

DRAFT SUMMARY

**Scientific Earthquake Studies Advisory Committee (SESAC)**

February 2-3, 2009

Seattle, Washington

**Meeting Participants**

SESAC Members

Mark Zoback, *Chair*, Stanford University, Stanford CA

Jim Dieterich, University of California at Riverside and Chair, National Earthquake Prediction Evaluation Committee

Art Lerner-Lam, Columbia University, Palisades NY

Vicki McConnell, Oregon Department of Geology & Mineral Industries, Portland OR  
(unable to attend)

Stu Nishenko, Pacific Gas & Electric, San Francisco CA

John Parrish, California Geological Survey, Sacramento CA

Ellen Rathje, University of Texas, Austin TX

Garry Rogers, Geological Survey of Canada, Victoria BC

Ralph Archuleta, University of California at Santa Barbara and Chair, Advanced National Seismic System Steering Committee

USGS Staff

David Applegate, Earthquake Hazards Program (EHP), Reston VA

Elizabeth Barnett, Earthquake Hazards Team (EHT), Seattle WA

Mike Blanpied, EHP, Reston VA

Tom Brocher, EHT, Menlo Park CA

Art Frankel, GHT, Golden CO

Joan Gomberg, EHT, Seattle WA

Ken Hudnut, EHT, Pasadena CA

Elizabeth Lemersal, EHP, Reston VA

Nicolas Luco, GHT, Golden CO

Jill McCarthy, Geologic Hazards Team (GHT), Golden CO

Brian Sherrod, EHT, Seattle WA

Craig Weaver, EHT, Seattle WA

Guests

Paul Bodin, University of Washington

Jack Hayes, NEHRP Director, National Institute of Standards & Technology

Susan Newman, Seismological Society of America, El Cerrito CA

Bill Perkins, civil engineer, Shannon & Wilson

Peter Somers, structural engineer, Magnessun Klemencic

Chad Trabant, IRIS Consortium

Maureen Traxler, City of Seattle

John Vidale, University of Washington

Tim Walsh, geologist, Washington Department of Natural Resources

## Welcome and introductions

After introductions, the meeting began by noting the previous Friday's (Jan. 30) magnitude-4.5 earthquake with its epicenter 22 kilometers west of Seattle beneath Bainbridge Island. Over 2,700 Did You Feel It responses were recorded on the USGS event webpage with reports of light shaking throughout the Puget Sound region. The committee reviewed and approved the summary of its July 31-August 1, 2008, meeting at the USGS offices in Menlo Park CA. The committee reviewed action items from the same meeting.

**\*\*\* Action Item: Zoback will forward the committee's 2007 report and cover letter to USGS Acting Director Suzette Kimball. \*\*\***

## Update on Earthquake Hazards Program

Applegate gave a presentation on recent program activities and the state of program finances. He touched on the success of the Great Southern California ShakeOut public preparedness drill using a USGS-generated scenario. He reviewed the program's recent funding history, including the President's request and congressional action for Fiscal Year (FY) 2009, which was still pending five months into the fiscal year. The President's FY 2009 budget requested significant cuts to the Earthquake Hazards Program, and the House appropriations bill restored those cuts, criticizing the "reckless budget request to reduce earthquake science grants" in particular. He discussed the inclusion of language in the House-passed economic stimulus bill that would provide funding to USGS for "seismic and volcano monitoring systems" among its purposes. The Senate version did not include specific language on seismic or volcano networks. A final compromise bill was expected soon. Were funds to be made available, USGS would be able to quickly move economic stimulus funding into the economy, through existing contracts, grants and cooperative agreements. Funds would go to colleges, universities, seismic and other geophysical equipment manufacturers, and geophysical service contractors. Funds would be targeted for modernization within the Advanced National Seismic System, the Global Seismographic Network, and the USGS Volcano Observatories. Applegate cautioned that the stimulus funds would be one-time only and were not to include support for long-term operations and maintenance, so USGS investments would be focused on improvements to modernize existing stations rather than network expansion.

## NEHRP Update

NEHRP Director Jack Hayes encouraged committee members to look at the recently released NEHRP strategic plan, which represents cross-agency priorities. In particular, he directed the committee's attention toward NEHRP strategic priorities including full funding of ANSS, greater focus on scenarios, and development of a post-earthquake information management system. For the last, he noted John Filson's view that the publications generated following the 1964 Great Alaska earthquake should be a model. The agencies have been working on a statutorily required management plan to implement the strategic plan. From a budget standpoint, NIST is in same limbo as USGS for FY 2009. The agency has requested budget increases in the past two years for NEHRP

activities, but they are still waiting to see that money materialize since continuing resolutions have not included new funding. It is his understanding that the economic stimulus bills include funding for earthquake work at NIST. FEMA funding seems to be on the rise, restoring some earlier cuts to earthquake hazard mitigation program.

The NEHRP-wide Advisory Committee on Earthquake Hazard Reduction (ACEHR) provided its first report in 2008 and was planning an abbreviated letter report in 2009. Chairman Chris Poland focused the first report on funding issues for the agencies. Zoback, who sits on ACEHR ex officio, noted that ACEHR seems to have interest in NIST taking on a larger functional role, for example post-earthquake investigations. Hayes noted that NIST and USGS had agreed that should the post-earthquake investigation leadership should not transfer to NIST until there is funding at NIST to carry out that coordination role. Zoback asked if there is a plan at NIST for capacity-building to staff up and carry out the functions. Hayes noted that plans have been initiated with a commitment to have half the growth be extramural.

The reauthorization process is underway in Congress for NEHRP. The House Science and Technology Committee staffers have invited Jack to visit this month to initiate discussions with the goal of having a reauthorization bill this year. Agencies are working on suggestions for changes to the legislation. ACEHR is working to provide its own perspectives on reauthorization changes.

***Action Item: Share legislative language with SESAC for comment.***

Seismological Society of America Executive Director Susan Newman reported that former USGS Director Mark Myers had indicated that OMB defeated a proposal for an integrated NEHRP budget. Hayes and Applegate clarified that the authorization legislation calls for “coordinated” agency budgets, and that during the agency-head NEHRP Interagency Coordinating Committee discussions, OMB may have indicated the challenge of that. ICC members did agree to share information so long as agencies treated the information as confidential prior to public release of the President’s budget request.

Art Lerner-Lam noted that hurricanes and floods have models for post-disaster investigations. He also asked about inclusion of social sciences. Hayes noted a recent FEMA-funded workshop on post-earthquake information management with representatives from all disciplines. Lerner-Lam also asked if there was talk of taking a multi-hazard approach to NEHRP, and Hayes replied that earthquake could serve as a model for other hazards.

Craig Weaver emphasized that NEHRP needs to have strong coordination with the states in addition to the federal interagency coordination.

### **External Research Support Update**

Elizabeth Lemersal reported back to SESAC on the status of the external research support activity within the Earthquake Hazards Program, which was still facing the \$3 million cut proposed in the President’s FY 2009 budget request. So far, only 23 grants with

December and January start dates had been funded, leaving 44 proposals on hold pending final action on appropriations and yet another group in a less certain category but with a similar March timing for decision. Three-year network cooperative agreements will be up for renewal next year.

Committee members asked clarifying questions about the distinction between competitive and non-competitive grants and cooperative agreements. Other questions centered on the impact of funding delays on the annual process and whether it could be compressed in order to avoid this uncertainty. The committee discussion reflected the debate over whether USGS should fund fewer grants for multi-year projects rather than the current focus on single-year funding along with how to address the challenge of writing follow-up proposals for funding-delayed grants where little work can be accomplished before the next deadline. There was also discussion on how to assess success rates and whether the grants were meeting criteria for program goals to which Lemersal noted that the first step is for the program's regional and topical coordinators is crafting a well-prioritized announcement and then getting panel to appreciate that those priorities reflect overall program goals. That led to a discussion as to whether the regional/topical priorities in the grant announcement should be narrower and what impact that would have on the flexibility of the review panels to support the best proposals.

### **Update on the Geologic Hazards Team**

Team Chief Scientist Jill McCarthy provided a presentation on the current status of the Central Region Geologic Hazards Team, showing charts on demographics with a wave of new employees joining the team in the past several years across administration, technical support, and scientific staff. The dominant age spike is currently in the 55-60 range. About 42% of team members are new in the last 6 to 7 years, and one-third of the people who were there 7 years ago are not there now, the difference reflecting team growth to 129 full-time equivalents up from 100 four years ago. In terms of fiscal status, health is good not great. The team receives earthquake program funding for salaries and for operational expenses, but across-the-board salary increases erode away flat funding at a clip of \$350K per year. The resulting shortfall has to be made up through additional sources of reimbursable funding, which last year totaled \$3 million for other temporary staff and for operating expenses.

She reported that Tish Tuttle was starting that day as the earthquake program's Central-Eastern US coordinator based in Memphis, replacing Buddy Schweig. The team has hired a number of other permanent and term employees, seeking to maintain a balance between stability and injection of new talent. Summarizing a wish list of staffing needs, she noted that the hazards group has not recovered from the retirement of Rob Wesson and needs a senior person. The team also needs to strengthen its civil engineering expertise and to provide support for the monitoring side in order to meet commitments for web products such as ShakeMap and PAGER that carry great expectations for performance. She noted that the bad economy is slowing retirements and that it is going to be hard to identify positions that do not need backfilling, a challenge given flat funding and rising salary costs.

She highlighted a number of team activities, including recent proposals to the international Global Earthquake Model (GEM) project for work that complements the USGS mission but would be able to do without external support. Team members are working with the Earthquake Hazards Team on the next phase of the Unified California Earthquake Rupture Forecast. Work is underway to learn from last year's Wenchuan earthquake. The team is getting support from the U.S. Nuclear Regulatory Commission (USNRC) to evaluate site license applications and undertake research. A commemoration is being planned for the 50th anniversary of the Hebgen Lake (MT) earthquake. She expects support from the U.S. Agency for International Development (USAID) for work in Afghanistan to support capacity building. They are having fruitful conversations with the Volcano Hazards Program about coordinating event response, including the recent Yellowstone swarm. On the monitoring side, funds are being found through reimbursable sources to pursue product development.

Zoback asked about what benefits the team derives from reimbursable funds and whether that work aligns with program goals. Archuleta asked whether USGS would be called to testify on the USNRC site license reviews, and McCarthy answered yes that was part of the contract with USNRC.

### **Update on Earthquake Hazards Team**

Team Chief Scientist Tom Brocher noted that the team's work in the Pacific Northwest would be discussed during the afternoon. In October, there was a successful commemoration of the 1868 Hayward earthquake. Scenario losses are similar to the Shakeout scenario in southern California with economic losses over \$200 billion. As part of the commemoration, a US-led alliance sponsored earthquake drills that involved several hundred thousand students and employees, and a tabletop emergency management exercise was done by the California Office of Emergency Services involving 70 different agencies throughout the Bay Area. There were over 200 participants in a concurrent Bay Area research workshop. Plans are underway to develop a statewide Earthquake Country Alliance with local chapters in southern California, the Bay Area, and North Coast region. There has been discussion at the California Seismic Safety Commission of trying to emulate the Japanese national earthquake drill with a statewide drill in the fall near the beginning of the school year.

The Seventh US-Japan Natural Resource Panel for Earthquake Research meeting took place in Seattle in November. Team members are being supported by USAID and the U.S. Trade and Development Agency for follow-up studies of the Wenchuan earthquake. A proposal has been submitted to the California Earthquake Authority to update and improve the Uniform California Earthquake Rupture Forecast model to address some of the issues identified in preparation of the last model, and the earthquake team has also requested support for postdocs from GEM. The Veterans Administration is interested in instrumenting its hospitals in high to very-high earthquake hazard zones across the US, an ambitious project that would include half the hospitals in California; USGS is partnering with the California Geological Survey to pursue that opportunity. The team is working with Geologic Hazards Team to support USNRC licensing needs and doing work in central California through a cooperative R&D agreement with Pacific Gas &

Electric (PG&E) to improve understanding of onshore and offshore faults using new aeromagnetic and marine magnetic data.

The Earthquake Hazards Team has 147 permanent FTE and 12 temporary, term and postdoc appointments. Primary funding comes from the Earthquake Hazards Program (84%) with 8% from other USGS programs and remaining 8% from reimbursable sources. Half of the team is retirement eligible; in five years, 60% will be eligible. The big demographic peaks are between 50-65 in age and 30-40 years of service. The team has three projects in earthquake monitoring, four in earthquake hazard assessment and earthquake effects, and three projects that conduct earthquake research, each led by a senior scientist with 5 to 25 staff members. Recent retirements include Bob Simpson and Bill Stuart. The team recently hired Erol Kalkan, a structural engineer from the California Geological Survey (CGS). Jack Boatwright will be taking over as the earthquake program's Northern California coordinator. David Shelly, currently a Mendenhall postdoc, won the inaugural Kei Aki award; he will be moving to the Volcano Hazards Team but still available to work on earthquake tremor.

Changes to the National Engineering Strong Motion activity include moving the data processing group to the Northern California Seismic Network with the rest of the project moved into a task in the Earthquake Effects project. Kalkan is being groomed to take over leadership of structural instrumentation and research from Roger Borchardt and Mehmet Celebi when they retire.

The team's draft staffing plan identifies immediate as well as intermediate operational and research needs with the goal being to strengthen current high-priority activities such as earthquake simulations, geotechnical engineering, strong ground motions, paleoseismology, seismic hazard analysis and statistical seismology, and expand expertise in new areas such as 3D regional fault modeling, 3D wave propagation modeling, lidar-based fault mapping, risk analysis and site response. He is asking a group of senior scientists to help develop a science plan for the team.

Dieterich asked about what is being lost and how planning is being done to deal with cross-program staffing needs. Archuleta noted that the team has an opportunity to ask itself what should we be doing, emphasizing the need to engage people from outside to be involved in this process, so not self-serving and so that the resulting plan is responsive to external needs. Dieterich added that strategic planning is needed to look at where USGS will need to be in order to be relevant five years from now. Zoback suggested it was appropriate to reach outside the organization to look at that. Applegate noted plans to engage the external community in the five-year planning process. Archuleta noted that the USGS is doing a tremendous amount of outreach but needs people dedicated to outreach, citing the challenge of maintaining institutional memory.

### **Great Southern California Shakeout Update**

Ken Hudnut provided an overview of lessons learned from the Great Southern California Shakeout and development of the scenario that underpinned it, which was itself inspired by scenario efforts in the Bay Area and Seattle. He described the extensive partnership

collaboration that went into development of the scenario as well as the huge task of responding to all the requests for talks for the public, officials, and utilities following its release. The ShakeOut organizers tried to focus on basic preparedness messages given the evidence after the recent magnitude-5 Chino Hills earthquake that people were not doing the “drop-cover-hold on” technique. Great partnerships enabled broad distribution through radio, TV, billboards, and many other media including new media methods like YouTube, podcasts, Facebook, websites and more. He showed the four-minute “Preparedness Now” video prepared by the Pasadena Art Center College of Design. In conjunction with Shakeout, the City of Los Angeles sponsored an International Earthquake Conference, the California Emergency Management Agency held a Golden Guardian exercise, and a Get Ready Rally took place across the street from the Staples Center where the Los Angeles Lakers were playing.

Zoback asked about the timescale for doing this again, noting the interest in doing a statewide drill. Hudnut noted county-level interest in re-doing Shakeout in 2009 to improve on what happened but doing so will need to identify a funding source since the state’s Golden Guardian exercise will not be taking place, and the USGS Multi-Hazards Demonstration Project will be focused on developing a winter-storm scenario.

Total participation was just under 5.5 million, including 2.7 million in LA County. Of that, nearly 4 million were public and private schools and another 0.5 million were colleges and universities, and significant numbers from businesses, government at all levels, faith and community organizations, and medical facilities.

Lessons learned included the importance of providing real-time feeds to new digital map screen devices at emergency operations centers as well as the need for hard copies in the field where people do not have computer access. Next steps include continued interaction with utilities and first responders, working on the many identified gaps, continued scientific research to improve simulations and underlying understanding; improved earthquake monitoring systems; implementing ShakeCast and related products for broad use; and developing scenarios for other disasters to continue the multi-hazards approach.

Stu Nishenko reported that at a California Integrated Seismic Network Advisory Committee meeting the previous week, network operators reported a lot of weak points in terms of redundancy of their monitoring systems and telecommunications. He emphasized that we have been victims of our own success with public expectation that all these information products will be available after a big event yet there is very little chance that we will have a lot of information available after a significant quake in the US. He emphasized the need for greater investments in ANSS and the importance of getting the message across to policymakers of key operational lessons learned.

### **Update on Seismic Risk Maps**

Nico Luco explained the process involved with risk-targeted design maps derived from the newest USGS National Seismic Hazard Maps, which were released last year. These maps feed into the building code development process, first through the NEHRP Recommended Provisions in 2009 which in turn feed into the ASCE7 standard in 2010

which feeds into the International Building Code in 2012, which is what local building codes reference. The NEHRP Provisions, which are design maps, are prepared by the Building Seismic Safety Council with funding from FEMA in a process that first happened in 1997. This time around, a major change from how it was done before is the introduction of risk-targeted design maps. The motivation is that designing for uniform-hazard ground motions (e.g. 2% probability of exceedance in 50 years) does not result in uniform risk in the sense of uniform probability of collapse in 50 years. Quantifying risk of collapse is similar to the process used by USNRC for site licensing. The risk-targeted design maps will attempt to achieve a target of performance (e.g. 1% likelihood of collapse). The committee discussed how to interpret the risk coefficient, which combines information about several times of buildings, and a generic fragility curve for new buildings. Luco reported that the effect of the risk coefficient is to modestly drop the risk across the greater New Madrid Seismic Zone and the Cascadia coast, and increases it for much of central, interior and southern California. Overall, it produces a modest drop across most of the country. This is because the 2% in 50 year hazard may be the same in Memphis and San Francisco, but the shapes of the hazard curves are very different, and the comparison is sensitive to choice of 2% versus some other level. The risk approach uses the entire hazard curve. The 1% collapse target is similar to current practice, but now is uniform across the country.

USGS will still produce the uniform-hazard product (for transparency and comparison) as well as a suite of additional products including the risk coefficient map, all of which feed into the 2009 NEHRP Provisions due out in spring. Online tools are being used by many, with new approaches (e.g. Google Maps) being rolled out. Seminars are offered to train engineers on their use. This approach also makes it simpler to treat portfolios of buildings rather than just one by one. USGS gets the bulk of public inquiries on interpretation and use of the design maps, despite not being the authors, because USGS hazard role is recognized.

Luco and Erdam Karaca are working on products that simplify and clarify the interpretation of hazard and risk information for building owners. The Risk Maps web tool is out and being improved, transitioning to Google Earth. PEER would like to use it to illustrate the effect of removing unreinforced masonry structures. They are also working on post-event risk maps that flow from short-term aftershock probability maps and include the reduced capacity due to probability of building damage from the mainshock. This tool could lead to more efficient building tagging.

Nishenko asked how these tools compare with what FEMA is doing and whether there was coordination. Luco responded that risk mapping came out of a White House Office of Management and Budget requirement through the Program Assessment Rating Tool (PART) process to demonstrate collaboration between USGS and FEMA on the hazard to risk handoff. FEMA was not concentrating on earthquakes at the time this was beginning, so many of the actions were focused on the USGS side. Nishenko noted that communities are required to use FEMA's HAZUS loss estimation software, asking if that was a problem. Luco responded that HAZUS does not answer the same questions, but that we are seeking to be as consistent as possible.

Archuleta asked how these products are being reviewed and vetted and further asked why no bullets in the grant announcement about research on risk interpretation. Luco responded that the design maps procedures went through an extensive committee vetting process, and that the tools are based on existing, reviewed methods. He added that there are items in the regional and topical priorities accompanying the announcement under earthquake effects and the Central-Eastern US for this sort of work.

### **ANSS Steering Committee Report**

Archuleta reported on the previous week's meeting of the ANSS National Steering Committee, which was established as a subcommittee of SESAC. The principal points from the meeting were as follows:

Fully implementing ANSS is the #1 cross-cutting strategy necessary for fulfillment of the NEHRP strategic plan released in October 2008. ANSS has been the top-ranked major IT investment in the Department of the Interior as measured by cost effectiveness. There is hope in the stimulus bill of getting a shot in the arm, and there are clear plans on how to spend the money through existing contracts and agreements. At present, without the economic stimulus bill there would be about \$870K for ANSS development (as opposed to O&M) at FY08 funding levels using multi-hazard initiative funds for Southern California and the Pacific Northwest. The VA Instrumentation Project calls for multi-channel instrumentation for medical centers, somewhat satisfying needs on the structural monitoring side of ANSS. These buildings are in high-hazard areas around the nation, include multiple types of construction, and have heights ranging from 1-15 stories; long-term O&M of the instrumentation to be fielded in these structures is not funded.

Some USArray Transportable Array stations are being assimilated into regional seismic networks. The number is small, around 30. This can be a win-win situation, but some do not have a home within ANSS planning, for example in lower-hazard states like Arizona, which poses a challenge in terms of how future O&M will be supported.

The ANSS Steering Committee met in Golden in part to review the USGS National Earthquake Information Center (NEIC), which has become the face of the USGS. Total web traffic is within the top 2,500 worldwide, and in May 2008 following the Wenchuan earthquake the USGS site ranked 9th among the global web of "movers and shakers." PAGER and ShakeMap are in an operational mode, but questions need to be answered about how much farther should these products be developed and are there other products that could be developed. NEIC redundancy operations need to be improved, including a recommendation from the committee to move the backup site to Albuquerque.

The NEIC is working well, and a lot of credit goes to Jill McCarthy, Harley Benz and others. They went fully on-site 24/7 after Sumatra and are showing that it works. This success, however, is very fragile with one-deep staffing, so need greater redundancy in personnel as well as system redundancies.

The other major focus of the steering committee is the restructuring of the National Strong Motion Project within ANSS. There is concern about the need for buy-in by

various groups, including network operators, who need to recognize the criticality of obtaining strong-motion data from large earthquakes. A further issue is that once data are collected, the National Center for Strong-Motion Data (a collaboration between USGS and the California Geological Survey) needs to have better-defined goals. Engineers are not interested in small earthquakes yet such records are important to other users.

A real concern for the committee is that current state budgets are going to impact regional network operations, and that in turn is a big problem for USGS. If the economic stimulus funds come through, that may help but is at best a temporary fix.

Finally, the California Integrated Seismic Network (CISN) presented an earthquake early warning (EEW) system proposal that raised concern in the committee that EEW could run in parallel as a competitor to, and not coordinated with, ANSS. EEW cannot be undertaken as a stand-alone but needs to be part of regular network operations. CISN needs to ask itself what its primary priority is and what are the implications for normal day-to-day operations. Nishenko noted that state budget cuts present a related challenge and that EEW was a carrot in front of the state legislature. Archuleta emphasized that EEW should be treated as a product of ANSS.

### **Putting USGS Science to Work in the Pacific Northwest**

Craig Weaver introduced the afternoon session in which stakeholders provided their perspectives on how USGS earthquake science was being put to work in the Pacific Northwest. He emphasized the heavy partnering and leveraging that has characterized USGS work in the Pacific Northwest.

The first user perspective came from Tim Walsh with the Washington Department of Natural Resources, who discussed tsunami inundation maps. While the region has experienced historical damage from distant tsunamis, he emphasized that the big concern is for near-field tsunamis for which the earthquake itself will be the warning and people need to know where to evacuate to and from. Work by Brian Atwater of USGS and others have demonstrated that the subsidence and uplift patterns seen in other subduction zones are also seen in the Cascadia subduction zone. Models are grounded by paleotsunami data, from which tsunami evacuation maps are produced. But the missing piece is the liquefaction that would result from a magnitude-9 earthquake, which could have a major impact on evacuation. In many areas, the inundation zones would also be subject to significant liquefaction as shown by modeling developed by USGS landslide scientists with ground motions from Art Frankel of USGS. There is also a tsunami hazard from faults crossing the Puget Sound, including the Seattle and Tacoma faults. Using land-level changes provided by USGS geologists, inundation maps were produced for tsunamis generated by both faults. The next project is to look at tsunami effects in Lake Washington from an earthquake on the South Whidbey Island Fault, including the effects on the Route 520 floating bridge. In the following discussion, Nishenko brought up the public-service video being developed for Pacific Northwest to help people understand how to respond, state by state. There was also a discussion about time to inundation.

Bill Perkins from the Seattle geotechnical engineering firm Shannon & Wilson went over some of the regional lifeline infrastructure projects that have used USGS data. Over the past twenty years, he has seen a dramatic shift in the hazard map information available to engineers and designers from 1980 when there was no evidence for megathrust earthquakes but only the hazard from smaller intraplate, Benioff-zone quakes as occurred in 1949 and 1965. As an engineer, he heavily uses the probabilistic ground motion hazard assessments and delineation of seismogenic sources of the Cascadia subduction zone and crustal sources. Example projects using USGS science include the Tacoma Narrows Bridge (\$800 million), Alaskan Way Viaduct Replacement (\$3-4 billion estimated cost), Brightwater Treatment Plant (~\$1.8 billion), and State Route 520 Bridge (~\$3-4 billion). The second span of the Tacoma Narrows is a mile-long bridge with two very different periods of response. Using the latest USGS-generated information led to inclusion of both the crustal Tacoma Fault and Cascadia Subduction Zone as safety evaluation considerations. The Alaska Way Viaduct is a major transportation route very similar to Cypress structure that collapsed in Loma Prieta earthquake. Having the latest information on the Seattle fault was invaluable to proper design for this huge project, including fault directivity effects. At the time that the Brightwater Sewage Treatment Plant project began, USGS conducted additional studies that extended the apparent length of the South Whidbey Island Fault using lidar and trenching. That same data is leading to revised hazard analysis for the SR 520 Bridge, which is also benefiting from Art Frankel's Seattle urban seismic hazard map, which looked at three-dimensional basin effects, directivity effects, and soft-soil effects. The resulting spectral acceleration was twice the level calculated using the national seismic hazard maps.

Discussion included the cost impact resulting from the increased resistance needed to withstand stronger forces, liquefaction, and other effects of stronger shaking and whether there were savings from designing to the right level.

Maureen Traxler from the City of Seattle spoke to the committee about why Seattle is considering a unreinforced masonry (URM) retrofit ordinance. Improved earthquake information has guided the area towards policy decisions about the need to mitigate hazard from bad vulnerable URMs. The new USGS urban seismic hazard maps were crucial in making case to elected officials. Last year, Seattle Mayor Nickels said that the URM retrofit project was the right thing to do. Previous mayors had been briefed since the 1990's but the issue had not risen to the top. Consensus was built first among scientists, then engineers, then city officials, then public officials. Sharing of information among USGS, engineers, city officials makes difficult policy decisions possible, and it takes patience. Two advisory committees are meeting to evaluate the technical questions and policy questions. They are addressing questions such as what design standard to aim for, what earthquake(s) to use in the analysis, what types and uses of buildings to target (for example, whether to include single-family homes), and what types of incentives and assistance are needed to avoid a lot of demolition or vacating. Additional factors that need to be considered include a local awareness of natural versus terrorism hazards, and a strong environmental sensitivity. Earthquakes in other areas provide educational illustrations of what effects Seattle may encounter.

Peter Somers from the structural engineering firm Magnusson Klemencic serves as the technical committee representative on the policy committee for the City of Seattle URM program. URM's in Seattle are as high as six stories. In the Nisqually earthquake, URM damage was disproportionate to other building types with damage greatest in areas of soft soils. This program would be the first mandatory retrofit program outside California. Focus is on "the worst of the worst." Questions that come up are what seismic hazard to consider (rare/large vs. common/small), which hazard maps to use, what consideration to give to building occupancy, and how to address prior retrofits that neglected site amplification. Maps are a tool to identify priority locations but not for engineering design, which has to be based on the national maps. However, he sees similar numbers from Seattle urban hazard map to the Site Class E using national maps. Discussion followed about how to deal with responsible owners who did the right thing. The planned ordinance would include a number of trigger levels accommodating everything from voluntary efforts to mandatory retrofits.

### **Open Committee Discussion**

During the committee's open discussion period, there were further questions for Nico Luco about the implications of the shift to risk-based maps. Zoback asked Hayes to provide a brief discussion of the plans for an upcoming National Research Council study on NEHRP. The impetus for this study came from the need to follow on to a study that EERI did five years ago providing a roadmap for costs of full implementation. At the last ACEHR meeting, Poland pressed for need to revisit the EERI study in such a way as to provide greater credibility for the costing of NEHRP. Across the programs, there was agreement that it should be done by the National Research Council to provide a 20-year timeframe look at the technologies and tools needed to address earthquake risk reduction in the future. NRC is using the approach of a small steering committee that will hold a national workshop. The study is being staffed by David Feary with assistance from Bill Anderson who has retired from the NRC but is staying involved given his long experience in this arena. Dieterich and Frankel served on an earlier NRC study on earthquake science for which there was instruction not to include dollar costs. The committee also discussed upcoming plans to raise awareness on earthquake hazards in the Central US.

***Action Item: Committee should hold its February 2010 meeting at Memphis. At the next meeting, the committee should hear about the New Madrid bicentennial plans.***

The committee adjourned for a late-afternoon site visit of the Pacific Northwest Seismic Network (PNSN) at the University of Washington. John Vidale and Paul Bodin gave presentations on the current state and future plans for the network as well as discussing broader collaborations between USGS and the university. They also discussed the role of the ANSS regional advisory committee. They then led a tour of the network facilities.

### **New Research Pathways in the Pacific Northwest**

The next morning, Craig Weaver talked about how the USGS office at the University of Washington uses partnerships to expand its impact in the region. Starting in 1991, Rob

Wesson emphasized the need for USGS earthquake offices to engage with communities. Since the mid-1990's, USGS in the Pacific Northwest has been building cooperation, collaboration, partnership, and ultimately co-investigation. Partners include the University of Washington, state and local emergency management, Cascades Volcano Observatory and others. The initial driver was Cascadia hazards and FEMA recognizing the need to improve public understanding of such large earthquakes. In 1996, funding was provided for the Puget Sound Urban Hazards project to do large geophysical investigations. Weaver hopes to use the move of the multi-hazards initiative to the Pacific Northwest to reinvigorate these partnerships. The City of Seattle was one of the first FEMA Project Impact communities, which led to development of USGS landslide and earthquake hazard maps and development of scenarios for effects of large earthquakes. Project Impact also led to regional partnerships like the Puget Sound LIDAR Consortium, which was flown 8,000 square miles of terrain with funding derived from many sources, providing an invaluable dataset for paleoseismologists to focus their fieldwork.

The partnership philosophy underpins the USGS involvement in the National Tsunami Hazard Mitigation Program (NTHMP), a federal-state partnership led by NOAA. USGS activities that support the goals of NTHMP include monitoring (approximately \$12 million), research (\$3 million), and assessment (\$2 million) in support of mitigation activities funded by states. NOAA provides support for 54 coastal broadband stations installed as part of the CREST network and maintained by the Pacific Northwest Seismic Network. The NTHMP changed dramatically following the Sumatra earthquake and Indian Ocean tsunami, expanding to all US coastal states and territories. Until 2005, the NTHMP funds went toward assessment, warning, and mitigation with block funding to a coordinating committee that included federal and state partners. After Sumatra, leadership moved to NOAA headquarters, resulting in significant turbulence. Authorizing legislation passed in December 2006, narrowing the focus of NTHMP to exclude monitoring support. In Summer 2008, the National Research Council began a review of NOAA's tsunami programs. In November 2008, NTHMP reorganized, shifting monitoring funds that go to USGS and universities to the warning centers. The new coordinating committee has a complicating voting formula. The national program mandated by Congress has been overlain with a regional structure. NTHMP is expecting a significant increase in funding due to portion of funds from sale of radio spectrum being directed to NTHMP.

Finally, Weaver discussed the expansion of the USGS multi-hazards initiative to the Pacific Northwest, which began with congressionally added funds in FY 2008. Because of uncertainty about future funding, the initial activities focused on ANSS equipment purchase and one-time lidar and aeromagnetic data acquisition while at the same time engaging stakeholders in a series of workshops to plan future projects. The acquisitions focused on better understanding the eastern extent of crustal structures identified in the Puget Sound area in order to better constrain the potential magnitude of earthquakes that these structures could generate. Based on recommendations from the stakeholder workshops (and assuming congressional restoration and possible expansion of funding in FY 2009), USGS plans to undertake a scenario of the Southern Whidbey Island Fault with a vulnerability-based GIS assessment, community workshops to discuss needs and uses, and obtaining proprietary economic activity data through Washington Emergency

Management Division. Continuing multi-hazard funds would also be used for flood pathway model improvement and seismic instrumentation for landslide monitoring along with additional aeromagnetic and lidar data acquisition and ANSS expansion using Netquakes sensors. Both the earthquake and flood studies and the scenario will provide valuable information for the Washington State Hazard Mitigation Plan, bringing together USGS geology, water and geography expertise.

Discussion included the need to make use of the deformation signal from the standpoint of hazards, the long-term support for lidar data archiving, and the importance of addressing both intraplate coupling and crustal signatures.

Joan Gomberg provided an update on episodic tremor and slip developments in the past half-year, following up on the presentation the previous summer. The USGS activities are supported by the Earthquake Hazards Program under the Pacific Northwest project in the Earthquake Hazards Team. Recent findings of accumulated slow slip on the Cascadia subduction zone by Tim Melbourne at Central Washington University indicate that the locked zone extends farther inland beneath Puget Sound than previously thought. This down-dip extension has a huge impact on the ground motions expected in Seattle from a major plate-boundary earthquake. The committee's background materials included an open-file report from the recent USGS-EarthScope supported workshop, and a special *Journal of Geophysical Research* volume with over 30 papers is well under way. She emphasized that the study of ETS is a very active field. People are looking everywhere and generating more observations of slow slip in more places, including up-dip of the locked zone to complement previous down-dip observations. New scaling relations and predictive models are being developed. Newly available high-resolution, continuous tremor catalogs provide new insights for Cascadia, looking not just at the ETS events but all the time, providing tremor density maps that indicate constant tremor and creating opportunity to understand its temporal and spatial scales. Use of arrays by UW researchers promises to dramatically sharpen resolution, revealing the first-ever low-frequency earthquakes in Cascadia as previously seen in Japan. EarthScope plans an experiment for capturing an upcoming ETS event this summer with an array of arrays. Low-frequency earthquakes (LFE's) are emerging elsewhere, including work done on the San Andreas Fault by USGS Mendenhall postdoctoral fellow David Shelly. EarthScope Plate Boundary Observatory strainmeters are proving useful at precisely tracking ETS tremor and slow slip. Strain signals can be modeled to see where slip is occurring as shown by work by USGS postdoctoral fellow Wendy McCausland and others. Progress is being made in understanding triggered tremor as seismic waves from large earthquakes pass through, work being done by USGS postdoctoral fellow Justin Rubinstein and colleagues. Observations are coming from more places, showing that the size of the triggering wave size is not the only factor. Two Mendenhall postdoctoral fellow opportunities have been advertised to look at policy implications for seismic and aseismic slip on the Cascadia subduction zone and to explore tremor, slow slip and earthquakes in Alaska and the Aleutian Arc. An upcoming workshop in March will promote a collaborative synthesis of all the results of the many different studies of slow slip and tremor in Cascadia from January 2007 to the present.

Discussion included whether there were any plans to install remaining EarthScope PBO

borehole strainmeters, who was working on this issue in USGS (Gomberg, Evelyn Roeloffs, several postdoctoral fellows, and USGS external grant support to several academic researchers), and whether any linkage exists between tremor events and moderate to large earthquakes.

Elizabeth Barnett discussed an atlas she has compiled of data collected for active tectonic deformation in the Puget Sound region. This compilation is being released as an open-file report that is currently under review. Prior to 1985, the location of crustal faults was based on prior geophysical and field data. Since then a great deal of work has been done to derive earthquake histories. Thematic maps show paleoseismic studies of surface deformation and extent of lidar coverage, seismic studies, thickness of unconsolidated sediments based on well data, aeromagnetic anomalies, and a summary map of all crustal deformation data and inferred active faults.

Discussion included how this project would feed back into the USGS Quaternary fault and fold database and whether there was any movement toward developing an equivalent to California's Alquist-Priolo act requiring fault setbacks. Weaver noted that there are almost no crustal earthquakes associated with these faults, so there is a need to assemble a rich dataset that shows faults even in absence of earthquakes. He added that the state is looking at high-priority pipeline crossings.

Brian Sherrod presented a recent study on the Seattle Fault zone and the Southern Whidbey Island Fault. Trenching evidence shows four Holocene earthquakes along one strand with a large jump in activity 1,100 years ago after a period of quiescence back to 10,000 years. Initial work suggests that the cumulative GPS rate for intraplate shortening with the subduction rate removed fits cumulative paleoseismology evidence. The hope is to extend paleoseismic research into central and eastern Washington with permits pending.

Art Frankel discussed ground-motion issues in the Pacific Northwest. He described science needed to produce advances, noting that this was an exciting time whereby improvements in fundamental science can directly improve synthetic seismograms and seismic hazard maps used by engineers to promote public safety. Urban seismic hazard maps take a number of different forms with different levels of complexity. The simplest approach is to use generic attenuation relations with a map of soil effects and basin depth, then use nonlinear factors within the probabilistic seismic hazard analysis approach. More complex is to use vertical S-wave propagation based on a layered model for an area as was done for Memphis. In Seattle, he and his colleagues used multiple 3-D finite-difference simulations as the culmination of more than 12 years of research and outreach efforts to develop a 3D velocity model using many data types. They recorded and analyzed earthquake ground motions to supplement the PNSN array and then validated the 3D model using recorded waveforms. All of this was underpinned by work to determine fault parameters, recurrence times, GPS rates and other data that feed the national seismic hazard maps. Outreach efforts including workshops and briefings related to the Seattle hazard maps were organized by Weaver, resulting in strong community interest and media coverage. The Nisqually earthquake reminded people that the earthquake hazard is real. It also showed the importance of understanding basin surface

waves and including those effects in hazard maps. In addition to further improvements to the Seattle maps, the next target is to develop seismic hazard maps for Portland, working with the Oregon Department of Geology and Mineral Industries. That effort would include 3D simulations for a great Cascadia earthquake, a Portland Hills Fault earthquake and a deep intraplate slab quake as well as putting out a USGS seismic array for the Portland area. Engineers often request synthetic strong motions for M8-9 Cascadia earthquakes wanting to better understanding how high-rise buildings in particular will respond, so he is planning to do simulations to address whether constant stress-drop model is appropriate for great earthquakes. A key challenge is to get the long-period synthesis right in the 2-6 second period realm. Coherence of the rupture is another issue that needs investigation. Inversions of strong-motion data for kinematic parameters may suggest different levels of coherence than dynamic rupture simulations. There is a need for more extensive modeling of well-recorded large and great earthquakes – the earthquake program’s external grants request for proposals has a priority for this in the earthquake effects topic.

Questions focused on whether there were plans to formalize what has been done in Seattle and institute in other metropolitan areas, also on the connection between Frankel’s ground motion studies and the strong-motion component of ANSS.

The meeting adjourned at noon.