DISRUPTION SCENARIO ANALYSIS FOR A NUCLEAR WASTE REPOSITORY IN HANFORD SITE BASALTS, WASHINGTON STATE

An Initial Iteration

J. D. Davis
Basalt Waste Isolation Project
Rockwell Hanford Operations
Richland, Washington 99352

A. K. Runchal
Analytic & Computational Research, Inc.
Los Angeles, California 90066

ABSTRACT

An initial application was made of the Delphi Method of expert opinion consensus-forming to disruption scenario analysis of a candidate high-level nuclear waste repository at the Hanford Site, Washington State. Expert scientific and engineering opinion was elicited for the purpose of identifying, categorizing, and ranking of site-specific scenarios within the framework of occurrence probability categories established by the U.S. Nuclear Regulatory Commission and the U.S. Environmental Protection Agency. After refinement by a second Delphi iteration, the disruption scenarios selected to be of most concern will be characterized in detail for use in assessing long-term repository performance under disruption scenario conditions.

INTRODUCTION

Rockwell's Energy Systems Group is responsible for assessing the feasibility of siting a repository for terminal disposal of nuclear waste in the basalts underlying the Hanford Site near Richland, Washington. Should feasibility be demonstrated, Rockwell will develop and design the associated facilities and technologies required for the permanent isolation of radioactive waste in basalt formations. Demonstration of feasibility requires that such a repository's isolation performance objectives comply with criteria of 10 CFR Part 60[1] and proposed criteria of 40 CFR 191.[2]

The objective of our study was to obtain expert scientific and engineering opinion on the identification, categorization, and selection of credible disruptions, unexpected conditions, or changes from nominal conditions that could potentially affect radionuclide isolation capability of the candidate Hanford Site repository.[3] A Delphi method of eliciting expert opinion was utilized. The Delphi method is a structured, balanced, auditable means of eliciting expert opinion that commonly is used for guidance on questions in the arena of public policy. Several of the scenarios identified and categorized by the Delphi panel will constitute the starting point for future scenario characterization and consequence analyses. Results of such consequence analyses will be compared to regulatory criteria to evaluate whether or not the repository is likely to perform in compliance with the regulatory criteria.

Several methods of scenario analysis were considered prior to choosing a Delphi method. Methods considered included event/fault tree, simulations, and systems analysis. The Delphi approach was chosen because of (1) the considerable length of time for which repository performance must be assessed and (2) the qualitative nature of presently available data for predicting occurrences of conditions, events, or processes whose initiating mechanisms are not fully understood. Such factors importantly contribute to the controversy of selecting scenarios adequate for modeling repository isolation performance.

The main consideration in selecting the Delphi panelists was to obtain the expert opinions of the persons most highly regarded in those fields of science and engineering most closely related to repository disruption scenario analysis--hydrology, geology, geophysics, mining engineering, and climatology. Fifteen nationally or internationally known scientists and engineers were chosen based on a nationwide reputational survey of major professional societies and issue- and site-specific expertise. The panel included persons knowledgeable of nuclear waste disposal issues and the geologic and hydrologic characteristics of the Hanford Site (Table I). Selection of the Delphi panel and implementation of the Delphi survey were made by a consultant, free of any direct involvement by Rockwell.

For purposes of the study, disruption scenarios were considered in a framework of four disruption types:

1. Uncertainties and potential omissions associated with characterization of the candidate site. (Includes present conditions not recognized, planned for, or taken into account in design.)
2. Potential disruptions due to the dynamics of natural site systems. (Includes, for example, such potential events as earthquakes and volcanism.)

TABLE I.

The Delphi Panel.

Name	Discipline	Current position and organization	Education
Mary P. Anderson	Hydrology	Associate Professor, Dept. of Geology and Geophysics, University of Wisconsin, Madison	Ph.D. Hydrogeology, 1973, Stanford University
William F. Brace	Geophysics	Professor, Dept. of Earth and Planetary Sciences, Massachusetts Institute of Technology	Ph.D. Geology, 1953, Massachusetts Institute of Technology
Howard A. Coombs	Geology	Professor and Chairman Emeritus, Dept. of Geology, University of Washington	Ph.D. Geology, 1935, University of Washington
Neville G. Cook	Mining Engineering	Professor, Dept. of Materials Science and Mineral Engineering, University of California, Berkeley	Ph.D. Geophysics, 1962, University of Witwatersrand, Johannesburg, South Africa
Stanley N. Davis	Hydrology	Professor, Dept. of Hydrology and Water Resources, University of Arizona	Ph.D. Geology, 1955, Yale University
Richard D. Ellison	Mining Engineering	Executive Vice-President and Consulting Engineer, D'Appolonia Consulting Engineers	Ph.D. Civil Engineering, 1968, Carnegie-Mellon University
Charles Fairhurst	Mining Engineering	Distinguished Professor and Head, Dept. of Civil and Mineral Engineering, University of Minnesota	Ph.D. Mining Engineering, 1955, Sheffield University, England
John Handin	Geophysics	Distinguished Professor, Dept. of Geology and Geophysics, and Director, Earth Resources Institute, Texas A. & M. University	Ph.D. Geophysics, 1949, University of California, Los Angeles
Harold L. James	Geology	Chief Geologist (Retired) U.S. Geological Survey	Ph.D. Geology, 1945, Princeton University
William W. Kellogg	Climatology	Senior Scientist, Advanced Study Program, National Center for Atmospheric Research	Ph.D. Meteorology, 1949, University of California, Los Angeles
Konrad B. Krauskopf	Geology	Professor and Chairman Emeritus, Dept. of Geology, Stanford University	Ph.D. Geology, 1939, Stanford University
David T. Snow	Hydrology	Consultant, Groundwater Hydrology and Geological Engineering, Georesults, Inc.	Ph.D. Engineering Science, 1965, University of California, Berkeley
Howard H. Waldron	Geology	Consulting Geologist, Shannon & Wilson, Inc., and Geologist-in-Charge (Retired), Washington Field Office, U.S. Geological Survey	Graduate Studies, Geology, 1942, University of Washington
Stanley H. Ward	Geophysics	Professor, Dept. of Geology and Geophysics, and Director, Earth Science Laboratory, University of Utah	Ph.D. Geophysics, 1952, University of Toronto
Thompson Webb III	Climatology	Associate Professor, Dept. of Geological Sciences, Brown University	Ph.D. Meteorology, 1971, University of Wisconsin, Madison

3. Potential disruptions resulting from repository construction and operation. (Includes, for example, such potential processes as thermal perturbation of the host rock and mining-induced fracturing.)
4. Potential disruptions induced by human activity other than repository construction and operation. (Includes, for example, resource exploration and development.)

Based on review of U.S. Nuclear Regulatory Commission (NRC) technical criteria[1] and U.S. Environmental Protection Agency (EPA) proposed release-risk regulations,[2] Rockwell identified five occurrence probability categories within the context of which site-specific scenarios were considered (see section entitled, "Results" for definitions):

1. Reasonably Foreseeable - Anticipated
2. Reasonably Foreseeable - Unanticipated
3. Very Unlikely - Anticipated
4. Very Unlikely - Unanticipated
5. Extremely Unlikely - Unanticipated.

In keeping with accepted Delphi practice, a questionnaire prepared by Rockwell and refined by independent peer review (Table II) was administered by mail to each panelist during three rounds. Three tasks were required of the Delphi panelists:

1. Identify and categorize potential disruptions to repository isolation performance consisting of unexpected conditions or changes from present, nominal conditions. Place each of the scenarios identified in one of the five occurrence probability categories associated with each of the four disruption types to which it belongs.
2. Select the scenario from each occurrence probability category *for each of* the four disruption types that is most likely to adversely affect repository isolation performance.
3. Select the scenario from each occurrence probability category, for all four scenario types, that is most likely to adversely affect repository isolation performance.

TABLE II.

Independent Peer Review Committee Responsible for Refinement of Delphi Questionnaire.

Name	Current position and organization
Professor G. A. Davis	Professor and Past Chairman of the Geology Department, University of Southern California
Dr. B. Sagar	Principal Hydrologist, Analytic & Computational Research, Los Angeles, CA
Dr. C. M. St. John	Associate and Mining Expert, Agbabian Associates, El Segundo, CA
Mr. J. S. Nelson	Director of the Geophysics Department, Harding-Lawson Associates, Novato, CA
Dr. G. Kukla	Senior Research Associate, LaMont-Doherty Geologic Observatory, Columbia University, New York

An adverse effect was defined for the panelists as a decrease in groundwater traveltime and/or an increase in radionuclide flux to the accessible environment, at ≥10 km from the outermost limits of disposed radioactive waste, that results from the occurrence of scenarios identifed and categorized by completion of Task 1.

RESULTS

The potential undetected site conditions and disruptions or changes from nominal conditions that were identified during the study are listed in Fig. 1 to 4. Of the 45 disruption scenarios considered, 32 were initially identified by Rockwell and the independent peer review panel (Table II) based upon a survey of available information. The other 13 scenarios were identified by the Delphi panelists during the three consensus-forming rounds of questionnaire circulation. Out of 45 scenarios thus identified, the occurrence probabilities of 26 were agreed upon by 75% or more of the panelists expressing an opinion (Fig. 1 to 4). Of these, a complete consensus was reached in categorizing the site-specific occurrence probabilities of 9 scenarios (Fig. 1 to 4).

Considering each of the four types of scenarios in turn, the Delphi panelists reached majority agreement in selecting the following conditions, events, and processes as being potentially most adverse to repository isolation performance for each of the five occurrence probability categories (listed in order of decreasing panel consensus and decreasing probability):

- Reasonably Foreseeable - Anticipated

  1. Estimation uncertainties of greater than one order of magnitude in hydraulic conductivities (selected by 12 of 15 panelists, with 1 abstention)--Uncertainties and Potential Omissions Associated with Characterization of the Candidate Site.
  2. Estimation uncertainty of greater than 50% in host rock fracturing induced by shaft, tunnel, and emplacement hole boring or mining (selected by 8 of 15 panelists, with 2 abstentions)--Potential Disruptions Resulting from Repository Construction and Operation.
  3. Seismicity of less than 6.7 magnitude, with faulting (selected by 7 of 15 panelists, with 2 abstentions)--Potential Disruptions Due to the Dynamics of Natural Site Systems.
  4. Nuclear fuel recovery by deep mining methods (selected by 5 of 15 panelists, with 5 abstentions)--Potential Disruptions Induced by Human Activity Other than Repository Construction and Operation.

- Reasonably Foreseeable - Unanticipated

  1. Nuclear fuel recovery by deep mining methods (selected by 4 of 15 panelists, with 9 abstentions)--Potential Disruptions Induced by Human Activity Other than Repository Construction and Operation (split of opinion with No. 4 above).

- Very Unlikely - Anticipated

  1. Undetected flow breccia of areal extent greater than 1/2 mi^2 (selected by 4 of 15 panelists, with 9 abstentions)--Uncertainties and Potential Omissions Associated with Characterization of the Candidate Site.

- Very Unlikely - Unanticipated

  1. Change in transport properties causing a decrease of more than 50% in groundwater traveltime (selected by 10 of 15 panelists, with 2 abstentions)--Potential Disruptions Due to the Dynamics of Natural Site Systems.
  2. Irrigation or other human-caused perturbation of the hydrologic system (selected by 4 of 15 panelists, with 7 abstentions)--Potential Disruptions Induced by Human Activity Other than Repository Construction and Operation.

- Extremely Unlikely - Unanticipated

  1. Criticality (assumes unreprocessed spent fuel in the repository) (selected by 5 of 15 panelists, with 9 abstentions)--Potential Disruptions Resulting from Repository Construction and Operation.

Considering all four types of scenarios collectively, panelists expressing an opinion reached majority agreement on the scenario judged likely to have the most adverse radionuclide release potential for three of the five occurrence probability categories. No clear majority was reached for the other two categories. The scenarios selected are as follows:

- Reasonably Foreseeable - Anticipated

Estimation uncertainties of greater than one order of magnitude in hydraulic conductivities (selected by 10 of 15 panelists, with no abstentions).

- Very Unlikely - Anticipated

Undetected flow breccia of areal extent greater than 1/2 mi^2 (selected by 7 of 15 panelists, with 2 abstentions).

- Very Unlikely - Unanticipated

Change in transport properties causing a decrease of more than 50% in groundwater traveltime (selected by 9 of 15 panelists, with 2 abstentions).

The disruption scenarios that were judged by the Delphi panel to be most likely to occur and to be potentially most adverse to repository isolation performance will be considered in future risk assessment studies. This selection of an initial group of disruption scenarios is guided by the precept that the scope and depth requirements of completed consequence analyses will be met through an iterative process. Disruptions or changes from nominal conditions that have low probability of occurrence and high risk potential will be considered as will those that have high probability and low risk potential.

REFERENCES

1. NRC, Disposal of High-Level Radioactive Waste in Geologic Repositories, Enclosures A and C of draft 10 CFR 60, June 30, 1982, U.S. Nuclear Regulatory Commission (1982).

2. EPA, Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes, draft 40 CFR Part 191, MPRM, December 17, 1982, U.S. Environmental Protection Agency, Washington, D.C. (1982).

3. J. D. DAVIS, A. K. RUNCHAL, N. A. BAUMANN, and O. L. ERVIN, Delphi Analysis of Radionuclide Release Scenarios for a Nuclear Waste Repository at the Hanford Site, Washington State: An Initial Iteration, RHO-BW-ST-42 P, Rockwell Hanford Operations, Richland, Washington (1984).

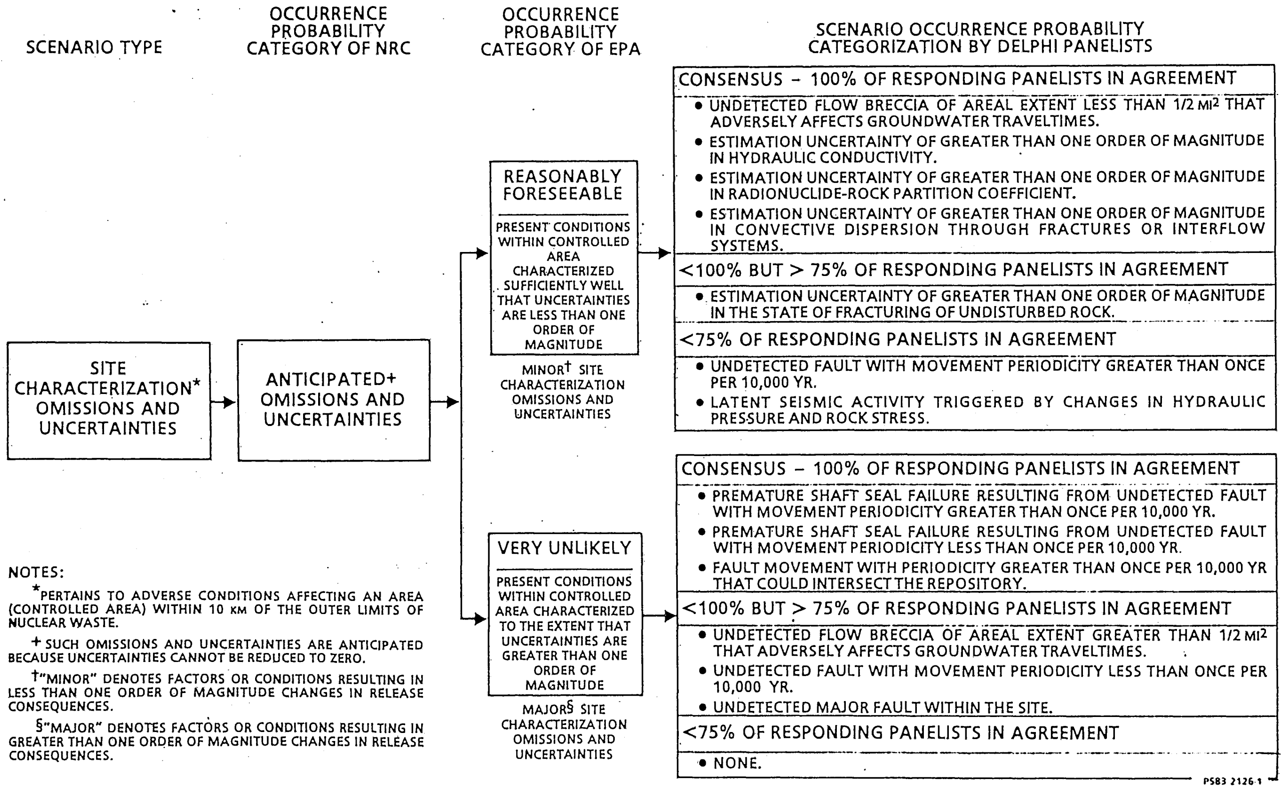

Fig. 1. Summary of Delphi expert opinion distribution for probabilities of potential Site Characterization Omissions and Uncertainties.

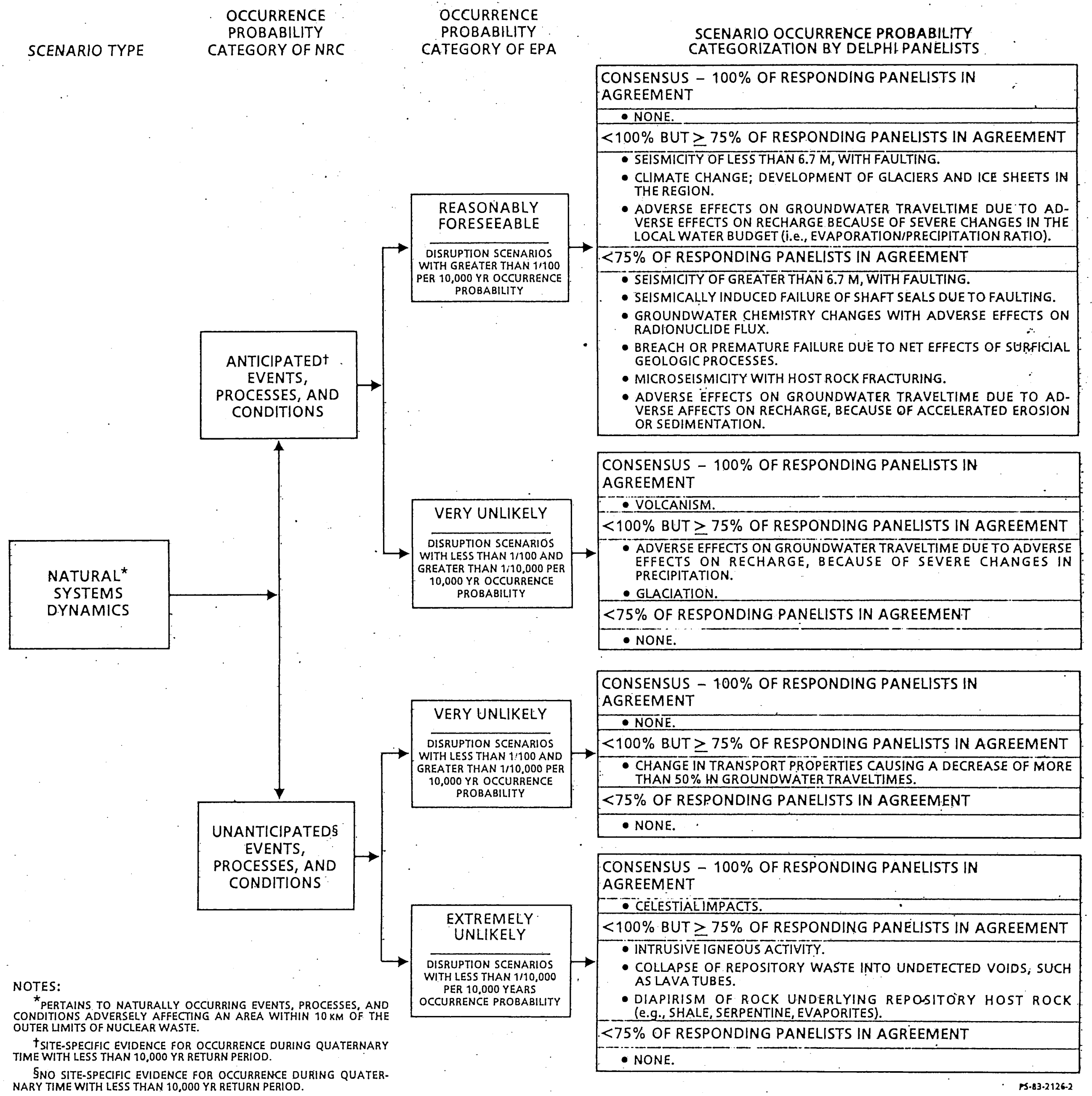

Fig. 2. Summary of Delphi expert opinion distribution for probabilities of site-specific disruption scenario occurrence - Natural Systems Dynamics.

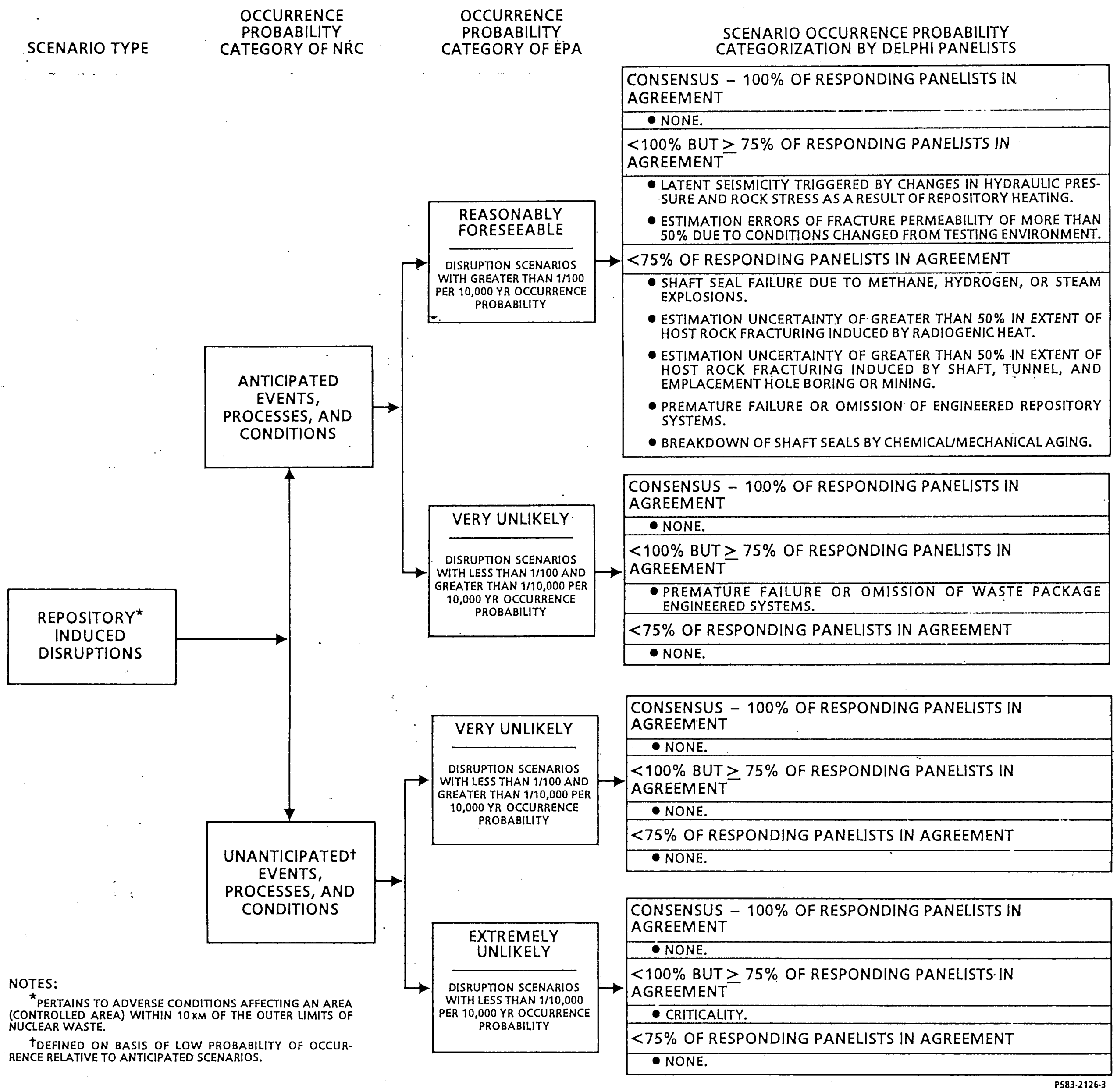

Fig. 3. Summary of Delphi expert opinion distribution for probabilities of site-specific disruption scenario occurrence - Repository Construction and Operation.

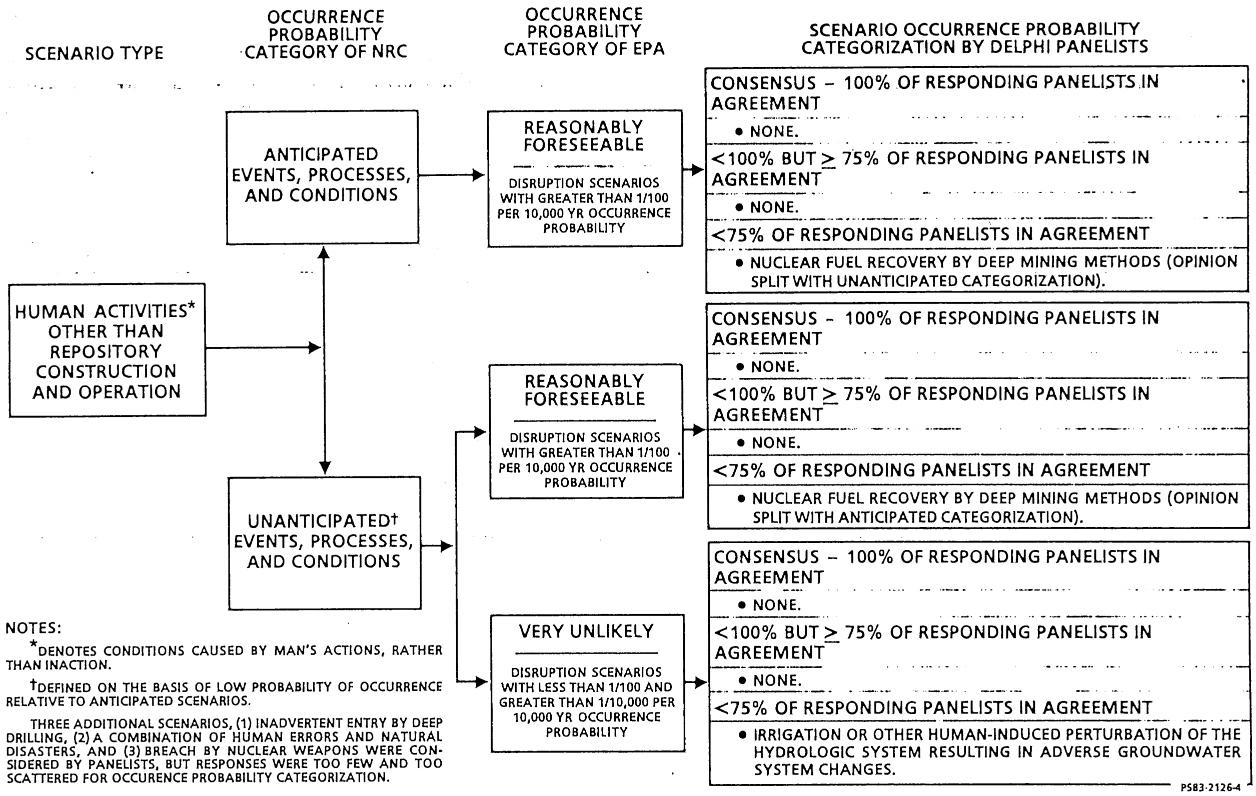

Fig. 4. Summary of Delphi expert opinion distribution for probabilities of site-specific disruption scenario occurrence - Human Activities Other Than Repository Construction and Operation.