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May 10, 2012

Dr. Marcia McNutt, Director
U.S. Geological Survey
12201 Sunrise Valley Drive, Mail Stop 100
Reston, VA 20192

Dear Director McNutt,

On behalf of the members of the Scientific Earthquake Studies Advisory Committee (SESAC), I am providing the committee's report on the U.S. Geological Survey (USGS) Earthquake Hazards Program for transmission to Congress, the Department of Interior, and the USGS's federal partner agencies in the National Earthquake Hazards Reduction Program (NEHRP).

This report is based on the SESAC meeting of March 29 and 30, 2012, which you attended and provided your thoughts about issues affecting the USGS. Because the issues affecting the USGS Earthquake Hazards Program arise continuously, the SESAC thought it appropriate to provide summaries that follow our meeting. Following our discussions of this meeting, the committee makes two principal recommendations:

1. The USGS needs to play a direct, active role in its operation and/or certification of Earthquake Early Warning (EEW). The technical development of EEW algorithms is only one element. The USGS should also explore potential sources of support for the significant costs for implementation and operation of EEW; define the links between EEW and the existing Advanced National Seismic System (ANSS) structure; and examine how EEW might have different effects depending on the region affected.
2. The USGS should continue to support the basic program that evaluates the effectiveness of earthquake prediction methods. However, making earthquake forecasting operational for short-term predictions is in an embryonic stage. Nonetheless, the USGS should develop a strategy for how it will respond to the public's basic question about the probability of a larger earthquake given that an earthquake has just occurred.

The attached report provides more detail on these recommendations. These two issues have a significant intersection between the USGS scientific expertise and societal response. The USGS has always been aware that the public is interested in any forewarning for earthquakes. The issues that are arising have both a scientific aspect and a societal aspect, both of which will need considerable thought.

As before, SESAC continues to be appreciative of your direct involvement with the committee and keeping it informed about the most recent developments. Similarly SESAC truly appreciates the dedication, expertise and professionalism of the USGS personnel. The information and reports SESAC receives are of the highest quality, allowing SESAC to focus directly on the issues before it. If you think that there is an issue in the Earthquake Hazards Program that should be discussed, please do not hesitate to let me or any member of SESAC know.

With warm regards,

Ralph J. Archuleta

Ralph J. Archuleta
Professor of Earth Science

cc: Members, Scientific Earthquake Studies Advisory Committee
David Applegate, Associate Director, Natural Hazards
William Leith, Acting Program Coordinator, Earthquake Hazards

Scientific Earthquake Studies Advisory Committee
Report for March 2012
To the Director of the U. S. Geological Survey

This is the report of the Scientific Earthquake Studies Advisory Committee (SESAC) to the Director of the U. S. Geological Survey (USGS) for transmission to Congress. This report covers the period between November 11, 2011 and March 29, 2012. Rather than wait for a full year to issue a report, SESAC decided to issue reports following each meeting. This will ensure that current topics are discussed in a timely manner. This report addresses issues that arise through the USGS's role in the National Earthquake Hazards Reduction Program (NEHRP). The members of SESAC are listed in Appendix 1 at the end of this report.

SESAC MANDATE

The Scientific Earthquake Studies Advisory Committee was appointed and charged, through Public Law 106-503 re-authorizing NEHRP, to review the USGS Earthquake Hazard Program's roles, goals, and objectives; assess its capabilities and research needs; and provide guidance on achieving major objectives and the establishment of performance goals.

INTRODUCTION

To provide the context for this report the Committee reiterate the mission of the USGS within NEHRP: *To develop effective measures for earthquake hazards reduction, promote their adoption, and improve the understanding of earthquakes and their effects on communities, buildings, structures, and lifelines,* as well as *to provide the Earth science content needed for achieving these goals through research and the application of research results, through earthquake hazard assessments, and through earthquake monitoring and notification.*

SESAC met March 29 and 30 at the USGS headquarters in Reston, Virginia. During this meeting the Committee had an extensive briefing and discussion with Dr. Marcia McNutt, Director of the USGS. Acting coordinator of the USGS Earthquake Hazards Program, Dr. John Filson, provided an overview of the 2013 proposed budget and new initiatives related to induced seismicity and seismic hazards in the eastern US. SESAC was briefed by other members of the USGS on topics such as induced seismicity, eastern US hazard studies following the Virginia earthquake of August 23, 2011, earthquake early warning, opportunities for expanding the Advanced National Seismic System (ANSS) in the central and eastern US, changes to the National Earthquake Information Center (NEIC) web pages, and status of the Uniform California Earthquake Rupture Forecast (UCERF3). In addition the Committee heard from Dr. Terry Tullis, SESAC member and chair of the National Earthquake Prediction Evaluation Committee.

Based on the discussions of this meeting SESAC makes two recommendations:

1. USGS needs to play a direct, active role in its operation or certification of Earthquake Early Warning (EEW). The technical development of EEW algorithms is only one element. The USGS should also explore potential sources of support for the significant costs for implementation and operation of EEW; define the links between

EEW and the existing ANSS structure; and examine how EEW might have different effects depending on the region affected.

2. The USGS should continue to support the basic program that evaluates the effectiveness of earthquake prediction methods. However, making earthquake forecasting operational for short-term predictions is in an embryonic stage. Nonetheless, the USGS should develop a strategy for how it will respond to the public's basic question about the probability of a larger earthquake given that an earthquake has just occurred.

PRIMARY POLICY ISSUES DISCUSSED IN THE MEETING OF MARCH 29-30, 2012

Earthquake Early Warning (EEW)

Earthquake Early Warning (EWW) systems use the rapid detection of significant earthquakes to provide automated warning of anticipated strong shaking. With sufficiently dense networks of seismometers, warning times of seconds to minutes can be achieved for locations that are 10's to 100's of kilometers from the earthquake epicenter. Operational EEW systems have already been implemented in Japan and Mexico, where they are being used to provide public warnings and to trigger the automatic shutdown of critical facilities. The development and implementation of a reliable EEW system is a complex endeavor that requires significant research, capital investment and operational costs, along with an important educational effort to ensure that the public and private sectors are aware of both the significance and limitations of relying on automated warnings. The cost for a robust operational system in California alone greatly exceeds the current resources of the USGS Earthquake Program. As the federal agency responsible with providing the nation with earthquake information, the USGS must take a leadership role in assessing the costs and benefits of EEW systems throughout the US, and encouraging public and private partnerships, at federal, state and municipal levels, that will be necessary to support eventual implementation and operation.

A group of academic institutions is now in the process of developing a prototype Earthquake Early Warning system for the west coast of the contiguous US. This effort was initially funded by the USGS. Recently, The Gordon and Betty Moore Foundation provided $6 million to three universities (University of California at Berkeley, California Institute of Technology and the University of Washington) to develop operational EEW algorithms. The USGS anticipates receiving a modest amount of funding from the Moore Foundation for a coordination role in this effort. As this, or another, prototype moves towards full implementation, the USGS would need to play a direct, active role in its operation or certification. Any warning would have to be issued by the USGS, not one of the universities. SESAC thinks that USGS needs to take a more active role now in not only the evaluation of the performance of this prototype but also in assessment of the capabilities, limitations and political/liability issues related to implementation of an EEW system for all parts of the US. An evaluation of the Caltech-Berkeley-UW prototype system will obviously focus on the western US where it is being developed, but the evaluation should consider the potential for such a system in other regions of the country as well. It is important that the capabilities and limitations of an EEW system are accurately assessed and not oversold or undersold.

The USGS evaluation should be specific about the situations for which an EEW system could and could not give an effective warning; these situations may be very different in the eastern and western US. For example, while large earthquakes are rare in the eastern US, low ground attenuation factors means that strong shaking is felt over a much larger area than in the western US. Thus, a broad region might benefit from warning about the coming seismic waves from an M>6 event in the East. A likely limitation of any EEW system is that the areas that experience the strongest shaking are very close to the fault(s), and thus the warning time may be zero or otherwise too short in regions close to where the earthquake initiates. However, faults in the western US and Alaska have the potential to generate large to great earthquakes, and the timeliness and effectiveness of warnings would be different for a number of plausible scenarios, such as an M6-7 event in urban California, an M7-8 event on the San Andreas fault, or great subduction earthquakes in Cascadia or Alaska. Potential events in Hawaii, Puerto Rico or other US territories should also receive consideration if the prototype system shows enough promise that it might move quickly to implementation.

Operational Earthquake Forecasting (OEF)

Support for the Collaboratory for the Study of Earthquake Predictability (CSEP) should be a high priority for the USGS. It is vitally important to understand to what extent earthquakes may be predictable and to evaluate the effectiveness of a wide variety of proposed methods for estimating the probability of occurrence of future earthquakes. This is not only an important scientific issue but also has important practical applications for the immediate benefit of society. Any method that might be envisioned for use in Operational Earthquake Forecasting (OEF) must first be shown to be viable by thorough testing in CSEP

The development of Operational Earthquake Forecasting is in it infancy. To what extent it will ever be practical for forecasting anything except earthquakes in an aftershock sequence is presently unclear, even though the physics of aftershock and foreshock occurrence may be the same. Accurately assessing the probability of aftershocks, especially those with large magnitude, has significant engineering consequences as a community rebuilds following a damaging earthquake. At present only the Short Term Earthquake Probability (STEP) and Epidemic-Type Aftershock Sequence (ETAS) methods are based on very well established seismological observations, the systematic occurrence of aftershocks and the frequency-magnitude relationship. Even the relative merits of STEP and various versions of ETAS need to be further evaluated by testing in CSEP before it is clear which is better for use in OEF. The next most likely concept to include in OEF may be that of Coulomb stress transfer. However, it has not undergone rigorous testing in CSEP and this is important to do. A variety of other methods require further research, such as, the UCERF3 forecast model, the incorporation of large earthquake clustering, analysis of geodetic transients, among others. These are further from being useful in OEF, if indeed they ever become viable approaches. Finally and even more exploratory, a wide range of often highly publicized, but totally unproven methods, such as space-or-land-based observations of electromagnetic anomalies or thermal anomalies, are currently only in the speculative stages. Many years of careful scientific research, including evaluation in CSEP, will be necessary before they could ever be considered as serious and viable approaches.

From a technical point of view, OEF has not reached the stage where it does more than provide a statement of increased or decreased probability of an earthquake. However, from a practical point of view, the public will want a statement from an authoritative agency, namely the USGS, about the probability of a larger earthquake given the occurrence of an earthquake or swarm of earthquakes, vis-à-vis, the 2009 L'Aquila, Italy, earthquake. This is the conundrum. For an earthquake with magnitude 5.5 or larger there is a probability ~5% that an earthquake as large or larger earthquake will follow in the same region within 21 days[1], but at present it does not appear that OEF provides anything more substantial. The statistics of aftershocks can be critical in assessing the probability of large aftershocks that might affect the design in the days, months years or decade(s) following a damaging earthquake, vis-à-vis the Canterbury sequence starting with the Darfield earthquake in September 2010, and followed by a series of damaging aftershocks, notably the February 22, 2011, Christchurch earthquake. Thus a quantitative assessment of the probability of a large aftershock is of major interest.

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[1] Luen, B. and P. B. Stark, 2008, Testing earthquake predictions, IMS Collections, Probability and Statistics: Essays in Honor of David A. Freedman, Vol. 2, 302–315, Institute of Mathematical Statistics, 2008, DOI: 10.1214/193940307000000509

SESAC Members
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