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ABSTRACT

The Seismic Safety Margins Research Program (SSMRP) is an NRC-funded, multiyear program conducted by Lawrence Livermore National Laboratory (LLNL). Its goal is to develop a complete, fully coupled analysis procedure (including methods and computer codes) for estimating the risk of an earthquake-caused radioactive release from a commercial nuclear power plant. The analysis procedure is based upon a state-of-the-art evaluation of the current seismic analysis and design process and explicitly includes the uncertainties inherent in such a process. The results will be used to improve seismic licensing requirements for nuclear power plants.

As currently planned, the SSMRP will be completed in September, 1984. This document presents the program plan for work to be done during the remainder of the program.

In Phase I of the SSMRP, the necessary tools (both computer codes and data bases) for performing a detailed seismic risk analysis were identified and developed. Demonstration calculations were performed on the Zion Nuclear Power Plant. In the remainder of the program (Phase II) work will be concentrated on developing a simplified SSMRP methodology for routine probabilistic risk assessments, quantitative validation of the tools developed and application of the simplified methodology to a Boiling Water Reactor. (The Zion plant is a pressurized water reactor.) In addition, considerable effort will be devoted to making the codes and data bases easily accessible to the public.

CONTENTS

I. Introduction

The Seismic Safety Margins Research Program (SSMRP) is an NRC-funded, multiyear program conducted by Lawrence Livermore National Laboratory (LLNL). Its goal is to develop a complete, fully coupled analysis procedure (including methods and computer codes) for estimating the risk of an earthquake-caused radioactive release from a commercial nuclear power plant. The analysis procedure is based upon a state-of-the-art evaluation of the current seismic analysis and design process and explicitly includes the uncertainties inherent in such a process. The results will be used to improve seismic licensing requirements for nuclear power plants.

The SSMRP was begun in 1978 when it became evident that the adequacy of seismic safety had to be assessed in a global fashion instead of concentrating individually on the fragmented steps used in the design process. To do this an accurate seismic risk analysis method needed to be developed to simultaneously consider all the interrelated factors that affect seismic risk. Risk, as measured by the probability of radioactive release, is then used to assess the adequacy and balance of the seismic design process. In the traditional design procedure, by contrast, each step is usually analyzed separately. These closely coupled steps are:

- The likelihood and magnitude of an earthquake.
- The transfer of earthquake energy from a fault source to a power plant, a phenomenon that varies greatly with the magnitude of an earthquake.
- Interaction between the soil underlying the power plant and the structure, a phenomenon that depends on the soil composition under the plant and the location of the fault source relative to the plant.
- Coupled responses of a power plant's buildings and the massive reactor vessels, piping systems, and emergency safety systems within.
- Numerous accident scenarios, which vary according to types of failures assumed and the success or failure of the engineered safety features intended to mitigate the consequences of an accident.

A nuclear power plant is designed to ensure the survival of all buildings and emergency safety systems in a worst-case ("safe shutdown") earthquake. The assumptions underlying this design process are deterministic. In practice, however, these assumptions are clouded by considerable uncertainty. It is not possible, for example, to accurately predict the worst earthquake that will occur at a given site. Soil properties, mechanical properties of buildings, and damping in buildings and internal structures also vary significantly.

To model and analyze the coupled phenomena that contribute to the total risk of radioactive release it is therefore necessary to consider all significant sources of uncertainty as well as all significant interactions. Total risk is then obtained by considering the entire spectrum of possible earthquakes and integrating their calculated consequences. In the SSMRP this approach to risk analysis is embodied in the seismic methodology chain, comprising five steps: determining seismic input characteristics for a site, calculating the effects of soil-structure interactions, calculating major structure response, calculating subsystem response, and calculating probability of failure.

The seismic input consists of the earthquake hazard in the vicinity of a nuclear power station, defined by an estimate of the seismic hazard function (i.e., the relationship between the probability of occurrence and a measure of the size of an earthquake) and a description of the free-field motion. The soil-structure interaction link in the chain transforms the free-field ground motion into basemat or in-structure response, accounting for the interaction of the soil with the massive, stiff structures present at a nuclear power plant. Determination of the major structure response follows the soil-structure interaction step, where "major structure" commonly denotes a building, but may also include very large components. The final step in the traditional seismic analysis and design process is predicting subsystem structural response. An additional step in the SSMRP is the prediction of failure and subsequent risk of radioactive release.

I.2 Objectives

The objectives of the Seismic Safety Margins Research Program (SSMRP) are to:

- Develop and apply a methodology for computing probability of radioactive release due to earthquakes.
- Determine major contributors to probability of radioactive release from seismic events.
- Develop a simplified, user-oriented version of the methodology for routine PRA applications.
- Rank R & D areas for prioritization of any needed research.

The approach toward achieving the program objectives is to develop probabilistic methodology that realistically estimates the behavior of nuclear power plants during an earthquake. This methodology will be tested against experimental data wherever possible. The work of the program is being performed in two phases:

1. In Phase I, completed in January 1981, the methodology was developed. Models for seismic input, soil-structure

interaction, dynamic response of structures and subsystems, and fragility were developed and combined using a probabilistic computational procedure. The methodology was implemented in three computer program: HAZARD, which assesses the seismic hazard at a given site, SMACS, which computes in-structure and subsystem seismic responses, and SEISIM, which calculates structural, component, and system failure probabilities and radioactive release probabilities. Sensitivity studies to gain engineering insight into seismic safety requirements have been started. The results will help determine priorities for the Phase II effort.

2. In Phase II, any necessary additional models and probabilistic procedures will be developed. Sensitivity studies started in Phase I will be completed. The probability of failure of systems, components, and structures, and the probability of radioactive releases from a range of earthquake levels will be used to define needed improvements in the methodology. Necessary validation will be carried out and the validated methodology will be used to refine estimates of conservatism and define the seismic contribution to reactor risk. The validated methodology will be used to recommend changes in the SRP seismic safety requirements, if needed, to obtain improved deterministic requirements.

Shortly after the completion of Phase I in January 1981, LLNL was asked to perform a risk analysis of the auxiliary feedwater system of the San Onofre Nuclear Generating Station (SONGS) using the SSMRP methodology, codes and data bases. Funds from the SSMRP ($900K) were to be used to support this work. The work began officially in May 1981. The analysis made use of every phase of the SSMRP methodology. Building structural models and piping models were constructed and detailed fault trees were prepared. Work on this project was terminated in February 1982 at the request of NRC-NRR when unavoidable schedule conflicts in the delivery of input from Southern California Edison prevented completion of the project in a timely fashion. Before termination, a number of building response comparisons and model evaluations had been performed and sent for use by NRR. Because of the scheduling complications, it was determined that the remaining work would be only marginally cost-effective. During the months of February and March 1982, the SONGS analysis was put into a "wrap-up" mode, in which all pertinent data were assembled into a retrievable format, and a final report was prepared to document all work completed.

For Phase II, we identified five major goals:

A. Sensitivity Studies
Having assembled the preliminary versions of the codes

HAZARD, SMACS, and SEISIM, and the preliminary fragility data base, we are in a position to make an initial determination of the relative importance of the various aspects of the seismic problem, using sensitivity studies.

The results will (a) give us confidence in the tools we developed, (b) help direct refinements in the tools and data developed, (c) allow us to compare our predictions with previous risk studies, and (d) identify future areas of research.

B. Complete Zion Risk Assessment
Having run sensitivity studies and improved our codes and data (to the minimum extent required), we can now complete the evaluation of the seismic risk at Zion. This will include uncertainty bands. This risk number will be based on our having completed all the necessary models (identified to date), fault trees, fragilities, etc., although many of them will be preliminary.

C. Develop Simplified Models
Given our experience with sensitivity studies and the risk calculations, we are in a position to simplify the risk calculation procedure in order to provide a procedure that can be used in a timely fashion to perform a routine probabilistic seismic risk assessment or to evaluate or benchmark risk assessments performed by other means.

D. Validation
Having calculated risk numbers, it is imperative that we devote considerable effort to "verifying" these numbers to the extent possible. Clearly the overall risk cannot be "verified" but we can perform studies; e.g., comparing with other codes, and comparing with data at the structural or system level.

E. BWR Risk Analysis
Application of our tools, codes, and methods to a BWR to:

1. demonstrate applicability of our simplified methodology to BWR's, and

2. provide a benchmark against which other BWR probabilisitic risk assessments can be compared.

F. Technology Transfer
To provide for a timely transfer of tools, computer codes and data bases both to groups within the NRC as well as to the general nuclear community. This includes generating and maintaining publicly-accessible versions of the computer codes developed as part of the SSMRP, generation of code users manuals and standard problems, and code configuration control.

LLNL has been directed by NRC to plan the completion of the SSMRP predicated on overall budgets of $3M for FY 83 and $2M for FY 84. In FY 83, $205K of the SSMRP funds will be used in support of the Eastern United States Seismic Hazard Characterization Program, a recent spin-off from the SSMRP now being directed by Earth Sciences Branch of the NRC Division of Health, Siting and Waste Management. The cost breakdown for FY 83 and FY 84 are as shown below.

	FY 83	FY 84
General Management	555	595
Sensitivity Studies	45	0
Completion Zion Risk Analysis	86	0
Development of Simplified Methodology	320	0
Validation	974	982
Technology Transfer	298	126
Extension to Boiling Water Reactor	517	233
Eastern U.S. Seismic Hazard Characterization	205	0
	$3000K	$1936K

This report presents a description of those tasks currently envisioned for the timespan through September 1984, the anticipated end of the program. Section II summarizes the work completed in Phase I, and presents the status of our progress towards the Phase II goals described above. Sections III through VIII give descriptions of tasks planned in FY 83 and 84 for each of the Phase II goals.

II. Status of the SSMRP

II.1 Phase I Results

As mentioned in the Introduction, the development of the SSMRP was initially envisioned as being accomplished in several stages. In Phase I, a preliminary version of the complete methodology, including both computer codes and data bases, was to be assembled, and demonstration calculations performed. This work was completed in January, 1981, and the results and technical products of Phase I are outlined below.

Plant/Site Selection and Data Collection. Unit 1 of the Zion Nuclear Power Plant was chosen as an appropriate "typical" plant. An independent study, based on a comparison with other operating power plants in terms of important design features, concurred in our choice.

Seismic Input. We developed the tools and models necessary to describe probabilistically the seismic hazard at the Zion site and to generate appropriate acceleration time histories. The models include (1) a delineation of zones of roughly uniform seismic activity in the central United States, (2) an occurrence model that describes the seismicity for each zone, and (3) a ground motion model that accounts for earthquake source effects and regional attenuation of ground motion. The computer program HAZARD was developed to produce the necessary seismic hazard curve, based on these models. The hazard curve is divided into six acceleration ranges, and 30 time histories were generated for each range.

Soil-Structure Interaction. Analysis of the coupled soil-structure system by the substructure approach is the first step in the SMACS calculational procedure. We provided as input the necessary characterizations of the soil, foundations, and structures at the Zion site. In a separate study, foundation embedment, accounted for in our calculations, was found to have a significant effect on computed structure response. The angle of incidences of seismic waves, on the other hand, was found to affect only torsional response. In a comparison of two computer programs (FLUSH and CLASSI) that implement alternative approaches to the analysis of soil-structure interaction, we found varying agreement.

Major Structure Response. Major structure response was obtained as part of the computation of soil-structure interaction. Input included detailed finite element models of the containment building (the cylindrical containment shell and the internal structures were modeled separately) and the auxiliary-fuel-turbine (AFT) complex. To assess the uncertainty due to modeling assumptions, we analyzed four mathematical models constructed to represent the AFT complex. Disagreement among the results was marked in some cases.

Subsystem Response. The third segment of SMACS computed the responses of piping subsystems given the structure response. We developed mathematical models of 13 piping systems as input and produced the software to perform the calculations. The software uses a pseudostatic-mode method with multisupport time-history input. Sensitivity studies have begun to evaluate the relative contributions of uncertainties in seismic input, soil-structure interactions, structure response calculations, and subsystem response calculations to the uncertainty in subsystem response.

SMACS and BE-EM. We developed the computer code SMACS to tie together the soil-structure interactions, structure response, and subsystem response calculations. Variations in input parameters (including ensembles of acceleration time histories for each acceleration level) reflected uncertainties about the Zion plant and site. Calculational results include peak and spectral accelerations at many points in the structures and subsystems, and peak moments in the piping subsystems. The input uncertainties are manifest in the range of responses computed for any node at each acceleration level. We also introduced the concept of comparing a best-estimate (BE) seismic analysis method, exemplified by the SSMRP methodology, with an evaluation method (EM), such as that embodied in the NRC's Standard Review Plan.

Fragilities. Fragility curves - normal or lognormal distributions describing the probability of failure as a function of a critical local response parameter - were necessary for all components and structures whose failure is accounted for in the SEISIM fault trees. Curves were thus developed for 37 generic categories of electrical and mechanical equipment and for 5 Zion structures. The curves were based on both available data and on carefully analyzed expert opinion.

Systems Analysis. To describe the Zion plant systematically, we developed (1) seven event trees that describe the possible event sequences that follow an earthquake and (2) fault trees that describe the possible failure modes for certain systems identified in the event trees as critical to safety. The computer program SEISIM accepts as input these event and fault trees, the responses computed by SMACS, the set of fragility curves (which, together with the calculated responses, establish the probabilities of the various fault tree failure modes), and probabilities of ground acceleration taken from the seismic hazard curve for the Zion site. SEISIM output includes structural, component, and system failure probabilities, and probabilities of radioactive release. Our first results were tentative, but reasonable.

II.2 Current Phase II Activities

Activities and accomplishments for the Phase II goals as of May 1982 are highlighted below.

II.2.1 Sensitivity Studies

Work on the sensitivity studies has been in progress since the beginning of the 1982 fiscal year. The objective of these studies is to determine the relative contributors to seismic risk at the Zion site. These studies are based on the responses, fragilities and accident sequences developed in Phase I of the SSMRP. These studies will provide a preliminary indication of which components, safety systems, and accident sequences tend to contribute most to seismic risk at Zion. They are also being used to determine the adequacy of the level of modeling used in Phase I, and to determine which (if any) areas of input require further attention, either analytically, experimentally or through seeking additional data.

To this end, two importance measure algorithms were programmed into the SEISIM code, the Vesely-Fussel measure and the Birnbaum measure. After checking out these algorithms, an initial evaluation of importance ranking was made (based on 95 of the 148 Phase I accident sequences). These preliminary results indicate that electrical components associated with the Emergency Safety Features electrical buses were most important followed by the power-operated relief valves. The most important safety systems identified were the Auxiliary Feedwater System and the Reactor Protection System. A final set of importance measure calculations will be made, using the entire set of accident sequences, and a set of input uncertainties chosen to include random uncertainties only. (Uncertainties due to modeling will contribute to confidence bounds on the final results.)

One very important aspect of the Birnbaum importance measure is that it can be used to determine which components (or safety systems) should be upgraded to decrease the risk of radioactive release or its uncertainty in the most cost effective manner. Thus it can be used to provide the "biggest bang for the buck"in determining additional testing or quality assurance procedure changes or retrofitting options.

II.2.2 Complete Zion Risk Analysis

The objective of this project is to complete the seismic risk assessment for the Zion nuclear power plant which began in Phase I. By contrast, calculations performed in Phase I were demonstrations of the methodology, aimed at providing an indication of any additional effort or scope required. Completion of the Zion seismic risk assessment involves three main additions to the Phase I calculations.

1. Completing the generation of all accident sequences and their corresponding minimal cut sets.

2. Developing and implementing a cost-effective procedure for separating random versus modeling uncertainties, and using the modeling uncertainties to compute confidence bounds on the final probabilistic risk results.

3. Completion of all needed piping models.

In the past two quarters, generation of all accident sequences and cut sets was 90% complete. Solving the remaining fault trees required using the FTAP fault tree computer code installed on a PRIME virtual memory computer. This code was modified to incorporate culling of the cut sets based on a dual probabilistic culling criteria. The use of probabilistic culling is a significant improvement over the manual techniques used in the Phase I calculations.

The task to develop and implement confidence bounds is proceeding on schedule. After initial investigation, eight possible avenues of approach were identified, leading to results of varying degrees of accuracy. A review panel consisting of Dr. C. A. Cornell (MIT), Dr. R. Wolf (U.C. Berkeley) and Dr. Jon Collins (Acta, Inc.) was convened to assist us in our review. As a result of this review, three alternatives were selected for further evaluation via pilot calculations to estimate computer cost. Final selection and implementation of the chosen method of computing confidence bounds will be performed next quarter.

All piping models selected for Zion were completed this last quarter. Four additional piping models for the Auxiliary Feedwater System were generated, which completes the modeling for the Auxiliary Feedwater System. Since this system was found to be the most important safety system in the sensitivity studies of the Phase I results, it was felt that the piping modeling for this system should be completed back to and including pertinent parts of the main steam system.

Activities for the remainder of FY 82 will consist of ascertaining the effect of the local soil column geometry under Zion, completing all the accident sequence cut set determination, re-running the SMACS structural response calculations to separate random and modeling uncertainties and, finally, computing the probabilities of failure and radioactive release with associated confidence bounds.

II.2.3 Develop Simplified Methods

The scope and specific tasks for this project were defined in February 1982, and preliminary activities began in March. The objective of this work is to develop a simplified version of the SSMRP methodology which could be used to perform a seismic risk assessment for a cost of roughly $600K and in a time frame of six to nine months. The methodology will initially be developed for a PWR, and then extended to a BWR in Project VIII. The methodology will utilize a standardized set of fault trees and accident sequences, design models and calculational results, and calibrated uncertainties determined from our more detailed calculations.

The seismic input (time-histories and hazard curve) will be determined in a standardized procedure, resulting from a task to complete the seismic zonation of the central and eastern United States. This task, originally planned as part of the SSMRP, was transferred to the Earth Sciences Branch of the NRC Division of Health, Siting and Waste Management so that a closer coordination between NRC geosciences personnel could be maintained. This task, titled Seismic Hazard Characterization of the Eastern United States, will be reported under FIN-A390.

II.2.4 Validation of Methodology

This project gathers together all the tasks devoted to benchmarking and validating the SSMRP methodology. Current tasks include review and validation of the fragility database used in Phase I, assessment of structural damping values, and assessment of the methods of generation of the synthetic earthquake time histories by means of alternative methods.

As part of the review of the Phase I fragility data base, the Fragilities Panel was reconvened for a two day meeting in February 1982. Besides reviewing our fragilities, the panel spent a significant portion of the meeting in assisting us in determining the most appropriate means of separating random and modeling uncertainties for the fragility curves, as required for the final Zion risk calculations. In addition to the Fragilities Panel review, an on-going search for additional data and for expert opinions has been underway. This was undertaken by identifying individuals with special knowledge of one or more of the generic fragility categories, and bringing the individual to LLNL to review those categories and make recommendations for modification if appropriate. This activity will continue as new sources of information are identified.

The assessment of structural damping values was completed, and a report is in preparation. Work on the ARMA models began in January, and is progressing on schedule.

II.2.4 *Technology Transfer*

This project has the responsibility for timely dissemination of the codes, data bases and methodology developed in the SSMRP. This will include both code configuration control and user's conferences in the future.

The main task in the past two quarters has been the preparation of a users version of the SMACS structural response code. This code and its associated graphics package was installed on the Lawrence Berkeley Laboratory 7600 computer system. This version of SMACS is thus available to the public via standard telephone (MODEM) hook-up. This version of SMACS will compute the statistics of all building responses including soil-structure interaction for any arbitrary shaped surface foundation overlaying a layered half-space model of the soil. Installation of this code was complete in February, and a draft of the users manual was released in early April.

II.2.5 BWR Risk Analysis

The scope of this project is to apply the simplified methodology developed for the PWR to a BWR, performing any required additional benchmarking in the process. This work will essentially follow the completion of the Development of Simplified Methods project and will be performed primarily in FY 1983, 1984. Other than scope planning, no activity was devoted to this project in the past two quarters. In the remainder of FY 1982, efforts will be devoted to obtaining existing fault and event trees for a BWR, and modify these to include seismic induced failures. This work can be performed as soon as final negotiations with the owner/operator of the BWR under consideration are completed.

III. Sensitivity Studies on Phase I Results

Objective

To make an initial determination of the relative contributors to seismic risk at the Zion site, using the building and component mechanical responses and the fragility data base developed in Phase I. These studies will identify any additional models or model refinements required and provide a preliminary indication of which components, safety systems and accident sequences tend to be the most important contributors to seismic risk at Zion. The results will play an important role in identifying areas in which significant validation effort should be devoted in the remainder of the SSMRP program.

Sensitivity studies will be performed in each area of the seismic risk assessment calculational chain. Specific tasks are described below.

Task III.1: Seismic Hazard Ground Motion Model Sensitivity Studies

In Phase I we found that one of the key contributors to the uncertainty in the hazard curve is the uncertainty in the ground motion model. Only a very limited range of ground motion models were considered in Phase I, and these models did not span the uncertainty in the ground motion model for the eastern U.S. The objectives of this study are to: (1) improve our best estimate ground motion model, (2) develop alternatives to the best estimate model which span the uncertainty in modeling eastern U.S. ground motion, and (3) evaluate the impact the uncertainty in the ground motion model has on the seismic hazard and develop confidence bounds for the seismic hazard. The improved best estimate model will be developed by making use of advanced regression analysis methods which allow for the incoporation of uncertainty in all variables used in the analysis, as well as, nonlinear regression models. The alternative models will be developed from the literature, our Phase I studies and in conjunction with our consultants.

Task III.2: Seismic Hazard: Influence of Ground Motion Earthquake Zonation and Occurrence Models on Time Histories

In Phase I we assumed that changes in the earthquake zonation and occurence models would only primarily alter the probability of getting a given PGA range and only have a minor effect on the set of time histories used for the given PGA range. This assumption needs to be either verified or corrections made to the Phase I results. The objective of the task is to determine if it is necessary to generate new time histories when major changes are made in either/or the ground motion and earthquake occurrence models. We hope to verify that the same time histories can be used and the influence of the changes in the model accounted for by only changing the hazard curve.

Task III.3: Soil-Structure Interaction Sensitivity Study

The objective of the sensitivity studies is to investigate the adequacy of the assumptions of the Phase I model and their effect on structural response and probability of radioactive release. Three key items require additional consideration:

1. flexible basemat for the Zion Auxiliary-Fuel-Turbine (AFT) Building - model the AFT foundation as a series of interconnected rigid blocks to more closely approximate the physical situation;

2. structure-to-structure interaction - include structure-to-structure interaction in computing structural response for seismic risk assessment of Zion Unit 1; and,

3. the effect of soil-structure separation on structural response will be assessed.

In each case, we will compare the results with those obtained in Phase I assuming rigid, isolated foundations. Comparisons will be made for specified in-structure response spectra, and piping responses for a limited number of piping systems.

Task III.4: Piping Support and Damping Sensitivity Study

The objective is to study the sensitivity of piping response due to variation in damping and flexible versus rigid pipe supports. The Zion-1 piping models to be used for this study are:

1. The auxiliary feedwater piping inside containment.

2. The residual heat removal and safety injection piping in the auxiliary building.

3. Portions of the service water piping.

In the Phase I studies, all piping supports were assumed to be rigid (except for the reactor coolant loop and the auxiliary feedwater line from the steam generator to the containment penetration). Due to the effort required to obtain data for and model flexible pipe supports, it is not considered feasible to include such flexible supports unless essential, as in the case of the reactor coolant loop. In part of this study, we will examine the error introduced by using rigid rather than flexible supports.

Damping in piping systems is determined by the stress level in the pipe as it vibrates. For the Phase I calculations, the nominal damping (for all earthquake levels) was assumed to be 2%, based on Reg. Guide 1.61. In this study, the nominal pipe damping will be varied, the responses computed, and then the resulting stresses used to determine the level of damping which should have been used. This will allow an assessment of the error induced by using fixed 2% damping values.

Task III.5: Systems Analysis Sensitivity Studies With SEISIM

This task has two parts: importance ranking and sensitivity measurement. In the importance ranking portion, components, systems, accident sequences, and input parameters will be ranked on the basis of their importance to release probability. Inputs will be based on Phase I results, and random and modelling uncertainties are combined. In the sensitivity measurement portion, the sensitivity of various output characteristics to changes or variations in significant input parameters is studied. These sensitivity measures will help the NRC develop an appropriate allocation of research resources.

A number of different questions will be evaluated in the SEISIM sensitivity studies. They include:

1. What are important components, safety systems, accident sequences, cut sets, terminal event sequences, and component groups? Importance will be measured by the Vesely-Fussel and Birnbaum measures.

2. What is effect of changing in μ_R, μ_S, β_R^2 and β_S^2 all at once or all in one category and for a component or cut set?

3. What is the effect of response correlation on probability of release?

4. What are effects of primary input variables on probability of release?

5. What effect do safety systems modeled as single components (i.e., not fault treed) have on probability of release?

6. What is effect of depth of fault tree analysis on probability of release? This will be examined for the AFWS and others.

Sensitivity Studies on *Phase I Results*

TASK	FY 82		FY 83				FY 84			
	3	4	1	2	3	4	1	2	3	4
III.1 Seismic Hazard: Ground Motion Model Sensitivity Studies										
III.2 Seismic Hazard: Influence of Ground Motion Earthquake Occurrence Models on Time *Histories*										
III.3 Soil-Structure Interaction Sensitivity Study										
III.4 Piping Support and Damping Sensitivity Study										
III.5 Systems Analysis Sensitivity Studies with SEISIM FY 83 $45K			Rpt.							

IV. Complete Zion Risk Analysis

Objective

To complete the analysis of the Zion nuclear power plant which was begun in Phase I. The results of the sensitivity studies performed as part of Project III will be used to guide any model refinements required. A major part of the completion of the Zion risk assessment is to develop a means of propagating random and modelling uncertainties separately through the entire seismic analysis chain, and hence end up with confidence bounds on the predicted probabilities of radioactive release.

The specific tasks involved with completion of the Zion risk assessment are described below.

Task IV.1: Confidence Intervals Development in SEISIM

Develop and implement techniques to construct statistical confidence intervals on the release histogram that simultaneously limit the probabilities in all release categories with a specified confidence. These intervals indicate the uncertainty due to sampling error in response and fragility. These confidence intervals can then be extended to include seismic occurrence data, random failure data, and input variables used in deriving response quantities.

Task IV.2: Complete SEISIM Computational Procedure

The following improvements will be made to the SEISIM code:

a. Incorporate Hunter's bound on the probability of accident sequences .

b. Where possible, analytical derivatives for computation of sensitivity of event probabilities to changes of component strength and response parameters, including correlation (Birnbaum measures.)

c. Incorporate acceleration-dependent containment isolation valve failure probabilities.

d. A statistical ranking of importance measures for all earthquakes levels in case ranks change at different levels.

Task IV.3: Modeling vs. Random Uncertainty for Fragilities

In order to be able to put uncertainty bounds on the final radioactive risk probabilities, it is necessary to separate the variance in each fragility curve into components due to random uncertainty (which cannot be further reduced by additional testing or analysis) and due to modeling, or systematic, uncertainty (which can be further reduced by testing or analysis). This has already been done for each independent mode in the expert opinion survey results, however, a valid statistical method must be devised to combine these independent modes into a single effective fragility curve with meaningful bounds.

Task IV.4: Probabilistically Cull All Fault Trees

All fault trees and event trees developed for Zion in Phase I will be probabilistically culled to assure that all significant cutsets will be used in the final SEISIM risk evaluation.

Task IV.5: Additional Zion Piping Models

Develop the models necessary to determine the dynamic responses of the piping from the auxiliary steam supply to the auxiliary feedwater pump (AFWP) turbine of Zion Unit 1. This system's piping models together with the models developed in Phase I will constitute all the models required for the auxiliary feedwater system. This task includes generation of dynamic models, identification of the support location (in the structure) of safety systems, and coordination of the fault trees with calculated responses for the auxiliary steam supply to AFWP turbine.

Task IV.6: SMACS Software Development

The objectives of this task are to develop and maintain the computer program SMACS by: (1) Implementing features necessary to permit sensitivity studies to be performed; (2) Improve the efficiency of SMACS; and (3) Develop machine independent versions of SMACS to the extent possible.

Task IV.7: Local Site Conditions

Local site amplification has a potentially significant effect on structural response at Zion and is a major source of modeling uncertainty. Phase I did not include the effect of local site conditions on the seismic hazard curve or on the free-field acceleration time histories. The objectives of this task are to:

- Investigate the effects of local site conditions at the Zion site with respect to recorded ground motions;
- Develop earthquake time histories reflecting local site effects for SMACS sensitivity studies;
- Evaluate the effect of local site conditions on the Zion seismic hazard curve for inclusion in the final Zion analysis.

Task IV.8: Final Zion Risk Calculations

After completion of all the above tasks, a final SMACS evaluation of the building and component responses will be made, followed by a final SEISIM evaluation of risk of core melt and radioactive release. A single final report will be prepared.

Complete Zion Risk Analyses

TASK	FY 82		FY 83				FY 84			
	3	4	1	2	3	4	1	2	3	4
IV.1 Confidence Intervals Development in SEISIM										
IV.2 Complete SEISIM Computational Procedure										
IV.3 Modeling vs. Random Uncertainty for Fragilities										
IV.4 Probabilistically Cull All Fault Trees										
IV.5 Additional Zion Piping Models										
IV.6 SMACS Software Development										
IV.7 Local Site Conditions										
IV.8 Final Zion Risk Calculations FY 83 $86K										

V. Develop Simplified Models for PRA

Objective

The goal of the project is to develop a simplified methodology for routine probabilistic risk assessments which can be implemented at a cost of roughly $600K and 6-8 months for any specific PWR. The methodology will use the tools, codes and data bases developed in Phase I of the SSMRP, but will use responses calibrated from the plant design calculations developed from our detailed analysis of the Zion plant.

A major task in the development of a complete, simplified seismic risk assessment methodology is the development of a unified scheme for inferring the seismic hazard curve at any give site. This will be accomplished by developing consistent, tectonic zonation and attenuation models for all parts of the U.S. east of the Rocky Mountains. A considerable amount of this work was already accomplished for the northwest U.S. as part of the Zion hazard definition in Phase I. The seismic hazard characterization work has been transferred to FIN A0390, under the direction of the NRC Earth Sciences Branch.

The tasks remaining are those associated with development of simplified building and piping response models, functional PWR accident sequences and testing the simplified methodology against the more detailed risk calculations for Zion performed under Project IV. These tasks are described below.

Task V.1: Building Response Calibration

A set of guidelines will be developed for scaling design building responses to best estimate responses for input to the SEISIM code. This will include a review and categorization of analysis and design approaches used in the nuclear industry for structure response. The relationship between design results and best-estimate, median responses will be estimated for various analysis scenarios. The definition of the seismic input, soil properties at the site, SSI analysis, and structure modeling will be considered. Uncertainties will be derived from our detailed Zion response calculations, as well as an appropriate means of including necessary response correlation.

Task V.2: Piping Response Calibration

This task has the same definition as for building response calibration above, and will be approached in the same fashion. However, a number of other issues (e.g. combination of loads, non-category I systems, etc.) must also be considered. The level of approximation here will be guided by our experience with previously computed piping failure probability estimates made for Zion.

Task V.3: PWR Functional Accident Sequences

Based on sensitivity studies and dominance rankings for the Zion plant, and on a review of different PWR Safety System interactions, a sufficiently general set of generic accident sequences will be selected to be recommended as a standardized basis for probabilistic seismic risk assessment of PWR's.

Task V.4: Categorize PWR Fault Trees

In this task we will seek to develop a set of functional PWR fault trees whose level of detail will be guided by our experience at Zion. These functional fault trees should be sufficiently general to apply to any U.S. designed PWR, and have provisions for tailoring them to any specific design. The important feature is that the level of detail recommended should be such that all essential seismically-induced basic events (failures) be included. There again, we will be guided by our sensitivity studies and dominance rankings.

Task V.5: Quantitative Comparison of Simplified Methods vs. Zion Phase II Results

The simplified methodology will be applied to Zion, and detailed comparison with the Phase II results will be made to quantify the approximations made in applying the simplified methodology.

Task V.6: Procedures and Limitations Report

A report describing recommended simplified methodology procedures and limitation of the procedures will be prepared.

Develop Simplified Models for PRA

TASK	FY 82		FY 83				FY 94			
	3	4	1	2	3	4	1	2	3	4
V.1 Building Response Calibration FY 83 $55K										
V.2 Piping Response Calibration FY 83 $90K										
V.3 PWR Functional Accident Sequences FY 83 $20K										
V.4 *Categorize PWR Fault* Trees FY 83 $20K										
V.5 Quantitative Comparison of Simplified Methods vs. *Zion Phase II Results* FY 83 $80K										
V.6 Procedures and Limitations Report FY 83 $55K										

VI. Validation of SSMRP Methodology

Objective

The objective of this project is to provide ongoing assessment and overall validation of the tools and methodology developed in the SSMRP. This includes evaluation and update of the seismic and fragility data bases, quality control and benchmarking of the computer codes and validation of the entire calculational scheme by comparison with actual data. Potential data sources for such overall validation are the ongoing tests being performed at the HDR facility in W. Germany (in which the NRC is an active participant) as well as tests at the Indian Point Power Plant in the United States and (possibly) data from the Chiba field station tests in Japan.

One major effort continuing through FY'83 and beyond will be to benchmark the fragility curves. A major part of this effort will be to obtain data from sources identified during the expert opinion survey performed in FY'80, and seek new sources of data existing both within and outside the nuclear community.

The tasks described below are those which are envisioned at this time. Better definition or redefinition of these tasks will result from our sensitivity studies in Project III scheduled for completion in FY 82. In addition, a concentrated effort to evaluate existing data sources (both NRC programs and others) will be made, culminating in a coordinated validation plan to be issued in October, 1982.

Task VI.1: Seismic Hazard Time Series Modeling Alternatives

Currently available methods to generate time histories attempt to match only the Fourier amplitude spectrum, hence, correlation between components phase content and energy is lost. Thus such approaches may not be an adequate representation of the set of real time histories from earthquakes particularly for nonlinear analysis. To overcome this problem, we initiated a research effort in Phase I to directly study the time series. The objectives of this task are to (1) select from available methods (including the ARMA model developed in Phase I) to generate time series the best (cost vs. statistical acceptability) method and acquire/develop necessary software, (2) use the selected method to develop new sets of time histories using overall hazard models of Phase I for input to SMACS, (3) assess the importance of the correlation between earthquake components in time series modeling.

Task VI.2: Ground Motion Model Validation

During the course of Phase I and in calculating the final Zion risk probabilities, work in the area of ground motion and earthquake source modeling was concentrated in sensitivity studies on regression models of existing data to determine a best-fit ground motion model with associated confidence bounds (Task III.1). The confidence bounds were obtained both from uncertainties in model parameters as well as using the same data base with different regression model formulations.

In this task, we will concentrate on the significant difference in source characteristics between the eastern and western United States. Because of differences in both the structure of the earth and the earthquake generating mechanism, coupled with the low rate of seismicity (but much larger felt areas in eastern U.S. as compared to the western U.S.) estimates of the ground motion from earthquakes for the eastern U.S. are very uncertain. Our studies seek to reduce this uncertainty by application of state-of-the-art modeling studies, and analysis of data recorded from the 1982 earthquakes in New Hampshire and New Brunswick as well as other eastern U.S. data currently available. This task will help us correct for systematic differences between the observed ground motion from western U.S. earthquakes and the ground motion to be expected in the eastern U.S.

Task VI.3: Local Site Conditions

Local site amplification has a significant effect on structural response and is a major source of modeling uncertainty. Phase I did not include the effect of local site conditions on the seismic hazard curve or on the free-field acceleration time histories. As part of the final Zion Analysis in FY'82, an assessment of local site effects at the Zion site was made using the new time histories modified for the Zion soil layer configuration based on linear viscoelastic soil properties and vertically propagating waves. The hazard curve was modified as a result of decreasing the uncertainty in the ground motion model to remove that uncertainty thought to be due to differences in site conditions at which ground motion data were recorded.

This task is a generalization of the preliminary local site analysis performed for Zion. The Zion analysis was limited to simple transfer functions. The main thrust of this task will be to examine more realistic calculational procedures for calculating local site effects correcting for such factors as topography, sloping interfaces, nonvertically incident waves, etc. Nonlinear factors are investigated in Task VI.5. The different calculational procedures will be validated using data from rock/soil pairs recorded from Friuli earthquakes, Oroville aftershocks, etc. and at stations which have recorded a number of earthquake, e.g., El Centro, Ferndale, Hollister. In addition, an attempt will be made to categorize sites at which site corrections should be considered in seismic risk assessment.

Task VI.4: SSI Analysis Techniques

The objectives of this task are to investigate and identify the characteristics of different nuclear power plant structures and sites relative to their soil-structure interaction characteristics. The results are necessary to evaluate the generic aspects of the SSMRP Phase I results for Zion. The approach is to use the results from the Zion site and structures as a starting point and hypothesize their placement on other sites. Since the Zion auxiliary - fuel storage - turbine building complex has some unique features, at least one additional structure typical of nuclear power plant structures will be considered. Several steps comprise the task:

- Select soil/structure combinations to be analyzed.
- Define situations to be analyzed--free-field ground motion (amplitude, wave propagation mechanism, frequency content), soil configurations, soil material behavior, foundations, embedment, structure-to-structure interaction, localized nonlinear behavior.
- Identify bases of comparison, e.g., structure response, foundation response, etc..
- Perform analyses and compare results.

Task VI.5: Non-linear Soil Response

An important effect in modeling coupled soil-structure interaction is the non-linear response of the soil, especially degradation of properties and cyclic effects. Such effects are commonly included only in an approximate "equivalent-linear" sense, as was done in Phase I. The validity of this equivalent linearization procedure has never been verified for high excitation levels, varying excitation levels and differing sites.

The first step toward this verification was taken in Phase I, with the implementation of the Prevost multi-surface plasticity soil model into the non-linear finite element codes DYNA 2D/3D. What remains is a systematic evaluation using these tools, to verify that significant non-linear effects have not been lost by the use of equivalent linearization used in Phase I Zion analysis, and to assess the uncertainty introduced by use of equivalent linearization.

Task VI.6: Nonlinear Structural Response

The task assesses the effect of nonlinear material behavior on structural response and assesses the features which equivalent linear models adequately capture and those which require special consideration.

Task VI.6.1: Constitutive Model

Several items comprise the approach:

- Assess available nonlinear constitutive models of typical structural materials--reinforced concrete, prestressed concrete block walls, etc. A literature review will be performed with assistance from consultants.
- Implement candidate constitutive models into LLNL general purpose nonlinear finite element program;
- Investigate model behavior at the point or element level.

Task VI.6.2: Structural Response

The following items comprise the task:

- Select typical nuclear power plant structure configurations for analysis. Structures whose behavior is expected to be distinctively nonlinear and are important from a risk standpoint will be emphasized.

- Perform nonlinear structural response at a super element level and for a fixed base structure. First, consider steady-state harmonic excitations at varying amplitudes and frequencies. Second, consider random-type earthquake excitations for varying excitation levels.

- Perform equivalent linear analysis (ELA) for the identical excitations and correlate structural response between the two cases.

- Recommend ELA models which best fit nonlinear results.

- Analyze selected configurations to failure to quantify structure capacities. Compare with capacities used for risk analysis.

Task VI.7: Compare Structure and Subsystem Response Predictions With Data

In typical nuclear power plant structures, soil and structures must be treated as coupled systems because SSI is important for massive structures supported on large basemats. The best method of benchmarking these predictions is to reproduce field-recorded motions - experimental or recorded earthquake motions. There is a small amount of such data available (Humbolt Bay, EPRI simquake, HDR). A second method is to verify different predictive calculational procedures by defining benchmark problems and solving them by alternative procedures. A comparison of these results is helpful in verifying analysis techniques. In this task, we will review existing data sources, and identify one or more facilities to benchmark our predictive capability against. Coordination and data gathering should be the major thrust of the FY'83 activities, with calculations and comparisons beginning late in FY'83.

Although limited data are available in each of these cases, the data would be used as a vehicle to benchmark the entire structural calculational scheme by performing a complete soil structure interaction analysis of the location and then a building and (if appropriate) piping response analysis for comparing against the data. The comparison would be between the measured response and the computed probability distribution of response. Such a study would provide confidence in our analytical prediction capability and, in fact, provides the only means of truly validating the overall structural and subsystem response calculations.

Task VI.8: Fragility - Data Gathering and Reduction

The effort to obtain and incorporate existing fragility data will be completed. Data will be sought from two main sources. The first source consists of the component manufacturers and independent testing laboratories which indicated that they had access to failure data during the expert opinion survey. The second source will consist of known testing programs associated with U.S. military site-hardening and crash worthiness programs. The data obtained will be compiled and compared with the fragility curves developed during Phase I.

Task VI.9: Fragilities - Verify Building Ductility Approach

In using the Newmark procedure to determine the fragility of the various structures associated with the nuclear power plant, the design load is multiplied by three factors: a strength factor, a ductility factor and a response factor. The ductility factor is roughly the ratio of the energy absorbtion capability of the actual structure behaving in a nonlinear fashion to the energy obsorbed as calculated using a linear analysis. This factor is usually greater than 1 and is the most important of the three factors used in estimating the ultimate strength of the structure. Calculation of the ductility factor follows a method developed by Newmark in which he analyzed a number of single degree of freedom systems under base excitation from a ensemble of recorded earthquake time histories. Both linear and nonlinear analysis were used to estimate the ratios of the computed energy absorbed. Other than the several papers by Newmark and his co-workers, there has been little further analytical or experimental work to verify or validate this approach.

In this task it is proposed that nonlinear analysis be used on a two dimensional model of a building to compute the actual ductility reached due to realistic earthquake motions and the amount of energy absorbed using a nonlinear elastic-plastic analysis. This could be done for a structure typical of nuclear power plant auxiliary building and would help justify the use of the Newmark ductility factor approach. One aspect deserving particular attention is the differences between old and new building designs. Newer designs tend to provide a more uniform level of ductility and it is suspected that the Newmark method applies most accurately to them. In older designs, ductility of the entire structure tends to be limited by the ductility of the construction joints. This particular question would be examined in the study.

Task VI.10: Design Defects

One important area of uncertainty which has not been previously included explicitly in the SSMRP methodology is that arising from errors in design and/or construction. Several reports in the literature (e.g., Okrent and Hsieh) have demonstrated the large effect which design errors can have on seismic risk. A short study performed under the auspices of the SSMRP (Apostalakis, et. al.) categorized the possible types of design errors which should be considered. To date, however, no generally accepted, practical means of including the effects of design errors in a risk calculation is available.

In this task, an attempt to include design errors in the risk calculation scheme will be made. As a first step, available literature will be reviewed to identify potential methods of including this effect. Secondly, a panel of experts will be convened to review and recommend one or more approaches.

Task VI.11: Containment Consequence Modeling

In the original scope of the SSMRP, for the analysis of the Zion plant, the decision was made to utilize the containment failure mode fault trees as developed in the WASH-1400 study completed in 1974. Since then, a considerable amount of research has been performed in the areas of fission product transport and release and containment failure modes. Such studies tend to indicate that the WASH-1400 methods were conservative. Since containment failure modes and release category assignments are incorporated at the end of the SEISIM failure calculations, a more realistic assessment could have a significant effect in reducing the final computed radioactive release probabilities.

In this task, we will examine recent work in containment failure mode analysis, and assess what effects these recent analyses would have if used in the Zion risk assessment.

Task VI.12: Validation of Confidence Intervals

We will develop alternative methods of estimating confidence intervals on probabilities of release. Two methods are the Taylor series expansion and discrete probability alternatives. We propose to develop and incorporate the alternative methods into SEISIM. We also propose to study a method which represents uncertain distribution functions as stochastic processes.

The objective of these alternates is to estimate simultaneous confidence intervals on release category probabilities. The widths of the intervals represents uncertainty in input parameters and sampling error.

Task VI.13: Evaluate Alternatives to Event Tree Analyses

Event trees probabilities are currently computed by computing cut set probabilities and bounding the probabilities of unions of cut sets. The cut sets representing events in the event trees are too large and the bounds are too wide.

We will examine alternative computation methods, for example the EPRI Go methodology and a method based on deletion of complemented events.

Task VI.14: Electrical Control Systems Reliability Validation

The objective is to review and verify fault trees of electric power control systems to identify feedback loops or sneak circuits that could cause failure in an earthquake. Relay chatter (which of itself is not a permanent failure) could cause changes in the state of a control system resulting in system failure. Digraphs will be used to analyze control circuits.

Validation of SSMRP Methodology

TASK	FY 82		FY 83				FY 84			
	3	4	1	2	3	4	1	2	3	4
VI.1 Seismic Hazard Time Series Modeling Alternatives FY 83 $70K	////	////	////	////	////	////				
VI.2 Ground Motion Model Validation FY 83 $70K			////	////	////					
VI.3 Local Site Conditions FY 83 $144K		////	////	////	////					
VI.4 SSI Analysis Techniques FY 84 $137K							////	////	////	////
VI.5 Non-linear Soil Response FY 83 $90K FY 84 $60K			////	////	////	////	////			
VI.6 Non-linear Structural Response FY 83 $ 70K FY 84 $144K					////	////	////	////	////	////
VI.7 Compare Structure and Subsystem Response Predictions Against Data FY 83 $235K FY 84 $270K	////	////	////	////	////	////	////	////	////	////
VI.8 Fragility - Data Gathering and Reduction FY 83 $60K	////	////	////	////	////	////				
VI.9 Fragilities - Verify Building Ductility Approach FY 83 $15K FY 84 $125K						////	////	////	////	////

Validation of SSMRP Methodology

TASK	FY 82		FY 83				FY 84			
	3	4	1	2	3	4	1	2	3	4
VI.10 Design Defects FY 83 $90K				//////	//////					
VI.11 Containment Consequence Modeling FY 83 $10K FY 84 $70K					//////	//////	//////	//////	//////	
VI.12 Validation of Confidence Intervals FY 83 $120K			//////	//////						
VI.13 Evaluate Alternatives to Event Tree Analyses FY 84 $110K							//////	//////	//////	//////
VI.14 Electrical Control Systems Reliability Validation FY 84 $66K								//////	//////	//////

VII. BWR Risk Assessment

Objectives

1. To develop complete event trees and fault trees for a typical BWR which will subsequently be used to develop simplified Systems Analysis models for the BWR.

2. To identify any salient differences between a BWR and PWR (from a seismic risk viewpoint) which might require additions or modifications to the Phase I SSMRP methodology.

3. To identify any major differences between seismic risk at Zion PWR and a BWR.

Task Description

General - The seismic risk methodology developed in Phase I of the SSMRP was demonstrated by application to the Zion PWR. Thus all the systems analysis models (initiating events, event trees and fault trees) and all the structural and piping models were developed for a PWR. Yet the methodology developed in the SSMRP must be equally applicable to both PWR and BWR systems. To identify any fundamental differences between PWR and BWR, and to verify the applicability of the SSMRP methodology to a BWR, a risk analysis of a BWR will be performed.

Task VII.1: BWR Fault Trees

In FY'82, the BWR analysis will be started by developing complete systems models (fault trees and event trees). In FY'83 these systems models will then be studied to ascertain any systematic differences between the systems aspects of BWR's and PWR's, and then simplified systems models can be obtained by performing sensitivity studies. Then the BWR risk assessment will be performed. The following tasks assume that an appropriate BWR has been identified, and suitable agreements set up with the owner/operator for provision of needed drawings and data. The fault trees developed by the Idaho National Engineering Laboratory as part of the NRC IREP program will be modified to include seismically-induced passive failures.

Task VII.2: Benchmark Building, Piping Response

The containment structure, vessel and piping layout design for a BWR is somewhat different from that for a PWR. Using structural/piping drawings, design analysis, and expert assistance, a study will be made to determine any salient differences between BWR and PWR structural response characteristics. The aim here is to ascertain whether the uncertainties determined from Zion risk analysis may be assigned to a BWR or whether a separate set of structural uncertainties must be determined.

Task VII.3: Investigate Hydrodynamic Loads

Hydrodynamic loads caused by SRV opening and closure, annulus pressurization, vent clearing, pool swell, chugging and condensation acceleration, etc., are unique for a BWR. All of these loads have common characteristics which involve higher modes of frequency compared to seismic loads. The hydrodynamic loads, which do not appear in PWR structural/piping analyses, might have an influence on the final structural/piping uncertainties to be assigned in the BWR risk analysis. In this task, previous LLNL experience (both experimental and theoretical) will be combined with limited calculations to determine the influence of these hydrodynamic loads on overall BWR seismic risk.

Task VII.4: Probabilistically Cull Fault Trees

The fault trees developed for the BWR safety systems will be reduced to minimal cut sets using the probabilistic culling procedures in the SETS and FTAP computer codes.

Task VII.5: Fault Tree Coordination

In this task, the basic seismic failure events identified on the fault trees will be correlated with physical location in the plant, and with the appropriate fragility generic category. For piping systems, the Beta Factor scaling technique will be used to normalize computed moments to a common parameter.

Task VII.6: BWR Site Seismic Input

Using the eastern United States hazard characterization (FIN A0392), the local site hazard curve and time histories will be developed. The estimated cost figure for this task assumes an eastern United States site.

Task VII.7: Develop Building Fragilities

For the specific BWR under consideration, building fragility descriptions will be developed with special emphasis on ascertaining the appropriate ductility for each structure.

Task VII.8: Perform SEISIM Risk Analysis Computations

Using responses from Task VII.2, fault tree cut sets from Task VII.4 and fragilities from Tasks VII.7, the SEISIM code will be used to compute probabilities of core melt and radioactive release. The release categories would be those used in WASH-1400.

Task VII.9: Prepare Final Report

A single final report will be issued. This task covers manpower costs to prepare this documentation.

BWR Risk Assessment

TASK	FY 82		FY 83				FY 84			
	3	4	1	2	3	4	1	2	3	4
VII.1 BWR Fault Trees FY 82 $30K		//////								
VII.2 Benchmark Building, Piping Response FY 83 $110K				//////	//////					
VII.3 Investigate Hydrodynamic Loads FY 83 $80K				//////	//////	//////				
VII.4 Probabilistically Cull Fault Trees FY 83 $55K			//////	//////						
VII.5 Fault Tree Coordination FY 83 $45K				//////	//////					
VII.6 BWR Site Seismic Input FY 83 $65K				//////						
VII.7 Develop Building Fragilities FY 83 $90K				//////	//////					
VII.8 Perform SEISIM Risk Analysis Computations FY 83 $72K FY 84 $126K						//////	//////			
VII.9 Prepare Final Report FY 84 $107K								//////	//////	

VIII. Technology Transfer

Objective

To provide for a timely transfer of tools, computer codes and data bases both to groups within the NRC as well as to the general nuclear community. This includes generating and maintaining publicly-accessible versions of the computer codes developed as part of the SSMRP, generation of code users manuals and standard problems, and code configuration control. Also included is a limited amount of on-call user assistance.

In addition, groundwork will be laid (in FY'82) for a Seismic Risk Assessment Code Users Workshop to be held in FY'83.

Specific tasks are described below.

Task VIII.1: Public Version of SMACS Code (Option 1)

A simplified version of the SMACS code will be set up and checked out on the Lawrence Berkeley Laboratory CDC 7600 computer system. This version can consider any surface founded isolated structure but no piping analysis capability would be included. This version will then be accessible to any interested party via a standard telephone-computer link-up. A user's manual and standard problem with example input and output will be generated

Task VIII.2: Public Version of SMACS Code (Option 2)

In FY'82 the first version of the SMACS code available for public use was released. This version was installed on the Lawrence Berkeley Laboratory computer system, from which it is accessible via standard commercial telephone link. A users manual for this version was prepared and released. In FY'83 a second public version of the SMACS code will be released. This version will have additional capability in the area of soil-structure interaction, but will not include any piping analysis capability. It will be a version which is more easily adaptable to any other computer system. This latter feature will be incorporated by re-organizing the input/output files so that a user can plug in his own graphics package. A revised user's manual will be issued.

Task VIII.3: Users Version of the SEISIM Code

The final version of the SEISIM code used for the Zion risk calculations, including sensitivity measures and confidence bounds computations will be put in a user accessible format, with simplified input and output, and will be fully documented in a users manual, including sample and benchmark problems.

Task VIII.4: Allocation of Resources

The NRC can allocate resources to reduce the radioactive release probability and the uncertainty about that probability. Resources which can be allocated to help reduce the release probability are better maintenance, better operation, better inspection, better construction and quality control, and better design. Resources which can be allocated to reduce the uncertainty about the release probability are better estimates of maintenance error probabilities, better estimates of operator error probabilities, better quality assurance systems, testing of strength of nuclear power plant components, analysis of plant response to earthquake and other shocks, and better estimates of release probabilities.

We propose to develop a method based on the Birnbaum measure incorporated in the SEISIM code to minimize the release probability subject to a constraint on the uncertainty in that probability and a budget constraint. The uncertainty constraint is a function of the release probability.

The method developed will use mathematical programming techniques. The inputs are (1) the rates of change of release probability per unit of those activites that were listed in the first paragraph (rates computed using SEISIM computer code) and the cost per unit of the activities. The output is an optimal ranking of which activities either reduce your release probability or reduce your uncertainty about that probability.

Task VIII.5: Users Version of the HAZARD Code

The version of the HAZARD code utilized in the Zion seismic risk calculations was a modification of a code developed by Chris Morgat of the TERA Corporation. Inasmuch as the code and its methodology were highly experimental at the start, no attempt was made to provide an easily understood, fully commented version of the modified code.

In this task, the modified code will be revised to provide the user with an easily decipherable code, with older (non-essential) coding removed and clean internal documentation. This will permit the user to modify the code as required for any special applications. Included in this task will be the generation of a code user's manual.

Task VIII.6: SSMRP Users Conference

A three day SSMRP Users Conference will be scheduled in the spring of 1983. This will be timely inasmuch as the final Zion risk analysis and simplified methodology will have been completed, as well as users versions of the three main codes, SMACS, HAZARD and SEISIM.

The purpose of the conference will be to acquaint potential users with the risk tools developed in the SSMRP and provide an up-to-date summary of our experience with these tools. Hands-on execution of simple sample problems with these codes will be available via terminal hook-up.

Technology Transfer

TASK	FY 82		FY 83				FY 84			
	3	4	1	2	3	4	1	2	3	4
VIII.1 Public Version of SMACS Code (Option 1)										
VIII.2 Public Version of SMACS Code (Option 2) FY 83 $90K										
VIII.3 Users Version of the SEISIM Code FY 83 $85K										
VIII.4 Allocation of Resources FY 84 $64K										
VIII.5 Users Version of the HAZARD Code FY 83 $75K										
VIII.6 SSMRP Users Conference FY 83 $48K										
VIII.7 Final Versions SMACS/SEISIM FY 84 $62K										