USGS
Earthquake Hazards Program

Summary of September 5, 2007 meeting of the
Scientific Earthquake Studies Advisory Committee (SESAC)
Paso Robles, California

Meeting Participants

SESAC Members
Mark Zoback, *Chair*, Stanford University, Palo Alto 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
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 (unable to attend)

USGS Staff
David Applegate, Earthquake Hazards Program (EHP), Reston VA
Mike Blanpied, EHP, Reston
Rufus Catchings, Earthquake Hazards Team (EHT), Menlo Park CA
Bill Ellsworth, EHT, Menlo Park CA
Ken Hudnut, EHT, Pasadena CA
Sue Hough, EHT, Pasadena CA
Malcolm Johnston, EHT, Menlo Park CA
John Langbein, EHT, Menlo Park CA
Bill Leith, EHP, Reston
Jill McCarthy, Geologic Hazards Team, Golden CO
Jessica Murray-Moraleda, EHT, Menlo Park CA
Andy Snyder, EHT, Parkfield CA

Welcome and introductions

Chairman Mark Zoback welcomed committee members and guests to Paso Robles. The committee approved the meeting summary from the February 2007 meeting in Reston with several requested modifications.

Action Item (Program): Edit February 2007 meeting summary to incorporate SESAC-suggested changes.

One modification related to the long-term operations of the geodetic and seismic stations being deployed by the National Science Foundation's (NSF) EarthScope initiative. The committee felt that it was not too early to have Director-level discussions about how those stations will be maintained beyond the lifespan of NSF's commitment. Bill Leith

described current efforts by regional seismic networks to make certain priority USArray stations permanent. A similar effort should be considered for Plate Boundary Observatory geodetic stations.

Action Item (SESAC): Recommend that USGS Director raise issue of long-term EarthScope O&M at NEHRP Interagency Coordinating Committee meeting.

A question was raised about the status of the new Advisory Committee on Earthquake Hazards Reduction (ACEHR), which was established by the last reauthorization of the National Earthquake Hazards Reduction Program (NEHRP). The committee held its first meeting on May 10-11, 2007, at the National Institute of Standards and Technology (NIST) headquarters in Gaithersburg MD. Several former SESAC members sit on the committee, which also includes the SESAC chair as an ex officio member. The next ACEHR meeting will be in October 2007 at the USGS National Earthquake Information Center in Golden CO.

Action Item (Program): Distribute minutes from first ACEHR meeting.

The committee asked about status of Earthquake Hazards Program (EHP) revised five-year plan, which Applegate indicated would be ready for review by the committee's next meeting. Applegate noted the hazards component in the newly released USGS science strategy (Circular 1309, which was distributed to the committee) and the new Geologic Discipline strategic plan development currently underway.

Action Item (Program): Provide drafts of revised EHP five-year plan and Geologic Discipline strategic plan to SESAC when they are ready for review.

Earthquake Hazards Program Update

Applegate and Leith provided an overview of recent program activities. Applegate thanked Leith for his leadership of the program for the past three months during which Applegate was acting associate director for geology.

Two recent seismic event responses emphasize the progress that continues to be made in seismic monitoring. The Utah mine collapse on August 6, 2007, demonstrated strong coordination between the University of Utah Seismographic Network (UUSN) and the National Earthquake Information Center (NEIC) as well as other university colleagues. As a regional network within the Advanced National Seismic System (ANSS), the UUSN had primary responsibility for the event and did an extraordinary job of responding quickly and accurately to deal with assertions by the mine owner. Indeed, UUSN Director Walter Arabasz (who will receive the USGS John Wesley Powell Award later this month) called the county sheriff several minutes before the mine called 911. NEIC provided valuable support for UUSN, and seismologists at the University of California at Berkeley provided crucial data. The event showed the importance of having a consistent message in the face of intense media scrutiny so that the focus stays where it should – on the humans impacted by the event. The event also highlighted the ongoing challenge of sparse station distribution and loss of monitoring capability in mining areas since the

elimination of the U.S. Bureau of Mines. USGS is also adjusting how it describes the automatic depth location used for shallow events to avoid any possible confusion.

Art Lerner-Lam asked if USGS was undertaking a systematic effort to catalog legacy seismic network responsibilities for non-earthquake events, noting potential coordination and leveraging opportunities. Jill McCarthy noted that USGS operates networks on behalf of the U.S. Bureau of Reclamation, and Leith noted the relationship with the Air Force for nuclear event detection. Stu Nishenko asked if USGS had seen any interest in increased nuclear plant monitoring; required monitoring is limited to strong-motion recording of the power block, but there is also a need for regional information. Leith noted that USGS is being pressed by a private company on the accuracy of its seismic event catalog and the lack of quantified uncertainty.

Applegate stated that the NEIC response to the August 15, 2007, magnitude-8.0 Peru earthquake was rapid and well coordinated in magnitude determination with the tsunami warning centers. The results of the Prompt Assessment of Global Earthquakes for Response (PAGER) system were available to aid agencies and other critical users within 20 minutes of the event. A prototype version of PAGER will become fully publicly accessible at the end of this month. USGS is sending a team of experts to Peru this month with support from the U.S. Agency for International Development's Office of Foreign Disaster Assistance. Vicki McConnell asked if a link to the NOAA tsunami warning centers could be put directly from the main earthquake.usgs.gov page.

Action Item (Program): Place link to tsunami information on earthquake.usgs.gov home page.

Applegate reviewed the status of the President's fiscal year (FY) 2008 budget request, and subsequent House and Senate action, which could result in an increase of over $5 million for the earthquake program in the House-passed bill.

Leith provided the update from the ANSS Steering Committee for chair Ralph Archuleta, who could not attend. He noted that if there is no increase for ANSS in the President's budget in FY 2008, then development funding will drop below $1 million for the first time since ANSS was initiated. That despite the fact that ANSS has been rated as the major capital investment with the highest business value and lowest risk in the entire the Department of the Interior. In FY 2008, funding will be used to complete structural sensors and deploy a wireless strong-motion sensor being developed (NetQuakes) in Southern California and possibly the Pacific Northwest and along the Hayward Fault in the Bay Area. The sensors are currently being testing at the USGS Albuquerque Seismological Laboratory. Rogers noted that these sensors were originally developed by the Geological Survey of Canada; they have been running in schools in Victoria BC for the past four years with very few problems.

Recommendations from the ANSS Steering Committee report included:

- A plan should be in place to ensure capturing the near-field ground motion from a major earthquake. These data are what are missing from the database used for the next generation of attenuation relations, recently developed.

- USGS should seek opportunities In the New Madrid area to instrument structures and for geotechnical borehole arrays, to better understand the expected amplification.
- USGS should implement its two-tiered plan for regional network software, which could lead to significant operational cost savings.
- There is a need for more information about the users of earthquake early warnings, in order to better gauge the benefits of establishing a warning system in the U.S.
- Progress in structural monitoring appears to be limited as a result of recent decreases in staff within the National Strong Motion Project.
- The National Center for Engineering Strong-Motion Data, developed jointly with the California Geological Survey, should provide "one-stop shopping" for ANSS and CSMIP data useful to the engineering community.

Zoback asked if USGS had a priority list for distributing sensors to capture near-field ground motions from major fault zones beyond the current focus on the southern San Andreas Fault. He recommended that one be developed.

Leith noted that there is currently no champion for earthquake early warning (EEW) on the ANSS Steering Committee. In particular, members fear that EEW could be a drain on limited resources for other parts of ANSS.

The National Strong Motion Project is poised for growth but has lost key staff; USGS is looking to reorganize in order to better support the engineering community. A joint advisory committee has been convened for the National Center for Strong-Motion Data, a collaboration between USGS and the California Geological Survey. A new website has been developed to improve access to data. McConnell encouraged USGS to work more closely with the engineering community, who are key customers for this data. Ellen Rathje noted that engineers tend to use the Next Generation Attenuation database at the Pacific Earthquake Engineering Research Center; it will be important to link these databases.

Leith noted that USGS is not in a position to universally adopt USArray Transportable Array stations and cannot promise long-term operations and maintenance support at current funding levels. ANSS can, however, serve as an advocate for alternative funding to add key stations into regional networks, such as at recent town-hall gatherings at national scientific meetings. McConnell noted that the Association of American State Geologists has been pushing to get the word out on adopting Transportable Array stations. Lerner-Lam urged that ANSS be characterized publicly as a highly leveraged multi-layer partnership. Leith noted that there are no obstacles to ANSS development except budgetary limitations; he sees continuing innovation and wants to maintain momentum.

Zoback asked if there were ANSS flagships that will be perceived as new and exciting and worth a funding boost. Leith emphasized that the current focus is on regional partnerships and high-profile products that are the result of network modernization and on providing improved situational awareness for emergency managers. Lerner-Lam noted that mitigation is a key selling point for ANSS in the National Research Council's cost-

benefit study; Applegate responded that mitigation is used as a key selling point for the hazards initiative as a whole.

Blanpied noted that earthquake early warning could be such a high-profile deliverable for ANSS. Sue Hough encouraged that EEW be thought of not just for California but especially in the central US where large events are felt over such large areas. Zoback noted that there are legitimate concerns about EEW being a resource drain but that USGS would be negligent not to at least have an active inquiry in this area. The recent announcement of large-scale EEW deployment in Japan can be expected to raise the public attention level.

Action Item (SESAC): An agenda item for the next committee meeting should be an update on earthquake early-warning activities, examining the current approach and state of the art. The SESAC's view that USGS needs to be giving serious consideration to EEW should be conveyed to the ANSS Steering Committee.

Nishenko urged that care and caution be used in how EEW is sold, noting that myths about utilities shutting off the power ahead of shaking still abound; the value is in decision support. This would be opening up a new era in how we respond to earthquakes; there are many technical and sociological questions. Jim Dieterich noted that we identify many possible uses for EEW but need a hard look at actual uses; he also noted that "early warning" is the worst possible name for what is better characterized as an imminent shake warning, "shake alert", or last-possible warning in the continuum of rapid post-earthquake information. Applegate noted that Jim Goltz of the California Office of Emergency Services has similarly encouraged that USGS undertake a hard look at how EEW will be used well ahead of any possible deployment. He noted that EEW should be seen as an extension of current efforts to provide information as rapidly as possible. Leith noted that in the current research being funded by USGS at Berkeley, Caltech, and the University of Southern California, ShakeMaps (predictive shaking models) are now being generated within 9 seconds of rupture initiation. McConnell emphasized that this is still essentially about response. Rathje stated that an important question to address is whether it is worth the cost to have ShakeMap in a few seconds rather than a minute.

National Earthquake Prediction Evaluation Council (NEPEC) Activities Update

Jim Dieterich reported on two NEPEC activities since the last SESAC meeting. On May 18, 2007, NEPEC met in Portland OR to discuss episodic tremor and slip (ETS) from both a research and public response point of view. He expressed appreciation to Vicki McConnell and Evelyn Roeloffs for hosting and organizing the meeting, and recognized Garry Rogers for his seminal role in identifying ETS on the Cascadia subduction zone. He noted that ETS is becoming a prevalent phenomenon spotted around the world. On the Cascadia subduction zone, there is clearly some probability gain for a megaquake with additional tremor-induced loading, but there have been hundreds of tremor events since the last megaquake. NEPEC is recommending (1) that ETS represents a very important scientific question that deserves research; (2) that research needs to be as well coordinated in the US as it is in Canada; (3) that there is no need for alerts at this time, but that it would be useful for USGS to prepare a public statement about the

phenomenon, which represents an educational opportunity; and finally (4) that USGS needs a plan if the pattern of activity changes such as ETS events that do not stop or that appear at multiple locations along the subduction zone or are accompanied by subduction-interface earthquakes. McConnell seconded the need for such a plan and for an assembly of people working on this issue. In response to Dieterich's caution that USGS is currently not well organized and in risk of missing an important opportunity on one of the most interesting scientific topics today, Blanpied noted that Joan Gomberg has now been tasked as the primary focal point for ETS, efforts are underway to better coordinate observation datasets through a website hosted by EarthScope, and Gomberg is organizing a follow-on workshop this winter focused on coming up with what those scenarios are that could represent a cause for concern. Rogers noted that the workshop will be held in Victoria BC.

Action Item (SESAC): An agenda item should be included in the next meeting's agenda for an update on the ETS workshop scheduled for Victoria, BC, in early 2008.

Nishenko noted that the response to these ETS events represents a public relations coup as an opportunity to demonstrate that we are on top of the phenomenon, showing the value of monitoring networks, and reporting during rather than after the events, which take place on a frequent enough cycle to be a constant reminder. Malcolm Johnston noted that slow-slip events were also seen on the Hayward Fault, where there is a similar issue about what level of change would be cause for concern. Applegate stated that this question should be addressed as part of the activities leading up to the 140th anniversary commemoration of the 1868 Hayward earthquake.

The other topic that NEPEC has been actively engaged in is the new time-independent and time-dependent seismic hazard maps being developed by the Working Group on California Earthquake Probabilities (WGCEP). A number of NEPEC members participated in the recent Scientific Review Panel meeting held in advance of the Sep. 1 deadline for delivering the time-independent map to the National Seismic Hazard Mapping Project group in Golden, and the Sep. 30 deadline for delivering a time-dependent map to the California Earthquake Authority (CEA). Much work remains to be done to adequately quality-control and review the 600 pages of appendices that accompany the WGCEP report, which itself has a long way to go. McCarthy noted that the general plan is to use internal administrative reports to meet the deadlines with numbers fixed but then further review of the explanation of methods to take place before public release.

Blanpied, who represents the program on the Scientific Review Panel, noted that the national seismic hazard maps are a flagship product of the USGS Earthquake Hazards Program. The new version of the maps is due at the end of September. The maps rely on a wide variety of source information for individual regions; for California the source model is the one being developed by the WGCEP, which will then be the same source for the time-dependent product for CEA, which is seeking uniform state-wide treatment of hazard based on the best available science. The WGCEP product is being developed in a way that can be meshed with the maps for the rest of the continental US. The biggest challenge for the WGCEP project is time with looming deadlines for delivery to CEA.

Other contributing challenges are the rate of earthquakes in the model relative to the observed rate around magnitude 6.5, which is a long-standing issue. The WGCEP has determined that the model should fall within the 95% confidence boundary for the historic rate; the model currently overpredicts the number of magnitude-6.5 events relative to the past 150 years; key questions are whether this is an artifact of the size of geologically mappable faults and whether the 150-year record is indeed representative of the long-term rate. Blanpied reported from WGCEP leader Ned Field (USGS Pasadena) that the current calculations were falling just within the 95% bounds. Blanpied noted that there are a suite of interesting and necessary science projects that should continue, and that CEA is interested in continued research support. Another big challenge is the big changes due to using the Next Generation Attenuation models with associated huge uncertainties that dwarf the above magnitude-6.5 bulge problem. McCarthy stated that it comes down to where people's comfort level is for best available science and the need to agree on saying done. Nishenko noted that the national risk maps will change based on the new hazard maps as well as incorporation of the 2000 census data; he emphasized the need to work the right language into explanations so that people do not feel whip-sawed by changes in the risk level. He asked where CEA stood on varying rates based on time-dependent maps. Dieterich responded that CEA regionally smooths hazard which should reduce the impact so they are less concerned about local-scale changes. Hough noted that understanding time-dependent models generates large uncertainties, asking what impact that might have on rates.

Dieterich stated that the role of NEPEC in the WGCEP process is not to perform a detailed technical review but to certify that the review process has the appropriate scientific rigor and that NEPEC certification is dependent on the WGCEP following the recommendations of the Scientific Review Panel. As a result of the recent meeting, NEPEC will review the documentation associated with the final scientific document that will appear as a journal article and be the public release describing methods and results. He stated that it is important for USGS and CGS to wait for the reviewed document before public release; he also noted the need for a non-technical explanatory pamphlet. Nishenko asked who had governmental accountability given that the WGCEP is a joint government-university entity. Blanpied responded that the leads of the Scientific Review Panel and the working group itself are both USGS employees and that the documentation will be official government reports. Lerner-Lam noted that the process appears to have evolved and that there is a need to better formalize the process going forward. Dieterich noted the significant growth in complexity since the original working group in the 1980's. Zoback noted that the current process is good in providing far more visibility and transparency on what goes into the hazard maps. Dieterich urged USGS to recognize the herculean efforts by Ned Field.

National Seismic Hazard Maps Update

Jill McCarthy gave a presentation on the status of the revised national seismic hazard maps. Developing the revisions has included half a dozen regional and special-topic workshops to get upfront input from the stakeholder community. In May 2007, an expert panel reviewed the draft maps, which were then publicly released for a 60-day comment period in June 2007. Project staff are now responding to comments, doing final quality-

control review and preparing for the Sep. 30 release to the Building Seismic Safety Council (BSSC). The process has been complicated by the delayed delivery of the WGCEP contribution. Time is tight in order to properly test models and be sure they are right with quality documentation that USGS can stand behind. Because feedback is expected from both the BSSC and CEA, what will be provided on Sep. 30 will be a near-final review draft, and the public release will take place later in the year. A number of questions were asked about the process that leads from the delivery of the maps on Sep. 30 to their subsequent incorporation into NEHRP Provisions, ASCE-7 and the International Building Code.

Action Item (Program): Distribute recent Seismic Waves article on nehrp.gov website on the translation of hazard maps to building codes (http://www.nehrp.gov/pdf/SeismicWavesJune07.pdf).

McCarthy reviewed regional changes and their impacts on the maps. Rathje asked about the implications of lowering the hazard, and it was noted that the maps are guidelines rather than absolutes. Rathje also noted that vector hazard is a big research area looking at the joint probability of occurrence of multiple ground-motion parameters for buildings or earthquake-induced landslides, asking how to do that for a hazard map. Zoback asked whether an effort was being made to link the hazard maps to scenarios, reflecting on the high impact of the shaking simulations developed for the 1906 centennial by Brad Aagaard and others. McCarthy replied that it was being done at the urban level. Nishenko asked what plans there were to update existing scenarios based on the new hazard values, noting that utilities were building infrastructure based on scenarios. Rathje reflected on her experience on committee overseeing the Earthquake Engineering Research Institute (EERI) scenario for Seattle and that some change in the hazard did not negate the basic message of a public call to arms for mitigation and preparedness. Hough noted the disconnect between physics-based simulations in southern California and the Next Generation Attenuation models. Zoback suggested that these disconnects should suggest a research agenda. Rogers noted that the move from zones to continuous hazard gradation had caused a number of problems for users who used zone boundaries as triggers to which McCarthy noted that this was an issue in the US in the 1990's when the first modern maps were developed but that the concern was waning as people became familiar with the new maps.

Action Item (SESAC): Agenda item for the next meeting with follow-up presentation on the changes in the new seismic hazard maps and to look at the next big research topics that need to be tackled for the next map update cycle.

Southern California Multi-Hazard Demonstration Project

Ken Hudnut provided an update of earthquake-focused activities within the new Southern California Multi-Hazard Demonstration Project. Developing a multi-hazard scenario for the impacts of a major earthquake on the southern San Andreas Fault is the major focus for the first year. The new Earthquake Hazards Program funding in FY 2007 is directed toward the Southern California Earthquake Center's (SCEC) Southern San Andreas Fault Evaluation (SoSAFE) project – which Ken is chief of – to define the fault's slip rate and

earthquake history of the past 2000 years. An initial workshop was held on January 8-9, 2007, in Pasadena; the next one will be on September 9, 2007, at the SCEC annual meeting in Palm Springs with 145 people registered. The fiscal uncertainty long into FY 2007 due to continuing resolutions delayed initiation of some work, but preliminary funding has enabled the extension of the earthquake history at several sites to six previous events and identified a whole new set of keystone sites. A rigorous in-field scientific review process while trenches are open has been instituted. LIDAR and a new suite of geochronologic methods are being used to improve slip rates, then hypotheses are being tested with a backhoe. The scenario is being developed at multiple levels of detail including a basic rupture description (magnitude-7.8 event starting at Bombay Beach and rupturing north), a static rupture description, and kinematic rupture description with physics-based modeling. The 2008 Golden Guardian statewide earthquake preparedness exercise will be based on this scenario. Nishenko asked whether the scenario would capture variations among different possible events in order to bracket impacts, noting that clients need to understand the full range of consequences; Hudnut noted the discomfort of stepping outside a probabilistic framework. Hudnut also noted that a focus of the scenario was on lifeline impacts. Multi-hazards include triggered landslides (a joint effort with CGS), wildfires caused by lifeline ruptures, and a possible dam failure. Dieterich asked about the problem of public perception from such a scenario conflicting with the probabilities coming out of the WGCEP process; he was concerned about newspaper reports that reported project chief Lucy Jones stating that this was the most likely event on the San Andreas, and that conflict could break out within the scientific community that would sidetrack the importance of what the project is trying to do. Zoback suggested that USGS should emphasize this as a planning event, not necessarily the most likely or historic but leading to an awareness of the consequences with attributes that are useful for planning. Rogers asked if variability of time of day and year would be incorporated in scenario. Bill Ellsworth asked how realistic the scenario would be during the exercise itself. Hough noted that Karen Felzer's studies suggest the possibility of a large aftershock near Sacramento.

Lunch at Paso Robles Inn

Geodesy and Deformation Activities

The committee heard a series of presentations on current geodetic observations and research carried out by the Earthquake Hazards Program and future opportunities from Ken Hudnut, geodesy coordinator for the Earthquake Hazards Program; long-time Earthquake Hazards Team (EHT) geodetic researchers Malcolm Johnston and John Langbein; and Jessica Murray, co-chief of the EHT's Deformation Project.

Hudnut emphasized that geodetic observations and research are necessary to fulfill the Earthquake Hazards Program's mission and to better understand the full range of earthquake behavior. He cited geodesy's relevance to all four NEHRP objectives for USGS as well as the Survey's Stafford Act role to ensure timely and effective disaster warnings.

Johnston presented on current and future USGS continuous strain and deformation activities. He described the move toward multi-parameter monitoring. The USGS operates telemetered and hardened borehole strainmeters to investigate the physics of fault failure. These instruments contribute to an improved understanding of strain state, earthquake sources, slow earthquakes, earthquake nucleation processes, teleseismic and local earthquake triggering, tremor and long-period earthquakes, material/fault response, and earthquake prediction. USGS currently operates 28 boreholes, including 11 on the Hayward and San Andreas faults in the Bay Area. The system being used by the EarthScope Plate Boundary Observatory (PBO) is simplified but may be using toward deployment of additional instruments in the boreholes. USGS equipment is getting old, and dwindling support staff cannot keep up with data or maintenance. The committee was particularly concerned by Johnston's assertion that little useful data was coming out of the PBO borehole installations at Parkfield and San Juan Batista. Johnston urged that high-level discussions were needed on the future of these PBO boreholes and the need to investigate real-time options and harden sites; he encouraged a push for replacement of bad sites in critical places. He also emphasized the need for more people and financial support for USGS efforts in this arena. In conclusion, Johnston stated that real-time strain/deformation monitoring is providing answers to fundamental questions in fault failure physics, that continuous real-time multi-parameter deformation observations are essential to the USGS leadership role in earthquake and volcanic hazard identification and reduction, and that with its current design and implementation, PBO stations seemed unlikely to contribute much to this role unless changes are made.

Ellsworth asked if there was a way to prioritize PBO instruments similar to what is being done by regional seismic networks seeking to make permanent the best USArray sites. Zoback asked if the proposed duplicate telemetry would result in interference to which Johnston replied that interference could be avoided by using an optical system. Rathje stated that it was unclear whether what was being proposed was taking advantage of an opportunity or simply seeking to save current capability. Parrish asked for Johnston's recommendation to which he replied: Keep what we have going and take advantage of what we can.

Langbein presented on four aspects of USGS geodetic monitoring. The number of USGS instruments has been steadily decreasing with time in part reflecting the good development of GPS coming on line, making some instruments obsolete, and the bad decrease in personnel to maintain stations. In the future, USGS will be relying on PBO instruments, both GPS and strain, for monitoring; in order to effectively augment USGS capabilities, priority PBO sites need to be chosen for hardening, improved telemetry and reduced latency in data streaming. The two-color electronic distance meter (EDM) network has been retired but we can learn from correlated noise data and apply to GPS and strain; it has been possible to mesh the time series between EDM and GPS, which have similar resolution and errors. Creepmeters have decreased from over 30 to 18 since 1989 (5 sites on Hayward, 3 in San Juan Batista, and 11 at Parkfield); GOES satellite telemetry is being upgraded. These instruments complement borehole strainmeters on the creeping section of the San Andreas Fault; there was no precursory creep prior to the 2004 magnitude-6 Parkfield quake. USGS is currently monitoring a subset of PBO strainmeters in the Pacific Northwest to see "slow" earthquakes; that is the only USGS

geodetic monitoring in the region outside Mt. St. Helens. A similar technique is being used to view USGS strainmeter data in the Bay Area; the goal is to monitor but also archive clean data for others to use. In the Cascadia slow-slip event, strainmeters clearly recorded the event, but we are grappling with how to calibrate instruments; tremor activity was not detected by strainmeters. He called for unifying analysis of USGS and PBO strainmeter data using only the best PBO strainmeters in regions of interest, but he noted that raw PBO strain data can only be obtained once a day with clean data coming with a two-week latency; editing and cleaning data is time-consuming as it must be done carefully with human input. Finally, Langbein discussed USGS externally directed funding for four GPS networks, strain measurements in the Bay Area, and creepmeters, totaling $450,000 annually.

Following the two negative appraisals of PBO borehole strainmeter capabilities from USGS presenters, Zoback asked the committee to be mindful that PBO representatives were not there to present their case. There was concern expressed by the committee that USGS was funding geodetic networks but not making proper use of the datasets being produced. Langbein noted that timely network maintenance is a problem for several external networks in the Bay Area, which require Menlo Park personnel assistance because of distant principal investigators; he recommended that USGS should take over the creepmeter sites, and PBO should take over the Gladwin instruments. Lerner-Lam asked if there had been any thought given to getting NEIC involved in geodetic monitoring. Leith noted that participants in a source-characterization workshop held last fall urged NEIC to integrate geodetic monitoring. He also noted that the ANSS Steering Committee was split between those who felt that were ANSS to be developed today, GPS would certainly be part of the system and therefore should be incorporated, and those who feel that with so little progress made so far on ANSS, it is not possible to add additional capabilities when the original ones are so ill-funded.

Jessica Murray's presentation focused on GPS. Past priorities had been campaign GPS surveys, collaboration to develop the Bay Area Regional Deformation (BARD) network at UC Berkeley, processing and archiving data at the Northern California Earthquake Data Center (also at Berkeley), and web-based display of results. Present priorities to meet evolving needs include data collection (new networks complementing PBO, collaborations with other groups, and a written response plan), data utilization (semi-automated tools for quickly obtaining and analyzing displacements), ongoing application of tools for detecting anomalies, and high-rate GPS data for research applications), and monitoring and response (improvements to processing and visualization, identification of anomalies, rapid processing and automated inversion for slip in response to event). There is a need for more staff time to complete the automation algorithm development; she would like a person working full-time on this. Response capability is predicated on accessibility of GPS data for response; we currently do not have robust and timely continuous GPS data access. USGS is not receiving data sub-daily from its partner networks; direct data access is needed using robust and redundant telemetry, not through the Internet or a third party; the goal is to obtain data as close to the time of an earthquake as possible. Real-time high-rate GPS data access could be used for rapid finite fault inversion to augment ShakeMap and guide postseismic response. In order to obtain real-time high-rate GPS data from BARD, USGS could create a second robust telemetry path

to support parallel response systems at Berkeley Seismological Laboratory (BSL) and USGS Menlo Park as already exist for seismic data through the California Integrated Seismic Network. Discussions are underway to send data from PBO sites in the Bay Area to the USGS microwave network; 40 sites have nominal line-of-sight to the network, and the plan is to try for the best 20 of those; memoranda of understanding are being developed with both BSL and UNAVCO (which operates PBO). For monitoring, USGS needs to bring collaborations to fruition for better data access, needs to obtain robust real-time processing software, needs to incorporate real-time data into alert and response systems, and needs to develop a means for joint use of GPS and strainmeter data. Future scientific investigations should include research that leads to greater incorporation of geodetic data into hazard assessment and an improved understanding of underlying processes.

McConnell asked how to move to real-time incorporation of geodesy. Lerner-Lam suggested what was needed was an appropriate model for turning a research enterprise into an operational one. Nishenko expressed a sense of déjà vu as geodesy is where seismic networks were 30 years ago prior to their transition to an operational mode. Zoback asserted the need to identify that part of the geodesy that serves the USGS mission best. As nobody is currently positioned to do real-time monitoring, what is needed is a plan to staff, fund, and maintain such an effort.

Action Item (Program): SESAC recommends that the USGS Earthquake Hazards Program develops a white paper on future geodesy needs to achieve the program mission.

Ellsworth stated the need to define what the uses of the data are going to be, citing the successes at Long Valley and Parkfield, which had clearly established goals.

Hudnut gave a wrap-up presentation on the Survey's GPS needs, including precise real-time displacements, in order to deliver earthquake early warning, volcano alerts, support tsunami warning, and achieve real-time processing. Real-time GPS precise point positioning was developed with NASA funding at the Jet Propulsion Laboratory; currently USGS gets software access and pays $50,000 annually for real-time clock corrections. One challenge is automation in processing; the sub-daily processing developed for the SCIGN network and later adopted by PBO is a success story that is now outmoded. With PBO now funding routine processing, USGS can focus on near-real-time processing. Robust GPS is needed at all key lifeline crossings on the San Andreas Fault; we currently have nothing at Cajon Pass, and instrumentation there is a top priority of the multi-hazard demonstration project. No funding has yet been identified to develop an operational system of GPS and accelerometer arrays for real-time slip detection, which currently takes geologists in helicopters going out after a major event. He also noted future opportunities for LIDAR and InSAR.

Take-home points from all four presenters were: (1) obtaining and using real-time multi-parameter deformation data is essential to meeting the USGS hazard reduction responsibility; (2) the role of PBO in USGS monitoring and response must be defined, (3) adequate staff and monetary support must be allocated in order to fulfill USGS

monitoring and response role; and (4) USGS must maintain its scientific program in parallel with monitoring and event response.

Future of USGS activities at Parkfield

Bill Ellsworth led a discussion of the long-term role of USGS at Parkfield CA, where the committee went on a field trip the following day. He began by noting that what goes on at Parkfield does not stay at Parkfield but has been broadly applied elsewhere with pioneering efforts in the application of geodetic methods to mapping strain, in real-time monitoring, and strategic partnerships with the California Geological Survey and Office of Emergency Services. Questions he sought to raise included what had been learned, what benefits had accrued to the scientific community and to emergency management, whether it is worth waiting for another magnitude-6 event, and what should USGS investments be. The San Andreas at Parkfield is the most densely instrumented fault in the world and the best characterized fault with a time-invariant pattern of earthquakes, which at a large scale are "characteristic". During the 2004 event, the strong-motion stations operated by the California Geological Survey recorded a spread of peak accelerations that covered the whole range expected for all magnitude-6 quakes in a single event. He described the seismic structural investigations to understand geologic controls on rupture with applications to the Hayward fault as well as the results from tripod LIDAR showing post-seismic deformation, which represented a significant amount of the total moment release. He feels that we should be capturing better InSAR data during the reloading period. The question was asked about CGS's commitment to continue strong-motion monitoring. EarthScope has increased the density of continuous GPS stations, including former USGS stations now part of PBO Nucleus; PBO has also installed borehole strainmeters to the south that include seismometers. Nishenko asked about long-term planning for modernization, and the response was that while the marginal cost to keep systems running is not high, replacement costs could be substantial. McConnell asked for a sense from the group of whether it was worth continuing the experiment, and there was general agreement that there was adequate scientific value. Lerner-Lam asked where USGS would do another Parkfield were funds available. Dieterich noted that years ago a USGS report that he authored called for a similar experiment in Southern California. Rathje noted the linkage to the ANSS Steering Committee's recommendation to instrument the southern San Andreas Fault. Ellsworth noted that following the 2004 event, he had a review done on the status of instrumentation along the San Andreas; overall, bases were well covered but with glaring holes so put instruments near the fault in the Coachella Valley. He emphasized that to catch big events, USGS should be looking globally. Hudnut added the need to get better near-field geodetic data from big events, citing the USAID-funded network in Sumatra that USGS was deploying with Caltech; following the recent Niigata event, strong-motion sensors recovered near-field static displacements but GPS sensors did not. Ellsworth suggested the value of robust but triggered strong-motion and GPS sensors for this type of near-fault experiment. Hudnut stated that fault displacement is a big issue for lifeline operators, and Nishenko added that it needs to be put in terms of the utilities' reliability concerns. Zoback closed the discussion noting that it had provided good context for the next day's fieldtrip to Parkfield.

Meeting Review and Annual Report Preparation

The committee held a brief executive session to review the day's discussions and address writing assignments for the annual report. Program staff provided the list of topics covered by the previous annual report as well as topics covered in the committee's March 2007 meeting in Reston VA. In addition to topics arising from committee deliberations, the report will include summaries from NEPEC and the ANSS Steering Committee. Zoback stated that the committee should identify topics that they want the USGS Director to carry forward to the NEHRP Interagency Coordinating Committee. There was agreement that the report should include the recommendation to the program for a white paper on the future USGS role in geodetic monitoring and research, recognizing the value of geodesy as an important component of the program. Additional concern was voiced about the public communication associated with the development of a Southern San Andreas Fault earthquake scenario.

A subsequent conference call or email exchange will be needed to finalize writing topics and assignments. To assist, the program office will provide this summary and suggested topics for the committee's consideration.

As noted throughout the summary, a number of agenda items were identified for the next committee meeting, which will tentatively take place in February or March 2008 in Reston, although alternate venues should be explored.

Action Item (Program): The program staff will check SESAC member availability for a meeting in the February/March 2008 timeframe.

The meeting adjourned at 5:45 p.m.