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December 4, 2014

Dr. William Leith
Senior Science Advisor for Earthquake and Geologic Hazards
U.S. Geological Survey
905 National Center
12201 Sunrise Valley Drive
Reston, VA 20192

Dear Bill,

I wanted to provide a summary of SESAC's recommendations and thoughts following the May 29, 30 meeting held at the USGS offices in Golden, Colorado. Some of our comments may be included in our report to the Director of the USGS and Congress as part of an annual report by SESAC. The content of this report has been through several iterations by SESAC and represents a consensus view. As always I am available for any subsequent discussions or clarifications.

With warm regards,

Ralph J. Archuleta
Professor Emeritus of Earth Science

cc: David Applegate, Associate Director
Natural Hazards Members, Scientific Earthquake Studies Advisory Committee

Scientific Earthquake Studies Advisory Committee (SESAC)
Meeting of May 29, 30, 2014
USGS Golden, Colorado

Attendees: SESAC
Ralph J. Archuleta, Chair, John Anderson, Greg Beroza, Julie Furr, John Parrish, Christine Powell, David Simpson, Terry Tullis (by phone on day 1) (Appendix A)

USGS EHP: William Leith, Mike Blanpied, Harley Benz, Bill Ellsworth (for Tom Brocher), Gavin Hayes, Keith Knudsen, Elizabeth Lemersal (by phone), Jill McCarthy, Mark Peterson, David Wald, and Cecily Wolfe (by phone).

Guest: Jack Hayes (NIST), Director of National Earthquake Hazards Reduction Program (NEHRP)

The focus of the meeting was to get an update on the Earthquake Hazards Program (EHP) with special interest in the direction of the EHP as it moves into the next decade (Agenda in Appendix B). It has been almost 40 years since NEHRP was authorized and funded. The EHP has about the same budget now as it did then. As SESAC we need to look to the future of the USGS. Is there another frontier for EHP? Should EHP be looking at 10-year projects that will come with separate funding? Should there be a paradigm shift in how the EHP takes on new projects? Getting 2-3% increases maintains the status quo, but how does one launch new research? What would that research be? Are there new technologies that should be exploited? What data does EHP need that it doesn't have now? What will the workforce look like in 10 years, 20 years?

Bill Leith gave an overview of the current state of EHP and some of its immediate issues. The budget of $53.8M for 2014 was an increase compared to 2013 (year of sequestration) but is basically about the same as 2012. New funding is available for induced seismicity, earthquake early warning, greater emphasis on products (e.g., PAGER-- Prompt Assessment of Global Earthquakes for Response) as well as increased monitoring and research for the Central and Eastern US (CEUS). While the 2014 budget allows for a sustained effort in the EHP research goals, the funding is not sufficient for development of large-scale initiatives such as earthquake early warning, dense monitoring of injection wells correlated with increased seismicity throughout the CEUS, or a large-scale, systematic evaluation of seismic hazards in the eastern US.

One EHP issue is the future of NSF's EarthScope, which has a sunset in 2018. This NSF project has been responsible for the USArray (operated by IRIS) as well as the Plate Boundary Observatory (PBO, operated by UNAVCO). This program has had an impact on both seismic and geodetic data that have been used by geoscientists in the US and throughout the world. A primary concern will be the acquisition and operation of the 160 USArray stations that will be transferred to the USGS. These stations are located in the central and eastern US (CEUS). Currently the NSF funds IRIS to operate these stations; NSF plans support their operation through 2018, with USGS contributing a part of the cost.

EHP is commended for its continued and expanded collaboration with federal, state, local government agencies as well as universities, private organizations and businesses. Its participation in the Alaska Shield earthquake response exercise (in concert with the 50th anniversary of the 1964 great Alaskan earthquake) was an excellent example of the EHP's expertise being used for the benefit of all involved. EHP has partnered with a wide range of federal, state, university, private and international institutions in its efforts to better understand induced seismicity and its effects (8 state agencies, 6 federal agencies/labs, 9 universities, 3 international government agencies, and 8 private industries). This collaboration points to the importance of this effort as well as the diversity of the EHP research effort.

Earthquake Early Warning (EEW) is highly visible to the Congress (House was to hold hearings on EEW on June 10) as well as the California Legislature. EEW is a consequence of comprehensive monitoring in real-time with a sufficient density of stations. However, as SESAC has commented before, EEW is not a project that can be instituted within the current EHP budget. As such EHP has prepared a budget for the implementation of EEW on the west coast. Ignoring the additional capital costs, the operating budget for this one project is roughly 30% of the entire EHP budget. The current EHP budget barely maintains the status quo and stifles launching new programs. SESAC reiterates that there must be a separate budget if EEW is to be implemented.

As this report was written, SESAC was informed of actions by both the House and Senate committees, which would allocate $5M toward EEW. This support, while needed, continues the dilemma for the EHP in that the funds are well short of what it will take to implement EEW in the western US. (see figure below) Thus only one area of California (southern California) might be equipped for an operational EEW by the additional $5M.

West Coast Implementation Cost	California	Pacific Northwest	West Coast (CA+PNW)
One-Time Construction costs	$23M	$15M	$38M
Annual Operation and Maintenance	$12M	$5M	$17M

Includes:
- Infrastructure upgrades, operation and maintenance
- Adds personnel to bring network staffing up to robust levels, operate new EEW 24/7, and test and monitor system performance
- Support for continued R & D

Does not include current network funding.

Induced seismicity continues to be a major thrust for the USGS. The seismicity rate in some states such as Oklahoma has increased by a factor of 10 or more since 2008. This increase could

potentially affect the earthquake hazard maps for the region. Induced seismicity represents a real challenge to the National Seismic Hazard Map Project (NSHM) because it is time dependent with forcing factors unrelated to natural processes. The National Seismic Hazard And Risk Assessment Steering Committee, chaired by John Anderson, will formulate plans by which the effects of induced seismicity can be incorporated into the national seismic hazard maps. The committee will meet in July 7 and 8 in Golden.

Reports by Jill McCarthy (Hazards Science Center -HSC- in Golden) and Bill Ellsworth (Earthquake Science Center –ESC- in Menlo Park) highlighted current activities and state of health for each center. McCarthy pointed out that among the most pressing problems are a lack of staff (research and technical) for the national seismic hazard maps and the need for more software developers. Ellsworth also focused on staffing issues. In particular, the demographics of the ESC illustrate a large number of GS-14 and GS-15 researchers who are eligible for retirement. This is an issue where forward planning will mitigate the effects. Ellsworth noted that replacing those who have separated since 2008 is not close to 1-to-1. Both centers are directing resources to monitoring and understanding induced seismicity, which is a new initiative within EHP.

SESAC heard reports on the National Seismic Hazard Map Committee (NSHMC) by John Anderson, the National Earthquake Information Center (NEIC) by Gavin Hayes, the Albuquerque Seismic Lab (ASL) by Lind Gee, the Advanced National Seismic System (ANSS) by Cecily Wolfe, the Unified California Earthquake Rupture Forecast version 3 (UCERF3) by Ned Field, and ShakeMap/PAGER by Dave Wald. NSHMC will hold its first meeting on July 7, 8, 2014. The next SESAC meeting will be an appropriate time for a report on its outcome. UCERF3 has been completed. These reports always point to new questions that can be addressed in a subsequent analysis. Of major concern is that UCERF3 has a substantial off-fault moment release with definite implications for the recurrence interval of large earthquakes on the major faults. ASL is the primary field support within the USGS for the Global Seismographic Network (GSN). The GSN has reached its target goal of ~150 stations for global coverage and no new GSN stations (either by IRIS/IDA, through UC San Diego or by USGS GSN, through ASL) have been installed in the past seven years. Equipment upgrade is underway with near-complete installation of new data acquisition systems at all stations. New borehole instruments have been acquired using funds provided by the Department of Energy, but there are no funds for installation. ANSS should be adopting as many as 160 of the NSF Transportable Array stations in the central and eastern US (CEUS). This will significantly improve monitoring in the CEUS. The annual operating cost though will be nearly $1.4M/yr for these 160 stations. At present the NSF funds IRIS to operate these stations. USGS will be updating the ANSS vision document, USGS Circular 1188, which was the original document that provided the justification and implementation plan for ANSS in 1999, with a new outlook on the needs for seismic monitoring within the US. ShakeMap/PAGER has been one of the most successful products developed by ANSS. ShakeCast has become a tool for agencies with critical facilities. The increasing number of requests for ShakeMap/PAGER from earthquake scenarios has started to drain resources. Induced seismicity is increasing the workload at the NEIC.

As SESAC looks to years 2017 and beyond it is important to know how the EHP sees itself as a research agency that has defined missions. McCarthy and Ellsworth provided overviews of the

important strategic decisions that will need to be addressed in the future. Although SESAC will review the entire EHP at its next meeting, there were several common themes. New data sets will likely come from arrays, which have a very large number of sensors. Consequently there will be the need to develop new tools for storing and analyzing such data sets in the context of high performance computing. This will require a workforce where computer scientists will comprise a significant fraction of the technical staff. Induced seismicity is likely to continue and affect a larger segment of the CEUS and even the WUS. The EHP will have to consider induced seismicity as a driving force for both funding and research opportunities. As the national seismic hazard maps are updated and as products such as ShakeMap/PAGER are improved, EHP will have to consider how far it will go into risk and loss estimation. Pursuing this activity has to be considered carefully. Risk and loss are areas that have generally been in the domain of private industry. It is a direction that will likely require more support from earthquake engineers, of which the EHP has very few at present, as well as individuals well versed in statistics. Both Centers recognized that remote sensing data are becoming more abundant and likely to impact the EHP missions.

Bill Leith gave an overview of issues currently in front of EHP as well as issues that might arise. One of the most pressing is that the NEHRP has not been reauthorized since the previous period 2004-2009. Reauthorization will not likely be brought before the current Congress. A positive development is that the USGS is recognized as a science agency within the administration and thus eligible for federal Research and Development Funds. The SESAC sees this as a very positive development. In its annual guidance to the science agencies, OSTP highlighted national needs such as sustainable energy and mineral development and climate. OSTP also identified areas of interest including energy, big data and natural hazards but did not specifically mention earthquakes.

The lack of reauthorization, and the reduced visibility of earthquake hazards within OMB and OSTP, may indicate that the EHP has a much lower priority at the upper echelons of the government. The last significant, damaging US earthquake was 20 years ago, Northridge, California. The 2011 Mineral, Virginia, earthquake alerted the eastern US to its vulnerability. Earthquakes in Oklahoma, Kansas, Texas, Colorado, etc. continue to reinforce the fact that almost any state could be vulnerable. The Administration and Congress must be reminded that the hiatus in strong earthquakes does not diminish the inevitability that one will occur. Lowering the priority EHP's role in mitigating the effects of earthquakes will seriously affect this nation's resilience when the next damaging earthquake occurs.

Appendix A
SESAC Committee May 2014

Professor Ralph Archuleta, Chair, University of California, Santa Barbara, CA
Professor John Anderson, Chair of the National Seismic Hazard Map Committee, University of Nevada, Reno, NV
Professor Greg Beroza, Chair of the USGS Advanced National Seismic System (ANSS), Stanford University, Stanford, CA
Ms. Julie Furr, Professional Engineer, Chad Stewart and Associates Engineering, Inc., Lakeland, TN
Dr. John Parrish, California State Geologist, Sacramento, CA
Professor Christine Powell, Center for Earthquake Research and Information (CERI), University of Memphis, TN
Professor Emeritus Terry Tullis, Chair of the National Earthquake Prediction Evaluation Council (NEPEC), Brown University, Providence, RI
Dr. David Simpson, President of the Incorporated Research Institutions for Seismology (IRIS), Washington DC

Scientific Earthquake Studies Advisory Committee (SESAC)

May 29-30, 2014
USGS National Earthquake Information Center, Room 535
Golden, Colorado

AGENDA - Final Draft

May 29th - Thursday

8:45	Meet-n-greet
9:00	Introductions, Agenda, SESAC business (Archuleta)
9:15	Program overview and 2014-2015 budgets (Leith)
10:00	Science Center SOH reports (Brocher, McCarthy)
10:30	Break
11:00	National Maps Steering Committee Report (Anderson, Petersen)
11:30	ANSS Steering Committee Report (Beroza, Wolfe)
12:00	Lunch
13:00	Global Seismographic Network (Gee, Wolfe)
13:30	Future direction of the NEIC (G. Hayes)
14:15	ANSS Products (Wald)
15:00	Break
15:30	UCERF3 and time dependent faulting models (Field)
16:00	Earthquake Likelihood Forecasting (Blanpied)
16:30	NEHRP update (J. Hayes)
17:00	Adjourn
19:00	Group dinner

May 30th - Friday

8:45	Meet-n-greet
9:00	2016-2020 Strategic Planning - Introduction (Leith)
9:30	Science Center perspective - ESC (Ellsworth)
10:00	Science Center perspective - GHSC (McCarthy)
10:30	Break
10:45	Issues and Opportunities, 2016-2020 (structured discussion)
12:00	Lunch
13:00	Executive Session - 2 hours
15:00	NEIC Tour
16:00	adjourn