The Advanced National Seismic System: A Sure Bet for a Shaky Nation

By David Hebert

If you were to learn that in 1886, a major U.S. city was ravaged by a magnitude-7.3 earthquake in which 60 people were killed and millions of dollars of damage done, where would you guess it had happened — Los Angeles? San Francisco? Anchorage?

Try Charleston, S.C.

In fact, damaging earthquakes have rocked several U.S. cities far from Alaska or California — Boston, Memphis and Salt Lake City, to name a few. Chances are, they will again, and those at risk need to be ready.

That’s where the Advanced National Seismic System (ANSS) comes in.

The ANSS is a proposed nationwide earthquake-monitoring system designed to provide accurate and timely data and information products for seismic events, including their effects on buildings and structures.

“The ultimate goal of the ANSS is to save lives, ensure public safety and reduce economic losses,” said Bill Leith, a USGS scientist and coordinator of the ANSS. “Rapid, accurate information about earthquake location and shaking, now available in parts of California, Washington and Utah, is generated by data from a dense network of seismic-monitoring instruments installed in high-risk urban areas. The information has revolutionized the response time of emergency managers to an earthquake in these areas, but its success depends on further deployment of instruments in other vulnerable cities across the United States.”

Although the frequency of earthquakes on the West Coast is higher than other areas of the contiguous United States, the geologic characteristics nationwide mean that research and monitoring are necessary everywhere.

“When people think of faults and earthquakes, they tend to think of the San Andreas Fault, but earthquakes in the eastern United States might be different,” said Eugene Schweig, a USGS geologist in Memphis, Tenn. “Assuming buildings will shake the same in the East as they do in California is probably not valid.”

ANSS network instruments are already at work in many areas and are planned for other earthquake-prone regions nationwide, including Northern and Southern California, the Pacific Northwest, Alaska, Salt Lake City, the New Madrid Seismic Zone, and along the Atlantic Coast in South Carolina, New York and Massachusetts.

The ANSS, when fully implemented, will integrate all regional and national networks with 7,000 new seismic instruments, including 6,000 strong-motion sensors in 26 at-risk urban areas. (See map for a list of these areas.)

Boston is one of those urban areas — indeed, it has experienced damaging earthquakes before. In 1755, an earthquake centered near Cape Ann, Mass., caused building damage and chimney collapses in Boston. The buildup of the city since then would likely make matters much worse if such an earthquake were to happen there today.

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John Ebel, a professor of geophysics at Boston College and northeast coordinator for ANSS implementation, estimates that damaging earthquakes (magnitude 5 or greater) happen in New England every 50 to 60 years. In 1940, there was a magnitude-5.5 quake in New England, and the clock is ticking.

“I talk to people all the time who ask, ‘Earthquakes don’t really happen here, do they?’ ” Ebel said. “And I answer, ‘Yes, they do.’ ”

Although the frequency of earthquakes is much greater in the West, the damaging effects of a quake in the East travel farther.

“The 1994 magnitude-6.7 Northridge, by David Hebert

USGS Earthquake Scientists — A Nationwide Notion of Pride

USGS scientists from across the country have been part of many incredible and memorable earthquake experiences. With that in mind, several of them were asked, “What has been your proudest, most exciting or most noteworthy moment in USGS earthquake science?”

The answers are as different as the scientists themselves.

Susan Hough

Title: Geophysicist/Seismologist
Location: Pasadena, Calif.
Length of service with the USGS: 14 years

In April of 1992, less than two months after joining the USGS office in Pasadena, Calif., I led the deployment of portable seismometers after the magnitude-6.1 “Joshua Tree” earthquake struck the Southern California desert near Palm Springs. My colleagues and I were able to keep these instruments running for the next few months, recording many thousands of aftershocks.

On the morning of June 28, 1992, the magnitude-7.3 Landers earthquake struck just to the north of where the Joshua Tree event had occurred. The portable seismometers — instruments developed by the USGS in Menlo Park — operated faithfully, recording invaluable close-in seismograms of the largest earthquake in California in 40 years.

Now, as in 1906, seismology remains a data-driven science: Our most important leaps in understanding have invariably come after large earthquakes not only strike but are recorded by increasingly sophisticated instrumentation. Earthquakes do not, however, record themselves. Long- and short-term monitoring requires ingenuity and commitment. The USGS has taken a leadership role with such efforts in the United States for nearly half a century. Looking back at my own career, I am proud of any number of accomplishments, but none more than the chance to contribute in a modest way to this tradition of excellence.

By David Hebert

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The answers are as different as the scientists themselves.
Calif., earthquake was not felt in San Francisco, less than 400 miles away,” Ebel said. “If that same earthquake happened in Boston, it would be felt in Minneapolis-St. Paul, more than 1,000 miles away. There is potential for several metropolitan areas to be damaged by a single, large earthquake in the East.”

In 1811 and 1812, a series of earthquakes, ranging in estimated magnitude from 7.5 to 8.0, started near New Madrid, Mo., and shook cities from St. Louis to Cincinnati. Although the probability for another 1811/1812-type sequence in the next 50 years is 7 to 10 percent, the probability for a magnitude-6 or greater during that same period is 25 to 40 percent.

“Based on paleoseismic work, we know that 1811- and 1812-like events have happened two or three times in the past,” said Mitch Withers, seismic networks director at the Center for Earthquake Research and Information at the University of Memphis. “So we know it’s not a fluke and that they tend to come in sequences, where there are several events clustered together in time. From a hazard and recovery point of view, it’s much more difficult if we have several in a row like that.”

Earthquake hazard concerns stretch to the Mountain States as well, where several earthquakes since 1935 have caused more than 30 deaths in Idaho, Montana and Wyoming. The threat of such a quake happening in a mountain urban area means preparation and monitoring are vital at-risk locations such as Salt Lake City.

“We haven’t had our 1906 earthquake in Utah yet, but our partnership with the USGS under the ANSS has made us feel much better prepared to deal with it when it happens,” said Gary Christenson, a geologist and manager of the Geologic Hazards Program at the Utah Geological Survey. “The USGS has been a partner in earthquake monitoring in Utah from the beginning, and implementation of the ANSS has been a major achievement in improving preparedness, response and scientific/engineering data gathering.”

The variety of earthquake hazard concerns that are both unique to and shared by urban areas nationwide illustrates the need for a consolidated, cooperative approach to information gathering and mitigation.

“The ANSS is working toward development and implementation of integrated software and human resources to more effectively use these with existing hardware resources to provide timely and valuable information to the public,” Withers said. Timely and valuable information is a key ingredient to effective mitigation. A possibility USGS scientists have been keenly aware of throughout the development of ANSS is that an early warning of even a few seconds would give school children enough time to get under their desks and would allow managers time to stop trains and subways, shut off pipelines and suspend medical procedures. These sorts of warnings can only be accomplished through national cooperation, so a nationwide network of science and civic partners is working to make the ANSS a reality.

“The USGS and its regional partners combine resources to augment ANSS-funded stations to operate regional seismic networks,” Withers said. These partners include state geological surveys, university researchers, emergency managers, engineering organizations and more. The USGS works to unify perspectives and efforts to create a single, national force with which to address earthquake concerns and provide timely information.

“To have the USGS as overseer and coordinator of the ANSS makes sense,” Ebel said. “The USGS is nationally involved in earthquake research and monitoring and it has expertise in house.”

The USGS is the only agency in the United States responsible for the routine monitoring and notification of earthquakes. The USGS fulfills this role by operating the U.S. National Seismograph Network, the National Earthquake Information Center, the National Strong Motion Program and by supporting 14 regional networks in areas of moderate to high seismic activity. All of these efforts are being integrated into the ANSS.

“The ANSS contributes to the infrastructure that enables monitoring to be much more cooperative and integrated, allowing information to the public that combines data from all regional partners,” Withers said.

The goal of USGS earthquake monitoring is to save lives, ensure public safety and reduce economic losses.

— Bill Leith

The ultimate goal of the ANSS is to save lives, ensure public safety and reduce economic losses.

Robert J. Anima
Title: Geologist
Location: Menlo Park, Calif.
Length of service with the USGS: 33 years
For the past six or seven years, I have had the opportunity to report, both locally and internationally, to the Spanish-speaking public on both television and radio, about earthquakes, tsunamis and other natural disasters. I feel that this is important because much of the information reported in English was not being reported to the Spanish-speaking community. Because we live in an earthquake-prone area — the entire West Coast of North, Central and South America — these communities need to be made aware of the potential hazards that surround us and them. As part of these assumed duties, I have also helped in translating two fact sheets concerning earthquakes and tsunamis. In 2001, I was asked to be part of the Tsunami Response Team that was invited to Peru in response to a series of tsunamis that occurred along the coast of Camana, Peru, as a result of a magnitude-8.4 earthquake off the coast of southern Peru. The study focused on tsunami deposits on the beaches between Ocoña and Mejía, Peru. I am currently working on mapping the rift valley of the San Andreas Fault, Tomales Bay. I am also mapping the continental shelf along the central California coast.

Ken Rukstales
Title: IT Specialist
Location: Golden, Colo.
Length of service with the USGS: 21 years
Along with Art Frankel and E.V. Leyendecker, we have produced seismic building-design maps that are the basis for the seismic design provisions of the International Building Code and the International Residential Code. These maps are the most significant product to ensure that buildings, bridges and other structures are designed to withstand expected levels of ground shaking caused by earthquakes. Properly designed, earthquake-resistant structures greatly reduce the loss of life and property from earthquakes.

USGS Earthquake Scientists — A Nationwide Notion of Pride
Taking it all in Slide —

How the Trans-Alaska Pipeline Survived a Big One

Compiled by Heather Friesen

The Nov. 3, 2002, magnitude-7.9 central Alaska earthquake was one of the largest recorded earthquakes in our nation’s history. The epicenter of the temblor was located near Denali National Park, approximately 75 miles south of Fairbanks and 176 miles north of Anchorage. It caused countless landslides and road closures, but minimal structural damage, and amazingly, few injuries and no deaths.

In contrast, the 1960 magnitude-9.5 earthquake and subsequent fires took 3,000 lives and caused $524 million in property losses. The remote location of the magnitude-7.9 Denali Fault earthquake played a role in ensuring that the earthquake was not more devastating. However, advanced seismic monitoring, long-term research and a commitment to hazardous preparedness and mitigation also played a key role. The science done before the Denali Fault earthquake aided in the successful performance of the Alaska pipeline, and the science done after the Denali Fault earthquake revealed more about large quakes that will help save lives and property during future temblors, especially in populated areas.

USGS seismologists and geologists serving on a federal task force were instrumental in ensuring that the Trans-Alaska Pipeline was designed and built to withstand the effects of a magnitude-8.0 earthquake with up to 20 feet of movement at the pipeline. The USGS design guidance proved to be on target. In 2002, the Denali Fault ruptured beneath the pipeline, resulting in an 18-foot horizontal offset. The resilience of the pipeline is a testament to the importance of science in hazard mitigation and decision making.

More than 30 years ago, Trans-Alaska Pipeline System (TAPS), formed by seven oil companies, confirmed the existence of a great deal of oil on the North Slope. In February 1969, TAPS announced plans to build a 4-foot diameter, 800-mile pipeline to carry crude oil from Prudhoe Bay to Valdez. Issues pertaining to the safety of the design emerged. Would the heat in the oil melt the pervasive, thick, permafrost layer and cause damaging spills? Would the pipeline be able to withstand a large earthquake in the nation’s most seismically active state?

Walter Hickel, then U.S. Secretary of the Interior (1969-70), was alerted about the proposed pipeline and immediately appointed Bill Pecora, then USGS director (1965-71), to chair a technical advisory board. Pecora appointed the Menlo Park working group, made up mostly of USGS scientists, to advise the board.

USGS created several scientific documents to be used in planning the pipeline location and construction. Documents included an estimate of potential earthquake shaking levels and a report on thermal effects of a heated pipeline in permafrost that described how the pipe would float, twist and break.

In 1971, Pecora brought the Menlo Park group to Washington and thanked them for telling the oil companies “what they can’t do,” but now he wanted them to tell the companies “what they can do.” Pecora locked the door of the conference room and told the group that he would not let them out until they had finished the analysis of the question “To bury or not to bury?” The group put together the necessary stipulations on the pipeline construction. Among other things, the stipulations required that the pipeline system be designed to prevent oil leakage from the effects of a magnitude-8.0 earthquake on the Denali Fault.

In April 1974, construction of a 400-mile, all-weather road from the Yukon River to Prudhoe Bay was started. Pipeline and storage tank construction at Valdez began in 1975. Large segments of the Trans-Alaska Pipeline were elevated above ground to keep the permafrost from melting, and about half of the 800-mile pipeline was buried. A special fault design was adopted for crossing the Denali Fault Zone. Here the pipeline is supported by rails on which it can slide freely in the event of fault offset. In mid-1977, the first tanker shipped Alaska north slope oil from Valdez.

More than 14 billion barrels (nearly 550 billion gallons) have moved through the pipeline since startup in 1977. After the 2002 quake, the pipeline continued to carry 1 million barrels of oil each day, though it was temporarily shut down for inspection. With the pipeline intact, an important source of revenue for the state of Alaska was preserved. Moreover, as Alaskans know all too well, the consequences to the environment, should the pipeline have failed, would have been catastrophic.

“Good science made the difference between an emergency and a tragedy,” said P. Patrick Leahy, USGS. “It’s an example of how partnerships between the USGS, the Federal Emergency Management Agency, universities, state and local officials, and business leaders and the community enable us to apply our scientific knowledge. We know we can’t stop the Earth from changing, but we can work together making public safety our primary goal.”

The 2002 Denali earthquake is the largest seismic event ever recorded on the Denali Fault system — one of the longest continental faults in the world. The earthquake was similar to the magnitude-7.9 1960 earthquake, which ruptured the San Andreas Fault in Northern California. Both fault systems exhibit strike-slip movement, where blocks of continental crust slip horizontally past each other.

“Studying the 2002 Denali Fault earthquake is an opportunity to understand the consequences of a very large earthquake to better prepare for the time when one will occur in a much more densely populated area,” said USGS scientist Peter Haeussler.

The Denali Fault earthquake was very directional. It ruptured rapidly over a long distance, focusing the earthquake energy in the direction of the earthquake epicenter of the temblor was located near Denali National Park, approximately 75 miles south of Fairbanks and 176 miles north of Anchorage. It caused countless landslides and road closures, but minimal structural damage, and amazingly, few injuries and no deaths.

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Measuring Magnitude

Often two or more different magnitudes are reported for the same earthquake. Sometimes, years after an earthquake occurs, the magnitude is adjusted. Although this can cause some confusion in news reports, for the public and among scientists, there are good reasons for these adjustments.

Preliminary Magnitude

Following an earthquake, the first magnitudes that seismologists report are usually based on a subset of seismic-monitoring stations, especially in the case of a larger earthquake. This is done so that some information can be obtained immediately without waiting for all the data to be processed. As a result, the first magnitude reported is usually based on a small number of recordings. As additional data are processed and become available, the magnitude and location are refined and updated. Sometimes the assigned magnitude is “upgraded” or slightly increased, and sometimes it is “downgraded” or slightly decreased. It can take months before a magnitude is no longer “preliminary.”

Sometimes the earthquake magnitude is reported by different networks of seismometers based on only their recordings. In that case, the different assigned magnitudes are a result of the slight differences in the instruments and their locations with respect to the earthquake epicenter. Depending on the specifics of the event, scientists might determine that the network closest to the event reports it most accurately. This is especially true where the instrumentation is denser. Other times, national networks, in which the instruments are often more state-of-the-art, produce the most reliable results.

Different Methods of Calculating Magnitude

The concept of using magnitude to describe earthquake size was first applied by Charles Richter in 1935. The magnitude scale is logarithmic so that a recording of 7.1, for example, indicates a disturbance with ground motion 10 times larger than a recording of 6.1. However, the difference in energy released is even bigger. In fact, an earthquake of magnitude 7.1 releases about 33 times the energy of a magnitude 6.1 or about 1,000 times the energy of a magnitude-5.1. Another way of thinking of this is that it takes about 1,000 magnitude-5.4 earthquakes to equal the energy released by just one magnitude-7.4 event. An earthquake of magnitude 2 is normally the smallest felt by people. Earthquakes with a magnitude of 7.0 or greater are considered major; great earthquakes have a magnitude of 8.0 or greater.

Through the years, scientists have used a number of different magnitude scales, which are a mathematical formula, not a physical scale. Although news reports often call all magnitudes “Richter,” scientists today rarely use Richter’s original method. Unless further detail is warranted, USGS simply uses the terms magnitude or preliminary magnitude, noted with the symbol “M,” in its news releases.

The Most Common Magnitude Scales in the United States

When earthquakes occur, energy is radiated from the origin in the form of different types of waves. Moment magnitude (Mw) is usually the most accurate measure of an earthquake’s strength, particularly for larger earthquakes. Moment magnitude accounts for the full spectrum of energy radiated by the rupture and is generally computed for earthquakes of at least magnitude 5.5 when the additional data needed for this computation are available and the effort is warranted. Using some sophisticated regional networks in which noise is limited, seismologists can compute moment magnitudes for earthquakes down to less than magnitude 3.5.

Surface-wave magnitude (Ms) is computed for shallow earthquakes, those with a depth of less than 30 miles. Body-wave magnitude (mb) is computed for both shallow and deeper earthquakes, but with restrictions on the period of the wave. And local “Richter” magnitudes (ML) are computed for earthquakes recorded on a short-period seismometer local to (within 370 miles of) the focus of the earthquake.

Seismologists may measure an earthquake’s magnitude with one scale. Then, once more data are available, reassign the magnitude using another scale deemed more accurate based on the additional data. For example, for the 1999 earthquake near Ismit, Turkey, the 7.8 magnitude first cited was a (Ms) surface-wave magnitude. The later figure of 7.4 is a (Mw) moment magnitude. Magnitudes assigned to a specific event for years can sometimes change.

Compiled with assistance from Steve Vandas.

USGS Earthquake Scientists — A Nationwide Notion of Pride

Brian Sherrod
Title: Research Geologist
Location: Seattle
Length of Service with the USGS: 11 years
One of my most memorable times as a USGS scientist is when I found evidence of surface rupture along the Seattle Fault near Bellevue, Wash. I was looking for evidence of the Seattle Fault east of Seattle — using old aerial photographs taken from biplanes in the 1930s, more recent laser mapping data, geologic maps and lots of field work. I had a good idea where I thought a strand of the fault zone traversed the area I was working in, so I obtained permission to do some detailed work on an undeveloped parcel of land near the shoreline of Lake Sammamish. After many hand-excavated test pits and soil auger holes, I thought I had found a trace of the fault that put weathered Miocene bedrock against young glacial deposits. The time had finally come to really test my ideas with a large excavation across what I thought was a fault. I remember being nervous when the backhoe arrived and we finally began excavating. Within a short time, though, we uncovered a thrust fault that placed weathered bedrock and old glacial deposits over a recent forest soil. The fault and buried soil were within a few meters of where I originally thought the fault was. Want to know what was most satisfying about this discovery? I had many modern tools at my disposal, including LiDAR (laser) maps, geospatial information systems and a host of detailed geophysical studies, but it was getting down on my hands and knees in the dirt (oops, soil...) and doing the field geology that really made this study succeed.

Joan Gomberg
Title: Research Seismologist
Location: Memphis, Tenn.
Length of Service with the USGS: 18 years
The most exciting thing for me was discovering the strong correlation between distant aftershocks and focusing of seismic waves (implying triggering by the waves) — a Eureka moment! Visiting Bhuj, India, was also memorable.

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Thanks to George Grye, Robert Page and Peter Haeussler.
O
n October 17, 1989, occupants of the Transamerica Pyramid in San Francisco were unnerved as the building started to shake. Sixty miles away, in the forest of Nisene Marks State Park in the Santa Cruz Mountains, the Loma Prieta earthquake had struck with a magnitude of 6.9. The seismic waves were channelled — focused by the geological features of the area — toward San Francisco.

USGS instruments installed in the building showed that it shook for more than a minute and that the top floor swayed more than a foot from side to side.

The earthquake caused more than $6 billion in damages and took 63 lives. Yet no lives were lost in the Transamerica Pyramid. Despite the intensity of the shaking, the 49-story building came through undamaged. Having been aware of the area’s potential for even larger earthquakes, engineers had designed the Transamerica Pyramid to withstand greater stresses than those from the Loma Prieta earthquake.

The biggest danger during an earthquake is often the failure of man-made structures. Not only are lives lost to falling buildings, collapsed bridges and crumbling facades, but disruption of infrastructure and utilities can cause additional hazards and actually keep emergency crews from life-saving resources. Earth scientists have been working for more than 100 years to improve our understanding of earthquake hazards. One of their most important goals is to provide designers, lawmakers and residents with the information they need to build structures that are better able to withstand the forces of the earthquakes they are likely to face.

Building Codes Help Protect Earthquake-Prone Communities

“The most common cause of damage to a structure (a building or bridge) during an earthquake is strong ground shaking,” says E.V. Leyendecker, USGS scientist emeritus. “The first line of defense against such shaking is the design and construction of structures to resist it.”

And as USGS scientist David Perkins points out, “Earthquake building codes are the primary means to prevent or limit damage to structures.”

Building codes help protect us by requiring that new construction meet certain safety requirements. In many earthquake-prone areas, these codes specify the levels of earthquake forces that structures must be designed to withstand.

“To ensure that the code is adequate without being excessively expensive to implement, engineers have to know the likelihood that certain levels of ground shaking will be experienced during the lifetime of the structure,” says Perkins.

But how do they know what conditions a building is likely to face? USGS has developed a number of products to show not only how probable it is that a structure will face small, moderate and large earthquakes, but also how much shaking buildings are likely to experience and how they tend to respond to these varying levels of shaking.

Hazard Maps to Reveal Nationwide Seismic Threats

Since 1948, scientists have been making national earthquake-shaking maps that show the variations in the seismic threat from one area to the next. These maps demonstrate the potential shaking hazard from future earthquakes across the country, and they are frequently updated as scientists learn more about earthquakes and the hazards they pose.

Looking to the Past to “Construct” Models of the Future

Coming up with these estimations can be very complicated. Basically, researchers do everything they can to learn about past events: where earthquakes have occurred, how frequently and at what size; how the vibrations have traveled through the ground; how those vibrations were affected by soil and bedrock; and how all of this affected both the land and the structures we have built. Researchers then combine this information to build models of future earthquakes.

As earth scientists look at historical earthquakes, they are particularly interested in the levels of shaking the earthquakes have caused. “Earth scientists can determine past shaking levels by studying the effects of past earthquakes on people, structures and the landscape,” says Perkins.

Scientists have been putting instruments in buildings since the 1940s. From this data, scientists and engineers can directly estimate how earthquake shaking will affect similar buildings in the future. When the information is less direct, researchers use computer models of buildings to indirectly generate the estimated effects.

Digging Deeper

What they don’t learn with instrumentation above the ground, researchers can sometimes learn from clues beneath the ground surface. The layers of the earth typically lie flat, but when an earthquake rumbles through these layers, they are disrupted, leaving breaks and folds and other clues scientists can use to learn more about an area’s susceptibility to earthquakes.

“Historical seismicity alone does not tell us all we need to know about future earthquake locations and magnitudes,” says Perkins. “Accordingly, earth scientists look for faults and signs of earthquake liquefaction or earthquake-induced landslides in the geological past in order to estimate the sizes and dates of these events.”

By Tania Larson

Unreinforced masonry buildings are especially vulnerable during strong earthquake shaking. Shaking-hazard maps are used to determine areas where these types of buildings need to be reinforced to make them safe during earthquakes. Photo: J. Dewey
events. This allows them to extend the ‘history’ of large events back as much as 10,000 years or more. From this longer history, earth scientists can also determine the rate at which earthquakes of all sizes occur.”

However, as Leyendecker points out, this does not tell the entire story. Designing a building requires knowledge not only of the earthquakes it will likely face, but also how those earthquakes will affect the building — the loads it will have to bear and how and to what capacity it will respond to those forces. “Research conducted since the 1906 San Francisco earthquake, particularly over the last 20 to 30 years under the National Earthquake Hazards Reduction Program, has contributed to these three areas of loads, response and capacity,” says Leyendecker.

**Science Advancements Help Refine and Improve Building Codes**

Thanks to increased earth science focus, building codes have seen regular major changes since the 1960s, and according to Perkins, these advancements have paid off.

“Structures built using recent building codes have withstood remarkably large levels of ground motion in the earthquakes that have been experienced since the 1990s,” says Perkins.

For example, in 1971, the magnitude-6.6 San Fernando earthquake left the Los Angeles dam badly damaged. This dam, so weakened that a strong aftershock could have caused a collapse, was all that stood between 80,000 people and 15 million tons of water. Residents in an 11-square-mile area were forced to evacuate their homes while the water behind the dam was lowered. With years of ground motion studies and advancements in earthquake studies to turn to, engineers built a new, safer dam. This new structure was tested in 1994 when the magnitude-6.7 Northridge earthquake hit the area. The new dam held, with very little damage.

“In 1996, a major revision of the ground-shaking-hazard maps, developed in collaboration with the earth-science community and design engineers, resulted in major improvement of building codes and design standards,” says Leyendecker. The revisions incorporated new descriptions of the hazard, such as the specific soil and rock conditions and how buildings experience vibrations in response to the vibrations of the ground.

“This new way of describing the hazard enables structural engineers to better predict structural response to ground shaking for design purposes. Knowledge of the site condition of the maps also enables engineers to adjust the design to incorporate the actual site condition. In the end, these improvements result in better protection of lives and property,” says Leyendecker.

By taking all of this information into account, scientists have created a powerful data set. “With all these forms of earth science information,” says Perkins, “researchers can compute the likelihood of future earthquake ground shaking at all locations in the U.S. It is maps of these probabilistic ground motions that are used to determine building code requirements.”

More than 20,000 cities, counties and local government agencies use building codes based on these maps, but shaking-hazard maps have many other applications. They are also used by insurance companies to set rates for properties in different areas, civil engineers to estimate the stability of hillsides, the Environmental Protection Agency to set construction standards for waste-disposal facilities, and the Federal Emergency Management Agency to allocate funds for earthquake education and preparedness.

To make sure users understand and get the best value out of the maps, the USGS offers workshops to familiarize users with the shaking-hazard maps and earthquake issues.

While both the Loma Prieta and Northridge earthquakes demonstrated that we can build safer structures that do withstand earthquakes, there were still considerable losses that revealed just how vulnerable major metropolitan areas can be when hit by an earthquake. Awareness of this vulnerability was reinforced by the 1995 Kobe, Japan, earthquake. With magnitudes of 6.7 and 6.9, respectively, both the Northridge and the Kobe events are considered moderate earthquakes, yet even in these areas known for their earthquake preparedness, the losses suffered by the densely populated urban areas were catastrophic.

**Looking Long Term**

The hazard maps that influence today’s building codes incorporate more than a century of seismic monitoring and decades of research. In their quest to find ways to protect people from the effects of earthquakes, USGS researchers have come up with many creative ways to expand their understanding of the hazards. They have traveled the globe, comparing notes and historical records with researchers around the world. They have dug through mud and sand and clay. They have bored through layers of rock. They have even learned about earthquakes by examining long-drowned forests and other side effects of earthquakes have had on the landscape.

By taking all of these efforts and turning them into products communities can use to protect themselves, USGS researchers have helped save many lives and millions of dollars. But they know their work is not done. In the next 100 years, they will continue to look for new ways to refine and enhance the maps and models that influence building codes, making all of our structures — from our homes, to our hospitals, to the infrastructures that support our resources — better able to withstand the earthquakes they will inevitably face.

Thanks to E.V. Leyendecker, Nicolas Luco, David Perkins and Robert Wesson for their help and expertise.
Working for a Safer Southern California
A Profile of Lucy Jones

By Stephanie Hanna and Diane Noserale

Lucy Jones, chief scientist of the Earthquake Hazards Program in Southern California, is truly a household name and the face of the USGS in Southern California. Over the past 23 years, she has worked tirelessly to calm shattered nerves following earthquakes and to convince Southern Californians that they can take steps to make their lives safer during an earthquake.

Born in Santa Monica in 1955, Jones is a fourth-generation Southern Californian who has earned an undergraduate degree in Chinese language and literature from Brown University and a Ph.D. in geophysics from the Massachusetts Institute of Technology. This somewhat unusual combination tells the tale of her diverse interests and helped her (as a graduate student in 1979) to become the first American scientist to work in China following the normalization of relations.

In 1983, Jones joined the USGS as a seismologist. Her first interview as an employee of the USGS was on PBS’s nationally televised “MacNeil/Lehrer Report” in 1985. During a spate of earthquakes that followed, she quickly became the go-to scientist for earthquake interviews, appearing on almost all the major network television news shows and making hundreds of appearances on local Los Angeles affiliates. An articulate spokeswoman, Jones has a knack for seeing through the question asked and responding to the concern or fear that prompted it.

Jones has appeared multiple times on many national programs, including “Dateline,” “Nightline” and “The Today Show.” She has worked with the staff of Universal Studios and even been to Disneyland to instruct the “Three Little Pigs” in earthquake safety and non-structural mitigation (They already had learned the construction lesson!) on Disney’s “Toon-Town Kids.”

For broadcasts across the nation, she must often appear awake, alert and articulate at 3 a.m., many times after live late-night newscasts. What little sleep afforded during these times is often interrupted by the shaking of local earthquakes or her beeper.

Jones’ most enduring media persona is that of the calm working mom. During a post-earthquake news conference in 1992, she comforted her fussy 1-year-old. She was shown carrying a baby and advising people not to abandon their homes and potentially be caught near freeway overpasses during powerful aftershocks. She is still asked, “How’s your baby?” and responds that he is a defensive tackle on his high school’s JV football team.

In her spare time — between earthquakes, media appearances, running the USGS office in Pasadena and family responsibilities with her two sons and husband, Egill Hauksson, a seismologist at Caltech — Jones has authored more than 80 scientific papers. Her research focuses primarily on earthquake-hazard assessment and forecasting earthquake aftershocks. Her theoretical geophysics work forms the basis for a Web service that provides 24-hour forecasts for strong shaking from aftershocks in California. [See page 34.]

Her contributions to public safety also include briefing local and state officials on complex earthquake topics, helping to develop safety plans for several cities, including Los Angeles, and helping to train first responders in cities and counties throughout Southern California.
The magnitude-5.0 Pasadena earthquake in 1988 was the most memorable [for me]. It was almost directly beneath my house during the night and literally threw us out of bed. Also, it was the first time my oldest child, Sven, then 2 years old, saw me on TV (in that case, a live interview) and told my husband, ‘Mommy’s in the TV!’”

Lucy Jones

Top 10 Things Northern Californians Should Do to Prepare for the Next Big Earthquake

Excerpted from material by the 100th Anniversary Earthquake Conference Steering Committee

The people, businesses and government agencies in Northern California will risk suffering loss of life and structural and financial damage when major earthquakes strike. Scientists, engineers and emergency-management experts gathered for the 100th Anniversary Earthquake Conference call on the region’s citizens, businesses and governments to take the following actions to increase safety, reduce losses and ensure a speedier recovery when the next major earthquake strikes.

✔ Develop a Culture of Preparedness at Home, Work and School

1. Know the seismic risks of the buildings you inhabit, the transportation systems you use and the utilities that serve them, and the actions you can take to protect yourself.
2. Be prepared to be self-sufficient for up to three days (72 hours) following a disaster.
3. Take steps to ensure adequate response care for all special-needs populations — seniors, the poor, the disabled and other vulnerable residents.
4. Get involved in preparing the region to respond to and recover from major earthquakes. This includes region-wide, multi-organizational plans, training, exercises and coordination assessments, as well as continuing improvements in our collective understanding of seismic risks.

✔ Ensure Resiliency in Recovery

8. Collaboratively plan for the regional relocation and housing, both short- and long-term, of residents displaced by potential fires, uninhabitable buildings or widespread economic and infrastructure disruption following a major earthquake.
9. Assess and plan for your likely repair and recovery costs following a major earthquake.
10. Ensure adequate post-event funding to provide economic relief to individuals and communities after a major earthquake, when resources are scarce yet crucial for recovery and reconstruction.

In conclusion, the earthquake professionals of the 100th Anniversary Earthquake Conference believe that, based on our current understanding of the hazards, local planning, stronger building codes and ongoing mitigation have substantially reduced the potential loss of life and property that a major Northern California earthquake could cause. While many areas are better prepared than ever before, the region is not yet sufficiently ready for the next major earthquake, and the social and economic consequences could prove to be long-lasting and ruinous to communities. A renewed emphasis on preparedness and safety is needed to fully prepare Northern California for a major natural disaster.

✔ Invest in Reducing Losses

5. Target those buildings that pose the greatest risk of collapse for seismic mitigation through retrofit, reduced occupancy or reconstruction.
6. Retrofit or replace all facilities essential for emergency response to ensure that they function following earthquakes. These facilities include fire and police stations, emergency communications centers, medical facilities, schools, shelters and other community-serving facilities.
7. Set priorities, and retrofit or replace vulnerable emergency- and community-serving infrastructure — including cellular communications, airports, ports, roads and bridges, transportation, water, dams and levees, sewage, and energy supplies — to ensure that functions can be resumed rapidly after earthquakes.

USGS Earthquake Scientists — A Nationwide Notion of Pride

John Solum
Title: Mendenhall Fellow, Earthquake Hazards Team
Location: Menlo Park, Calif.
Length of service with the USGS: 1 year
My proudest moment has definitely been working with the team of scientists from a large number of academic institutions, as well as the USGS, on the San Andreas Fault Observatory at Depth (SAFOD), which is part of the EarthScope project funded by the National Science Foundation.

The SAFOD hole successfully crossed the active San Andreas Fault at a depth of several kilometers this past summer. I spent the summer of 2005 driving between Menlo Park and the SAFOD site near Parkfield, Calif., spending a few days here and there at the drill site to tend a hand, and then driving back to Menlo Park to analyze samples using a powder X-ray diffractometer (a lot of people were also kind enough to ferry samples up to me from the drill site).

In Menlo Park, I also helped to prepare the sidewall and spot cores that came up from the hole, with the help of Sarah Draper (Utah State University), Sheryl Tembe (SUNY Stony Brook), Fred Chester (Texas A&M), Joe Svitik (USGS Menlo Park), Steve Hickman (USGS Menlo Park) and Dave Lochner (USGS Menlo Park). We devoted a lot of long hours to extracting the cores from the pieces of drilling equipment they were collected with and then preserving them, making thin sections from them and making a first pass at describing their mineralogy.

There were three sessions on SAFOD at the annual meeting of the American Geophysical Union in San Francisco in December 2005 (Naomi Bones, a post-doctoral student at Stanford University, and I were the conveners of those sessions). It was very heartening for me to see all of the effort that people had put into analyzing results from SAFOD pay off with a lot of really nice presentations at that meeting. I’m a newcomer to the SAFOD project, and I feel very privileged to have been able to work with so many highly dedicated scientists.
Taking Seismic Science into the Third Dimension

3D Models Help Predict Shaking Vulnerability in Your Neighborhood

By Tania Larson

During the Loma Prieta earthquake in 1989, 42 people were killed when the Cypress Structure, the freeway approach to the Bay Bridge from Oakland, Calif., collapsed. But it wasn't just the strength of the earthquake that contributed to its fall. There were factors beneath the Earth's surface that made this location particularly vulnerable to earthquake shaking.

Remember the parable of the wise man who built his house upon the rock and the foolish man who built his house upon the sand? Well, the principle is still true today, and a new tool from the USGS is taking it to a whole new level. The USGS has created a 3D geologic map and seismic-velocity model of the upper 30 miles of the Earth's crust in the greater San Francisco Bay Area and much of Northern California.

“The new 3D model is a result of the long and productive collaboration between the California Geological Survey and USGS,” said California state geologist John Parrish. “Its usefulness will be to test and predict the intensity and effects of shaking in future earthquakes and to build safer structures. This will be cost saving and life saving for residents of the Bay Area, now and in the future.”

Most loss of life and property damage during earthquakes stems from the effects of strong ground shaking, and scientists have shown that how long and how strongly a building will shake is directly influenced by the properties of the Earth beneath it. The Loma Prieta earthquake provided the first set of recordings of the levels of shaking on a wide variety of geologic materials, including soft, unconsolidated sand and clay.

These records clearly documented that ground shaking is much more violent on the soft sediments around the Bay margins than on bedrock. They also showed that differences in the Earth's crust can affect how seismic waves move through the ground. For example, at least two properties of the Earth's crust worked together to cause the collapse of the Cypress Structure. First, the structure was built on loose soils that shook much more strongly than surrounding regions on stronger ground. And second, there were variations in the thickness of the Earth's crust between the hypocenter and Oakland that actually focused energy toward Oakland and downtown San Francisco.

The 3D model is an important scientific advancement that combines 100 years of surface geologic mapping with decades of research into the seismic properties of rocks. It also incorporates information from boreholes and variations in the Earth's gravity and magnetic fields. In creating the model, scientists broke the upper 15 to 30 miles of the Earth's crust into irregular shaped blocks bounded by faults, making it a "fault and block" model. Since seismic waves can bounce off faults, bend and be focused as they cross faults, and be trapped and amplified in buried basins, the inclusion of subsurface faults and basins provides important information.

For the first time, we have a tool that allows us to forecast the strong shaking likely to be produced by large Bay Area earthquakes on a neighborhood-by-neighborhood basis.

― Tom Brocher

USGS Earthquake Scientists — A Nationwide Notion of Pride

Jack Townshend
Title: Special Projects Coordinator, USGS Geomagnetism Group
Location: Fairbanks, Alaska
Length of service with the USGS: 33 years
I remember the magnitude-9.2 Good Friday earthquake in Alaska on March 27, 1964. I was chief of the U.S. Coast and Geodetic Survey's Geomagnetic and Seismological Observatory at the University of Alaska, Fairbanks (The Observatory was transferred to the USGS in 1973.)

The house my family and I lived in was on the observatory grounds. We were 300 miles from the earthquake's epicenter, but I remember feeling the shaking and hearing the observatory's earthquake warning alarms. I rushed to the instrument room and saw red ink splashed all over the place. Visual seismographs used at the time had inkwells, and the instruments had been shaken off their piers. The magnetic instruments were also askew. I called in the staff, and after a few hours later, we had most of the instruments back up and working.

Later that night, I made a decision to do a preliminary intensity assessment in the Anchorage area. I managed to get on a flight chartered to fly doctors from Fairbanks to Anchorage to assist with medical care. We couldn't land until daylight because the airport tower was down and much of the runway was damaged. When we finally landed, I flagged down a car and driver and asked for a ride into town. The driver was a chief flight engineer with a major airline whose commercial jet had been grounded because of damaged runways. He volunteered to drive me around Anchorage and outlying areas to assess the damage and take photos.

After assessing the damage from the ground, we stopped at a seacoast airstrip, and I asked for a piloted plane to survey the landscape even further out and from the air. I was told that if I could find a pilot, they would lend me an airplane. Fortunately, I had a pilot with me! We flew around for a few hours taking photos and assessing the damage until the FAA restricted the airspace we were flying and instructed us to land.

The results of this and subsequent assessment trips were published by the Alaska Division of the American Association for the Advancement of Science, 1964 Proceedings of the Alaskan Science Conference held at The University of Alaska in Fairbanks, titled, Preliminary Intensity Evaluations of the Prince William Sound Earthquake of March 28, 1964, U.S.