth Science Enterprise remote sensing program.

Because the Stafford Act tasks the USGS Director with issuing warnings for earthquakes, volcanoes, and landslides, the Survey has a unique responsibility in this area. In light of that responsibility and the growing interest in short-term earthquake prediction, the SESAC report calls on USGS to step up to the plate: "We see an opportunity for the USGS to lead the scientific community and provide a unified position on short-term earthquake prediction. … The USGS must take on an aggressive role in evaluating and validating proposed prediction tools so the public understands the true risks associated with a given seismic area. A comprehensive, physics-based earthquake model coupled with a viable program to test the results of the prediction tool should be developed by the USGS."

SESAC has also recommended that USGS re-establish the National Earthquake Prediction Evaluation Council "to serve as a forum to review predictions and resolve scientific debate prior to public controversy or misrepresentation, so decision makers are not misled by unfounded short-term earthquake predictions." First established by the 1980 reauthorization of NEHRP, the council was active until the early 1990's, advising the USGS Director on how to respond to predictions, whether internally or externally generated, in keeping with the director's Stafford Act responsibility. Such a responsibility requires not only specific technical expertise to evaluate the validity of the prediction and its underlying physical basis, but also expertise from the social sciences and emergency management communities regarding how any official response to a prediction is likely to be received by the public. Conveying scientific uncertainty is always a challenge, and one that looms particularly large in such potentially contentious situations.

Indeed, managing public expectations may be the hardest task associated with a short-term prediction. Authoritative reviews are critically needed not at the point that the scientific community decides there is merit to a given prediction, but before that prediction has caught the full attention of the media and affected communities. Prior experience has shown that even the most sober and well founded evaluation has little impact once a media circus is underway.

Much to Be Done

The activities of the USGS Earthquake Hazards Program are ultimately directed toward the goals of saving lives and reducing the impacts that earthquakes have on the built environment and people's livelihoods due to economic disruption. The journey to reach that goal is long, but it is well worth every effort we can make. The broader seismological community has a tremendously important role to play in getting us to that goal. On behalf of the program, I am grateful for the community's support, particularly that of the Seismological Society of America, and I am looking forward to working with you down the road.

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