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REVIEW OF THE
LAWRENCE LIVERMORE LABORATORY
DRAFT SEISMIC HAZARD ANALYSIS

October 1979

prepared for

JERSEY CENTRAL POWER & LIGHT COMPANY
MORRISTOWN, NEW JERSEY

prepared by

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INTRODUCTION

The following report presents the results of a brief review by URS/John A. Blume & Associates, Engineers, of San Francisco, for Jersey Central Power and Light Company of Morristown, New Jersey, of a report prepared by Lawrence Livermore Laboratory (here called the LLL report).

The LLL report consists of three volumes titled as follows:

> *Draft Seismic Hazard Analysis: A Methodology for the Eastern United States*
>
> *Draft Seismic Hazard Analysis: Site Specific Response Spectra Results*
>
> *Seismic Hazard Analysis: Solicitation of Expert Opinion*

The fundamental test of a seismic hazard analysis that is based on a given record of historic seismicity is to compare the results with the historic record. The results of the LLL report do not compare well with the historic record. For the five sites in the eastern U.S., 200-year-return-period "synthesis" peak ground accelerations fall in the range from 106 to 141 cm/sec^2 (LLL, SRSS, 1979, pp. 6.52-6.56). The modified Mercalli intensity corresponding best to this range of accelerations is VII (100 cm/sec^2 according to Murphy and O'Brien [1977]; 130 cm/sec^2 according to Trifunac and Brady [1975]). Thus, for the five sites and for a vast area of comparable hazard in the eastern U.S., the LLL report calculates a 200-year recurrence of intensity VII damage. This result is demonstrably at odds with the historic record of seismogenic damage, which, at the intensity VII level, is complete for the past century and perhaps 50% complete for the previous century (McGuire, 1977). The characteristic maximum historic intensity at sites in the eastern U.S. is VI or less, rather than VII or more. Thus, an elementary test of the LLL report indicates that the ground motion estimates are too high by a factor of about 2.

In this review, we focus on two questionable aspects of the report. It is found that the use of an erroneous ground motion - distance relation contributes substantially to the hazard overestimate. To correct this error in itself would be a simple task. However, it is our opinion that there are also

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methodological errors in the solicitation of expert opinion and in the use of information acquired.

GROUND MOTION - DISTANCE RELATION

The peak ground motion equation used in the hazard analysis (p. 5.21, SRSS results) is

$$\ln a = 1.98 + 0.57I_0 - 0.0026r - 0.501r \quad (1)$$

where a is peak ground acceleration in cm/sec^2, I_0 is epicentral intensity, and r is epicentral distance in kilometers. This acceleration function has a singularity at the epicenter, $r = 0$, where the acceleration becomes indefinitely large. The hazard calculation involves an integration over each source area, and, because all the sites in question lie within seismic source areas, this involves an integration over a singularity. The result is indefinite.

In order to assess the error arising from the attenuation relation, URS/Blume compared the hazard calculated from the LLL equation (truncating the integral at an epicentral distance of 1 cm) with that calculated from a reliable equation (McGuire, 1977):

$$I_{site} = I_0 \qquad r \leq 10 \text{ km}$$
$$I_{site} = I_0 + 3.08 - 1.34 \ln r \qquad r > 10 \text{ km} \quad (2)$$

together with the acceleration-intensity correlation (Murphy and O'Brien, 1977):

$$\log_{10} a = 0.25 + 0.25I \quad (3)$$

The results are given in the following table, which lists the ratio of the rates of exceedance, according to the LLL and McGuire equations, of various relevant levels of peak ground acceleration.

EXCEEDANCE RATES CALCULATED FROM THE LLL AND MCGUIRE ATTENUATION LAWS

Peak Ground Acceleration (cm/sec^2)	Ratio, LLL Exceedance Rate/ McGuire Exceedance Rate	
	Case A (I_{0max} = VII-VIII)	Case B (I_{0max} = X)
50	3.34	2.84
100	3.74	3.01
150	3.93	3.15
200	4.08	3.29

In case A, events of intensity up to VII or VIII and with an intensity-frequency distribution (McGuire, 1977)

$$d\log_{10}N/dI_0 = -0.5 \tag{4}$$

occur homogeneously within 250 km of the site. Case B is the same but with a maximum intensity of X.

The results show that the rates of exceedance calculated from the LLL attenuation relation are a factor of 3 or 4 greater than those from the McGuire relation, depending on the maximum intensity and on the level of ground motion under consideration. Thus, a 200-year recurrence interval in the LLL calculation would be a 600- to 800-year interval in the McGuire calculation. An equivalent way of viewing these results is to compare peak ground accelerations for the same recurrence interval. Such a comparison shows that, for recurrence intervals in the range from 200 to 4000 years, the LLL accelerations are 1.63 times as great as the McGuire accelerations for both cases A and B. According to the Murphy-O'Brien correlation (Equation [3]), this ratio of accelerations corresponds to a difference in modified Mercalli intensity of 0.85, or almost one unit. Thus, if the site intensity that has a recurrence interval of 200 years were VII in the LLL calculation, it would be a little greater than VI according to the McGuire calculation.

As we have noted above, correction of the erroneous attenuation relation used by LLL would bring the hazard analysis closer to consistency with the historic record of seismogenic damage in the eastern U.S.

METHODOLOGICAL PROBLEMS OF THE LLL ANALYSIS

The major effort of the LLL report is in the development and application to several sites in the eastern U.S. of the so-called Uniform Hazard Model. It was intended that this model would include subjective expert opinion to enhance the credibility of the model; however, the result was far from what was desired. The independent spectral shapes, one for each expert, were primarily derived from incomplete answers to the questionnaires, and no attempt was made to arrive at a consensus of opinion. This has rendered the resultant site-specific response spectra of limited value.

The credibility of the Uniform Hazard Model suffers from a lack of expertise in the preparation, execution, and interpretation of results of an expert-opinion survey. The survey was prepared poorly in that it lacked the means of achieving statistical consensus of opinion from the experts such as that provided through the Delphi Method (Blake, 1977, pp. 78-88). Moreover, the survey questionnaire asked the experts to return their educated guesses on a few parameters; however, the range of variation of the results was preset by the model determined by the research directors (LLL, Methodology, 1979, pp. 5-20, 5-21). The experts had no idea of what the final product of their answers would be, and no feedback at this level was attempted; hence, it is entirely possible that the experts do not agree with the final results.

The execution of the survey shows a lack of concern about incomplete answers (e.g., Questions 1-2, 2-8, 3-6, and 3-7), differences in units -- for example, some experts answered questions in MMI, others in M_b (LLL, Solicitation, 1979, pp. 11, 15, 32) -- and feedback in the design and operation of the questioning methods. At the same time, the survey found no means of avoiding nonresponse The extensive nonresponse to many questions (e.g., 4-5, 4-12, and 4-20) gives the answers a bias that in a sense invalidates much of the survey (Cochran, 1963, pp. 355-359); this nonresponse was not considered in the interpretation of the results.

In addition to these very important flaws in the execution of the expert-opinion survey, the report shows a general lack of coherence and clarity of meaning.

Because the Uniform Hazard Model methodology does not incorporate state-of-the-art knowledge in its seismic risk analysis part, the published results are even less credible. The attenuation model used in the Uniform Hazard Model methodology does not pay attention to the way intensities scatter around the mean as other models have done for the eastern U.S. (Anderson, 1978, pp. 1147-1179). Also, through a misguided consideration of nonindependence between data and subjective opinion, Bayesian methods were discarded. Geological and geophysical evidence can be used to produce a set of alternative assumptions concerning a mathematical (stochastic process) prior model of seismicity in a given source area (Esteva, 1975), or historical seismicity data from areas with similar geological features can be used as a prior distribution (Esteva and Basan, 1978, pp. 657-688).

The projected approach to estimating seismic hazard in the eastern U.S. has several positive features. Among them, the inclusion of subjective expert opinion in a seismic risk model is the most interesting. However, to include the experts' opinion in any model, both a consensus of opinion (perhaps in the form of distributions for the several parameters) and a total knowledge by the experts of the final results are needed. To achieve this, the final results could be reviewed, for example, in terms of damage to existing cities given the occurrence of a predicted earthquake (a realization of the predicted site-specific response spectra). This would give the experts a much-needed grasp of reality that is very hard to obtain from a response spectrum shape.

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