Preliminary Identification of Scenarios for the Waste Isolation Pilot Plant, Southeastern New Mexico

Robert V. Guzowski
Science Applications International Corporation
2109 Air Park Road SE
Albuquerque, NM 87106

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PRELIMINARY IDENTIFICATION OF SCENARIOS FOR
THE WASTE ISOLATION PILOT PLANT, SOUTHEASTERN NEW MEXICO*

Robert V. Guzowski
Science Applications International Corporation
2109 Air Park Road SE
Albuquerque, NM 87106

ABSTRACT

The Waste Isolation Pilot Plant is being evaluated as a location for the disposal of defense-generated transuranic waste. One of the criteria to be used to determine the suitability of the disposal system is compliance with the Containment Requirements established by the U.S. Environmental Protection Agency. One step in determining compliance is to identify the combinations of events and processes (scenarios) defining possible future states of the disposal system that may affect the escape of radionuclides from the repository and transport to the accessible environment.

A list of previously identified events and processes was adapted to a scenario-selection procedure that develops a comprehensive set of mutually exclusive scenarios through the use of a logic diagram. Four events resulted in the development of 16 scenarios. Preliminary analyses indicate that four scenarios result in no releases. Six scenarios consist of combinations of drilling into a waste-filled room, drilling into a room and an underlying brine reservoir, and emplacement of withdrawal wells downgradient from the repository. Six additional scenarios consist of these same six combinations with the addition of potash mining and the associated surface subsidence.

The 12 retained scenarios will be screened based on consequence and/or probability of occurrence. During the course of performance assessment, additional data and information will be used to revise and update these preliminary scenarios where appropriate.

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PREFACE

This SAND report is a reproduction of the identically titled paper published in:

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INTRODUCTION

The Waste Isolation Pilot Plant (WIPP), which is located in southeastern New Mexico, is designed for the disposal of transuranic (TRU) wastes generated by the U.S. Department of Energy's (DOE) nuclear-based defense programs. This location is being evaluated for compliance with Subpart B of the U.S. Environmental Protection Agency's (EPA) Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes: Final Rule [1] (the Standard). In order to determine compliance, a performance assessment of the disposal system must be carried out. An integral part of any performance assessment is the identification of the scenarios that are appropriate for the disposal system [2]. The purpose of this paper is to describe the methodology used by the WIPP project for identifying these scenarios and to describe the preliminary results from applying this methodology to the WIPP [3]. These preliminary scenarios are being used to guide the development of the modeling system for compliance calculations and to identify the data needs for performance assessment. As more data and information become available for the WIPP disposal system, and the development of the modeling system progresses, the results of the preliminary scenario development will be revised and updated where appropriate.

REGULATORY BASIS FOR SCENARIOS

Subpart B of the Standard contains the environmental requirements that apply to the disposal system after the waste has been emplaced and the repository/shaft system has been sealed. The Containment Requirements [4] state that cumulative releases of radionuclides to the accessible environment for 10,000 years after disposal from all significant processes and events that may affect the disposal system shall meet certain criteria. By implication, "all significant processes and events" includes all significant combinations of these processes and events. These combinations of processes and events generally are referred to as scenarios.

In addition to the Containment Requirements, the definition of performance assessment [5] refers to an analysis identifying the processes and events that might affect the disposal system. As in the Containment Requirements, this definition implies that the combinations of processes and events also must be considered.
REQUIREMENTS OF A PROCEDURE FOR DEVELOPING SCENARIOS

Estimates of the cumulative releases of radionuclides from all significant processes and events in the performance assessment are to be incorporated into a probability distribution of cumulative releases to the extent possible [5]. Although the Standard does not mandate how this probability distribution is to be represented, Appendix B of Subpart B of the Standard is provided as "Guidance for Implementation of Subpart B." This appendix states that the EPA assumes the results of the performance assessment will be assembled into a complementary cumulative distribution function (CCDF).

The procedure for developing scenarios must produce a comprehensive set, so that no important scenarios are omitted. In addition, the scenarios must be mutually exclusive, so that the cumulative releases and the probability of occurrence can be combined in a CCDF.

DESCRIPTION OF SCENARIO-DEVELOPMENT PROCEDURE USED FOR THE WIPP

Much of the past work in identifying scenarios for nuclear-waste disposal systems was based on the use of event trees [6][7][8]. This type of analysis has been used to assess potential accidents at nuclear power plants [9]. Event trees were found not to be suitable for natural systems [10].

Because event trees cannot produce scenarios that adequately address the current formulation of the Standard, the WIPP project has adopted the scenario-development procedure developed by the Waste Management Systems Division of Sandia National Laboratories [11]. The application of this procedure to the WIPP will provide a final comprehensive set of mutually exclusive scenarios that are amenable to both consequence analysis and probability assignment.

In Cranwell and others [11], scenarios are defined as sets of naturally occurring and human-induced events and processes that represent realistic future changes to the repository, geologic, and hydrologic systems that may affect the escape and transport of radionuclides. The scenario-development procedure consists of five basic steps.

In the first step, the events and processes that may affect the escape of radionuclides from the waste panels and/or the transport of radionuclides to the accessible environment are identified. A panel of experts may be used to identify these events and processes, or an existing list of nonsite-specific events and processes compiled by panels of experts for previous studies can be used. Table 1 is the list from Cranwell and others [11].

The second step consists of classifying the events and processes in the comprehensive list into various categories as an aid in determining the completeness of the list. This step is organizational, and certain classification schemes can be beneficial to the modeling efforts.

In the third step, the events and processes are screened to eliminate those that are not pertinent to the specific disposal system being investigated or do not contribute to the integrated release to the accessible environment. Three screening criteria can be used: physical reasonableness, probability of occurrence, and consequence. In addition to these screening criteria, Appendix B of the Standard limits the severity of human intrusion into the disposal system to exploratory drilling for resources.
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The fourth step in the procedure is the construction of scenarios by combining the events and the processes that survive the screening process. A logic diagram is used to construct the scenarios. Figure 1 is an example of a logic diagram for what were classified as hypothetical release and transport events and processes. No temporal relationship is implied by the sequence of events and processes across the top of the diagram or within the constructed scenarios. At each junction within the diagram, a yes/no decision is made as to whether the next event or process across the top of the diagram is added to the scenario. The pathway defined by "no" decisions at all of the branch points leads to the base-case scenario, which is the undisturbed performance of the disposal system. The time at which an event or process occurs relative to the other events and processes in the scenario is a variable for consequence modeling. This time of occurrence can be sampled during the uncertainty analysis.

Screening the scenarios is the last step in the procedure. In a strict mathematical approach, no scenarios can be eliminated from inclusion in the construction of a CCDF, because the summation of the probabilities of occurrence of all the scenarios in the logic diagram must be equal to 1. In a practical approach, some scenarios can be identified as having so little effect on the shape and location of the CCDF that consequence modeling of the scenarios is not necessary, although these scenarios should be considered when evaluating overall compliance of the disposal system to the Standard.
FIG. 1. Demonstration logic diagram for the construction of scenarios for hypothetical events and processes [after 11].
The criteria for screening scenarios to identify which scenarios do not require consequence modeling are physical reasonableness, probability of occurrence, and consequence. Physically incompatible events and processes can be virtually eliminated from scenario development by not allowing specific parameter values or specific locations of occurrence to define events and processes. Scenarios with probabilities of occurrence less than some value will have a minimal impact on the CCDF. As with the individual events and processes, the probability for scenarios was assumed to be less than one chance in 10,000 in 10,000 years. To determine the probabilities of the scenarios, the probability of occurrence and nonoccurrence of each event and process is assigned to the appropriate "yes" and "no" legs at each junction in the logic diagram (Figure 1).

The final screening criteria is consequence. At this stage of the procedure, consequence means release of radionuclides to the accessible environment within 10,000 years. In the screening process, calculations may be used to determine whether releases occur.

PRELIMINARY IMPLEMENTATION OF SCENARIO-SELECTION PROCEDURE

The steps of the Cranwell and others [11] scenario-selection procedure have not been rigorously applied to the scenario-development efforts for the WIPP performance assessment. Events and processes originally identified for use in event trees had to be adapted for use in a logic diagram.

Identified Events and Processes

As a starting point in the identification of events and processes, Hunter [12] used a list of events and processes that had been considered for studies in support of waste disposal sites in bedded salt in southeastern New Mexico and elsewhere [6][11][13][14]. A total of 24 events and processes were evaluated as to their pertinence to the WIPP. Because of the geologic stability of the region, tectonic, volcanic, and plutonic events and processes were eliminated as potentially disruptive events and processes. Hunter identified "...normal flow of ground water, climatic change, the drilling of exploratory boreholes, solution mining, seal performance, the effects of drilling into a brine reservoir beneath the repository, leaching of the solid waste, nuclear criticality, waste/rock interactions, and waste effects" [15]. Waste/rock interactions and waste effects were considered applicable to all scenarios. The remaining 14 events and processes were determined to be of no significance to the WIPP.

Evaluation and Adaptation of Events and Processes to Scenario-Selection Procedure

Some of the events and processes retained by Hunter [12] are expected to occur and therefore are part of the base-case scenario. These events and processes contribute to the undisturbed conditions that define the base-case scenario and are not appropriate for use in the logic diagram to develop additional scenarios.

Events and processes that are part of the base-case scenario are normal flow of ground water, climatic change, seal performance, and leaching of solid waste. Remaining events are modified from the drilling of exploratory boreholes to drilling into a waste-filled room or drift; from solution mining to potash mining outside the WIPP boundary; and from the effects of drilling into a brine pocket beneath the repository to drilling through a room or drift and into an underlying brine reservoir. The emplacement of withdrawal wells downgradient was added as an event, because these wells can provide alternate pathways for radionuclides to reach the accessible environment. Nuclear criticality is being evaluated separately, and if this process turns out to be feasible for the WIPP inventory and the disposal system, the scenario-development step in this procedure will be revised.
Development of Scenarios

The next step in the scenario-selection procedure is the development of scenarios by the use of a logic diagram. This diagram produces $2^n$ scenarios, where $n$ is the number of events and processes incorporated in the diagram. With the four events retained for the WIPP, 16 scenarios are developed in the logic diagram (Figure 2). A separate task will determine the number of intrusions of each type of intrusion event. In addition, the location, the time of the intrusions, and the duration of pumping for withdrawal wells will be variables in the model(s) used for consequence analysis.

Two groups of scenarios can be delineated in the scenarios in Figure 2. One set consists of the various combinations of the intrusion events (E1 and E2) with the withdrawal well (E3), and the other set contains these same combinations with the addition of potash mining (TS).

STATUS OF SCENARIO SCREENING

Preliminary consequence modeling indicates that radionuclides only reach the accessible environment for those scenarios that include at least one event resulting in penetration of a room or drift. Because of these results, the base-case scenario and scenarios E3, TS, and TSE3 can be eliminated from further consideration. The assumptions made for these analyses will be reviewed and revised as needed for the final performance assessment. An additional effort to determine the probabilities of the events in the scenarios is in progress.
FIG. 2. Preliminary scenarios developed with a logic diagram for WIPP disposal system [3].
REFERENCES

Distribution

FEDERAL AGENCIES

U.S. Department of Energy (6)
Office of Environmental Restoration
and Waste Management
Attn: Leo P. Duffy, EM-1
      Jill E. Lytle, EM-30
      Mark Duff, EM-34
      Steve Schneider, EM-34
      Clyde Frank, EM-50
      Lynn Tyler, EM-50
Washington, DC 20585

U.S. Department of Energy (5)
WIPP Task Force
Attn: Mark Frei (2)
      G. H. Daly
      Sandi Fucigna
      Jay Rhoderick
12800 Middlebrook Rd.
Suite 400
Germantown, MD 20874

U.S. Department of Energy (4)
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      Ray Pelletier, EH-231
      Kathleen Taimi, EH-232
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Albuquerque Operations Office
Attn: Bruce G. Twining
      J. E. Bickel
      K. A. Griffith
      D. Krenz
      G. Runkle
      C. Soden
P.O. Box 5400
Albuquerque, NM 87185-5400

U. S. Department of Energy (10)
WIPP Project Office (Carlsbad)
Attn: A. Hunt (4)
      M. McFadden
      V. Daub (4)
      K. Hunter
P.O. Box 3090
Carlsbad, NM 88221-3090

U. S. Department of Energy, (5)
Office of Civilian Radioactive Waste
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U. S. Department of Energy (2)
Idaho Operations Office
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Bureau of Land Management
New Mexico State Office
P.O. Box 1449
Santa Fe, NM 87507

Environmental Evaluation Group (5)
Attn: Robert Neill
Suite F-2
7007 Wyoming Blvd., N.E.
Albuquerque, NM 87109

New Mexico Bureau of Mines
and Mineral Resources (2)
Attn: F. E. Kottlowski, Director
J. Hawley
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New Mexico Department of Energy & Minerals
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New Mexico Radioactive Task Force (2)
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Chris Wentz, Coordinator/Policy Analyst
2040 Pacheco
Santa Fe, NM 87505

Bob Forrest
Mayor, City of Carlsbad
P.O. Box 1569
Carlsbad, NM 88221

Chuck Bernard
Executive Director
Carlsbad Department of Development
P.O. Box 1090
Carlsbad, NM 88221

Robert M. Hawk (2)
Chairman, Hazardous and Radioactive Materials Committee
Room 334
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Santa Fe, NM 87503

Kirkland Jones (2)
Deputy Director
New Mexico Environmental Improvement Division
P.O. Box 968
1190 St. Francis Drive
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Jeremiah O'Driscoll
505 Valley Hill Drive
Atlanta, GA 30350

Christopher Whipple
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160 Spear St.
Suite 1380
San Francisco, CA 94105-1535

National Research Council (3)
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University of California
Berkeley, CA 94720

Thomas A. Cotton
JK Research Associates, Inc.
4429 Butterworth Place, NW
Washington, DC 20016

Robert J. Budnitz
President, Future Resources Associates, Inc.
2000 Center Street
Suite 418
Berkeley, CA 94704

C. John Mann
Department of Geology
245 Natural History Bldg.
1301 West Green Street
University of Illinois
Urbana, IL 61801

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Department of Geology and Mineralogy
Ohio State University
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5400 Greystone St.  
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Institute for Social Research  
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426 Thompson St  
Ann Arbor, MI 48109-1045

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Irvine, CA 92717

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Harry Otway  
Health, Safety, and Envir. Div.  
Mail Stop K-491  
Los Alamos National Laboratory  
Los Alamos, NM 87545

Martin J. Pasqualetti  
Department of Geography  
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Tempe, AZ 85287-3806

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Bracken and Baram  
33 Mount Vernon St.  
Boston, MA 02108

Wendell Bell  
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1965 Yale Station  
New Haven, CT 06520

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Department of Physics  
University of Pittsburgh  
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The Futures Group  
80 Glastonbury Blvd.  
Glastonbury, CT 06033

Duane Chapman  
5025 S. Building, Room S5119  
The World Bank  
1818 H Street NW  
Washington, DC 20433

Victor Ferkiss  
Georgetown University  
37th and O Sts. NW  
Washington, DC 20057

Dan Reicher  
Senior Attorney  
Natural Resources Defense Council  
1350 New York Ave. NW, #300  
Washington, DC 20005

Theodore Taylor  
P.O. Box 39  
3383 Weatherby Rd.  
West Clarksville, NY 14786

NATIONAL LABORATORIES

Argonne National Labs  
Attn: A. Smith, D. Tomasko  
9700 South Cass, Bldg. 201  
Argonne, IL 60439

Battelle Pacific Northwest Laboratories (6)  
Attn: D. J. Bradley  
J. Relyea  
R. E. Westerman  
S. Bates  
H. C. Burkholder  
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Battelle Boulevard  
Richland, WA 99352

Lawrence Livermore National Laboratory  
Attn: G. Mackanic  
P.O. Box 808, MS L-192  
Livermore, CA 94550

Los Alamos National Laboratory  
Attn: B. Erdal, CNC-11  
P.O. Box 1663  
Los Alamos, NM 87544

Los Alamos National Laboratories (3)  
HSE-8  
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Reynolds Elect/Engr. Co., Inc.
Building 790, Warehouse Row
Attn: E. W. Kendall
P.O. Box 98521
Las Vegas, NV  89193-8521

Roy F. Weston, Inc.
CRWM Tech. Supp. Team
Attn: Clifford J. Noronha
955 L’Enfant Plaza, S.W.
North Building, Eighth Floor
Washington, DC  20024

Science Applications International Corporation
Attn: Howard R. Pratt,
    Senior Vice President
10260 Campus Point Drive
San Diego, CA  92121

Science Applications International Corporation
Attn: Michael B. Gross
    Ass’t. Vice President
Suite 1250
160 Spear Street
San Francisco, CA  94105

Science Applications International Corporation (2)
Attn: George Dymmel
    Chris G. Pflum
101 Convention Center Dr.
Las Vegas, NV  89109

Southwest Research Institute
Center for Nuclear Waste Regulatory Analysis
(4)
Attn: P. K. Nair (3)
    B. Sagar (1)
6220 Culebra Road
San Antonio, Texas  78228-0510

Systems, Science, and Software (2)
Attn: E. Peterson
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Box 1620
La Jolla, CA  92038

TASC
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55 Walkers Brook Drive
Reading, MA  01867

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Attn: Janet Chapman
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5000 Marble NE
Suite 222
Albuquerque, NM  87110

Tolan, Beeson, and Assoc.
Attn: T. Tolan
2320 W. 15th Ave.
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TRW Environmental Safety Systems (TESS)
Attn: Ivan Saks
10306 Eaton Place
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Fairfax, VA  22030

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P.O. Box 2078
Carlsbad, NM  88221

Westinghouse Hanford Company
Attn: Don Wood
P.O. Box 1970
Richland, WA  99352

Westinghouse/Hanford
Attn: K. Owens
2401 Stevens Road
Richland, WA  99352

Weston Corporation
Attn: David Lechel
5301 Central Avenue, NE
Albuquerque, NM  87108

Western Water Consultants
Attn: D. Fritz
P.O. Box 3042
Sheridan, WY  82801

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<td>5532 Boelter Hall</td>
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<tr>
<td>Los Angeles, CA 90024</td>
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<tr>
<th>University of Hawaii at Hilo</th>
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<tbody>
<tr>
<td>Attn: S. Hora</td>
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<tr>
<td>Business Administration</td>
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<tr>
<td>Hilo, HI 96720-4091</td>
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<tr>
<th>University of New Mexico (2)</th>
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<tbody>
<tr>
<td>Geology Department</td>
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<tr>
<td>Attn: D. G. Brookins</td>
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<tr>
<td>Library</td>
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<tr>
<td>Albuquerque, NM 87131</td>
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<tr>
<th>University of New Mexico</th>
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<tbody>
<tr>
<td>Research Administration</td>
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<tr>
<td>Attn: H. Schreyer</td>
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<tr>
<td>102 Scholes Hall</td>
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<td>Albuquerque, NM 87131</td>
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<tr>
<th>Pennsylvania State University</th>
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<tr>
<td>Materials Research Laboratory</td>
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<tr>
<td>Attn: Della Roy</td>
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<tr>
<td>University Park, PA 16802</td>
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<tr>
<th>Texas A&amp;M University</th>
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<tr>
<td>Center of Tectonophysics</td>
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<tr>
<td>College Station, TX 77840</td>
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**University of Wyoming**

| Department of Civil Engineering  |
| Attn: V. R. Hasfurther           |
| Laramie, WY 82071               |

| Department of Geology           |
| Attn: J. I. Drever              |
| Laramie, WY 82071               |

| Department of Mathematics       |
| Attn: R. E. Ewing               |
| Laramie, WY 82071               |

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NEA/PSAC USER'S GROUP

Timo K. Vieno
Technical Research Centre of Finland (VTT)
Nuclear Engineering Laboratory
P.O. Box 169
SF-00181 Helsinki
FINLAND

Alexander Nies (PSAC Chairman)
Gesellschaft für Strahlen- und
Institut für Tieflagerung
Abteilung für Endlagersicherheit
Theodor-Heuss-Strasse 4
D-3300 Braunschweig
FEDERAL REPUBLIC OF GERMANY

Eduard Hofer
Gesellschaft für Reaktorsicherheit (GRS)
MBH
Forschungsgelände
D-8046 Garching
FEDERAL REPUBLIC OF GERMANY

Takashi Sasahara
Environmental Assessment Laboratory
Department of Environmental Safety Research
Nuclear Safety Research Center,
Tokai Research Establishment, JAERI
Tokai-mura, Naka-gun
Ibaraki-ken
JAPAN

Alejandro Alonso
Catedra de Tecnología Nuclear
E.T.S. de Ingenieros Industriales
José Gutiérrez Abascal, 2
E-28006 Madrid
SPAIN

Pedro Prado
CIEMAT
Instituto de Tecnología Nuclear
Avenida Complutense, 22
E-28040 Madrid
SPAIN

Miguel Angel Cuado
ENRESA
Emilio Vargas, 7
E-28043 Madrid
SPAIN

Francisco Javier Elorza
ENRESA
Emilio Vargas, 7
E-28043 Madrid
SPAIN

Nils A. Kjellbert
Swedish Nuclear Fuel and Waste Management Company (SKB)
Box 5864
S-102 48 Stockholm
SWEDEN

Björn Cronhjort
Swedish National Board for Spent Nuclear Fuel (SKN)
Skehsedtsgatan 9
S-115 28 Stockholm
SWEDEN

Richard A. Klos
Paul-Scherrer Institute (PSI)
CH-5232 Villigen PSI
SWITZERLAND

Charles McCombia
NAGRA
Parkstrasse 23
CH-5401 Baden
SWITZERLAND

Brian G. J. Thompson
Department of the Environment
Her Majesty’s Inspectorate of Pollution
Room A5.33, Romney House
43 Marsham Street
London SW1P 2PY
UNITED KINGDOM

Trevor J. Sumerling
INTERA/ECL
Chiltern House
45 Station Road
Henley-on-Thames
Oxfordshire RG9 1AT
UNITED KINGDOM

Richard Codell
U.S. Nuclear Regulatory Commission
Mail Stop 4-H-3
Washington, D.C. 20555
Norm A. Eisenberg  
Division of High Level Waste Management  
Office of Nuclear Material Safety and Safeguards  
Mail Stop 4-H-3  
Washington, D.C. 20555

Paul W. Eslinger  
Battelle Pacific Northwest Laboratories (PNL)  
P.O. Box 999, MS K2-32  
Richland, WA 99352

Budhi Sagar  
Center for Nuclear Waste Regulatory Analyses (CNWRA)  
Southwest Research Institute  
Post Office Drawer 28510  
6220 Culebra Road  
San Antonio, TX 78284

Andrea Saltelli  
Commission of the European Communities  
Joint Research Centre od Ispra  
I-21020 Ispra (Varese)  
ITALY

Shaheed Hossain  
Division of Nuclear Fuel Cycle and Waste Management  
International Atomic Energy Agency  
Wagramerstrasse 5  
P.O. Box 100  
A-1400 Vienna  
AUSTRIA

Daniel A. Galson  
Division of Radiation Protection and Waste Management  
38, Boulevard Suchet  
F-75016 Paris  
FRANCE

FOREIGN ADDRESSES

Studiecentrum Voor Kernenergie  
Centre D'Energie Nucléaire  
Attn: A. Bonne  
SCK/CEN  
Boeretang 200  
B-2400 Mol  
BELGIUM

Dist-10
Institut für Tieflagerung (4)
Attn: K. Kuhn
Theodor-Heuss-Strasse 4
D-3300 Braunschweig
FEDERAL REPUBLIC OF GERMANY

Kernforschung Karlsruhe
Attn: K. D. Closs
Postfach 3640
7500 Karlsruhe
FEDERAL REPUBLIC OF GERMANY

Physikalisch-Technische Bundesanstalt
Attn: Peter Brenneke
Postfach 33 45
D-3300 Braunschweig
FEDERAL REPUBLIC OF GERMANY

D. R. Knowles
British Nuclear Fuels, plc
Risley, Warrington, Cheshire WA3 6AS
1002607 GREAT BRITAIN

Shingo Tashiro
Japan Atomic Energy Research Institute
Tokai-Mura, Ibaraki-Ken
319-11 JAPAN

Netherlands Energy Research Foundation
ECN (2)
Attn: Tuen Deboer, Mgr.
L. H. Vons
3 Westerduinweg
P.O. Box 1
1755 ZG Petten, THE NETHERLANDS

Johan Andersson
Statens Kärnkraftinspektion
SKI
Box 27106
S-102 52 Stockholm, SWEDEN

Fred Karlsson
Svensk Kärnbransleforrsjning AB
SKB
Box 5864
S-102 48 Stockholm, SWEDEN