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9 November 1984

TO: ACRS Members Addressed
FROM: C. P. Siess *C.P.S.*
SUBJECT: EPRI-NRC WORKSHOP ON NUCLEAR POWER PLANT RE-EVALUATION
FOR EARTHQUAKES LARGER THAN SSE (SEISMIC MARGINS)
15-17 OCTOBER 1984, SAN FRANCISCO, CALIFORNIA

ATTACHMENTS:

- A. Agenda for the Workshop.
 - B. List of Attendees. (Those I know were not present are crossed out.)
 - C. EPRI Working Paper distributed in advance of the workshop. (Note restriction re distribution on first page.)
- 1-14. These are the papers handed out at the meeting, and referenced in the Agenda (Attachment A). Numbers 6 and 8 are missing; I will forward them when and if I get them.
- P2,12,13. For Papers Nos. 2, 12, and 13, the viewgraphs used in the are included. In some cases, these are more interesting than the written paper. Some have my notes on them.

COMMENTS

Paper No. 14

This paper, entitled "NRC Seismic Design Margins Program Plan", October 10, 1984, is essentially the same as the document previously given to Okrent and Siess and designated as Draft 3, September 27, 1984. It describes the NRC plan in two parts. Part I is directed chiefly at our recommendations for reviews of some plants for seismic margins. Most of this work is to be done by the "Expert Panel", and much of that is to be done by LLNL and SMA. Part II is to address "Information Needs"; the fulfilment of these needs will be through research programs in NRC and Industry, and much, if not all, of this research is not included in this "NRC Seismic Design Margins Program Plan." In other words, the NRC program is much larger than what is included in this Plan. For example, the current and proposed work on Seismic Fragilities is both extensive and expensive. It is mentioned in the Plan as a need but is not further described or considered, at least not at this stage.

Attachment C

This Working Paper (Note the disclaimer on the first page) has the title "Seismic Design Methodology Assessment." This actually was the subject of the Workshop. That is, the principal subject and the predominance of expertise was related to the methodology of analysis and design to be used to reevaluate seismic capacity of existing plants. (Actually, the word "design" is meaningless in the context of reevaluation, but this paper has some relatively strong suggestions that it is looking to improved or different design procedures for future plants.) Because of this emphasis or narrowing of scope, this paper does not mention PRA as a tool for assessing seismic margins. Nevertheless, it does a good job of identifying known sources of margins as well as known areas of uncertainty requiring further research. Because of its nature, it doesn't say who is going to do the research, or when.

Kennedy Papers

Paper No. 2 (see also viewgraphs Attachment P2) introduces two interesting points. The first is the definition of several different ways to define, calculate, and look at margins. This is well worth reading and will be helpful in understanding what different people are talking about when they refer to "margins". One point that was brought out in some of the discussion is that, if we know there is not a "cliff" or if we know we are not close to it, we are quite certain that the NRC-required design criteria, together with commonly-accepted and used analysis and design procedures, provide enough margin that it is ridiculous and wasteful of everybody's resources to spend a million dollars to show that a plant designed for 0.15g is safe for 0.17g. This has occurred!

Another interesting approach described in Paper No. 2 is the use of a "95-5" value to describe the seismic capacity or fragility. That is, instead of using the median and stating the uncertainty of this value, he has expressed the seismic fragility at the level of 95% confidence that the probability of failure will not be greater than 5%. Although this has the obvious disadvantage that the 95-5 value is influenced strongly by the uncertainty, it has the advantage of representing what some one could consider a reasonable lower bound on the fragility. Also, it is a concept not unknown in the nuclear industry.

Kennedy's second paper (No. 13) is equally interesting. It is based on a review of six seismic PRAs. The first paragraph of the paper presents an excellent argument for doing seismic PRAs. In my opinion, a seismic PRA is the only way to find out if the seismic margins are adequate, provided we have some reasonable and defensible idea of what level of seismic risk is adequate. Knowing margins in terms of fragility is useful in deciding when we should be concerned about small increases in seismic hazard, but PRA seems to be the only way to go in order to evaluate seismic safety in relation to the extremely large uncertainty in the seismic hazard.

Although this paper presents a generally comforting view of the seismic margins for large portions of a plant, it points out several important weak spots, or potential weak spots, that should receive attention, either deterministically or in PRAs.

Incidentally, or perhaps not so incidentally, Kennedy mentioned that 18 or 19 seismic PRAs had been performed. His paper, however, referred to only six.

Working Group Meetings

The Agenda shows Working Group Meetings on Tuesday and Wednesday. The attendees were divided into four groups, two each on "Structural and Geotechnical" and "Piping and Equipment". The division between the two groups in each category seemed both arbitrary and unnecessary. In addition, there was a dearth of experts in the geotechnical area.

I sat in on the meetings of the two Structural and Geotechnical Groups, and was not particularly impressed by the discussions or the results. However, the meetings seemed to be quite educational for the participants in many cases. The Groups were asked to come up with strategies or approaches in their respective areas. Oral reports were given at the end of the Workshop. It was my feeling at the time that these reports added little to what was already known or considered important, but I may think differently when and if I see something in writing.

SUMMARY

I am hard put to say what the Workshop accomplished. There were some interesting exchanges of ideas and information, and some of those present, especially from utilities, probably got a better idea of the problems and uncertainties involved in evaluating seismic margins. It was not apparent that the most knowledgeable people learned anything new.

What can be concluded is that the industry now understands the complexity and difficulty of evaluating seismic margins for earthquakes well beyond the design basis. What was not evident is that they know why such evaluation is desirable or necessary. After all, it is not now a requirement of the NRC, and the NRC has not decided whether or how to make it a requirement.

Nevertheless, there was some interesting and, in some cases, new information or thoughts presented, and I recommend that you read especially Attachments 1, 2, 13, 14, P2, P13, and C.

ERPI/NRC WORKSHOP ON NUCLEAR POWER PLANT
RE-EVALUATION FOR EARTHQUAKES LARGER THAN SSE

PAPER NO. MONDAY, OCTOBER 15, 1984

- ↓ 8:30 - 9:00 Administrative Procedures - R D Hanson
Purpose of Workshop - J. Richardson and I. Wall
- # 1 9:00 - 9:30 Current Estimates of the Eastern United States
Seismic Hazard - Leon Reiter (NRC)
- # 2 9:30 - 10:00 Various Types of Reported Seismic Margins and
Their Uses - R. P. Kennedy SLIDES ATTACHED (P2)
- 10:00 - 10:30 BREAK
- # 3 10:30 - 11:00 Factors Controlling Geometry, Configuration and
Strength of Structures, and Anticipated
Overstrength for Seismic Load Conditions - A. K.
Singh (Sargent & Lundy)
- # 4 11:00 - 11:30 Nonlinear Characteristics for Concrete Structural
Systems in Existing Plants - M. Sozen (U.
Illinois)
- # 5 11:30 - 12:00 Nonlinear Characteristics for Structural Steel
Systems in Existing Plants - S. Mahin (UC
Berkeley)
- 12:00 - 1:00 GROUP LUNCH
- # 6* 1:00 - 2:00 Influence of Soil Conditions on Nonlinear
Structural Response - J. Christian (Stone &
Webster)
- # 7 2:00 - 2:45 Seismic Response Characteristics of Structural
Systems at Various Levels of Post-Elastic Behavior
(Analysis and Evaluation) - W. Hall (U Illinois)
- 2:45 - 3:15 BREAK
- # 8* 3:15 - 4:00 Design of Piping Systems and Their Supports in
Existing Plants - D. Landers (Teledyne)
- # 9 4:00 - 4:30 Experience of Piping in Non-Nuclear Facilities
Subjected to Strong Ground Motion - J.D. Stevenson
(Stevenson & Assoc.)
- # 10 4:30 - 5:30 Use of Experience to Demonstrate Seismic Adequacy
of Equipment
- # 11
- # 12 #10 - Earthquake Experience - P. Ibanez (ANCO)
#11 - Additional Experience Data - G. Sliter (EPRI)
#12 - A-46 Resolution - N. Anderson (NRC)
- 5:30 FREE EVENING

SLIDES P12

*Copies not yet available.

TUESDAY, OCTOBER 16, 1984

- #13 8:00 - 9:00 Based on existing Probability Risk Assessments, what are the most critical components or systems in existing nuclear power plants? Why? - R. P. Kennedy (SMA) *SLIDES ATTACHED P13*
- 9:00 - 9:30 Instructions to Working Groups - R. D. Hanson
- 9:30 - 10:00 BREAK
- 10:00 - 12:00 Working Group Meetings
 (a) Structural and Geotechnical Systems Group
 (b) Piping and Equipment Systems Group
- 12:00 - 1:00 GROUP LUNCH
- 1:00 - 3:00 WORKING GROUP MEETINGS (CONTINUED)
- 3:00 - 3:30 BREAK
- 3:30 - 5:30 Working Group Presentations to All Participants - Preliminary Statements of Recommendations for METHODS, CRITERIA, VALUES, and RESEARCH needed to assess seismic response adequacy of an existing nuclear power plant
- 5:30 FREE EVENING AND DINNER

WEDNESDAY, OCTOBER 17, 1984

- #14 ^{8:30}~~8:00~~ - 9:00 NRC Seismic Research Program Plan - R. Budnitz (Future Resources Associates) and J. Richardson (NRC)
- "C" 9:00 - 9:30 EPRI Seismic Research Program - I. B. Wall
- 9:30 - 10:00 BREAK
- 10:00 - 12:00 WORKING GROUPS
- 12:00 - 1:00 GROUP LUNCH
- 1:00 - 2:30 Concluding Presentations by the Working Groups - Final statements on METHODS, CRITERIA, VALUES, and RESEARCH NEEDS.
- 2:30 - 3:00 WORKSHOP WRAP-UP

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Section I

Current Estimates of Seismic Hazard in the Eastern United States

Jeffrey K. Kimball and Leon Reiter, U.S. NRC

The purpose of this paper is to provide some background on the seismological and geological considerations which have, at least in part, led to consideration of earthquakes larger than the safe shutdown earthquake (SSE) and to discuss some preliminary results from an NRC funded program aimed at making probabilistic estimates of seismic hazard for all nuclear power plant sites east of the Rocky Mountains. The division between east and west is roughly made on the basis of activity and understanding. West of the Rocky Mountains, seismic activity, related to plate margin processes, is more frequent, better defined, and better understood. East of the Rocky Mountains, seismic activity, related to intraplate processes, is less frequent, not as well defined, and poorly understood. Most, but not all of the attention, has been focussed on earthquakes larger than the SSE in the eastern part of the country.

The seismological and geological factors stimulating this interest center around two topic areas; those relating to the magnitude or size of the potential earthquake and those relating to ground motion estimates for given size earthquakes. With respect to earthquake size, most attention has been focussed on the 1886 Charleston earthquake and its potential for occurring in other parts of the eastern seaboard. Since the 1970's much research has been aimed at defining the source of the 1886 event, whose estimated surface wave magnitude (M_s) 7.0 to 7.5, makes it the largest historical earthquake to have occurred on the eastern seaboard. In contrast to studies relating to the larger ($M_s = 8.0$ to 8.5), 1811 and 1812 New Madrid, Missouri events, this research has not been successful thus far in specific definition of the source. In recent years, many hypotheses (most of them speculative) have arisen defining different scenarios for the occurrence of large earthquakes in intraplate regions.

In the latter part of 1982, the U. S. Geological Survey forwarded a letter (Devine, 1982) to the NRC clarifying its past position with respect to the potential for the occurrence of large earthquakes along the eastern seaboard. This represented not so much a new understanding of the 1886 event but rather a more explicit recognition of existing uncertainties with respect to the causative

structure and mechanism of large earthquakes in the east. Nuclear power plants in the east have SSEs based on the nearby occurrence of magnitude 5.0 to 6.0 events. Explicit consideration of a nearby magnitude 7.0 to 7.5 event could represent increased ground motion values over two or three times that previously inferred, depending upon the particular scenario being considered. NRC is presently engaged in extensive probabilistic and deterministic studies aimed at further defining whether, where and to what extent additional consideration of such large earthquakes is warranted.

Another area of the country where new, as yet unproven, hypotheses are being considered so as to argue for larger than previous assumed earthquakes, is the Pacific Northwest. Heaton and Kanamori (1984), among others, point out that this part of the country has some similarity with other parts of the world where large magnitude (8+) events have occurred on active subduction zones. Present hazard estimates typically consider magnitude 6.5 to 7.0 as the maximum earthquake potential in that region.

Along with new hypotheses, new events or discoveries have raised questions with regard to previous assumptions about maximum earthquakes. The New Brunswick earthquake of 1982, a magnitude 5 3/4 event, occurred in a region where some, but not all, argue there was little or no indication that it would occur. A great deal of excitement has been generated over the Meers fault in southwestern Oklahoma, which may be the first example of recent (less than 35,000 years old) surface tectonic faulting east of the Rocky Mountains. If present research eventually shows this fault to be seismogenically recent, then initial estimates (Gilbert, 1983) suggest it could be capable of generating a magnitude 6 to 7 earthquake in a region of sparse seismicity where the largest event in this century was only about magnitude 4 1/2. In the foreseeable future some hypotheses will prove incorrect, some will be modified, some will prove correct and new ones will be proposed. New earthquakes will also continue to generate uncertainty, as to estimates of maximum earthquake potential.

Another area of seismological research that has had an impact upon increased consideration of earthquakes beyond the SSE, is that of ground motion. As our data set has expanded, particularly at near fault locations and in the eastern United States, questions are being raised as to the appropriateness of past assumptions regarding high frequency (greater than 10 Hz) and vertical ground motion. These issues are related to another topic, that of the effect of local

site conditions. There is a great deal of debate as to whether some recent, large, high frequency motions are related to source or site conditions. Shallow soil sites and some rock sites appear to be particularly prone to transmitting and/or enhancing these high frequencies.

Finally another reason for the interest in earthquakes beyond the SSE is that of perception. In the past, despite indications to the contrary by many seismologists and geologists, the SSE was viewed implicitly by some as having an upper bound beyond which no larger earthquake was possible. The NRC staff's indications, in recent years (see Reiter, 1984), have been that SSEs typically have exceedence probabilities on the order of $10E-3$ to $10E-4$ per year. There were those who viewed this as a surprise and as having violated previous assumptions. None of the above indicates that there is anything wrong with the present level of nuclear power plant design. There is and should be a difference between a design value and the earthquakes beyond which there is no possible chance of occurrence. Indeed if that were not the case, all design values for all structures everywhere should be based on magnitude 8+ earthquakes. More explicit recognition of the uncertainty with respect to earthquakes beyond the SSE does call for more explicit definition of what the true earthquake capacities of nuclear power plants are and for more explicit definition of the techniques to define those capacities.

In order to define the seismic hazard at nuclear power plant sites, at and beyond the SSE level, the NRC and its contractor, Lawrence Livermore National Laboratory (LLNL), have, since 1978, embarked on a comprehensive effort in the field of probabilistic evaluation of seismic hazard. This program originated in helping define reevaluation criteria for the older plants included in the Systematic Evaluation Program (SEP). The results of this program were published in contract reports (Bernreuter et. al, 1981), while the staff's review and use of this information are discussed in Reiter and Jackson (1983). The NRC recently published a contract report entitled "Seismic Hazard Characterization of the Eastern United States: Methodology and Preliminary Results for 10 Sites" (Bernreuter, et. al. 1984). This report will be summarized in this paper.

This study originated to address some of the seismological issues discussed above, and also to provide a methodology to assist in our review of Probabilistic Risk (or Safety) Assessments (PRAs) carried out for both individual plants and

for the resolution of generic issues such as the seismic capability of decay heat removal systems.

With respect to the current LLNL program, its objective is to develop a methodology for defining seismic hazard at any place in the United States east of the Rocky Mountains. Results of this program will provide the NRC staff with seismicity and ground motion parameters useful for seismic hazard or safety assessment studies. This information will also be an important component assisting the staff with respect to the Charleston earthquake issue.

The basic approach of the effort at LLNL is to expand, improve and apply methods from previous studies, particularly those initiated under the SEP. The backbone of this approach is the use of two expert panels; a seismicity panel and a ground motion panel. A list of participants on these panels is included at the back of this paper (Tables 1 and 2). The seismicity panel experts have each provided zonation maps and the necessary seismicity parameter information for each zone. These parameters include activity rates, slope of the earthquake recurrence curve and the upper magnitude cutoff. Each expert was also asked to provide uncertainty estimates in all of the above parameters. An example of a zonation map is shown in Figure 1. The attenuation panel experts have provided weights on various attenuation models, including peak acceleration, peak velocity and spectral ordinates, and uncertainty estimates attached to these models.

The current methodology developed by LLNL includes an assessment of the uncertainty in all the hazard input parameters. This was accomplished by creating a software package which could efficiently accommodate thousands of hazard calculations for any site. The LLNL project has also included feedback meetings with both expert panels to review the physical reasonableness of their inputs, review the LLNL interpretation of their inputs and finally make any changes to their models and assumptions that they feel is necessary. Finally, the program is undergoing peer review by four individuals listed in Table 2. Figure 2 displays the 10 test sites selected by the NRC and LLNL for the initial computations. Reasons for selecting these sites included providing; a good regional coverage, a representation of plant vintage, a representation of sites with other hazard estimates available for them (SEP, PRA), and a representation of different site conditions. The following figures display the type of information available for each site. The Millstone site is used only as an example. Figure 3 displays constant percentile hazard curves, the result of over

2000 hazard runs. Figure 4 displays uniform hazard response spectra for different return periods and Figure 5 shows the 50th percentile "1000" and "5000" year uniform hazard spectrum versus the SSE for Millstone.

Although these examples are shown, and some very tentative observations will be discussed, it is necessary to emphasize that these results and observations are preliminary in nature because feedback changes and peer review comments have not been fully assessed. It is our current impression that the calculated probabilities for a given acceleration may decrease as a result of feedback, and that the spread between the 15 and 85 constant percentile curves may decrease somewhat more than the absolute change in the 50th percentile.

These results are consistent with previous assertions that SSEs have annual probabilities of exceedance on the order of $10E-3$ to $10E-4$. Initial results have also shown that the SSE probability of exceedance is likely to be frequency dependant, with lower frequencies associated with lower probabilities of exceedance. This comment is particularly true for sites whose SSE is associated with the Regulatory Guide 1.60 broad band spectral shape. The relative ranking of the results for the 10 sites also appears to be consistent with the staff's judgement of higher and lower earthquake hazard regions in the east.

Figure 6 displays a comparison of the "1000" year spectra generated as part of the SEP, to that of the SHCP, for the Millstone site. This comparison shows that results are roughly comparable. At LaCrosse comparison of SEP and SHCP results displays consistency of results for frequencies as low as 7 Hz, but lower results for the SHCP below 7 Hz. Although more comparisons are needed, these results give some indication of hazard estimate stability (using expert opinion) over a time span of 3 to 5 years.

In general, the results indicate that for the typical SSE acceleration values the hazard changes by about a factor of 5 to 7 as one doubles the peak acceleration. This factor increases to about 7 to 12 for accelerations in excess of about 0.40g. Thus, probabilities associated with 2 to 4 SSEs, those that appear to be significant in PRA analysis, will be approximately one to two orders of magnitude lower in probability than the SSE itself. However, it is clear when looking at Figure 3 that uncertainties due to parameter and model variation are very wide, increasing as the peak acceleration increases. It is important to point out that wide uncertainty bands are not necessarily a "negative" aspect of the hazard

analysis process. For example, at a given probability, differences of opinion with respect to SSE values would not necessarily imply large differences with respect to levels of confidence. This type of information can assist the decision making process in dealing with seismological and geological controversy.

The SHCP schedule currently calls for revised hazard curves and spectra to be completed for the ten test sites toward the end of 1984. Hazard results for all sites east of the Rocky Mountains will be completed during 1985. It is our intent to utilize these results, along with those developed as part of the Electric Power Research Institute program, and an NRC sponsored USGS probabilistic hazard study, to assess the Charleston earthquake issues during the later part of 1985. The various studies, and workshops such as this, can only help NRC in reaching decisions that it must make in the future.

Table 1

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Professor Gilbert A. Bollinger (1)

Mr. Richard J. Holt (1)

Professor Arch C. Johnston

Dr. Alan L. Kafka

Professor James E. Lawson

Professor L. Tim Long

Professor Otto W. Nuttli (1)&(4)

Dr. Paul W. Pomeroy (1)

Dr. J. Carl Stepp

Dr. Anne E. Stevens (3)

Professor Ronald L. Street (1)

Professor M. Nafi Toksoz (1)&(4)

Dr. Carl M. Wentworth (3)

- Notes:
- (1) Also participated in the SEP Panels
 - (2) Only provided zones and seismicity parameters for Canada
 - (3) Only provided zonation -- no seismicity parameters
 - (4) Also member of the Ground Motion Panel (Table 2-2)

Table 2

EUS GROUND MOTION MODEL PANEL MEMBERS

David M. Boore (1)
Kenneth Campbell
Professor Otto W. Nuttli (1)&(2)
Professor Nafi Toksoz (2)
Professor Mihailo Trifunac (1)
Professor Daniele Veneziano

- Notes: (1) Participated as a member of the SEP EUS Ground Motion Panel.
(2) Also member of the Seismicity Panel (See Table 2_1)

Peer Review Panel

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References

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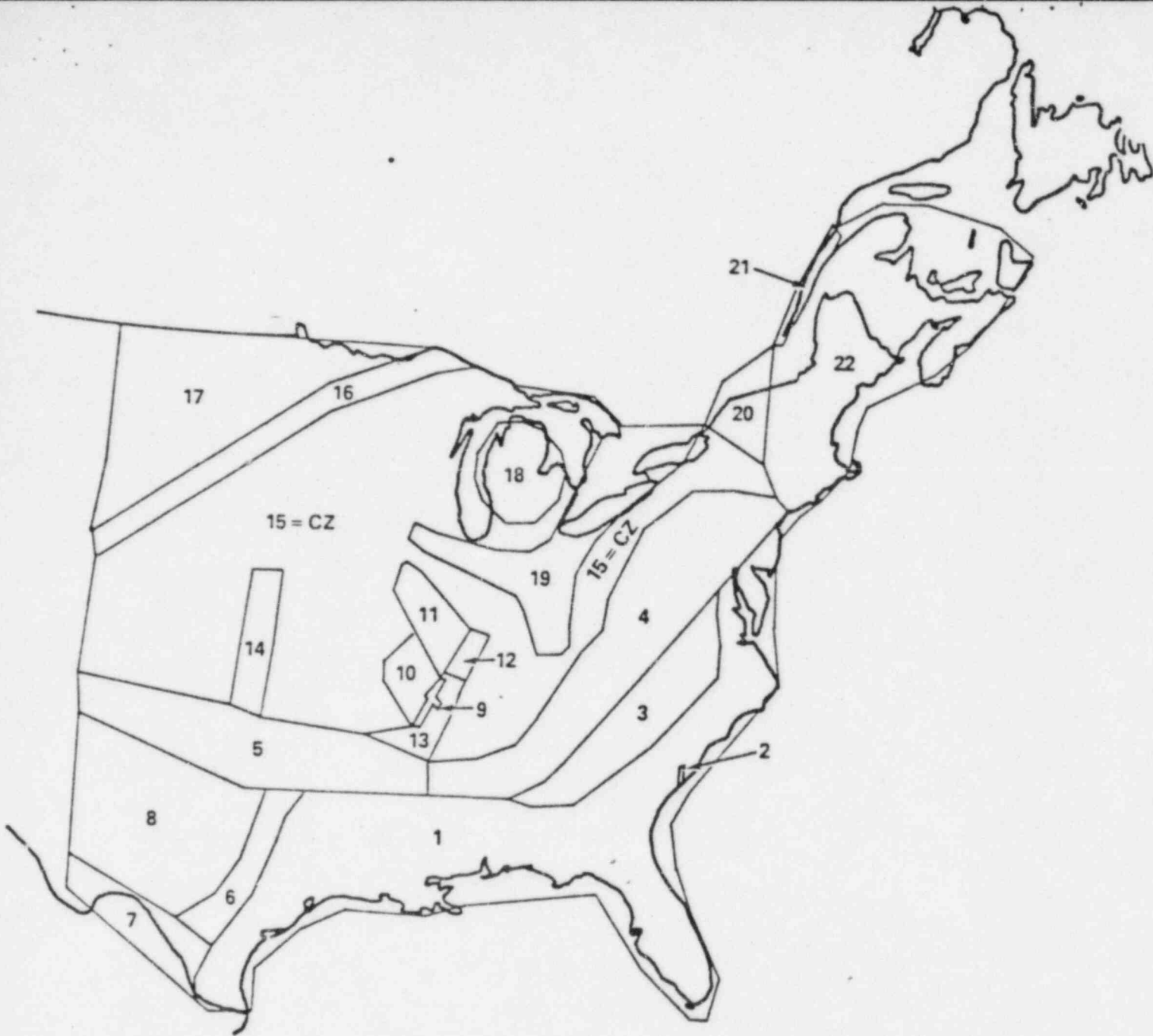


Figure 1 Seismic Zonation Base Map for Expert 1

LLNL
NUREG/CR-3756



Figure 2 Location of the Sample Sites in the EUS.

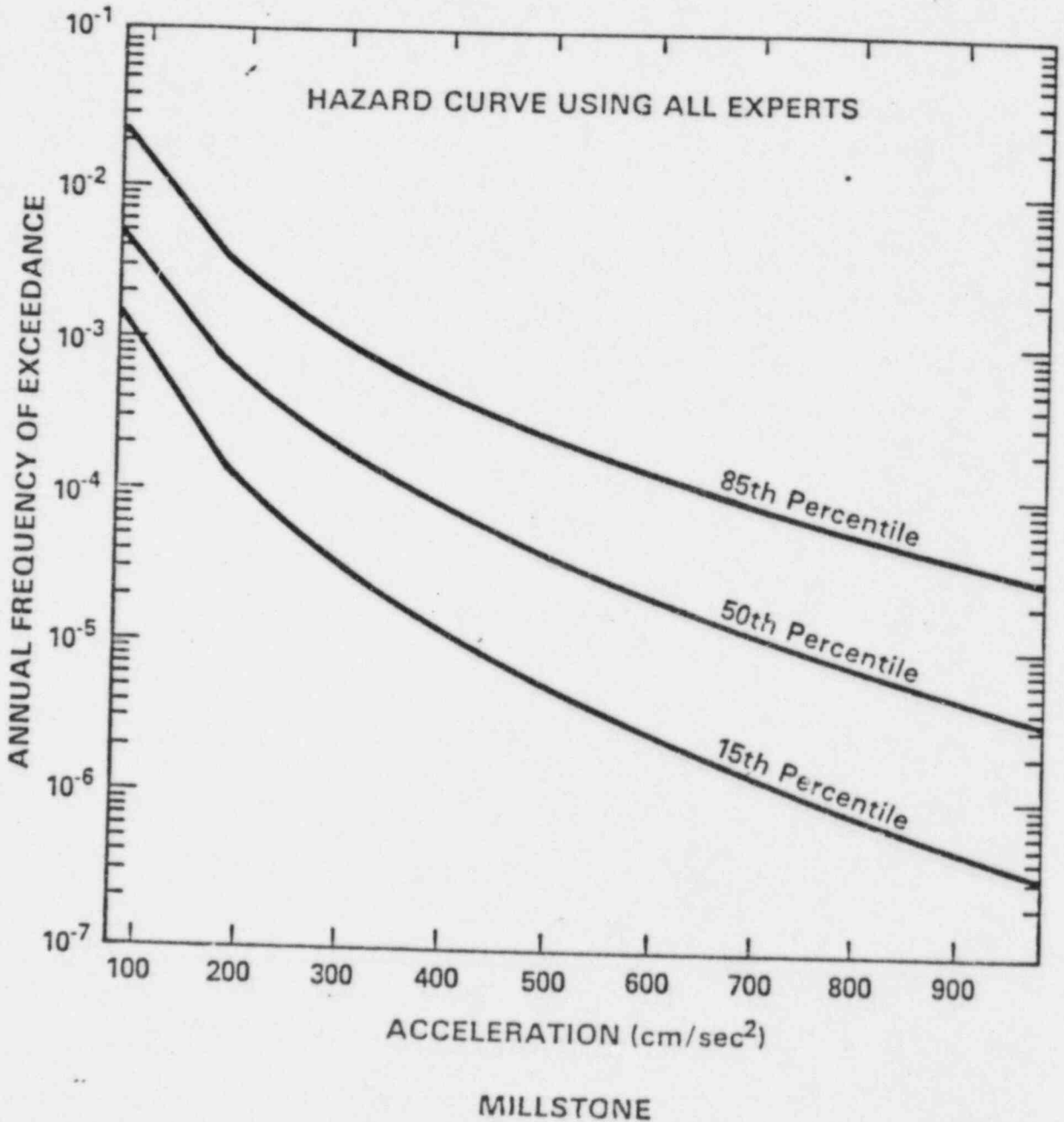


Figure 3 Constant Percentile Hazard Curves (CPHC) Over All Experts.

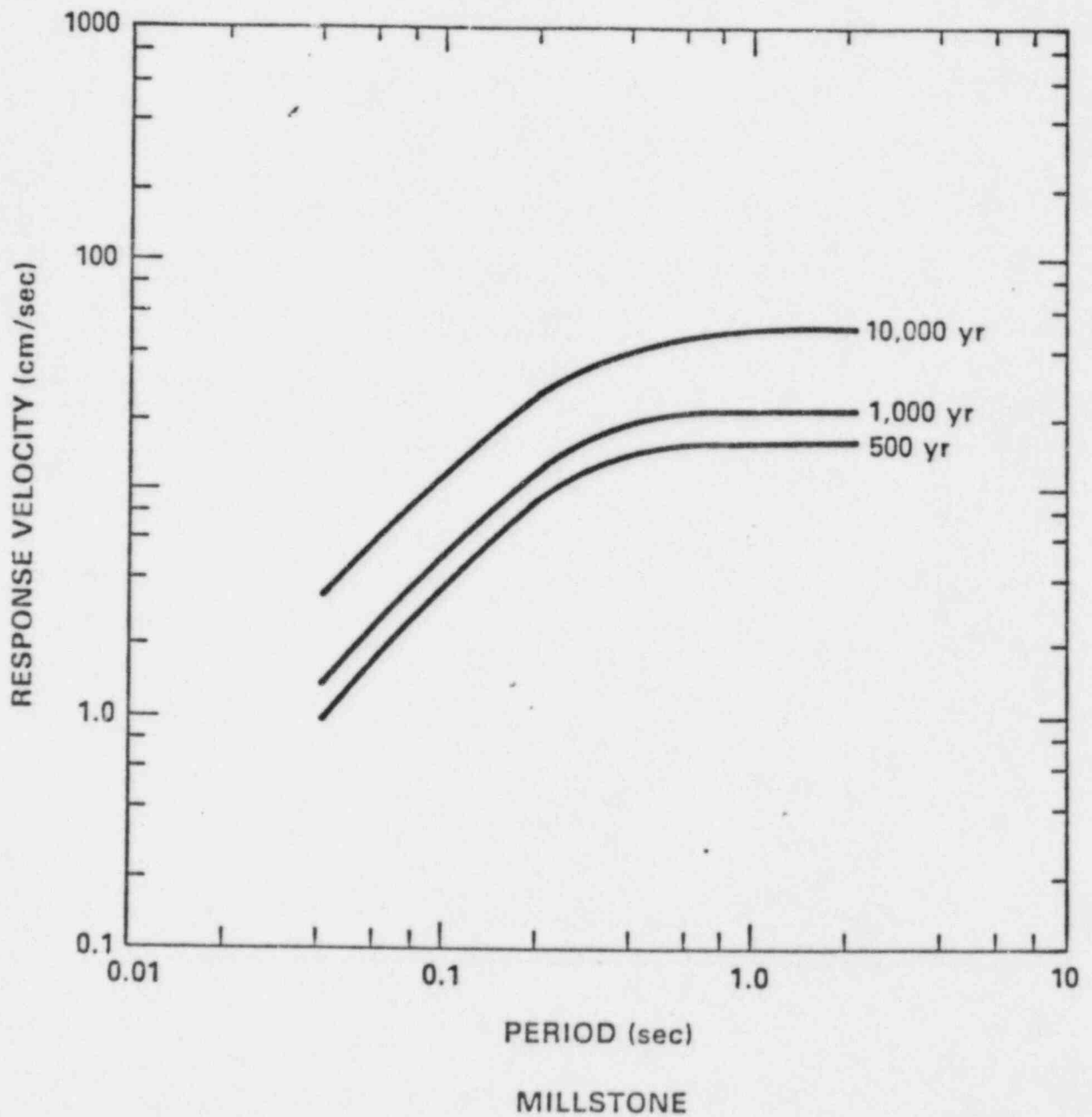


Figure 4 Constant Percentile (50th) Uniform Hazard Spectra For Three Return Periods.

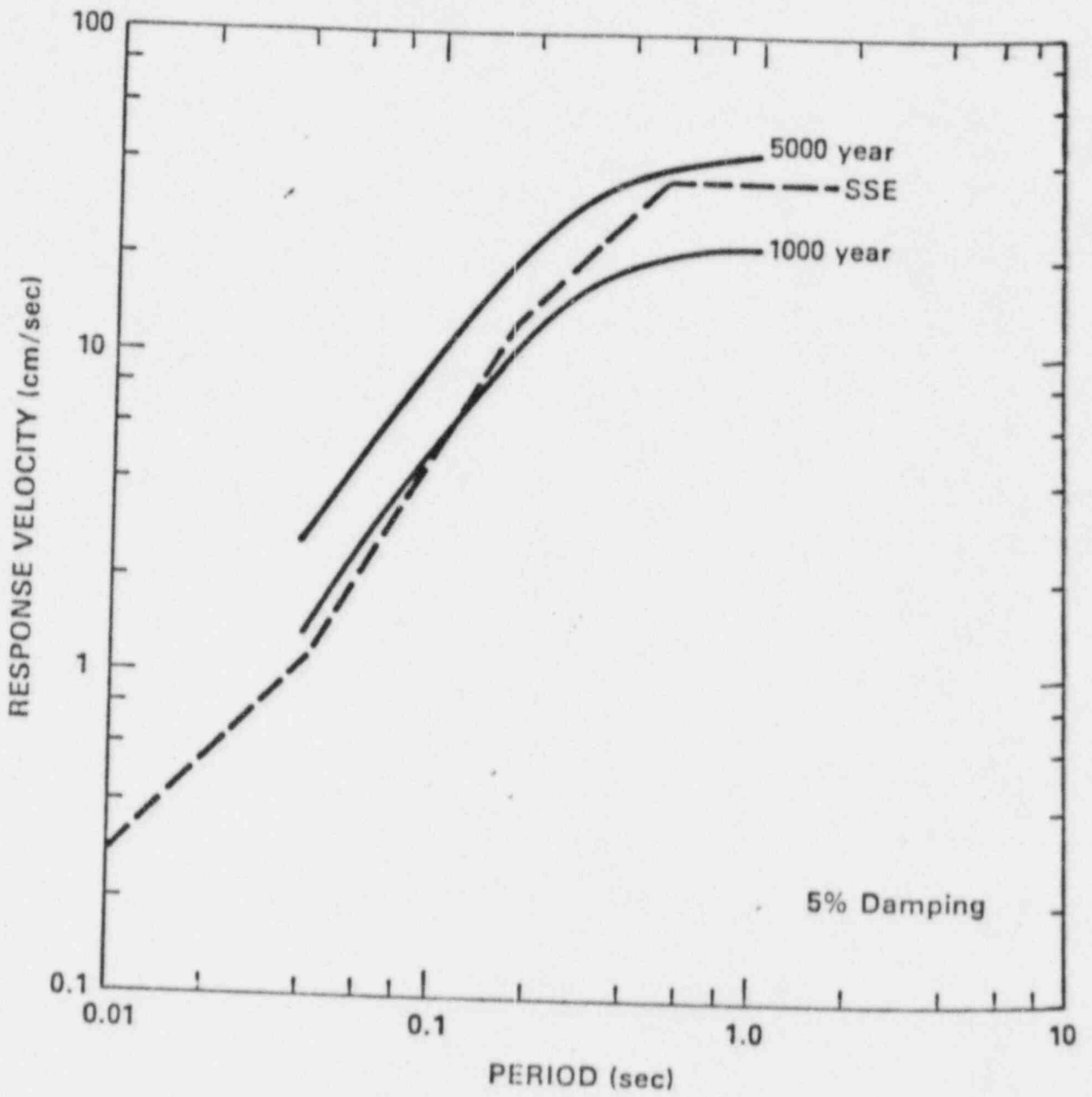


Figure 5 Comparison of Millstone-3 SSE to 50th Percentile Uniform Hazard Spectrum For Two Return Periods.

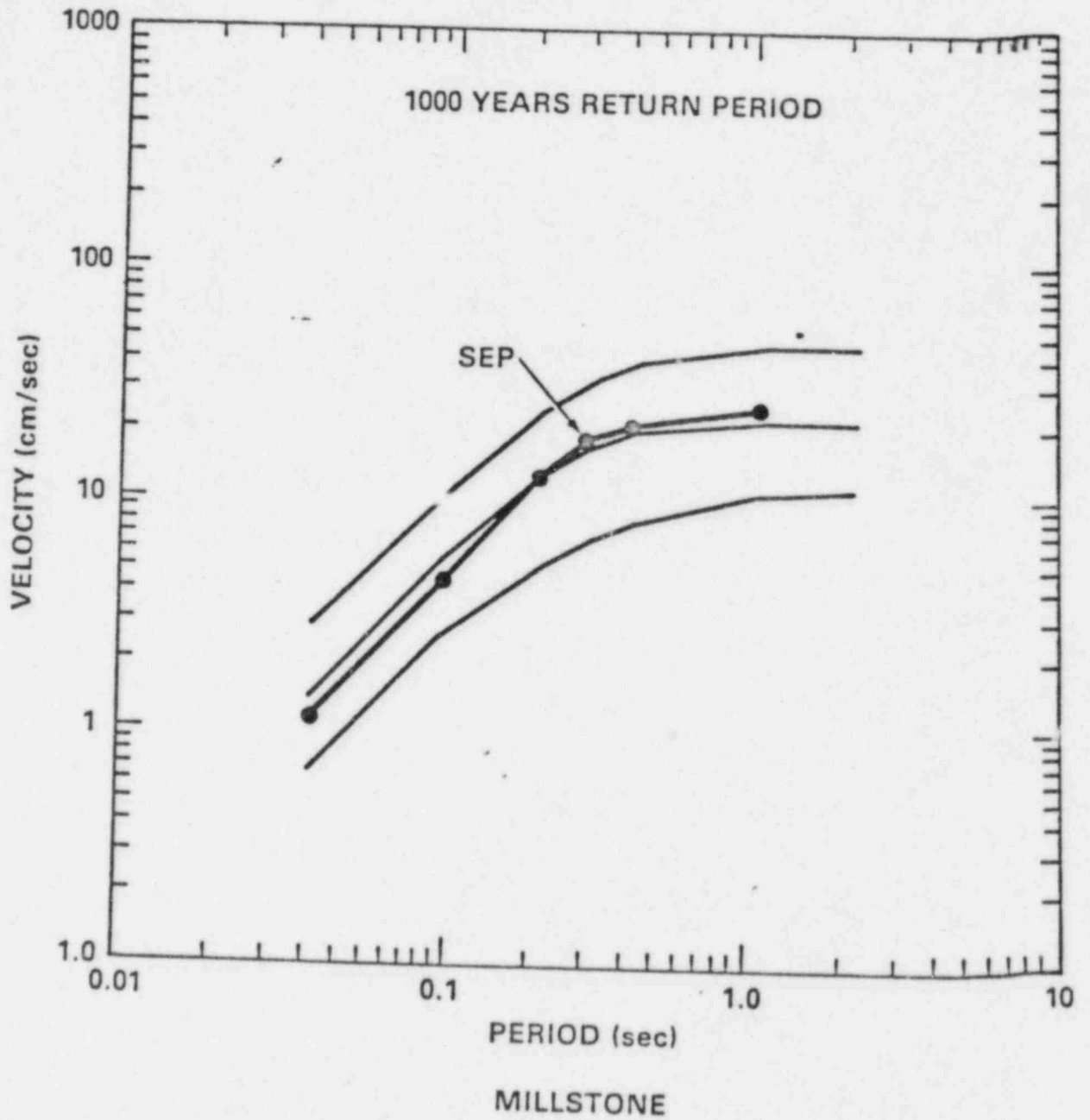


Figure 6 Comparison Between the 1000 Year Return Period CPUHS and the SEP 1000 Year Return Period UHS