Mr. James Reilly, Director
U.S. Geological Survey
12201 Sunrise Valley Drive, Mail Stop 100
Reston, VA, 20192

October 11, 2019

Dear Director Reilly:

The Scientific Earthquake Studies Advisory Committee (SESAC) is charged with reviewing the USGS Earthquake Hazard Program's (EHP) roles, goals, and objectives; assessing its capabilities and research needs; and providing guidance on achieving major objectives and the establishment of performance goals. The SESAC was involved in two meetings in its efforts to fulfill its mandate: a SESAC joint subcommittees meeting on November 27-28, 2018 and a full SESAC meeting on August 6-7, 2019.

The attached report summarizes SESAC discussions during its meeting. It contains our recommendations and points of emphasis, which are underlined in the report. Among the most important capabilities of the EHP is to respond to earthquakes, and we lead our report with the USGS response to the 2019 Ridgecrest, California earthquake sequence. If any issues require clarification, please don't hesitate to contact me.

Regards,

Gregory C. Beroza, Chair of SESAC.
Wayne Loel Professor of Geophysics

Cc: David Applegate, Associate Director, Natural Hazards
Jonathan Godt, Acting Science Director for Earthquake and Geologic Hazards
Members, Scientific Earthquake Studies Advisory Committee

The 2019 Ridgecrest Earthquake Sequence. The July 2019 *M* 7.1 Ridgecrest, CA earthquake sequence stress-tested many aspects of USGS response, including: ShakeAlert performance in the seconds following the largest quakes, web demand spikes that reached ~60,000 requests per second, intense media interaction, and the rapid deployment of field teams to acquire critical measurements quickly and in coordination with the US Navy, on whose land much of the rupture was located. The sequence exposed the extent to which the erosion of core capabilities, which the SESAC has noted in previous annual reports, has left little margin for error throughout EHP. Ridgecrest stretched USGS capabilities to the limit, which leads SESAC to question whether EHP is sufficiently supported to respond effectively to a similar-sized earthquake in an urban environment, where public demand for products and services would be far higher than for this geographically remote sequence. We review the USGS response to the Ridgecrest sequence in three general categories: ShakeAlert, science products, and field deployments.

ShakeAlert. For the July 4, 2019 *M* 6.4 foreshock, ShakeAlert issued a first alert 7 seconds after the earthquake began with excellent initial event location error (1 km). By 10 seconds the assessed magnitude had grown to M 6.0, and nearly 60 updates followed over the next half-minute. For the *M* 7.1 mainshock 34 hours later, the system significantly underestimated the magnitude (*M* 6.4 vs. *M* 7.1). Citizens of Los Angeles did not receive alerts from the ShakeAlertLA app, but see our comments on ShakeAlert below. Nearly 70 additional alerts were generated for the largest of the nearly 8,000 aftershocks with ~9 seconds average delay, and only one false alert.

Science Products. The generation of EHP science products, including operational aftershock forecasting, delivered through the National Earthquake Information Center (NEIC) was successful and highly appreciated by the US Navy. The Ridgecrest sequence, however, revealed bottlenecks in critical internet product distribution due to the spiking of user requests, which increased to nearly 300 times above background levels, peaking at 3.2 million requests per minute. If this had been an urban earthquake, data requests would have greatly exceeded these numbers. We recommend that EHP develop the ability to dynamically scale web services following large earthquakes. Ensuring the staffing and budgets to remove these IT bottlenecks should be a high priority for EHP.

Field Deployments. Despite taking place on the 4th of July holiday weekend, the USGS demonstrated an impressive mobilization and deployment of science teams to the Ridgecrest area. Fault rupture reconnaissance started the day of the *M* 6.4 event, and within several days surface offset mapping, LIDAR scanning of the rupture, and the deployment of portable seismic and geodetic instruments were all under way (in substantial collaboration with the US Navy at China Lake Naval Station). For the Ridgecrest data the USGS has instituted vetting procedures followed by immediate release to assure that the unique data sets they acquired are both accurate and openly available.

ShakeAlert/Earthquake Early Warning (EEW). ShakeAlert represents an important, rapidly developing aspect of the EHP. The July 24, 2019 Report of the Earthquake Early Warning External Working Group to SESAC recommended that the initial ShakeAlert rollout for California (currently slated for October 2019) include the entire state. Experiences during the recent *M* 5.6 Petrolia earthquake of June 23 and the July 4 *M* 6.4 and July 5 *M* 7.1 Ridgecrest earthquakes highlight the benefits and opportunities of an EEW system with a wide geographic capability. These earthquakes revealed issues with the system including those related to ShakeAlert magnitudes and what

messages should accompany the alerts. Public response to this sequence demonstrated a desire for alerts for felt, and not just for damaging, shaking levels. Changing ShakeAlert for that purpose would reclassify ShakeAlert as both an information stream and as a safety-of-life tool. We support the notion that multiple alert levels should be issued. This raises issues, such as how to differentiate WEA messages warning of an "imminent threat" from those for felt, but not dangerous, shaking. It also provides an opportunity to provide information for more effective post-earthquake response, which could be highly beneficial. SESAC supports the recommendation of a statewide California rollout with appropriate protocols for working with adjacent states and nations that might benefit from an alert to a California event.

National Seismic Hazard Mapping. The National Seismic Hazard Model (NSHM) Steering Committee reported that NSHM personnel have completed an update for the Lower 48 states, which is on the verge of being released. An updated model for Hawaii is progressing towards completion. There was a critical meeting in Honolulu on September 18, 2019 to describe the preliminary version of the update and seek more local review. The next priority of the NSHM team is updating the Alaska model. Following that, the next update for the lower 48 states is currently scheduled for 2023. The NSHM Steering Committee is very pleased that the President's budget request for FY 2020 included a $2.65 million base budget supplement to support the NSHM project and hopes that Congress will support that increase. The NSHM Steering Committee report reiterated their conclusion from 2015 that with sufficient resources, new classes of data (e.g. lidar, global positioning system geodesy, improved seismic networks) could be fully utilized to reduce significantly the uncertainties in the NSHM, with benefits to all users of their seismic hazard information.

Participation of USGS Personnel in Scientific Conferences. Recent changes to travel policy for USGS personnel negatively affect EHP's effectiveness by reducing engagement with national and international colleagues and with regional stakeholders. Allocating participation at scientific meetings on an annualized basis is problematic because major earthquakes, and the corresponding impetus to engage at critical meetings, may occur at any time. Difficulties of this kind are currently being encountered in authorizing USGS participation at the December AGU meeting in San Francisco regarding the Ridgecrest, California earthquake sequence. This is the largest such sequence in the state in two decades and constitutes a clear wake up call for more densely populated areas. The present travel policy compromises the ability of the USGS to communicate essential findings on this sequence, including those in earthquake early warning, fault rupture studies, and aftershock forecasting, and to highlight its activities within the science community and in the broader public interest. SESAC recommends changes in USGS travel policies that will allow EHP members to attend major earthquake science meetings as needed (specifically those of the American Geophysical Union, Seismological Society of America, and the Geological Society of America).

Towards a Sustainable EHP Program. SESAC has noted in previous years the erosion and loss of capabilities due to the reduced buying power of a flat 'core' budget. This results in capabilities lost through retirements that cannot be refilled, and new requirements that divert staff from previous work. In some cases, these changes result in essential capabilities that are one-deep or are held by staff who are eligible to retire. Among the outcomes due to lost capabilities and reduced funding are:

(1) Flat budgets for the ANSS (outside of ShakeAlert) have led to the cessation of support for a growing number of regional seismic networks (RSNs). This has resulted in diminished earthquake monitoring capability in seven states (Virginia, Kentucky, Massachusetts, Rhode Island, Maine, California, and Montana) and changes in three more (New York, Vermont, and New Hampshire). SESAC learned of the USGS' intent to defund two additional networks in 2020: the Lamont-Doherty (Columbia University) and St. Louis University networks, which will further impact earthquake monitoring and regional engagement. Some of the monitoring functions from these networks are being absorbed by the USGS, but this trend leads to reduced local expertise and to the loss of key partnerships. Regional seismic networks get only a fraction of their funding from the USGS (they are highly leveraged by states, universities, and other partners), and the effects of such cuts are thus amplified. The USGS and RSNs have been creative in limiting costs, but that can only go so far. SESAC views this ongoing situation with alarm.

(2) The USGS can no longer afford to sustain an office in Memphis and the corresponding research focused on the Central and Eastern US (CEUS). Although regional seismic network organizations have attempted to continue USGS efforts in conjunction with their own programs, closure of the Memphis office, and departures of key outreach leaders across the CEUS, has dramatically reduced public engagement and USGS effectiveness in the region.

(3) In addition to the networks mentioned above, the USGS has reduced or eliminated support for borehole strainmeters, fault creepmeters, EM sensors, and water level monitoring in wells. The USGS' instrument pool available to respond flexibly to future earthquakes is now extremely limited, and existing earthquake monitoring hardware is aging and is difficult to maintain with no clear path to equipment upgrades.

(4) The USGS has had to slow down its work on urban seismic hazard maps (USHMs) for Salt Lake and Reno/Carson City, and is understaffed for developing parallel work for the earthquake-threatened cities of the SF Bay Area, Seattle/Tacoma, and Charleston. Supporting work to map ground motion amplification and liquefaction has also been compromised by retirements that have not been filled.

(5) The USGS has had to cease work for OFDA, NRC, and DOE in reimbursed seismic hazard analysis abroad because existing staff are fully occupied meeting domestic deliverables.

(6) A broad range of capabilities in geodetic monitoring, active-source seismology, understanding earthquake source properties, fault mapping, and public outreach for hazard maps, among others, are in danger of being lost entirely.

This list is not exhaustive, but it illustrates the breadth and depth of the challenges facing the EHP. The nation depends on the USGS to provide reliable, state-of-the-art, and authoritative information on earthquakes to guide response and to mitigate their effects. The EHP has done a remarkable job under a flat budget, but the situation is unsustainable. The $2.65 million enhancement this year was a step in the right direction, but without a deeper and sustained commitment from Washington, core capabilities will erode, and the nation's vulnerability to earthquakes will increase unnecessarily. The effort required is substantial[1,2], but it is essential given what is at stake. SESAC reaffirms its belief and recommendation from our 2018 report: the budget for the EHP should be in line with the

findings of the National Research Council report[1] that documents a need for nearly quadrupling the EHP budget if the EHP is to fulfill the expectations of the nation.

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[1]National Earthquake Resilience: Research, Implementation and Outreach, The National Academies Press, ISBN 978-0-309-18677-3, 244 pp (2011).

[2]U.S. Geological Survey, 2017, Advanced National Seismic System—Current status, development opportunities, and priorities for 2017–2027: U.S. Geological Survey Circular 1429, 32 p., doi:10.3133/cir1429.