EARTHQUAKE EARLY WARNING FEASIBILITY IN THE BAY AREA

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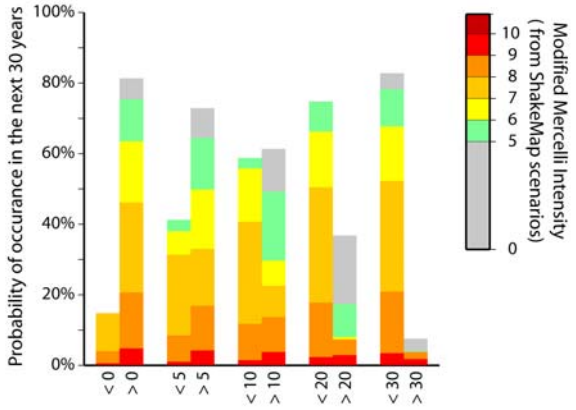
RESEARCH OBJECTIVES

The goal of this NEHRP-funded research was to assess the feasibility of implementing an earthquake warning and alerting system in the Bay Area using existing seismic infrastructure. We have focused our study on three objectives: 1) What would the probabilistic distribution of warning times be in the Bay Area given future likely earthquakes? 2) What is the accuracy of hazard estimates using the ElarmS methodology (www.ElarmS.org) in northern California? 3) How can potential users assess the cost-benefit of implementing an early warning response, and of taking action during a specific event?

ACCOMPLISHMENTS

The ElarmS algorithms have now been ported to northern California for use with the Berkeley and USGS networks. Time dependent hazard prediction maps have been generated for an initial set of ~20 historical earthquakes in the region with magnitudes ranging from 4.0 to 7.1.

Using the set of likely future earthquakes identified by the Working Group on California Earthquake Probabilities [2003] the warning time probability density function has been calculated for various locations across the region. An example is shown for the City of San Francisco. The figure shows the probability of an earthquake by 2032 for which there could be more or less than 0, 5, 10, 20 and 30 sec of warning using the existing seismic networks. It shows that there is an 80% probability of an event for which there could be warning and only a 15% probability of an event for which there would be no warning during the next 30 years. The color scale in the figure shows the estimated intensity of ground shaking in the city. For the most damaging events (MMI $\geq$ 5 shown red) it is more likely there would be more that 20 sec warning that less.



Probability of greater than or less than 0, 5, 10, 20, and 30 seconds warning for San Francisco for all identified WG02 earthquake scenarios

The errors in hazard estimates generated by ElarmS have been modeled using a dataset from southern California. The uncertainties introduced at each step of the processing sequence have been isolated, modeled and then propagated through the entire system. The complete error model provides a measure of the aggregate accuracy of the system which can be used offline to assess the cost-benefit of using the system in the future. The error model can also be used online during an earthquake to provide the uncertainty in a hazard prediction. The same error analysis framework can be applied in northern California.

SIGNIFICANCE OF FINDINGS

Warning times that could be available to residents of the Bay Area range from a few seconds to ~80 sec depending on the epicenter of the earthquake. While little to

no warning time would be available at the epicenter, many of those experiencing damaging ground shaking would receive warning for most earthquakes.

Application of the ElarmS algorithms to earthquakes in northern California shows a similar magnitude-period scaling relation (used to assess hazard) to that in southern California. The ~25 km spacing of stations in the Bay Area that could be used by ElarmS provides rapid hazard assessment for moderate sized events in the region while the sparser coverage to the north and south can provide advance warning of major ruptures propagating toward the metropolitan areas.

The error analysis of the ElarmS methodology provides a framework to understand the errors in future warning information and during an earthquake. This framework allows potential users to assess the utility of the warning system through cost-benefit analysis.

PUBLICATIONS

Papers

Olson, E.L., and R.M. Allen (2005) The deterministic nature of earthquake rupture. *Nature* **438**, 212-215, doi:10.1038/nature04214.

Lockman, A.B. and R.M. Allen (2005) Single station earthquake characterization for early warning. *BSSA* **95** (6), 2029-2039, doi: 10.1785/0120040241.

Papers in review

Allen, R.M. Probabilistic warning times for earthquake ground shaking in the San Francisco Bay Area.

Grasso, V.F. and R.M. Allen. Uncertainty in real-time earthquake hazard predictions.

Allen, R.M. The ElarmS earthquake warning methodology and application across California.

Abstracts

Allen, R.M. and E. Olson (2005) The relation between rupture initiation and earthquake magnitude. AGU Fall Meeting 2005.

Grasso, V. and R.M. Allen, (2005) Earthquake Warning Systems: Characterizing Prediction Uncertainty. AGU Fall Meeting 2005.

Wurman, G. and R.M. Allen, (2005) ElarmS Earthquake Alarm System: Application in Northern California. AGU Fall Meeting 2005.

Allen, R.M. (2005) Application of ElarmS across California. Earthquake early warning workshop, Caltech.

Allen, R.M. and E. Olson (2005) The Deterministic Nature of Earthquake Rupture? Chapman Conference: Radiated Energy and the Physics of Earthquake. Portland, Maine, June 2005.

Allen, R.M. (2005) Earthquake early warning in northern California, EERI/ISSS First International Conference on Urban Disaster Reduction, Kobe, Japan, January 2005.

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